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FARM IRRIGATION CONSTRAINTS AND FARMERS' RESPONSES: COMPREHENSIVE FIELD SURVEY IN PAKISTAN

By Max K. Lowdermilk,
Alan C. Early and
David M. Freeman

Water Management Research Project
Colorado State University
Fort Collins, Colorado
September 1978

WATER MANAGEMENT
TECHNICAL REPORT NO. 48-A
Volume I

FARM IRRIGATION CONSTRAINTS AND FARMERS' RESPONSES:

COMPREHENSIVE FIELD SURVEY IN PAKISTAN

VOLUME I
SUMMARY

Prepared under support of
United States Agency for International Development
Contracts AID/ta-c-1100 and AID/ta-C-1411
in cooperation with
Master Planning and Review Division
Water and Power Development Authority
Lahore, Pakistan

Prepared by

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Alan C. Early
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Water Management Research Project
Engineering Research Center
Colorado State University

September 1978

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ABSTRACT

This volume summarizes the findings of the six volume study, "Farm Irrigation Constraints and Farmer's Responses, Comprehensive Field Survey in Pakistan". The purpose of the study was to answer a major question, "What are the significant farm level constraints confronting farmers in their irrigation systems which are presently responsible for low crop yields and crop production?" As a problem identification field survey, the goal is to describe how farmers respond to selected constraints as they manage irrigation water for their crop production systems.

The findings are based upon a sample more fully described in Volume VI, Appendix I, Part A. Data were collected during 1975 and the winter-spring months of 1976 on a sample of 387 farmers located in 16 villages and 40 watercourses stratified by head, middle and tail location. The research sites were selected so as to represent the major agro-climatic zones of the Pakistan Punjab and Sind, but because of USAID's emphasis on the small farmer, the sample includes a disproportionately large sample of villages characterized by small farmer owner-operator majorities.

Chapter 1 sets forth major findings related to the irrigation system: delivery to the farm, field application efficiency and irrigation efficiency; agronomic factors: crop yield per acre, cropping patterns, intensities; and farmers' perceived constraints with regard to economics, knowledge of agricultural practices, water codes and regulations, and farmer organization. Each of the findings is followed by one or more policy implications.

Employing base-line knowledge gained from the survey, Chapter 2 describes possible criteria--physical, economic and social--to be considered in the selection of watercourse commands for comprehensive improvement of water management in Pakistan.

Chapter 3 discusses implications of subsequent projects, survey and/or implement improvement programs, in terms of delivery efficiencies and application efficiencies.

Appended to the text of this volume are glossaries which include photographs taken in Pakistan during the survey, English and Urdu/Punjabi terms.

Overall the structure of the report which follows in the subsequent five volumes is:

Volume II: States research objectives and describes major features of the irrigation system being studied--rivers, canals, moghas, watercourses, tubewells, and the organization of village social networks.

Volume III: Establishes the consequences of the existing irrigation system, a major one being low agricultural productivity in a part of the world which has potential to be one of the most productive regions on this planet.

Volume IV: Examines major constraints confronting farmers within the existing system which are associated with the low productivity discussed in Volume III.

Volume V: Presents farmer responses to the constraints detailed in Volume IV.

Volume VI: Contains supplementary appendix materials relating to methodology, data summaries, watercourse profiles and maps.

Water Management Research Project
Engineering Research Center
303/491-8216

Colorado State University
Fort Collins, Colorado
80523

September 11, 1978

Mr. Mian Mohammad Ashraf
Chief Engineer
Master Planning and Review Division
Water and Power Development Authority
Lahore, Pakistan

Dear Mr. Ashraf:

We are transmitting herewith our final reports in six volumes on the watercourse survey entitled "Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan." These volumes represent a tremendous amount of work by your organization, the U.S. Agency for International Developme[nt] and Colorado State University. We have enjoyed the long standing working relationship and diligent efforts of your staff in completing this task.

As you are well aware, numerous members of your staff participated in the field data collection program report in these six volumes. At the same time, our field staff in Pakistan has spent numerous man-months in cooperatively accomplishing the field work and some of the initial data analysis. Most of the analysis has been done on the campus of Colorado State University in Fort Collin[s]. Besides the authors of these reports, numerous university staff members have participated in the data reduction and analysis, as well as drafting the preparation of tables.

This study has consumed tremendous resources of this project, but we have felt the effort was worthwhile. Hopefully, your staff will also feel proud of this particular effort.

We sincerely appreciate your leadership in facilitating the completion of this effort and we look forward to continued cooperation in seeking to improve on-farm water management in Pakistan.

Sincerely,

Gaylord V. Skogerboe
Project Codirector

John O. Reuss
Chief of Party

W. Doral Kemper
Project Codirector

UF-86

PAKISTAN

Water And Power Development Authority

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MASTER PLANNING & REVIEW DIVN,

251-A NEW MUSLIM TOWN, LAHORE.

No. MP/CE/S&R/Works/1W-WCS/6702

Date September 24, 1978

Mr. Mohiuddin Khan,
General Manager,
MP&RD., WAPDA,
WAPDA House, LAHORE

Subject: Report on "Farm Irrigation Constraints and Farmers' Responses".

I have the honour to transmit herewith the final report of comprehensive field survey carried out on 40 sample water-courses in Pakistan, jointly by Survey and Research Organization, WAPDA and Colorado State University. The survey work was under-taken under the provision of the Agreement No. 204-76-1 dated Nov. 7, 1975 signed between the Government of Pakistan & USAID.

The report presented under the title, "Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan" spreads over six volumes and is in fact a continuation of research work at Mona Reclamation Experimental Project on a wider area covering the entire irrigated area of Indus plains. The findings of this report further elaborate the new strategy that along with the development of present water resources, the prevailing wasteful irrigation practices beyond the outlet must be improved. This report contributes towards highlighting the social constraints in the field of water management thus providing sound guidelines for future planners.

Contd../2.

It would not be out of place to mention that this survey made useful contribution in providing guidelines for the main Watercourse Chak Farming Survey Project to organize its activities in addition to providing trained staff and necessary equipment.

Nevertheless I wish to place on record my appreciation and thanks for CSU Field Party as well as Campus Staff, U.S. Agency for International Development who provided funds for this study and the staff of Watercourse Chak Farming Survey Project who made this monumental task a reality. I avail this opportunity to express my thanks for the interest and valuable guidelines provided by you from time to time without which it would have not been possible to accomplish this arduous task.

24-9-78

(Mohammad Ashraf)
Chief Engineer,
Survey & Research Organization

ACKNOWLEDGEMENTS

Initiating, conducting, analyzing and reporting results of a field study of this size requires the skill and active cooperation of a large number of individuals. It is estimated that more than 30 man-years of planning, training, field work, data reduction, analysis, drafting and reporting have been contributed by Pakistani cooperators with the Water and Power Development Authority, Pakistani staff of Colorado State University in Lahore, part time staff of Colorado State University in Fort Collins, and Colorado State University principal investigators.

The authors wish to acknowledge the financial support of the United States Agency for International Development,[1/] the cooperation of the WAPDA Master Planning and Review Division, Chief Engineer Mian Moh'd Ashraf, and Director of Watercourse Studies Chaudhry Rehmat Ali, the patience and endurance of the CSU Water Management Field Research Team in Pakistan and in Fort Collins, and Wayne Clyma, who helped initiate the original study of a single village near Lahore which ultimately led to this survey.

Special thanks is due to Waryam Ali Mohsin who helped throughout the survey from selection of personnel through data reduction and who inspired everyone associated with the survey to higher pursuits and greater efforts. The initial field team members who became supervisors in the later phase Allah Bakhsh Sufi, Abdul Rehman, Barkat Ali Khan and Nazir Ahmad, plus Zahid Sayeed Khan, Peter Joseph and A. R. Bhatti are due a special thanks for all their long hours of work put forth in

1/The study was conducted with resources provided under Colorado State University contract with the United States Agency for International Development, Contract No. AID/ta-C-1411, supplemented by a USAID rupee grant--Watercourse Survey 204-87-1.

the cause. David A. Lauer deserves special mention for his substantial assistance in coding of the data and with establishment of a system for data management. Gail Woods and James Layton have contributed substantially to this report by virtue of their willingness to render additional assistance. In addition, we extend our deepest appreciation to all of those unnamed Pakistani farmers who so willingly gave of their time and energy to make this research effort possible.

We gratefully acknowledge the helpful review comments submitted by WAPDA personnel, Dr. John Reuss of the CSU Field Party, Dr. Michael Cernea of the Rural Development Division of the World Bank, and Mr. Ken Lyvers of USAID/Pakistan. The authors, of course, accept full responsibility for any errors of fact or interpretation.

INDIVIDUALS WHO PROVIDED ADMINISTRATIVE SUPPORT OR FIELD ASSISTANCE

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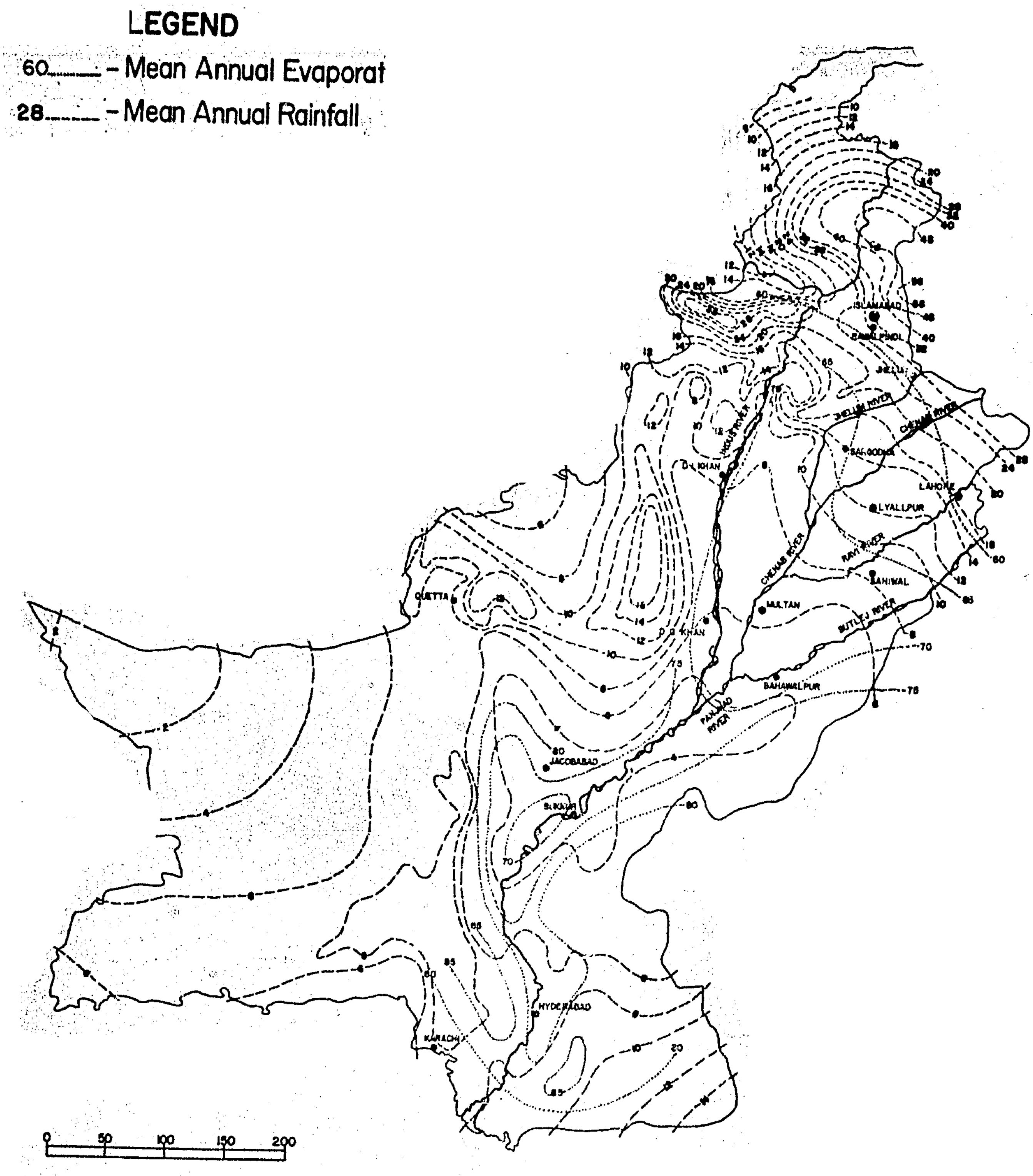

Figure I. Contours of Mean Annual Evaporation and Mean Annual Rainfall in Pakistan (after Sir A. Gibb et. al., Programme for the Development of Irrigation and Agriculture in West Pakistan, 1966)

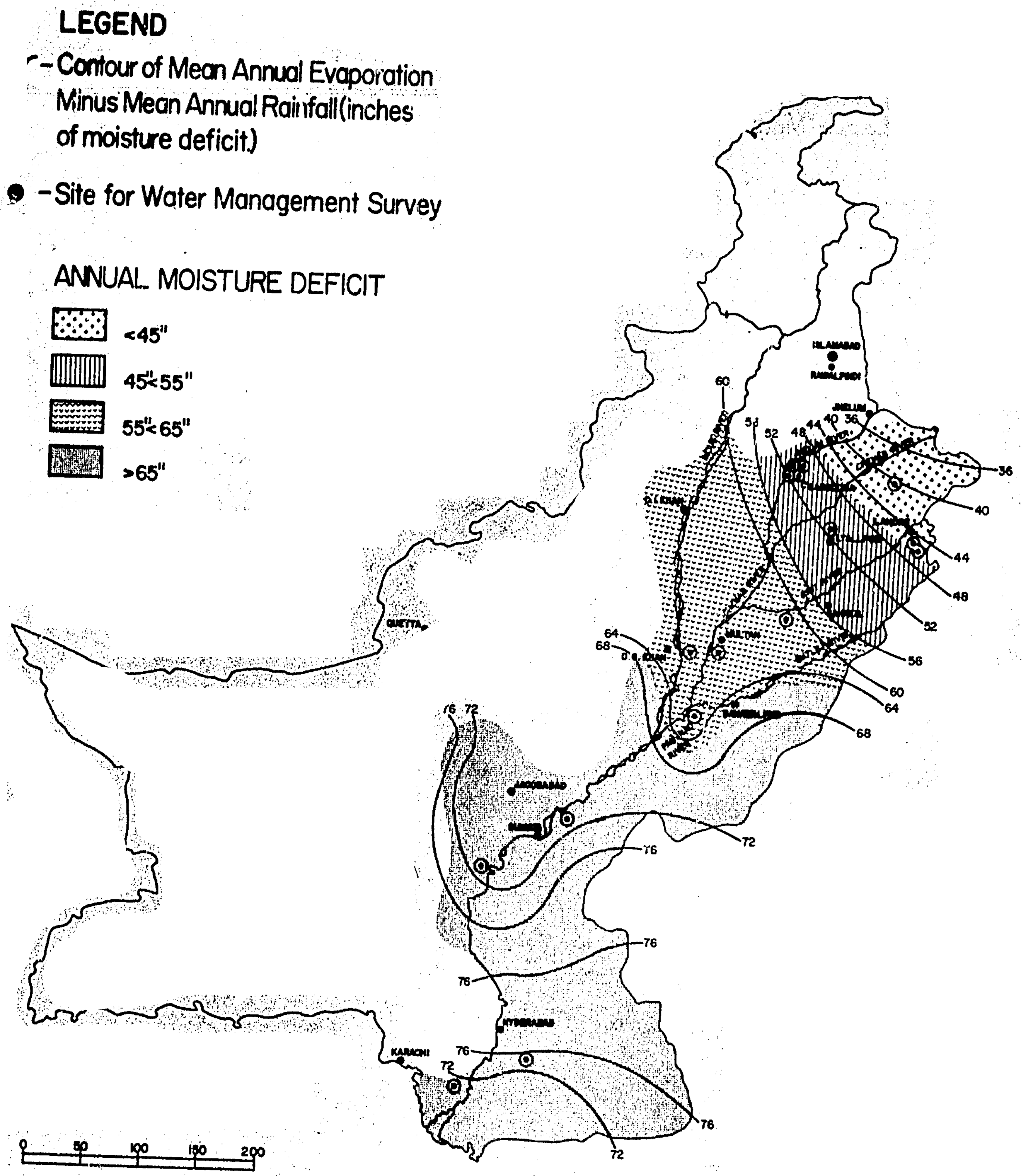

Figure 2. Climatic Regions in Irrigated Portions of Punjab and Sind Provinces of Pakistan, Based on Annual Moisture Deficit.

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EXECUTIVE SUMMARY OF SELECTED FINDINGS

1. Losses of irrigation water in conveyance from the mogha to the field outlet average about 47 percent over the sample of 40 watercourses. Losses range from 65 to 33 percent. Recovering water lost in conveyance imposes energy costs for pumping, frequently degrades water quality, and reduces welfare of farmers without means to reclaim it via pumping.

2. In general, the more water available on a watercourse command, the lower the watercourse conveyance efficiency. Sample SCARP public tubewell augmented watercourses, for example, have a weighted mean efficiency of 47 percent as compared to a value of 54 percent for sample watercourses without public tubewells. Private tubewell commands, however, in the sample have a weighted mean efficiency of 58 percent as compared to 51 percent for commands with neither public nor private tubewells.

3. Losses per thousand feet of watercourse length for the sample watercourses (n = 40) average 26 percent or .36 of a cubic foot per second.

4. Wherever and whenever ample water supplies are available, farmers tend to overirrigate. Farmers on watercourses served by public tubewells or numerous private tubewells tend to overirrigate more than those without such sources of supply. Field application efficiency refers to the proportion of water entering the field basin which is stored in the crop root zone. Mean field application efficiency is about 50 percent for sample farmers. Sample farmers located at tail reaches of watercourse commands, where water is less available, had higher mean and median field application efficiencies than those at the head of watercourse commands.

5. Although no difference is found in field application efficiencies by farmer tenure class, larger farmers (25 acres or more) had lower mean application efficiencies (64 percent) than did smaller farmers (80 percent). Larger farmers tend to secure greater tubewell supplies.

6. Farmers on public tubewell commands and those who have access to private tubewells had average crop yields per acre higher than farmers with no tubewell supplies:

   a. wheat--3 maunds/acre greater

   b. rice--5-7 maunds/acre greater

   c. cotton--3-4 maunds/acre greater

7. Water supply significantly affects cropping intensity. Tubewells not only make higher intensities possible, they provide greater control over timing of irrigation deliveries--a condition often more important than water quantity. Given substantial losses of water in conveyance, tail farmers have lower intensities than do farmers located toward the head of watercourses.

8. Tubewell water, to supplement canal supplies, is easily available for 37 percent of sample farmers, available with difficulty for 18 percent and not available for 45 percent.

9. Of 349 sample wheat farmers, 92 percent grew high yielding varieties, but yields are constrained by low nitrogen and phosphorous fertilizer applications.

10. About 70 percent of the sample farmers report that they do not receive advance information from the Irrigation Department about canal closures for maintenance.

11. Extension workers, serving the world's largest contiguous irrigation system, are not minimally trained in water management.

12. Stipulations of the Canal and Drainage Act (1873) which could be employed to support watercourse improvement are evaded with high frequency. Many other stipulations must be evaded for the farmer to secure a minimum of control over his water supplies--e.g. water trading, water purchasing, and unauthorized modifications in moghas are widespread and probably essential to sustain existing production levels. A thorough review of the uses and limits of the Canal and Drainage Act is justified by the evidence.

13. If watercourses are to be improved and maintained to a higher standard, farmers must be organized to provide themselves with this collective good. Farmer water user associations at the local watercourse levels are essential for a successful watercourse improvement program.

14. Major reasons for the currently low level of watercourse cleaning and maintenance are:

a. lack of effective local organization to discipline farmers who fail to contribute their fair share to such maintenance;

b. lack of farmer knowledge about the magnitude of their water losses;

c. lack of technical knowledge necessary to improve watercourses.

CHAPTER ONE

MAJOR FINDINGS AND POLICY IMPLICATIONS

This chapter presents major findings, each of which is referenced to the more detailed discussion in the following volumes of the report. Findings precede specific policy implications.

1.0 FARM CONVEYANCE EFFICIENCIES-Volume III, Chapter 2

Watercourse conveyance efficiencies low

1.1. Farm conveyance efficiencies are low on all 40 sample watercourse commands--they range from 35 to 67 percent Weighted mean and median conveyance efficiencies from the mogha to the farm are both 53 percent.[1/]

POLICY IMPLICATIONS

Losses are sufficiently high on all sample watercourses to merit remedial measures. If the sample is representative of 78,000 watercourses in Sind and Punjab Provinces of Pakistan (see Vol. VI, Appendix I-A for qualifications of the sample) watercourse improvement programs may be justified on a nationwide basis. It might be contended that so-called "lost" water is simply a resource to be pumped on demand and that, therefore, it is unfair to characterize it as a loss. However, pumping incurs increasingly high energy costs, and in many areas, water quality degradation. Furthermore, insofar as

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1/Conveyance efficiencies express the proportion of water passing through the mogha which actually reaches the farmer's nakka outlet. Both are calculated and the difference in discharge divided by the mogha discharge, times 100, gives an efficiency value expressed as a percentage.

$$\text{Conveyance efficiency} = \frac{\text{Mogha Discharge} - \text{Nakka Discharge}}{\text{Mogha Discharge}} \times 100$$

the "lost" water is reclaimed via private tubewells there may be welfare transfers from the poorer to wealthier farmers who have the means to install such capital equipment. If watercourse conveyance efficiencies are low, and one pumps previously "lost" water back into leaky watercourses, one must pump several times as much water as one needs to secure delivery to the field outlet. The costs of such pumping are substantial and it is fair to refer to water "lost" in watercourse conveyance.

1) A country-wide emphasis may be justified to make farmers <u>aware</u> of the magnitude of losses and the benefits of reducing these losses. A mass media campaign complemented by other sources of information would help farmers become more aware of the magnitude of watercourse losses.

2) A nationwide emphasis may be needed to <u>require</u> that farmers begin making watercourse improvements such as removing trees and grass along main watercourses and adopting more regular watercourse cleaning and maintenance schedules. Both incentive systems and system of sanctions will probably be needed to gain farmer compliance.

3) The present comprehensive farm water management improvement pilot project to include 150[illegible] [illegible]course commands deserves high priority among g[illegible] [illegible]nt development projects. Such a program needs to be carefully evaluated because findings will be needed for more large scale future programs. Plans for

other comprehensive programs should be considered if trained manpower can be made available.

4) The data resulting from this study should be carefully compared to data from the WAPDA watercourse study now underway. Such data needs to be made widely available in Pakistan to planners and the general public.

Higher Losses For SCARP Tubewell Watercourse

1.2 Watercourse conveyance efficiencies are lower for SCARP than for NON-SCARP watercourse commands. Conveyance efficiencies for SCARP public tubewell augmented watercourses range from 43 to 51 percent with a weighted mean efficiency of 47 percent. This is compared to a weighted mean delivery efficiency of 54 percent for NON-SCARP commands. Private TW augmented commands have a weighted mean conveyance efficiency of 58 percent as compared to non-augmented commands of 51 percent. The greater the volume of water available to watercourse commands, usually the lower the conveyance efficiency. The weighted mean conveyance efficiency for four watercourse commands in Sind is 35 percent due to year-round excess canal supplies.

POLICY IMPLICATIONS

In terms of volume of water to be saved, SCARP public tubewell supplemented watercourses should probably be given first priority in programs for comprehensive watercourse improvements. Data show that both delivery and field application efficiencies are lower on these watercourses. Reduction in losses also will aid in the reduction of waterlogging and salinity in these areas. Second priority, if total water savings are the criterion, should be given to watercourses with substantial numbers of private tubewells. Where these are located in areas with a high potential for waterlogging problems, they should be given priority with SCARP watercourses. Thirdly, priority should be given to those watercourses with few or no private tubewells in areas with low potential for waterlogging. In these areas, as part of the program for comprehensive water management improvements, small discharge private or public tubewells located strategically on watercourses would add to existing irrigation supplies.

1.3 Watercourse conveyance efficiencies of 40 sample watercourses are from 13 to 16 percent lower for farms located at the tail reaches of command areas as compared with farms located at the head. Distance from the mogha to the farm explains about 18 percent of the total variation explained for differences in conveyance efficiencies.

Tail Farms At Greater Disadvantage in Total Losses

POLICY IMPLICATIONS

Along with programs of watercourse improvements on pilot watercourse commands, the needs of tail farmers merit special attention. Even with substantial watercourse improvements they will remain at a disadvantage in terms of water supplies on watercourses. Total watercourse losses are a function of distance from the mogha. Given the fact that small farmers often pool their resources for installing small private tubewells, incentives should be considered such as liberal credit programs for private tubewells to increase "middle" and "tail" watercourse supplies.

Efficiencies Higher When Owner Irrigates And Maintains His Part Of The Watercourse

1.4 Watercourse conveyance efficiencies are from 6 to 16 percent higher for farms where owner operators irrigate, inspect and repair leaks and spills, and remain at their fields throughout irrigation turns as compared to farmers who do not observe these practices. Sample farms where servants irrigated had a weighted mean conveyance efficiency from the mogha to the farm of 38 percent compared with 54 percent where owner operators irrigated.

POLICY IMPLICATIONS

Farmers should be made aware of the importance of these human problems. To date they have not received extension services focused on helping them understand the causes of such losses or how to correct them. Farmers would likely provide more supervision for irrigation if they learned the high cost of poor irrigation practices.

Loss Rates/ 1000 Feet High

1.5 The weighted mean and median percentages of losses per 1000 feet of watercourse length for the 40 sample watercourses are 26 and 17 percent of total available supplies. The mean and median cubic feet per second (CFS) of total water lost in transit per 1000 feet are .36 and .19 CFS for all command areas.

1.6 Median loss rates in CFS per 1000 feet for public tubewell supplemented sample watercourses equal .32 CFS as compared to .17 and .18 CFS respectively for private TW supplemented and non-TW supplemented watercourses. Loss rates are less the further from the mogha to the farm (about .35 CFS for farms under 1000 feet from the mogha versus .13 CFS for farms 6000 feet or more distance from the mogha). Distance from the mogha as a factor in a multiple regression analysis explained 27 percent of the differences in losses per 1000 feet of watercourse length. This factor, and mogha discharge rates in cusecs, explained about 30 percent of the variation in percent loss rates per 1000 feet of watercourse length.

Loss Rates/ 1000 Feet Greater For Public TW Supplemented Commands And Greater For Farms Nearer To The Mogha

POLICY IMPLICATIONS (1.5 and 1.6)

A high percentage of conveyance losses occur between the mogha and the first junction on main watercourses. These losses are higher on public tubewell supplemented watercourses due to the high volume of discharge of the large public tubewells. As the photo glossary pictures show clearly, these losses are high due to excessive grass, weeds and trees growing in the fertile silt deposits along the banks. Watercourse banks have high infiltration rates and pipe-like holes due to action of insects, rodents and larger animals which have burrows in the banks. Washouts result due to larger discharge rates and soil that is constantly removed from fields and watercourse banks for building small bunds to pond water at junctions.

Given the particular discharge of moghas and public tubewells, soil characteristics and other conditions creating losses along the main watercourse, this section of the watercourse requires special attention such as a larger cross-section and installation of permanent turn-out structures at junctions. Each watercourse, however, has its own particular problems; improvements for each must be tailored to those conditions.

One must not become so preoccupied with the problem of low watercourse conveyance efficiencies that one overlooks the fact that simply increasing the water supplies at the field outlet will not improve water management and crop production. Data are consistent throughout the sample that the greater the quantity of water available, the lower the field application and over-all irrigation efficiencies. Increased water supplies are, by themselves, insufficient to increase crop production. Reduction of watercourse losses must be accomplished in an integrated water management program which relaxes other constraints on the farmer--credit, seed, fertilizer, pesticides, land leveling and most of all, lack of control over the timing of water delivery.

2.0 FARMERS FIELD APPLICATION EFFICIENCIES-Volume III, Chapter 3

Field application efficiency is obtained by dividing the soil moisture deficiency by nakka discharge (in equivalent inches), multiplied by 100 to yield a percent value.

2.1. Of 559 individual evaluations of field applications, 229 or 41 percent were underirrigations. Underirrigations inflate field application efficiencies, values of which range from 32 percent to 100 percent. Sample farmers both over- and underirrigate--primarily in relationship to the water available. Data indicate that whenever and wherever water supplies are amply available, farmers tend to over-irrigate. Even given inflated values due to underirrigation, sample farmers on public tubewell supplemented commands have weighted mean field application efficiencies of about 58 percent as compared to a weighted mean of 83 percent for farmers on commands not supplemented with tubewells.

Under-Irrigations Inflate Field Application Values

More Available Irrigation Water Equals Lower Field Application Efficiencies

2.2 When underirrigations are removed, field applications range from a low of 29 percent to a high of 88 percent. Mean and median field application efficiency values respectively fall to 50 and 60 percent. The weighted mean percentage of field application efficiencies for farmers on commands with different water supply situations are:

Public Tubewell Farmers Have Lower Efficiencies

Public tubewell supplemented commands - 44%

Private tubewell supplemented commands - 59%

Non-supplemented commands - 57%

2.3 Farmers who are more careful in applying irrigation water to fields (remaining at fields throughout irrigation period, repairing bunds and spills, etc.) have from 6 to 10 percent higher field application efficiencies than farmers who do not follow such practices.

Careful Irrigators Have Higher Efficiencies

2.4 On the basis of evaluations made at the time of the survey (non-time series data), farmers on public tubewell augmented commands and farmers on commands with a high density of private tubewells (6 or more) on the average applied about 100 percent more water than required to replenish the soil moisture depletion (SMD). Farmers using public tubewell supplies applied mean and median applications of 3.5 and 2.7 acre inches. Farmers without a high density of private tubewells applied 2.4 (mean) and 2.1 (median) acre inches. Farmers with no tubewell supplements applied mean amounts of 2.0 and fewer acre inches.

At Particular Irrigations Some Farmers Apply Double The Amount Required Or More

2.5 At the time of the survey, sample farmers applied the following median acre inches of water for various types of irrigations:

Median Irrigation Applications In Acre Inches

Borders with fodder crops	- 3.2 inches
Preirrigations	- 2.9 inches
Sugarcane	- 2.8 inches
Cotton	- 2.3 inches
Mixed crops (other than garden)	- 2.2 inches
Fodder crop	- 1.9 inches
Wheat	- 1.9 inches

2.6 The data show that farmers over- and underirrigate at different months of the year as irrigation water is more or less available. Median application efficiencies from August through March range from 19 to 100 percent (mean, 13 to 92) and from April through July, from 95 to 100

Application Efficiencies Vary Seasonally According to Availability Of Water

percent (mean range, 78 to 90). Where there are public tubewells, sample farmers consistently have low application efficiencies whatever the season of the year.

Day And Night Field Application Efficiencies

2.7 No significant differences are found between day and night field application efficiencies for sample farmers.

Higher Field Application Efficiencies For Tail Farms

2.8 Sample farms located at the tail reaches of watercourse commands had mean and median field application efficiencies greater than those of sample farms located at head reaches of commands. This is due to less total available water resulting from larger conveyance losses.

Field Application Efficiencies By Farm Size And Tenure Classes

2.9 Farms with 25 acres or more in cultivated acreage had mean and median field application efficiencies of 64 and 59 percent compared to farms of under 25 acres which had mean and median efficiencies of 80 and 98 percent. Larger farmers tend to have more private tubewell water available than smaller farmers. Almost no difference is found in field application efficiencies by farm tenure classes.

POLICY IMPLICATIONS

1) Increased supplies of irrigation water do not provide the answer for improving farmers' field application efficiencies. Improvements in the application of water requires: level fields for efficient control of water, reliability of irrigation supplies, and radical changes in farmers' present irrigation practices. Farmers have no means of adequately controlling water on their fields except by using

small basins. Any program to improve water management practices must do more than provide increased supplies of water or land leveling technologies. The program must be comprehensive and include intensiv extension services which help farmers to know when, how and how much to irrigate particular crops. This will require a totally new approach to training extension field workers in Pakistan. Systems suited to Pakistan's conditions for irrigation scheduling should be tested using adaptive research methods to determine the feasibility of this approach to helping farmers apply correct amounts of water to crops.

2) On many watercourse commands there are more ample irrigation supplies and even surplus supplies during some months of the year. As monsoon rains begin, some mogha outlets are blocked by farmers who do not require canal water. We observed that due to many blocked moghas on one distributary, canal waters were over-topping the banks which leads to dangerous erosion of canal banks. Presently, there are no adequate storage areas on watercourse commands. As part of a comprehensive water management program, consideration should be given to large ponds or storage reservoirs for excess water. Given such reservoirs, farmers could utilize lift pumps when extra water is required for crops. Such tanks would also provide a place for fish culture which would

provide means to supplement village diets currently extremely low in protein foods.

3) Since lack of control over irrigation supplies tends to lead to overirrigation, alternative programs to make more small discharge tubewells available should be examined. Presently, larger farmers with private tubewells have more control over supplies than smaller farmers. Farmers at middle and tail reaches of many command areas need extra water and increased control over irrigation water. Liberal policies for private tubewell installation could be skewed to these farmers and especially to small operators.

3.0. IRRIGATION EFFICIENCIES -Volume III, Chapter 4

Irrigation efficiency, the proportion of water passing through the mogha which is stored in the root zone of a crop, is derived as follows:

Irrigation efficiency equals farm conveyance efficiency multiplied by farm field application efficiencies.

Weighted Mean Irrigation Efficiency For Sample Commands Is 41 Percent - A Conservative Estimate

3.1 Weighted mean irrigation efficiencies are inflated by 229 underirrigations yet, the weighted mean irrigation efficiencies for sample farms range from a low of 16 percent to a high of 62 percent. The weighted mean and median irrigation efficiency is 41 percent.

POLICY IMPLICATIONS

Watercourse command efficiency data from 40 sample watercourse commands are much lower than those assumed in previous studies where actual field measurements were not taken. Earlier estimates of irrigation efficiencies were made by the following reports: (World Bank, 1976, Annex 3, Table 3.1)

Source	Date	Estimated Efficiencies
Sir Alexander Gibbs and Partners	1966	63
Lieftnick Report	1967	63
Tipton and Kalmbach (Regional Plan Northern Indus Plains)	1967	60-75
Sir M. MacDonald and Partners	1966	50-60 (61-82)
Sehwan Barrage Complex Report WAPDA Part I	1969	54.4
Indus Basin Review Mission	1970	63
Expert Committee on Water Losses in the Irrigation System	1972	63

As stated by the IBRD agricultural sector survey mission findings, "There is no evidence that watercourse command efficiency does or can match the 63 percent assumed for existing irrigation systems or developed canal commands in Pakistan." They estimate a watercourse command efficiency of about 49 to 50 percent and base their estimates in part on Colorado State University (CSU) field research reported in 1974. The earlier data of CSU are confirmed by this survey. If earlier CSU data, recent World Bank estimates, and the data of these 40 watercourse commands (559 evaluations) are representative of the farm irrigation system in Pakistan, previous estimates utilized for planning purposes for over 10 years were grossly incorrect. "A one percent error in the earlier Indus special study assumption is equivalent to about 1.40 MAF of water at the watercourse outlet." (World Bank, 1976; Preface p i.) This indicates the magnitude of such errors, and the radical need for Pakistan to establish water conservation at the farm level as a top priority in future development plans.

Public TW Command Areas Have Lower Command Efficiencies

3.2 Watercourse command irrigation efficiencies are lower on commands supplemented by public tubewells (26%) than commands with no tubewell supplements (42%). Commands with some private tubewell supplements have a weighted mean and median command efficiency of 47 percent. Where there are 7 or more private tubewells the weighted mean command efficiency is 37 percent.

POLICY IMPLICATIONS

As stated under 1.1 above, there is urgent need for a proper mix of policies and action programs to reduce the costly losses at the watercourse command area. If water savings constitute the major criterion, immediate attention should be given to the reduction of losses at commands supplemented by public tubewells. Other criteria, however, should be included such as benefits to small farmers, cooperation of farmers in improvement programs, considerations of reducing waterlogging and salinity, increases in cropping intensities and crop yields.

3.3 Farms located at watercourse tails have irrigation efficiencies which are about 15 percent lower than those farms located at heads of command reaches.2/

Tail Farmers Have Lower Irrigation Efficiencies Than Head Farms

POLICY IMPLICATIONS

Consideration should be given to adjusting warabundi schedules so that farmers with land near the tail of the watercourses are given more minutes of flow per acre served than they presently receive. Programs of water management improvements should include the special needs of farmers located at the middle and tail reaches of command areas. Incentives for private tubewell installation at middle and tail reaches are one alternative. Another is that small discharge public tubewells could be installed at these watercourse reaches.

3.4 In summary, the results of a multiple regression model show that the following factors explain about 42 percent of the variation in irrigation efficiencies: Number of underirrigations, water supply situation, distance of the farm to the mogha, season of the year and number of private tubewell equivalents.

Multiple Regression Model And Watercourse Command Efficiencies

Since a large number of underirrigations inflate field application efficiencies, irrigation efficiencies are inflated. Our estimate of 41 percent watercourse

2/Tail farmers typically lose smaller amounts of water than operators located toward the head when efficiency values are computed on a percent per 1000 feet basis. The typical earthen watercourse can convey relatively efficiently the smaller absolute quantities that reach middle and tail sections. On an absolute quantity basis, tail farmers sustain high losses.

irrigation efficiency for the sample commands is high. The water supply situation (public TW, private TW, no TW) has been discussed earlier in the findings as well as distance to mogha. The number of private TW equivalents is a measure including public tubewells. The greater the total supply of supplemental water, the lower the command efficiency. It is important to compare these data with time series data over at least two full crop seasons.

4.0 CROP YIELDS PER ACRE, CROPPING INTENSITIES AND CROPPING PATTERNS - Volume III, Chapters 5 and 6

The Summary has been concerned with the efficient transfer and use of water. The proportion of water lost is greatest where most water is available: proximity to mogha, supplementation by SCARP tubewells or a high density of private tubewells. Careless and inadequate water management put farmers (at the tail of a command reach) at a real disadvantage; significant quantities of the water due him are lost.

In applying water that is discharged from the nakka, to replace soil moisture deficiency in fields, efficiency is lowest where the greatest supply is available--due to overirrigation. However, the farmer who remains in the field to check for leaks, etc. during an irrigation is more efficient in conveyance and use of water. More water, while imperative in situations of deprivation, does not assure increased crop production. Control over the irrigation supply, informed agronomic practice and the availability of inputs constitute an interrelated package required for increased crop yields.

4.1 Crop Yields From Survey Data

4.1.1 Average yields for sample farms respectively are:

Yields Of Major Crops For Irrigated Agriculture Among Lowest In World

	lbs/acre
Wheat	1722
Rice	1230
Cotton	738

Yields vary greatly between watercourse commands, agro-climatic regions and general water supply situations. Within given command areas crop yields vary due to control of water supplies, fertilizer inputs and availability of credit for inputs.

POLICY IMPLICATIONS

Yields of major food and export crops in Pakistan are among the lowest in the world. The major consideration in Pakistan today is to increase the production of these crops. Increased water supplies through improved water management and other production practices offer a good avenue for rapid increase in yields per acre.

Rice and Cotton Yields Related To Agro-Climatic Regions

4.1.2 Yields of rice in the rice growing areas average about 25 mds./acre as compared to a range of 5 to 18 mds./acre for non-rice growing areas. Yields of seed cotton in the cotton belt average 10 mds./acre as compared to a range of 3 to 8 mds./acre in non-cotton belt areas. Wheat yields show much less variation across agro-climatic regions.

Increased Water Supplies And Control Of Irrigation Supplies Related to Crop Yields

4.1.3 Farmers on public tubewell commands and those who have use of private tubewells have average wheat yields of about 3 mds./acre higher than farmers with no tubewell supplies. Tubewell farmers have weighted average rice yields 5 to 7 mds./acre greater than non-tubewell farmers and cotton yields from 3 to 4 maunds greater. The greater the availability of tubewell supplies on command areas, the higher the crop yields. Of 8 water-course command areas in the cotton belt, yields/acre of cotton and wheat are significantly related to the density of private tubewells as shown below:

Private TW Density, CCA Acres/TW	Wheat Mds./Acre	Seed Cotton Mds./Acre
1:81	29	13
1:450	15	7

POLICY IMPLICATIONS

Private tubewells provide greater control over irrigation supplies and farmers who have use of private tubewells can irrigate in relationship to crop demands. Public tubewells also increase total irrigation supplies but do not have the flexibility of private tubewells because public tubewell water is delivered with canal water. Consideration should be given to more flexibility in the supply of public tubewell water to farmers. Farmers report that public tubewells are operated only 50 to 60 percent of the time.

4.1.4 Rice and cotton yields of farms located at the head reaches of watercourse commands are higher than those farms located at the tail reaches of commands due to limited water supplies. Differences in average yields range from 1 to 7 mds./acre for rice and 2 to 5 mds./acre for cotton. Little or no difference is found for wheat yields and location of farms on watercourse commands.

Farmers At Head Reaches Of Watercourse Commands Have Higer Yields

POLICY IMPLICATIONS

As discussed earlier, farmers at tail reaches of watercourse commands need special consideration in a watercourse improvement program because even with improved earthen watercourses, they will receive less total irrigation supply than head farms.

4.1.5 Crop yields of wheat, rice and seed cotton per acre respectively average 5, 5 and 3 maunds greater for farms on perennial command farms as compared to farms on nonperennial watercourse commands.

Difference In Per Acre Yields Of Farms On Perennial Versus Nonperennial Commands

POLICY IMPLICATIONS

Where groundwater quality is acceptable, consideration is needed for more tubewells on nonperennial commands.

4.1.6 Farmers who report credit/capital easily available for fertilizer have slightly higher average crop yields (wheat, rice, cotton) per acre than other farmers. Farmers who utilized institutional credit for fertilizer for the 1975-76 wheat crop achieved

Credit Availability And Crop Yields

an average yield of 23 mds./acre as compared to 19 mds. by farmers who used no credit for fertilizer However, of 328 farmers reporting, only 16 percent reported institutional credit was utilized for the 1975-76 wheat crop.

POLICY IMPLICATIONS

The present institutional credit program initiated by the State Bank is sound but needs to be expanded, especially for fertilizer credit for small and medium sized farmers.

Farm Size And Tenure Classes Not Significantly Related To Major Crop Yields

4.1.7 No significant differences are found between farm size and tenure classes in average yields/acre for wheat, rice and cotton crops.

POLICY IMPLICATIONS

Given increased control of irrigation water and availability of credit for essential inputs, small and medium size farmers can greatly expand per acre yields. Assisting smaller farmers in increasing their production is a means of improving income distribution.

Major Factors Related To Major Crop Yields

4.1.8 In a summary multiple regression model, about 40 percent of the variation in wheat yields was explained by the following factors: Level of nitrogen applied, number of irrigations, use of tubewell (water control), seeding depth, and extension contacts. Using the same regression model, the major factors explaining the difference in rice and cotton yields were level of fertilizer use and use of tubewell water (water control).

POLICY IMPLICATIONS

Increased water supplies, water control, essential inputs, and improved extension services are needed for yield increases.

4.1.9 Yields/acre of wheat, cotton and rice were also found to be influenced by availability of irrigation supplies, reliability of irrigation supplies, levelness of fields,[3/] waterlogging and salinity, and climatic-soil conditions.

POLICY IMPLICATIONS

Field studies and trials are needed to isolate the influence of precision land leveling on yields as well as waterlogging, salinity and climatic-soil conditions. For example, adequate data do not exist to document the costs and benefits of precision land leveling though a large scale land leveling program has been initiated.

Indicators Of Economic Outcomes And Farmers' Control Over Irrigation Supplies

4.1.10 The following summary of data show that the water supply control situation creates substantial economic difference between watercourse commands:

3/Secondary data are used for field levelness and yields.

Indicators of Dualism (Weighted Averages)	Type of Water Supply Situations and Degree of Farmer's Control of TW Water		
	Public TW Farms (some control)	Owners Private TW (control)	No. TW Supplies (no control)
Yields			
Mds./acre Wheat	20	24	18
Mds./acre Rice	19	23	15
Mds./acre Seed Cotton	8	13	7
Cropping %			
Wheat	37	48	43
Rice	10	8	6
All Crops	160	151	140
No. of Irrigations (Whea	5-6	8-9	4-5
Nutrient Lbs. N/acre (Wh	55	57	45
Percent of Perennial WC farms where farmers woul increase present acreage of crops by 50% or more given doubling of irrigation supplies.			
Wheat	0	0	45
Cotton	0	0	35
Rice	0	0	35
Sugarcane	0	0	30
Average Rupee returns per acre.			
Wheat (rabi)	381	547	317
Rice (kharif)	248	380	145
Cotton (kharif)	NA	429	55

Average rupee returns for head and tail farms with no tubewell supplies obtained are:

	Head Farms	Tail Farms
Wheat	383	298
Rice	174	137
Cotton	69	12

Major Perceived Constraint-Irrigation Water

4.1.11 In order of importance, the responses of 354 sample farmers to the question, "What do you presently perceive to be the major constraint to obtaining increased per acre yields in your farm operation?" are as follows:

Major Constraint	% of Reports
Insufficient supplies of irrigation water	73.0
Lack of fertilizer and improved seed	9.3
Improved implements and farm machinery	6.0
Lack of land	2.8
Lack of capital or credit	2.0
Lack of insecticides	1.7
Lack of extension services and improved roads	1.7
Seasonal labor shortages	.9
No major constraint	2.6
	100.0

POLICY IMPLICATIONS

If we can depend on farmers' reports, the two major constraints are lack of sufficient water, fertilizer and improved seed. Other data in this report tend to confirm farmers' views. Sample farmers overwhelmingly perceive lack of irrigation supplies as the major constraint. Water problems are identified about three times more than all other nonwater constraints combined. As expected, middle and tail farmers give this response about twice as often as head farmers.

4.2 Cropping Patterns and Intensities

Increased Water Supplies And Control Equals Increased Cropping Intensities

4.2.1 Farmers adapt their cropping intensities and cropping patterns to the actual water supply situation. For example, the following weighted mean cropping intensities under varying water supply situations for sample farmers for perennial commands (PC) and nonperennial commands (NPC) are:

	Cropping %	
	(PC)	(NPC)
No tubewell supplies	143	131
Public TW supplemented supplies	160	133
Less than three private TWs	146	121
Three to six private TWs	148	-
Seven or more private TWs	157	-
Owners of private TW	153	144

POLICY IMPLICATIONS

Increased irrigation supplies through reduction of losses at the farm level and/or installation of tubewells will result in increased cropping intensities. Tubewells also provide greater control over irrigation supplies--a consideration often more important than quantity of water.

Increased Water Supplies Are Especially Important For Increases In High Water Demand Crops

4.2.2 No differences are found in cropping intensities between climatic zones but fodder-wheat commands have a weighted mean cropping intensity of 165 as compared to a range of 141 to 149 percent for other crop dominated commands.

POLICY IMPLICATIONS

Except for cotton which produces best in the cotton belt and rice which requires special soil conditions, increased irrigation supplies are needed for increases in rice and sugarcane crops especially.

Cropping Intensities Higher For Head Farmers For All Types of Watercourse Commands

4.2.3 Cropping intensities for farms at head reaches of both perennial and nonperennial commands are about 10 percent greater than for farms at tail reaches of commands.

POLICY IMPLICATIONS

Even given earthen watercourse improvements, tail farms will have less available water, therefore, less cropping intensities unless consideration is given to warabundi changes or tubewell supplements for tail farms.

Rabi Cropping Intensities Less Than Kharif Season (Due To Increased Evapotranspiration Rates)

4.2.4 Cropping intensities for rabi season are about 15 percent less than for kharif season on perennial commands, and about 25 percent less for rabi as compared to kharif season on nonperennial commands. Tubewells on commands operate to smooth out the differences in cropping intensities between rabi and kharif seasons.

POLICY IMPLICATIONS

Tubewells are needed to smooth out cropping intensities between rabi and kharif seasons.

The Larger The Farm Operation Usually The Lower The Intensity

4.2.5 Cropping intensities are only slightly greater for sample farms under 25 acres as compared to sample farms with holdings over 25 acres in size. Perennial sample farms under 25 acres have a cropping intensity of 161 percent as compared to only 144 percent for farms with 50 acres or more in holdings.

POLICY IMPLICATIONS

Large farms face a labor constraint in increasing cropping intensities. Tractor farmers can overcome this constraint but tractors and related capital equipment may well lead to serious problems associated with displacement of tenants and landless farm labor.

Tractor Use For Land Preparation And Cropping Intensities

Of the sample farmers on perennial commands, those who do not use tractors for any land preparation have a weighted average cropping intensity of 146 percent compared with farmers who hire tractors with 153 percent. Owners of tractors on perennial commands have a weighted mean cropping intensity of 160 percent. The same trend is not evident on nonperennial commands due to greater water supply constraints.

POLICY IMPLICATIONS

For more intensive cultivation there is often a time constraint in harvesting rabi crops and land preparation for kharif season. About 44 percent of the sample farmers use tractors periodically for land preparation. The demand for tractors in sample villages is great, especially for land preparation. Further studies are needed to ascertain the degree of use of tractors on a hire basis. Policies and programs should be investigated for making tractors available to farmers on a hire basis. Also studies are needed to ascertain the importance of mechanical threshers for wheat.

Factors Which Influence Cropping Patterns

4.2.7 Cropping patterns reflect the particular agro-climatic zone and the water supply situation. Other factors which influence farmers' choices of cropping patterns are degree of control of irrigation supplies, home consumption needs, soil conditions, farm size and tenure status, market demand and location of markets.

Use Of Fallow In Crop Rotations Related To Water Supplies

4.2.8 Recommended crop rotations are not systematically followed by sample farmers due to land constraints faced by small farmers, scarce water supplies, and lack of reliability of canal deliveries from season to season. Sample farmers utilize fallow in rotations primarily when water supplies are the major constraint. For example, 38 percent of non-perennial command farmers utilize fallow in rotations as compared with 17 percent for perennial farmers. The greater the supplemental irrigation supplies the less the use of fallow in crop rotations. Whatever the authorized CCA on sample commands, farmers attempt to exceed this by use of tubewell and Persian well supplements and the use of crops with lower water demands.

POLICY IMPLICATIONS

Studies are needed to ascertain the benefits of fallow in crop rotations for major crops in Pakistan given the pressure on land and water resources.

High Water Demand Crops Related To Water Supplies And Distance To Markets.

4.2.9 Within agro-climatic regions, the percentage of rice, cotton and sugarcane increases in relationship to the availability of canal and tubewell supplies. Distance to urban markets is found to be important for fodder crops and vegetables. (Distance to sugar mills and the availability of irrigation supplies is found to be important for sugarcane crops.) The present sugarcane mill act should be examined in relationship to possible constraints on increased production.

POLICY IMPLICATIONS

Given increased irrigation supplies and proper price policies, one can expect an increase in crops such as rice, cotton and sugarcane except where there are soil and climatic constraints. However, unless higher yielding cotton varieties and pest control measures are made available to farmers in the cotton belt, farmers may begin to shift present cotton acreage to other crops even given improved water supplies.

Farmers' Estimates Of Increased Acreage In Crops Given A Doubling Of Present Irrigation Supplies

4.2.10 The data show the importance of water supplies to increases in cropping percentages for particular crops. Farmers were asked to estimate possible increases in crop acreages over present acreages given the perceived doubling of irrigation supplies. Responses are shown for farmers who would increase particular crop acreage by 50 percent or more under various present water supply situations. This does not imply that farmers will <u>in fact</u> make such increases nor does it imply that farmers are always able to perceive or understand all their major constraints.

Present water supply situation	Percent of farmers who would increase cropped area by 50% or more				
	Wheat	Rice	Cotton	SC	Fodder
Perennial commands					
No TW supplements	44	36	36	30	20
Public TW supplements	0	0	0	0	0
Less than 3 private TWS	7	0	3	0	0
3 to 6 private TWs	0	0	0	0	0
7 or more private TWs	0	0	0	0	0
Nonperennial commands					
No TW supplements	65	43	52	48	32
Public TW supplements	19	56	29	45	26
Public and private TWs	0	0	0	0	0
Less than 3 TWs	52	18	35	34	5
Perennial commands					
Farms at head reaches	10	9	11	4	7
Farms at tail reaches	28	22	24	23	2

POLICY IMPLICATIONS

If ways and means are found for an improvement in irrigation supplies, especially for farmers with no tubewell supplements and farmers or nonperennial commands, a substantial increase in cropping intensities of major crops can be expected. Given the extra canal supplies for rabi from Tarbella storage, Government of Pakistan (GOP) estimates of a 50 percent increase for rabi appear too high, because farmers with tubewell plus canal supplies appear to reach a ceiling of about 160 to 170 percent cropping intensity for rabi and kharif seasons. For example, one non-commanded site with only 120 acres of cultivated land had 8 private tubewells or one for about 15 acres of land. The average cropping intensity reached by farmers under an excellent water supply situation was only 165 percent. Further studies are needed for GOP projections of cropping intensities to ascertain the level expected under various water supply situations. Such empirical field studies should include constraints other than water which limit cropping intensities. These factors should include labor and capital constraints, timing of crops, market demands and price policies. In many areas, waterlogging and other soil conditions limit cropping intensities whatever the water supply situation. Perhaps a more important consideration is the proper mix of food and cash crops to meet local and foreign demands.

5.0 AGRONOMIC AND ECONOMIC CONSTRAINTS - Volume IV, Chapter 3

Input availability and credit for inputs are problems for all farmers except those with holdings of 25 acres or more. As expected, there is a significant relationship between the availability and use of most inputs and farm size.

5.1 Major Findings About Input Availability

About Half Of The Sample Farmers Report Fertilizer Not Easily Available

5.1.1 Forty-three percent of the farmers report that fertilizer is not "easily available" at the time required.

Insecticides Hardly Available

5.1.2 Sixty-three percent of the farmers report pesticides as "not available" and 19 percent report "available with difficulty".

Tubewell Water Availability

5.1.3 Supplemental tubewell water is "not available" for 45 percent of the farmers, is "available with difficulty" for 18 percent and "easily available" for 37 percent of the sample farmers.

Who Gets Institutional Credit

5.1.4 Credit or capital availability for all inputs and household use are significant problems to all except farmers with 25 acres or more land. Fifty-four (15%) of 349 farmers reporting used institutional credit for fertilizer in 1975-76 under the new Government loan program. Sixty-two percent of farmers with 50+ acres used the credit and only

7 percent of the farmers with under 7.5 acres of land used the credit.

Sources of Agricultural Credit

5.1.5 The major sources of credit for sample farmers are family and friends (72%). Only 19 percent reported using institutional credit and the remainder (9%) reported using money venders, landlords, and commissioned agents as sources of agricultural credit.

POLICY IMPLICATIONS

Both the present water management improvement pilot project and future comprehensive programs with a focus on improving farm water management should make provisions for essential inputs and credit, especially for small farmers. If farmers are to significantly increase crop yields, they must utilize more inorganic fertilizer, insecticides and other requisite inputs with better management of irrigation water. Presently, farmers face problems in the acquisition of fertilizer and pesticides are hardly available for most farmers. Credit problems, as known, are greater for small farmers. While some small farmers use the new bank short term credit program for fertilizer, more larger than small farmers take advantage of this program. Consideration should be given to expanding this innovative credit program to include pesticides and credit for precision land leveling. Small farmers will require longer term credit to pay their share in the proposed cost-sharing scheme for land leveling where costs per acre may average Rs. 500 to 600. Membership in watercourse water users associations for implementing the water management improvement programs could be used as a criterion for farmers to qualify for land leveling and other loans from institutional sources. Special incentives such as these may help to build farmers' interest in the proposed programs.

5.2 Utilization of Fertilizer Inputs[4/]

Fertilizer Use For Wheat

5.2.1 Of 369 farmers, 19 percent used no purchased inputs of nitrogen for wheat in 1975-76 and 76 percent used no phosphorus.

Extremely Low Level Of Nitrogen Used For Major Crops

5.2.2 In terms of average nutrient lbs. of nitrogen/ acre, for the following crops the amounts are often less than half the recommended rates: Wheat - 48 lbs; cotton - 34 lbs; rice - 35 lbs; berseem - 17 lbs; and sugarcane - 54 lbs.

Factors Related To Fertilizer Use

5.2.3 The following types of farmers use more fertilizer per acre on the average:

- Those with farm sizes 25 acres or more in size.
- Those who are owner operators.
- Those who report credit easily available.

4/In terms of recommendations for crops, fertilizer inputs are extremely low. Agricultural Department recommendations are usually based on maximum yield plot data which may not reflect farmers' conditions adequately. Also, these recommendations assume no capital constraints.

- Those who are located closer to the agency.
- Those who are located on perennial commands.
- Those who have access to public and private tube well water.
- Those who own private tubewells.

5.2.4 Of 349 wheat farmers, 320 grow high yielding varieties, however, nitrogen and phosphorus inputs are low.

Factors Influencing Low Yields Of HYV Wheat

- About double the nutrient lbs. of nitrogen and phosphorus are applied to high yielding varieties (HYV) of wheat as compared to local varieties.
- Average levels of nitrogen and phosphorus per acre for HYV wheat are 51 and 11 lbs.
- Of 320 HYV wheat farmers, only 50 farmers applied as much as 2 bags of nitrogen in the form of urea (101 nutrient lbs.) and only 31 farmers applied the equivalent of 50 lbs. of phosphorus.

Wheat Yields And Fertilizer Use

- Yields of wheat in maunds/acre when correlated wit nitrogen and phosphorus have coefficients of .43 and .48 which are highly significant at the .001 level.

POLICY IMPLICATIONS

1. The data from sample farmers indicate that, by any standard, levels of fertilizer utilization for all crops are extremely low. Along with water management problems, the levels of fertilizer inputs for crops must be increased. Data show that along with other problems, the levels of use of fertilizers are closely related

to the availability of irrigation supplies and the control farmers have over water for crops. Fertilizer use in Pakistan peaked in 1972-73 and slowed about the time private and public tubewell installation slowed down. Special studies are needed to ascertain the factors affecting fertilizer use such as price incentives, credit facilities, pricing and marketing policy, marketing arrangements, relationship to irrigation supplies and other structural constraints.

2. The data suggest a major reason why the high yielding varieties program has reached a plateau. Nitrogen use is less than half the recommended levels and over three quarters of the growers of HYV of wheat use no purchased inputs of phosphorus. Small farmers and tenants need to have more flexible methods of obtaining credit for fertilizer other than having large landlords co-sign with them. Farmers report that there are transportation problems from fertilizer agencies. These data show that the closer to the fertilizer agency, the more use of fertilizer by farmers. Crop responses to nitrogen fertilizer have probably decreased due to the lack of use of phosphatic fertilizers and the leaching of nitrates when overirrigations are applied. Most fields have low spots which receive too much water, and studies

are needed to ascertain the amounts of nitrogen in the nitrate form that is leached through the root zones of crops. Farmers simply cannot apply recommended rates of fertilizer due to lack of credit and control of irrigation supplies. In recent years, farmers have been faced with high prices for fertilizer, disruptions in the distribution system and periods of inadequate supplies. Even when supplies may be generally available in fertilizer factories and the larger markets, there are supply problems in large areas of the hinterland. Perhaps one of the most complex policy problems in agriculture today is to find the proper mix of actions that will result in increased fertilizer use by the majority of farmers. The data of this survey suggest that given more available water supplies and more reliability of the timing of supplies, farmers will utilize more fertilizer.

5.3. Ownership and Utilization of Improved Farm Technologies.

More Borrowing And Rental Use Of Implements

5.3.1 As is expected, the ownership of improved technologies is highly correlated to farm size; however, many more farmers than expected borrow or hire improved technologies as shown below:

Farm equipment item	% Owners	% Use (owners included)
Bullock cultivator	9	20
Bullock mouldboard plow	14	29
Bullock rabi wheat drill	8	15
Tractor	5	47
Threshing machine	3	9
Tubewell	12	44
Tractor with leveling blade	2	12

5.3.2 Utilization of these improved technologies is also positively and significantly correlated with farm size and tenure status.

POLICY IMPLICATIONS

1. Farm implements, such as the bullock cultivator, mouldboard plow, and the rabi wheat drill, have been recommended by the Agriculture Department since the early 1900's. Though these implements are fairly low cost, they have been adopted by a small minority of farmers. Studies are needed to determine why farmers, on a wider scale, have not used these implements. Farmers complain that the draft of the mouldboard plow, for example, is greater than the traditional plow. Bullocks probably don't receive adequate nutrition for this plow which requires a draft of about 170 pounds compared to 130 pounds for the local plow. Farmers complain that it takes

longer to plow an acre with the improved plow due to resting of animals. Other reasons given for lack of adoption of improved farm implements is that local blacksmiths can't provide spare parts. Given the increased attention to small and appropriate farm technologies, there is need to focus attention on these problems and make necessary improvements in those needed by farmers.

2. More large scale farm technology is used by sample farmers than expected. Tractor hire is especially important for land preparation which becomes a seasonal problem for intensive cropping. While only five percent of sample farmers own tractors, about forty-seven percent of the farmers use them from time to time in land preparation, especially in preparation for kharif crops. Likewise, small farmers benefit from the existence of private tubewells. If as many farmers benefit from tractors and private tubewells as the data show, special policies should be considered for making them more widely used. Small threshers, in some areas, have a thriving custom business. Where these are available on a hire basis, farmers make use of them to overcome the time constraint of threshing grain in time to prepare

for kharif crops and escape the early monsoon rain damage.

5.4 Trial and Adoption of Selected HYV of Crops and Practices.

Trial And Adoption Related To Farm Size

5.4.1 The trial and adoption of the following practices are also significantly related to farm size. The larger the farm the greater the trial and adoption.

Sixty-six percent of the sample farmers tried Chenab 70 wheat and 57 percent have adopted. Eighty-six percent of the sample farmers who gave Chenab 70 a trial, adopted it.

Forty-two percent of the farmers have tried SA 42 variety of wheat and 36 percent have adopted. Again, as in the case of Chenab 70 wheat, 86 percent of those sample farmers who tried SA 42 wheat, adopted it.

HYV Of Rice Adoption Rates Very Low

Of 293 farmers who cultivate some rice, 34 percent have tried the HYV and 21 percent have adopted it.[5/]

Improved Practices A Problem

Of 290 reporting rice farmers, 18 percent have tried line planting of rice seedlings and 8 percent have adopted the practice. Only 17 percent of the rice farmers report having used insecticides and 11 percent report adopting them.

Lack Of Insecticide Use

- Only 20 percent of the cotton farmers report having used insecticides and 11 percent report adopting them.

5/In general, there seems to be a low rate of trying the improved rice varieties, possibly due to poor presentation of the innovation, but 64% of those who gave HYV of rice a trial adopted it, a reasonably high rate of adoption.

Two-thirds of Sample Farms Have Not Adopted Phosphatic Fertilizer

Of 377 reporting farmers, only 43 percent report having ever used phosphatic fertilizers and only 31 percent report adopting this fertilizer.

POLICY IMPLICATIONS

1. Data from 381 reporting farms on the 40 commands show that about 90 percent had adopted HYV of wheat. This is higher than the GOP estimate for 1975-76 season, but close to the projection for 1979-80 for irrigated regions. While it was impossible to select a completely representative sample of the universe of over 78,000 commands, the data from this study show wide-scale adoption of high yielding wheat varieties. For the cropping season 1974-75, 93.4 percent of the sample farms reported use of HYV wheat. Looking at this sample by farm size:

Acres	% Adopting HVY Wheat
less than 2.5	84.7
2.5-7.5	95.4
7.5-12.5	92.4

This indicates that greater efforts must be made with the very small farmers in seed distribution and extension services.

2. Only 21 percent of the rice farmers had adopted the HYV varieties which results primarily from taste and cooking qualities and the higher price for Basmati varieties which is about 2 to 2.5

times greater than for the HYV varieties. A viable policy option is to focus more research on breeding higher yielding Basmati varieties which have an economic advantage over the HYV varieties.

3. Rice yields remain low for Basmati and HYV primarily because farmers are not using adequate fertilizer inputs, high plant populations and improved practices. Line planting and use of insecticides are used by only a small percentage of rice farmers. Likewise, only 11 percent of cotton farmers reported adopting insecticides. The major problem is supplies and lack of extension services. Likewise, only 43 percent of the farmers report ever using phosphatic fertilizers and only 31 percent report adoption. Both price policies and extension services need to be studied, related to farmers' use of phosphatic fertilizers.

5.5 Utilization of Recommended Management Practices for HYV of Wheat

5.5.1 Farmers exhibit relatively low levels of use of selected management practices due to lack of extension services, lack of credit as well as control over irrigation supplies.

Poor Seedbed Preparation

- Thirty-three percent of 344 wheat farmers used the correct range of seeding dates in 1975-76, and 27 percent used the recommended seedbed preparation method of deep plowing.

Traditional Seeding Practices

- Thirty-five percent used the correct range of seeding depth and 38 percent used the pora or drill seeding method.

Low Level Of Fertilizer Use

- Only 14 percent were able to use the recommended level of nitrogen and 25 percent used the correct level of phosphorus.
- Thirty-six percent used split applications of nitrogen and 57 percent used the recommended seed rate of 40 seers or more.

Large And Small Farmers

5.3.2 The use of each of the above practices is found to e significantly related to farm size. The larger he farm size the greater use of these practices hich suggest both economic and information contraints.

doption of improved practices is found to be ignificantly related to farm size, level of managelent knowledge, level of education and type of atercourse command (perennial versus nonperennial). hese factors explain about 60 percent of the ariation in adoption using an adoption index.

Needed: Credit, Knowledge, Education And Water

OLICY IMPLICATIONS

hese data suggest clearly that while farmers have dopted the new HYV wheat seed, they have not been ble to adopt the package of inputs and improved anagement practices required for improved yields.

Those practices which require insignificant outlays of capital suggest that the major problem is lack of extension services (to be discussed in a special section later). Credit for fertilizer is a perennial problem for small holders and yields are not expected to rise significantly until farmers use more fertilizer and have improved water supplies or improved control over available supplies.

5.6 Major Factors in Farmers' Cropping Decisions

Home Consumption

5.6.1 Major factors in farmers' decisions to cultivate wheat, fodder, rice and sugarcane are "home use and tradition."

Market Price

5.6.2 Where fodder, sugarcane, rice and cotton are cultivated for market, and water supplies are adequate, farmers report market price as the most important factor.

Water Supplies

5.6.3 Where the water supply situation is fair, the major decision given by farmers for cultivating cash crops is their perceived irrigation supplies.

Given Improved Water Supplies, Market Price Is Important

5.6.4 Farmers on public tubewell supplemented commands report that the first factor determining whether they cultivate cash crops is market price rather than perceived irrigation supplies.

POLICY IMPLICATIONS

These and other data of the survey suggest that removal of the water constraint will enable farmers to cultivate more cash crops once home consumption needs are fulfilled.

Farmers are responsive to price policies in their cropping decisions within the major constraint of water supplies.

6.0 KNOWLEDGE CONSTRAINTS - Volume IV, Chapter 4

6.1 Farmers in Pakistan receive almost no extension services related to water management; therefore, they use estimates derived from trial and error practices of deciding when to irrigate, how often to irrigate, and how much water to apply per irrigation.

Farmers' Decision Making About When To Irrigate

6.1.1 The vast majority of farmers on all types of commands report that they make their decisions to irrigate by visual indicators of plants or the soil surface. Only 11 of 376 farmers reported checking the sub-soil moisture levels as a method of deciding when to irrigate.

Farmers' Decision Making About When To Stop An Irrigation

6.1.2 Of 378 farmers, 47 percent reported that they stop an irrigation when water has reached the far border and 33 percent reported "when all high spots were covered."

How Much To Irrigate And When?

6.1.3 Farmers do not know crop water requirements or what stages of plant growth require more critical demands of water. Sixty-one percent of the farmers report that wheat requires more total water than cotton or report they don't know. Farmers tend not to know the irrigations for four stages of cotton growth at which irrigation is most essential.

6.1.4 Farmers on a given watercourse vary radically in their estimates of water requirements for crops.

Factors Related To How Much Water To Apply

6.1.5 The factors which explain most of the variation in amounts of water farmers apply to their crops in order of importance are: Amount of water available at the field for a given irrigation, type of irrigation, days since the last irrigation, farmers' estimate of water infiltration depths, and season of the year.

- More water is applied to cotton, sugarcane, gardens and for preirrigation than other irrigations.
- More water is applied during kharif season than rabi for all crops.

6.2. Agronomic

Knowledge Of Infiltration Of Water

Farmers share a common concept that crop root systems penetrate only a few inches into the soil and that a five inch application of water infiltrates only to depths of 12 to 24 inches.

6.2.1 Only 30 percent of the farmers report water infiltration depths of 24 inches or more.

Rooth System Depths

6.2.2 The majority of the farmers report that sugarcane, rice, wheat and berseem root systems penetrate to depths of 1.5 to 6 inches. The majority of farmers report that cotton root systems penetrate to depths of only 12 inches or less.

Extension Field Assistants' Knowledge At About Farmer Level

6.2.3 The 19 extension field workers interviewed in one area also exhibit lack of knowledge of root system depths and depth of infiltration of water.

6.3 Water Loss

Farmers Aware Of Some Types Of Watercourse Conveyance Losses But Not Magnitude Of Losses

Farmers are aware of some of the causes of watercourse losses such as silt deposits (19%); improper ditch elevations (28%); leaks and spills (21%); vertical ditch seepage (14%); grass, trees and phreatophytes (14%); and rodent holes in banks (3%), but they are not aware of the magnitude of these losses. Farmers likewise report that more regular and improved cleaning of watercourses and installation of permanent turn-out structures at watercourse junctions will reduce losses, but they have no solutions for improper elevation of channels or vertical and horizontal ditch seepage.

6.4 Wheat Management

Farmers' Knowledge Of Recommended HYV Wheat Management Practices Is Low

The following percentage of farmers in a knowledge test of recommended management practices for wheat could provide the correct answers for items below:

*Range of seeding dates	-34%
*Proper seedbed preparation	-33%
Proper seeding depth	-32%
Proper seeding method	-43%
*Proper levels of N	-27%
*Proper levels of P	-36%
*Split levels of nitrogen	-42%
Proper seed rates for late sowing	-61%

(The * denotes those which are significantly related to farm size.)

6.5 Extension and Institutional Services

Farmers' Knowledge Of Extension And Other Institutional Services

Farmers exhibit low levels of knowledge about extension workers and others assigned to serve them except the canal patwari.

6.5.1 Fifty percent of the farmers could not give the name or office location of the agricultural assistant (AA).

6.5.2 Forty percent of the farmers could not give the name or office location of the field assistant (FA) assigned to their area.

6.5.3 Eighty-five percent of the farmers report no contact with either the AA or FA in the last three months.

6.5.4 The great majority of farmers know their patwari and over 32 percent had contacts with this official over the past three months.

6.5.5 Knowledge of extension workers and contacts with them are significantly related to both farm size and distance from the farm to the main paved road.

Extension Workers And Large Farmers

6.5.6 Knowledge of and contacts with fertilizer agents, bank officials and canal officials are significantly related to farm size and usually related to tenure status and distance of the village from the main road.

6.6 Canal Closure

About 70 percent of the farmers report that they do not receive advance information from the irrigation department

Farmers Need Advance Information About Canal Closures

about canal closures for repairs and cleaning. About 50 percent report no advance information about closures for rationing canal water.

6.6.1 The degree to which information is received by farmers about closures is significantly related to both mass media exposure and farm size.

6.7 Radio Positive Direction

Importance of Radio

Radio as a mass media is used by a high percentage of the farmers and this is related to farm size.

6.7.1 About 50 percent of the farmers report owning radios and 56 percent report casual listening.

6.7.2 Fifty-four percent reported listening to the farm radio program in the last week.

6.8 Trial and Adoption

Farmers' Sources of Agricultural Information At Trial And Adoption Stages

Farmers' primary sources of information at the trial and adoption stages of five improved farm practices are: other farmers (54%); extension personnel (23%); farm radio (20%); and other sources (3%).

POLICY IMPLICATIONS

1. We would like to emphasize as clearly as possible that the data about farmers' lack of knowledge of improved water management practices and soil-water-plant relationship in no way is meant to imply ignorance or lack of farmer rationality. To the contrary, we have learned that in Pakistan, the expert on water management problems at the farm level is the farmer himself. We are impressed by the level of his operation and in relationship to the physical, legal, social

and economic constraints he faces daily in farm operations. The problem lies not so much with the farmer as with the lack of institutional services and incentives. The major problems are organizational and structural. For example, neither extension workers nor irrigation engineers have been trained in irrigation problems and their solutions at the farm level.

Our purpose was to attempt to gain a knowledge base: the farmers' perspective of why he operates as he does, his farming practices, knowledge to assist the farmer to improve his traditional methods. We recommend that institutional studies be conducted by the agricultural extension service, agricultural universities, research stations and Irrigation Department. In addition:

- Place highest priority on training of water management extension personnel at the University of Agriculture at Faisalabad to support the water management improvement project.
- Conduct an on-going evaluation of the training program at the university, especially of the six months field training phase. Continue evaluation of all field workers to provide feedback for improvement of the training program.
- Strengthen and institutionalize the present cells in agricultural departments with priority to the selection of well trained personnel.
- Provide an incentive system for personnel trained as water management advisors or irrigation engineers.

Develop adequate training manuals based on Pakistan data for trainees and field manuals to be used by field workers.

Study the university in regard to the relevance and adequacy of its present educational programs. Considerations need to be made for institutionalizing courses tailored to farm needs, especially irrigation. Since, realistically, farm water management problems require interdisciplinary approaches in research and development, students should be trained in economics, extension, sociology and engineering; in areas related to farm water management skills.

Since a large percentage of agricultural students have had no practical farm level experience, the university should initiate practical field research and training programs affording students and staff first hand experience in farm level problem solution. Such programs would provide feed-back for the substantive teaching of students.

The pilot training program of watercourse engineers and land leveling technicians conducted by the SCS group in Pakistan and the Agricultural Department requires careful evaluation to ascertain both the context and the results of the training offered. Carefully selected individuals should be provided the necessary training required to make this an ongoing program.

Special in-service programs are needed for all extension personnel on a regular basis. Such training should focus on skill acquisition by demonstration instead of the usual method of lecture.

Extension Service

3. While the present extension service of some 4000 employees needs to be expanded, the greatest requirement is improved discipline, supervision and management along with retraining in farm level skills. Supervision of field personnel is weak due to lack of subject-matter technical backup and the heavy load of regulatory duties of present supervisors.

- A nation-wide program should be developed to study various incentive methods, facilities and supervision of extension personnel to improve the morale, the image and the work of the present field staff.

4. The Agricultural Department should experiment with several extension models to ascertain which is most relevant to Pakistan's needs.

- Small pilot projects, involving the farmer in planning and implementation of the projects, should be developed for the testing of various extension strategies.
- Unlike the IRDP model, expansion should be in easy stages only after results have been obtained.
- Replication of successful pilot projects on a large scale may be difficult to accomplish adequately. Therefore, necessary pre-requisites for this replication should be carefully developed.

5. Perhaps a possible basis of the transformation of the present extension service is the current water management improvement program and the training required to provide personnel.

6. A more difficult problem will be to achieve improved cooperation of the Irrigation Department, WAPDA and the Agriculture

Department. The first two have some working relationships which could be improved; however, the Agriculture Department and the Irrigation Department exist as separate domains. It may not be possible to develop a comprehensive water management improvement program that can be successful without close cooperation between these departments.[6/]

Knowledge/ Contact Farmer/ Extension Personnel

Data on farmers' knowledge of extension personnel and contacts with field workers suggests a major problem. It is impossible to expect that a large percentage of farmers should know extension personnel because the present ratio of agricultural assistants (AA) to farms is about 1 per 8355 farms. The ratio of field assistants (FA) is only about 1 per 1245 farms. In terms of watercourse commands, this is about one AA per 209 commands and one FA per 31 commands. Transportation alone is a tremendous problem and field workers have use of only their bicycles. One strategy is to use the pilot project for improved farm water management on 1500 watercourse commands and its training programs as a means of re-training field personnel by:

- Carefully selecting outstanding agricultural assistants to participate in the one year training course for water management extension at Faisalabad.
- Upon successful completion of the training course, provide incentives such as increases in salary grade and transportation facilities (motor bikes).

6/The canal patwari, known by more farmers than extension workers, could, with other irrigation officials, be used more effectively in communicating to farmers information regarding: canal closures, expected seasonal supplies and irrigation policies. Farmers report they do not receive such information in time to make rational cropping plans.

Develop how-to-do training materials and field manuals in the local language for the training of field assistants by agricultural assistants.[7/]

The first of these materials should be based on problem identification skills to train field assistants in diagnosis of problems. Problem areas identified in this survey and other CSU research indicate areas of skills and types of skills required such as:

- Measurement of water and estimation of losses.
- Identification of moisture stress and crop fertility needs.
- Estimation of soil moisture deficits.
- How to estimate the need for land leveling.
- How to conduct problem identification surveys with farmers.
- How to communicate effectively with farmers.

Extension workers, to date, have not learned problem conceptualization, diagnosis or solution. In the past, without adequate training, they have attempted to simply pass on information to farmers. Once field workers have been trained in problem identification skills, they will need to learn other skills aimed at problem solving, such as: Crop water requirements, how to design improved farm layout, the need and importance of land leveling, how to help farmers install low cost structures at main nakkas and junctions

7/An alternative short-run policy option, given resource constraints, is to select a minimum package of the most essential practices that provide maximum payoff and promote the extension of these zealously on a wide-scale basis. Such an approach also requires training and careful supervision.

of watercourses, how to organize farmers for improved maintenance of the conveyance system, improved irrigation practices, program planning techniques, extension teaching and communication methods.

Given the large ratio of field workers to farmers, changes in extension methods should be examined. Trained workers could be assigned to two or three watercourse commands under careful supervision of the AA for a six month period. They should focus more on using group methods in working with farmers than in the past. The western model of working with individual farmers has many weaknesses when used in LDC's. On these commands, farmers' organizations should be developed and members taught how to properly clean and maintain watercourses. Farmers in the past used wandaras as time keepers for irrigation turns. They are accustomed to paying such individuals in kind for their salary. Such a system should be tried because one or more individuals could check and repair leaks and spills, provide surveillance to limit stealing and notify members when cleaning should take place.

Such a program would limit the efforts of FA to a small area where he has a chance to make a solid impact. Such an approach could be tested during the pilot program underway. As experience is gained, an FA could perhaps take on other areas. If each FA had 4 commands each 6 months, he would cover almost all the water commands in his present area, which has from 30 to 40 command areas, in about three years.

8. To support extension programs, it is necessary to have research findings relevant to the priority farm level needs. No extension service can be effective without good linkages and two-way communication between research institutes and extension. At present, good cooperation and coordination between these two services does not exist. The organizational structure of both services is such that coordination and planning is difficult to achieve. Researchers are faced with severe problems of funding, lack of personnel and facilities.

Research Programs And Extension Service

- Research Institutes should have agricultural and irrigation engineers on their staffs to participate with soil scientists, plant breeders, plant pathologists, etc. in team research projects. Joint activities between extension and research may be facilitated by posting extension specialists at research stations. Subject matter specialists, who provide technical backup to field staff, should receive part of their training at such stations. Such interdisciplinary research would provide needed information about:
  - water management and yields in terms of various irrigation practices
  - costs and benefits of precision land leveling
  - research watercourses equipped to test measuring devices and permanent structures

Agricultural Department farms could be made into substations, making adaptive research findings more specific to the areas where they will be used. Also, young scientists would be provided with opportunities for professional advancement.

Such substations could be developed for sorely needed water management research.

The Agricultural Research Council, which establishes policies, priorities, and controls funds, needs to be further strengthened in staff.

- Extension specialists and researchers could review research proposals.
- An evaluation system is needed to assure limited funds will be used to meet priorities that exist at the farm level.
- ARC could use its authority to encourage research institutes to provide technical support to farm level adoptive research programs. For example, since most water management technology is known, the focus of this area should be on applied and adaptive research. This would bring the researcher face to face with the farmer and his problems/priorities.

Radio

9. Radio listening is widespread in rural Pakistan. The present farm radio program is one of the top listening preferences reported by sample farmers. With about 50 percent of the farmers owning radios and over half listening regularly, much use should be made in making farmers aware of the new water management programs of the government. Other than news about crops and market news, farmers also need information about canal closure dates for repairs and cleaning, and seasonal estimates of expected canal water supplies in order to reduce their risks. Farmers presently do not receive this information with any regularity. Farmers can be made aware of new government programs for regular

watercourse cleanings and minor improvements by radio. Radio can help farmers know about the new programs of land leveling and watercourse improvements. To reinforce these messages, however, extension workers also need to contact farmers on a more regular basis.

7.0 WATER CODES AND REGULATIONS-Volume II, Chapters 2 and 4

Canal And Drainage Act Of 1873 Out Of Date

The water codes and regulations which govern the distribution of water, the maintenance of the farm system, settlement of disputes and other activities at the farm level irrigation system were included in the Canal and Drainage Act of 1873 (Canal and Drainage Act, 1974). These have changed little except for minor amendments for over 100 years. Selected codes and regulations are listed below with findings from the survey which indicate that these operate as constraints to farmers. Farmers must evade laws to obtain more flexibility in water distribution. The absence of enforcement of many of these codes have led to a lack of respect for irrigation authorities.

philosophy of the Act is one of benign neglect of farm system blems which survey data confirm.

7.1. Selected Codes Related to the Farm Irrigation System

Benign Neglect Of Farm Level Irrigation System By Department

7.1.1 Subdivisional canal officers or higher authorities can terminate water supplies if watercourse is not maintained (page 28). Of 40 watercourse commands, no case was documented where this code had been enforced in the knowledge of key informants.

Farmers Buy And Sell Canal Water

7.1.2 No person can sell or sublet canal water (page 22). Thirty-four percent of the sample farmers report buying and selling of canal water. Where water is allotted for village roads, ponds, etc., this is often sold to farmers for irrigation purposes. Twenty-two percent of sample farmers reported buying and selling canal water with other farmers; 7 percent report buying water allotted for village roads, and 5 percent report buying water allotted to village ponds. Fourteen percent of sample farmers report trading canal water for tubewell water.

Illegal Moghas

7.1.3 Making cuts in a distributary and creating unauthorized moghas is illegal (page 26). Numerous cuts were found at site 103 and at sites 115 and 116. There was a total of 8 illegal moghas documented on survey maps.

Use Of Water From One Mogha Outlet For Another Command Area!

7.1.4 Applying water outside the mogha outlet area or command boundary is illegal (page 28). As our data on watercourse channels and field channels show, when there is land in another command that can more easily be irrigated by water from another outlet, farmers take advantage of this fact. Also, there is usually an area between two commands that is irrigated by water from both mogha outlets. Farmers who have land in these areas on both commands obtain more flexibility in irrigation supplies.

Actual Vs. Prescribed Mogha Discharge Flows

7.1.5 Tampering with the moghas is illegal, yet measurements of the actual discharge in the various watercourses show that there are discrepancies between authorized and actual flows. The discrepancies, however, are not always in the direction of the watercourse receiving more water than is allocated. About half of the watercourses are not obtaining what is legally allocated to them.

Difference between Actual and Authorized Mogha Discharge Flow

Actual < Prescribed		Actual > Prescribed	
Degree of Discrepancy (cfs)	Watercourses N	Degree of Discrepancy (cfs)	Watercourses N
Slight (0.01-0.29)	10	Slight (0.01-0.29)	8
Medium (0.30-0.89)	5	Medium (0.30-0.89)	7
Large (0.90≥)	3	Large (0.90≥)	3

Widespread Trading Of Canal Water

7.1.6 Taking water out of turn is illegal (page 28). Survey data show that trading is widespread and this is not limited to nonregulated warabundi systems. Farmers are under a constraint to trade to obtain more flexibility of supplies in times of demand. Sixty-eight percent of sample farmers report trading partial turns and 33 percent report trading full warabundi turns.

7.1.7 Allowing water to run to waste is illegal (page 25). Pictures in Photo Glossary Figures 5-F, 6-C, 7F, 7AA, and 11P, show that farmers allow water to run to waste. Observations at irrigation evaluations revealed that farmers often irrigate and leave the fields and allow water to fill basins that overflow into other fields and roads. Evidently this regulation is seldom enforced. Some farmers irrigate at night and allow water to run until morning creating a micro-flood situation. This was much more prevalent on SCARP public tubewell commands than other commands. Wasted water is a function of lack of their control over water supplies.

Water Does Run To Waste Especially On SCARP Commands

7.1.8 Claims for remission of assessed tax revenue for crops damaged by natural causes can be made by cultivators concerned or by the numbardar by application to Divisional Canal Officer (page 76). About 60 percent report paying regular fasalana to patwaris to reduce their water rates in times of no natural damage by writing in less acreage irrigated and/or reporting some areas as damaged by natural causes.

Fasalana Payments

7.1.9 If water from a well or any other source is conveyed in the same channel as canal water in the same season, the whole of the irrigation from that channel during that season is liable to be treated as irrigation from the canal (page 79). Farmers with private tubewells on all sample command areas must

A Questionable Regulation

utilize the same channels used for canal water and do so without any sanction from the Irrigation Department officials.

7.1.10 The schedule of canal water rates is to be accessible to villagers. It should be posted by the patwari in a conspicuous place in the village (page 81). Farmers uniformly report that water rates are not posted by the patwari in the village. Village numbardars usually have such lists but they are not posted.

Stealing of Canal Water Related to Private Tubewells

7.1.11 It is illegal to steal canal water. Thirty-five percent of sample farmers reported stealing. The degree of stealing is related to water availability and control. That is, farmers located on commands with a high density of private tubewells report less stealing; sixty-two percent of sample farmers on commands with no tubewells (public or private) reported stealing. The relationship of stealing is significantly related to density of tubewells.

Do Farmers Receive Adequate Information About Canal Closures?

7.1.12 Irrigation Department officials must notify farmers of closures for repairs, cleaning, and rationing purposes for canal deliveries.

The following is a summary of farmers' reports about information received about types of canal closures.

Type Closure	Degree of Information Received (%)		
	Never	Sometimes	Usually
Canal repairs	69	12	19
Canal cleaning	69	13	18
Canal rationing	45	29	26

POLICY IMPLICATIONS

The existing water law and its codes and regulations were developed for conditions of a hundred years ago, and its philosophy, objectives and assumptions are not entirely relevant to the development needs of today. The 1873 Act designers could in no way conceptualize the needs of the massive irrigation system that exists today and the demands on the present system. This is not to say that the 1873 Act was not a notable achievement in its day, but it must be recognized that in many ways it is now an inhibitor to change and progress.

1. A careful study of the Canal and Drainage Act (1873), the Revenue Manual, and the Canal Manual, used by the Irrigation Department, should be undertaken by a select technical committee to ascertain those regulations which are definite constraints to the development of the system at the farm level.
2. Through trial and error, farmers have learned to manipulate the system, resulting in considerable loss of revenue to the government. The problem is highly complex (fasalana payments to officials, etc.). To change these practices is a task the ramifications of which we do not fully understand. However, there are definite physical and institutional reasons why the practices are widespread. The present legal system must be radically transformed to meet demands. Improved supervision

and enforcement of more rational codes would benefit the small holders and tenants who suffer the most.

The goal must be to design and implement a code that will provide incentives to the farmers to utilize each unit of water for increased crop production, coupled with production possibilities to enable them to continue to reduce their per unit cost of operation by increasing per unit output. This implies both: improved institutional services and water codes, and improved physical technologies to stimulate sufficient change.

8.0 FARMER ORGANIZATIONS-Volume IV, Chapter V

It has been shown that delivery efficiencies, application efficiencies, and overall irrigation efficiencies are uniformly low across all sample watercourses. If these problems are to be alleviated, farmers must organize to: 1) construct and maintain improved watercourses, 2) build linkages to sources of irrigation and agricultural knowledge, and 3) secure greater control over the timing and amounts of water. The problem of building effective farmer water user associations becomes, then, the central sociological problem. The approach to this problem is made in two parts. First, the general social environment of sample villages is described; second, the analysis addresses the question as to how to select those villages which would be the best candidates for programs of improved water management.

8.1. Social System Factors and Farmer Organizations

The first portion of the sociological section describes the general social environment found in villages and patterns of water management found therein. Specifically, it was learned that:

Influence Of Brotherhood Kinship Groups

8.1.1 Biradari (brotherhood) groups are the most central networks influencing farmer behavior--most farmers must subordinate individual perference to biradari group needs. Furthermore, the greater the level of trust required in a social relationship, the more farmers tend to want to keep the relationship within brotherhood networks--most probably because that is where violators of agreements can be most firmly sanctioned. The obvious implication is that water users associations must be adapted to the reality that farmers support and oppose policies in brotherhood units.

Water Supplies The Major Problem

8.1.2 Sample farmers are most concerned about the problem of water availability - no other farm problem is ranked above it. Farmers do not understand the extent to which they lose water in poorly constructed watercourses or the degree to which they misapply it. Farmers need technical assistance which will demonstrate and reduce the extent of water waste typically existing.

Rigid Water Allocation System

8.1.3 An increase in farmer knowledge, while necessary, is not a sufficient condition for water management improvement. Farmers need more flexibility in the allocation of irrigation water than is now possible. In effect, farmers have little control over the timing and quantity of their canal water supplies but they struggle to secure increased amount of control over the irrigation system in four ways:

Trading And Buying And Selling Of Canal Supplies

- Over 68 percent of sample farmers engage in illegal water trading of at least partial irrigation turns. There is no significant relationship between socio-economic status and trading. In addition, 34 percent of the sample farmers indicate that they illegally buy and sell canal water supplies.

Extra Water Availability When Needed

- Only about 12 percent of the sample farmers own a tubewell but over 63 percent claim that they can obtain tubewell water either from a private source or by securing nonscheduled public tubewell deliveries.

Stealing

- Over one-third (35%) of the sample farmers report that they have had water stolen from them one or more times during the past rabi and kharif cropping seasons.

Farmers Pay Fasalana

- Irrigation officials, who control the means to help or hurt farmers, are frequently approached for "concessions"--to be had in exchange for cash or commodities. About 60 percent of the sample farmers in all villages report payment of fasalana to the patwari to obtain a reduction in the crop assessments. Sample farmers in all villages report that, at one time or another they have taken up collections among watercourse colleagues to either pay a bribe to secure a mogha repair, to obtain a mogha enlargement, or both.

By these means, farmers have created an illegal quasi-demand system on watercourses, but it still yields insufficient control over water supplies given the needs of modern agriculture .

8.1.4 Existing methods of organizing to construct and maintain collective goods such as schools and mosques, and to undertake watercourse cleaning, are invariably informal in nature. The biradari group in all cases is the central mobilizing social unit. Formal incorporated organizations capable of entering into enforceable contracts for specialized water management services are nowhere found in sample villages.

8.2 Criteria for Selection of Villages for Pilot Water Management Programs

Equality
Strength Of
Leadership

One portion of the sociological research is addressed to the question: If farmer water users associations are an important element of water management improvement programs, how might one go about selecting those villages with social environments most conducive to the reception and support of such associations? Two sociological criteria are suggested which can be used to screen candidate villages. The criteria are:

8.2.1 Villages can be subjected to the test of equality in the distribution of farmer power/influence. It is hypothesized that villages, in which inequality is great, are poorer candidates for farmer organization than those in which equality is greater--more exactly, villages where it takes half of the farmers to account for half of the power/influence scores.

8.2.2 Those villages surviving the screeening on equality can then be ranked according to the strength of leadership as evidenced by centrality scores - the proportion of farmers scoring over eighty percent (or some other selected level) of the highest potential score.

Because data are not available to establish that these criteria are central to the problem of successfully establishing water users associations, it is suggested that further research be undertaken in which the same organizing attempts are uniformly made in three samples of villages: (1) those meeting the above two criteria, (2) those not meeting the criteria, and (3) a sample of villages chosen without regard to the criteria. Such research would make it possible to systematically explore the extent to which the three criteria affect water management behavior, the propensity to accept organizational efforts, and the success of those efforts.

8.3 Watercourse Cleaning and Maintenance of Main Watercourse Channels

Cleaning Main Watercourse

8.3.1 Farmers generally do not clean and maintain main watercourse channels with sufficient regularity or maintain main channels adequately.

Why Have A Rule That Is Not Enforced?

8.3.2 For the 40 watercourse commands, farmers report that the Canal and Drainage Act related to regular cleaning had never been enforced.

Farmers In Ad Hoc Organization Apply Sanctions

8.3.3 Farmers on most watercourse commands have ad hoc arrangements for cleaning and use of a variety of sanctions to ensure participation.

Regulated Warabundi Systems More Organized Than Nonregulated

8.3.4 Over ninety percent of the sample farmers report preference for the regulated warabundi system to the nonregulated system. Farmers on regulated warabundi commands in comparison to farmers on non-regulated commands tend to:

- Clean main watercourse channels with more regularity,
- Apply more sanctions for noncompliance in cleaning,
- Have more informal committees for cleaning watercourses and settling water disputes.

Who Can Violate Group Sanctions?

8.3.5 Large farmers and powerful village leaders tend to violate sanctions more than other watercourse members.

Times Cleaned, Organization, And Silt Loads

8.3.6 There is great variation in the number of times main watercourses are cleaned per year, depending primarily on silt problems and degree of informal organizations.

Division Of Labor In Cleaning Main Channels

8.3.7 There is great variation in the amount of effort expended, measured in man days, cleaning main watercourse channels.

8.3.8 Main reasons for low level of watercourse cleaning and maintenance are:

Why Do Farmers Not Clean Main Watercourse Channels With More Regularity?

- Lack of farmer interest,
- Lack of knowledge of magnitude of losses,
- Lack of knowledge of how to control such losses

8.3.9 Watercourse alignment and improper cross section of channels are problems on most main watercourses and field channels.

Watercourse Alignment Problems

8.3.10 Silt deposits due to lack of adequate cleaning creates severe problems of dead storage, over-topping, and submergence of mogha on many water-courses.

Silt Problems

POLICY IMPLICATIONS

There is an urgent need for more enforced discipline on all water-course commands related to cleaning and maintenance of water-course channels. A system of incentives and sanctions is urgently required to assure improved maintenance and cleaning schedules. There already exists ad hoc arrangement for watercourse cleaning that may provide a basis for building more efficient farm level organizations. There is a need for better watercourse command organizations of farmers for improving the delivery and distribution of irrigation water. To date, no such organization exists and farmers are not given incentives for formal organization. Though it is beyond the purpose of this report, one of the missing components in development at the village level is the lack of farmer organization. It is doubtful if any watercourse improvement program in Pakistan will be successful until it becomes a farmers' program. The government should consider the importance of formal grass roots organizations to achieve its goals in water management. Data indicate that farmers are more organized on regulated versus nonregulated warabundi systems Over 90 percent of the sample farmers report preferring the regulated warabundi system. This appears to be because large landlords tend to take advantage of small farmers and tenants on the nonregulated systems.

CHAPTER TWO

SUGGESTED CRITERIA FOR SELECTION OF WATER MANAGEMENT WATERCOURSE COMMANDS FOR COMPREHENSIVE IMPROVEMENTS[8/]

The findings of this study can be utilized to develop criteria for selection of priority watercourse command areas for comprehensive improvement programs. Decisions must be made about areas in which improvement programs are likely to result in maximum benefits to farmer clients. Once the districts and the divisions of the provinces are selected for pilot project programs, specific watercourses for major improvements should be carefully screened on the basis of objective criteria. The purpose is to select specific watercourse commands where a substantial degree of success is expected in mobilizing farmers for participation and where benefits will accrue to small farmers and landless laborers as well as to larger operators.

Before specific criteria for selection are discussed, it is important to stress the importance of several types or levels of programs for water management improvements. First, there is a need for broad public and official concern for water resource management and water use efficiency for increased crop production. This can be done by government officials up to the Office of the Prime Minister. The major project in improving water resource use is to change the attitudes of both the public and officials at every level. Such a continuous campaign can be conducted with the help of a mass media and other imaginative approaches. Secondly,

8/ These criteria or guidelines are only suggestive. Some are based on the data of this survey and others are from experiences in Pakistan. These criteria are provided only to highlight possible problem areas to be considered in the implementation of a development program.

a general program including mandatory watercourse cleaning and maintenance could be implemented by government at low cost on a nationwide basis. The World Bank estimates that such a program would probably result in a saving of about 5 MAF of water by 1978 which valued at the cost of Tarbella storage is a total saving of about 2.1 billion dollars--assuming that the "saved" water could be put to productive use. To achieve this farmers would be required to remove silt from watercourse channels, build up channel sides to prevent overtopping, and remove trees, shrubs, and grass from watercourse banks. In addition farmers should adopt a regular routine of cleaning and maintenance. Well-prepared instructions could be made available to farmers on how-to-do-it and what it will achieve for them in additional supplies. Both sanctions and incentives would have to be used in order to gain widespread compliance for improved cleaning and maintenance of the farm irrigation system. Certain fines might work as sanctions and remission of land or water tax might be considered as incentive.

The selection of specific watercourse commands for major improvements is complicated by several types of watercourse command environments in Pakistan which include the following: SCARP public tubewell supplemented, private tubewell supplemented, perennial and non-perennial commands, commands with various degrees of waterlogging and salinity problems, commands with various degrees of groundwater quality and commands that are nontubewell supplemented.

These various types of watercourses are not mutually exclusive. As an example, SCARP watercourses include perennial and nonperennial types, and many are in areas where there are problems of waterlogging or a high potential for such problems.

Government, for political reasons and other considerations, will have to make a decision as to how much focus will be given to the various types of watercourses and the locations of projects for on-farm water management improvements. The nature of the improvement activities will vary in relationship to the critical areas chosen. These areas will be chosen on the basis of the following:

- Waterlogging--salinity status. We suggest including those commands in areas of poor groundwater and those in areas with no groundwater problems which have critical shortages of water and few or no tubewells. Within this group, first priority should be given to those watercourses with good groundwater where supplies can be increased by watercourse improvements and the installation of small discharge private or cooperative tubewells. In these areas, water is a major limiting factor and total crop production can be rapidly increased. Among small farmers, this would be a means of rapidly increasing farm income and the achievement of higher levels of living. Second priority would then be given to watercourses with poor groundwater where all canal water saved will result in benefits to farmers. The lack of supplemental water from tubewells on these watercourses make total benefits less than those for farmers in good groundwater environments.
- Water supply adequacy. Where there are SCARP tubewells and several private tubewells, considerable savings of water can be achieved. Water saved can be used to increase both cropped area and cropping intensities. Such an environment is favorable because farmers have more control of irrigation water and can be taught to apply amounts necessary to replenish the soil moisture deficit.

Usually there are very large losses on such commands as the data show because conveyance systems have not been redesigned for the conveyance of tubewell plus canal supplies.

Degree of topographical problems. Where precision land leveling services can bring additional land into cultivation, design larger improved farm layouts. Some command areas have substantial areas of CCA and other land which can be developed for irrigation given increased water supplies obtained from improvements.

hysical, economic, and social criteria are presented with a brief discussion of their importance. These should be viewed as suggestive alternative criteria which must be consistent with the particular political obje

1.0 Physical Factors

1.1. Magnitude of Losses

This criterion can be estimated at a level whereby considerable savings can be realized from improvements. For example, where efficiencies of the conveyance system are 35-40 percent or less, these can be raised to 70 or 80 percent by comprehensive low cost improvements. Measurements of candidate watercourse commands can quickly be made at the head, middle and tail reaches of the watercourse to determine the level of conveyance losses.

Where farmers' fields are not too small and too fragmented the potential for design of level and larger fields is possible.

1.2. Perennial Versus Nonperennial Commands

Generally, only perennial watercourse commands should be included in the first phase of the program, because farmers with regular year-round supplies of water have greater potential for increasing total crop production through higher cropping intensities and per acre yields. This decision rule would greatly reduce the number of watercourse commands to be considered. If, however, public tubewells or a high density of private tubewells exist on nonperennial commands there would also be a high potential for water savings and increased crop production.

2.0 Economic Factors

2.1. Potential for Increased Cultivated Acreage

There are some command areas where increased acreage can be brought into production given extra water supplies and means for leveling uncultivated areas of higher elevation. These are usually areas in the relatively new canal colonies developed from the late 1920's and afterwards. Considerable increases in cultivated acreage are possible and this can result in increased aggregate crop production.

2.2. Potential for Increased Cropping Intensity

Where cropping intensities are about 120 percent or less, there is substantial potential for higher intensities with water saved by improvements of the conveyance system.

2.3. Potential for Increased Yields Per Acre of Food Crops

Given several low yields, this criterion is such that almost any command area would qualify. We suggest commands where per acre yields of wheat and rice can be increased by 50 percent or more. Such a goal should not be difficult to obtain, however, it places priority on wheat and rice commands.

2.4. Potential for Benefiting Small Farmers

If the policy objective is to benefit small farmers, it is important to establish a criterion for this purpose. We suggest that 75 percent of the farmers on specific watercourses have holdings of under 35 acres. This refers to total holdings on other watercourses and is not simply the unit on a given watercourse. However, considerations should be given to joint farms where several brothers or other relatives conduct joint operations. If improved watercourse conveyance systems reduce losses substantially, as we think they will if done properly, large landlords most likely will be influenced by the demonstration effect. This eventuality would correct the common fallacy of a "trickle down" effect. Instead, diffusion would be from the small and medium sized farms to the large landlords.

2.5 Land Fragmentation

An important consideration is the present degree of land fragmentation that has taken place on watercourses. If excessive fragmentation exists, it will create impediments for land leveling. Also, as found in the survey, farmers are suspicious of government programs which have even indirect relationships to land consolidation. This might create problems of gaining confidence and participation of farmers. We suggest that the median number of separate parcels per farm unit on watercourses should not exceed four or five. Given ten acres, average size farm units, fields of 2 to 2.5 acres could still be leveled and designed into more efficient units.

3.0 Social Factors[9]

3.1 Equality of Power/Influence

Commands should be selected where power and influence in decision making about village projects are shared by major brotherhood or agricultural caste group leaders. Villagers usually have their own methods of gaining concensus in decision making by using leaders from major brotherhood or caste groups.

3.2 Presence of Watercourse Leadership

Watercourse commands should be included where there is evidence of strong leadership shared by major group leaders. There is an indication from the data of this study that villages with a past history of cooperation by major caste and brotherhood groups in the establishment and upkeep of common mosques, schools, and other organizations can be expected to cooperate in other matters as well. It is relatively easy to gain this information by observing mosques, schools, and other village facilities and by interviews with key informants.

9/These are hypotheses which require testing, therefore, it is essential to include a special evaluation of the Pilot Project Program in terms of farmer organization.

3.3 Evidence of farmer interest and commitment to establishing a watercourse level and implementing a regular program of watercourse cleaning and maintenance.

Other criteria to use are the full agreement of all watercourse members to form a watercourse level organization (water users' association suggested) and willingness to implement a routine watercourse cleaning and maintenance program. It is also highly important for farmers to know clearly all details about what is to be expected of them in terms of participation in program activities.

In conclusion, it is necessary to emphasize that these are suggested criteria only. These could be used for establishing objective means for selection of command areas.

CHAPTER THREE

IMPLICATIONS OF THE DELIVERY AND APPLICATION DATA REGARDING ECISIONS TO CONTINUE SURVEYS OR IMPLEMENT IMPROVEMENT PROGRAMS

. Delivery Efficiencies

A delivery efficiency va

to the watercourse by canals and tubewells which reaches the field outlet (nakka). The measured delivery efficiency averages for 40 sample watercourses are presented in the following table for deliveries to the head, middle and tail areas along with averages for deliveries to entire commanded areas. The respective standard deviations, at 95 and 99% confidence limits are also included.

Summary of Delivery Efficiency Data for Water Delivered to the Head, Middle and Tail Reaches of the Watercourses.

Area to which water is delivered	Delivery Efficiency (%) Mean	SD	Confidence Interval 95% Prob.	99% Prob
Head	62	15.5	57-67	55-69
Middle	52	17.4	46-58	44-60
Tail	44	18.3	38-50	36-52
Overall	53	11.6	49-57	48-58

These data taken in 1975-76 have about the same means and standard deviations as other watercourse loss data (Clyma, Ali and Ashraf, 1975b; Trout, Bowers and Wahla, 1977). Consequently, seasonal and yearly variations do not appear to be significant and the delivery efficiency data of this survey might be representative of all seasons and the area in which the samples were taken (Punjab and Sind) Provinces. (See Volume VI, Appendix I, A for qualifications about sample representatives.)

The cost of this survey, including analyses and publication, was about $250,000, of which 25% might be ascribed to collection and analysis of the delivery efficiency data. If the sample is representative of the larger watercourse population, there is a 99% probability that the average loss from watercourses in the irrigated areas of the Sind and Punjab Provinces lies between 48 and 58% of the water obtained from the mogha (and tubewells). Taking data on 120 more watercourses could add more precision to this estimate as indicated in Figure 3 and would narrow the 95% probability confidence range to 5% (e.g. 51% to 56%).[10] In terms of planning a development program, the increased precision of the mean is not of much value. The present data indicate at least 40% loss of water, which identifies a potential for increasing water delivery to farmers fields by at least 70% if all losses could be eliminated. The Pilot Watercourse Improvement Program at WAPDA's Mona Reclamation Experimental Project (CSU Technical Report No. 45, May, 1977) has shown that farmers can raise deliveries to their fields by earthen improvements of their watercourses coupled with concrete control structures and that the benefits/costs ratios of these improvement projects exceeds 2 and may go as high as 6.

10/A current suggestion for surveying 400 more watercourses could reduce the confidence range to about 3% (e.g. 52 to 55%) for the delivery efficiency. The necessary accompanying expenditure of manpower and resources cannot be justified in terms of improved precision of the estimate of the delivery efficiency.

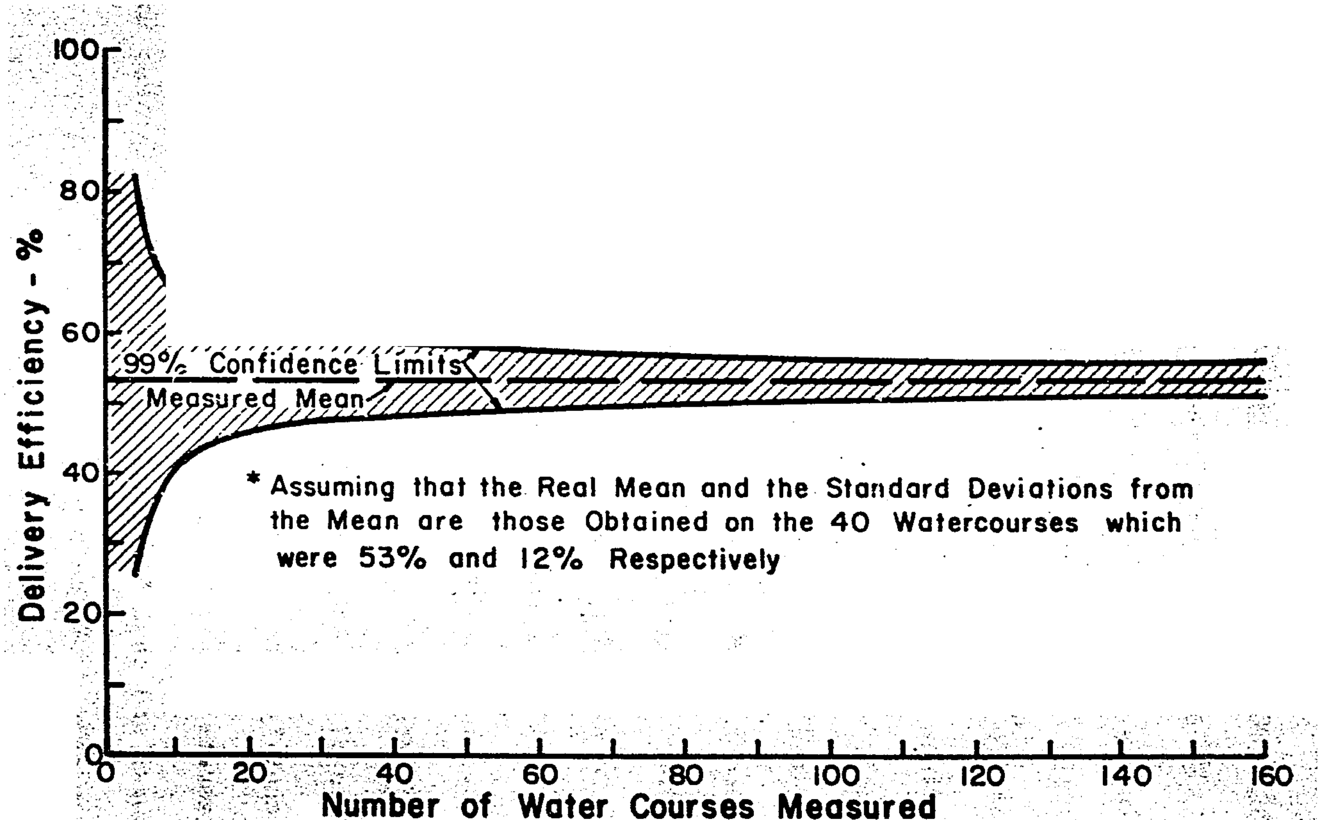

Figure 3. Effect of Number of Watercourses Measured on the Accuracy with which the Real Average Delivery Efficiency is Estimated.*

Limited water is a major constraint on crop production and it has been verified that farmers with government guidance can save the major portion of this water being lost, thereby increasing supply of water to their fields by about 50%. Consequently, part of the costs of continuing surveys and not implementing an improvement program would include loss of that extra supply of water to the farmers. This could amount to over 20,000,000 additional acre feet of water per year, or about 6 times the amount of water delivered from Tarbella dam to the fields each year. On this basis it would appear reasonable to invest substantial funds immediately in a major program to help farmers improve the watercourses of Pakistan.

2.0 Application Efficiencies

Application efficiencies were calculated as the percentage of water coming into the field which is retained in the root zone for use by the crops. The application efficiency means and the standard deviations are shown in the following table for water applied in the head, middle, and tail reaches of the watercourses.

Application Efficiency Means and Standard Deviations

Area in which water is applied	Application Efficiency	
	Mean	Standard Deviation
Head	81%	23%
Middle	76%	21%
Tail	81%	21%

Differences between the head, middle and tail sections were small and practically insignificant. However, differences between these data and those obtained by Clyma et al. in 1973-74 (Clyma, Ali, Ashraf, 1975a) indicate major fluctuations in application efficiencies which are a function of the season or year. Consequently, it was decided that additional data should be collected on application efficiencies for at least one year. Such data were collected (Clyma and Afzal - in process) on the Mona Reclamation Experimental Project and are being collected on 61 watercourses by the Water Management Survey currently being conducted by WAPDA. This data should adequately define the potential for improvement of irrigation application efficiencies. Assuming that there is a potential for improving the application efficiencies, the next step should be to determine the methods which have the highest benefits to cost ratio. Land leveling, irrigation scheduling and furrow irrigation (rather than basin flooding) appear to have potential for increasing application efficiency and increasing crop production.

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ENGLISH GLOSSARY

Agro-Climatic Zone - A region where climate makes a well defined demand for water and a general cropping pattern prevails on a majority of the farms.

Alidade and Plane Table - Engineering telescope and table tripod tools used for preparation of maps to scale in the fields.

Alkaline Soil - A high pH soil that contains sufficient sodium to cause deleterious effects on most crops.

Application Efficiency - The quotient of soil moisture deficiency and nakka discharge in inches equivalent multiplied by one hundred to construct a percentage value.

$$Ea = \frac{\text{soil moisture deficiency}}{\text{nakka discharge (in depth of water equivalent)}} (100)$$

Authorized Supply - The design discharge of water from a mogha.

Barrage - Headworks with movable gates that allow flood waters to pass over their crests. Not to be confused with storage dams.

Barren Land - Land which is not cropped due to salinity, waterlogging, lack of water, presence of sand dunes, etc.

Brotherhood (Biradari) - A lineage group of families related as brothers, sons, uncles, etc. typically with common interests on various issues. A subdivision of a caste group.

Bunded Unit - The smallest field unit irrigated as a separate unit, surrounded by a small earthen ridge or bund.

Canal Colony - Large areas of land brought into production by Irrigation Department and settled by cultivators.

Caste - Ancestral, occupational grouping of people implying prestige gradations.

Centrality of Power - The amount of power/influence attributed to watercourse farmers by 25% sample of farmer/judges. A watercourse centrality value expresses the percentage of all farmers who score at a specified level or above.

Command Area - The area served by a watercourse or set of watercourses in a village.

Concentration of Power - The extent to which power/influence is distributed equally on a watercourse.

Conflict Cleavage - Line of division between opponents over an issue.

Conveyance (Delivery) Efficiency - The percentage of water passing the mogha which reaches the field nakka outlet. The nakka discharge is divided by the mogha discharge and the quotient is multiplied by 100 to create a percentage value.

Cropped Area - The sum of the acreage under rabi or kharif crops in a watercourse command area.

Cropping Intensity - The number of crops grown on a given field in a given year times 100 to express a percentage value. Applied to a farm, it is the acreage of all crops grown in a year divided by the area on which they were grown times 100.

Cropping Pattern - The combination and sequence of crops grown on a given farm over a year's time.

Cross Cutting Cleavage - Opponents on one conflict issue are allies on other conflict issues. Makes for cooperation and negotiability of issues.

Cultural Command Area - The cultivated area of a watercourse command area which can be served by gravity irrigation.

Cutthroat Flume - A water measuring flume device especially suited for low gradient watercourse channels.

Delivery Efficiency -- See Conveyance Efficiency.

Delta - Amount of water applied for an irrigation.

Depth of Application - The average depth of water applied to a field obtained as the product of nakka discharge (in cusecs) times the time of application in hours divided by the area irrigated in acres.

Discharge - the volumetric rate of water flow or delivery, expressed as cubic feet per second (cusec)

Discharge Factor - The mogha outlet design capacity from distributary to watercourse expressed as discharge per 1000 acres of command area.

Distributary - The smallest water channel maintained by the government. The size hierarchy of channels would be, in descending order, major canal, minor canal, distributary. Moghas may be placed on any of these channels.

Duty - The area irrigated per unit of water per season of the year.

Evaporative Moisture Deficit - Estimated annual atmospheric evaporation.

Evapotranspiration - The total water lost to the atmosphere via evaporation and plant transpiration.

Farm Irrigation Efficiency - The proportion of water, passing the mogha, which is stored in the root zone of a crop, calculated as the product of the conveyance efficiency and application efficiency times 100 to create a percentage value.

Gross Command Area - The portion of the entire village area that is commanded by gravity canal irrigation; includes roads, schools, graveyards, canals, etc.

Groundwater Recharge - Deep percolation which replenishes the water table.

Headworks - A division with controllable gates on a major canal dividing water into two or more minors.

Landlord - Owner of land who does not cultivate the land.

Link Canal - Largest of the canals -- each carries water from the western to eastern rivers as part of the Indus Basin Replacement Project mandated by the Indus River Treaty with India (1960).

Local (person) - Person living, or whose family has lived, at present location since before partition of British India into India and Pakistan.

Minor - A water supply canal smaller in discharge than a major canal but greater in capacity than a distributary.

Non-perennial - A single season, kharif, water supply situation for a watercourse command area.

Overlapping Cleavage - Opponents on one conflict issue are opponents on all conflict issues. High polarization. Issues become difficult to negotiate. Hurts cooperation.

Percolation - The downward movement of water through soils.

Perennial - A year-round water supply situation for a watercourse command area.

Persian Well - A water lifting device used on a deep open well comprised of a chain of buckets or earthen pots powered by a pair of bullocks or a camel moving in a horizontal circle.

Potential Evapotranspiration - The maximum evaporative demand which a given climate can place on a given crop when there is no constraint on water availability and crop maturity.

Private Tubewell - A small discharge irrigation well individually or jointly owned by farmers.

Province - Administrative unit such as Sind, Baluchistan, Punjab and North West Frontier areas.

Public Tubewell - Large discharge tubewells installed and operated by WAPDA and Irrigation Department.

Refugee - Person displaced from India at partition.

Saline Soil - Soil which contains a sufficient percentage of soluble (non-sodium) salts to impair crop growth.

SCARP - Acronym for the Salinity Control and Reclamation Project areas where public tubewells are used for lowering watertables and augmenting water supplies.

Seepage- The lateral movement of water through soils.

Soil Moisture Deficiency - Estimated inches of soil moisture depleted due to evapotranspiration.

Tenant - A non-landowner who cultivates a block of land on a share-cropping basis with a landlord.

Time of Application - The duration of an irrigation application of turn.

Tubewell - An irrigation well.

Union Council - A governmental subdivision of a tehsil comprised of approximately 8 to 10 villages.

WAPDA - Acronym for the Water and Power Development Authority - a government corporation.

Watercourse - A water supply channel placed on a 16 foot wide government right of way, constructed and maintained by farmers to deliver water from a mogha outlet to a farmers field ditch.

Watercourse Command Area - The area served by the water passing through an authorized mogha.

Waterlogging - Soil condition where water table is at or above the ground surface.

GLOSSARY OF URDU/PUNJABI AND LOCAL ENGLISH TERMS

Abadi - Land set aside for a village site.

Abiana - Water rate.

Agricultural Assistant - Supervisor of field assistant level extension workers in the Agricultural Extension system. Usually has a Bachelor of Science degree in agriculture.

Bagh - Orchard.

Bajra - Spiked millet

Bakhsheesh - Gratuity.

Barani - Rainfed cropping.

Berseem - Egyptian clover.

Bhusa - Wheat straw used as animal feed

Biradari - A brotherhood lineage group of families related through brothers, sons and uncles within the same caste. Typically members take common interests on issues.

Bund - Small earth ridge.

Caste - Ancestral, occupational grouping of people implying prestige gradations.

Chaj Doab - Land between Jhelum and Chenab Rivers.

Chak - Block of land set aside as smallest administration unit.

Chula - Earthen hearth.

Crore - Ten million, 100 Lakh.

Dab - Preplanting, irrigation and cultivation to control weeds

Deh - Administrative division below Tehsil

Deputy Commissioner - Administrative officer at the district level

Desi - Indigenous, unimproved.

District Revenue Collector - Revenue officer for the District Revenue Department.

Divisional Canal Officers - Administrative head of a divisional branch of a canal command system.

Doab - Land between two rivers in Punjab.

Executive Engineer - Mid-level Irrigation Department or WAPDA Official.

Field Assistant - Local lowest level extension worker, education usually 10th class plus one or two years of general training in agriculture.

Fasalana - Payment for reduced water rates.

Guara - Cluster bean.

Gur - Indigenously prepared country sugar.

Gunta - 1/40 of an acre.

Halqa - Circle of villages of which a canal patwari is in charge to make water dues assessments.

Hakim - Local doctor.

Hari - Share cropper or tenant.

Henna - English translation "Myrtle" and known by botanical name Lawsonia alba. Used as a local orange dye.

Hukka - Waterpipe.

Hul - Local plow.

Jhallar - Persian well adapted to low water lifts.

Jhenab - Land unit used in Sind for one-half acre.

Jowar - Sorghum.

Kacha - Unripe, unimproved, earthen, random, poor quality.

Kanal - 1/8 of an acre.

Kassi - Hoe-like shovel used by irrigators.

Khal - Watercourse, conducts water from mogha to fields.

Khati - Process of removing silt from the watercourse.

Kharaba - Crop failure, declaration for reduced water rates.

Kharif - Warm season cropping, approximately April-October.

Khasrah - Register on revenue due on units of land.

Kiari - System recommended by Agriculture Department for compartment of a field into very small basins for irrigation.

Killa - Area of land equal to 1.11 acre.

Kistiwar - Random layout of land in bunded units.

Karah - Indigenous two team bullock pulled scraper for moving earth.

Karahi - Same as karah but powered by one bullock team.

Lakh - One hundred thousand.

Lucerne - Alfalfa.

Mal - Property.

Mandi - Chartered market center.

Maraba - A square of land made of 25 parcels, usually acres or squares

Marla - 1/160 of an acre; 1/20 of a kanal.

Muhavir - Person or family migrated from India.

Maund - Unit of measure, 82.3 pounds equivalent to 40 seers.

Mauza - Village, smallest division of government.

Moeen - Non-agricultural castes who perform services for a share of agricultural produce (also kami).

Mogha - An ungated outlet of fixed size passing water from irrigation canal to a watercourse.

Mukamis - Local resident.

Nakka - Outlet from branch watercourse; inlet to a field.

Numbardar - Village headman -- function of government who collects land revenues.

Nikal Water - Water left in watercourse at the end of a complete rotation of warabundi.

Overseer - Irrigation Department functionary over patwari, responsible for maintenance and repair of moghas.

Pansal Nawees - Irrigation Department gate keeper.

Pahar - Turn of wat r of five hours.

Patwari - Title of revenue officer for Irrigation Department and Land Revenue Department.

Patti - Division of a village under the responsibility of a numbardar or village leader.

Pora - Seed tube attached behind plow for seeding crops.

Pucca - Ripe, improved, concrete, specified to order, high quality

Parchas - Chits of paper used for notifying farmer of revenue assessments.

Rabi Hul - Bullock pulled mouldboard plow.

Rabi - Cool season cropping; approximately November-March.

Rauni - Presowing irrigation.

Rechna Doab - Land between Rayi and Chenab rivers.

Rej - Irrigation prior to land preparation.

Rosewari - Irrigation schedule to a particular block of land on a particular day.

Saip System - Traditional system by which village artisans exchange their goods and services with landed agriculturalists for a portion of the crop.

Sarkari Khal - Watercourse constructed by farmers on a 16 foot right-of-way provided by the government for the purpose of conducting water from the mogha outlet to the individual farmers field ditches.

Seer - Unit of measure, smaller than kilogram, 2.08 lb. Forty seer equal one maund.

Sem - Waterlogged soil condition.

Shamlat - Village common land usually used for grazing.

Sohaga - Wooden plank or beam drawn by bullocks used in land preparation.

Square - 25 acre, 27.5 acre of 16 acre block of land depending on location.

Subdivisional Officer - Irrigation Department Official under the Executive Engineer.

Superintending Canal Engineer - Irrigation engineer who heads up a canal command hydrologic unit.

Tehsil - A sub-unit of a district.

Tehsildar - Official at Tehsil level.

Thal Doab - Land between Indus and Jhelum rivers.

Thur - Salinized soil condition.

Tonga - Horse drawn two-wheeled carriage.

Union Council - Political subdivision of a tehsil.

Vattar - Farmers' concept of optimum soil moisture condition for plowing.

Wahn - Watering of a field for first ploughing for seedbed preparation.

Warabundi - Schedule of irrigation turn rotations agreed to by farmers either informally (katcha warabundi) or under formal agreement through the Irrigation Department (pucca warabundi).

Warashikni - Taking irrigation water out of turn.

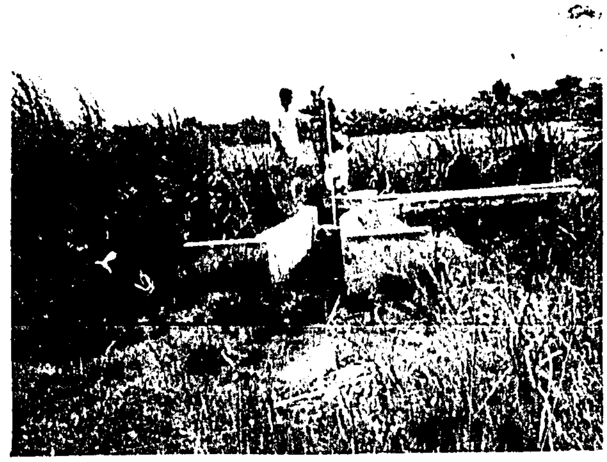
Zilladar - Junior member of Superior Revenue establishment of Irrigation Department.

Zamin - Land

Zamindar - Landholder - farmer

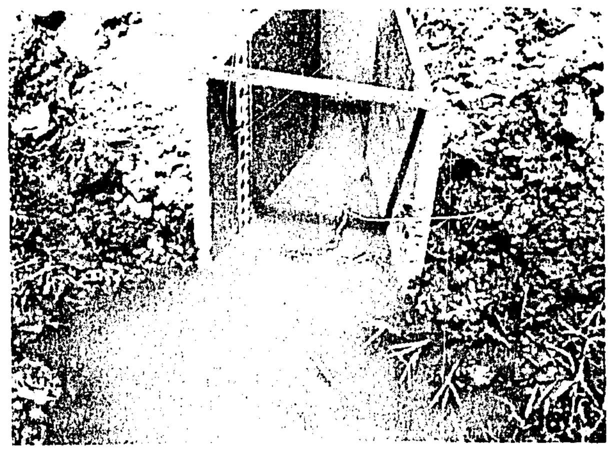
Figure 1

A. Topographical survey of farmers fields.



B. Survey of watercourse level.

C. Installing flume near mogha.

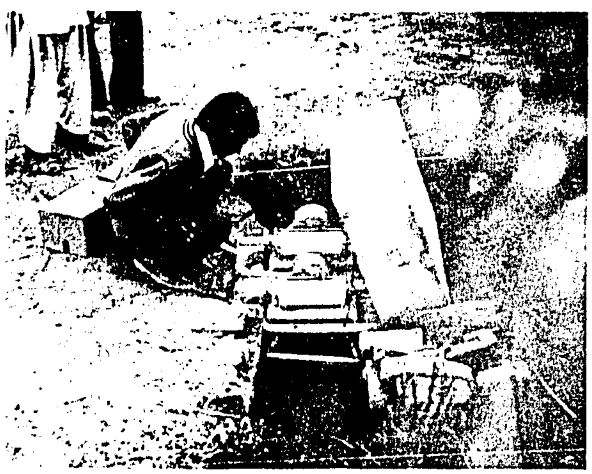


D. Installed Cutthroat flume.

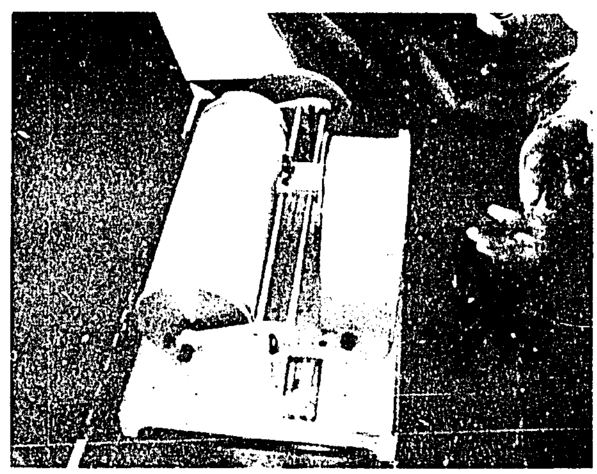
E. Rodman in watercourse survey.

Figure 1 (cont.)


F., G. Engineer installing Cutthroat flume with recording device, for measurement of continuous mogha discharge.



H. Reading stage recorders on Cutthroat flume.

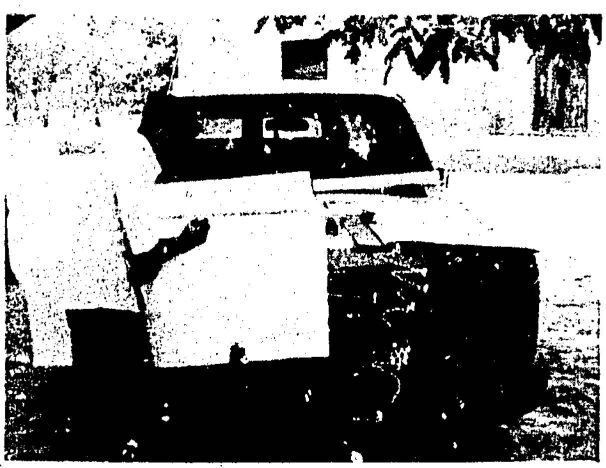


I. Continuous recording of discharge measurements to the farm.

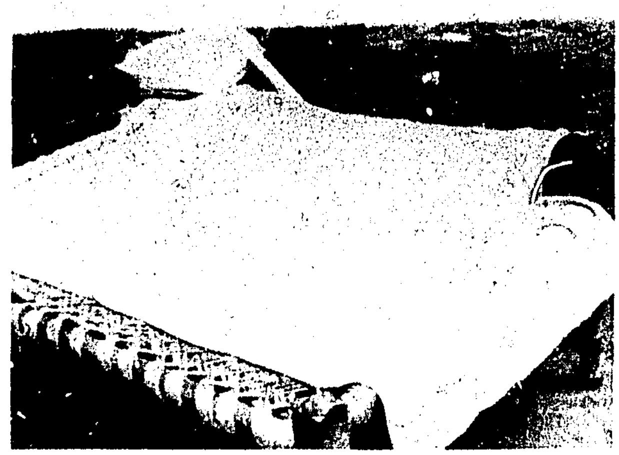
Figure 2

A. Conducting interview with sample farmer.

B. Several team members in a light moment.



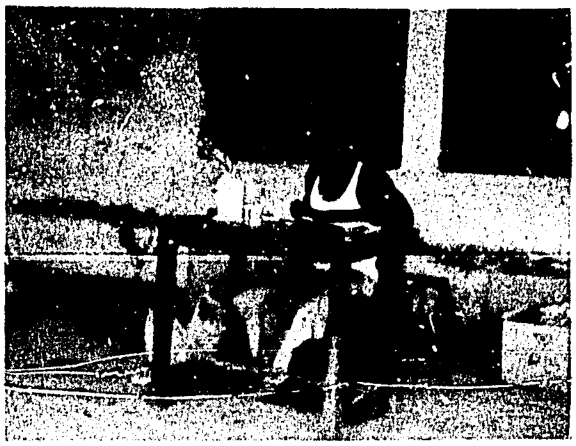
C. Preparing farm ownership map.



D. Map of farms on watercourse.

E. Sun drying of moisture samples.

Figure 2 (cont.)



F. Weighing moisture samples and recording data.

G. Sun drying moisture samples with village helpers.

H. Engineer with survey instrument surveying either cross section of watercoarse or topographical survey.

I. Recording data from survey.

J. Advisor in the field checking socio-economic data.

Figure 3

A. Reliability checking reinterview of sample farmer.

B. Cutthroat flume removed by farmer who felt flume was preventing his receiving a normal full supply.

C. Handpump provided by field team to village boys school as token of appreciation for villagers' cooperation and reception.

D. Team members providing lesson at village school after regular hours.

E. Field map preparation.

F. Planning session after obtaining village leaders' permission to conduct survey.

Figure 3 (cont.)

G. Determination of discharge of a tubewell.

H. Obtaining warabundi list and other important information from a key informant.

I. Participation in prayer five times daily in village Mosque: important to gaining acceptance in village.

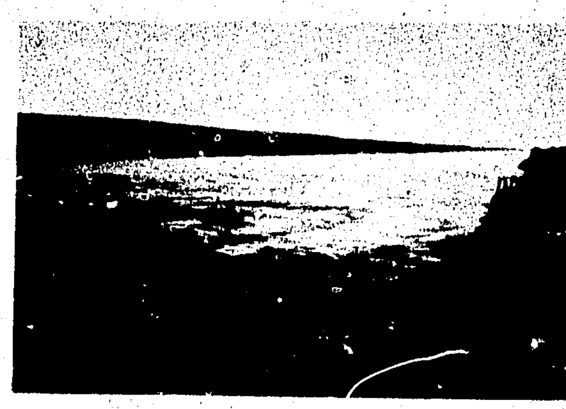
J. A well deserved breather.

K. Movement of equipment, personnel and baggage from village site to site.

L. Data reduction in office included map drafting and information tabulation.

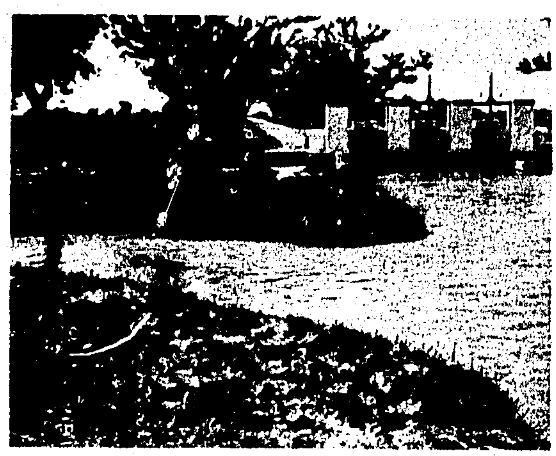
Figure 4

A. A modern dam and spillway (Mangla).



B. A major link canal connecting Punjab's Rivers.

C. A major canal.



D. An offtake with head control gate from canal to minor.

E. Distributary

F. An inundation type of ungated offtake from canal to nonperennial

Figure 5

A. Mogha outlet at distributary.

B. Mogha outlet.

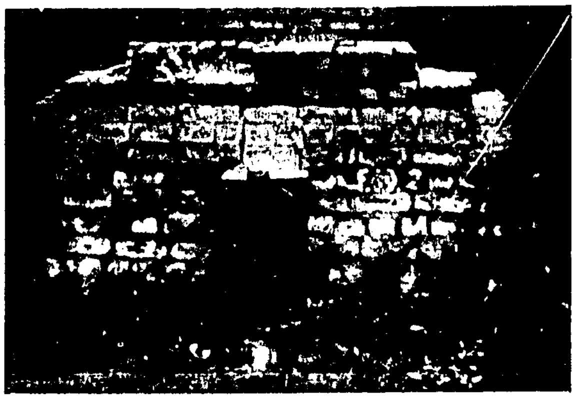
C. View of a mogha outlet.

D. Mogha at canal distributary

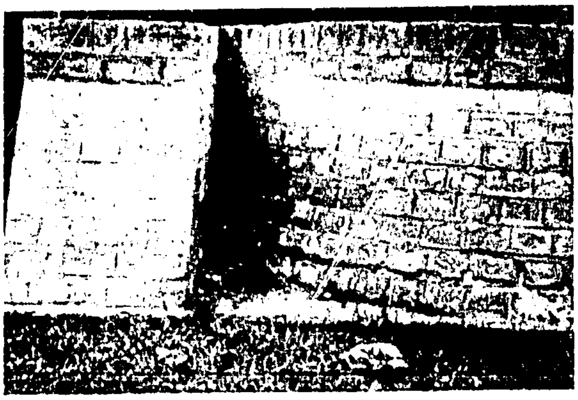
E. Cutthroat flume with automatic recorder installed near mogha.

F. Washout and pond at mogha.

Figure 5 (cont.)

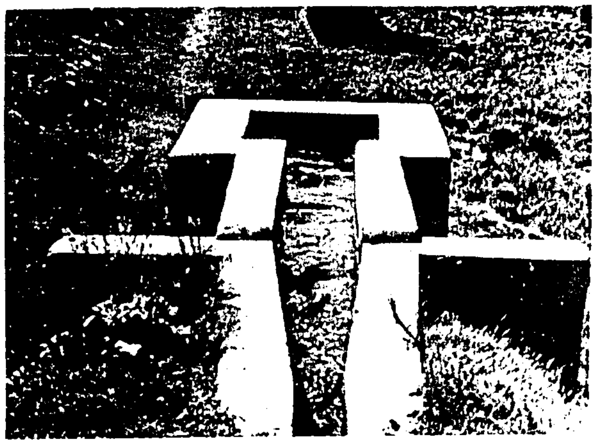


G. Submerged inlet pipe orifice mogha.

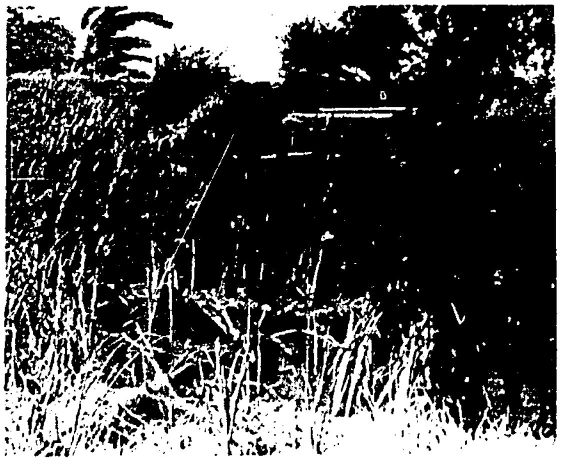


H. Submerged rectangular adjustable cross section type mogha -- view from distibutary side.

I. Submerged rectangular adjustable cross section type mogha--view from watercourse side.

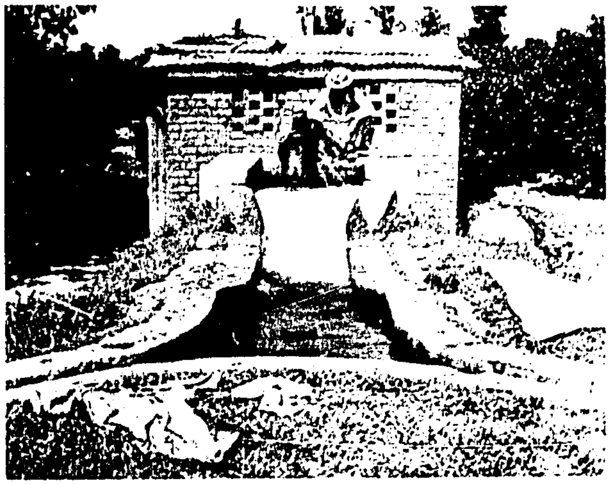


J. Inverted siphon providing water from a public (SCARP) tubewell.



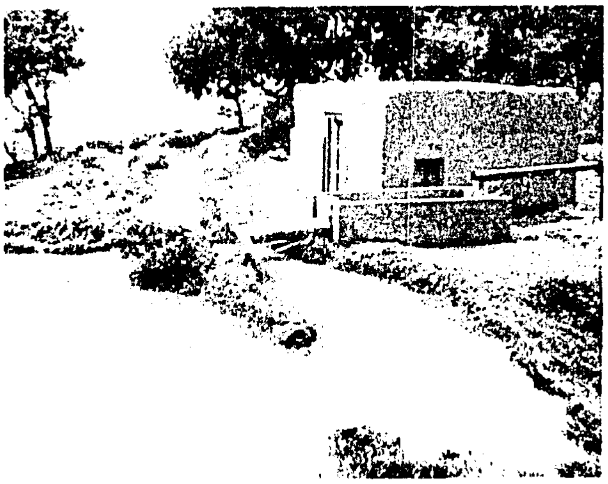
K. Distributary extremely blocked with aquatic plants hindering flow to mogha.

Figure 6

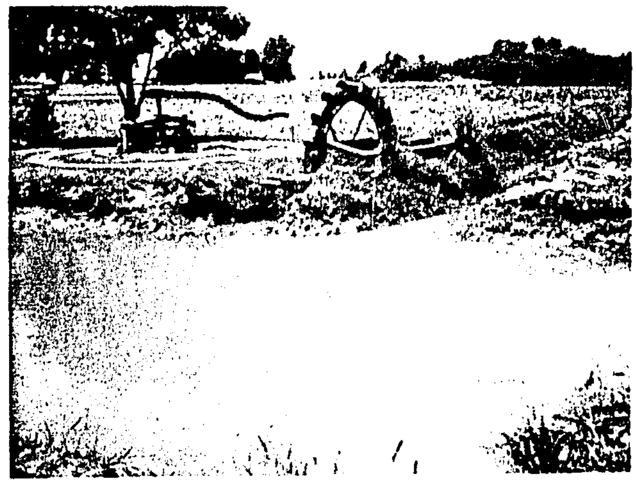


A. Public tubewell in SCARP area bifurcated to supply two watercourses.

B. Public tubewell in SCARP area.

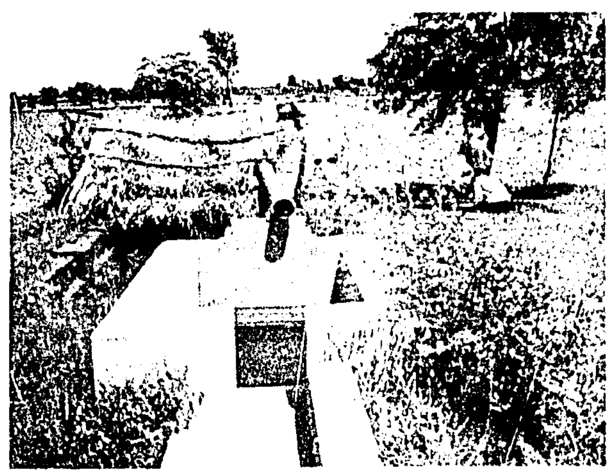


C. Farmer's private small discharge tubewell.



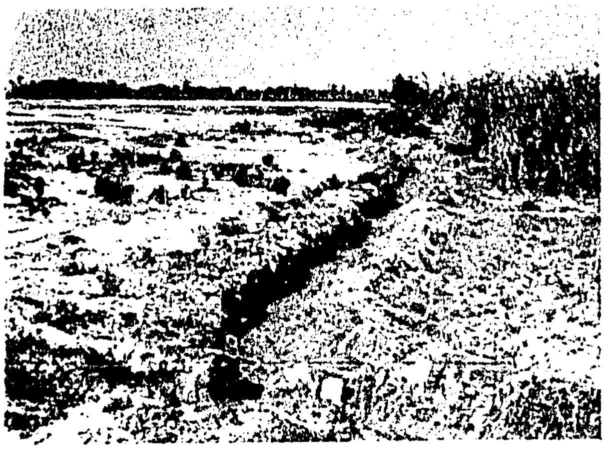
D. Jhalar water lift and reservoir.

E. Tubewell water transferred across drainage ditch via pipe.



F. Private diesel tubewell on SCARP watercourse.

Figure 7



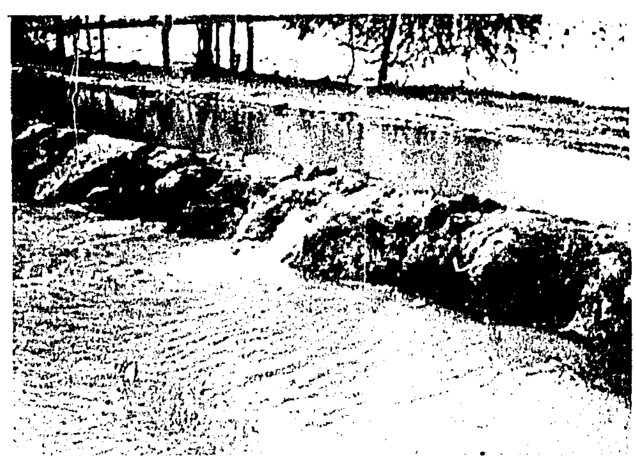
A. Irregular field ditch in a water-logged saline area.

B. Multiple side by side watercourses due to legal limitation on number of naccas.

C. Leak at a nucca (field outlet).

D. Poor alignment of main watercourse.

E. Lack of freeboard--more water than the course could handle.



F. A watercourse with insufficient freeboard.

Figure 7 (cont.)

G. Poor condition of junction, buffalo wallow.

H. Waterlogged area.

I. Silt mounds due to sediment and undergrowth of a watercourse.

J. Undergrowth.

K. Drainage ditch and waterlogged area.

L. A zig-zag watercourse which could be made more efficient by straightening.

Figure 7 (cont.)

M. A poor watercourse. Weeds, undergrowth, and phreatophytes.

N. Typical leaks and spills along a watercourse.

O. Washouts along a main watercourse.

P. The result of heavy rains and no drainage system.

Q. Animal crossing through the watercourse.

R. Unlevel fields resulting in over irrigation.

Figure 7 (cont.)

S. Buffalo wallow in the watercourse.

T. Washout at watercourse junction.

U. Watercourse near village site.

V. Main watercourse with farmers' parallel ditches.

W. Typical loss due to leaks.

X. An earthen "kacha nacca": potential source of leakage.

Figure 7 (cont.)

Y. Undergrowth along major watercourse.

Z. Trees and grass along watercourse.

AA. Major break along watercourse.

BB. A farm delivery ditch.

CC. Extensive field areas are taken up by watercourses, junctions and water spillage areas adjacent.

DD. Buffaloes wallowing in distributaries and watercourses lead to bank deterioration.

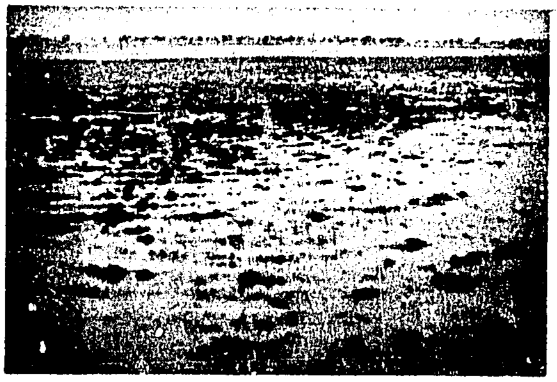
Figure 8

A. Irrigating unlevel field.

B. Salinity due to waterlogging prevents plant growth.

C. Sand dunes left by damaging flood of early 1970's: fields left very unlevel.

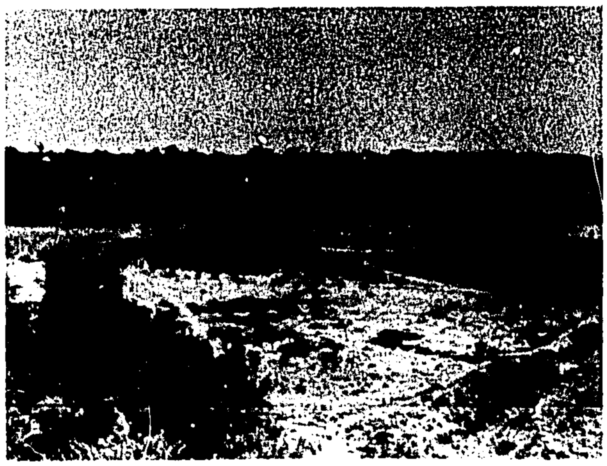
D. Unleveled "tibba" sand dune on margin of field: nonproductive use of land.



E. An attempt at irrigating from a "nacca" at low end of a field.

F. Margin of field affected by leakage from watercourse: tillage and crop maturity differences influenced greatly by moisture differentials across the field.

G. Water logged areas.

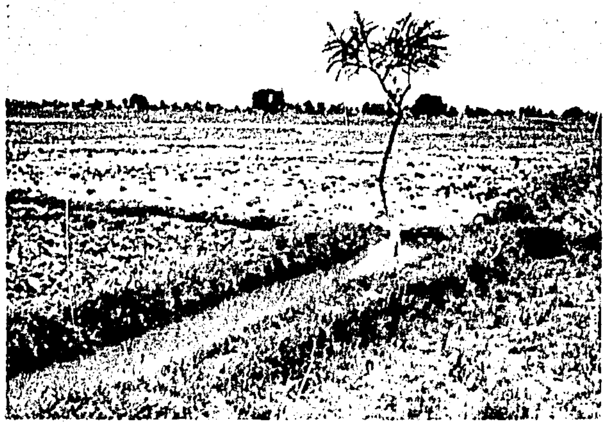


H. Non-cultivatable field because of salinity in a waterlogged area.

I. Waterlogged area.

J. Waterlogged area.

K. An uncultivated saline area due to waterlogging.



L. Irrigating unlevel fields on a waterlogged command area.

Figure 9

A. Village periphery where cattle and goats are tethered.

B. A "goath" or single family settlement of Sind Province.

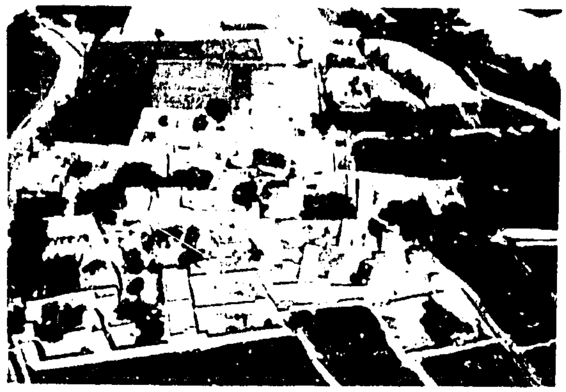
C. A village boys school.

D. Migrant labor encampment or village periphery.

E. Village pond.

F. Village domestic compound.

Figure 9 (cont.)

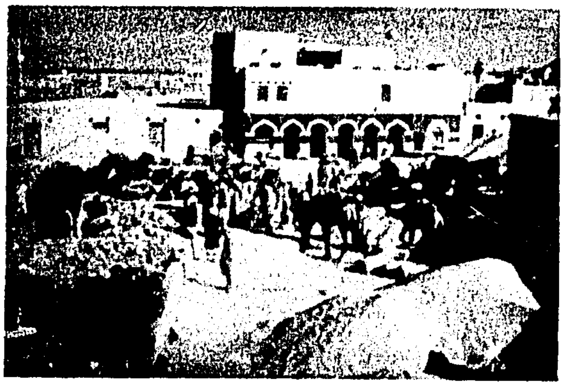


G. Oblique aerial view of a village.

H. A village.

I. City gates of a Punjabi town.

J. A city in Sind Province.



K. A Mandi, or registered market center.

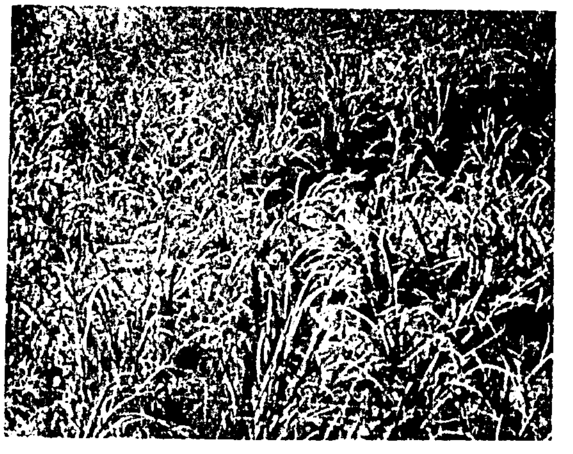
L. Wheat arrival and storage in Mandi.

Figure 10

A. Polyculture of wheat in mango orchard.

B. Polyculture of tobacco and vegetables.

C. Cotton being picked by women workers.



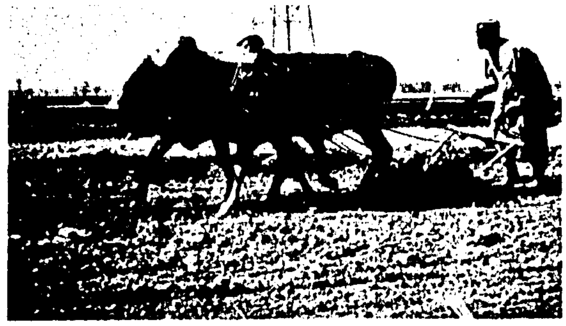
D. Sugarcane ratoon crop.

E. Maize fodder crop.

F. Paddy rice crop.

Figure 10 (cont.)

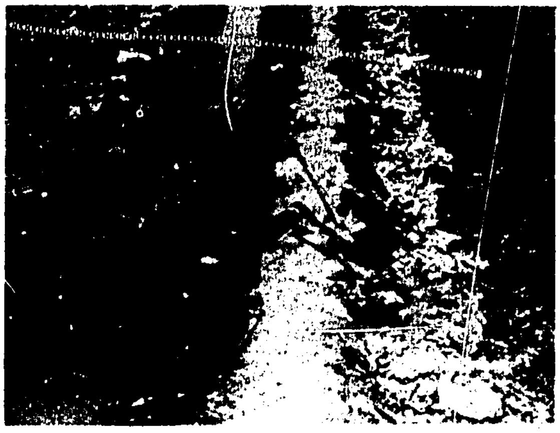
G. Farmer with plow over his shoulder.



H. Farmer doing touch-up leveling with "krah."

I. Farmer breaking clods with "sohaqa."

J. Farmers preparing field bund.



K. The kassi--all-purpose digging tool of Pakistani farmer.

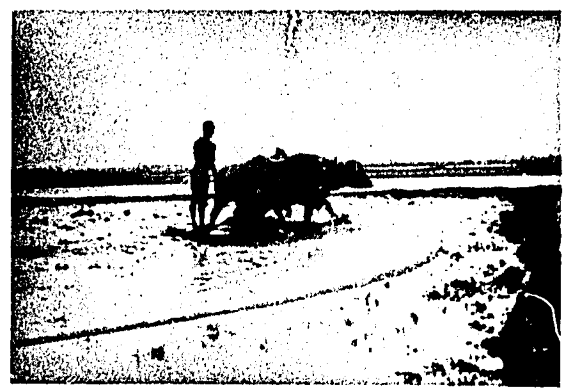
L. Farmer trimming the watercourse bank with kassi to add a few inches more of field area for cultivation. Thin banks also cause leaks.

Figure 10 (cont.)

M. Close-up view of plow in wet soil.

N. Farmer plowing soil in "waffar" condition.

O. Farmer plowing field for rice cultivation

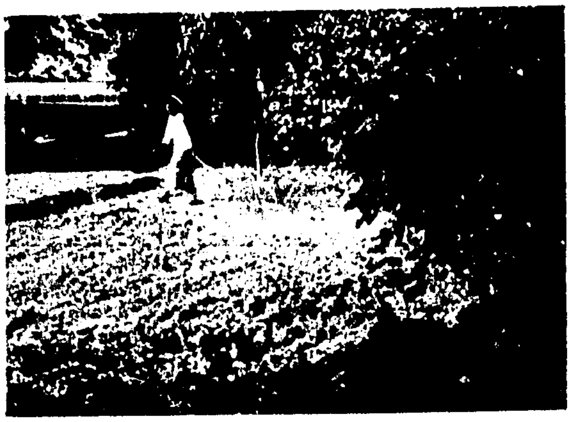


P. Sohaga used to prepare soil for rice cultivation.

Q. Farmer measuring fertilizer preparatory to broadcasting.

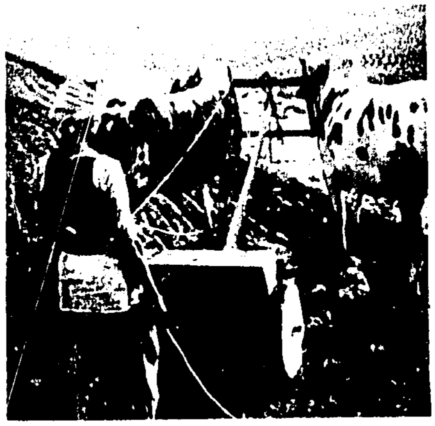
Figure 10 (cont.)

R. Farmer broadcasting seed of fodder crop.



S. Farmer covering fodder seed by dragging branch over field.

T. Seeding paddy rice.



U. Seeding wheat with bullock drawn "rabi" drill.

V. Seeding cotton with "kharif" drill equipped with "pora" tube.

W. Seeding potato crop on ridges by hand.

Figure 10 (cont.)

X. Wheat harvesting.

Y. Fodder harvesting.

Z. Rice harvested and awaiting threshing.

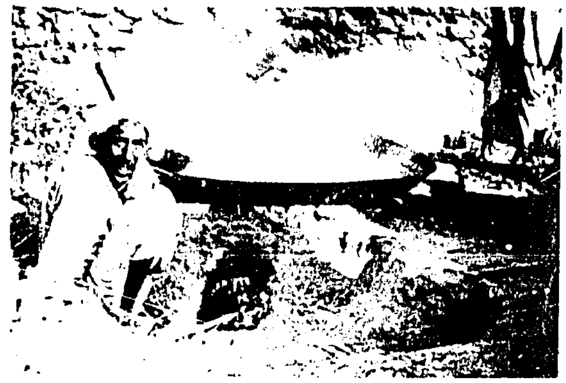
AA. Boy cutting "ghas" from cotton field to use as fodder.

BB. Sugarcane harvest.

CC. Fodder chopper/shredder.

Figure 10 (cont.)

DD. Sugarcane being crushed for village consumption



EE. Sugarcane syrup being boiled as part of village processing.

FF. Wheat threshing.

GG. Wheat winnowing.

HH. Village to market transport.

II. Village grain storage.

Figure 11

A. Farmer coaxing water while irrigating unlevel field.

B. Farmer closing nakka after completion of irrigation.

C. Farmers cleaning watercourse.

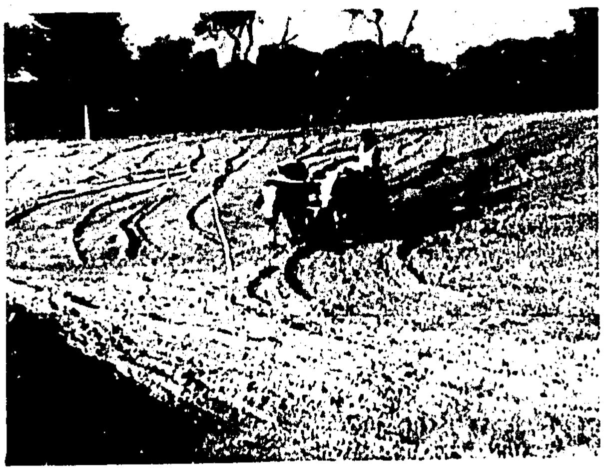
D. Traditional method of leveling fields.

E. Unlevel field - high spots with salt accumulation evident.

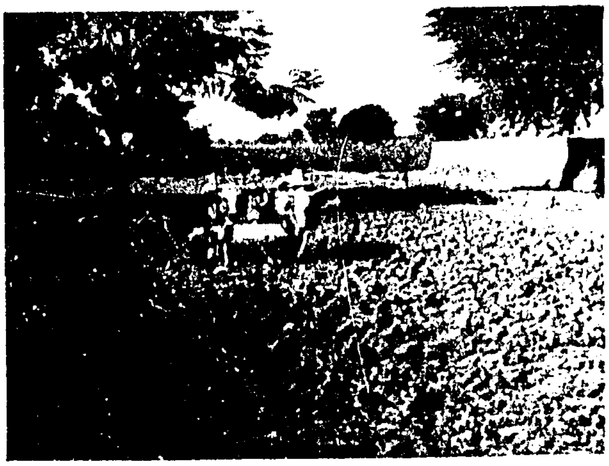
F. Unlevel field with water ponded in low spot.

Figure 11 (cont.)

G. Farmers cooperating to clean main watercourse.



H. Farmer's attempt to level fields with bullock power using karah scraper.



I. Heavy roller breaking dirt clods in area with heavy soils.

J. Using karah scraper with tractor power. Traditional implement, modern power

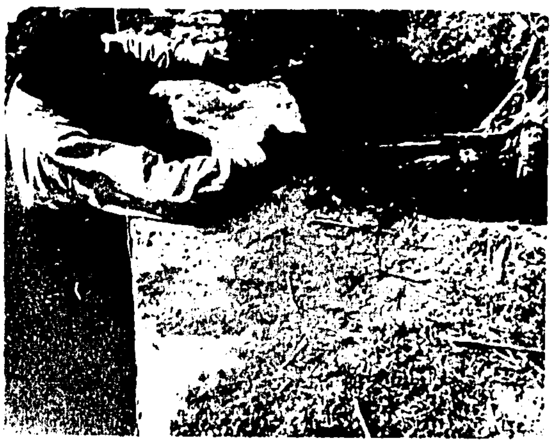
K. Unlevel fields resulting in uneven irrigation.

L. A farmer trying to close a mogha because of too much water.

Figure 11 (cont.)

M. An unauthorized mogha.

N. Farmer constructed pucca unauthorized mogha.



O. Farmer using banana stalk to close mogha.

P. Excessive distributary flow and actual overtopping due to farmers closing many "mogha" outlets.

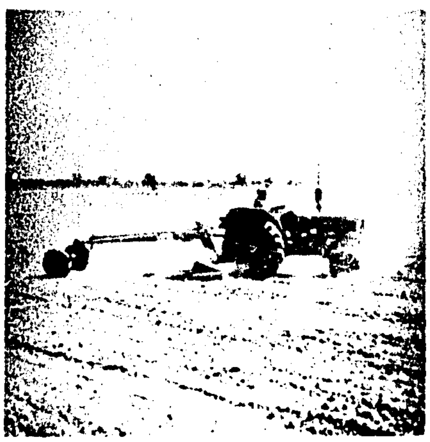
Q. Site of an unauthorized mogha used primarily for rice in kharif season.

R. Farmer "borrowing" irrigation turn from another farmer.

Figure 12

A. Major importance for improved water management is placed on upgrading Extension Services as in this training session.

B. Precision land leveling is an important component of improved water management: scrapers for moving soil.



C. Land plane for final touch-up leveling.

D. Result of land leveling is large-long borders adapted to efficient irrigation.

E. Furrow irrigation adapted to row crops is possible after precision land leveling.

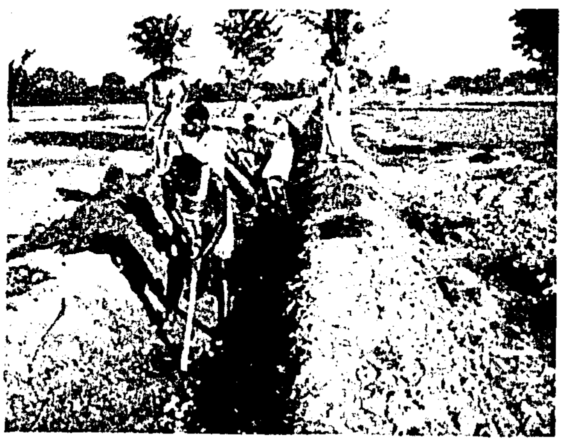
F. Furrow irrigation allows use of syphon tubes to replace always potentially leaky earthen naccas.

Figure 12 (cont.)

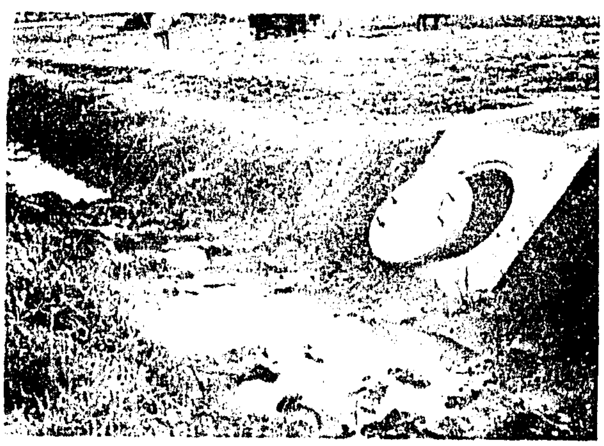
G. Regular maintenance is an important part of reducing watercourse delivery losses.

H. Farmer participation, organization and management of water management improvement activities is essential.

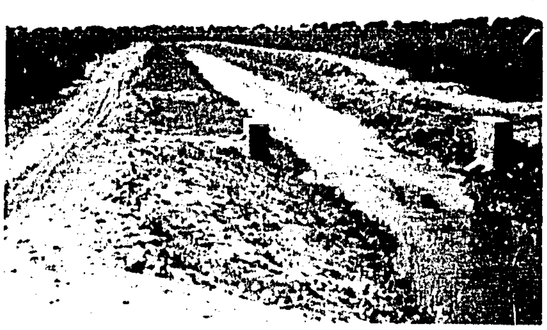
I. Some uncommon soil conditions require lined watercourse sections.



J. Low cost renovated earthen watercourses will be most economical answer to reducing watercourse losses.



K. Improved leakproof concrete turnouts to fields and branch watercourses are low cost solution to leaky nacca problems.



L. Clean, well maintained drainage ditches are important for removal of seasonal water excesses and runoff.