THESIS

LAND LEVELING AND WATERCOURSE IMPROVEMENTS FOR PAKISTAN

Submitted by
MUHAMMAD SIDDIQUE SHAFIQUE

In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado State University
Fort Collins, Colorado
Spring, 1977

COLORADO STATE UNIVERSITY

Spring 1977

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY Muhammad Siddique Shafique ENTITLED LAND LEVELLING AND WATERCOURSE IMPROVEMENTS FOR PAKISTAN BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ENGINEERING

Committee on Graduate Work

Sam H. Johnson III

W. D. Kemper

Wayne Clyma

Sidney A. Bowers

Adviser

ABSTRACT OF THESIS

Despite the intensified efforts and the technological advancement in agriculture over the past three decades, Pakistan is still faced with the challenge to produce enough food to feed her people. The problems posed by this challenge are further compounded by the fact that often there are both economic and trained manpower constraints on irrigated agricultural development.

An extensive irrigation network was built in Pakistan to provide an increased water supply. While the network brought more areas under cultivation and increased crop production, it later created the twin menace of waterlogging and salinity. At this stage a viable, effective, and economical alternative which should be considered is the improved on-farm water management for efficient use of water. Better on-farm water management provides improved delivery and application efficiencies and minimizes the dangers of waterlogging, salinity, and short water supplies.

In this study, the research was conducted on the benefits of land leveling and watercourse improvements. For this purpose the Kanjra watercourse command area, near Lahore, was selected. Necessary surveys were made to collect the required information. About 20 percent of the area was precisely leveled to determine the seasonal impact of land leveling on application efficiencies. The average seasonal application efficiencies were found to range from 81-90 percent on leveled fields to 49-50 percent on unleveled fields.

The cost data for precision land leveling was collected from the watercourse command area as well as from the other parts of the country. The average operational cost was Rs. 2.5 per cubic yard. The benefit cost ratios always exceeded unity against three selected rates of return. For better on-farm water management, economical "Katcha" watercourse improvement alternatives were also undertaken. Water measurements were made with cutthroat flumes to determine the differences in delivery efficiency before and after improvement. The average delivery efficiency of a four branch watercourse system at the before and after stages were 70 and 90 percent, respectively. The benefit cost analysis, with alternatives consisting of renovation of branches A and D, essential improvement of branch B, and cleaning of branch C, gave highly acceptable ratios. Had the improvement activity stopped at intermediate stage of branches A and B, the cost per unit of water saved would have been more attractive. The average improvement cost per linear ft for the four branch watercourse was a little more than Rs. 0.50.

The role of water user associations for implementation and efficient use of water was discussed. At the end, recommendations were made for a package of land leveling and watercourse improvements for Pakistan.

Muhammad Siddique Shafique
Agricultural Engineering Department
Colorado State University
Fort Collins, Colorado 80523
Spring, 1977

ACKNOWLEDGEMENTS

It gives me a great pleasure to acknowledge the help of all those who assisted me in the completion of this thesis.

First and foremost, I would like to thank my advisor, Professor Wayne Clyma, who spared no effort in advice and guidance in the process of carrying out the research work in Pakistan. My association with him was a stimulating experience and a source of great inspiration. I am also grateful to Professor William E. Hart, my first advisor at Colorado State University, Fort Collins, for his help and guidance in planning my course work.

I am particularly thankful to other members of my committee, Professors W. D. Kemper, S. A. Bowers, and S. H. Johnson III for their assistance and time which they proffered so generously.

I would especially offer gratitude to Dr. S. A. Bowers for his continuous help in completing this thesis. I also appreciate the help provided by Dr. A. C. Early during my research work. Thanks are due to Mushtaq Gill for implementing this research project.

The author feels very grateful to Dr. Mohammad Nasim, Secretary to the Government of the Punjab, Agriculture Department for making the research arrangement in the Punjab Water Management Project under the Integrated Rural Development Program. Special assistance, interest and supervision provided by the three Directors of Integrated Rural Development Program, Mrs. Taleat Khalid Umer, Ch. Hassan Ali, and Mrs. M. Sadiq Cheema is highly appreciated.

Also, acknowledgement and appreciation is due the farmers of the Kanjra Watercourse for their direct participation and for sharing the cost of the land leveling and watercourse improvement. Their cooperation and patience while making physical measurements is worth mentioning.

A note of thanks to Mr. Mohammad Ali, Field Assistant Ghulam Mohammad, Zafar Iqbal, and Mohammad Bashir, my younger brother, for their great assistance in the implementation of physical improvement work and collection of data. The timely assistance in land leveling, provided by Mr. Khalid Sharif, Agricultural Engineer; and Gulzar Ahmad and Rana Khalil, Assistant Agricultural Engineers of Precision Land Leveling, is appreciated.

Course work at Colorado State University, Fort Collins, was completed as a project under Contract AID/ta-c-1100 between Colorado State University and the United States Agency for International Development. The funding extended under the above arrangement at Colorado State University is highly appreciated.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN APPENDIX

GLOSSARY

Abbreviation/Term	Explanation
WAPDA	Water and Power Development Authority, Lahore
HARZA	Harza Engineering Company, International of USA. General Consultants to WAPDA.
IBRD	International Bank for Reconstruction and Development, World Bank.
Gibb	Sir Alexander Gibb and Partners of U.K. 6 - Ordinating Consultants for Indus Basin Special Study carried out by IBRD.
HUNTINGS	Hunting Technical Services Limited of U.K. Consultants to WAPDA for Lower Indus Basin Area.
IACA	International and Agricultural Consultants Association, Consultants to IBRD for the Indus Special Study. The Association comprised of Gibb, Huntings and ILACO.
MAF	Million acre feet.
CCA	Culturable commanded area under a canal.
Cusecs	Cubic feet per second (CFS)
Ed-	Delivery efficiency
Ea.	Application efficiency
Eo.	Overall irrigation efficiency
aEdst	Weighted Average Delivery Efficiency of the System on a time basis.

Units of Measurements

One Maund	=	82.28 lbs.
One Ton	=	2,240 lbs
One Acre	=	43,560 sq. ft.

GLOSSARY - Continued

Abbreviation/Term	Explanation
Currency	
Rs. 9.85 =	$1.00
Other Terms	
Kharif Season	Crops sown in late spring or in the beginning of summer and harvested in autumn (April 15 to October 15).
Rabi Season	Crops sown in autumn and harvested in the following spring (October 15 to April 15).
Mogha	Water outlet from canal, distributary or minor to the farmer's watercourse.
Kacha Warabundi	Temporary water allocation turn system mutually arranged by the farmers.
Pakka Warabundi	Permanent turn system for water allocation on a watercourse authorized by canal authorities.
Bund	Embankment for retaining water.
Karah	An indigenous wooden scraper.
Free-rider	Those who benefit from any improvement without contributing to its cost.
Nakka	Outlet from watercourse to field.
Rosewari	Daily turn.
Jhallars	Persian wheel water lifts.

Chapter I

INTRODUCTION

Background

Pakistan is fortunate because its soils, topography, and climate are all very suitable for agriculture. Its total area is 197 million acres of which 48 million acres or 24.4 percent is cultivated. Irrigated agriculture covers about 33 million acres or 16.7 percent of the total country area. Despite its favorable climate the cropping intensity is only 111 percent (45).

Although Pakistan has great agricultural potential its crop yields are among the lowest in the world. The following table shows a comparison of crop yields in Pakistan to those of other countries.

Yields per Acre of Different Crops in Selected Countries in 1968 (lbs and maunds)

Crop	Pakistan	USA	France	India	Japan	UAR	Mexico
Wheat	955.0 11.6	1704.0 20.7	3267.0 39.7	988.0 12.0	- -	- -	2354.0 28.6
Cotton	272.0 3.3	518.0 6.3	-	115.0 1.4	-	625.0 7.7	650.0 7.9
Sugarcane	37,200.0 452.0	50,780.0 617.0	-	42,630.0 518.0	-	82,135.0 998.0	-
Rice	1,053.0 12.8	4,435.0 53.9	-	1,432.0 17.4	5,111.0 62.1	4,568.0 55.5	-
Maize	905.0 11.0	4,411.0 53.6	-	897.0 10.9	-	-	1,078.0 13.1

With such excellent soils, climate, and the worlds largest irrigation system, Pakistan's crop production should be much higher.

Seventy-three percent of the irrigated area is served by a 38,000 mile canal irrigation system. The annual diversion into the system exceeds 100 million acre feet. More than 127,000 tubewells provide supplemental water to 15.5 percent of the irrigated land. The remaining 11.5 percent is irrigated by approximately 200,000 Persian wells and other sources of irrigation water.

Agriculture is the main stay of Pakistan's economy contributing 43.3 percent to the gross national product. It provides 48.0 percent of the total direct-export earnings; if the indirect-export earnings are also included, it amounts to 75 percent of the total. Agriculture employs 60 percent of the total labor force and provides the raw material to most of the industries. However, with a population growth rate of 3 percent the wheat production, even in a good year like 75-76, must be supplemented by one million tons of wheat import. This points out the serious need for greater agricultural development.

Agricultural development requires water. The dependence of Pakistan's agriculture on irrigation is well known. Thirty-three million acres of farmland drawing water from the Indus river and its four major tributaries makes it the world's largest contiguous irrigation system. A system of major dams, barrages, large canals, linking rivers, tubewells, irrigation canals, and watercourses delivers water to the farmer's field.

Such an irrigation system required unprecedented investment. Yet, for all this, the system operates at less than 30 percent overall efficiency. From the 100 MAF of water annually diverted, at the most, 30 MAF, probably less, are effectively stored in the crop root zone. Considering the climate, which could allow a cropping intensity from 200 percent to 300 percent, one acre foot of water annually available for crop consumptive use is certainly an inadequate water supply. As a matter of fact in Pakistan's present agricultural economy, water is the limiting factor for further development. But for this acute shortage of water, more lands could be placed into production.

The World Bank Report (44) makes this background statement concerning Indus Basin irrigation.

> Throughout the Indus Basin flood irrigation has been practiced since the earliest settlement along the rivers. The British realized the limitations of the inundation system and about the turn of the century initiated a massive development program which gave Pakistan its existing irrigation system. By any standards this is a massive achievement of engineering skill and technology. The most recent additions to the system are storage reservoirs like Tarbela, the worlds largest earth filled dam, which evens out the seasonal river flow. When the system was planned, irrigation was still an empirical art and much of the modern irrigation practice was derived from the experimentation and experience gained on the South Asian Sub-Continent. Design parameters were built into the system to satisfy agricultural objectives which are now superseded. More important, the assumed socio-economic and political objectives have fundamentally changed and do not relate to present day requirements. For example, at the time

of construction, lack of population and land pressures permitted very low cropping intensities; in the present day the situation is quite different.

The basic feature of the canal system is that it was built to operate on a constant discharge basis and not to respond to irrigation needs. When changes in supply are made it is generally governed by the water availability and not by agricultural demands.

The existing irrigation system below the distributary or minor canal head regulator consists of about 78,000 watercourses which operate on a fixed discharge and continuous flow basis. The Irrigation Department is not involved in water management on the watercourses. As the government has no design and operational function at this level, the result is 1.5 million miles of poorly constructed and poorly maintained earthen channels.

Recent research on watercourse losses showed that previous assumptions substantially underestimated the extent of delivery losses (Clyma, et al. 11). Until recently there were few measurements made of irrigation application efficiencies. These measurements relate the amount of water stored in the root zone to the amount applied to the field. Hundreds of field observations over the last three or four years have shown these efficiencies to be quite low.

Given the magnitude of water losses now known to occur below the mogha (glossary) it is imperative to launch watercourse improvement and precision land leveling programs to increase both the delivery and application efficiencies for Pakistan.

Precision land leveling is a basic requirement for any successful irrigation project and is essential for improving water management and reducing waterlogging and salinity. Though much of the agricultural land in the Indus plains has a topography well suited for irrigation, there is great need for precision land leveling to allow uniform application of irrigation water, to prevent over irrigation, and to improve irrigation control.

The farmers in Pakistan level their fields with an indigenous karah (glossary). Consequently, fields are not precisely leveled. They remain sloping with high and low spots which result in wastage of water and non-uniform applications. Low places receive much more water than those at the higher elevations. Thus, all areas in the undulating fields do not simultaneously reach wattar conditions, a term which describes the proper moisture content for planting. By the time the low areas come to wattar the high areas are too dry for optimum seed germination; consequently, poor crop stands are the result. Reduced water applications on high spots can result in salinization and low crop yields. Substantial water savings and improved crop yields can be obtained if the field is leveled to permit uniform irrigations.

Water is a basic natural resource; without proper control over its distribution and use, progressive agriculture is not possible. Because present institutional controls end at the mogha there is a need for some organization to accept the responsibility for its efficient use. Pakistan has no system of water user associations through which her farmers can jointly pursue optimizing a mutual task. Many of the problems faced by the irrigator, and in particular the small farmer, can be partially reduced by providing him an opportunity to formally organize with his neighbors. The water users associations can become the nucleus of mutual on-farm water management activities pursuing objectives of equitable water distribution, resolving disputes, watercourse rehabilitation, irrigation scheduling, assistance in land leveling, augmenting water supplies through tubewells, conservation practices, integrating water quality control through conjunctive use of ground and surface water, proper drainage, and collection of fees and assessments.

Pakistan needs to give priority to efforts aimed at realizing maximum benefits from its under utilized and misused resources. The watercourse command areas require maximum attention since 50 percent of their water is lost. Farmer organizations could effectively handle this problem by creating an environment conducive for more efficient use of water.

Objectives

1. To identify the physical problems of watercourse sub-system improvements, to implement some improvement alternatives, to document the savings of water, and to determine the cost of incorporating these alternatives in watercourse construction.

2. To examine the results of integrating watercourse and land use improvements for better over-all irrigation efficiencies, to understand the problems associated with land leveling, and to determine the cost of introducing this practice.

3. To organize farmers for carrying out the activities of land leveling, watercourse improvements and maintenance, and to document the problems associated with the organization of farmers.

Chapter II

REVIEW OF LITERATURE

Watercourse Environment

The term watercourse system used in Pakistan means either the total area commanded or as referred to in this paper the network of delivery ditches fed by one outlet.

General Description

In each canal command area, the land is divided into watercourse command areas which receive an irrigation supply from watercourse outlets. While there are various types of outlets, the device is generally not gated but simply joins the watercourse to the government canal. It is designed to pass an authorized flow of water to the watercourse when the canal is at the designed supply level. Flow through all outlets decreases as the canal supply level decreases but at different rates depending on whether the outlet is an open flume type or a submerged orifice. Their flow rates are proportional to the "head" and square root of the "head" respectively. The water flows from the canals through the outlets (moghas) supplying water to the village areas. The farmers operate and maintain their distribution system. Since there are no headgates at these outlets if any particular canal has water, there is water in every watercourse on that canal. It is like a river system flowing in reverse with each tributary receiving its share.

Pakistan's watercourses have an average command area of 400 acres. The average watercourse serves 40 families;

a normal village of 100 to 120 farms will, on the average, have three watercourses. Watercourse command areas are topographically determined and land ownership is not; it can happen that one watercourse serves land owned by farmers in different villages.

Water Distribution

The watercourse command area acts as an irrigation unit with specific built-in operational characteristics. Within this unit, water supplies are distributed on a time rotation basis or warabundi (glossary) with each farmer taking all the water supply by turn for a period proportional to the area irrigated. The time allowed in a warabundi defines the water right of a farmer and is carefully protected and regimented by legislation. The inflexibility of the irrigation system and the long established social and legal determinants make it difficult to change even small details in the present arrangement unless government decides to become involved within the watercourse command area. At present direct responsibility of the government ends at the watercourse outlet. Below this structure legislation is aimed at protecting the system from corruption and securing efficient revenue collection; neither objective has been fully achieved.

On the basis of the warabundi the farmer has a fixed time for irrigation in each week. If during a particular farmer's turn there is insufficient water, he forfeits his share and waits for the next turn. There are some unofficial variations, but water on demand is unknown except in those areas served by farmer operated tubewells.

In addition to the above fixed turn or pakka warabundi (glossary) there is another arrangement which is called kacha warabundi (glossary). This is not an official water rationing but a mutually accepted set pattern of water distribution. Under this arrangement, even with canal closure, no one forfeits his turn; it is simply delayed. When water is turned back into the canal the turn schedule continues from where it stopped even if it takes one week, two weeks, or a month depending on the availability of water in the canal or distributary.

State of Affairs Within the Watercourse System

In reality no one is responsible except the farmers for the conveyance of water from the outlet to the field. The existing technical, legal, and institutional framework at the watercourse level is rigid and more than 100 years old. It was formulated to avoid government involvement within the watercourse command area. The difficulty facing the government is that the benefits of the massive investment in development of water resources can only be realized within the watercourse command area. At present this is governed by the level of farmer competence which depends only on his limited experience and limited available resources. Based on these facts the irrigation practices of Pakistan have been compared with those of the middle ages. The Revelle Report (39) states:

> In West Pakistan we have the wasteful paradox of a great and modern irrigation system pouring its water on lands cultivated as they were in the middle ages.

The watercourse command area has become a "no man's land" due to the absence of any government involvement in efficient use of water. Because of essentially no engineering design, rigid operational criteria, inadequate maintenance, and sustained neglect in providing related assistance to the farmers, an ineffective watercourse distribution system has resulted. The responsibility for the proper management of water from the reservoir to the outlet in the canal or distributary rests with engineers; the economical use of irrigation water beyond the outlet is generally neglected since this responsibility falls primarily on the cultivators who rarely understand the economics of water use.

Macro Development Planning Studies and Watercourse System

From the early 1960's to the early 1970's serious consideration was given to waterlogging and salinity problems. Since this time all existing irrigated areas of the Indus Basin have been intensively studied. Comprehensive plans were developed for the Lower Indus region by Sir M. MacDonald et al. (34) and the Upper Indus by IACA (24) for IBRD which covered all aspects of water resources development. The master plans were recalculated in the Lifetink Report by IBRD (32); Tipton and Kalmbach (42) published their plans for the development of the North Indus with heavy emphasis on a continuing SCARP program.

All of these previously cited reports and the later Harza (22), Revelle (39), Hunting Technical Services Limited (24), concluded that waterlogging, salinity, and water supply augmentation problems would largely be solved by the SCARP tubewell program. The suggested solution for shortage of irrigation water was the construction of more dams. Tubewell installation was proposed for eradication of the waterlogging and salinity problems. Hence, emphasis has been on development investment to assure water availability without examining the efficient use of water as a development alternative. The rationale for such findings seems to be the assumption that farmers were efficiently using water; hence, the short supply problem could easily be solved by increasing the available water. In this connection a paragraph from Revelle (39) is quoted:

> Water applied to the land either by irrigation or precipitation, was mostly lost through evapotranspiration and never reached the water table except in those relatively small areas where the groundwater stood close to the surface.

Efficient use of water requires higher delivery and application efficiencies. Concerning delivery or the watercourse conveyance efficiency, the Harza (22) analysis states:

> Losses in the watercourses have been estimated as 10 percent of the amounts delivered to them (to field point) from canal and tubewells.

Similarly conclusions on delivery efficiency were drawn by the other mentioned analyses. In all the above studies, 90 percent delivery efficiency was either estimated or adopted from the figures suggested by others. The assumption of 90 percent conveyance efficiency represents a picture of a very efficient earthen watercourse delivery system. However, in the summer of 1962, a team of consultants to Harza made the following recommendations (Hanson, Bower and Williams, 19):

> ...thus it is important that sufficient field studies be conducted to obtain a reasonable estimate of water application efficiency that can be expected under different cropping conditions. Likewise, the losses in the conveyance by seepage, evaporation, and plant use should be determined for the entire water distribution system.

This advise was evidently ignored in the Harza reports (22).

Briefly, all previous studies conclude and suggest that Pakistan faces problems of short supplies, salinity, and waterlogging. The suggested solution is more tubewells and dams to increase the water availability, greater applications to flush the salt from the root zone, and drain the groundwater by tubewells. There is no concern shown over the delivery of water from the canal outlet to the field and its field application. As previously cited, in the MACRO - Development Studies, this part of the irrigation system was considered very efficient and hence very low water losses were "assumed."

Present Studies of Watercourses (1970's)

Even in recent studies, the importance of greater availability of water is accepted. As stated by Clyma and Corey (9):

> It is true, even today, that many areas need additional irrigation water for maximum cropping intensity and maximum yields.

In recent field studies of the watercourse command areas, Colorado State University completely changes the emphasis on greater availability of water from water resource development to its more efficient use. It not only proposes an alternative solution to the problems of waterlogging, salinity, and water availability, but also negates the assumption made in the previous studies that Pakistan farmers were doing a good and efficient irrigation job.

CSU publications on present watercourse field losses show loss rates much greater than those assumed in MACRO Development reports. Many reviewers criticize the finding on the basis that the data collected for a typical area consists of spot measurements and are not applicable to all irrigated areas over a complete crop cycle. But, as is mentioned in the document of the World Bank (44):

> ...given these limitations on the quantitative values of results the CSU work has been of immense value because it has been widely circulated throughout Pakistan in a series of regular papers. Even if CSU has over-estimated their case, no one in government can now avoid the issue and it is on CSU critics to prove that the case is over-estimated.

Whether the watercourse command losses are an over or under estimate, this very criticism shows that CSU has developed quite different results from those assumptions made in the past. In all master planning reports, the overall irrigation efficiency ranges from 54 to 81 percent. In the western United States, according to Clyma and Corey (9), the irrigation efficiency is 27 percent. For Pakistan, CSU Field Party results show the overall watercourse command efficiencies as low as 12 percent; this is much less than the average assumed in the previous analyses (44).

In this recent analysis concerning the watercourse losses, Clyma and Corey (9) further report that:

> ...losses along the watercourse from the mogha to the field are high in Pakistan, especially on tubewell augmented watercourses. Total losses (seepage, wastage, and evapotranspiration by non beneficial plants) frequently range from 30 to more than 90 percent of the flow at mogha.

Similarly, Early and Lowdermilk (15), in their Watercourse Survey of Punjab Phase I Report which is based on data collected from 16 Punjab watercourses, give an average delivery efficiency of 60 percent. Clyma, Ashraf, and Arshad (11) have found that water delivery efficiency of many watercourse ranges between 50 to 90 percent with an average of 60 percent.

Kemper, Clyma and Ashraf (2), presented the following table showing average loss rates as a function of watercourse discharge with and without tubewell augmentation:

Average Value of Water Loss Rates

	Total Discharge (cusecs)	Losses/1000 ft (cusecs)	%	Average Loss/4000 ft %
Canal Water only	1	0.075	1.5	30
	2	0.13	6.5	26
	3	0.20	6.7	27
Canal plus tubewell water	1	0.16	16	64
	2	0.25	13	32
	3	0.32	11	44
	4	0.40	10	40
	5	0.51	10	40

Obviously, from the above table, tubewell supplemented watercourses have higher loss rates.

Watercourses having loss rates higher than those shown above probably require improvement. Such improvements may vary from lining the watercourse to simple cleaning and maintenance.

In considering conveyance losses, Eckert, Dimick, and Clyma (16) conducted a comprehensive study of watercourse improvement alternatives. They considered four improvement alternatives:

1. Lining of the entire watercourse command system. This they rejected due to a benefit-cost ratio less than one.

2. Lining of main channel and main branches. The benefit-cost ratio in this case is also less than one.

3. Lining of the main channel only. While the benefit-cost ratio is slightly more than one, any unforeseen cost could make it uneconomical.

4. Improvements of earthen channels. The benefit-cost ratio for every type of earthen watercourse improvement is more than one.

It is concluded that the lining of Pakistani watercourses on a large scale is both premature and possibly unnecessary except in those areas where light, permeable soils exist. It appears that on a very large scale much greater benefit can be realized by concentrating on the existing earthen watercourse system.

Water losses can be reduced if a preventive maintenance standard should be imposed in the watercourse collectively operated. If the government would become involved and explain why losses occur and what maintenance improvement should be made (or government action would be taken) a savings of five million acre feet per year is possible by 1978. Savings of at least 9.7 million acre feet per year would be a realistic target by 1982 if given the full government backing with normal expenditures as stated in the Document of the World Bank (44).

Suggestions and Recommendations

After reviewing the literature the author comes to the following suggestions and recommendations for reducing watercourse losses:

1. Serious attention should be given to the efficient use of water as a development alternative.

2. Lining of watercourses is somewhat premature at this stage; the reconstruction, with maintenance, of earthen channels could result in an annual savings greater than Tarbela storage.

3. Government should become involved in watercourse improvement to realize immediate benefits.

4. For long term benefits, fundamental changes in the existing irrigation system are necessary.

Land Leveling

General Information

Precision land leveling is defined as grading and smoothing of the land to a smooth level field with little or no slope. The purpose of such land leveling is to facilitate efficient irrigation and water use. Substantial water savings can be obtained if fields are leveled so that all the parts are evenly irrigated.

It is worth noting that all Master Planning Reports of the 1960's assumed very high application efficiencies; the Harza Report (22) assumed 76 percent, Tipton and Kalmbach (42) 78 percent, and the World Bank Report (44) mentions 70 percent. Other reports have similarly assumed high application efficiencies.

Inputs other than land leveling are required for improving application efficiencies. There is a lack of information concerning when, how, and how much water to apply. Similarly, the amount of available water and other constraints which hinder the proper preparation of fields for irrigation are factors which require consideration. Although land leveling is only one contributing factor, it is a very important one because it is prerequisite for the optimum use of other inputs. Eckert, Dimick and Clyma (16) reviewed the advantages of land leveling as follows:

1. Improved irrigation efficiency
2. Uniform soil moisture and seed germination
3. Improved fertilization efficiency

4. Higher yields

5. Lower probability of salt accumulation

6. Increase cultivated land

7. Reduce delivery loss

The old and traditional technique is not suitable for precision leveling. It is time consuming, rough, and incapable of providing the accuracy required for uniform controlled application of water to the field. By using engineering techniques an accuracy of ±0.05 ft can easily be obtained. In the engineering method, the required cut and fill volume calculations are based on a prior topo-survey. For Pakistani conditions, after staking, tractor drawn scrapers or planers are sufficient to level the land within the ±0.05 ft specification. The cost of this leveling operation was estimated by Ashad Ali, Wayne Clyma, and Alan C. Early (2) as follows:

Range of Elevation (Max-Min)	Approximate Volume of Soil Yd^3	Approximate Cost of Leveling Rs/Acre
0.2	40.0	120.0
0.4	80.0	240
0.6	120.0	360
0.8	160.0	480
1.0	200.0	600
1.2	240.0	720
1.4	280.0	840
1.6	320.0	960

From this analysis the median cost of leveling is Rs. 480 to Rs. 600 per acre.

Eckert, Dimick and Clyma (16) calculated benefit-cost ratios for precision land leveling without watercourse improvements; these ratios exceeded two.

Suggestions and Recommendations

After reviewing the literature, land leveling is recommended to achieve better water application and fertilization efficiencies and to solve the problems of water loss, salinity, shortage of water, and controlled irrigation.

Farmers Associations

Historic Development of Water User's Organizations

Since ancient times, communities have combined their efforts to obtain water and to protect themselves against the effect of droughts and floods. Technological progress in the development, control, and use of water in agriculture has led to the creation of more or less formally organized Water User Associations.

Due to the present trend of reintegration of engineering, agricultural, and socio-economic aspects of irrigation, the important role of irrigation associations will have a broader field of activities and require different organizational forms than those of the past.

Considering the changing technological and socio-economic parameters of agriculture, the functions of the water user associations do change from time to time, and from country to country. Still some of their important functions are explained by Sagardoy (40) and Chin (7) as:

1. Allocation of water to the user within a scheme.

2. Operational control of water.

3. Construction, improvement, operation and maintenance of irrigation systems.

4. Administration of budget for operation and maintenance including water charges.

5. Liaison with government water administration (local, regional, national).

6. Establishment of their own regulations within existing laws.

7. Allocation of land if appropriate.

8. Assignment of agrultural support facilities.

9. Financing of project investment.

10. Study and development of the benefits of irrigation.

11. Planning of water users.

Advantages of water users associations as stated by A. Radosevich (38) in Water Organizations for Small Farmers are:

1. The creation of an independent body which performs dual functions.

(a) Planning, construction, operation and maintenance of the community water works.

(b) Administration of organizations objectives.

2. Economics of scale can be achieved by the farmers through pooling of human capital resources for water development and use of presently available water resources.

3. An identifiable element of the community is responsible for water distribution on an informal and calibrated basis.

4. The entity serves as a spokesman for the community in seeking government support for development programs, and conversely, it serves as a permanent responsible body with which the government and others can enter into contracts.

Types of Water User Associations

In order to understand the activities of different water users associations, five types were selected as the most representative among the great variety of agricultural water users associations throughout the world.

1. Traditional Irrigation Associations - Their activities are limited to the operation and maintenance of the existing schemes; additional services such as administration of investment funds, advice to farmers, etc., are not provided. Example of such traditional water users associations can be found in Afghanistan and Spain.

2. Irrigation Organizations in Settlement Projects - These are established in new irrigation schemes for settlement of farmers and include all necessary agricultural services for assistance to farmers to whom modern irrigation is new. In the beginnings of the project these organizations are under complete government control, which is gradually relaxed in favor of more direct participation of the farmers as their training progresses.

3. Public Irrigation Districts - The main purpose of this type of organization is to create a semi-autonomous body to administer all investment and operational funds needed for irrigation and drainage.

4. Commercial Irrigation Enterprises - The purpose is to produce a certain amount and quality of certain commercial crops such as sugarcane. Therefore, the irrigation organization is usually under the strict control of the parameters of private and government enterprises.

5. Irrigation Cooperative and State Farmers - A characteristic of this type of organization is the centralized agricultural management of the area concerned; this also includes irrigation project management.

Water Users Organization Study for Pakistan

At present there is no organization or association of farmers in Pakistan, concentrating on water use and conservation. There is no legal foundation for such an organization. Custom and religion, which play an important role in determining the farmers behavior, can be considered a helpful element along with existing legal provisions.

A Comprehensive Study of the Organizational Alternatives to Improve On-Farm Water Management in Pakistan by George E. Radosevich (38) gives some conclusions and recommendations. Since little serious effort has been made to study, analyze, conclude, and recommend some pertinent ideas about Pakistani water users associations, a complete set of conclusions and recommendations from the aforementioned publication is given below:

1. The institutionalization of water users associations requires a simultaneous effort at both the macro and micro levels. It is recommended that a government agency be

established or designated at the macro level with responsibility for developing and administering programs designed to assist the farmers, such as watercourse rehabilitation, land leveling, insuring dissemination of vital information on water availability and delivery schedules, improved practices and technologies and with authority to negotiate and contract with water users associations for implementation of such programs. The entity, in addition, should be the liaison between the micro level efforts of the associations and other provincial and national agencies with responsibilities and programs in water and related resources.

2. Induce the establishment of associations through governmental incentive programs, as opposed to penalty or enforcement techniques.

3. Permit a wide degree of variations in organizational scope of authority so as not to restrict or constrain future development (i.e., allow the organization to start from an embryo and mature as the needs arise).

4. Draft a charter stating policy and purpose of organization.

5. Include in the objectives the goal of improving efficiency in water delivery and use from ground and surface waters and prevention of excessive return flow.

6. Formulate rules and regulations for operation and maintenance of association works.

7. Allow the association to levy assessments for the operation and maintenance of the system as well as providing a portion of these assessments for a capital improvement fund, and empower the association to collect water charges such that individual and collective (community) responsibility can materialize, and perhaps even eliminate the propensity for corrupt practices.

8. Failure to pay assessments or for other material infractions should result in the loss or suspension of the right to receive water and voting privileges.

9. Draft bylaws for administrative functioning of the association.

10. Provide the association with jurisdiction over main and minor watercourses within the command area.

11. Prohibit associations from becoming involved in politics.

12. Establish internal organs of the association to permit greatest amount of farmer participation in decision making (an assembly of users), a managing body (executive organ) and body to resolve disputes quasi-juridical in nature. Ensure equitable representation of all members through graduated voting rights, rights which would extend not only to the operating landowners but also tenants.

13. Provide for obligations, rights, and liabilities of association members.

14. Create the recognition of the right of each member to a share of his water and provide for the

enforcement of such right consistent with the Islamic concept of equitable apportionment.

15. Provide means of enforcing charter provisions and rotating directorship.

16. Technically assist the association in delivering water to the shareholders in due time, place, and amount when water is needed by the plants.

17. Keep use of water by the association consistent with the ability of the Irrigation Department to deliver water, although it may be necessary to modify the customary practices of water use within the watercourse, i.e., shifting within the types of warabundi - pakka, kacha, rosewari (glossary), nakka (glossary) by nakka, or reverse warabundi.

18. Defray or minimize, through cost sharing, the initial and subsequent costs of improving the delivery and use system.

19. Induce and/or assist cultivators in the installation of turnouts or gates at the nakka in place of the present practice of removing the dirt. The organization should provide a ditch rider who is the only employee (or his organizationally designated assistant) who can open and close the nakkas.

20. Consider, and where possible induce, the conjunctive use of ground and surface waters (e.g., give the association the authority to realign major and minor watercourses but within the constraint of water delivery through the mogha and tubewells where they exist).

21. Assist the members through financial and educational means (which in turn requires a training program for extension type personnel) to learn of, provide for, and implement improved farming and irrigation practices.

22. Extension and training efforts must be directed not only to water users, but also the water purveyors.

23. Provide for an integrated hierarchical organization among user associations to accomplish various magnitudes of development.

24. Establish at the federation level, an independent juridical body, consisting of association presidents, to resolve water disputes within the federation command area.

25. Develop a line of communication to the provincial and national governments either through a hierarchy of associations or a new or existing governmental agency particularly concerned with rural affairs.

26. Permit the divisional canal officer and other nonirrigator types as impartial technical advisors to the association with no voting power.

27. Strengthen the authority in the Canal and Drainage Acts that presently exist regarding the rights and responsibilities of divisional canal officers to inspect delivery systems at the farm levels, i.e., from the mogha onward.

28. Examine the impact of land tenure practices and regulations upon the proposed program of improved water management.

Broad View of Land Leveling and Watercourse Improvements for Pakistan

Land leveling and watercourse improvements will result in a better overall irrigation efficiency. Land leveling helps to control the amount of water applied to the field; watercourse improvement results in better delivery efficiency.

As a matter of fact, land leveling and watercourse improvement activities are a prerequisite for farmers, extension workers, planners, and researchers in making a reasonable estimate of the amount of water required for optimum crop production.

Land leveled today may become unleveled tomorrow. Improved watercourses may deteriorate. Hence, there is a need for water users organizations to assume leadership in organizing farmers for improvement and maintenance of watercourses and land leveling in the command area. Land leveling, watercourse improvements, and water users organizations are required for effective water management advisory service.

Chapter III

PROCEDURE

General Information About the Area Selected

The area selected for the watercourse improvements and land leveling study consists of 262.8 acres; two acres are in buildings, 4.2 acres for roads, and 8.3 acres are occupied by water channels. Since 1.7 acres is non-culturable, the net area under cultivation is 246.6 acres.

Crop surveys were completed during the Rabi (glossary) seasons of 72-73, 73-74, 75-76, and Kharif (glossary) seasons of 1973 and 1975. The major Kharif crops in this area are fodder and rice, and wheat and fodder during Rabi. Fodder is the dominant crop because this study area is very close to Lahore. For example, during Kharif 1975, and Rabi 1975-76, the respective acreage under fodder was 42.2 and 62 percent of the total cultivated area. Crops like rice and wheat during the same periods utilized 27 and 21 percent of the area respectively. The cropping intensity was 175 percent. During 1972-73 the intensity was 150 percent due to a lesser canal discharge rate during the Kharif season.

Watercourse outlet No. 15545/L of Niazbeg distributary has an official flow of 3.0 cusecs. This discharge rate, 1 cusec for 87.5 acres, is much greater than that authorized for other watercourses in the canal commanded areas. Water allocation to each farmer is made on the basis of his acreage. It is distributed on a permanent turn arrangement, or pakka warabundi, and serves each farmer weekly.

Most farmers on this watercourse have small holdings; the average farm size is about 5 acres. The education status of the 53 watercourse families is very low. There is a farmer cooperative society in Kanjra village, but all families in this watercourse area are not members.

Basis for Area Selection

1. This area was considered representative of most of Pakistan's watercourse command areas. The whole cultivated area is irrigated by gravity; there is no need for lifting the water by jhallars (glossary).

2. The watercourse did need improvement. The leaky nakkas and banks implied high loss rates.

3. Because of undulating fields the area required precision land leveling.

4. The existing village cooperative society did not adequately represent the farmers of this watercourse.

5. The watercourse location was suitable for demonstration work.

Land Leveling and Watercourse Improvements Survey

1. Pakistan's Department of Soil Survey classified the soil as a loam, but some patches are silt loam or silty clay loam. There are also some saline-alkaline patches.

2. A topographic map of the whole area was prepared by taking four shots in each field.

3. Crop survey of Kharif 1973, 1975, and Rabi 1972-74, 1975-76 were completed.

4. A map of watercourse channels, showing nakka locations, was prepared.

5. Ownership boundary map was completed, and for each farmer a warabundi time table was prepared on the basis of allowed time per acre.

Procedures for Watercourse Improvement

The second step towards the objectives was to select some watercourse improvement alternatives, to consider the problems associated with each, and to determine their solution. Details about the design criteria and specification were prepared. The following points of design criteria were considered.

Design Criteria

1. Full supply level in the main watercourse should be at least 0.5 ft above the ground surface of the field served. This requires a properly designed channel cross section based on the variables in Manning's equation.

2. In most books and publications the suggested value for Manning's "n" for an earthen channel is from 0.03 to 0.035. Considering the maintenance procedures and standards in Pakistan, an "n" value of 0.04 was used in the Manning's equation.

3. To avoid bank erosion the average velocity for earthen watercourse design is kept below 1.5 ft/sec for loam soils. Hence, a velocity of 0.7 to 0.8 ft/sec was considered appropriate.

4. Two side slopes were tried, one horizontal to one vertical (1:1), and one horizontal to two vertical (1:2).

5. Head loss through the check structures and culverts was taken into account.

Selection of Watercourse Alternatives

Many alternatives for watercourse improvement were considered including lining of the watercourse with different construction materials and various cross sections. Kacha improvements included complete renovation of the earthen channel, partial renovation, essential improvements, cleaning, etc. Complete renovation could be done by either a tractor or ditcher, or manually.

Lining was rejected on the following grounds:

1. The economic feasibility is doubtful unless soils are highly permeable.

2. Even if some new lining technique becomes reasonably economical, small farmers, such as those within the study area would still be reluctant to accept it because their financial resources are extremely limited.

3. Under subsidy by the Punjab Water Management Research Program, lining had already been tried at two places; one near Lahore, and the other at Lar near Multan.

Water Measurements

To measure water losses, cutthroat flumes were installed as follows:

1. One permanent cutthroat flume with an automatic recorder was installed near the watercourse mogha.

2. At different sections of all three branches, discharge measurements were made by another cutthroat flume. One lateral was also included for study purposes. Loss was equal to the difference in discharge measured at two locations.

3. Loss measurements were made both before and after improvement.

Data Collected for Cost Calculations

The cost data was collected for each type of improvement alternative. The information collected covered the charges for design, supervision of labor, hired masons, and material costs.

Procedures for Land Leveling

The following steps were followed in the land leveling operations:

1. A topo-survey was made of the farms selected for land leveling.

2. Farm mean elevations were calculated after consulting with the farmer and considering the soil type and crops to be planted. In calculating the mean elevation, the cut/fill ratio was taken at 60:40.

3. The farm was staked to guide the tractor operator and supervisor in making cuts and fills.

4. After scraping, when the ground profile was close to the mean elevation, the finishing was completed with a planer. The finished requirement was ±0.05 ft from the mean elevation.

5. Cost data were collected.

6. Application efficiencies were measured on both leveled and unleveled fields.

Procedure for Farmers Organization

In Pakistan, there is no formal farmers organization to promote the improvements in irrigated agriculture and to take the responsibility for more efficient on-farm water management.

As there is no legal arrangement at present, the procedure for involving farmers in land leveling and watercourse improvement, and in decision making and cost sharing was informal. The watercourse is community property. In informal organizations, collective goals are often difficult to achieve because many water users are free-riders (glossary) and there are no legal sanctions requiring their participation and contribution. To reduce this problem, the farmers of this watercourse were organized into small informal groups; in such groups it is more difficult to be a free-rider. Hence, the farmers on each branch were organized separately for decision making, execution of improvements, and cost sharing.

In carrying out land leveling activities, as land holdings are under private ownership, there was no need for group action. It was only required to approach and convince the individual farmers.

Chapter IV

RESULTS

Both watercourse improvement and land leveling operations were initiated on the Kanjra watercourse command area, 11 miles from Lahore (Pakistan). The data collected before and after the operations were used to prepare tables and figures depicting the improvement resulting from the introduction of any new practice, method, or change. The results obtained from both watercourse improvement and land leveling are discussed below.

Watercourse Improvement

As shown in Figure 1, four branches on the Kanjra watercourse A, B, C, and D, were selected for improvement.

Branch A, which is 4,000 feet long, runs parallel to the Niazbeg distributary for 880 feet and then turns from an east-west to a north-south direction. The first 880.0 ft section was completely renovated. The old banks were removed and replaced with manually compacted banks built with new soil according to design specifications shown in Figures 2 and 3. Afterwards, the remaining 3,120.0 ft was partially renovated. This consisted of realignment where possible, strengthening the banks, cleaning the watercourse, and installing the check and nakka structures at the predetermined elevations specified in Figure 3. Both the skilled and non-skilled labor required for watercourse improvement was provided by the farmers; all materials including check and nakka structures were provided by the Punjab Water Management Research Project.

On Branch B, which is 4,000 ft long, the essential improvement alternative was applied. Essential improvements include clearing, strengthing banks where needed, and installing concrete check and nakka structures. These improvements, without technical guides, were completed by the farmers. The Punjab Water Management Research Project supplied structures and cement; the remaining material and labor requirements were provided.

Branch C, which is also 4,000 ft long, is an off-shoot of Branch B. It draws its water from Branch B at a point 1,000 ft from the mogha. Cleaning was the only treatment applied to this branch. No contribution was made by the research project. Building diversion structures at the mogha and at the head of Branch C provided the farmers with 20 percent more water and facilitated the irrigation operation.

Branch D runs parallel to the Niazbeg distributary and in the opposite direction to Branch A for 820 ft then 200 ft southeast, and 580 ft in the south direction. The banks of this sub-branch were removed and rebuilt according to the design specifications shown in Figure 4. A tractor with scraper was used for construction of the watercourse pad; a tractor and ditcher was used to open the channel. The branch was finished manually according to specifications. However, in one section donkeys were used to bring in additional soil. For installation of structures, the material was provided by the project and the masons and laborers by the farmers. During the renovation operation the final finishing was done by project laborers.

Water loss measurements were made "before" and "after" improvements; however, on Branches A and B, additional measurements were made at intermediate improvement stages. The intermediate improvement stage on Branch A consisted of renovation of the first 880 feet only, and installation of a diversion box and three panel nakkas. On Branch B, the intermediate improvement stage consisted only of the installation of the diversion box.

The water loss rates are presented in two standard forms: one as losses in cusecs per thousand feet, and the second as losses in percent per thousand feet. These average water loss rates calculated by two different procedures, are presented in Tables 1 (a-b). Table 1a shows the average values calculated on the basis of the mid-point of time and space. According to the warabundi schedule, the mid-space and time point for Branches A, and B is 2,000 ft from the mogha. For Branch C it is 2,500 ft from its head. In the case of Branch D, this point occurred 1,200 ft from its emerging point. The weighted average loss rate, the second method, is shown in Table 1b.

Accordingly, the rate of water saving was also expressed in cusecs per thousand feet or percent per thousand feet of watercourse. To calculate the average rate of water saving, again, two techniques were used; i.e., on the basis of mid-space and time and the weighted average. Table 1 also shows both water saving rates.

The loss rates for Branch A per 1,000 ft at the "before," "intermediate," and "after" improvement stages, based on mid-space and time, were respectively 0.47 cusecs or 16.49 percent, 0.23 cusecs or 7.63 percent, and 0.09 cusecs or 2.96 percent (Table 1).

Thus, the water saved per 1,000 ft at the intermediate and after improvement stages were 0.24 cusecs or 8.86 percent and 0.38 cusecs or 13.58 percent, respectively. The difference between the two improvement stages was a saving per 1,000 ft of 0.14 cusecs or 4.67 percent. For this same Branch A, the weighted average loss rate per 1,000 ft for the "before," "intermediate," and "after" improvement stages were respectively 0.43 cusecs or 14.88 percent, 0.18 cusecs or 6.07 percent, and 0.07 cusecs or 2.37 percent. Again the difference between the two improvement stages was a saving per 1,000 ft of 0.11 cusecs or 3.7 percent.

The water loss rates per 1000 ft for Branch B, on the basis of mid-space and time, at the "before," "intermediate," and "after" improvement stages were 0.36 cusecs or 12.0 percent, 0.28 cusecs or 9.08 percent, and 0.18 cusecs or 5.86 percent, respectively. The water saving rates per 1,000 ft were 0.08 cusecs or 2.92 percent and 0.18 cusecs or 6.14 percent; the saving difference is 0.1 cusec or 3.22 percent (Table 1).

When the weighted averages are considered, then the water loss rates per 1,000 ft for Branch B at the "before," "intermediate" and "after" improvement stages are 0.44, 0.25, and 0.19 cusecs or 15.0, 8.22, and 5.71 percent, respectively. The water saving rates are at "intermediate" improvement, "after" improvement and from "intermediate" to "after" improvement stages were 0.19, 0.25, and 0.06 cusecs or 6.78, 9.29, and 2.51 percent per 1,000 ft, respectively (Table 1).

Water loss rates per 1,000 ft on the basis of mid-space and time, for Branch C at "before" and "after" cleaning were 0.33 cusecs or 11.42 percent and 0.17 cusecs or 5.96 percent. The saving rate due to cleaning was 0.16 cusecs or 5.46 percent per 1000 ft (Table 1).

On the weighted average basis, the loss rates per 1,000 ft "before" and "after" cleaning were 0.29 and 0.15 cusecs or 10.21 and 5.21 percent, respectively. The water saving rate due to cleaning was 0.14 cusecs or 5.00 percent per 1,000 ft (Table 1).

On Branch D, the water loss rates per 1,000 ft based on mid-space and time, at "before" and "after" improvement were 1.29 cusecs or 45.16 percent and 0.19 cusecs or 6.47 percent, respectively. The water saving rate due to improvement was 1.10 cusecs or 38.69 percent per 1,000 ft.

Figures 5, 6, 7, and 8 show for each branch, curves relating loss rate in cusecs/1000.0 ft and total water loss in cusecs to distance. The difference between curves at any point shows the water saving rate or total water saved.

The initial cost for improving the delivery efficiencies of the watercourse system, varies with the different improvement alternatives adopted. Table 2 gives the cost analysis of panel nakkas and diversion box installation. The total initial cost for each improvement alternative on the four branches is given in Tables 3-5.

On Branch A, where the first 880 ft were renovated, the cost per linear foot was Rs. 0.94; the remaining 3,120 ft were partially renovated and the cost per linear foot came to Rs. 0.76. The average cost per linear foot for improvement of the whole Branch A came to Rs. 0.80. Under essential improvement technique, the cost per linear foot for Branch B was Rs. 0.48. Branch A, which was completely renovated, cost an average of Rs. 1.13 per linear foot. The cleaning operation on Branch C cost only Rs. 0.04 per foot.

Land Leveling

The following section discusses the cost of land leveling operations and the benefits relating to better irrigation application and water use efficiencies.

Table 6 shows the cost of land leveling operations on 12.11 acres at the Mirza farm of the Kanjra watercourse. Total cost per cubic yard, including operational, supervisory, survey, and design is Rs. 2.42; the total cost per acre is Rs. 667.45. This total cost could have been reduced by leveling the area at two elevations, but the farmer insisted on one mean elevation for the entire farm and was willing to pay more. Hence, Rs. 667.45 per acre can be considered as the maximum leveling cost.

This cost of Rs. 2.42 per cubic yard includes an operation cost of Rs. 2.38 per cubic yard which is less than the operational cost Rs. 2.54 per cubic yard in Table 7. Table 7 data were collected from four districts of the Punjab Province, where, under the Integrated Rural Development Program, 250.22 acres were leveled. The higher cost per unit of soil volume is partially due to inexperienced tractor drivers.

The benefits of land leveling were measured in terms of improved irrigation application efficiencies. The water saved could be used for increasing the cropping intensity. Land leveling helped to control excessive over-irrigation during early stages of crop growth and under-irrigation at the latter stages. The result was increased yields.

During Rabi 1975-76, seasonal data relating to application efficiencies on leveled and unleveled wheat fields were collected. The seasonal irrigation application pattern is shown in Figures 9-11. The average seasonal application efficiency on leveled fields of wheat based on soil sampling is 83 percent (Figure 9); based on a combination of field and pan evaporation the application efficiency was 92 percent (Figure 10). The average seasonal application efficiency for an unleveled field is 51 percent (Figure 11). In addition to these seasonal studies, continuous observations, as shown in Tables 8 and 9, were also made. Forty-six measurements were made on leveled and unleveled fields within the watercourse command area. The 24 measurements on leveled field showed average application efficiency of 81 percent. For the 22 observations on unleveled fields, the average application efficiency was 50 percent.

Achievements

1. Of the 13,600 ft of improved watercourse, 2,480 ft was completely renovated, 3,120 ft was partially renovated, 4,000 ft received essential improvements, and the remaining 4,000 ft was cleaned only.

2. To acquire cost data, 12.11 acres were precisely leveled. In cooperation with the Precision Land Leveling Project and the Punjab Water Management Program, an additional 40 acres were leveled within the watercourse command area.

3. Farmers on all four branches were organized separately. These organizations were informal and without any binding rules and regulations. These four farmer groups decided the nature, share, and operation for construction and improvement activities on their particular branch of the watercourse. These farmer groups were organized for implementation of watercourse improvements only.

Problems

1. Watercourse improvement requires the collective participation of all farmers in the command area. It requires formal or informal organization to insure equitable contribution from all farmers. On the Kanjra watercourse there was no formal or informal farmers organization to assume the collective responsibility of the watercourse improvement program. To overcome such difficulty the farmers on four branches were informally organized into four small groups. Small grouping was done intentionally to avoid the free-rider problem.

2. For efficient program operation immediate access to funds is necessary. This is also true for field research where immediate availability of funds is required since delay may cause serious damage to the planned research objectives. In the beginning, under the Water Management Program, a complicated funding procedure hampered the research work. On becoming aware of the limitations, program officials made satisfactory funding arrangements.

3. Another problem was the installation of check structures in the watercourse. The topography of the command area is flat; in Branch A there is only a 2.5 ft drop over its 4,000 ft length. Design and location limits permitted installation of only 8 check structures.

A controversy over location occurred when installing the check structures. The most common reason for insistence on certain locations was the "water allowance" required in filling the watercourse. There was also a personal desire by most farmers to have their own check structures. This problem was overcome by installing one extra check structure and changing some locations. These check structures were installed at 0 ft, 535 ft, 1,200 ft, 1,500 ft, 2,000 ft, 2,325 ft, 2,700 ft, 3,025 ft, and 3,825 ft from the mogha. This additional check structure had little effect on the full supply level and other design criteria considerations since head loss through this structure (0.03 ft) was offset by not building two proposed and designed culverts. This is the only change in the design as shown in Figure 3.

4. There existed a very serious problem of "cuts" in the main branches. The farmers were persuaded to stop cutting the main branch banks for irrigation purposes and use the sub-branches. In the sub-branches, except for one each on A, B, and D Branches, panel nakkas were installed. In spite of these efforts, there are still many cuts made from the main branches. For example, in Branch A there were 111 cuts before improvement, and 22 after improvement. This problem was only partially solved; serious consideration is needed to eliminate this source of water loss from the system.

5. In land leveling, the lack of required machinery is the major constraint.

6. There exists no formal or informal farmers organization with established rules and regulations for water management. After improvement of this watercourse there was no organization provision for its maintenance.

Chapter V

CONCLUSIONS

Watercourse Improvement

Measurements "before" and "after" watercourse improvements support the following conclusions:

1. All previous Water Resource Development studies conducted in Pakistan assumed that the watercourse delivery efficiency was as high as 90 percent. Measurements on the Kanjra watercourse do not support the delivery efficiency assumed in these previous reports. The delivery efficiencies before improving the watercourse system were quite low; at the tails of branches they ranged from 40 percent to 63 percent. As shown in Table 10, the weighted average delivery efficiencies for Branches A, B, C, and D were 68.8, 68.3, 76.2, and 55.3 percent, respectively. The weighted average of the four branch watercourse system, on the basis of time that water flows in each branch, is 71.2 percent. Before improvement the Kanjra watercourse loss rate was 0.40 cusecs per thousand feet, which is two times the average watercourse loss rate determined from data collected by CSU at different localities in the Punjab Province (27).

2. The kacha watercourse improvement extends over 13,600 ft of the four main branch system. There were different alternatives for different sections of watercourse branches. After carrying out such improvement activities, water measurements were made at different points on the branches. As shown in Table 10, item b, the weighted

average delivery efficiency of the four branch watercourse system after improvement was 88.3 percent. This is 17.1 percent greater than the "before" improvement delivery efficiency. This improvement from 71.2 to 88.3 percent means an additional 327.3 acre feet/year (325 days) of water are available to the fields. This is only 80.7 acre feet less than that total amount of water delivered to the watercourse during Rabi 1975-76. The water loss rate was reduced from 0.40 cusecs/1000 ft before improvement to 0.13 cusecs/1000 ft after improvement. The individual delivery efficiencies of Branches A, B, C, and D are 94.6, 81.7, 86.1, and 94.8 percent, respectively (Table 10, item b).

3. The initial cost of system improvement was Rs. 7,195.80 or Rs. 0.53/linear ft; the annual maintenance cost should be Rs. 4,548.84 (Table 11). The benefit-cost analysis, shown in Table 11, is calculated at three discount rates: 10 percent, 12 percent, and 15 percent, and at four different water costs of Rs. 50/AF, 80/AF, 100/AF, and 200/AF. Two watercourse life periods of five and ten years were considered. In every case the benefit-cost ratios are more than unity fluctuating from 2.20 to 11.44.

Land Leveling

1. Application efficiencies were used to measure the improvement due to land leveling. From data collected during the Rabi Season 1975-76 (Table 8), the average application efficiency on unleveled fields was 49.5 percent; the application efficiency on leveled fields was 81.35 percent

(Table 9). The difference, 31.83 percent, results from better control of irrigation water due to land leveling.

2. Within the Kanjra watercourse command area, the cost/cubic yard of cut volume was Rs. 2.42; the cost per acre was 667.45. The average leveling cost for four districts of the Punjab was Rs. 619.64/acre (Table 7).

Integrated Approach for Land Leveling and Watercourse Improvements

Irrigation efficiency is the product of application efficiency and delivery efficiency. It is affected both by the field profile and watercourse condition. As shown in Table 12, the irrigation efficiency before watercourse improvement was 35.26 percent. After watercourse improvement and land leveling it was 71.81 percent. This average "before" irrigation efficiency of 35.26 percent is much less than the 63.0 percent assumed in most previous MACRO - development planning studies.

This 102 percent increase in irrigation efficiency demonstrates a tremendous potential for precision land leveling and watercourse improvement operations. This makes available an additional 695.86 AF per year.

Farmers Organizations

Pakistan has no institutionalized system of water users associations by which the farmers can jointly pursue optimizing a mutual task. In most irrigation systems the cooperation that has developed among the farmers needs only to be formalized in a permanent organization. It is recognized that among the farmers in the many villages throughout Pakistan, there is cooperation in the use of water; for example, in the warabundi and in watercourse cleaning operations.

At the Kanjra watercourse command area, except for cleaning operations, there existed no cooperation. In the case of watercourse rehabilitation, small groups on each branch were organized to involve the farmers in watercourse improvement and to contribute their share in labor and other required forms.

This temporary arrangement of the farmers organization in different small grups on each branch of the watercourse helped to assure the full participation of the farmers in the program. For the future, there is an urgent need of some organization to take responsibility for watercourse improvement, maintenance, and land leveling, and become a source of agricultural support facilities.

It is concluded that although the necessity for some formal legal organization of farmers is necessary, an informal organization would serve the purpose on a temporary basis.

Recommendations and Suggestions

The results of the research case study are derived from the measurements made and data collected at Kanjra, one of the watercourse command areas in Pakistan. Based on the results, which in some instances are surprising and in others consistent with published data, a number of recommendations and suggestions seem necessary and worth consideration. These are as follows:

1. Farmers in Pakistan must be provided with factual information about field and watercourse losses and with recommendations for land leveling and watercourse improvement. Also, procedures for maintenance of the watercourse and the leveled fields are required.

2. Farmers need help to build well compacted improved watercourses integrated with land leveling along both sides of the watercourse. When leveling the surrounding fields, the cut volume of soil from the high fields should be used to build the pad for improving the watercourse.

3. Except where soils are highly permeable only the earthen channel improvement alternative should be considered.

4. Standards and design criteria considerations must be strictly followed to achieve quality construction.

5. The farmers must be persuaded to stop making illegal cuts in the main channel banks. Instead, they should be encouraged to use only laterals for this purpose.

6. Check structures should be provided at required intervals to prevent farmers from thinning banks to acquire soil for constructing dams. This reduces leakage of the banks and filling and overtopping of the channel. The warabundi should be readjusted according to the spacing and placement of the check structures. An additional water allowance should be given to that farmer who first fills the watercourse section between two structures.

7. Different irrigation methods should be tested to determine which ones are most efficient under Pakistani conditions.

8. Either the Agriculture or Irrigation Department should assume regulatory responsibility for the design, construction, maintenance, and efficient use of the watercourse system. The authority which lies in the Canal and Drainage Act should be strengthed for better maintenance of this miniature irrigation system.

9. A formal institution of water users should be developed to take care of the following activities:

(a) Direct involvement of the farmers in the improvement program.

(b) Managing the efficient delivery of water in the watercourse.

(c) Resolving disputes and problems among the water users.

(d) A legal contact point for the farmers and the government.

(e) Forum for dissemination of technical information on improved water use.

(f) Managing all agricultural support facilities, etc.

10. To reduce the uncertainty of canal water, the following two possibilities should be considered: (a) Tubewell (if underground water is suitable), and (b) Storing the water when not needed and using when required.

11. An effective extension program must be developed to provide services to the farmer such as seed, fertilizer, insecticide, the knowledge and "know-how" of improving crop production, and proper use of irrigation water. This extension program should be of a dynamic nature which is continually self-evaluating and self-improving.

12. Farmers should be provided with on-farm water management advisory service. Such services will achieve maximum effectiveness when the physical restraints of unleveled field and unimproved watercourses are removed.

13. For implementing the land leveling and watercourse improvement program, there must be an innovative institution having the following characteristics:

(a) For development efforts an innovative organization must be evolved which can adapt to the realities of the dynamic system of production and service needs of the rural sector.

(b) Staff members of such organization must be well trained, dedicated, highly skilled, and highly motivated individuals.

(c) There should be a continuous process of personal improvement. This would include in-service training, evaluation of the work, performance, and promotion on merit basis.

14. In the beginning there should be an economic incentive to promote land leveling and watercourse improvement.

15. For an efficient land leveling and watercourse improvement program an immediate access to the developmental funds should be available for continuous progress without any interruption.

16. The staff responsible for land leveling and watercourse improvement must be provided with monetary incentive, such as fields allowance and transportation to allow technicians to concentrate on their work.

REFERENCES

1. Ahmad, Bashir, and Ronald L. Tinnermeier, "The Economics of Land Levelling," Department of Economics, Colorado State University, Fort Collins, Colorado, July 1974.

2. Ali, Arshad, Wayne Clyma and Alan C. Early. "Improved Water and Land Use Management Through Precision Land Levelling," presented at the International Conference on Waterlogging and Salinity, Department of Civil Engineering, University of Engineering and Technology, Lahore, Pakistan, October 1975.

3. Ali, Arshad, Wayne Clyma and Mohammad Ashraf. "Irrigation Practices for Traditional and Precision Levelled Fields in Pakistan," presented at CENTO Panel Meeting on Optimum Use of Water in Agriculture, Nuclear Institute for Agriculture and Biology, Lyallpur, Pakistan, March 3-5, 1975.

4. Arar, A. "Surface Irrigation Methods and Practices," *Irrigation and Drainage Paper 12*, FAO/UNO, Rome, 1972.

5. Booher, L. J. *Surface Irrigation*, FAO/UNO Publication, Rome, ~~1967~~. 1974.

6. Cheong and Chuplin. "Integrated Farm Water Management," *Irrigation and Drainage Paper 10*, FAO/UNO, Rome, 1971.

7. Chin, L. T. "Irrigation Associations," *Irrigation and Drainage Paper 12*, 1972.

8. Chow, Ven Te. *Open Channel Hydraulics*, McGraw-Hill, New York, 1959.

9. Clyma, Wayne and Gilbert L. Corey, "The Importance of Farm Water Management in Pakistan," Colorado State University Water Management Research Contract, Pakistan, Field Report No. 2, 1975.

10. Clyma, Wayne, Arshad Ali, and Mohammad Ashraf. "Irrigation Practices and Application Efficiencies in Pakistan," Colorado State University Water Management Research Contract, Pakistan, Field Report No. 3, 1975.

11. Clyma, Wayne, Arshad Ali and Mohammad Ashraf. "Watercourses Losses," presented at CENTO panel meeting on the Optimum Use of Water in Agriculture, Nuclear Institute for Agriculture and Biology, Lyallpur, Pakistan, March 3-5, 1975.

12. Code, W. E. "Farm Irrigation Structures," Colorado State University Biolateral Experiment Station Bulletin 496-S, Fort Collins, Colorado, October 1966.

13. Corey, Arthur T., and William E. Hart. "Soil Water Engineering," Department of Agricultural Engineering, Colorado State University, Fort Collins, Colorado, 1975.

14. Dimick, Niel A. Guide for Precision Land Farming in Pakistan, United States Aid to International Development, Pakistan, 1972.

15. Early, A. C., and M. K. Lowdermilk. "Preliminary Delivery and Application Efficiency Results for the Watercourse Survey of Punjab: Phase I." A progress report for Colorado State University Water Management Research Program, Pakistan, 1975.

16. Eckert, Jerry, Niel A. Dimick, and Wayne Clyma. "Water Management Alternatives for Pakistan: A Tentative Appraisal," Colorado State University Water Management Research Contract, Pakistan, Technical Report No. 43, June 1975.

17. Gibb, Sir Alexander. "Programme for the Development of Irrigation and Agriculture in West Pakistan," Hunting Technical Services, Ltd. Comprehensive Report, Volumes 7 and 10, London, May 1966.

18. Grant, Eugene L., and W. Grant Ireson. Principles of Engineering Economy, The Ronald Press Company, New York, 1970.

19. Hansen, V. E., C. A. Bower and F. J. Williams. "Salinity Control and Reclamation Program in the Lower Indus Basin: A Review Made During July and August 1962." Harza Company International, Lahore, Pakistan, March 1963.

20. Hart, William E. Irrigation System Design, Department of Agricultural Engineering, Colorado State University, Fort Collins, Colorado, 1975.

21. Harza Engineering Company International. A Program for Water and Power Development in West Pakistan 1963-75, Supporting Studies, An Appraisal of Resources and Potential Development, a report prepared for WAPDA, Lahore, West Pakistan, September 1963.

22. Hassan, Nisar. Water Management for Farmers, Department of Agriculture Publications Wing, Government of the the Punjab Technical Bulletin No. 1.1, Lahore, Pakistan, December 1972.

23. Howe, Charles W. "Benefit Cost Analysis for Water System Planning," Water Resources Monograph 2, American Geophysical Union, Washington, D.C., 1971.

24. Hunting Technical Services Limited, and Sir M. MacDonald and Partner. "Lower Indus Report Part I, Present Situation," a report prepared for WAPDA, 1966.

25. IACA Study (Sir Alexander Gibb and Partners - see item 17).

26. Israelsen, O. W., and V. E. Hansen. Irrigation Principles and Practices, John Wiley and Sons, Inc., New York, 1962.

27. Kemper, W. D., Wayne Clyma and Mohammad Ashraf. "Improvement and Maintenance of Earthen Watercourses to Reduce Waterlogging and Increase Water Supplies for Crop Production," presented at the Waterlogging and Salinity International Conference, Lahore, Pakistan, October 1975.

28. Kemper, W. D. et al. "Aids for Watercourse Design and Improvement Research," Colorado State University Management Research Contract, Pakistan, July 1976.

29. Khan, Qurban A. "Irrigation Management in Pakistan," Department of Agricultural Engineering, Colorado State University, Fort Collins, Colorado, 1974.

30. Kissan, Phillip. Surveying Practice: The Fundamentals of Surveying, McGraw-Hill, 1971.

31. Kraatz, D. B. "Irrigation Canal Lining," Irrigation and Drainage Paper 2, FAO/UNO, Rome, 1971.

32. Lieftink, Pieter, A. R. Sadove, and T. C. Creyke. "Water and Power Resources of West Pakistan," A Study in Sector Planning, Vol. I, World Bank and Johns Hopkins Press, Baltimore, 1968.

33. Lowdermilk, Max K., Wayne Clyma and Alan C. Early. "Physical and Socio Economics and Dynamics of a Watercourse in Pakistan's Punjab: System Constraints and Farmers' Responses," Colorado State University Water Management Research Contract Technical Report No. 42, December 1975.

34. MacDonald, Sir M., and Partners. "Lower Indus Reports, Part 1 and 2," Vols. 16 and 18, a report prepared for WAPDA, 1966.

35. Marr, J. C. The Border Method of Irrigation. University of California, California Agricultural Experiment Station and Extension Service Circular 408, 1954.

36. Marr, J. C. Grading Land for Surface Irrigation. University of California, Davis, Circular 438, July 1957.

37. Marr, J. C. Furrow Irrigation. University of California, California Agricultural Experiment Station and Extension Service Manual 37, November 1967.

38. Radosevich, George E. "Water User Organizations for Improving Irrigated Agriculture: Application to Pakistan," Colorado State University Water Management Research Contract, Pakistan, Technical Report No. 44, December 1975.

39. Revelle, R. et al. "Report on Land and Water Development in the Indus Plain," for the White House, Washington, D.C., January 1964.

40. Sagardoy, J. A. Irrigation Organizations: Operation and Management of Irrigation Scheme (Irrigation and Drainage), Irrigation and Drainage Paper 12, FAO/UNO, Rome, 1972.

41. Skogerboe, Gaylord V., Ray S. Bennett and Wynn R. Walker. "Selection and Installation of Cutthroat Flumes for Measuring Irrigation and Drainage Water," Department of Agricultural Engineering, Colorado State University Experiment Station, Fort Collins, Colorado, December 1973.

42. Tipton and Kalmbach. "Regional Plan, Northern Indus Plains. Development and Use of the Water Resources of the Indus Plain," a report prepared for WAPDA, Vol. I, 1967.

43. Turner, J. Howard, and Carl L. Anderson. "Planning for an Irrigation System," American Association for Vocational Instructional Materials, Engineering Center, Athens, Georgia, June 1971.

44. World Bank. "Pakistan Special Agriculture Sector Review Volume III: Annex on Water Management," Report No. 922a-Pak, January 28, 1976.

45. 1975 Statistical Data on Agriculture Sector in Pakistan. FAO/UNO Pakistan, February 1976.

TABLES

Table 1. Summary of Kanjra Watercourse Losses

Branch	Before Improvement (1)		Intermediate Improvement (2)		After Improvement (3)		Improvement (1-2)		Improvement (1-3)		Improvement (2-3)	
	Losses Cusecs/ 1000	Losses %/1000	Losses Cusecs/ 1000	Losses %/1000	Losses Cusecs/ 1000	Losses %/1000	Savings Cusecs/ 1000	Savings %/1000	Savings Cusecs/ 1000	Savings %/1000	Savings Cusecs/ 1000	Savings %/1000
Watercourse Losses on the Basis of Mid-Space and Mid-Time												
A	0.47	16.49	0.23	7.63	0.09	2.96	0.24	8.86	0.38	13.58	0.14	4.67
B	0.36	12.00	0.28	9.08	0.18	5.86	0.08	2.92	0.18	6.14	0.10	3.22
C	0.33	11.42	-	-	0.17	5.96	-	-	0.16	5.46	-	-
D	1.29	45.16	-	-	0.19	6.47	-	-	1.10	38.69	-	-
Watercourse Losses on Basis of Weighted Average												
A	0.43	14.98	0.18	6.07	0.07	2.37	0.25	8.81	0.36	12.51	0.11	3.70
B	0.41	15.00	0.25	8.22	0.19	5.71	0.19	6.78	0.25	9.29	0.06	2.51
C	0.29	10.21	-	-	0.15	5.21	-	-	0.14	5.00	-	-
D	1.22	42.29	-	-	0.15	4.90	-	-	1.07	37.39	-	-

Table 2. Cost of Installing Check or Nakka and Division Box

Cost of Nakka and Check Structure

	Description		Amount
a.	20" Dia. R.C. Structure (including transport)	Rs.	60.00
b.	100 Bricks @ Rs. 230/1000 (including transport)		23.00
c.	Cement - 3/4 bag @ Rs. 22.5		16.88
d.	Sand		2.00
e.	Mason and Laborer		
	(Mason Rs. 30/day)		
	(Laborers Rs. 10/day)		
	One mason and one laborer can install 3 structures a day		13.33
	Total	Rs.	115.21

Cost of Division Box

	Description		Amount
a.	20" Dia. R.C. Structure		
	3 structures @ Rs. 60/day	Rs.	180.00
b.	700 Bricks @ Rs. 230/1000		161.00
c.	Cement - 5 bags @ Rs. 22.50/Bag		112.50
d.	Sand		10.00
e.	5 Days of One Mason and One Laborer		
	@ Rs. 40/day (both)		200.00
	Total	Rs.	663.50

Table 3. Cost of Watercourse Improvement - Branch A

Renovation of Branch "A" - 880 Foot Section

	Description		Amount
a.	Installation of 3 structures @ Rs. 115.21	Rs.	345.63
b.	Share in cost of Division Box Installation		11.20
c.	Labor cost @ Rx. 1.25/hr. (total hrs. spent - 327.5)		409.38
d.	Survey, design charges @ Rs. 20/day		40.00
e.	Supervisory charges @ Rs. 2.5/hr.		20.00
	Total	Rs.	826.21
	Cost per Linear Foot		0.94

Partial Renovation of Remaining 3120 Feet of Branch "A"

	Description		Amount
a.	Cleaning the watercourse @ Rs. 0.04 ft	Rs.	124.80
b.	Strengthening the weaker banks @ Rs. 0.04 ft		124.80
c.	Installation of 17 structures @ Rs. 115.21/structure		1,958.57
d.	Sahre in cost of Division Box		168.39
	Total	Rs.	2,376.56
	Cost per Linear Foot		0.76

Cost per Linear Foot of Branch "A"

	Description		Amount
a.	Cost per Linear Foot of 880 ft of "A"	Rs.	0.94
b.	Cost per Linear Foot of 3,120 ft of "A"		0.76
c.	Average Cost per Linear Foot of "A"		0.80

Table 4. Cost of Watercourse Improvement Branches B and C

Cost of Essential Improvement of Branch "B"

	Description		Amount
a.	Cleaning of watercourse 133.33 man hours @ Rs. 1.25/hr	Rs.	166.67
b.	Strengthening weaker section 133.33 man hours @ Rs. 1.25/hr		166.67
c.	Ten structures installation cost @ Rs. 115.21/structure		1,152.10
d.	Share in the cost of Division Box		416.22
	Total	Rs.	1,901.66
	Cost per Linear Foot		0.48

Cleaning of Branch "C" 4000 Ft Section

	Description	Amount
A.	Cleaning charges 133.33 hours @ Rs. 1.25/hr	166.67
	Cost per foot	0.04

Table 5. Cost of Watercourse Improvement Branch D

Renovation of Branch "D", First Section of 800 Feet

	Description		Amount
a.	Tractors hours for pad making and ditcher operations @ Rs. 35/hr	Rs.	507.50
b.	Scraper and ditcher renting charges @ Rs. 2/hr		28.00
c.	Labor cost 47.5 hrs @ Rs. 1.25 hr		59.38
d.	Survey and design charges 16 man hrs @ Rs. 2.5/hr		40.00
e.	Supervisory charges - 8 man hrs @ Rs. 2.5/hr		20.00
f.	Cost of installation of 3 structures @ Rs. 115.21/structure		345.63
	Total	Rs.	1,000.51
	Cost per Linear Foot		1.25

Renovation of Branch "D", 2nd Section of 800 Feet

	Description		Amount
a.	Labor cost: (i) Man hours spent - 272.75 @ Rs. 1.25/hr	Rs.	340.94
	(ii) 4 donkeys @ Rs. 10/day		40.00
b.	Tractor hours - 3 hours @ Rs. 35/hr		105.00
c.	Scraper and ditcher Rs. 15/day		15.00
d.	2 structures installed @ Rs. 115.21/structure		230.42
e.	Share in the cost of Division Box		10.19
f.	Supervisory survey and design charges 24 man hours @ Rs. 2.5/hr		60.00
	Total	Rs.	801.55
	Cost per Linear Foot		1.00

Renovation Cost for Branch "D"

Total Cost:	800 ft first section		1,000.51
	800 ft second section		801.55
	Total Cost for 1600 ft	Rs.	1,802.06
	Average Cost per Linear ft		1.13

Table 6. Cost of Precision Land Leveling within Kanjra Watercourse Command Area

General Information

a. Area leveled - 12.11 acres

b. Cut volume - 3,340.0 cubic yards

c. Tractor hours - 216.0 hours

d. Scraper days - 25 days

e. Planer and other days - 2.0 days

Land Leveling Operational Cost

a.	Tractors - 216 hours @ Rs. 35/hour	Rs.	7,560.00
b.	Scraper - 25 days @ Rs. 15/day		375.00
c.	Planer, ditcher and other - 2 days @ Rs. 15/day		30.00
d.	Survey and design cost - 16 hours @ 3.75/hour		60.00
e.	Supervisory charges - 1 hour per day @ Rs. 2.5/hr		67.50
	Total	Rs.	8,092.50

Land leveling cost/yard^3 = Rs. 2.42

Land leveling cost/acre = Rs. 667.45

Table 7. Cost of Precision Land Leveling Operations at Manawala, Hujra, Lar, and Kamar Mashani

Job No.	Total Cut Cu. Yards	Acres	Equipment Hours Tractor	Scraper	Other	$Yards^3$ Per Hour	Rs./$Yard^3$	$Yards^3$ Per Acre	Cost/Acre (Rs.)
1	905.0	6.00	40.0	32.0	8.0	22.63	1.63	150.83	245.86
2	1182.0	5.00	56.0	48.0	8.0	21.11	1.75	236.40	413.70
3	2009.0	5.00	104.0	96.0	8.0	19.31	1.91	401.80	767.44
4	607.0	3.00	32.0	24.0	8.0	18.97	2.21	202.33	447.16
5	719.0	4.75	72.0	64.0	8.0	9.99	3.69	151.37	558.55
6	767.0	3.00	40.0	32.0	8.0	19.18	1.92	255.67	490.88
7	1517.0	6.00	104.0	96.0	8.0	14.59	2.65	252.83	670.01
8	870.0	2.50	56.0	48.0	8.0	15.54	2.37	348.00	824.76
9	1041.0	3.00	56.0	48.0	8.0	18.59	1.98	347.00	687.06
10	1226.0	6.00	80.0	72.0	8.0	15.33	2.41	204.33	492.44
11	952.0	6.00	64.0	56.0	8.0	14.88	2.48	158.67	393.49
12	1411.0	4.00	160.0	144.0	16.0	8.82	4.11	353.75	1449.80
13	4023.0	10.00	216.0	200.0	16.0	18.63	1.98	402.30	796.55
14	1073.0	4.00	104.0	96.0	8.0	10.32	3.57	268.25	957.65
15	398.0	2.00	21.0	16.0	5.0	18.95	1.88	199.00	374.12
16	251.0	2.00	32.0	24.0	8.0	7.84	4.70	125.50	589.85
17	926.0	4.00	82.0	80.0	2.0	11.29	3.28	231.50	759.32
18	1377.0	5.00	110.0	88.0	22.0	12.52	2.95	275.40	812.43
19	565.0	4.10	40.0	32.0	8.0	14.13	2.61	137.80	395.67
20	595.0	3.00	38.0	34.0	4.0	15.66	2.36	198.33	468.07

Table 7. Cost of Precision Land Leveling Operations at Manawala, Hujra, Lar, and Kamar Mashani (continued)

Job No.	Total Cut Cu. Yards	Acres	Equipment Hours Tractor	Scraper	Other	Yards^3 Per Hour	Rs./Yard^3	Yards^3 Per Acre	Cost/Acre (Rs.)
21	1572.0	5.00	144.0	128.0	16.0	10.92	3.38	314.40	1062.67
22	959.0	5.00	92.0	88.0	4.0	10.42	3.55	191.80	680.89
23	989.0	4.17	44.0	40.0	4.0	22.40	1.65	236.45	390.14
24	706.0	3.30	30.0	24.0	6.0	23.53	1.57	213.95	335.88
25	415.0	4.66	40.0	32.0	3.0	10.38	3.55	89.06	316.15
26	895.0	4.77	40.0	32.0	8.0	22.38	1.65	187.63	309.59
27	1099.0	4.22	48.0	40.0	8.0	22.90	1.61	260.43	419.29
28	1230.0	4.25	55.0	45.0	10.0	22.35	1.65	289.41	477.53
29	4120.0	15.00	300.0	288.0	12.0	13.73	2.69	274.67	738.85
30	10584.0	35.00	855.0	825.0	30.0	12.38	2.98	302.40	901.15
31	1325.0	5.00	102.0	96.0	6.0	12.99	2.84	265.00	752.00
32	6547.0	15.00	440.0	432.0	8.0	14.87	2.65	436.42	1156.64
33	1324.0	5.00	85.0	70.0	15.0	15.58	2.37	264.80	627.58
34	1423.0	5.00	92.0	88.0	4.0	15.47	2.39	284.60	680.19
35	4048.0	14.50	268.0	260.0	8.0	15.10	2.44	279.11	681.18
36	2917.0	10.00	195.0	187.0	8.0	14.96	2.47	291.70	720.50
37	923.0	5.00	90.0	85.0	5.0	10.26	3.61	184.60	666.41
38	999.0	3.00	53.0	48.0	5.0	18.85	1.96	330.00	652.68
39	2642.0	9.00	140.0	132.0	8.0	18.87	1.96	294.33	567.89
40	1638.0	5.00	90.0	80.0	10.0	18.20	2.03	327.60	665.03
AV	-	-	-	-	-	-	2.54	-	619.64

Table 8. Application Efficiencies on Unleveled Fields

Date	Moisture Deficiency (inches)	Methods to Determine M Deficiency	Amt. Water Applied Ac - In/Ac	Application Efficiency (percent)	Required Efficiency (percent)	Remarks
22 Dec 75	0.63	Oven Dry	2.33	27.04	-	Wheat Crop
25 Jan 76	1.13	Oven Dry	2.19	51.60	-	Wheat Crop
8 Feb 76	0.7	Pan	2.25	31.11	-	Wheat Crop
25 Feb 76	0.6	Feel	3.65	16.44	-	Oats Fodder
29 Feb 76	1.57	Pan	2.56	61.17	-	Wheat Crop
7 Mar 76	0.84	Pan	2.22	37.84	-	Wheat Crop
9 Mar 76	0.8	Feel	2.86	27.95	-	Oats Fodder
9 Mar 76	0.8	Feel	1.95	41.03	-	Oats Fodder
9 Mar 76	0.9	Feel	3.0	29.95	-	Oats Fodder
9 Mar 76	0.6	Feel	2.63	22.80	-	Oats Fodder
9 Mar 76	0.5	Feel	2.5	25.0	-	Oats Fodder
10 Mar 76	0.4	Feel	2.33	16.80	-	Oats Fodder
10 Mar 76	0.6	Feel	2.56	23.41	-	Oats Fodder
10 Mar 76	0.6	Feel	2.66	22.56	-	Oats Fodder
12 Mar 76	0.6	Feel	3.82	15.70	-	Oats Fodder
7 Apr 76	2.39	Pan	4.24	56.37	-	Wheat Crop
7 Apr 76	2.39	Pan	2.32	100.0	97.07	Oats Fodder
7 Apr 76	2.39	Pan	2.13	100.0	89.12	Oats Fodder
7 Apr 76	2.39	Pan	2.23	100.0	23.31	Oats Fodder
15 Apr 76	1.8	Pan	2.07	86.96	-	Oats Fodder
15 Apr 76	1.8	Pan	2.88	25.74	-	Oats Fodder
15 Apr 76	1.8	Pan	1.80	100.0	-	Oats Fodder

Table 9. Application Efficiencies on Leveled Fields

Date	Moisture Deficiency (inches)	Method for Estimation	Water Applied AC In/Ac	Application Efficiency (percent)	Required Efficiency (percent)	Remarks
13 Dec 75	2.0	ET Est	3.5	57.14	-	Wheat 1st Irr.
20 Dec 75	1.47	" "	3.0	49.00	-	" " "
22 Dec 75	1.47	Oven Dry	3.01	48.83	-	" " "
24 Jan 76	2.10	" "	3.15	66.67	-	" " "
24 Jan 76	2.01	Pan Est	3.43	58.60	-	Wheat 2nd Irr.
7 Feb 76	1.41	Pan Est	2.08	67.79	-	Wheat 3rd Irr.
7 Feb 76	3.59	ET Est	2.08	100.0	57.94	Wheat 2nd Irr.
7 Feb 76	3.59	" "	2.08	100.0	57.94	Strict Expt. Scheduling
7 Feb 76	2.87	" "	2.55	100.0	88.85	Wheat 2nd Irr.
8 Feb 76	2.81	Oven Dry	2.15	100.0	84.31	" " "
14 Feb 76	1.67	" "	1.59	100.0	95.21	" " "
21 Feb 76	1.39	ET Est	2.06	67.48	-	Wheat 4th Irr.
26 Feb 76	1.10	Feel	1.75	62.82	-	Strict Schedule
26 Feb 76	1.10	Feel	1.80	61.01	-	Wheat Crop
26 Feb 76	1.2	Feel	1.59	75.47	-	" "
28 Feb 76	1.51	Oven Dry (gravity)	2.25	67.11	-	Wheat 3rd Irr.
28 Feb 76	2.08	ET Est	1.93	100.00	92.79	Wheat 3rd Irr.
28 Feb 76	1.70	Pan Est	1.82	93.41	-	" " "
29 Feb 76	2.08	Oven Dry (gravity)	1.80	100.00	86.54	Wheat 3rd Irr.
5 Mar 76	1.60	Pan Est	1.85	86.49	-	Wheat 5th Irr.
27 Mar 76	3.45	ET Est	2.6	100.00	75.36	Wheat 4th Irr.
27 Mar 76	2.72	Pan Est	2.6	100.00	95.59	Wheat 6th Irr.
29 Mar 76	3.69	ET Est	2.7	100.00	73.17	Wheat 4th Irr.
29 Mar 76	3.69	Oven Dry (gravity)	2.40	100.00	65.04	Wheat 4th Irr.

Table 10. Weighted Average Delivery Efficiency of Four Branch System of Kanjra Watercourse

---

(a) Before Improvement Case

Branch "A"	68.8%
Branch "B"	68.3%
Branch "C"	76.2%
Branch "D"	55.3%

Delivery efficiency of "System" on the basis of the hours/week, the water flows in each four branches of watercourse:

$$aEd_s = \frac{68.8 \times 56 + 68.3 \times 38 + 76.3 \times 68 + 55.3 \times 6}{168} = 71.2\%$$

(b) After Improvement Case

Branch "A"	94.6%
Branch "B"	81.7%
Branch "C"	86.1%
Branch "D"	94.8%

$$aEd_s = \frac{94.6 \times 56 + 81.7 \times 38 + 86.1 \times 68 + 94.8 \times 6}{168} = 88.3\%$$

Table 11. Benefit-Cost Ratio Calculations for Kanjra Watercourse Improvements

(a) Initial Cost

		Amount
Initial cost of Branch A @ Rs. 0.81/ft length 4000	Rs.	3,240.00
Initial cost of Branch B @ Rs. 0.48/ft length 4000		1,920.00
Initial cost of Branch C @ Rs. 0.04/ft length 4000		160.00
Initial cost of Branch D @ Rs. 1.13/ft length 1600		1,875.80
Total Initial Cost - Rs.		7,195.00

(b) Annual Costs

Maintenance - 1 person @ 250/month	Rs.	3,000.00
Cleaning (2 times each year) @ 0.04/ft		1,088.00
Replacement of Structures - 4/year @ Rs. 115.21/structure		460.84
Total Annual Cost - Rs.		4,549.84

(c) Present Value of Cost

	Interest Rate		
Life	10%	12%	15%
5 Years	24440.45	23594.37	22443.51
10 Years	35143.87	32896.75	30026.43

(d) Annual Water Savings Benefits

Kanjra Watercourse System Delivery Efficiency Before Improvement Case - See Table 10, item a. 71.20%

Kanjra Watercourse System Delivery Efficiency After Improvement Case - See Table 10, item b. 88.27%

Water Savings/Year in AF
325 days of canal supply/year @ average discharge 2.95 cusecs =

$$2.95 \times \frac{(88.27 - 71.20)}{100} \times \frac{24 \times 325}{12} = 327.32 \text{ AF}$$

Table 11. Benefit-Cost Ratio Calculations for Kanjra Watercourse Improvements (continued)

(e) Present Worth of Annual Benefits

Price of Water AF	Total	Life Years	10%	12%	15%
Rs. 40-50 (45)/AF	14729.40	5	55839.16	53099.49	49372.95
		10	90497.43	83221.11	73926.86
Rs. 80/AF	26185.60	5	99269.61	94399.09	87774.13
		10	160884.33	147948.64	131425.53
Rs. 100/AF	32732.00	5	124087.01	117998.36	109717.66
		10	201105.41	184935.80	164281.91
Rs. 200/AF	65464.00	5	248174.02	235997.72	219435.33
		10	402210.82	369871.60	328563.82

(f) Cost Benefit Rations

Price/AF	Life "n" Years	10%	12%	15%
a. Rs. 40-50 (55)	5	2.28	2.25	2.20
	10	2.57	2.53	2.46
b. Rs. 80-0	5	4.06	4.00	3.91
	10	4.58	4.50	4.32
c. Rs. 100.0	5	5.08	5.00	4.89
	10	5.72	5.62	5.47
d. Rs. 200.0	5	10.15	10.00	9.78
	10	11.94	11.24	10.94

* (a) Tubewell waters costs Rs. 40-50 per AF

** (b) Rs. 80.0 per AF at nakka across the year

* (c) Rs. 100.0 per AF, current cost for SCARP water at the nakka

*** (d) Rs. 200.0 per AF

* Ch. Moh'd Hussain, Ch. Barkat Ali and Sam Johnson. "Private Tubewells in SCARP II Water Costs and Utilization." Forthcoming WAPDA Mona Reclamation Project (Report 1976).

** Carl A. Gotsch et al. "Linear Programming and Agricultural Policy" Micro Study of the Pakistan Punjab, Food Research Institute, ____________, Vol. XIV, No. 1, 1975 (Stanford, Calif.)

*** According to Indus Special Study Report (155)

Table 12. Average Overall Irrigation Efficiency for Kanjra Watercourse

---

<u>Before Improvement</u>

Average Ed_S = 71.20

Average Ea on unleveled fields = 49.52

Overall average irrigation effficiency

$$Eo = Ea \times Ed = 71.20 \times 49.52 = 35.26$$

<u>After Improvement</u>

Average Ed_S = 88.27

Average Ea on leveled fields = 81.35%

Overall average irrigation efficiency

$$Eo = Ea \times Ed = 88.27 \times 81.35 = 71.81\%$$

FIGURES

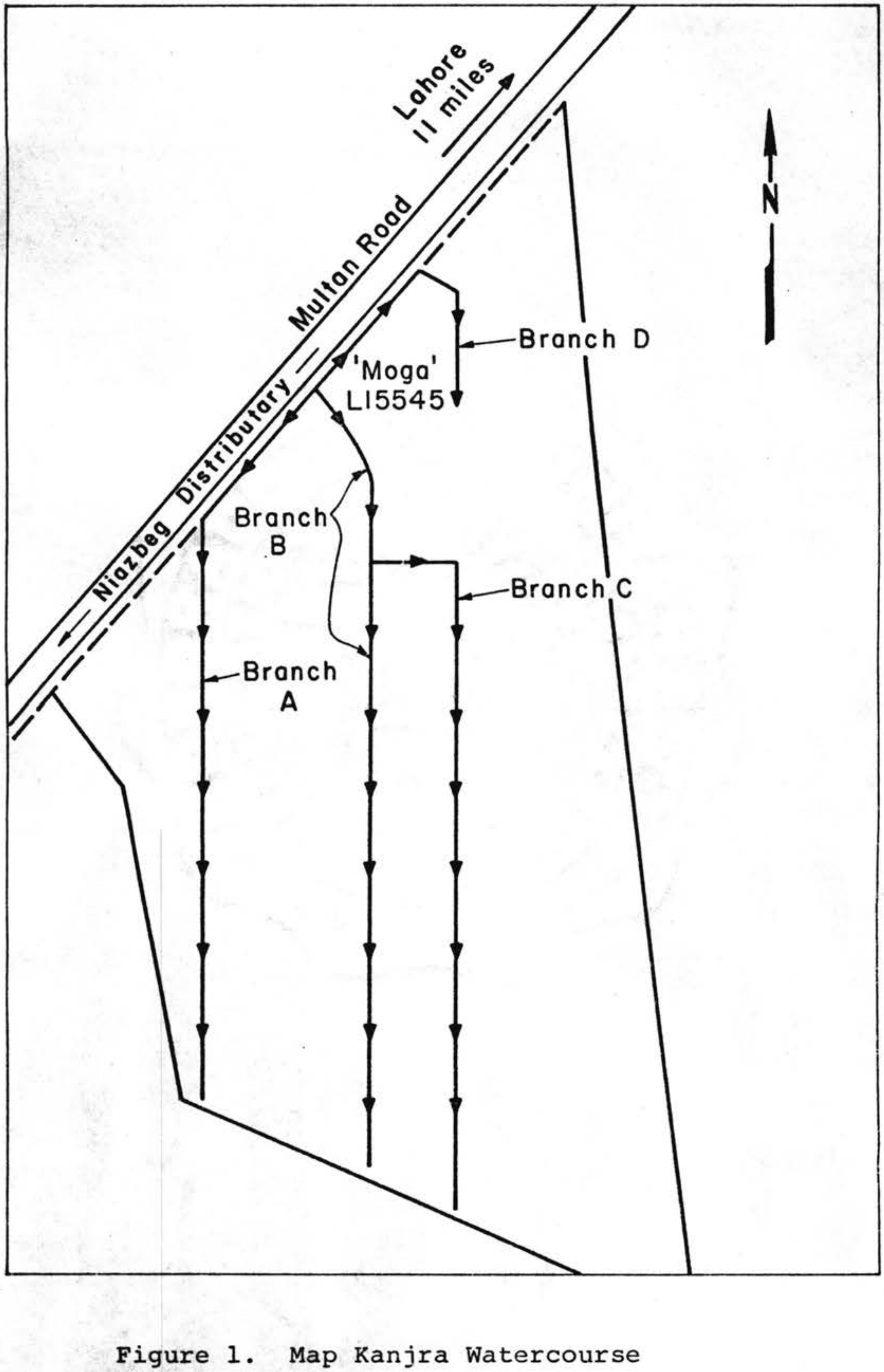


Figure 1. Map Kanjra Watercourse

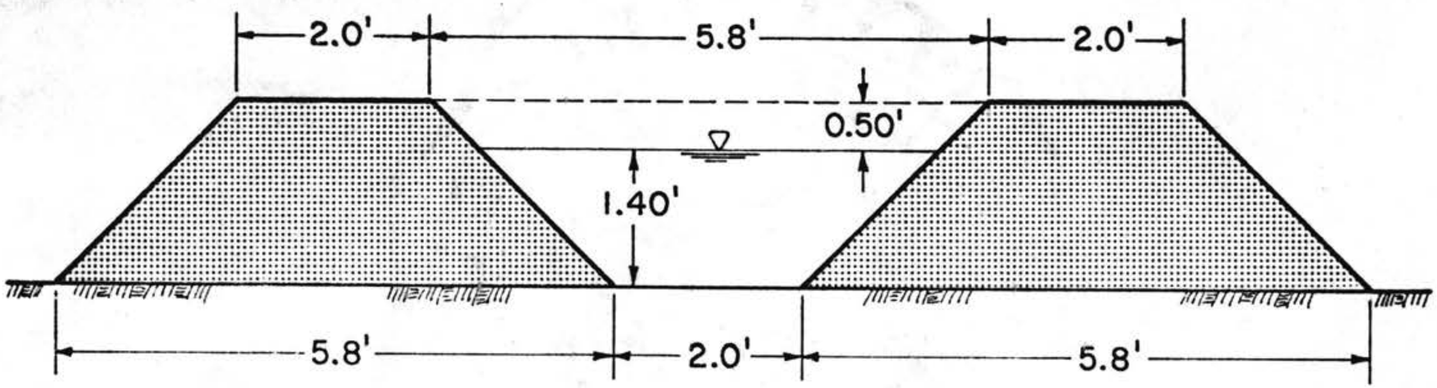


Figure 2. Designed Cross Section for Branch A

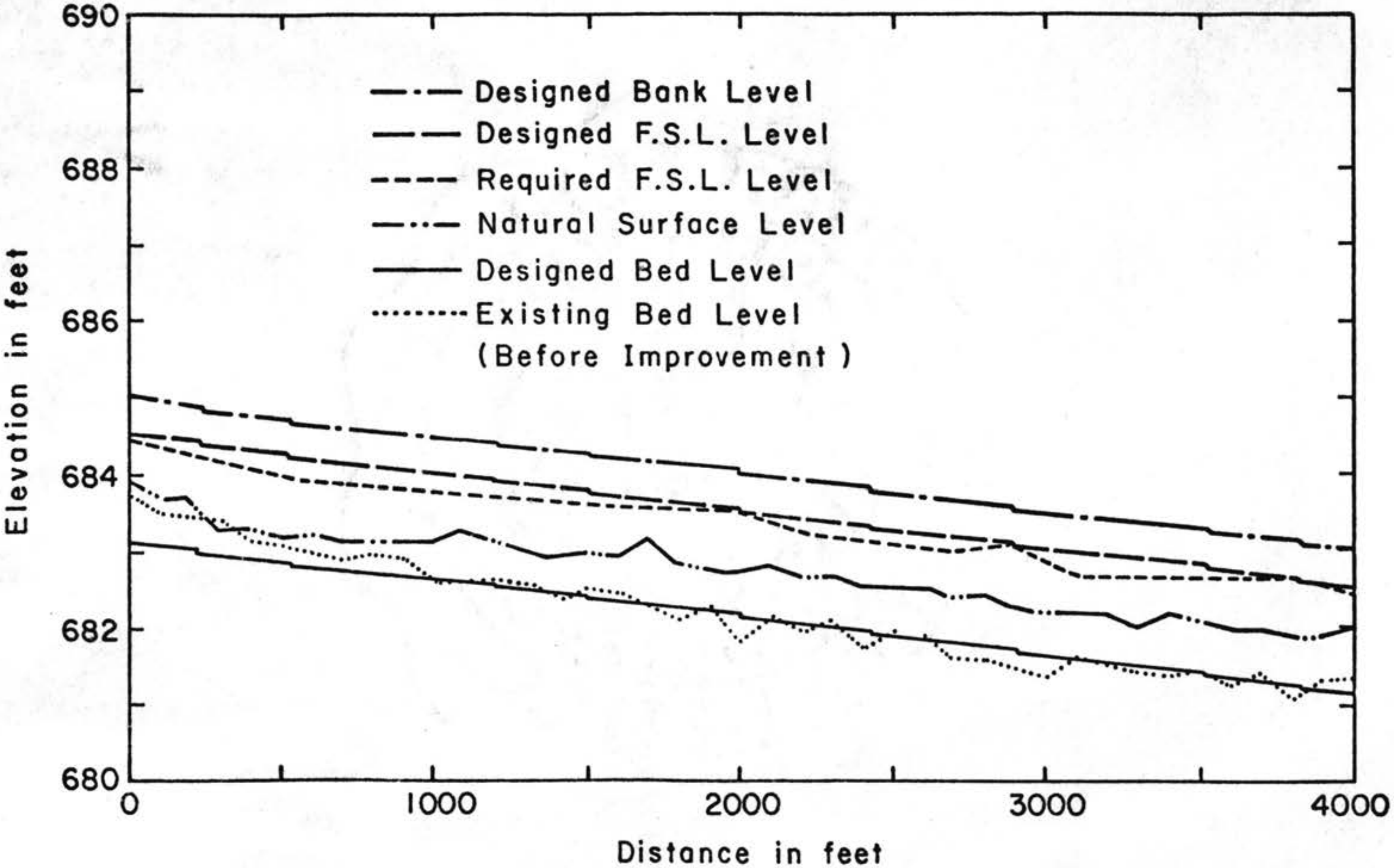
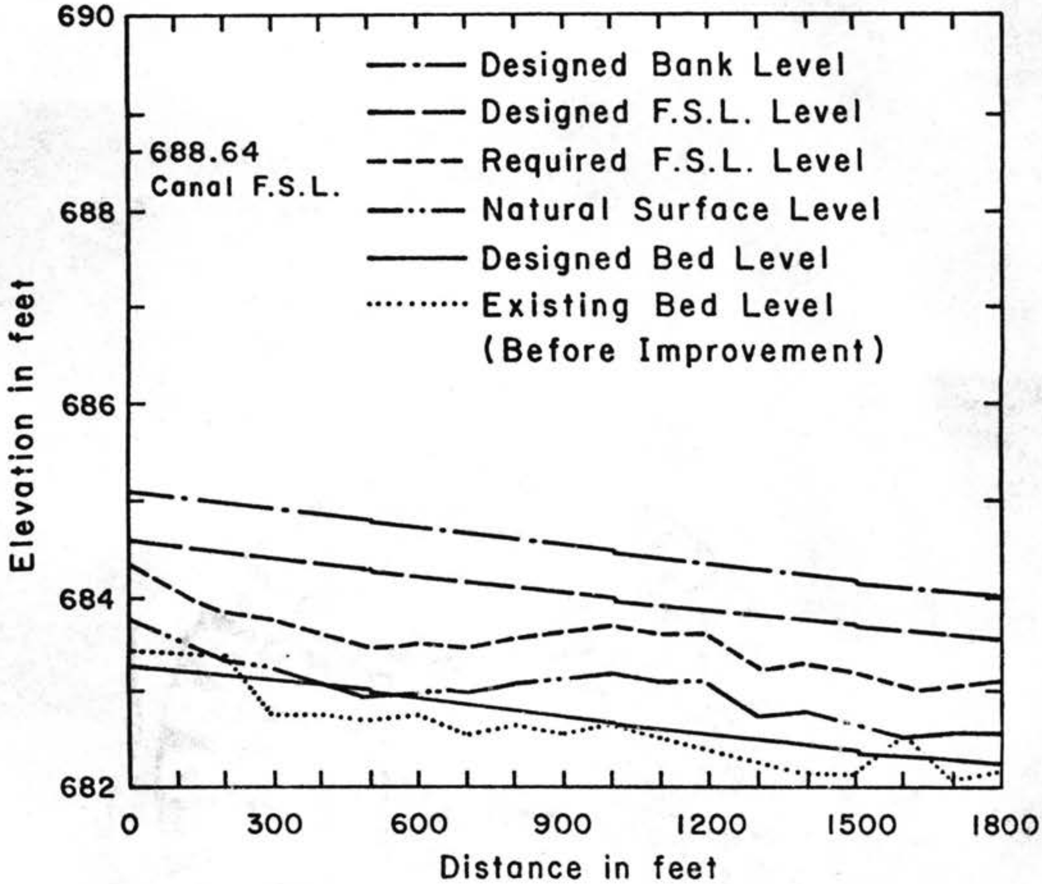
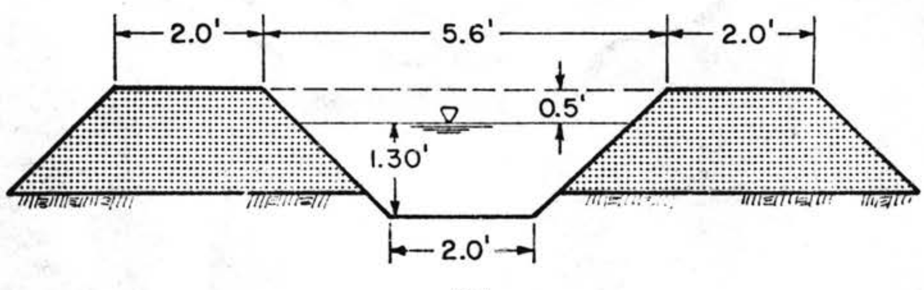


Figure 3. Kanjra Watercourse Branch A Profile Before and After Design



(a)



(b)

Figure 4. Kanjra Watercourse Branch D: (a) Watercourse Profile Before and After Design; (b) Cross Section of Watercourse

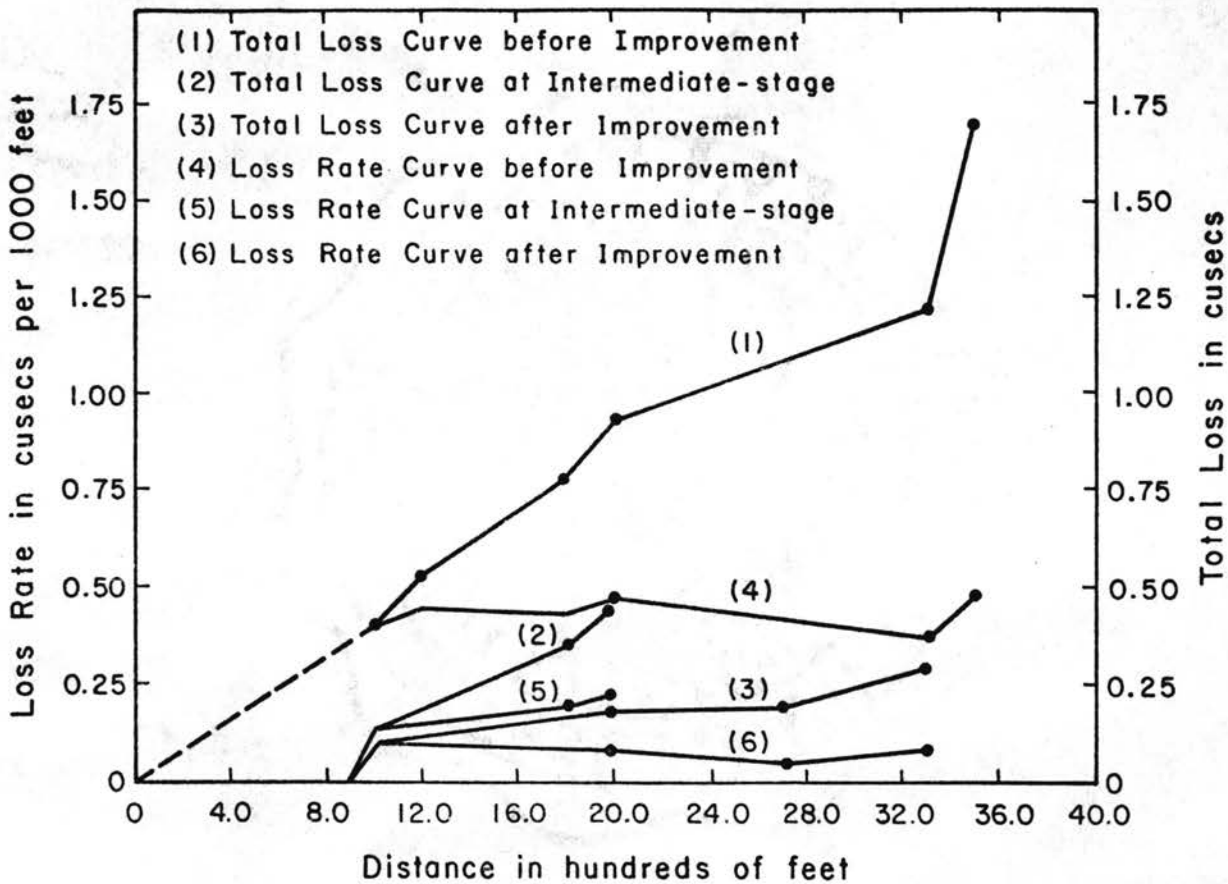


Figure 5. Total Loss and Loss Rate Comparison at Before, Intermediate and After Improvement Stage for Kanjra Watercourse Branch A

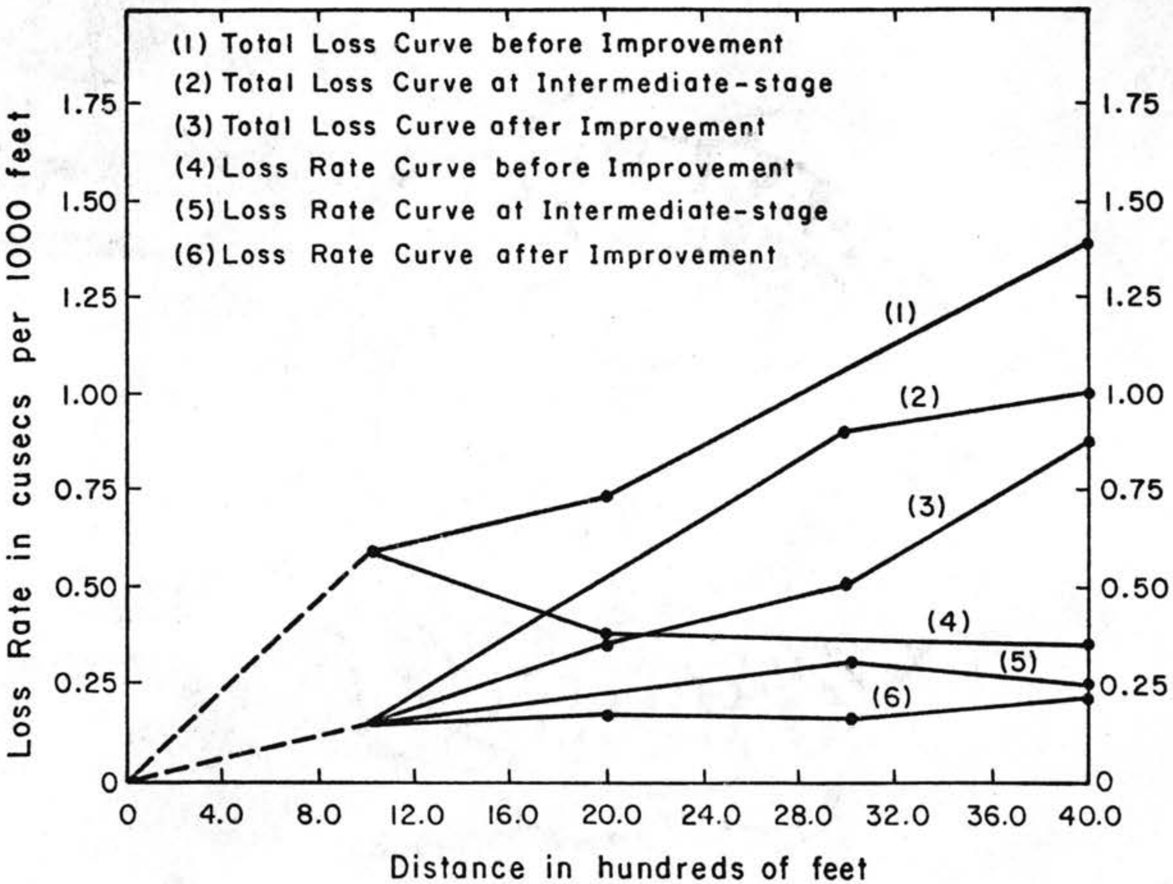


Figure 6. Total Loss and Loss Rate Comparison at Before, Intermediate and After Improvement Stage for Kanjra Watercourse Branch B

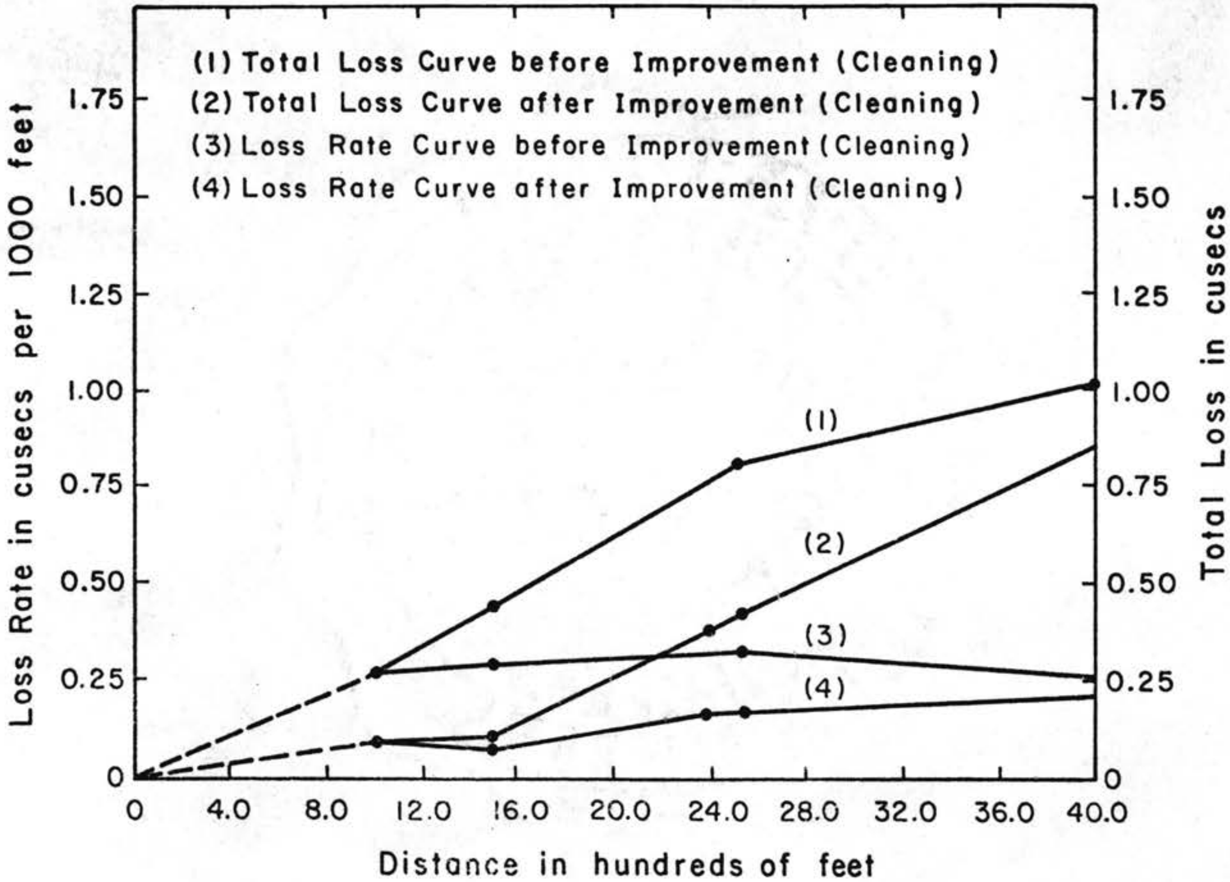


Figure 7. Total Loss and Loss Rate Comparison at Before and After Cleaning for Kanjra Watercourse Branch C

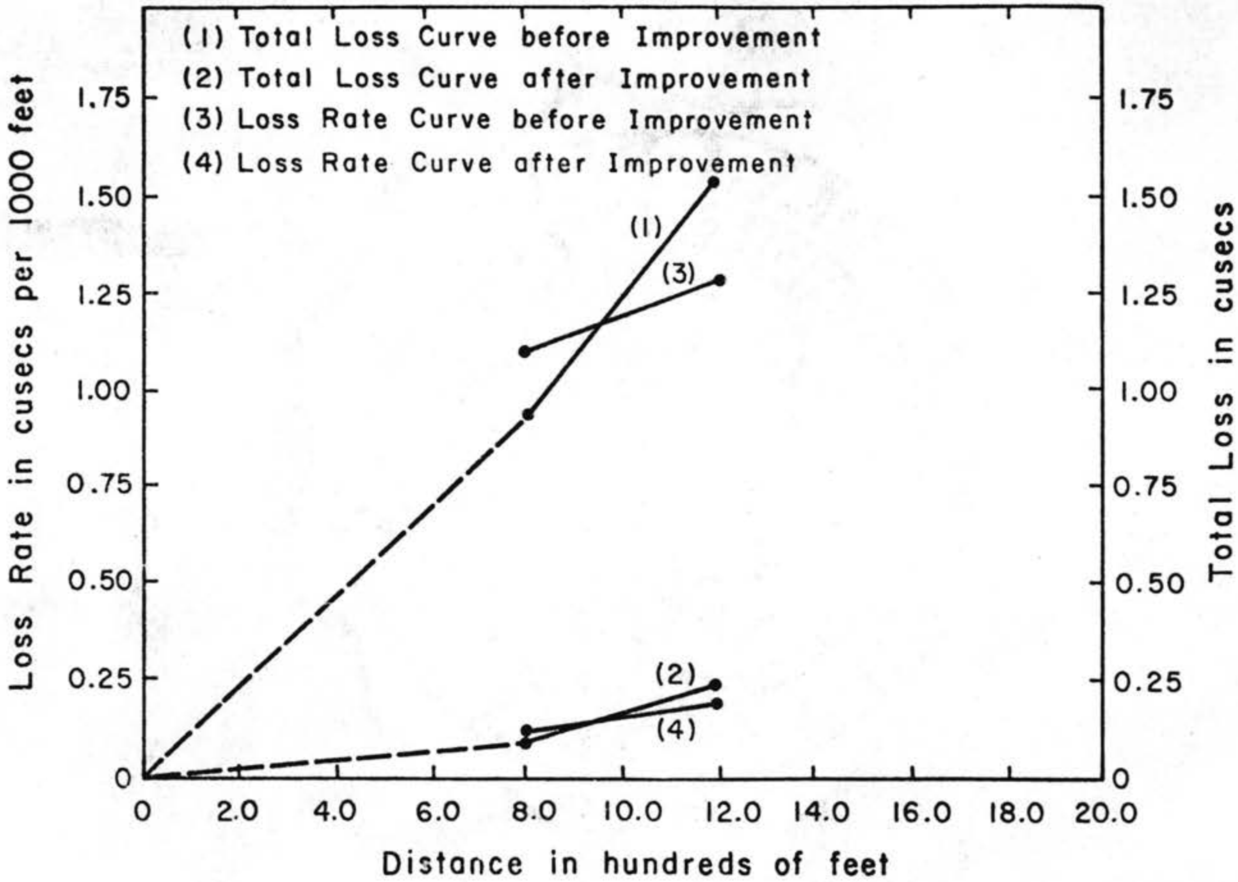


Figure 8. Total Loss and Loss Rate Comparison at Before and After Improvement Stages for Kanjra Watercourse Branch D

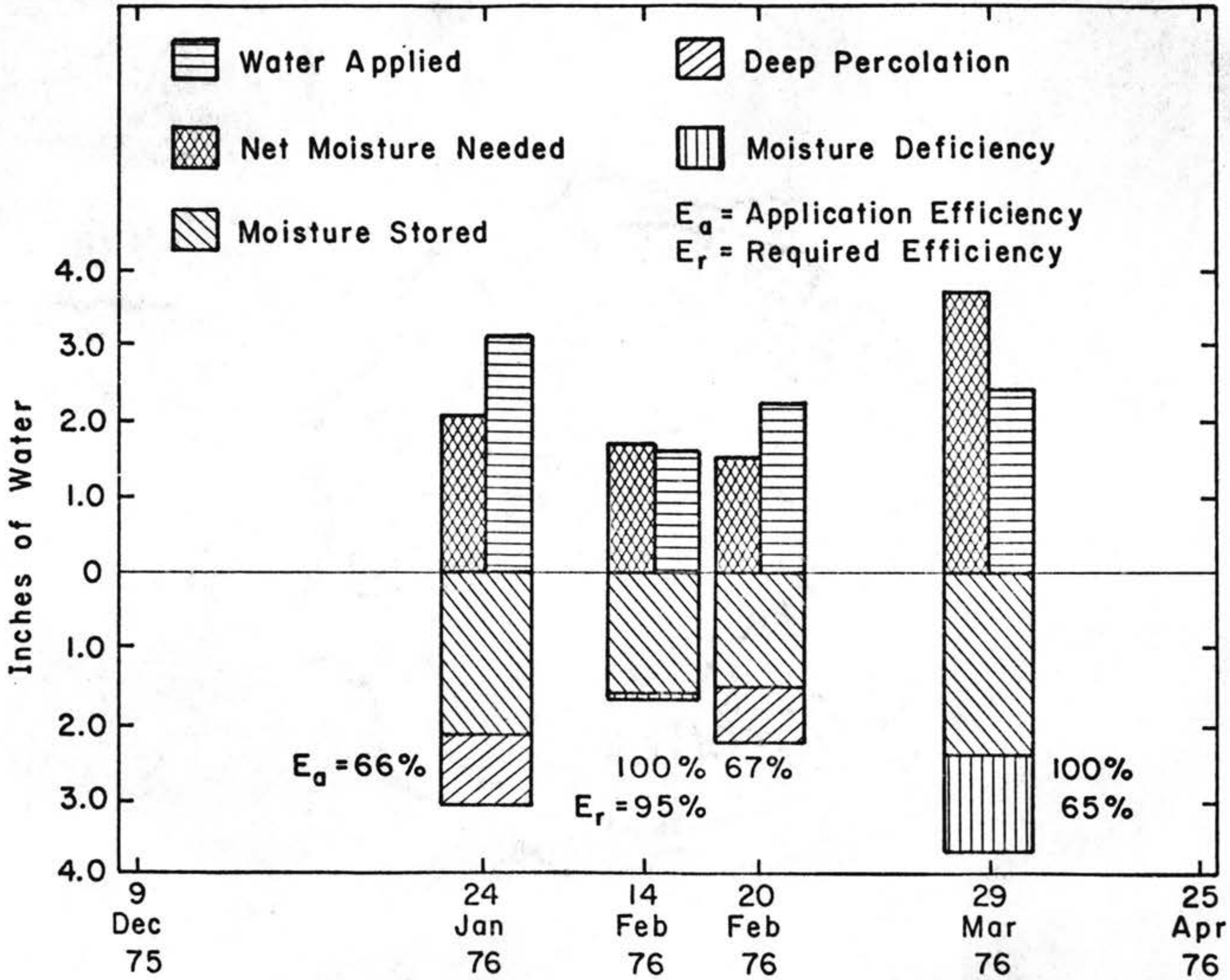


Figure 9. Seasonal Application Efficiencies on Leveled Wheat Field (1)

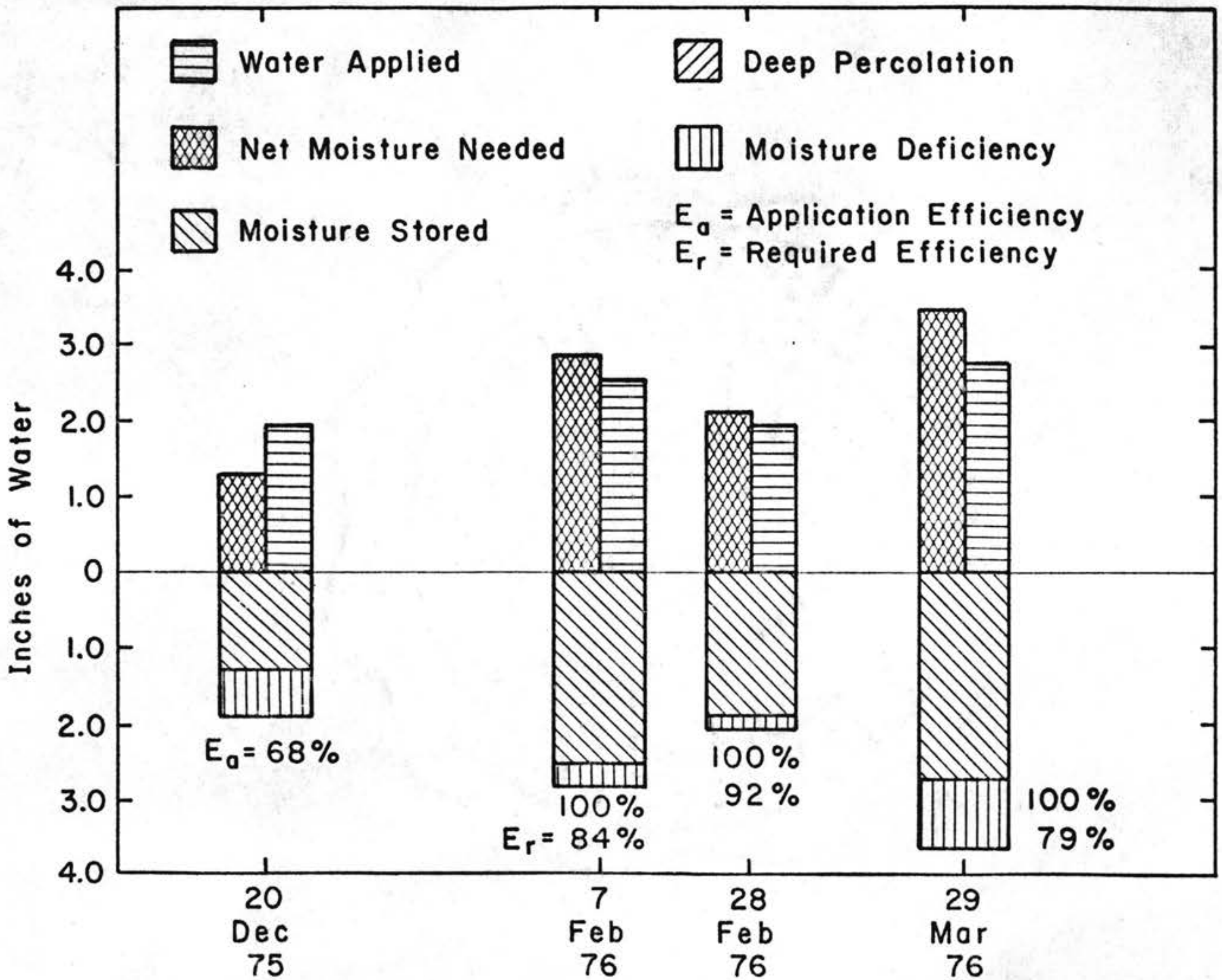


Figure 10. Seasonal Application Efficiencies on Leveled Wheat Field (2)

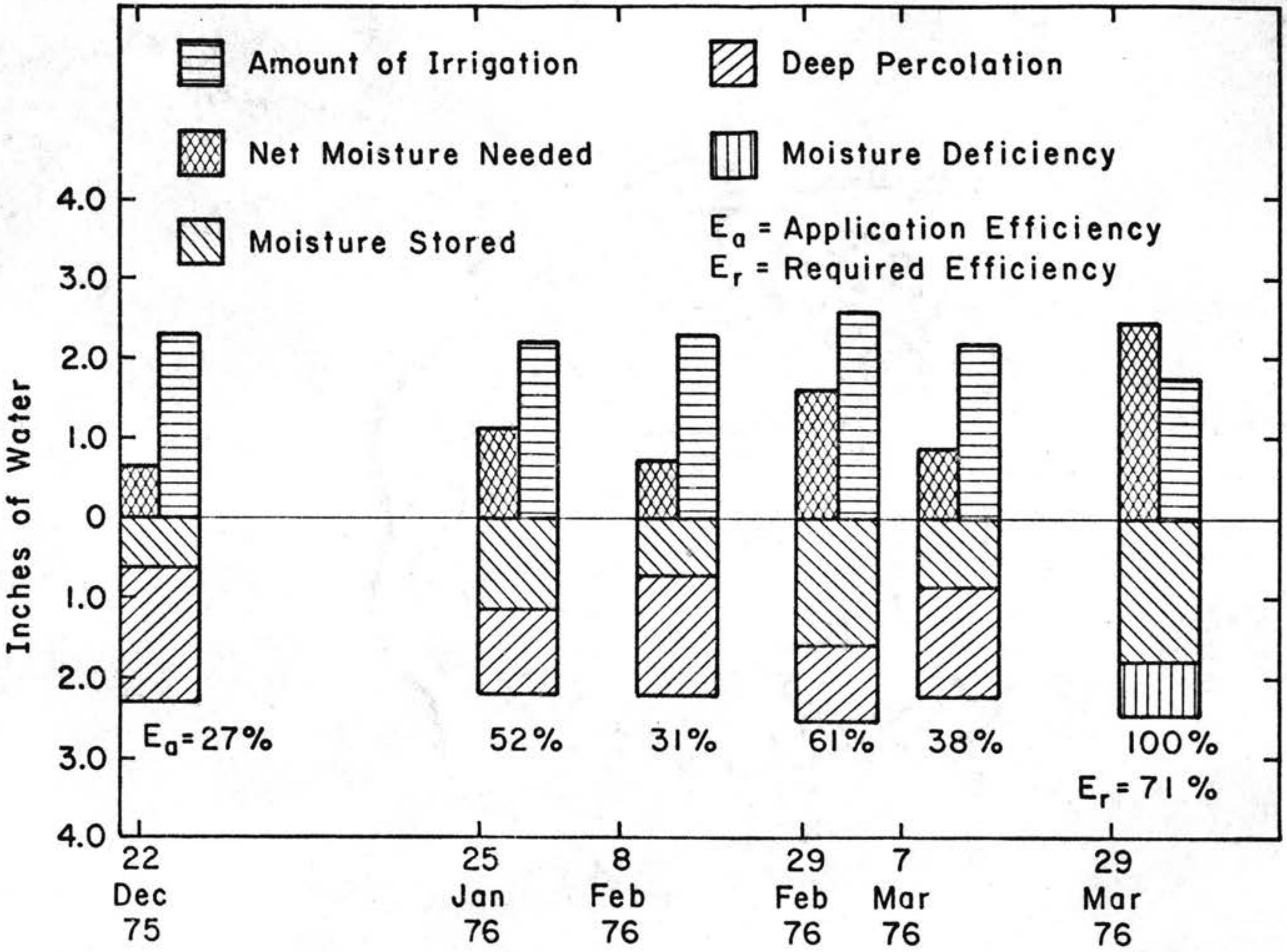


Figure 11. Seasonal Application Efficiencies on Unleveled Wheat Fields

APPENDIX

Table 1A. "BEFORE IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch A

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
24 Nov 75	3.10	2.85	91.94	1000.0	0.25	8.06
24 Nov 75	3.10	2.85	91.94	1000.0	0.25	8.06
24 Nov 75	3.10	2.80	90.32	1000.0	0.30	9.68
24 Nov 75	3.10	2.80	90.32	1000.0	0.30	9.68
24 Nov 75	3.10	2.75	88.71	1000.0	0.35	11.29
24 Nov 75	3.10	2.75	88.71	1000.0	0.35	11.29
28 Nov 75	3.00	2.00	66.67	1000.0	1.00	33.33
29 Nov 75	2.89	2.10	72.66	1000.0	0.66	22.78
29 Nov 75	2.89	1.70	58.82	1200.0	0.99	34.32
29 Nov 75	2.89	1.52	52.60	2000.0	0.69	23.70
29 Nov 75	2.89	2.60	89.97	1200.0	0.24	8.36
29 Nov 75	2.89	2.55	88.24	1200.0	0.28	9.90
29 Nov 75	2.89	2.55	88.24	1200.0	0.28	9.80
13 Dec 75	2.83	2.20	77.74	1800.0	0.35	12.37
13 Dec 75	2.83	2.40	84.81	1800.0	0.24	8.34
13 Dec 75	2.83	2.40	84.81	1800.0	0.24	8.34
13 Dec 75	2.83	2.28	80.57	1800.0	0.31	10.79
13 Dec 75	2.83	2.45	86.57	1800.0	0.21	7.46
13 Dec 75	2.83	2.35	83.04	1800.0	0.27	9.42
13 Dec 75	2.83	2.35	83.04	1800.0	0.27	9.42
13 Dec 75	2.83	2.05	72.44	1800.0	0.43	15.31
13 Dec 75	2.83	2.25	79.51	1800.0	0.32	11.38
13 Dec 75	2.83	1.16	40.99	1800.0	0.93	32.78
13 Dec 75	2.83	0.63	22.26	1800.0	1.22	43.19
20 Dec 75	2.80	1.90	67.86	1200.0	0.75	26.78
20 Dec 75	2.80	2.00	71.43	1200.0	0.67	23.80
20 Dec 75	2.80	2.35	83.93	1200.0	0.38	13.39
20 Dec 75	2.80	2.50	89.29	1200.0	0.25	8.93
20 Dec 75	2.80	2.35	83.93	1200.0	0.38	13.39
20 Dec 75	2.80	2.50	89.29	1200.0	0.25	8.93
20 Dec 75	2.80	2.45	87.50	1200.0	0.29	10.42
20 Dec 75	2.80	1.95	69.64	2000.0	0.43	15.18
20 Dec 75	2.80	2.03	72.50	2000.0	0.39	13.75
20 Dec 75	2.80	2.03	72.50	2000.0	0.39	13.75
20 Dec 75	2.80	1.90	67.86	2000.0	0.45	16.06
22 Dec 75	2.94	1.38	46.94	3300.0	0.47	16.08
22 Dec 75	2.94	1.60	54.42	3300.0	0.41	13.81
22 Dec 75	2.94	1.83	62.24	3300.0	0.34	11.44
22 Dec 75	2.94	1.83	62.24	3300.0	0.34	11.44
22 Dec 75	2.94	2.00	68.03	3300.0	0.28	9.69
22 Dec 75	2.94	0.92	31.29	3500.0	0.58	19.63
22 Dec 75	2.94	1.53	52.04	3500.0	0.40	13.70

Table 2A. "INTERMEDIATE IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch A (effect of 880 feet of watercourse renovation and installation of a diversion box near outlet)

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
24 Jan 76	2.86	2.70	94.41	1800.0	0.09	3.11
24 Jan 76	2.86	2.70	94.41	1800.0	0.09	3.11
7 Feb 76	2.95	2.65	89.83	1800.0	0.17	5.59
7 Feb 76	2.95	2.75	93.22	1800.0	0.11	3.77
7 Feb 76	2.95	2.70	91.53	1800.0	0.14	4.71
7 Feb 76	2.95	2.60	88.14	1800.0	0.19	6.59
7 Feb 76	2.95	2.80	94.92	1800.0	0.08	2.82
7 Feb 76	2.95	2.70	91.53	1800.0	0.14	4.71
7 Feb 76	2.95	2.70	91.53	1800.0	0.14	4.71
7 Feb 76	2.95	1.90	64.41	2000.0	0.53	17.80
7 Feb 76	2.95	2.80	94.91	2000.0	0.08	2.55
7 Feb 76	2.95	2.80	94.91	2000.0	0.08	2.55
21 Feb 76	2.97	2.90	97.64	1000.0	0.07	2.36
21 Feb 76	2.97	2.90	97.64	1000.0	0.07	2.36
21 Feb 76	2.97	2.95	99.33	1000.0	0.02	0.67
21 Feb 76	2.97	2.95	99.33	1000.0	0.02	0.62
21 Feb 76	2.97	2.95	99.33	1000.0	0.02	0.67
21 Feb 76	2.97	2.05	69.02	1800.0	0.51	17.21
21 Feb 76	2.97	2.30	77.44	1800.0	0.37	12.53
21 Feb 76	2.97	2.45	82.49	1800.0	0.29	9.73
21 Feb 76	2.97	2.50	84.18	1800.0	0.21	8.79
21 Feb 76	2.97	2.10	70.71	1800.0	0.48	16.27
21 Feb 76	2.97	2.40	80.81	1800.0	0.32	10.66
22 Feb 76	3.02	2.90	96.03	1000.0	0.12	3.97
22 Feb 76	3.02	2.95	97.68	1000.0	0.07	2.32
28 Feb 76	2.98	2.60	87.25	1800.0	0.21	7.08
28 Feb 76	2.98	2.75	92.28	1800.0	0.13	4.29
28 Feb 76	2.98	2.80	93.96	1800.0	0.10	3.36
28 Feb 76	2.98	2.60	87.25	1800.0	0.21	7.08
28 Feb 76	2.98	2.55	85.56	1800.0	0.24	8.02
29 Feb 76	2.87	2.55	88.85	1000.0	0.32	11.15
29 Feb 76	2.87	2.65	92.33	1000.0	0.22	7.67

Table 2A. "INTERMEDIATE IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch A (effect of 880 feet of watercourse renovation and installation of a diversion box near outlet) (continued)

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
29 Feb 76	2.87	2.68	93.38	1000.0	0.19	6.62
29 Feb 76	2.87	2.68	93.38	1000.0	0.19	6.62
29 Feb 76	2.87	2.65	92.22	1000.0	0.22	7.78
29 Feb 76	2.87	2.68	93.38	1000.0	0.19	6.62
5 Mar 76	2.98	2.40	80.54	1800.0	0.32	10.81
5 Mar 76	2.98	2.70	90.60	1800.0	0.16	5.22
5 Mar 76	2.98	2.90	90.60	1800.0	0.16	5.22
27 Mar 76	2.97	2.65	69.23	1800.0	0.18	5.99
27 Mar 76	2.97	2.70	90.91	1800.0	0.15	5.05
27 Mar 76	2.97	2.75	92.59	1800.0	0.12	4.11
27 Mar 76	2.97	2.60	57.54	1800.0	0.21	6.92
27 Mar 76	2.97	2.80	94.28	1800.0	0.09	3.18
27 Mar 76	2.97	2.90	97.64	1800.0	0.04	1.37
27 Mar 76	2.97	2.65	89.23	1800.0	0.18	5.99
27 Mar 76	2.97	2.60	87.54	1800.0	0.21	6.92
27 Mar 76	2.97	2.60	87.54	1800.0	0.21	6.92
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0

Table 3A. "AFTER IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch A

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
12 Apr 76	3.00	3.00	100.00	900.0	0.0	0.0
11 July 76	3.05	2.75	90.16	3300.0	0.09	2.98
11 July 76	3.05	2.76	90.16	3300.0	0.09	2.98
11 July 76	3.05	2.70	88.52	3300.0	0.11	3.48
11 July 76	3.05	2.75	98.16	3300.0	0.07	2.98
11 July 76	3.05	2.95	96.72	2700.0	0.04	1.40
11 July 76	3.05	2.95	96.72	2700.0	0.04	1.40
11 July 76	3.05	2.90	95.08	2700.0	0.06	1.82
11 July 76	3.05	2.90	95.08	2700.0	0.06	1.82
18 July 76	3.04	2.95	97.04	1000.0	0.09	2.96
18 July 76	2.95	2.85	96.61	1000.0	0.10	3.39
18 July 76	2.95	2.85	96.61	1000.0	0.10	3.39
18 July 76	2.95	2.85	96.61	1000.0	0.10	3.39
19 July 76	3.04	2.86	94.08	2000.0	0.09	2.96
19 July 76	3.04	2.86	94.08	2000.0	0.09	2.96
19 July 76	3.04	2.86	94.08	2000.0	0.09	2.96

Table 4A. "BEFORE IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch B

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
25 Nov 75	2.95	2.30	77.70	1000.0	0.66	22.30
25 Nov 75	2.95	2.30	77.70	1000.0	0.66	22.30
26 Nov 75	3.02	2.25	74.50	1000.0	0.77	25.50
26 Nov 75	3.02	2.30	76.16	1000.0	0.72	23.84
27 Nov 75	2.83	2.45	86.57	1000.0	0.38	13.43
27 Nov 75	2.83	2.45	86.57	1000.0	0.38	13.43
27 Nov 75	2.83	1.85	65.37	1000.0	0.98	34.63
27 Nov 75	2.83	1.85	65.37	1000.0	0.98	34.63
27 Nov 75	2.83	1.80	63.60	1000.0	1.03	35.40
27 Nov 75	2.83	2.45	86.57	1000.0	0.38	13.43
27 Nov 75	2.83	2.45	86.57	1000.0	0.38	13.43
27 Nov 75	2.83	2.45	86.57	1000.0	0.38	13.43
27 Nov 75	2.83	2.40	84.81	1000.0	0.43	15.19
27 Nov 75	2.83	2.50	88.34	1000.0	0.33	11.66
3 Dec 75	2.94	2.40	81.63	1000.0	0.54	18.37
3 Dec 75	2.94	2.60	88.44	1000.0	0.34	11.56
3 Dec 75	2.94	2.45	83.33	1000.0	0.49	16.67
3 Dec 75	2.94	2.40	81.63	1000.0	0.54	18.37
3 Dec 75	2.94	2.40	81.63	1000.0	0.54	18.32
3 Dec 75	2.94	2.45	83.33	1000.0	0.49	16.67
4 Dec 75	2.96	2.15	72.64	2000.0	0.41	13.68
4 Dec 75	2.96	2.20	74.32	2000.0	0.38	12.84
4 Dec 75	2.96	2.30	77.70	2000.0	0.33	11.15
4 Dec 75	2.96	2.20	74.32	2000.0	0.38	12.84
4 Dec 75	2.96	2.25	76.01	2000.0	0.36	12.00
4 Dec 75	2.96	2.30	77.70	2000.0	0.33	11.15
12 Dec 75	2.83	1.50	53.00	4000.0	0.33	11.75
12 Dec 75	2.83	1.40	49.47	4000.0	0.36	12.63
12 Dec 75	2.83	1.45	51.24	4000.0	0.35	12.19
26 Dec 75	2.92	1.50	51.37	4000.0	0.36	12.16
26 Dec 75	2.92	1.60	54.79	4000.0	0.36	11.30

Table 5A. "INTERMEDIATE IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch B

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
24 Feb 76	2.94	2.70	91.84	1000.0	0.24	8.16
24 Feb 76	2.94	2.80	95.24	1000.0	0.14	4.76
24 Feb 76	2.94	2.70	91.84	1000.0	0.24	8.16
24 Feb 76	2.94	2.70	91.84	1000.0	0.24	8.16
24 Feb 76	2.94	2.70	91.84	1000.0	0.24	8.16
24 Feb 76	2.94	2.80	95.24	1000.0	0.14	4.76
9 Mar 76	2.94	2.86	97.28	1000.0	0.08	2.72
9 Mar 76	2.94	2.86	97.28	1000.0	0.08	2.72
9 Mar 76	2.94	2.86	97.28	1000.0	0.08	2.72
9 Mar 76	2.94	2.86	97.28	1000.0	0.08	2.72
9 Mar 76	2.94	2.86	97.28	1000.0	0.08	2.72
10 Mar 76	2.99	2.91	97.32	1000.0	0.08	2.68
10 Mar 76	2.99	2.91	97.32	1000.0	0.08	2.68
12 Mar 76	2.98	1.85	62.08	4000.0	0.28	9.48
12 Mar 76	2.98	2.20	73.83	4000.0	0.20	6.54
15 Apr 76	3.05	1.88	61.64	3000.0	0.39	12.79
15 Apr 76	3.05	2.05	67.13	3000.0	0.33	10.96
15 Apr 76	3.05	2.33	76.39	3000.0	0.24	7.87
15 Apr 76	3.05	2.08	68.20	3000.0	0.32	10.60
15 Apr 76	3.05	1.05	61.64	3000.0	0.37	12.79
15 Apr 76	3.05	2.10	68.85	3000.0	0.32	10.38
15 Apr 76	3.05	2.40	78.69	3000.0	0.22	7.10
15 Apr 76	3.05	2.50	81.97	3000.0	0.78	6.01
15 Apr 76	3.05	2.10	68.85	3000.0	0.32	10.38
15 Apr 76	3.05	1.90	62.30	4000.0	0.29	9.43
15 Apr 76	3.05	1.95	63.93	4000.0	0.28	9.02
15 Apr 76	3.05	2.10	68.85	4000.0	0.24	7.79
15 Apr 76	3.05	2.15	70.49	4000.0	0.23	7.38

Table 6A. "AFTER IMPROVEMENT CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch B

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
18 June 76	2.85	2.50	87.72	2000.0	0.18	6.14
18 June 76	2.85	2.55	89.47	2000.0	0.15	5.27
18 June 76	2.85	2.50	87.72	2000.0	0.18	6.14
7 July 76	3.00	2.70	90.00	1000.0	0.36	10.00
7 July 76	3.00	2.80	93.33	1000.0	0.20	6.67
7 July 76	3.00	2.85	95.00	1000.0	0.15	5.00
7 July 76	3.00	2.90	96.67	1000.0	0.10	3.33
7 July 76	3.00	2.90	96.67	1000.0	0.10	3.33
7 July 76	3.00	2.70	90.00	1000.0	0.30	10.00
7 July 76	3.00	2.85	95.00	1000.0	0.15	5.00
7 July 76	3.00	2.95	96.67	1000.0	0.10	3.33
7 July 76	3.00	2.90	96.67	1000.0	0.10	3.33
8 July 76	3.04	2.60	85.53	2000.0	0.22	7.24
8 July 76	3.04	2.70	88.82	2000.0	0.17	5.54
8 July 76	3.04	2.75	90.46	2000.0	0.16	4.77
8 July 76	3.04	2.25	74.01	3000.0	0.26	8.67
8 July 76	3.04	2.40	78.95	3000.0	0.27	7.02
8 July 76	3.04	2.35	77.30	3000.0	0.23	7.57
8 July 76	3.04	2.30	75.66	3000.0	0.25	8.11
8 July 76	3.04	1.90	62.50	4000.0	0.29	9.38
8 July 76	3.04	2.15	70.72	4000.0	0.22	7.32
8 July 76	3.04	1.90	62.66	4000.0	0.29	9.38
8 July 76	3.04	2.15	70.72	4000.0	0.22	7.32
13 July 76	3.00	2.90	96.67	1000.0	0.15	3.33
13 July 76	3.00	2.90	96.67	1000.0	0.10	3.33
13 July 76	3.00	2.90	96.67	1000.0	0.10	3.33
14 July 76	3.00	2.35	98.33	1000.0	0.05	1.67
14 July 76	3.00	2.95	98.33	1000.0	0.05	1.67
14 July 76	3.00	2.95	98.33	1000.0	0.05	1.67
16 July 76	3.04	2.80	92.11	3000.0	0.08	3.95
16 July 76	3.04	2.90	95.39	3000.0	0.05	1.54
16 July 76	3.04	2.96	95.39	3000.0	0.05	1.54
16 July 76	3.04	2.30	75.66	4000.0	0.19	6.09
16 July 76	3.04	2.30	75.66	4000.0	0.19	6.09
16 July 76	3.04	2.30	75.66	4000.0	0.19	6.09
16 July 76	3.04	2.30	75.66	4000.0	0.19	6.09

Table 7A. "BEFORE CLEANING CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch C

	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % Per 1000.0
24 Feb 76	*2.75	2.30	83.64	1000.0 (M-2000)	0.45	16.36
24 Feb 76	2.75	2.55	92.73	1000.0	0.20	7.27
24 Feb 76	2.75	2.60	94.55	1000.0	0.15	5.45
24 Feb 76	2.75	2.40	87.27	1000.0	0.35	12.73
24 Feb 76	2.75	2.60	94.55	1000.0	0.15	5.45
24 Feb 76	2.75	2.60	94.55	1000.0	0.15	5.45
24 Feb 76	2.75	2.60	94.55	1000.0	0.15	5.45
9 Mar 76	2.86	2.35	82.17	1000.0 (M-2000)	0.51	17.83
9 Mar 76	2.86	2.50	87.41	1000.0	0.36	12.95
9 Mar 76	2.86	2.40	83.92	1000.0	0.46	16.08
9 Mar 76	2.86	2.70	94.41	1000.0	0.26	5.59
9 Mar 76	2.86	2.70	94.41	1000.0	0.26	5.59
9 Mar 76	2.86	2.20	76.92	1500.0 (M-2500)	0.44	15.39
9 Mar 76	2.86	2.35	82.17	1500.0	0.34	11.89
9 Mar 76	2.86	2.55	89.16	1500.0	0.21	7.23
9 Mar 76	2.86	2.60	90.91	1500.0	0.17	6.06
10 Mar 76	2.91	1.85	63.57	4000.0 (M-5000)	0.27	9.11
10 Mar 76	2.91	1.88	64.60	4000.0	0.26	8.85
10 Mar 76	2.91	1.95	67.01	4000.0	0.24	8.25
10 Mar 76	2.91	1.95	67.01	4000.0	0.24	8.25
10 Mar 76	2.91	1.80	61.86	4000.0	0.28	9.54
6 Apr 76	2.93	2.40	81.91	1000.0 (M-2000)	0.53	18.09
6 Apr 76	2.93	2.60	88.74	1000.0	0.33	11.26
6 Apr 76	2.93	2.70	92.15	1000.0 (M-2000)	0.23	7.85
6 Apr 76	2.93	2.70	92.15	1000.0	0.23	7.85
6 Apr 76	2.93	2.70	92.15	1000.0	0.23	7.85
6 Apr 76	2.93	2.80	95.56	1000.0	0.13	4.44
6 Apr 76	2.93	2.80	95.56	1000.0	0.13	4.44
6 Apr 76	2.93	2.71	92.49	1000.0	0.22	7.51
6 Apr 76	2.93	2.65	90.44	1000.0	0.28	9.56
6 Apr 76	2.93	2.60	88.74	1000.0	0.33	11.26
6 Apr 76	2.93	2.55	87.03	1000.0	0.38	12.97
6 Apr 76	2.93	2.65	90.44	1000.0	0.28	9.56
6 Apr 76	2.93	2.70	92.15	1000.0	0.23	7.85
6 Apr 76	2.93	2.70	92.15	1000.0	0.23	7.85
6 Apr 76	2.93	2.81	95.90	1000.0	0.12	4.10
6 Apr 76	2.93	2.76	94.20	1000.0	0.17	5.80
7 Apr 76	2.85	1.60	56.14	2500.0	0.50	17.54

* Q = 2.70 AF 1000' from mogha which 0.0 Branch "C"

Table 7A. "BEFORE CLEANING CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch C (continued)

	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % per 1000.0
				(M-2000)		
7 Apr 76	2.85	1.80	63.16	2500.0	0.42	14.74
7 Apr 76	2.85	1.60	56.14	2500.0	0.50	17.54
7 Apr 76	2.85	1.75	61.40	2500.0	0.44	15.44
7 Apr 76	2.85	1.60	56.14	2500.0	0.50	17.54
7 Apr 76	2.85	1.70	59.65	2500.0	0.46	16.14
7 Apr 76	2.85	1.85	64.91	2500.0	0.40	14.04
7 Apr 76	2.85	1.80	63.16	2500.0	0.42	14.74
7 Apr 76	2.85	2.00	70.18	2500.0	0.34	11.93
7 Apr 76	2.85	1.90	66.67	2500.0	0.38	13.33
7 Apr 76	2.85	1.90	66.67	2500.0	0.38	13.33
7 Apr 76	2.85	1.80	63.16	2500.0	0.42	14.74
7 Apr 76	2.85	1.70	59.65	2500.0	0.46	16.14
7 Apr 76	2.85	1.60	56.14	2500.0	0.50	17.54
7 Apr 76	2.85	2.10	73.68	2500.0	0.30	10.53
7 Apr 76	2.85	2.50	87.72	2500.0	0.14	4.91
7 Apr 76	2.85	2.65	92.98	2500.0	0.08	2.81
7 Apr 76	2.85	2.65	98.25	2500.0	0.08	2.81
7 Apr 76	2.85	2.65	92.98	2500.0	0.08	2.81
7 Apr 76	2.85	2.65	98.25	2500.0	0.08	2.81
7 Apr 76	2.85	2.50	87.72	2500.0	0.14	4.91
7 Apr 76	2.85	2.50	87.72	2500.0	0.14	4.91

Table 8A. "AFTER CLEANING CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch C

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % per 1000.0
16 June 76	*2.77	2.70	97.47	1000.0	0.07	2.53
16 June 76	2.77	2.70	97.47	1000.0	0.07	2.53
				(M-3500)		
16 June 76	2.77	2.45	88.45	2500.0	0.13	4.62
16 June 76	2.77	2.30	83.03	2500.0	0.19	6.79
16 June 76	2.77	2.90	86.64	2500.0	0.15	5.34
16 June 76	2.77	2.95	88.45	2500.0	0.13	4.62
				(M-2500)		
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.96	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
22 June 76	2.90	2.80	96.55	1500.0	0.07	2.30
23 June 76	2.84	2.80	98.59	1500.0	0.03	0.94
				(M-3500)		
23 June 76	2.75	2.00	72.73	2500.0	0.30	10.91
23 June 76	2.25	2.23	81.09	2500.0	0.21	7.56
23 June 76	2.75	2.10	76.36	2500.0	0.26	9.46
23 June 76	2.75	2.18	76.36	2500.0	0.26	9.46
				(M-2500)		
7 July 76	2.95	2.80	94.92	2500.0	0.06	2.03
7 July 76	2.95	2.75	93.22	2500.0	0.08	2.71
7 July 76	2.95	2.80	94.92	2500.0	0.06	2.03
				(M-2000)		
13 July 76	2.95	2.85	96.61	1000.0	0.10	3.39
13 July 76	2.95	2.90	98.31	1000.0	0.05	1.69
13 July 76	2.95	2.90	98.31	1000.0	0.05	1.69
13 July 76	2.95	2.80	94.92	1000.0	0.15	5.08
13 July 76	2.95	2.90	98.31	1000.0	0.05	1.69
13 July 76	2.95	2.85	96.61	1000.0	0.10	3.39
				(M-2000)		
14 July 76	2.95	2.85	96.61	1000.0	0.10	3.39
14 July 76	2.95	2.90	98.31	1000.0	0.05	1.69
14 July 76	2.95	2.90	98.31	1000.0	0.05	1.69
				(M-3400)		
14 July 76	2.95	2.40	81.36	2400.0	0.23	7.77
14 July 76	2.95	2.60	88.14	2400.0	0.15	4.94

* Q = 2.70 AF 1000' from mogha which 0.0 Branch "C"

Table 8A. "AFTER CLEANING CASE" - Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch C (continued)

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses % per 1000.0
14 July 76	2.95	2.55	86.44	2400.0	0.17	5.65
14 July 76	2.95	2.40	81.36	2400.0	0.23	7.77
14 July 76	2.95	2.60	88.14	2400.0	0.15	4.94
14 July 76	2.95	2.60	88.14	2400.0	0.15	4.94
14 July 76	2.95	2.90	91.53	2400.0	0.10	3.53
14 July 76	2.95	2.68	90.85	2400.0	0.11	3.81
14 July 76	2.95	2.70	91.53	2400.0	0.10	3.53
14 July 76	2.95	2.10	71.19	4000.0	0.21	7.79
14 July 76	2.95	2.10	71.19	4000.0	0.23	7.79
14 July 76	2.95	2.10	71.19	4000.0	0.21	7.79
14 July 76	2.95	2.10	71.19	4000.0	0.21	7.79
14 July 76	2.95	2.00	67.80	4000.0	0.24	8.70

Table 9A. Delivery Efficiencies and Average Loss Rates for Kanjra Watercourse Branch D

"BEFORE IMPROVEMENT CASE"

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses per 1000.0
24 Jan 76	2.86	1.46	51.05	1200.0	1.17	40.79
24 Jan 76	2.86	1.30	45.81	1200.0	1.29	45.16
24 Jan 76	2.86	1.16	40.56	1200.0	1.12	49.53
30 Jan 76	2.88	1.90	65.97	800.0	1.23	42.54
30 Jan 76	2.88	2.10	72.92	800.0	0.98	33.85
30 Jan 76	2.88	2.00	69.92	800.0	1.10	37.60

"AFTER IMPROVEMENT CASE"

Date	Initial Flow (Cusecs)	Final Flow (Cusecs)	Delivery Efficiency Percent	Distance Feet	Losses Cusecs/ 1000.0	Losses per 1000.0
2 July 76	2.97	2.95	99.33	800.0	0.03	0.84
2 July 76	2.97	2.95	99.33	800.0	0.03	0.84
2 July 76	2.97	2.95	99.33	800.0	0.03	0.84
2 July 76	2.97	2.95	99.33	800.0	0.03	0.84
2 July 76	2.97	2.75	92.59	1200.0	0.18	6.18
2 July 76	2.97	2.75	92.59	1200.0	0.18	6.18
16 July 76	3.04	2.90	95.39	800.0	0.18	5.76
16 July 76	3.04	2.90	95.39	800.0	0.18	5.76
16 July 76	3.04	2.98	97.04	800.0	0.11	3.70
16 July 76	3.04	3.00	98.68	800.0	0.05	1.65
16 July 76	3.04	2.90	95.39	800.0	0.18	5.76
16 July 76	3.04	2.90	95.39	800.0	0.18	5.76
16 July 76	3.04	2.90	95.37	800.0	0.18	5.76
16 July 76	3.04	2.80	92.10	1200.0	0.20	6.58
16 July 76	3.04	2.80	92.10	1200.0	0.20	6.58
16 July 76	3.04	2.80	92.10	1200.0	0.20	6.58
16 July 76	3.04	2.80	92.10	1200.0	0.20	6.58
16 July 76	3.04	2.80	92.10	1200.0	0.20	6.58

Table 10A. Check and Alignment Sheet of Kanjra Watercourse Branch A

Station	Description	Bed	FSL	Bank
0+000		683.10	684.50	685.00
0+100		683.06	684.46	684.96
0+200		683.02	684.42	684.92
0+225	Culvert HL=0.06'	683.01	684.41	684.91
0+225		682.95	684.35	684.85
0+300		682.92	684.32	684.82
0+400		682.88	684.28	684.78
0+500		682.84	684.24	684.74
0+525	Check Nakka HL= 0.03'	682.83	684.23	684.73
0+525		682.80	684.20	684.70
0+600		682.77	684.17	684.67
0+700		682.73	684.13	684.63
0-800		682.69	684.09	684.59
0+900		682.65	684.05	684.55
1+000		682.61	684.01	684.51
1+100		682.57	683.97	684.47
1+200	Check Nakka HL = 0.003'	682.53	683.93	684.43
1+200		682.50	683.90	684.40
1+300		682.46	683.86	684.36
1+400		682.42	683.82	684.32
1+500	Check Nakka HL = 0.03'	682.38	683.78	684.28
1+500		682.35	683.75	684.25
1+600		682.31	683.71	684.21
1+700		682.27	683.67	684.17
1+800		682.23	683.63	684.13
1+900		682.19	683.59	684.09
2+000	Culvert 18" D HL = 0.06'	682.15	683.55	684.05

Table 10A. Check and Alignment Sheet of Kanjra Watercourse Branch A (continued)

Station	Description	Bed	FSL	Bank
2+000		682.09	683.49	683.99
2+100		682.05	683.45	683.95
2+200		682.01	683.41	683.91
2+300		681.97	683.37	683.87
2+400		681.93	683.33	683.83
2+425	Check Nakka HL = 0.03'	681.92	683.32	683.82
2+425		681.89	683.29	683.79
2+500		681.86	683.26	683.76
2+600		681.82	683.22	683.72
2+700		681.78	683.18	683.68
2+800		681.74	683.14	683.64
2+900	Culvert 18" D HL = 0.06'	681.70	683.10	683.60
2+900		681.64	683.04	683.54
3+000		681.60	683.00	683.50
3+100		681.56	682.96	683.46
3+200		681.52	682.92	683.42
3+300		681.48	682.88	683.38
3+400		681.44	682.84	683.34
3+500		681.40	682.80	683.30
3+525	Check Nakka HL = 0.03'	681.39	682.79	683.29
3+525		681.36	682.76	683.26
3+600		681.33	682.73	683.23
3+700		681.29	682.69	683.19
3+800		681.25	682.65	683.15
3+825	Check Nakka HL = 0.03'	681.24	682.64	683.14
3+825		681.21	682.61	683.11
3+900		681.18	682.58	683.08
4+000		681.14	682.54	683.04

Table 11A. Check and Alignment Sheet of Kanjra Watercourse Branch D

Station	Description	Bed	FSL	Bank
0+000		683.25	684.55	685.05
0+100		683.20	684.50	685.00
0+200		683.15	684.45	684.95
0+300		683.10	684.40	684.90
0+400		683.05	684.35	684.85
0+500		683.00	684.30	684.80
0+500		682.95	684.25	684.75
0+600		682.90	684.20	684.70
0+700		682.85	684.15	684.65
0+800		682.80	684.10	684.60
0+900		682.75	684.05	684.55
1+000		682.70	684.00	684.50
1+000		682.65	683.95	684.45
1+100		682.60	683.90	684.40
1+200		682.55	683.85	684.35
1+300		682.50	683.80	684.30
1+400		682.45	683.75	684.25
1+500		682.40	683.70	684.20
1+500		682.35	683.65	684.15
1+600		682.30	683.60	684.10
1+700		682.25	683.55	684.05
1+800		682.20	683.50	684.00