FINAL REPORT

of the

Technical Assistance Study
(TA-1481 PAK)

on

CROP-BASED IRRIGATION OPERATIONS

VOLUME I: SYNTHESIS OF FINDINGS AND RECOMMENDATIONS

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CROP-BASED IRRIGATION OPERATIONS STUDY IN THE NORTH WEST FRONTIER PROVINCE OF PAKISTAN

VOLUME I: SYNTHESIS OF FINDINGS AND RECOMMENDATIONS

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ACKNOWLEDGEMENTS

This study on Crop-Based Irrigation Operations in the North West Frontier Province of Pakistan was undertaken by the International Irrigation Management Institute on requests made by both the Federal Government of Pakistan and the Government of NWFP. A number of government officials participated in various study-related activities ranging from proposal development and formal approval processes to some field work and data analysis.

At this concluding stage of the study, it is essential that we should recall with gratitude the special interests shown in initiating this study by Maj. Gen. (Rtd) Manzoor A. Rauf, the retired Additional Secretary of the Federal Ministry of Water and Power; Mr. Mohammad Akhtar, former General Manager (Water) North, WAPDA, and his successor Mr. Naeem Akhtar; and Mr. Amin Khattak and Mr. F. Ahmed Paracha, the former Secretaries of NWFP's Irrigation and Public Health Engineering Department (IPHED), Mr. Jalil Khan, the former Chief Engineer of IPHED; and Mr. Khalid Mansoor, former Secretary, and Mr. Dost Muhammad former Director Water Management of the Agriculture Department of NWFP. Special mention should be made of the support given by Mr. F. A. Zuberi, Director General, and his staff of IWASRI, for processing the PC II proforma and participating at various stages of study appraisal.

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The authors alone take the responsibility for any shortcomings in the material presented in this Final Report.

EXECUTIVE **SUMMARY**

"Volume I: Synthesis of Findings and Recommendations" is a part of the Final Report on Crop-Based Irrigation Operations Study in the Northwest Frontier Province of Pakistan. This Volume I of the Report, in its present version, has benefited from a number of comments and suggestions on an earlier draft, which were received during a workshop held in D.I. Khan during March 1994. The purpose of presenting this document as Volume I provides an overview of the study and the major findings and recommendations, while "Volume II: Research Approach and Implications" documents the study activities and results in greater detail, and "Volume III: Data Collection Procedures and Data Sets" provides a set of organized information collected during the study. The Final Report comprising these three volumes is the result of a technical assistance study conducted by the International Irrigation Management Institute (IIMI) with financial support from the Asian Development Bank.

Study sites were located in Distributaries # 3 and # 4 of the Chashma Right Bank Canal (CRBC) Stage I, and Distributary # 3 and Sheikh Yousaf Minor served by Distributary # 8 of the Lower Swat Canal (LSC) system. These sites were selected on the basis of widely expressed interests for exploring how increased water allocations given to the two systems, CRBC and LSC, could be operationally used for increasing agricultural productivity. Most of the study activities were concentrated on CRBC, while only an institutional study was undertaken on LSC rehabilitation; therefore, a major part of the findings and recommendations relate to the CRBC system.

Volume I starts with a set of recommendations covering a number *of* issues, arranged in terms of their technical and policy implications. From a technical viewpoint, specific field-oriented interventions are proposed, including a program for calibration of hydraulic structures, fixing of flow limits in the main canal and distributaries, modifications of current operational practices, and changes in selected off-take structures. The use of mathematical simulation techniques, an improvement of existing data collection and project monitoring processes, the enhancement of crop water requirements techniques, and an upgrade of present communication facilities are also highlighted as important technical improvements

On Policy issues, the study calls for clear government decisions to move towards a crop-based irrigation operations mode in Pakistan on a wider scale, to revise and upgrade the legal framework to suit more flexible water distribution and management, and to strengthen the working relationships among irrigation-related agencies. Also, there are recommendations for increased participation of both extension agents and farmers in pursuing innovative management interventions, thereby leading to higher economic returns from the systems.

These recommendations are derived from project findings, of which only a summary is presented in this Volume along the main study themes: i) system operation, ii) supply and demand of irrigation water, iii) irrigation facilities, iv) irrigation institutions, v) economics of crop-based irrigation operations, and vi) policy. (The details are given in Volume II).

In essence, the study findings underline the importance of seeking a better match between the supply and the demand of irrigation water ---the essence of crop-based irrigation--- as opposed to the traditional approach of a continuous fixed-supply delivery irrespective of crop needs. An overview of the study accomplishments and implications suggests that from a technical viewpoint, the management of irrigation systems in Pakistan could be re-directed to deliver water more in accordance with crop water requirements rather than just allowing an available water supply to pass through the system. This could be accomplished especially in those systems where higher water duties could be secured, infrastructure could be added, and managerial capabilities could be enhanced.

However, the study reveals that the mechanisms and resources required to effect the change have to go beyond a pure technical approach. The strengthening of the irrigation-related agencies with adequate budgetary provisions and appropriately trained manpower resources, and a restructuring of the institutions themselves to make them more flexible and responsive to change, are also prerequisites for a successful transition. Most importantly, a more active role, than at present, will be required from the water users at the level of watercourse and distributary management. In turn, greater support will be needed from the operating agencies to make the role of farmers more meaningful.

This report draws implications regarding the design and future operations of Stage III of the Chashma Right Bank Canal Irrigation System, which is presently being planned. In particular, it calls the attention of irrigation professionals and policy makers alike to the dangers of supply over-deliveries in Stage I and II that can lead to serious water shortages in Stage III (10% to 15% is a conservative estimate that could easily be exceeded).

Some study constraints have made it difficult to achieve all of the planned outcomes. Only two of the study objectives, "i) the identification of a flexible management approach for irrigation operations that responds to crop water requirements; and ii) increasing the general understanding of concerned actors about crop-based irrigation operations", could achieve results of a satisfactory level. The study was less successful in advancing the other two objectives, "iii) field-testing and refining the management approach identified; and iv) evaluating the ,benefits and costs of crop-based irrigation to seek opportunities for implementation on a wider scale".

The reasons for these deficiencies are attributable to the delays in infrastructure development, as well as the lack of institutional preparedness for the required changes in management. While planning the study interventions, the concerned parties under-estimated the time required for developing and establishing a novel approach such as crop-based irrigation operations in the traditional irrigation context of Pakistan. In fact, while the necessary conditions were being completed, the study period came to an end.

Finally, while the document brings forward the fact that a main limitation of the study has been the relatively short time span, it recommends that the government seeks financial support to initiate further research efforts in continuation of these activities. In particular, new research efforts should address, among others, computer-based mathematical simulation work to verify the Stage III main canal design and operations, development of a management information system for monitoring and evaluation of irrigation activities, more effective ways to organize farmers at the watercourse and distributary levels, and mechanisms to strengthen inter-agency collaboration.

RECOMMENDATIONS

While project findings, summarized in Volume I and detailed in Volume II of the Final Report, are presented around themes that had been specifically suggested under the Technical Assistance Agreement, the recommendations given below are clustered around the identified main issues, and divided into two categories --technical (T) and policy (P). Furthermore, these are not separated in terms of the two irrigation systems covered by the study, although some are specifically intended for either the CRBC, or the LSC.

The reason for this arrangement is aimed at facilitating the review to be done by government officials and other interested persons. Particularly, it is expected that concerned persons will be able to concentrate in either more technical matters or those related to institutional and policy oriented concerns.

TECHNICAL (T) ASPECTS

Water Releases from the Barraae

T1. The study recommends that the present inflow in the main canal of **40** cumecs **(1400** cusecs) for the lower water requirement be increased to no less than **57** cumecs **(2200** cusecs), in order to provide greater operational flexibility. The canal should be operated between **57** and **85** cumecs **(2200** and **3000** cusecs) for the operation of Stages I and II in order to achieve higher than currently measured canal velocities and to reduce the already emerging sediment deposition problems in the lined section. It is possible to operate the canal in this range without disturbing the yearly allocation for CRBC before the completion of the project. After the completion of the project, escapes can be used to regulate the flows in the main canal.

Svstem Calibration

T2. As a top priority, a program for calibration of all hydraulic structures in the CRBC Irrigation System should be established and institutionalized in the shortest time frame possible. This program could fall under the direct supervision of the Water Management Unit for CRBC coordination mentioned in the Fourth Policy (P4) Recommendation. The end-product of this program will be a water delivery accountability scheme which is non-existent at the moment and a main cause for present supply over-deliveries.

T3. In addition to the implementation of the structure calibration program described above, proper measuring structures should be fitted at all off-taking canals. Given the hydraulic downstream conditions of the canals, the best type of structures would be broad-crested weirs or flumes. Head versus Discharge relationships for these structures can be easily developed under the existing set-up. This proposal will be particularly helpful to the PID who already is using non-calibrated gauges as the cornerstone of its water distribution operations.

Main Canal Operations

T4. While the calibration program is developed and introduced, it will be necessary to tackle the present problem 'of over-deliveries. Upper flow limits (given, for example, by the peak water requirements under the designed cropping pattern) should be established for each one of the off-taking channels in Stages I and II and then efforts should be made to keep water deliveries below those imposed limits. Subsequently, the upper limits should be reduced on a seasonal basis until deliveries are more in line with both: (a) real water needs; and (b) the future operational capacity of the system once construction is completed. An additional advantage of this flow rationalizing approach is that it will prevent farmers from further skewing the cropping pattern towards high water demanding 'crops like rice and sugarcane.

T5. With respect to operational velocities in the main canal, a study should be undertaken to establish the critical velocities required to transport the incoming sediment out of the main system. At present, the sediment load can be diverted to those distributaries that have purposely been designed with bigger cross-sections. Application of these velocities to main canal operation will also help reduce sediment associated maintenance costs.

T6, Following the above paragraph, it is recommended that the present practice of storing water at the tail of Stage I for operational purposes. be reduced as much as possible. Field data indicates that deliveries to off-takes (especially those for Distributaries # 1 and # 2) can be maintained by using the maximum gate openings of the respective head regulators. The recommendation regarding increased minimum flows is also designed to alleviate this situation.

T7 **WAPDA** should reconsider **its** target of achieving the design bed level in the unlined section, particularly from **RD 0+000** to **RD 97+000** where five to eight feet of sediment deposits have already accumulated. The section is in high fill, higher than the command area; furthermore, there is no offtake from this section. Some bed-raising is still required from RD 98+000 to RD 120+000, but as the lower pipes for the link-feeders are working properly, there is no urgent need to achieve the designed bed level. The sediment transport to the lined section has already increased during recent years because of the decrease in the deposition rate for the unlined section. Hence, the management should start thinking about sediment control at the head of the main canal.

T8. In order to assure the long-term sustainability of CRBC, a water table monitoring program, presently under implementation in selected areas of the command area, should be extended throughout. Rising water tables, both along the main canal and in the new areas of Stage I, warrant consideration of this proposal.

T9. Operations of the CRBC system can be greatly assisted by a mathematical simulation model, such as the one utilized during the study. The model, if adopted as a regular decision support tool, will provide information about the hydraulic and operational conditions of the system to supplement the knowledge of managers through routine field monitoring activities. Simulation can be particularly useful when managers are faced with several operational alternatives and these need to be evaluated quickly before a final decision is made. A simulation model can be used to develop a management schedule for main canal operation based on calculations of hydraulic parameters, which will assist initially in a more appropriate operation of Stages I and II. Importantly, this type of schedule will provide gate settings for cross-regulatprs, escapes and off-take structures, as well as water supply levels at selected points in order to supply water in accordance with crop water requirements.

Distributary System Operations

T10. The PID, which is responsible for irrigation management of the distributaries, will benefit considerably from upgrading its present system of monitoring activities. The study identifies two specific items that point towards a need for PID to improve its capability for capturing farm-level information. One item is the farmers' behavior in opening and closing of outlets, that directly relates to its potential as an operational feedback mechanism to managers (for example, to decide on the settings for distributary headgates in order to stabilize, conditions at the tail). The PID could incorporate into their daily system monitoring activities the assessment of open/closure of outlets with the end-objective of deriving a method that will allow gatekeepers, based on the number of outlets closed in a particular distributary, to modify water deliveries. This is a relatively inexpensive and easy way to be able to react quickly to changing conditions in the field. The other item is the widening gap between the present cropping pattern and the one presumed during the design of the system; the peak and minimum water requirements are now different and occur at different times of the year. This points to the need to formulate and develop a simple method that will allow the PID to calculate on a regular basis the seasonal crop demands that can be fed back into operational plans. Such a scheme should be flexible in order to respond to climatic changes (i.e. rainfall), variations in crop data, farmers' practices such as pre-sowing irrigations. A management information system (MIS) package will assist in tackling this type of problem.

Communication Svstem

T11. A significant constraint towards improved system operation, at present, is due to the weak and cumbersome communication set up. Flow of information is sluggish and far less from desirable both among, and between, agencies. In order to upgrade communications so that managers can base their decisions on real time information originating from the field, wireless phones should be installed at strategic control points in the system (barrage, cross-regulators, escapes etc.). In addition, gate operators should be literate so that they can play a more active role in data collection, recording and simple computations. Finally, regular transport facilities for moving up and down the system should be established and coordinated among the managers of both agencies. These vehicles should also be provided with mobile communication units.

T12. The present data collection process, being implemented by both ACOP's CRBC Monitoring Project and the regular WAPDA local staff, should be reinforced and made readily available to canal managers in the field for prompt use. There is now more than a one year lag between collection of data and its availability to managers. In addition, the selection and subsequent introduction of one of the several existing Management Information Systems **(MIS)** packages should be given serious consideration in order to facilitate system control and operations. The package, which would be a set of simple databases, does not require sophisticated hardware; it could be implemented with the present facilities available to managers at **D. I.** Khan.

POLICY (P) ISSUES

Movina Towards Crop-Based Irriaation Operations

P1. Pakistan is unlikely **to** make the leap from **the** present irrigation operation mode into the more flexible crop-based approach without a firm policy commitment to go beyond the current "pilot trials" efforts This can be achieved if a larger irrigation system is placed on trial under the new approach so that a proper evaluation of the benefits and costs of the crop-based operations can be evaluated under real field and institutional conditions. For this purpose, the Lower Swat Canal Irrigation System can be selected as infrastructure geared towards a crop-based irrigation operations approach that can be quickly installed. An alternative could be the entire Stage I of the Chashma Right Bank Canal Irrigation system.

P2. A strong argument commonly adduced against crop-based irrigation operations relates to some constraints imposed by the existing Canal and Drainage Act (VIII of 1873) and accompanying departmental regulations and procedures. Therefore, it will be necessary that the conflicting portions of the law be reviewed. A special task force should be created to undertake a careful review of these documents and submit to the government its recommendations for bringing the legal framework more in line with the present requirements of flexibility for Pakistan's irrigated agriculture.

Water Releases

P3. A clear policy decision, at the appropriate government level, should be taken regarding the question of water releases from the Chashma Barrage, for purposes of the day-to-day operation of the CRBC system. Whether the flexibility will exist to draw water from the barrage above particular crop water requirements, or whether releases will necessarily follow those requirements strictly, will determine the type of management intervention needed to move the system towards crop-based irrigation operations. If the former, more managerial-based solutions can be designed; if the latter, a more hardware oriented approach would be necessary. Thus, an early and firm decision on this matter will be more beneficial for the CRBC project.

In taking this policy decision, consideration should be given to the need to avoid running the canal continuously at peak water requirements because of the negative environmental impact. At present, high water surface levels in the unlined section creates high seepage losses with the consequent waterlogging effects on adjacent areas. Similarly, high water elevations along the main canal increase waterlogging conditions of adjacent areas. Likewise, in the escapes, erosion of the embankments is increasing. Also, waterlogging in downstream areas is on the rise.

Institutional Aspects

P4. Water Manaaement Unit at System Level: Regardless of the final operational mode adopted for CRBC, which in any case has to be directed towards achieving optimum agricultural production in the CRBC system, there is a need to enhance the working relationship between the two agencies involved in the day-to-day operation of the system ---WAPDA and PID--- and their relationships with the Agriculture Department. The establishment of a coordination team, CRBC WATER MANAGEMENT UNIT, composed of representatives from each agency is recommended. The group will meet on a regular basis to plan, coordinate and implement system operation activities. At present, each agency is too independent of the others in its decision making process, which negatively affects the performance of the irrigation system.

A reasonable return on investment in infrastructure development can only be realized by paying special attention to the institutional requirements for the management of operation and maintenance. An important realization in this regard should be the need to achieve a high degree of coordination among various agencies, and between agencies and farmers, considering all activities contributing to a production process. The above recommendation for a Water Management Unit should be considered as an initial step towards establishing appropriate integrated formal organizational mechanisms for irrigated agriculture in CRBC.

An operational coordination group, such as mentioned above, is also recommended for LSC.

Performance Monitorins: In connection with the recommendation above, there is a need to pay more attention to system performance. This can be done by institutionalizing the function of performance monitoring within the proposed Water Management Unit. The unit should be responsible for enhancing data collection for monitoring purposes and performance evaluation, and should act as a feedback mechanism to managers. The success of this unit can only be achieved if it is created through a joint policy decision' and a firm commitment of all the agencies involved in the operation of the two systems.

P5. Water Users Associations: Increased suppiies have already encouraged farmers to deviate from strict warabandi schedules. To make maximum use of this opportunity for flexible water management at the watercourse level, it is essential that greater emphasis be placed on social organization. This leads to a recommendation that more serious attempts should be made to promote water users associations aimed at the primary task of managing water at the watercourse as well as distributary levels, and this responsibility should be placed on an appropriate agency, which can monitor this activity on a more permanent basis.

P6. "Institutional Impact Assessment": The case study of the LSC rehabilitation exercise leads to a strong recommendation that an evaluation based on the institutional implications of the design should be required at the stage of project preparation, taking into account the existing social and institutional background of the project. This may be seen as a pre-project "Institutional Impact Assessment", which can be used as a criterion for project approval.

In the planning and designing of new irrigation systems, and the rehabilitation of old ones, the agencies involved in their operation and maintenance should necessarily be involved throughout the entire process. It is recommended that the present arrangements at the provincial level for project preparation and approval be reviewed to ensure the maximum participation by the operating agencies in design decisions relating to irrigation development.

P7. Adequate Manpower Resources: In the case of the LSC, since a large investment has already been made to remodel the canal system with new structures requiring more intensive operational attention, it is recommended that policy consideration be urgently given to provide the necessary staff and equipment to PID as suggested by the project planners. Any further delay in taking control of the proper distribution of increased water supplies is likely to result in perpetuating a form of haphazard and liberal use of water, thereby exacerbating drainage problems and causing a decline in agricultural productivity.

In both LSC as well as CRBC, lack of trained personnel and budget considerations were advanced by the agency as constraints towards implementation of more flexible management systems. Therefore, urgent policy attention is necessary to provide sufficient resources to operating agencies, if the planned return on investment is to be achieved.

Economic Aspects

P8. O&M Financing: The discrepancy between designed and current levels of funding for the Operation and Maintenance of the system (with its potential impact on the physical sustainability of the system), as well as the questions of water charges and their collection, point to the need for policy makers and system managers to urgently address the issue of financing for O&M in both the CRBC and LSC systems. A provincial-level task force should be established with the task of proposing. an appropriate financing system to be implemented and tested in these two irrigation systems.

P9. The reported difference in rice yields between the newly irrigated area and the Old Paharpur command area suggests that significant improvement in yields could still be expected for the new areas of Stage I. It is recommended that a special extension effort be made in the new areas of the CRBC irrigation system, with a specific focus on messages related to water management and irrigation practices adapted to the site specific situation being encountered in this system.

The design and economic appraisal for Stage III of CRBC should be based on an in-depth analysis of farming systems and on the relationship between irrigation water supplies and agricultural production. The changes in agricultural production that have already occurred in the Stage I command area, as a result of the new water duties, are to be analyzed from an economic point of view in order to provide sound assumptions regarding the expected demand for irrigation water, cropping pattern and yields.

Further Studv Interventions

P10. One of the main limitations of this study has been the relatively short time span under which the activities were pursued. There is a real need to expand these research efforts to provide suitable information to the GOP and GONWFP that will assist them in making relevant decisions on how to proceed. The GOP and GONWFP should give serious consideration to continuing these studies, but with more emphasis on facilitating implementation. In particular, these studies should address, among others, mathematical simulation to verify Stage III main canal design and operations, development of a management information system for monitoring and evaluation of irrigation activities, more effective ways to organize farmers at both the watercourse and distributary levels, and mechanisms to strengthen inter-agency collaboration..

Chapter 1

INTRODUCTION

1.1 Coverage

Volume. I of this Final Report, "Synthesis of Findings and Recommendations" summarizes the study achievements and presents a set of recommendations for consideration by: (1) the authorities of the Government of Pakistan, both at federal and provincial levels, who have been involved in the project since its inception; and **(2)** the Asian Development Bank who financed the studies.

Section **1.2** below gives an account of the history and rationale that led to .the implementation of a study of this nature. The purpose of including this background information in some detail is to enable the study findings to be interpreted in the perspective of the importance that has been attached to the subject matter..The review of activities given in Section 1.3 will provide some details regarding the implementation effort that was made, and the many difficulties confronted, during the study of Crop-based Irrigation Operations in the North West Frontier Province (NWFP).

The main final report is intended to be self-contained in a manner that will provide the reader with the results emanating from the study and the follow-up actions that are being proposed. However, this is only part of the complete final report; the second volume incorporates the essential back-up material to support the findings presented in Volume I, while a third volume presents the data collected over a two-and-half year period of field activities.

This Final Report (Volume I) was thoroughly discussed, in a round-table type of meeting, with government agencies as well as with other interested organizations in the country. The results of those discussions have been incorporated into this report prior to being submitted to the GOP, the GONWFP and ADB as the final study document.

At the request of the **ADB,** this Final Report (Volume I) was presented and further discussed at a meeting of the Federal level Project Supervision and Coordination Committee (PSCC) of the CRBIP, held in Islamabad on 28 August 1994. The discussion at this meeting was followed by IIMI's letters addressed to the members *of* the Committee requesting their comments on the report. The only response received was from WAPDA authorities in the NWFP, which generally endorsed the report and encouraged further interventions for internalizing the study findings.

Consequently, on the written request of 8 December 1994 from the CRBIP's Project Director in D.I. Khan, IIMI presented a proposal for a Phase II Action Research Program to follow up on the Phase I study. This proposal is now under consideration by the NWFP Government.

1.2 Historical Review of the Study

The rationale for a study on the possibilities of introducing cropbased irrigation operations in Pakistan has its origin in a series of recurring policy concerns on the country's traditional supply-based irrigation. A 1979 report by the Water and Power Development Authority (WAPDA)' was one of the first policy documents to refer to the limitations of existing irrigation systems in Pakistan. The report highlighted' the prevailing mismatch between water supplies and crop.water requirements (demand), and linked this mismatch to the following:

i) The design canal capacities. of the present system did not permit an increase in water supplies to match the crop requirements even if excess supplies were available in the rivers during the summer season;:

ii) Inadequate supplies available at the time .of sowing .restricted 'the area being cultivated,, although excess supplies were available later in the season, which also caused the sowing period to be protracted beyond the proper time for sowing of some crops;

iii) Low agricultural productivity as water supplies fell short of the' crop water requirements during critical stages of crop growth; and

iv) Irrigation supplies in excess of the crop requirements caused drainage problems that resulted in waterlogging and salinity.

More recently, further official concern on this problem of mismatch.between supply and demand was expressed by the National Commission on Agriculture[2]. In their view, the most adverse effects of the seasonal variability of water supplies are:

i) the chronic inequity which affects the tailenders; and

ii) the shortages that occur during critical periods of the crop growth cycle, which contributes to water stress and consequently lower yields in large areas of the command of Pakistan's irrigation systems.

The seasonal variability in supplies and their effects appeared to be more directly attributable *to* two easily identifiable factors: inadequate maintenance of the physical conveyance system, and the dependency of water availability in these systems on the hydrograph of the water source.

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1 "Revised Action Programme for Irrigated Agriculture". Vol 1, Chapter V, pp 60-73

2 National Commission on Agnculture. 1988 Report of the National Commission on Agnculture, Ministry of Food and Agnculture. Government of Pakistan, p 289.

The difficulties linked with environmental constraints and poor maintenance were greatly accentuated by the low water allowances and channel capacities in the traditional "protective" irrigation systems, which were designed primarily for extensive irrigation to distribute water over large areas. An adequate supply of irrigation water was considered a prerequisite for a shift from the traditional approach of "protective" irrigation towards that of "productive" irrigation. In the North West Frontier Province (NWFP) of Pakistan, an opportunity for such trials arose when the remodelling of the Lower Swat Canal (LSC) system (supported by the World Bank) and the construction of the new Chashma Right Bank Canal (CRBC) system (supported by the Asian Development Bank) were to be designed. The issue of designing for a higher water allowance was paramount in the planning for both of these projects. The design for remodelling the LSC and of the new CRBC are based on canal capacities to provide 0.77 lps/ha and 0.60 lps/ha (11 and 8.6 cusecs per 1000 acres), respectively, compared with the more traditional system capacity of 0.28 lps/ha (4 cusecs/1000 acres).

In the light of the policy interests for changing the traditional modes of irrigation. and in view of the dictates of conventional wisdom. which tended to highlight the constraints against such a move, the government authorities in Pakistan were keen to launch a pilot study. The Federal Government of Pakistan (GOP) was interested in a pilot trial in the newly constructed CRBC Stage I, where the designed water allocation per hectare of land was almost twice the national average. During the appraisal for Stage II of the CRBC in 1987, the Federal Ministry of Water and Power requested the Asian Development Bank (ADB) for technical assistance to carry out an action-oriented study on demand-based irrigation system operations[3]. Meanwhile, the Government of the North West Frontier Province (GONWFP) was exploring the appropriateness of introducing demand-based irrigation operations in the LSC system, which was being remodelled with a substantially increased water allocation and with physical features that suited an immediate switch from the existing traditional supply-based operations. Following up these interests, both the GOP[4] and the GONWFP[5] requested IIMI-Pakistan's participation in a collaborative effort to undertake pilot studies on crop-based irrigation.

Following these requests, IIMI started reconnaissance activities in the two project areas in which infrastructure improvements and higher water duties were being implemented. In March 1989, IIMI staff along with Dr. Gilbert Levine, Professor Emeritus of

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3 ADB Fact-Finding Mission Aide Memoire dated 16/12/1989.

4 Letter dated 1/3/1988 from the Government of Pakistan Ministry of Water and Power, Mr. Khalid Mahmood. Chief Engineering Advisor.

5 Letter dated 611011988 from Government of NWFP Irrigation and Public Health Engineering Department, Engr. Muhammad Anwar Shah Section Officer (Construction).

Agricultural Engineering, Cornell University and also a Senior Associate of IIMI, visited the two project areas and held discussions with officials of the NWFP Department of Irrigation and Public Health Engineering (IPHED),[6] the NWFP Agriculture Department (PAD) and the northern division of the Federal Water and Power Development Authority (WAPDA), as well as with some farmers. Later, discussions were also held with the National Consultative Committee for IIMI-Pakistan. IIMI staff also met with the World Bank consultants and the expert who installed an on-demand pilot .project in the LSC and visited its 60 acre pilot area. These visits and discussions clearly identified the need for a more careful consideration of design and supply, constraints before embarking upon a full-scale on-demand system of irrigation operations in either of the two projects.

In December 1989, the ADB Fact-Finding Mission which visited the project areas, along with IIMI staff, held similar discussions with officials and farmers, and recognized these constraints. They noted the confusion resulting from apprehensions by those who tend to interpret the term "demand-based irrigation" to mean complete freedom for farmers. The actual intent of the design changes, particularly in the CRBC, was seen to have been aimed generally at reducing the mismatch between water deliveries and crop water requirements. Discussions with officials of the Federal Ministry of Water and Power, and the Economic Affairs Division, confirmed this position. Accordingly, the concept of "crop-based irrigation" was adopted to mean the most appropriate management system for irrigation operations based on assessed crop-water requirements under the given and anticipated project constraints.

After further discussions with Government officials and Bank staff', IIMI prepared the proposal document that was submitted for ADB's and GOP's consideration in February 1990. A Bank Fact-Finding Mission visited Pakistan between 2 and 10 April 1990 to finalize the details of the proposed advisory technical assistance. Subsequent to this Mission, a PC-II document was prepared for the project and approved by GOP's Ministry of Water and Power, Departmental Development Working Party (DDWP) on 21 August 1990.

Based on this formal approval, GOP through its Economic Affairs Division formally requested ADB for technical assistance for this study to be undertaken by IIMI, and' a Memorandum of Understanding was'signed by GOP, IIMI and ADB on 24 September 1990. After ADB's decision on the provision of TA for the proposed study, ADB fielded an inception mission on 16 March 1991 for discussions with the concerned parties and

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6 The Department of Irrigation *and* Public Health Engineering (IPHED) is also commonly referred to as Provincial Irrigation Department (PID), these names were used interchangeably throughout the study (hence, in its publications).

7 To follow up on the Mission in December 1989, the Bank fielded a Consultation Mission in February 1990.

to finalize the terms of reference for the study. As expected at the .inception mission deliberations, IIMI initiated preparatory work for the study in March 1991 with the intention of starting field activities from the beginning of the Kharif season, but administrative delays in signing the TA Agreement tended to retard the process. Eventually; the TA Agreement between GOP, GONWFP, IIMI and ADB was signed on 25 July 1991, which paved the way for study implementation activities as described in the section below.

1.3 Brief Account of Study Implementation

A recognition *of* the need to formalize policies and procedures for managing the two systems with higher water allocations ---Chashma Right Bank Canal and Lower Swat Canal Irrigation Systems--- led to the identification *of* the following specific points which formed the rationale for the study:

i) water resources are limited/constrained despite increased water availability at the system level;

ii) inefficient use of increased water availability may result in waterlogging and deprive downstream areas of adequate access to required water resources; and

iii) agency personnel and farmers are not prepared for effective' utilization of the increased water availability.

The study objective was "to enhance the overall productivity of water through improved system management and irrigation operations, in accordance with crop water requirements within the authorized system-level water allocations and subject to available supplies" in the two systems. More specifically, the study aimed to:

i) identify a flexible management approach for irrigation operations that responds to crop Water requirements under prevailing supply constraints;

ii) increase the understanding by agency personnel and farmers about crop-based irrigation operations, and identify training needs;

iii) field-test and refine the management approach identified for crop-based irrigation operations; and

iv) evaluate the benefits of crop-based irrigation operations and identify costs and opportunities for implementation on a wider scale.

In the original work plan for the study, the intention was to establish similar field research efforts in both project areas, the CRBC and the LSC. The set of activities was to be the same and similar field teams were to be deployed in each location. Figure 1 shows the geographical location of the study areas.

1.3.1 Chashma Right Bank Canal Irrigation System

The CRBC is a major perennial surface irrigation project designed to irrigate 230,675 ha (569,767 acres) with a 271.92 km long (approximately. 160 miles) gravity flow main canal carrying a discharge capacity of 138.07 cumecs (approx. 4850 cfs). The canal feeds a network of subsidiary canals with an aggregate length of 603.37 km (approx. 357 miles). It derives its supplies from the combined river flows of the Indus and Kabul rivers as regulated by Tarbela Dam and again downstream by the Chashma Barrage on the Indus.

The CRBC project, currently under implementation, has been designed in three stages, for construction purposes. Stage I serving 56,680 ha (140,000 acres), a quarter of the total culturable command area (CCA), has been completed. This stage comprises 42,105. ha (104,000 acres) within the old Paharpur Canal. System with the remainder constituting the so-called New Area.

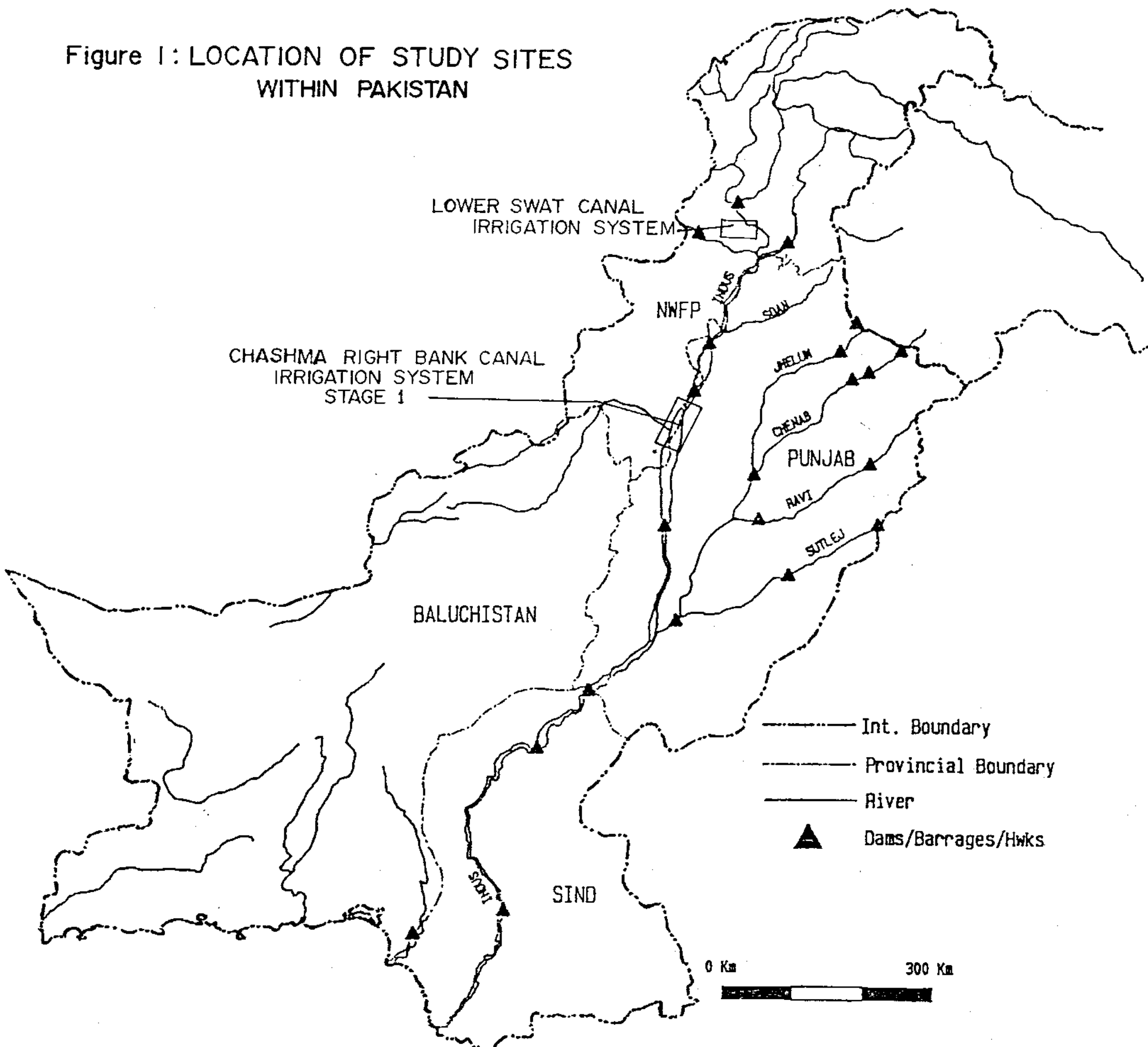
Stage II was still under construction at the time of study inception; only three of 13 distributaries, namely Nos. 5, 5a and 6, had been completed and made operative: The respective command areas, however, were in the initial stages of development. Inspection of those areas led IIMI to conclude that there was little scope for conducting any study-related activities under Stage II at that time.

Stage III, on the other hand, is still in the planning phase and not scheduled to be in operation until the late 1990s, perhaps the year 2000.

With the above information in mind, it was clear that the alternatives for selecting a study site in the CRBC system lay in Stage I. Three options could be considered: within the new area, within the old Paharpur canal system, or a combination of the above given the constraints in the LSC described in Sec. 1.3.2 below.

Both the new and old areas had their pros and cons with respect to their suitability for selection towards study implementation. For example, the former was much more physiographically representative of the future area's to be developed in stages II and III. In addition, the soils' were generally heavier, clay to silty clay, than those encountered in the Indus alluvial plain, which are sandy to silty loam, typical of the latter area.

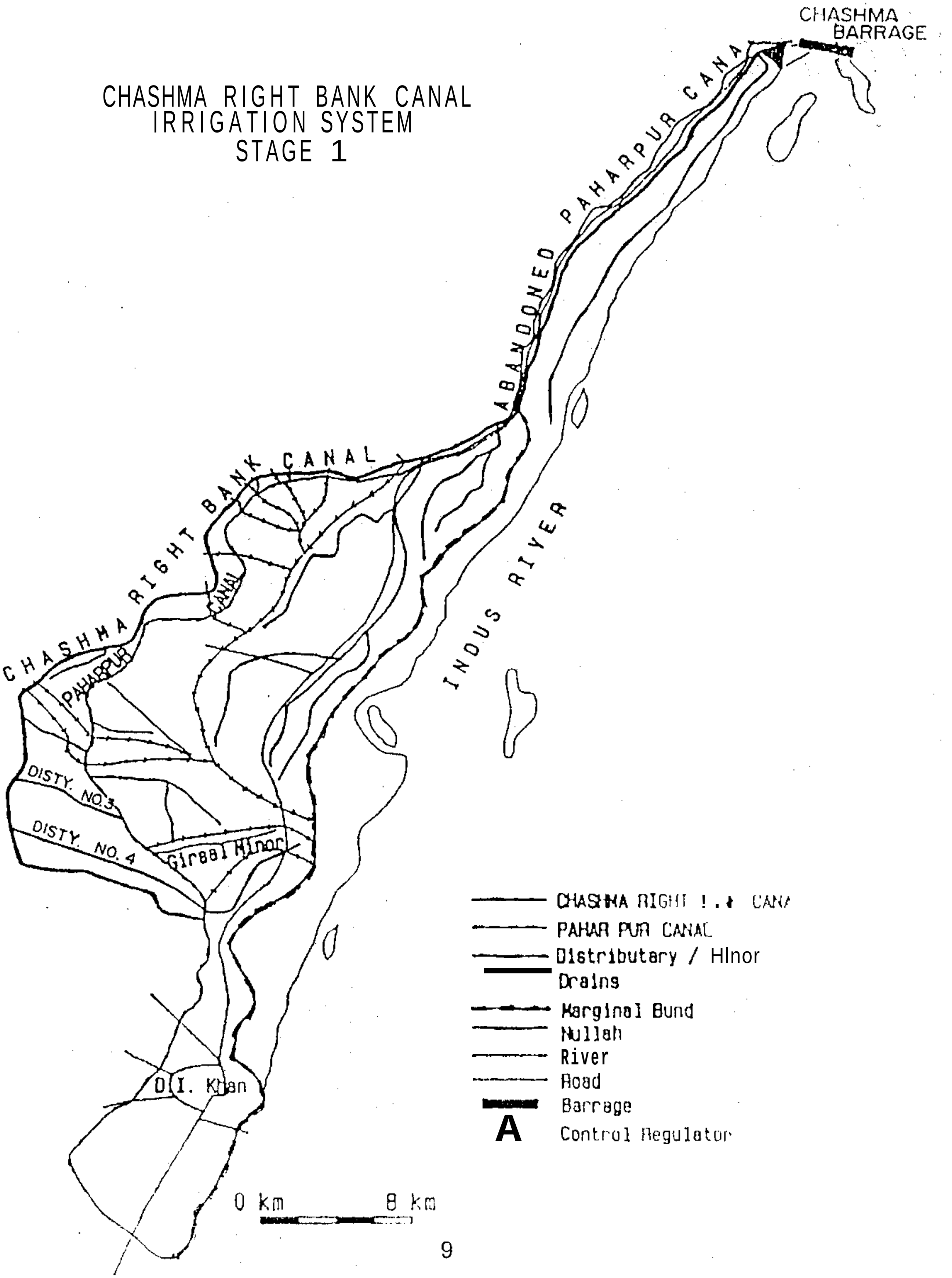
Figure 1: LOCATION OF STUDY SITES WITHIN PAKISTAN



On the other hand, the Paharpur canal system being a relatively old scheme had farmers who were experienced with irrigation practices. The new area, on the contrary, was obviously a new settlement where a large percentage of the occupants had little or no previous experience with irrigated agriculture, which would be more relevant to the conditions that would be encountered in the near future by stages II and III. Therefore, the choice was made to locate the study area in the New Area of Stage I. However, as a compromise it was also decided to select a minor canal within the Paharpur System to be included in the field activities.

Within Stage I four distributaries (numbers 1,2,3,and 4) were considered. However, it became clear that the first two, because of their small command areas, would not be good choices. That left numbers 3 and 4 for consideration. The team decided to start work on Distributary 3 which presented some practical and technical advantages, and then work on Distributary 4 as the study made progress. In addition, it was decided to select the Girsal Minor of the Paharpur system, which receives water from the "tail" of Distributary # 3 off-taking at RD 237+320. Figure 2 shows the general. layout of the Chashma Right Bank Canal Irrigation System.

Figure-2



CHASHMA RIGHT BANK CANAL
IRRIGATION SYSTEM
STAGE 1
CHASHMA
BARRAGE
ABANDONED PAHARPUR CANAL
CHASHMA RIGHT BANK CANAL
PAHARPUR
CANAL
INDUS RIVER
DISTY. NO.3
DISTY. NO. 4
Gireel Minor
D.I. Khan
0 km
8 km
PAHAR PUR CANAL
Distributary / Hlnor
Drains
Marginal Bund
Nullah
River
Road
Barrage
A
Control Regulator

Basic characteristics on the two research areas are summarized below:

TABLE 1. CRBC RESEARCH SITES - BASIC INFORMATION

ITEM (UNITS)	DISTY # 3	DISTY # 4	GIRSAL MINOR
		10002	1788
Lenath (m)	5058	10832	9085
Design Discharge (cumecs)	3.21	5.81	1.07
Canal bed width (m)	7.22	9.15	3.43
Full supply level (m)	0.92	1.03	0.67
# of Outlets (pipes)*	20	36	22
# of farmers (approx)	600	1260	450

After a careful field inspection of the selected canals, to assess structural conditions of pipe outlets and other structures, watercourses were chosen for the study that were evenly distributed per canal quartile. These are identified by the reduced (running) distances for each canal in Table 2 below..

TABLE 2. CRBC - SAMPLE RESEARCH OUTLETS

DISTRIBUTARY # 3	DISTRIBUTARY # 4	GIRSAL MINOR
570-L	1860-R	5767-L
690-R	3168-L	13526-R
6468-R	8980-L	21516-L
6468-L	12860-R	29650-TAIL
10150-R	20752-R	
11920-L	21516-L	
14810-R	24495-L	

Personnel were hired as early as September 1991 and a field staff house established in D.I.Khan. An 8-member field team under the direction of a Field Research Professional and supported by a Senior Field Assistant carried on field activities until November 1, 1993. They were supported at all times by IIMI international and local (Lahore-based) staff.

A detailed data collection process was pursued in order to both diagnose and improve system performance. By studying the actual operation and management of the system, with particular attention to water distribution, the study was able to identify management innovations geared towards overall system improvement. A mathematical simulation model, SIC, was introduced early in the study implementation stage to verify the main canal design parameters; the modelling was later extended to selected distributaries level in order to obtain a comprehensive notion of system performance. General data were collected to address the four main thrusts of the study: i) irrigation system operation, ii) supply and demand of irrigation water, iii) irrigation institutions, and iv) economics of irrigation.

Eventually, the study monitored four cropping seasons: Rabi 91/92, Kharif 92, Rabi 92/93 and Kharif 93. The entire study was carried out with the collaboration of the Provincial Irrigation Department, the Agricultural Department (through its Agricultural Extension component) and the Water and Power Development Authority, with all of these representations being in the North West Frontier Province. A complete set of the data collected are presented in Volume III that constitutes an integral part of the CBIO Final Report.

1.3.2 Lower Swat Canal Irrigation System

Although the original work plan was to undertake similar field research efforts in both project areas, the CRBC and the LSC, for reasons elaborated below, this work plan had. to be changed to develop alternative study objectives for the LSC.

The Lower Swat Canal Irrigation System (LSC) is located in the Mardan District of the North West Frontier Province (NWFP), the northwestern part of the Vale of Peshawar on the left bank'of the Kabul river plain. The main canal offtakes from the Swat river at Munda, and conveys water: (1) to feed the Sholgara Canal offtaking from the main canal at a distance of about 6.5 kilometers from Munda and serving a command area of 4,250 hectares (10,500 acres); and (2) to cover another 40 km distance to serve its own command area of 54,430 ha (134,500 ac). The LSC system consists of 10 distributaries having a total length of 112 kms and 19 minors having a total length of 133 kms. Figure 3 provides the general layout of the Lower Swat Canal Irrigation System.

LOWER SWAT CANAL IRRIGATION SYSTEM

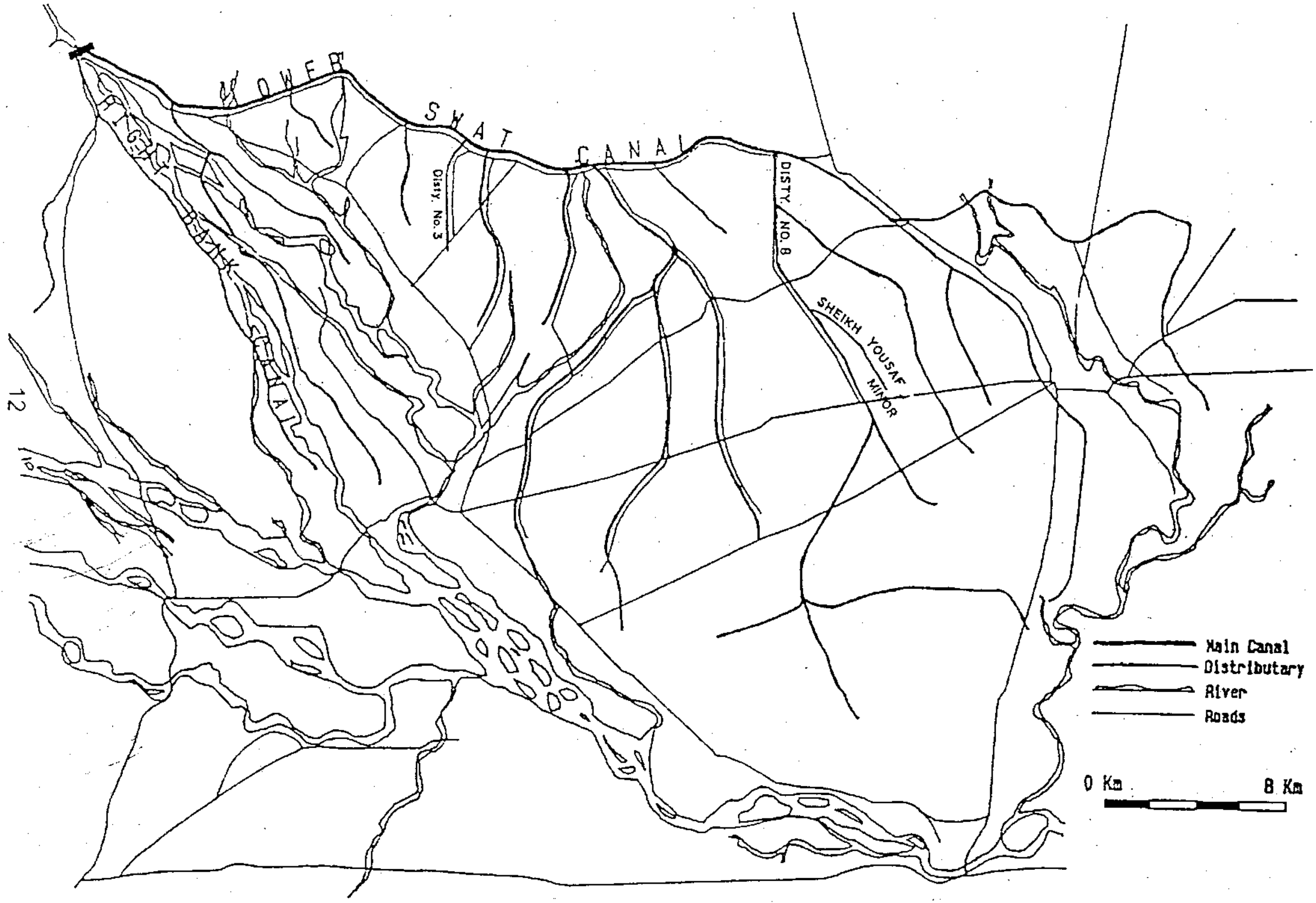


Figure 3

With an authorized full supply of **23.52 cumecs (830** cusees), the average irrigation allowance of the LSC was about 0.43 liters per second per hectare, or **6 cusecs** per **1000** acres, already in the higher range when compared with most of the canal systems in Pakistan. By the early **1970s**, the LSC system, like many others elsewhere in Pakistan, was experiencing a shortage of water for its increased cropping intensity in the command area, and needed to be enhanced in its capacity.

The remodeling of the LSC, however, was included as a part of the Salinity Control and Reclamation Project (SCARP) in Mardan. The primacy of the drainage component of Mardan SCARP had a significant effect on both the project design and implementation processes in the LSC rehabilitation effort. **As** mention'ed in the Water Sector Investment Plan (WSIP, **1990:4-21)**, based on **1981** estimates, about half.the project cost was for drainage work consisting of providing subsurface drainage for **29,555** hectares **(73,000** acres) and surface drains for **40,890** ha **(101,000** ac), and only **10%** was meant for canal remodeling work accounting for an area of **49,797** ha **(123,000** ac). Basically, the remodeling of the canal system appears to have attracted less attention at all stages of project development'.

A prolonged delay in completing the remodelling of the LSC system according to design, and a lack of preparedness on the part of the operating agencies to take over the responsibility for managing the remodelled system with additional infrastructure (gates, cross regulators, etc.), characterized a period of uncertainty in the early part of **1991** regarding the LSC study. Meanwhile, the Irrigation Department asked WAPDA to discontinue the use of the outlet gates which were a dominant feature of the new design, and not to install any new ones. As recorded in the SCARP Mardan Project (Cr 877-Pak) World Bank Review Mission Aide Memoire of **1/8/91,** this request also referred to an exception in the Sheik Yusuf Minor, the selected canal in which gates were to be installed for a pilot trial by IIMI.

IIMI, however, thought that an isolated effort of this nature would not be very productive, or not even be feasible, but would negate the study objectives indicated in the original proposal. A rapid appraisal, which was conducted especially to check on this aspect of feasibility and the usefulness of such a pilot attempt in the Sheik Yusuf Minor, confirmed that experimenting with an idea which appears to have been already discarded by the Irrigation Department could not be productive.

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[8] **Since the remodeling of the canal system was basically seen as an** effort **to enhance its capacity** for **the requirements** of **the already increased cropping intensity, it appears that the modernization** of **irrigation operations was not among the priorities of the initial design objectives, but as a concept was introduced fairly late in the design process.**

These evaluations encouraged the shift from a pilot trial effort in the LSC as originally .intended, to **a study of the circumstances leading up to the installation of gates in the LSC and the subsequent decision to remove them, and of the short term effects of increased water duties and related management issues.**

The LSC study activities for these new objectives included a review of planning documents, World Bank's project appraisal reports, and subsequent feasibility reports and aide memoirs; a study of design concepts and their implied or suggested management plans; interviews with key officials in the planning and operating agencies relating to the LSC project; interviews with farmers to assess their understanding on the implications of this new design and to obtain their perceptions of how the present situation is operationally handled; and a rapid appraisal to assess the remodelling effort and the current operation of the LSC system.

The study concentrated on two secondary channels ---the Distributary No. 3 and Sheikh Yusuf Minor offtaking from the Distributary No. 8. The Distributary No. 3 had been remodelled two years before and already was receiving a higher irrigation water supply, whereas remodeling work was under progress in Sheikh Yusuf Minor during 1992, thus having a negative impact on the canal water supply during that year. Field interviews were carried out in 1992 and 1993, using a sample of 12 watercourses and 69 farmers representing various locations along the two selected channels. Discharge measurements were conducted on these two channels in June 1993.

Chapter 2

OVERVIEW OF STUDY ACCOMPLISHMENTS & IMPLICATIONS

An implied objective of the study was to determine the feasibility of establishing a crop-based approach towards irrigation in Pakistan. The fact that this particular question was not explicitly mentioned as an objective in project documents does not diminish its importance.

Besides the normal resistance to change from a long-ingrained irrigation operations approach to a relatively unknown and unproven operational scheme, serious questions pertaining both to the institutional changes required and the potential environmental impact, had to be dealt with under the study.

The study on **Crop-based Irrigation Operations in the NWFP** has gone a long way to answer these questions. The findings suggest, that from a technical .viewpoint, irrigation systems in Pakistan could be re-directed to deliver water more in accordance with crop water requirements rather than just allowing an available water supply to pass through the system. This could be accomplished specially in those systems where higher water duties could be secured, infrastructure' could be added, and managerial capabilities could be enhanced. However, the mechanisms and resources required to effect that change remain formidable. At a minimum, it would require that a crop-based irrigation operations approach become policy at a national level and not just an isolated effort of a Provincial Government in a particular system; that is, there has to be a firm commitment on the part of the GOP.

The study's two-and-a-half years effort, indeed a very small time frame for the task at hand, has shown that just the increase of water duties alone will not accomplish the desired change. **A** significant enhancement of water control ---be it through a hardware or software-led focus--- must take place in .parallel. Unfortunately enough, a pure technical approach will not be sufficient either. The strengthening of the irrigation-related agencies, translated in better training of staff and a restructuring of the institutions themselves to make them more flexible and responsive to change, will be prerequisites for a successful transition.

In addition to the above, the degree of farmers participation in the operation of the system is an important point to be resolved. Among government agencies, the PID showed more concern than others under the perception that the new approach would allow farmers to "takeover" with the consequent displacement of irrigation personnel jobs. This is simply the result of a misguided impression, which the study went a long way to correct, that under the proposed scheme farmers would be operating the system's infrastructure. What crop-based really calls for is an enhanced farmer-agency communication, non-existent at .present, that will allow the latter to plan ahead given proper and timely information on crop-related practices on the part of the farmers. The degree of sophistication of the information would depend on the particular conditions of the system and the social-cultural level of the farmers.

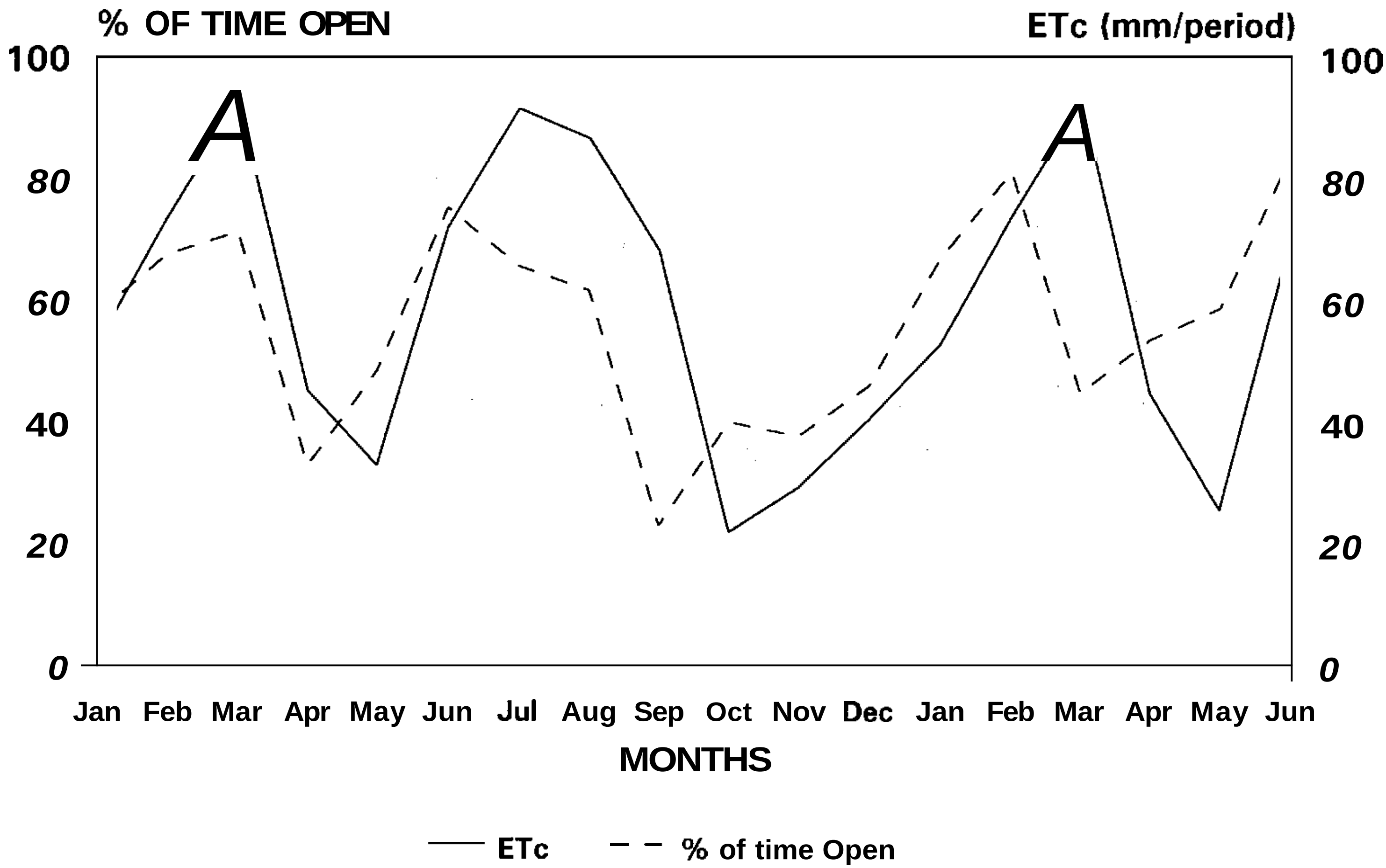
The study disclosed that farmers have a much better understanding of the soil-plant-water relationships than what they are usually given credit for. The relatively high water deliveries faced by farmers in Stage I of CRBC gave way to a water "refusal" approach by which they closed the head of the watercourse utilizing the *nakka*. Farmers proved to be well aware of the inconveniences and negative effects of too much water in their fields and acted accordingly. This repeated opening and closure of outlets, documented regularly during study field activities, constitutes a first in the context of Pakistan's irrigation research. The relationship between crop water needs and the percentage of time that farmers kept outlets open showed a remarkable fit (see Figure 4) and indicates that farmers, if given proper instructions, could play a very positive role in assisting the irrigation agency in improving irrigation operations.

Undoubtedly, given the stagnant conditions observed in the past few years 'in the country's agricultural production, there is a lot of merit in exploring ways to move away from an irrigation delivery process that served the sector well in the past, but seems to be incapable of doing so now.

On the environmental side, detractors of the crop-based concept are quick to point out that an increase in water duties will inevitably lead to rising water tables and the consequent salinization and unsustainability of the agricultural systems. The high cost associated with the remedy as they perceive it, an extensive surface and subsurface drainage system, adds to their skepticism. While these are legitimate concerns, and more so given the peculiar physiographic and.climatic conditions of the country --- particularly the Indus Basin where the bulk of the country's irrigation is concentrated--- they stem mostly from a misconception of the term "crop-based". Seeking a better match between the supply and demand for the irrigation water (the essence of crop-based) cannot, and should not, be immediately associated with an inefficient use of the water resource. There is, of course, the need to strike a balance between the requirement of the crops and the impact upon the immediate surroundings generated by that application.

Study findings did confirm an excess of water delivery in Stage I of CRBC, and in the LSC. In the case of the former this result, however, is not entirely surprising since it is of common occurrence in a system that is being built by stages and where the total design discharge is available to smaller areas that become operational. As other phases are fully developed, the excess water will tend to diminish with time. Nonetheless, the detrimental effects of this situation, as observed in CRBC, relates to farmers becoming accustomed to over-deliveries and establishing ***de*** facto water use rights in excess of system capacity.

Figure - 4
WATERCOURSES OPEN RECORDS : DISTY # 3
COMPARISON OF ETc WITH FARMERS BEHAVIOR



Jan 1991 - Jun 1993

A major gap in study implementation was the fact that no actual crop-based operation was ever established at the field level. Despite the negative reaction that this statement might generate regarding the perception of study accomplishments, it represents an actual situation and allows the underlying reasons for this drawback **to** be highlighted. For one, the failure in the implementation of the remodelling activities at LSC not only put in jeopardy the crop-based efforts, but also caused both agency and farmers alike to associate the construction-led problems with the introduction of the proposed innovative irrigation operations. At CRBC, the persistent notion that the system was in a state of flux and, therefore, that any intervention would necessarily be temporary, prevented the agencies from moving towards implementation of the proposed management changes. Drawing lessons from study achievements and pitfalls, as described in the previous paragraphs, it can be concluded that pursuing a crop-based approach for Pakistan's irrigation schemes, is a sensible one that requires considerable time before any real impact can be expected. In addition, serious consideration should be given to moving beyond the "pilot" study approach **to** full implementation in a particular scheme; only then can the real benefits and costs be properly assessed. Extending the study's coverage in the CRBC area would be an appropriate step towards that goal. That effort, however, will require longer-term support on the part of international agencies.

In retrospect, the pretense that such an innovative idea could be developed and established within a two year period (the project document really foresaw this happening after only one year of activities) was a gross miscalculation by the concerned parties. Paradoxically, after the field work had been terminated and preparation of final project documents begun, the interest in the potential of this concept is beginning to gain more favor. The opportunity to build upon earlier work should be clear to policy makers, as well as to irrigation-related professionals concerned with improving the productivity of the irrigated agriculture sector of the country.

A direct implication of project findings relates to the on-going efforts on the design and construction of Stage III of the Chashma Right Bank Canal Irrigation Project. Lessons learned from the study can be applied in order **to** avoid both design and operational constraints which have been identified, primarily, in Stage I but are also being faced in Stage II.

With respect to the design, the study has concluded that after seven years of operations the existing physical parameters for the main canal differ considerably from design values. and therefore need to be revaluated for Stage III, among these: roughness, seepage rates, canal slope, bed-width to depth ratio, critical velocities, etc. The lined section being in a "deep cut" also resulted in the off-takes being installed at a low elevation relative to the CCA, which results in submerged flow conditions from the off-takes; in addition, unnecessary "dead water" was created below the sill levels in the main canal. Finally, the lack of measuring devices downstream of off-takes hampers the reliability and equity of water distribution. All of the above limitations can be removed through the help of both simulation and field work.

On the operational side, the implementation of a structure calibration program to go parallel with the expansion of the area under irrigation, the improvement of communication facilities, the training of agency personnel and some organized behavior of farmers around watercourses and dislributaries can help diminish some of the negative experiences of the recent past.

Another, and perhaps the most important, impact of the study vis-a-vis Stage III of CRBC deals with the short-term water.availability outlook for this area. Conservative estimates indicate that if the present water delivery pattern observed in Stage I were to continua, between 10% and 15% of the area of Stage III would necessarily suffer acute water shortages; if stage II is operated similar to Stage I, then the water deficits for State III are more likely to 'be 15-18 percent. This percentage would further increase if cropping intensities were to move from the present 130% to the designed 150%, in Stage I. The implications of this situation should be a clear warning to both irrigation professionals and policy makers alike. The economic viability of the CRBC irrigation project is very much at stake.

Summarizing project achievements against the specific objectives that were pursued, as described in Section II above, it can be stated that good results were obtained for the first two objectives: i) the identification of a flexible management approach for irrigation operations. that responds to crop water requirements; and ii) increase the general understanding of concerned actors about crop-based irrigation operations. Certainly, the foundation for such an accomplishment has been laid. The project was less successful in advancing the other two objectives: iii) field-test and refine the management approach identified; and iv) evaluate the benefits and costs of crop-based irrigation to seek opportunities for implementation on a wider scale.

The reasons for the shortcomings in the latter two objectives can be well justified as follows:

> CRBC was found in need of a structures calibration effort, a necessary requisite for crop-based irrigation operations. While the IIMI team tried, as part of the' study's activities, to fill in this gap, the lack of an institutionalized water measurement and accountability program prevented moving forward with the field-testing of the proposed management innovations.

* The perception by CRBC's management that the system is in a "transitional" stage due to its on-going construction resulted in a strong resistance on the part of the agencies in trying out new operational approaches. IIMI was not successfull in convincing the participating agencies in going ahead with the proposed innovations.

* Since the new management approach could not be field-tested, it was not possible to carry on an economic evaluation under real crop-based irrigation operation conditions. It should be obvious that this last objective was intimately dependent on the implementation of the field trials.

The fulfillment of these two goals will await the continuation of these type of research efforts.

As a concluding point for this section ,it is proper to note that the project has generated a considerable amount of literature related to the concept of crop-based irrigation operations. Twenty-four publications, catering to different audience levels, have been produced and published in various forums both nationally and internationally. The list of these publications is given in the Annex-I, *Chapter* 3

MAIN FINDINGS---CHASHMA RIGHT BANK CANAL IRRIGATION SYSTEM

Project findings in this section will be presented according to the major subjects of interest as stated in the projects' Technical Agreement. Inevitably, as they are discussed, some overlapping will occur between categories since there is no clear cut division between these themes.

3.1 System Operation

The Chashma Right Bank Carial Irrigation System was designed to provide a higher water duty that would give the system, managers a greater degree of flexibility. This would eventually allow the establishment of a crop-based operation mode that would seek to deliver the irrigation water supply according to the demand or requirements of the crops. Instead, after seven years of operations in Stage I of this system, water is still being delivered on a continuous and fixed-supply basis, in disregard of crop needs; this latter method is the country's traditional approach to irrigation water delivery.

The water delivery dichotomy mentioned above is responsible for the relatively poor hydraulic performance of the system, as measured against CRBC's operational objectives. This was determined as part of the study's system evaluation activities.

Mathematical simulation conducted during the study dispel the notion that the present design of CRBC does not allow the system to be operated on a crop-based mode. Despite some limitations, which can, mostly, be overcome through purely management interventions, it is possible to deliver water in Stage I based, on crop water requirements. However, this technique requires close accountability of water distribution, something still not being developed by system management.

In connection with the above, the study reveals ---both from the simulation and direct field data analysis--- that physical limitations do exist at the main canal level in order to deliver water at low flows (minimum,,crop water requirements). While this can be overcome with the operation of existing cross-regulators it would result in very low flow velocities upstream of the control structures, thereby resulting in sediment deposition. An alternative is to increase the present minimum flow by 25 % which will result in better velocities.

Sedimentation is already occurring at the tail of Stage I, partly due to the low flows, but more so to water ponding in the reach as a result of present operating practices. The critical velocity required in different reaches, and the appropriate combination of working heads and gate openings, were simulated by the study, but are still to be field tested.

Analysis of main canal secondary data shows that seepage losses from both the unlined and lined section are in the range of 105 to 210 mm/day [4-8 cubic feet per second per million square feet (cfs/MSF)] for inflows less than 85 cumecs (3000 cfs). There' is slightly more seepage from the brick section as compared with,the concrete section. For higher discharges, seepage increases rapidly in the unlined section causing waterlogging *of* adjacent areas. This has imposed a limitation on management which has restrictions in operating the canal at the maximum possible flow,

At the distributary level, the simulation studies indicate that water can be delivered to all offtakes at fairly low discharges, but again with sacrifices in the design velocity, as well as requiring a high level of operational input in order to maintain the water head at different control points. At present, both PID staff and farmers often utilize *karries* ***(stop-logs),*** since no gated control structures are available, in order to raise water levels upstream of the weirs. Thus, again, some design limitations can be replaced by increased managerial inputs.

Performance analysis of outlets, both daily operational data and simulation, show that: i) actual outlet discharges have little correlation with the design discharges; and ii) at distributary design discharge pipe outlets are taking between 80 to 300 % of design flow. While these outlets are meant to be temporary, they cause significant disturbance to the agency and the irrigation practices of farmers.

Limited measurements conducted on water losses in the distributaries yielded values of 112 to 147 mmlday (4.3 to 5.6 cfs/MSF) , that translates into a seepage flow per unit length of approximately 15.2 Ilslkm. This seepage rate is quite comparable with the values used in the CRBC feasibility report (1987) of 258 cfs from 1.9 million feet of canal length or 13 l/s/km. Thus, this seems to be a reasonable seepage rate that can be utilized during future work in the area.

Results on measurements of water losses conducted at the watercourse level indicate that seepage losses from unlined reaches are in the range of 430 to 864 mm/day (16.4 to 32.8 cfs/MSF). This loss will remain independent of actions taken to remove all other managerial types of losses. Losses in lined stretches were found to be smaller, ranging from 0 mm/day in well maintained watercourses with no signs of breakage in the lining, to 690 mm/day (26.2 cfs/MSF) in.those with less appropriate maintenance conditions and where leaks from *nakkas* were present. Again,. these values were found' comparable with those reported in similar canal conditions in the Punjab of 1120 mm/day (42.6 cfs/MSF).

The routine monitoring and data recording process advocated in the system's operational manuals, which is to be used as a feedback mechanism for project evaluation, is almost entirely missing No canal structure has been calibrated by the concerned agencies over the past six years of system operations.

A detailed evaluation of the system, undertaken during the study, in which objective setting, as well as operational and output performance-related indicators, were carefully determined and analyzed. The results showed that system performance could be improved considerably. Twelve indicators revealed that the performance of the system

is relatively better at the watercourse level and then deteriorates further upstream at the distributary level and the main canal, in that order. The evaluation thus suggests that improvement efforts should concentrate at the main system level (canal and distributaries) with less emphasis going towards the more farmers associated activities.

In general, the findings related to the operation of the system indicate that considerable improvement from present performance levels can be achieved through additional managerial interventions like an enhanced accountability in water distribution, optimization of control point operations, and staff training.

3.2 Supply and Demand of Irrigation Water

A main finding of project activities refers to the irrigation supply over-deliveries, far and beyond the demand, that currently exist throughout Stage I of **CRBC.** The excess supply has been documented through various independent, yet linked, procedures, among these:

i) monitoring of daily flows at strategic points in the system, and comparison of these with expected targets;

ii) the emergence *of* a farmers water **refusal** system by means of opening/closure of pipe outlets, a unique farmer behavior not readily seen in other irrigated areas of the country,

iii) documentation on cropping patterns and cropping intensities through time which show an evolution towards higher water demanding crops;

iv) limited night irrigation observed in the area, meaning that farmers seem quite content with the diurnal allocations;

v) farmers are moving away from the traditional *warabandi* water delivery scheme because of an ample water supply: and

vi) the parameter Relative Water Supply (RWS) at different levels of system operation consistently exceeds unity, which means that the water supply is greater than the demand for water.

Each one of the procedures utilized above to monitor the supply/ demand relationship provided it's.own interesting findings, as indicated below.

Data analysis from daily flows indicate that while these' followed a trend that 'is roughly associated with crop water requirements, for example higher average seasonal flows during *Kharif* than Rabi, there is no correlation of flows between operations at the watercourse level and at higher levels in the system. At the distributary and main canal level, the basic objective of the operating agencies is to run the system within a certain range of discharges to cope with issues related to the operation of the canal itself rather than the.demand for irrigation water.

Further analysis 'of monitored flows from the Chashma Barrage revealed that water releases are fairly constant among seasons without regard to irrigation demand; this further confirms that there is yet no set objective for following a crop-based approach. The flow variations observed in the headwork releases, over time, were found to be associated with repairs and/or maintenance work at the barrage and the normal canal closure period of the main canal.

A rather unique feature found in CRBC relates to the opening and closure of the pipe outlets from the distributaries. The particular configuration of the watercourses, with the provision of a simple check structure at its head (downstream side of the outlet), allows the farmer to manipulate at will the amount of water that he **does not want *to* receive.** Because of the great potential that this simple farmer practice could offer in moving towards a more flexible approach in system operation, the opening and closing of outlets was monitored from the study's inception. Results show that throughout the period monitored (four full cropping seasons) there has been at least a few outlets **closed** at any one time; suggesting over-deliveries that the' farmers want to avoid.

Monitoring of the cropping pattern in the area during the study period indicates that a significant deviation from the designed cropping pattern has taken place. While economic reasons are certainly playing **a** role in this change, the fact that crops having a high.water demand are being grown on more and more land suggests that access to higher than expected irrigation supplies are also a principal driving force. Most notably, rice with a designed cropping intensity of 2 % shows an increasing trend as it reached 23 % in *Kharif* 92 and 26 % during Kbarif 93. Likewise, sugarcane has gone from **5 %** in Kharif 92 to 9 % during Kbarif 93, although still below the expected 15 % cropping intensity used in the design. Figure 5 presents the type of cropping .pattern monitoring that was carried out during project implementation: in this particular case, for Watercourse 11920-L of Distributary # 3.

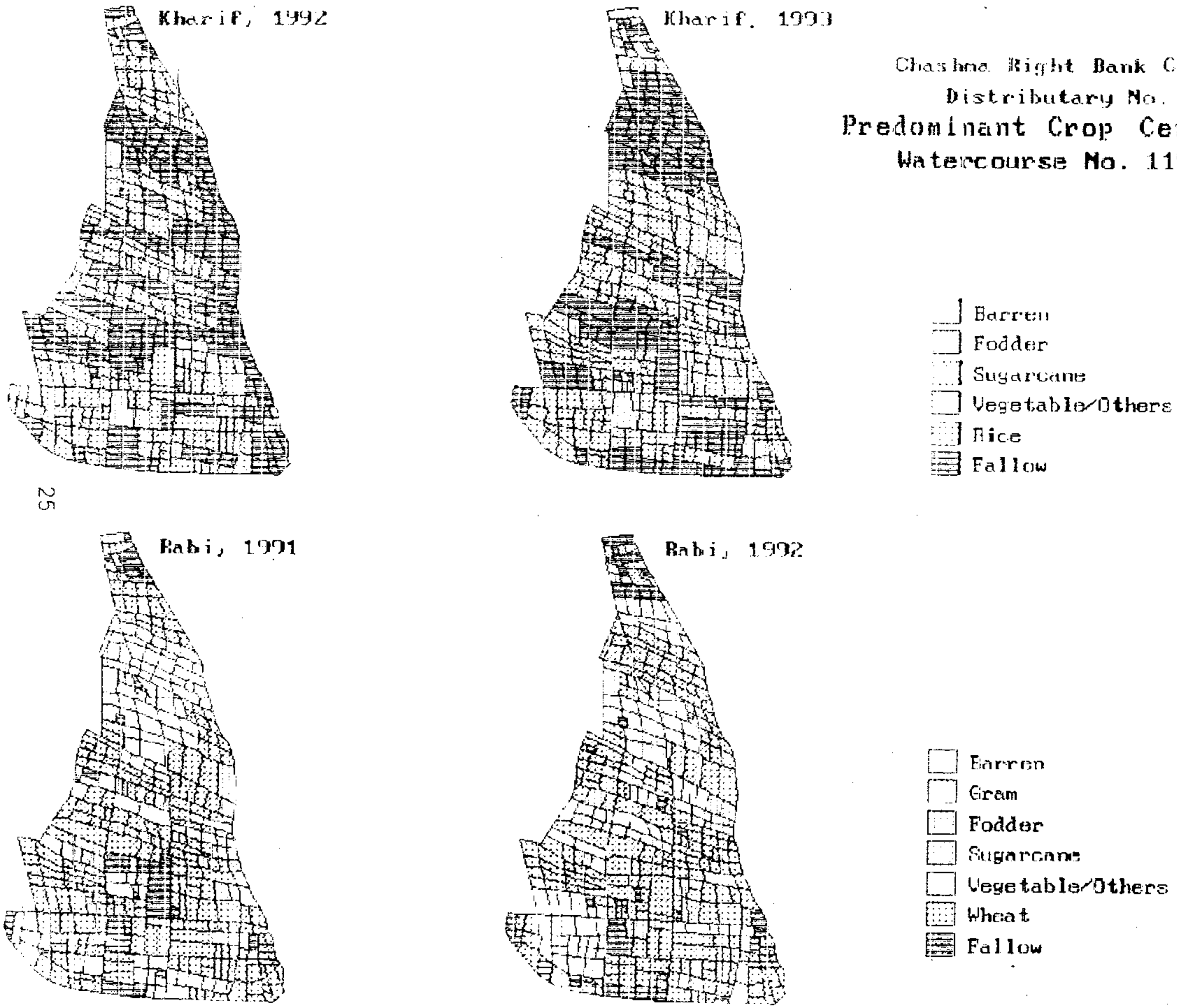
Yearly cropping intensities remained around 130 % during the two periods, falling short of the 150 % target. The deficit occurs during the Kbarif season in both cases. Given the shift towards rice and sugarcane indicated in the paragraph above, it is unlikely that the cropping intensity.can increase beyond the present level. Farmers have chosen to plant less area in order to cultivate two high water requirement crops which are both economically and socially more acceptable.

Figure 5

Chashma Right Bank Canal

Distributary No. 3

Predominant Crop Census for Watercourse No. 11920L



Regular assessment of farmers practices (which also included structured and open-ended interviews) shed light into the status of night irrigation in the area. During the *Rabi* seasons, no evidence of significant farmers nocturnal irrigation practices by farmers was documented. In the *Kharif* seasons, although water was left running onto the rice fields, rather than using structured night irrigations per *se* the practice was more related to the excess water readily available.

Under the same set of activities just described above, the absence of a formal *warabandi* scheme in the area provided another indication of water abundance. In the areas under study, several types of unstructured and informal on-farm water distribution methods were recorded. In only a few watercourses has there been a serious attempt by farmers of approaching the PID for the establishment of the traditional water distribution method. Project field personnel often recorded two, three and more farmers sharing a particular water turn. In all cases, the perception by farmers of being able to draw water as needed led to this unusual water sharing with little, if any, major conflict' reported

A final element to assess the supply-demand equation was the utilization of the parameter Relative Water Supply (RWS) which is in fact the ratio of the two terms. The RWS was obtained at the main canal, distributary and watercourse levels on a weekly basis throughout the duration of the study.

In a broad statement about this parameter, the values of RWS were always above unity at all system levels, thereby indicating that water requirements 'were being generously met. The values of RWS increased when moving "up" in the system from watercourses to the main canal, confirming the earlier statements made above about system performance.

As a general conclusion of this section, the findings suggest that unless a **sustained reversal** in the current over-deliveries of irrigation water takes place, there is a real danger of experiencing water shortages 'at the tail of the CRBC system (Stage-Ill) in the not so distant future. Likewise, the excess has already created the perception among farmers at the head (Stage I) that the system is water-abundant, thereby setting a precedent that will become a headache for management, when the trend needs to be reversed as the other stages become operational. More on these two points will be said later in the report.

3.3 Irrigation Facilities

The simulation studies undertaken at the main system level show that the role of existing cross-regulators is indispensable in moving to crop-based operations. However, the way these are being operated is related more to the safety of the canal and facilitation of system construction than to the crop water requirements, *per* **se.** The studies also indicate that while consideration of extra regulators could have some merit from an operational improvement point of view, the disruption that would occur on the canal regime, as associated with the possible additions, suggests that managerial-based improvements are by far a much better choice.

In addition to the above, at the main canal level, several problems related to the existing structural layout were identified; most notably, the conditions at the transition point between the lined and unlined sections of the canal. A combination of water ponding up-stream of the transition wall and the section reduction due to the transition, itself, creates a canal under-capacity problem that has a negative effect on system operations.

The disposition of both the head offtakes of distributaries # 1 and 2 forces management to pond water at the tail-end of Stage I in order to raise the hydraulic head to properly supply these distributaries. In addition *to* the sedimentation problem already mentioned elsewhere, this operation also causes undesirable backwater effects and hampers equitable water distribution at low flow demand levels?

At the distributary level, many of the outlets are over-sized and hence are drawing water beyond design discharge levels; the limited pipe diameters readily available in the market, undoubtedly, contributed to the problem. Other reasons are the poor location of the outlets in respect to the command area, tampering of structures by farmers, and the disrepair of outlets due to poor maintenance.

The absence of scapes at the watercourse level constitutes a disadvantage to management towards the implementation of crop-based irrigation operations. At high flows, the likelihood of on-farm flooding increases which, in fact, diminishes the operational alternatives to the concerned agency under these circumstances. It can be stated that the current mode of water deliveries is already having an impact in those areas where drainage is impaired by an impermeable subsoil.

3.4 Irrigation Institutions

The CRBC system is viewed by many as a new canal system designed with an increased water allowance primarily meant for crop-based irrigation operations. However, the common understanding is also that a shift from the traditional supply-oriented operations cannot be introduced easily. In the absence of a clear operational plan, the agency staff and farmers have both started to take a cautionary approach to irrigation water management in the completed sections of the system.

Irrigation practices in the new areas are still at an evolutionary stage, with neither the traditional *warabandi* strictly in place, nor with any alternative set pattern in water distribution. In some watercourses, farmers themselves have taken the initiative to prepare *warabandi* schedules with the help of the patwaris, and yet in another few cases, official *warabandis* have been drawn. In either case, there is considerable flexibility in practice. Meanwhile; in an environment of abundant water supplies, the farmers have: (1) proceeded to grow more cash crops that have also provided fairly satisfactory yields; and (2) taken the liberty to open and close the outlets at their will. However, there are no institutionalized mechanisms for farmers to make collective decisions.

The agencies have not taken much initiative to intervene in this evolving development situation: Through field interviews, an inference can be made that the involvement of the Irrigation Department in Stage I can be characterized by a continuing emphasis on the remodelling aspects of the adjacent old system, and a general reluctance to interact closely with the construction agency, WAPDA, which has a dominant role in the main system operations. Similarly, the involvement of the Agriculture Department in the new areas is also a modest one. Farmers do not acknowledge a strong linkage with officials, whose services at this stage could be seen as crucial for initial agricultural development.

During the study period, a gradual, but distinctly marked, increase in interest could be seen among the officials and farmers towards improving system's inanagement practices. As the concentration shifts from the present pre-occupation in the development of CRBC Stages II and III, a greater involvement can be expected.

3.5 Economics of Crop-based Irrigation Operations

The changes in water duties have had a favorable impact on the agricultural production in the projecf area. The new command area of CRBC now has much higher yields than the previously rainfed area. For the Old Paharpur command area, the impact of the increased water duties has also been significant, with a shift towards more crops with high water requirements, i.e. rice and sugarcane, and an important increase in crop yields. The analysis of rice and wheat yields in the Girsal Minor of the Old Paharpur command area shows that only part of the yield increases is related to the changes in water duties in the area, with the increase in the use of fertilizers also responsible for part of the recorded gain in productivity. However, it can be argued that the availability of additional water has prompted farmers to grow higher cash value crops, that also justifies the increased fertilizer investments.

However, several concerns arise when looking at the current performance of the irrigated agriculture in more detail. These are summarized in the following paragraphs.

Rice and wheat yields per unit area collected by IIMI for sample fields in the command area of Distributary # 3, Distributary # 4, and the Girsal Minor are higher than the average values reported by government agencies for the NWFP and the Punjab. However, they are significantly lower (especially for the wheat crop) than the values expected after 5 years of system operation, or the yields utilized in several project documents for the economic justification of the project.

The comparison between distributaries # 3 and # 4 and the Girsal Minor shows that, while wheat yields are comparable for the two areas, rice yields in Girsal Minor are significantly higher than those in the command areas of distributaries 3 and 4. The longer tradition in irrigated agriculture of farmers located in the Old Paharpur command area could explain this difference.

The impact of high irrigation water supplies on the cropping intensity has been significant: after 5 years of operation, cropping intensities are at, or even higher than, expected levels. However, the importance of rice and sugarcane is much higher than anticipated, and is still increasing. With the resulting higher irrigation water requirements, the cropping intensity in the CRBC Stage I command area is not expected to increase significantly, nor to reach its expected level of 150 percent.

Lower yields and lower cropping intensity than designed are expected to have a significant and negative impact on the overall economic performance of the CRBC irrigation project. The current performance of irrigated agriculture in CRBC Stage I, along with the constantly increasing costs of construction recorded since the beginning of the project, will have *to* be incorporated in the economic appraisal of CRBC Stage III, whose design is currently under preparation.

The significance of rice in the Stage I command area will have an important impact on the distributional aspects of the project. With the current cropping pattern, the peak irrigation water requirements of Stage I are already 8 percent higher than the designed maximum peak requirements. In terms of quantity of water, that would mean less canal water supplied to the Punjab, or, if the allocation of water to the Punjab is respected, less irrigation water available for the tail of the NWFP portion of the system,

As this inequity, not only in terms of irrigation water supply but also in economic terms, is not foreseen as being acceptable, there is a need to integrate the future needs of the command areas of the three stages with the two Provinces in the current management of the CRBC irrigation system. Moreover, if the feared inequity would eventually take place due to the unwillingness to modify the current operation, lower cropping intensities and yields would be expected for these tail areas, with direct negative consequences for the economic viability of the CRBC irrigation project.

The economic analysis performed under the CBIO project to investigate the relationship between irrigation water supply and agricultural production has shown that farmers are rather rational in their decision making. It has also highlighted that some, of the assumptions regarding agricultural production were made at the appraisal stage of the CRBC irrigation project without enough evidence or analysis. A typical example is the design cropping pattern used to calculate the peak crop water requirements and to perform the economic appraisal of the project. The discrepancy between design and current cropping pattern has in fact two origins: (i) the relative over-supply of canal water (described above) that has induced farmers to plant more rice than expected; and, (ii) inappropriate assumptions regarding farmers' cropping decisions due to an inadequate analysis of irrigated agriculture in the area.

It is rather astonishing to know that the area under rice included in the original design cropping pattern was only 2 percent, while the Paharpur Canal Irrigation System with lower water duties had already 4 percent of its CCA under rice in 1970. Some of its distributaries and minors had even much higher percentages under rice; for example, the Girsal Minor had already 13 percent. With the higher water duties under the CRBC irrigation project, a further increase in the area under rice could have been foreseen. As part of the study, economic modelling of sample farms of distributaries # 3 & # 4 of CRBC, taking into account physical and economic constraints of farming systems, confirmed that, for the design water duties, at least 20 percent of the area under rice could have been expected.

3.6 Policy

An important policy-related issue, directly affecting system operation, was the lack of a decision on the part of the concerned government agencies as to the *modus* operand; of the water releases from the Chashma Barrage into the CRBC system. If releases are to strictly adhere to the designed crop water requirements, management options for operating the main canal at higher than necessary discharge values, particularly during periods of low crop water requirements, would have to be reviewed. On the other hand, if some flexibility in these allocations is possible, then managerial rather than structural-based interventions may be more appropriate.

Very much related to the lack of defined policy on barrage water deliveries is the fact that the study found that the mode of operation of the CRBC irrigation system itself in not clearly defined in either planning or design documents. No policy decision in this regard appears to have been taken, and the result is the permanent disagreement among operating agencies as to the future operation of the system.

As the CRBC irrigation system moves from the construction to the operational phase, plans for a rational maintenance program will be required in order to ensure the physical sustainability of the CRBC irrigation system. At present, the funds allocated for the maintenance of the distribution system are significantly lower than the designed allocations. And there is no clear procedure for a rational and optimal allocation of the scarce financial resources.

With the increasing budgetary constraints of the line agencies, a major improvement in the amount of water charges collected would be required in order to cover a larger share of the Operation and Maintenance costs as specified in the PC-I document for the project. The analysis of the impact of an increase by 30 percent of the current level of water charges shows that this increase would have little effect on farmers' economic performance and would be acceptable. A larger increase of water charges (i.e. 300 rupees per hectare for all crops), to enhance the self-financing capability of the system, would have a significant impact on farmers' decision making. Their gross income would be reduced. Also, they would shift their cropping pattern towards less water consuming crops. This would ultimately reduce the demand for irrigation water.

However, increasing the level of water charges would have no impact on the amount of water charges collected if other components of the financing system are not modified simultaneously. A proper assessment and collection of water charges, a direct link between water charges collected and funds allocated to the Operation and Maintenance of the system, a clearer relationship between the level of water charges and the quality of irrigation services received by the end-users, are important ingredients that need to be considered in order to improve system performance.

Chapter 4

MAIN FINDINGS---LOWER SWAT CANAL IRRIGATION SYSTEM

4.1 Design-Management Interactions

Planning for a Gradual *Shift to* Demand *Irrigation*: The planning documents for SCARP Mardan indicate that the introduction of demand-based irrigation operations in the remodelled LSC system was foremost among the design intentions. For this purpose, the structures required for a demand system (canal head regulators, wasteways, flow and discharge controls, and gated outlets) were to be provided. However, recognizing the possible constraints on acceptance of a demand system by farmers and agency staff, the 1981 Final Project Plan (FPP) advocated *a* cautious approach. The FPP recommended that general designs should be developed in such a way that structures could be conveniently and economically adapted, by a later addition of gates and control devices, for a demand system at a future date, while all canal sections should be enlarged according to the requirements for demand irrigation.

The general design criteria included: 1) remodelling of watercourses and supply channels to an initial capacity of 0.77 lps/ha (11 cusecs per 1000 acres) with provisions for increasing to an ultimate capacity of 1.33 lps (19 cusecs per 1000 acres); ii) designing of all outlets as proportional modules, but providing for the installation of a gate at a future date when demand for regulation of the watercourse flow occurs; and iii) designing supply channels with adequate check structures and wasteways so that water can be delivered under fluctuating crop water requirements.

Lack *of* Consideration for the Interim Period: Although the systems' peak capacity requirements were determined, considering the variations in cropping that could be anticipated, the structural requirements for coping with the seasonally variable crop water requirements and the implied variations in the channel flows appear to have been given less consideration in the design, probably for want of a operational plan at that stage. Although an operational plan was developed later (Operation and Maintenance Manual, April 1985), which recognized the need for a progressive shift *to* demand-based operations, it had not sufficiently explored the options for systems operation in the interim-period.

In remodelling the LSC, controls have been provided, as designed, at all diversion points and at the drop structures, but without considering the specific need for cross regulators at specific locations. These controls are hardly in use. The main reason is the absence of a system of operational rules and the lack of required operational staff or users' involvement. The other reason is that, instead of the intended flexibility in water delivery, the same traditional supply-oriented system of uniform flows is still the preferred practice, despite the increased water supplies. However, as the escapes that were to be provided on all distributary channels have not been constructed as intended in the design, a liberal use of water irrespective *of* crop water requirements is fast becoming a normal practice.

Present Management Situation: The remodelled LSC system currently demands a fairly concentrated management effort. The operating agency has not only to cope with the problems of a physical system which is still in a confused state due to the acceleration *of* construction work for the last stage, but also to work out an appropriate operational plan in the context of a new remodelling design. No clearly detailed operational plan has been developed during design that provides the necessary decision rules for the various control structures, or diversion points.

The situation relating to the watercourse outlets illustrates the present status. Depending on the design, the outlet *(mogha)* to a watercourse can determine not only the quantity of water to be used, but also the scope and nature of interactions between the operating personnel and the water users, and among the users themselves. The outlet design can also determine the type of procedures and rules that have to be adopted for these interactions. In this sense, the outlet design can decide whether the institutional arrangement at this agency-user interface is to be agency-dominated or user-oriented. The design of a gated outlet in the LSC has been decided with a narrow view of shifting to a demand based irrigation system, but without a full consideration of its implications in terms of institutional requirements. With the gated outlets, as provided in the design, constant adjustment of the gates would be an important operational requirement as the outlet discharge would vary with fluctuating upstream head. However, a lack of preparedness in this regard has resulted in not having in place either the necessary operating staff, an operational plan, or the water users associations.

Even what the designers have planned for management appears to have been neglected by policy. The design stage intentions regarding short-term and long-term operation and management were mentioned in the 1985 Manual. These recommendations have not been seriously pursued during remodelling and have also escaped policy attention. Also, the same organizational structure that existed before the remodelling exercise has remained unaltered, but it has also been entrusted with additional responsibilities. It has to fine-tune the hurriedly completed physical infrastructure at the distribution level, and also to sort out the urgent operational needs of the recently remodelled system.

Thus, the present operational conditions in the system reflect the effect of a lack of consideration towards design-management interactions in the remodelling exercise.

4.2 Design Changes During Construction

Original Design: In the Final Project Plan, the proposal was to install Adjustable Proportionate Modules (APMs) as outlets, which deliver supplies more or less in proportion to the supply in the feeding channel, but with a modified design allowing the outlet to be converted to gated operation at a later date when the users would be ready to take over greater responsibility.

Midcourse Changes: In actual construction, however, instead of the proposed modified APM, an entirely different design was adopted. This design was for an over-sized concrete pipe outlet, which would act as submerged orifice, be equipped at the entrance with vertical slide gates, have stilling wells to measure the upstream and downstream heads for calculating the discharge. The change in design seems to have taken place after the planning stage, as no planning document refers to this outlet, or to the intention of starting off immediately with a demand-based system having such gated outlets replacing the traditional APMs. These gated outlets were installed in the distributaries of the upper reaches of the system, including Distributary No.3 and in the Sheikh Yusuf Minor where they were specially installed for experimentation purposes.

The changed design incorporated gates in the outlets without any form of locking arrangement, resulting in widespread tampering of the gates wherever they were first installed. The farmers in this area, especially in the head reaches of the distributaries, quickly reacted to maximum openings of the structures, thereby availing full irrigation supplies at their convenience. Consequently, tail-end farmers were not receiving enough water during the peak demand period and were compelled to irrigate at night when head-end farmers were not irrigating anymore. To take control over the situation, the authorities intervened and introduced locking devices to the gates.

Towards the completion of construction work, the Irrigation Department, while taking over the remodelled system from WAPDA, started to install yet another outlet, a different version of the original APM. This version is an improvement by changing the traditional APM with the addition of a gate instead of the roof-block, and appears to be a much simpler structure than any of the outlet structures designed by the project.

4.3 Short-Term Effects of Remodelling

Increased Supplies: The average 10-day flow data at the head of the Lower Swat Canal, kept by the Irrigation Department for the period 1988 to 1992, show that the supplies have gradually increased during the period. In 1992, the supplies at the head of LSC were about 60% more than that of 1988. The maximum 10-day average discharge in 1992 was 39.2 cumecs (1383 cusecs) as compared with 24.3 cumecs (858 cusecs) in 1988. This increase in water supplies does not reflect the full supply level, as the construction of the aqueduct in the main canal was completed only in late 1992. During 1993, the supply at the head of the LSC was expected to increase further to reach the new design values. The remodelling exercise has clearly brought about an increase in supplies at the head of the LSC. Interviews with farmers confirmed this situation.

Reduced Control Over Wafer: A conclusion from the field interviews is that there is a lack of control in the distribution of the supplies in the system. This situation is exacerbated by the inability of operating authorities to ascertain the quantities of water delivered at various points in the system. There are three sets of outlets of different design, drop structures and radial gates, and none has been .provided with rating curves.

Discharge measurements taken during the rapid appraisal confirm the above conclusion. On *two* days during a petiod of peak demand, the discharges at the head were measured, and it was found that the Sheikh Yusuf Minor was drawing more than its design capacity, 108% and 129 % of the remodelled design capacity, whereas the discharges entering Distributary # 3 were only 83% and 87 % of the design. This represents an apparent anomaly as Distributary # 3 is located at the head of the system, whereas Sheikh Yusuf Minor is towards the tail-end, and can be explained only by the free access that the farmers in Sheik Yusuf Minor recently gained from the newly increased water allowances in the channel, and the inequitable social background of these farmers.

That there is inadequate control on the operation *of* the outlets also comes out clearly from the finding that there is no consistent trend in the outlet discharge in relation to the inflows *of* the channels. Some outlets were drawing much more than the design amount; one outlet in Sheik Yusuf Minor was getting more than 3 times its design discharge, clearly demonstrating the ease with which the system could be arbitrarily used.

Increased Cropping Intensity: Interviews with the sample of farmers representing head, middle and tail reaches *of* the two channels indicate that, in general, the remodelling has provided them with increased water supplies, and helped them to increase cropping intensities. On the average, cropping intensity in the LSC has increased from 160 percent before remodelling to almost 200 percent. Important changes include increased mixed cropping (crops grown within the orchards) and intercropping (two crops sown together). Farmers have also reported an increase in the cropping intensity with three crops instead of two during each year as a result of remodeling.

Changing Cropping Pattern: The increase in cropping intensity has been accompanied by a change in the cropping pattern. The trend for cultivating .cash crops, like tobacco and potato, hasemerged significantly in the head reaches of the LSC. The cropping pattern during the period from 1980 to 1991 reveals that the area sown under high water requirements crops, such as sugarcane, has gradually increased during the period.

Flexibility in Sharing of Water Water distribution below the outlet using the warabandi has been the normal practice in the LSC before it was remodelled. With increased water supplies, the time to irrigate a given plot of land has significantly decreased, and has allowed some flexibility to be enjoyed by the farmers, deviating from the strict warabandi practice. Farmers tend to irrigate only during day time and rarely at night, except during the peak demand period. Only 28 percent of the farmers interviewed reported the need to irrigate during night.

Reduced Water Disputes: Interviews indicate that remodeling has had a considerable impact on the socio-economic conditions of the farmers, a significant change being the marked reduction in water related disputes among the farmers. All the farmers are sensitive to their water turn duration, although they do not strictly adhere to the timings. During the periods of high demand, farmers tend to trade or share water, outside their strict turns, demonstrating a fair degree of cooperative behavior.

Effect of Improved Drainage: In contrast to responses in Distributary # 3, the 33 farmer respondents representing 6 watercourses in the head, middle and tail of the Sheikh Yusuf Minor reported that much of the economic benefits have been due to the improved drainage system rather than due to increased supplies. The new tile drainage system is perceived as having helped in the removal of excess water and salts from the soil. However, this improved drainage has also abetted the rapid percolation of water, thus necessitating more frequent irrigation of some crops, particularly sugarcane.

4.4 Farmers' Perception on New Structures

According to farmers, the control of gated outlets by the Irrigation Department staff offered them the least flexibility in making optimum use of irrigation allocations, thereby resulting in situations that had existed prior to the system remodelling. This in effect, in their opinion, does not justify the expenditure towards purported improvements in the physical system. Farmers perceive the gated outlet as an opportunity for the officials to advance to this additional point of control, and add to the existing official pressure on them.

In case of Sheikh Yusuf Minor, farmers reported that although the gated outlets have been installed recently, they are not operational yet. In some watercourses, the farmers are using both the old open flume type outlet as well as the newly installed outlet.

Regarding the radial gates in the distributary, farmers observed that their expectations were high for a more sophisticated operation, but they now had an apprehension on the type of control by the operating staff for these structures. For example, while it is easier to lower the radial gates along the distributaries, it is difficult to open them subsequently, thereby necessitating strict monitoring by ID staff to prevent canal breaches.

4.5 Institutional and Policy Issues

The initial rehabilitation objective was to enhance the LSC system's capacity to meet the requirements of an increased cropping intensity., but when the capacity enhancement was meant to meet the peak water requirements, it was an extrapolation of this initial objective by the project planners; which also established the concept that the remodelled irrigation system should be used to meet the crop water requirements. This concept implied a demand-based irrigation system. Subsequent. evaluations of prevailing management institutional conditions, planned for a gradual change from the present operational mode to a demand system. All the'interviewees from the operating agency acknowledged this initial understanding. It is clear, therefore, that the decision to install part of the physical infrastructure (cross regulators in the distributaries and gated outlets) that was meant for immediate demand-based operations was a deviation from the common understanding, and was taken without much consultation, or a thorough appreciation of the implications.

The O & M Manual is based on some broad assumptions for suggesting demand-based irrigation. One assumption is the present institutional capacity (or even adaptability) to undertake an immediate shift to demand-based operations. The demands of the individual farmers were to be aggregated by a designated representative of the "Water Users Association" (which is non-existing) in the form of a demand water order, which is supposed to specify the timing when the supply to the Watercourse is to be turned 'on and off (i.e. the supply period) and the varied flow rates,to be allowed for discrete time intervals during the supply period. Considering that the farmers in this area are less educated than elsewhere, it would be unrealistic to expect that even after a period of training they would be in a position to determine with any exactitude their periodic water requirements.

A second assumption was that the users were ready to introduce immediate flexibility in their daily or weekly irrigation practices, and in their related habits and customs. For example, the demand water order implies that irrigation supplies to the watercourses would be intermittent, and presumably during each supply period, the demands of all the irrigators on the watercourse would be met.

A third assumption was that the social background in the LSC area was harmonious, or at least self-sustaining, in dispute resolution. There was no mention of how the adjustments were to be made in the individual demands to make them realistic, nor the procedures to be followed to resolve competing demands. For the distribution of the irrigation supply to the different farms at.the watercourse level, and again between different watercourses, no methodology had been developed. The operation of the system with widely varying crop water requirements during the cropping seasons is another subject which has not been treated comprehensively.

The process of planning and designing that was seen in remodeling the Lower Swat Canal Irrigation System has conspicuously left out an important consideration; namely, the institutional capacity for post-project system operation. While a substantial effort has been made to introduce a modernizing effect through the remodelled physical system, this has been done with very little regard towards the capabilities, aptitudes and preferences of the water users and the agency staff. Adequate consultation with these groups during various stages of the project could have avoided the dilemma that the operating agency is now required to confront.

Thus, the increased intensity of physical infrastructure in the remodelled LSC system had not been matched with an enhancement of the required institutional framework for its operation and maintenance.

Despite the precautionary approach taken by the FPP, the decision to design and put in place a physical system that immediately suited demand-based irrigation operations raises two important questions: (1) whether this action was based on consultation with all the parties concerned; and (2) whether all the operational implications of such a course of action were fully appreciated at the design stage. The responses by both the water users, as well as by the operating agency personnel, clearly show that the answers to both of the above questions would be negative. In the head reaches of the canal, where the gated outlets and radial gates for distributary regulation were first installed, the water users wasted little time in damaging the new infrastructure. The agency staff quickly pointed out how unfeasible the design was in the light of this immediate rejection by the farmers, and saw the system as a waste of resources. This deficiency in coordination reflects a common attitude by government officials towards projects funded by external aid.

An effort to correct this situation has been made by the initial interventions of the Donor missions. The donor's good intentions were to pursue at that stage a shift frum the traditional supply-oriented irrigation operation to a new and more flexible system taking into account the increased water supplies and the related need to make them more responsive to crop water requirements. However, this idea seems to have been abandoned when project implementation delays were starting to exert a greater pressure than the good intentions. After several years of inordinate implementation delays, the project fell back to the usual confluence of interests of the donor, the executing agency, and the consultant to place emphasis on finishing the infrastructure components of the project. At the policy level, there has been inadequate consideration on the post-rehabilitation institutional requirements.

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