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THIRD SEMI-ANNUAL PROGRESS REPORT

1 July 1969 through 31 December 1969

for

WATER MANAGEMENT RESEARCH IN
ARID AND SUB-HUMID LANDS OF
LESS DEVELOPED COUNTRIES

CONTRACT NO.: AID/esd-2162

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INTRODUCTION

This Progress Report continues the reporting of progress as requested by AID/Washington as shown in Appendix A of the Progress Report for the first year. It includes a list of personnel, a statement of General Objectives and Specific Objectives by departments for the period of time involved, a Plan of Work, and Future Plans for each of the departments.

Appendices give the detailed Progress Reports for each of the sub-projects together with the proposed sub-projects described for the Project Agreement to be established with the various agencies of the Government of West Pakistan.

ADMINISTRATIVE PERSONNEL

Maurice L. Albertson, Project Director

TECHNICAL PERSONNEL

Department of Agricultural Engineering

Faculty: Arthur T. Corey, Project Leader
Gaylord V. Skogerboe
John A. Brookman

Graduate Research Assistants
Norman S. Illsley
Paul S. Osborne

Department of Agronomy

Faculty: Willard R. Schmehl, Project Leader
William T. Franklin

Graduate Research Assistants
Mehdi Monadjemi
James L. Puckett

Department of Civil Engineering

Faculty: Everett V. Richardson
Albert G. Mercer

Graduate Research Assistants
Della L. Langeland
Wen-Sheng Liang
Yasumi Yamaguchi
Muhammad I. Haque
Khalid Mahmood
Allah Rakha

Department of Economics

Faculty: Kenneth C. Nobe, Project Leader
Melvin D. Skold
Huntley H. Biggs

Department of Economics (cont'd)

Graduate Research Assistant
Debebe Worku

Department of Political Science

Faculty: John A. Straayer, Project Leader
Phillip O. Foss

Graduate Research Assistants
Robert F. Schmidt
Arlene G. Dwyer
Robert S. Dildine

Department of Sociology

Faculty: David M. Freeman, Project Leader
Carl W. Birky
One faculty member to be assigned

Graduate Research Assistant
Lonnie O. Trautman

GENERAL OBJECTIVES

To continue the on-campus research projects as outlined in the first and second semi-annual progress report and through CSU faculty travel and coordination with government institutions and agencies in West Pakistan, begin to apply the on-campus research being done to field plot experimentations within West Pakistan. To establish re-search projects in Pakistan to be done by Pakistanis for more actual on-the-farm water management application.

SPECIFIC OBJECTIVES

Agricultural Engineering

The plan of work for this project is to use models to study the efficiency of several possible types of skimming well arrangements, and later to test the most promising schemes in the field in West Pakistan in an area with a shallow depth to salt water.

The model studies will be done at Colorado State University using primarily mathematical models analyzed with the aid of a CDC 6400 computer. These equations are to be used to determine the optimum penetration of a vertical skimming well.

A Project Agreement with the West Pakistan agency to carry on the field work has not yet been signed. However, a verbal agreement with WAPDA has been made to assign a Pakistani engineer to supervise this work. The engineer proposed is expected to take part in the model studies conducted at CSU. The initial work to date on this project has consisted of a study of the performance of vertical wells compared to the performance of horizontal collectors using approximately the same conditions existing in the region of Lyallpur, West Pakistan.

Agronomy

Fifty-eight soil samples representing eleven soil profiles were obtained from various locations from SCARP I and SCARP II in West Pakistan. The soils first were analyzed for fertility status. Then organic matter and lime were removed from sub-samples, and each was separated into ten size fractions. Mineralogical analysis of all size factors is now in progress.

Civil Engineering

The Bibliography with Annotations on Water Diversion, Conveyance and Applications for Irrigation and Drainage has been published. Five hundred copies were printed. Copies were given to AID Lahore, Irrigation Research Institute, Lahore, the University of Peshawar, West Pakistan University for Engineering and Technology, and Devlet Su Isleri in Ankara, Turkey. A mailing list is being prepared for further dissemination of the bibliography. A report on the fluorescent dye technique of water measurement has been prepared and is ready for publication. A file has been established containing reports relating to systems analysis of water resources in the United States. A model canal in which model farm turnouts, bifurcation, and lateral turnout can be placed is under construction at CSU and will be finished in January 1970. The first models will be typical of West Pakistan farm turnout. A field trip was made in September to West Pakistan to meet and discuss with Pakistani officials the problems associated with management, delivery, applications, and removal of irrigation water. It became apparent after this trip that the civil engineering proposal should organize its research efforts in Pakistan with the Irrigation Department. The Irrigation Department must be made a party of the research or the practices will not be accepted.

Economics

Mr. Tyler Sturdevant, USAID, Lahore, is assisting Economics in securing data from the Agricultural Department, Government of West Pakistan. Data for the wheat crop in the Lahore district had been obtained as arranged for during the December 1968 visit to Pakistan. Preliminary tabulations have been made on these data. Based upon the preliminary tabulations, some methodological problems arising as to how these data can best be analyzed as severe measurement problems exist.

Political Science

Three sub-projects are currently under way. These are:

1. A descriptive structural analysis of the major West Pakistan water agencies, including WAPDA, the ADC's, the Irrigation Department, and others;
2. A study of Pakistan personnel systems and practices with emphasis upon the impact this has on water policy formation and administration. Special attention is given to recruitment, training, and reward systems -- of the Civil Service of Pakistan in particular; and,

3. A comparative study of the SCARP projects in an effort to determine the variables which are crucial to project success and/or failure.

Sociology/Anthropology

To collaborate in the investigation of sources of resistance to, and inducement for, village farmer construction of satisfactory water-courses related to convey tubewell water to field distribution ditches. The location of this study would be SCARP II-A approximately 65 miles northwest of Lahore to the nearest boundary. SCARP II-A includes approximately 1,000 villages, 100,000 families, and 1300 publicly owned tubewells with a total 1,052,000 acres in the project area with about 751,000 acres under irrigation.

Attached and to be considered a part of this report are the detailed departmental progress reports (Appendix A).

PLAN OF WORK

1. To establish an overseas position for a CSU research coordinator to establish continuity between the on-campus research and the research in West Pakistan.
2. To continue the collection of data and to establish research projects in West Pakistan through cooperation with USAID and with various government institutions and agencies.

FUTURE PLANS

Agricultural Engineering

Khalid Mohtadullah, senior engineer, WAPDA, will be employed as the temporary research associate at CSU to supervise mathematical and physical model studies. WAPDA has promised to assign him to field studies in West Pakistan when model studies have been completed at CSU.

A research project for water control and land preparation with the Ayub Research Institute in West Pakistan has been proposed to be included in the new Pro-Ag to begin a research project in West Pakistan. The purpose of this research project is to determine the amount of increased production which results from various alternative methods of land farming and primary tillages in water application. Such data should provide the basis for more extensive demonstration projects in the future and economic determination for maximizing return on investments. It will also show the effect of combining improved irrigation practices with mechanized farming.

Agronomy

Mineralogical analyses will be completed for the on-campus research. Emphasis will be placed on making quantitative determinations of non-swelling minerals in the clay and identification of minerals found in several soils. The on-campus research will be directed toward answering field problems related to water quality and methods and rates of applying irrigation water on Pakistani soils. Proposals have been submitted for cooperative research with three institutions in West Pakistan: West Pakistan Agricultural University, Ayub Research Institute, and Land Reclamation Directorate. The proposed program is adaptive research design to study interaction among the following variables: water quality, time and rate of evaporation of water, physical properties of the soil including infiltration rates and hardpan formation, chemical properties such as salinity, sodium and fertility levels. Three proposed cooperative research programs have been incorporated in the new Pro-Ag agreement for specific research projects in West Pakistan. The proposed programs recommend a full time soil scientist for West Pakistan. These research programs are as follows:

1. Management as Related to Water Quality and Field Cultural Practice - Ayub Research Institute;
2. Characterization and Classification of Irrigation Water and Soils - the West Pakistan Agricultural University;
3. Utilization of Saline Water for Irrigation - Land Reclamation Directorate.

Civil Engineering

The bibliography will be disseminated and updated if additional material is brought to light.

A Pakistan graduate research assistant will be brought into the system analysis study at CSU and as rapidly as possible, we will get a study under way in Pakistan. It is proposed that through the Irrigation Department directly or through the Irrigation Research Institute, a systems management study of their operations can be conducted.

A model study of the farm turnout in use in Pakistan will be studied at CSU. Eventually, this study will be transferred to Pakistan. A study of on-farm application of water will be started as soon as a cooperative agency is found in West Pakistan.

Economics

1. To complete the study as set forth in the objectives of the research proposal.
2. To clarify some issues relating to these data; to follow up on leads about research developing similar in design to our studies, and to attempt, in the absence of support for research in Pakistan, to align our efforts with on-going and planned research in Pakistan.
3. Research in Pakistan will be clarified and hopefully initiated after Melvin Skold returns from his trip to West Pakistan the end of December 1969.

Political Science

1. Completion of the three sub-projects currently underway.
2. Completion of a sub-activity report by 31 March 1970 which will digest and analyze the data produced in the three sub-projects along with other data.
3. The design of specific plans for research both in the U.S. and Pakistan during the period following 31 March 1970.

Sociology/Anthropology

Proposed research as submitted in the new Pro-Ag Agreement with the West Pakistan Agricultural University, "Social Inducements and Constraints Effecting Village Farmer Optimization of Water. Specific research will be on the village leadership structure and social inducements and constraints in farmer watercourse construction as it applies to on-the-farm water application. The objective is to investigate sources of restraint to, and inducement for, village farmer construction of a satisfactory watercourse as required to convey tubewell water to distribution ditches and fields.

More detailed information on these proposals and to be included as a part of this report are attached as Appendix B.

EDUCATIONAL FILM ON LAND PREPARATION FOR
LEVEL BASIN IRRIGATION

2 July 1969 until completion of film

CONTRACT NO. : AID/esd-2162
Amendment #1

GENERAL OBJECTIVES

To produce an educational film that can be used by AID and other personnel to demonstrate the principles of proper land preparation for irrigation to government officials, students, and farmers, particularly those in the Indus Basin.

SPECIFIC OBJECTIVES

A tentative script has been written and tentative verbal approval has been received by AID. This script was written by CSU personnel after consultation with USAID Mission personnel in West Pakistan as well as officials from the Department of Agriculture of Pakistan. Some photography has already been done in Colorado. Dr. Arthur T. Corey, Film Project Director, and Mr. Carlos W. Seegmiller, Jr., Film Cameraman from CSU, departed the middle of November to film the major portion of the photography work to be done in Turkey and in Pakistan during the months of November, December, and January.

Attached and to be considered a part of this report is the detailed progress report (Appendix A).

PLAN OF WORK

Film to be produced on the campus of Colorado State University with some photography being done in Colorado and other parts of the U.S.A. However, most of the photography will be done in the Punjab region of West Pakistan and also on the USAID land leveling program in Turkey. Photography work will be done by a CSU cameraman in cooperation with the Department of Agriculture of Pakistan and the USAID Mission. The film will be in both English and Urdu sound tracks with provision for dubbing sound tracks in other languages as desired.

FUTURE PLANS

As soon as the photographing has been completed overseas and in the U.S., the rough cut screening will be done at CSU's studio followed by interlock screening in Washington, D. C., to make changes required and prepare a 16mm print for submission. This will be followed by check prints from the internegative, a photography of scenes as called for by the approved master shooting schedule. After editorial work, workprints, music and effects are made as required, professional narration and recording on a 16mm magnetic tape with separate music and effects track will be produced and presented to Washington for approval.

APPENDIX A

Progress Reports for Sub-Projects

Progress Report for On-Campus Research

CUSUSWASH Project

by A. T. Corey, Project Leader

- I. Department: Agricultural Engineering
- II. Project Title: Skimming of fresh water from aquifers in which fresh water is underlain by saline water.
- III. Personnel:
 - Arthur T. Corey - Project Leader
 - Paul Osborn - Graduate Assistant, conducting mathematical model studies
 - Khalid Mohtadullah - Senior Engineer, WAPDA - will be employed as temporary research associate at CSU to supervise mathematical and physical model studies. WAPDA has promised to assign him to field studies in West Pakistan when model studies have been completed at CSU.
- IV. Objective: The research is a study of methods by which fresh water can be pumped from a free-surface aquifer with maximum efficiency and minimum displacement of underlying saline water.
- V. Work in the U.S.: The plan of work for this project is to use models to study the efficiency of several possible types of skimming well arrangements, and later to test the most promising schemes in the field in West Pakistan in an area with a shallow depth to salt water.

The model studies will be done at Colorado State University. The present plan is to use primarily mathematical models analyzed with the aid of a CDC6400 computer. One physical model study is contemplated for the purpose of establishing the validity of equations developed by Flora Chu Wang. These equations are used to determine the optimum penetration of a vertical skimming well, but the validity of the results have been questioned by ground water field men.
- VI. Work in West Pakistan: A project agreement with a West Pakistan agency to carry on the field work has not yet been signed. A verbal agreement with WAPDA has been made to assign a Pakistani engineer to supervise this work. The engineer proposed is expected to take part in the models studies conducted at CSU.
- VII. Progress to Date: The initial work on this project has consisted of a study of the performance of vertical wells compared to the performance of horizontal collectors. To make an initial comparison, a fresh water aquifer of 40 feet lying on top of a salt water aquifer was assumed. This is approximately the condition existing in the

region of Lyallpur, West Pakistan. A radius of $\frac{1}{2}$ feet was assumed for both the vertical and horizontal collectors.

The procedure was to assume an aquifer permeability of 0.002 feet/sec., a value used by Wang who has previously studied skinning well performance in the Indus Plain. It was also assumed that neither the vertical wells or the horizontal collector would produce any salt water.

For the case of the vertical wells, equations by Wang were solved with the computer. It was found that under the assumed conditions, it would require 60 vertical holes penetrating to the optimum depth to produce 2 cfs.

CUSUSWASH Agronomic Research Program on Water Management

- I. Department: Agronomy
- II. Project Title: On-the-farm Water Management Research - West Pakistan
- III. Research Staff:

Department of Agronomy - Colorado State University

Willard R. Schmehl, Professor (Soils) - Project Leader

William T. Franklin, Assistant Professor (Soils) - Associate
Project Leader

Mehdi Monadjemi, Graduate Research Assistant - Mineralogical
and chemical analysis of clays

James Puckett, Graduate Research Assistant - Mineralogical
analysis of sands and silts

Cooperators in West Pakistani Institutions:

Dr. Inam-Ul-Hoque, Head, Department of Soils, WPAU

Dr. Shah Muhammad, Senior Research Officer, WPAU

Ghulam Hassan, Agronomist, Ayub Research Institute

Muhammad Hussain, Director, Land Reclamation Directorate

Nur-Ud-Din, Senior Research Officer, Land Reclamation Directorate

- IV. Purpose: Research will be conducted to determine the optimum use of irrigation water for various crops in relation to:
1. water quality;
 2. amount and frequency of application and;
 3. physical and chemical properties of the soil.

Outline of the Research Program: Research will consist of a two-phase program:

1. adaptive research in the field conducted in cooperation with West Pakistani institutions to study on-the-farm water management practices and;
2. on-campus laboratory research to define chemical and mineralogical properties of soils from typical sites in West Pakistan.

The field and laboratory phases of the research will be closely coordinated.

- V. On-Campus Research: Fifty-eight soil samples representing eleven soil profiles were obtained from various locations from SCARP I and SCARP II in West Pakistan. The soils first were analyzed for fertility status. Then, organic matter and lime were removed from sub-samples, and each was separated into ten size fractions (2 clay, 3 silt, and 5 sand). Mineralogical analysis of all size fractions is now in progress.

The fertility analysis based on interpretations for upland field crops has shown that all surface soils except two are very low in available phosphorus and organic matter (0.2 to 1.0%).

The pH for all soils ranges from 8.3 to 9.3 (1-5 soil-water suspension). Available potash appears adequate in all but one profile, and available iron and zinc appear adequate in all soils. All soils are calcareous.

The principle minerals in the clay and fine silt fractions have been identified by x-ray diffraction techniques. The principle minerals in the coarse silt and sand fractions have been identified by examination with the petrographic microscope. The mineral types in the clay and fine silt fractions are predominately: mica (illite), chlorite, smectite, vermiculite, interstratified minerals, and possibly kaolin. The relative amount of each type appears to vary somewhat within some profiles and from site-to-site.

The mineral assemblage in the sand and silt fractions is given in the following table:

<u>Light Fraction</u>	<u>Heavy Fraction</u>	
Quartz	Biotite	Magnetite
Muscovite	Muscovite	Zircon
K-feldspars	Phlogopite	Others*
Ca-feldspars	Augite	
Others*	Amphibole	

*Not identifiable under petrographic microscope because of advanced weathering

The light fraction generally makes up from 60 to 80 per cent by weight of each size separate. The relative amount of mineral types also varies from site-to-site.

- VI. Field Research Program - West Pakistan: Professors Schmehl and Franklin visited West Pakistan in September-October, 1969, to develop a cooperative program of research. Proposals have been submitted for research cooperative with three institutions: West Pakistan Agricultural University (WPAU), Ayub Research Institute, Land Reclamation Directorate. The proposed program is adaptive research designed to study interactions among the following variables: water quality, time and rate of application of water, physical properties of the soil including infiltration rates and hardpan formation, chemical properties such as salinity, sodium and fertility levels.

When the proposed cooperative research is approved by the West Pakistani Government and by AID Mission, specific research projects will be designed for implementation. The proposed program recommends a full-time soils scientist for West Pakistan.

The proposed research in West Pakistan will be conducted as a cooperative program among the three institutions named. The field experiments will be conducted at the Ayub Research Institute and

WPAU. Laboratory and lysimeter investigations associated with the field program will be conducted at WPAU and the Land Reclamation Directorate, respectively. Subsequently, field experiments will be conducted at other experimental stations in West Pakistan under the direction of the Ayub Research Institute.

- VII. Future Plans (On-campus research): Mineralogical analyses will be completed. Emphasis will be placed on making quantitative determinations of non-swelling 2:1 and 2:2 minerals in the clay fraction. The Ca and Mg-containing silicates in the sands and silts will be determined quantitatively also. Following mineralogical analysis ESP value for varying SAR solutions will be determined in laboratory and greenhouse experiments. The on-campus research will be directed toward answering field problems relating to water quality and methods and rates of applying irrigation water on Pakistani soils.

CUSUWASH Project for Research on Water Management
in West Pakistan

Department of Civil Engineering

I. Title: Research to Improve the Management, Delivery, Application and Removal of Irrigation Water for Farms in Semi-Arid Regions

II. Objectives: To determine the factors which affect the amount of water that can be delivered to the farm which affect the cost of the irrigation conveyance system to the farm and to study these factors to determine ways of optimizing the amount of water delivered and efficiently utilized on the farm and minimizing costs. The areas to be studied include: (1) the management of the delivery system; (2) the maintenance requirements of the system; (3) water losses due to seepage and associated waterlogging; (4) the effectiveness of hydraulic structures for controlling the flow and alleviating the silt problem; (5) silt deposition in the smaller canals and on the farm; (6) methods of on-farm application; and (7) the importance of changes in river behavior in the operation of the irrigation system.

III. Work Plan

In United States

- A. Preparation of bibliography with annotations on water diversion, conveyance and application for irrigation and drainage.
- B. Development of techniques for water and sediment measurements and tracing for small canals and on farm application.
- C. Development of methods and mathematical models for system analysis of irrigation distribution systems.
- D. General model study of farm turn outs, bifurcations and lateral turn outs to improve their sediment and water handling characteristics.
- E. Determine the general effects of sediment in the flow on the irrigation distribution system and on-farm application.

In Pakistan

- A. Review and update the bibliography.
- B. Help irrigation department officials develop methods for the measurement of water and sediment and tracing the movement of water in open channels and aquifers.
- C. Work with Pakistani engineers in the development of mathematical models that describe the operation of their irrigation systems. System Analysis of the delivery systems to determine where changes in on-farm water management can improve crop production, to develop operational procedures that will help the operating officials in the distribution of irrigation water taking

into account power requirements, link canals, reservoir storage and season of the year, and, in general, allow a systematic study of the outcome of any decision so that at least the economic consequences can be determined.

- D. Prototype studies of the water and sediment handling characteristics of the irrigation canals, bifurcations, farm turn outs and lateral turn outs. Model studies of specific problems that are encountered.
- E. Studies of specific sediment problems that affect or may affect the irrigation distribution system or on-farm application of the water.

IV. Work Done to Date

- A. The bibliography has been published. Five hundred copies were printed. Copies were given to AID, Lahore; Irrigation Research Institute, Lahore; University of Peshawar; West Pakistan University for Engineering and Technology and DSI in Ankara, Turkey. A mailing list is being prepared for further dissemination of the bibliography.
- B. A report on the fluorescent dye technique of water measurement has been prepared and is ready for publishing.
- C. Reports containing system analysis of water resources in the United States have been assembled. A system analysis of the Cache La Poudre Irrigation System in Colorado (Colorado funds) has been started. The Irrigation Department, Irrigations Research Institute, University of Peshawar, West Pakistan University of Engineering and Technology and WAPDA have been contacted to determine their interest and capabilities. The Irrigation Department and Irrigation Institute are interested and could benefit the most from the capability of system analysis.
- D. A model canal in which model farm turn outs, bifurcations and lateral turn outs can be placed is under construction at Colorado State University. It will be finished in January. The first models will be typical Pakistan farm turn outs. The study will provide data useful to Pakistani engineers in designing new farm turn outs and remodeling existing ones. It also will provide Pakistani students at Colorado State University in designing ones and using research equipment appropriate to the type of research needed in Pakistan.
- E. A Study by the University of Peshawar on the sources of sediment in West Pakistan is slated to be finished this year. The study will delineate problem areas and suggest remedial measures for sediment in farm ditches, canals, and rivers.

V. Professional Staff

E. V. Richardson

Project leader with primary responsibility for Items III B, C, and E.

A. G. Mercer

Primary responsibility for Items A and D.

H. W. Shen

Worked on Item III E.

M. E. Holland

Not funded by AID but advises on Item III C.

VI. Graduate Research Assistants

K. Mahmood, Pakistan

Prepared the bibliography and Item III A and is now working on Item III E.

A. Rakha, Pakistan

Working on Item III D.

I. Ul-Hague, Pakistan

Working on Item III D.

M. Kilinc, Turkey

Working on Item III A, B, and E.

W. Liang, Taiwan

Worked on Item III B. (Is no longer on project).

J. Duke, U. S. A.

Item III C. (Not paid with AID funds)

R. Thiemert, U. S. A.

Item III C. (Not paid with AID funds)

VIII, Future Activities

- A. The bibliography will be disseminated and updated if additional material is brought to light.
- B. A study of the loss of fluorescent dye by interaction with suspended sediment, dissolved solids and biota in the flow.
- C. A Pakistan graduate research assistant will be brought into the system analysis study at Colorado State University and as rapidly as possible, we will get a study underway in Pakistan. We hope to interest the Irrigation Department (either directly or through the Irrigation Research Institute) in conducting a systems management study of their operation. It will do little good to develop mathematical models of their system and conduct systems type analysis of their operation unless we have their cooperation.
- D. A model study of the farm turn out in use in Pakistan will be studied at Colorado State University. Eventually the study will be transferred to Pakistan. A study of on-farm application of water (border, furrow, wild flooding, etc.) will be started as soon as a cooperative agency is found in Pakistan.
- E. Study the sources of sediment in West Pakistan. Investigate the effect of changes in sediment load as the result of the reservoirs and link canals on the distribution system and on-farm application of water.
- F. A proposal will be submitted in the near future with a request for a Colorado State University Civil Engineering staff member, who has had previous experience in Pakistan, involving the Irrigation Department, Irrigation Research Institute, University of Peshawar West Pakistan University of Engineering and Technology and WAPDA, to be stationed in Pakistan for a period of three months to initiate research in the Irrigation Department Research Institute patterned after the research work being done at CSU. It is proposed that this staff member will visit Pakistan in June 1970 for a two week period prior to being stationed in Pakistan for the three month period in September, October, and November 1970.

Economic Research on On-Farm
Water Management in West Pakistan

Department of Economics

- I. Title: Economic Analysis to Achieve an Efficient Allocation of Water in Pakistan.
- II. Objectives: To examine the relationships between inputs to crop production and the resulting crop yields. The functional relationships to be studied will be used to demonstrate the usefulness of this type of analysis to guide decisions about the allocation of resources, particularly water.

III. Work Plan:

All work is being done in the United States.

- A. Mr. Tyler Sturdevant, USAID, Lahore, is assisting us in securing data from the Agricultural Department, Government of West Pakistan.
- B. Data for the Wheat crop in the Lyallpur District have been obtained as arranged for during the December 1968 visit to Pakistan. Preliminary tabulations have been made of these data. We have attempted to isolate the effects of the various variables on wheat yields. For instance, wheat yields under different soil types are compared as well as yield comparisons between varieties, cultivation methods, types of fertilizer, irrigation sources, irrigation types, previous crops, planting dates, etc. Considerable attention has been given to the conceptual framework for the analysis. Based upon our preliminary tabulations, we see some methodological problems arising as to how these data can best be analyzed as severe measurement problems exist.

IV. Staff:

Melvin D. Skold, Project Director
Kenneth C. Nobe, Project Director
Huntley Biggs, Participant
Debebe Worku, Graduate Assistant (Ethiopian)

No research funds to hire Pakistanis.

V. Future Activities

- A. Because of the methodological problems encountered, we are less than optimistic about being able to perform the analyses which we had planned in a satisfactory manner. To empirically estimate the

production functions for wheat via multiple regression techniques, one must have data that are relatively free from measurement bias. Much of these data which we have obtained are not measured quantitatively in a manner which is suitable for regression analysis. Thus, we may have to rely on "dummy" variables for much of our statistical analyses. Consequently, the computations related to production function studies will be limited as will the ability to demonstrate how these data can be used for water allocation decisions. The potential for this type of analysis can be illustrated, however, and the importance of the information generated to water allocation decisions can be stressed.

- B.** To clarify some issues relating to our data. To follow up on some leads about research developing similar in design to our study. To attempt, in the absence of support for research in Pakistan, to align our efforts with ongoing or planned research in Pakistan.

Progress Report

CUSUSWASH PROJECT FOR RESEARCH ON
WATER MANAGEMENT IN WEST PAKISTAN

submitted by

THE DEPARTMENT OF POLITICAL SCIENCE
COLORADO STATE UNIVERSITY
DECEMBER 22, 1969

CUSUSWASH Project for Research on Water Management
in West Pakistan

Department of Political Science

- I. Research Area: Public Administration
- II. Project Title: Organization of Water Management for Agricultural Development in West Pakistan
- III. CSU Project Personnel: 1969-70
 - Senior Resident Faculty Director: Phillip O. Foss
 - Senior Resident Faculty Project Associate: John A. Straayer
 - Resident Research Assistants: Robert Schmidt
Arlene Dwyer
- IV. Progress Report for Period from April 18, 1969, to October 31, 1969:

Work to date has focused upon the West Pakistan Public water agencies in an attempt to determine institutional changes essential for optimizing water utilization, so as to maximize on-farm agricultural production. Within this framework, three sub-projects have been delineated. Each is designed to identify certain organization and management practices which facilitate or impede the effective utilization of modern developmental technology in the area of agricultural production. The three include:

 1. An analysis of the major West Pakistan water management agencies, including WAPDA, WPADA, the Irrigation Department, the Agriculture Department, and the Land and Water Development Board, with emphasis upon specification of the organizational structure and identification of the formal and informal patterns of interaction that exist within and among these organizations.

2. An examination of Pakistani personnel systems and practices, with emphasis upon the impact of recruitment, training, reward structures, value systems and behavior upon the capacity of the water management agencies to develop, utilize, and communicate relevant technological information throughout the water resources system.
3. A comparative study of the SCARP projects, with emphasis upon the development of an analytical model to be used in the identification and analysis of the variables which most critically affect project success. These variables include project size in terms of land area, personnel, funding, and water, seed and fertilizer use, project location, project age, the amount and nature of advance planning, and others.

Work on the above-described projects is progressing on schedule and all three will be completed on or about March 1, 1970. Plans then call for the integration of the data contained in these projects with data drawn from administrative and development literature, to form the project report. Professional publication outlets in the U.S. and Pakistan are being investigated.

VI. Future Plans:

The objectives and plan of work for 1970-71 and beyond are spelled out in a separate research proposal. They involve cooperative research efforts with personnel at the University of the Punjab.

An agreement in this regard was reached during the November-December trip to West Pakistan by Dr. John A. Straayer. Additionally, of high priority in our work during 1970-71 will be significant expansion of our cooperative working arrangements in West Pakistan. This will be done in cooperation with AID/Pakistan and with the assistance of Dr. Garth N. Jones. (See attached Addendum.)

Addendum I

Research Proposal

CUSUSWASH PROJECT FOR RESEARCH ON WATER MANAGEMENT IN WEST PAKISTAN

- I. Research Area: Public Administration
- II. Project Title: Organization of Water Management for Agricultural Development in West Pakistan.
- III. Colorado State University Project Personnel:
 - Phillip O. Foss, Department of Political Science, Director
 - Henry P. Caulfield, Department of Political Science
 - John A. Straayer, Department of Political Science
 - Garth N. Jones (Proposed)
 - Resident Research Assistants: Three to be named later.
- IV. Cooperating Pakistani Personnel:
 - Dr. M. Afzal, Head, Department of Administrative Science, University of The Punjab, Lahore, Pakistan.
 - Three others to be named later.
- V. Objectives:
 - A. To expand and strengthen the research which has been underway during 1969 and early 1970, with focus upon the following sub-projects:
 1. The SCARP Projects: A case study in planned development. This study involves the identification and analysis of the organizational and resource variables which contribute to the success or failures of the SCARP projects. Additionally, this segment of our work will result in the development of an analytical model for use in the identification and analysis of variables which facilitate or impede the success of development projects.

2. Water and Power Development Authority (WAPDA): Specification of the organizational structure and identification of formal and informal patterns of interaction. The basic goal of this sub-project is to determine how organizational structure and behavior affect the use of technical information in decision-making for the procurement and allocation of resources. Additionally, this study will assess the implications for inter-governmental relations of the dissolution of the single unit in the west wing, the implications of the bifurcation into separate water and power wings, and will examine the planning and programming processes for water resources development including internal and external sources of resources and resource allocation decision-making.
 3. Irrigation Department: The Irrigation Department will be examined and analyzed according to the criteria described above for WAPDA.
- B. Publication of an analytical bibliography on water management in developing countries with emphasis upon West Pakistan. This will involve an examination, classification and analysis of work which has been done and an inventory of areas of future needed research. Some of the work needed for the accomplishment of this objective has already been done as a part of our work in 1969 and early 1970.
 - C. Compilation and publication of a set of papers containing the highest quality and most significant papers and articles on water management for agricultural development with emphasis on West Pakistan. Again, substantial progress toward the accomplishment of this objective has already been made.

- D. The initiation of a study of water law (custom, practice, and written regulations) and water allocation processes. Sub-projects under this objective will include the following:
1. Publication of an analytical bibliography.
 2. Examination and analysis of the relation of canal water to tube well water.
 3. Examination and analysis of the legal implications of tube well development.
 4. Examination and analysis of the implications of the use of a demand allocation system to permit water allocation and use according to crop and land needs rather than according to a scheme of time-table distribution based solely upon acreage.
 5. Examination and analysis of the machinery for the adjudication of legal disputes, especially relative to tube well water.
 6. Examination and analysis of the relation of the land tenure system to water allocation and use.
- E. The recruitment of three Pakistani scholars for three month tours at Colorado State University to consult with C.S.U. personnel, take courses, give lectures, work with C.S.U. faculty and graduate students in advanced design, execution and publication of this research, and to work closely with us upon their return to their home institutions in West Pakistan.

VI. Justification:¹

New and progressive methods of agricultural production are ultimately of value only if they are transmitted to and used on the farm; and of critical importance to the organized and effective accumulation and transmission of new information, technical assistance and materials is the smooth and efficient functioning of a water management administration which is staffed by trained personnel and which is dedicated to the concept of development. More specifically, water technology can improve on-farm water management and productivity only if sound organization and management practices are followed in water agency efforts to deliver and remove irrigation and saline waters.

In the case of Pakistan, however, there is considerable evidence to suggest that certain aspects of the organizational structure, personnel systems, intra and inter-agency linkages, agency interaction patterns, as well as the reward, authority and communication systems within the water bureaucracy, often act to impede rather than facilitate effective delivery and removal of water. It has been suggested, in short, that some of the most serious impediments to Pakistani development are administrative and not primarily technical, and that it is therefore essential to accelerated

¹The justification which follows has to do with Pakistan specifically. But, perhaps a more forceful and uncontroversial demand for public administration research was made by Brooks Adams: "Administration is the capacity of coordinating many, and often conflicting, social energies in a single organism, so adroitly that they shall operate as a unity. This presupposes the power of recognizing a series of relations between numerous special interests, with all of which no single man can be intimately acquainted. Probably no very highly specialized class can be strong in this intellectual quality because of the intellectual isolation incident to specialization; and yet administration and generalization is not only the faculty upon which social stability rests, but is, possibly, the highest faculty of the human mind." (The Theory of Social Revolutions, (New York: Macmillan, 1913), pp. 207-208.)

See also AID sponsored study, Milton J. Esman and John D. Montgomery, "Systems Approaches to Technical Cooperation: The Role of Development Administration," (Public Administration Review, Sept. 1969, pp. 507-539).

agricultural development that attention be given to Pakistani public administration.²

The specific contributions of this project are as follows:

- A. The publication of an analytical bibliography and a set of papers on agricultural development will aid in the identification of areas of needed research and will make available under one cover some of the best work already done.
- B. Our analysis of the SCARP projects, the Irrigation Department and of WAPDA will help in the identification of organizational factors which facilitate or impede rational planning, programing and resource allocation processes. This is of special importance since it is critical that skilled people make decisions using all available scientific knowledge (rather than hunches) and that inter and intra-agency communications and relations be such as to insure maximum transfer and use of expertise and information.
- C. Our interaction and collaboration with Pakistani scholars and institutions will help upgrade both their ability and ours to identify and execute significant research projects.

²Reports which call attention to administrative problems as real or potential impediments to development include: Report on Land and Water Development in the Indus Plain (Washington, D.C.: The White House, Department of Interior Panel on Waterlogging and Salinity in West Pakistan, 1964), Chapter Four especially (this report is better known as the Revelle Report); M. A. Mannan, Economic Problems and Planning in Pakistan, (Lahore: A Hameed Kahn at Ferozsons Ltd., 1968), Chapter XIII, p. 207; The Second Five Year Plan, 1960-65, (Planning Commission, Government of Pakistan, June 1960), Chapter V; The Third Five Year Plan, 1965-70, (Planning Commission, Government of Pakistan), June 1965, Chapter IX.

D. This work will help to generate both the interest and skill of Colorado State University graduate students in work on developing countries, West Pakistan especially.

VII. Plan of Work:

Some of the work necessary for the publication of an analytical, annotated bibliography has already been completed. The remaining work will be done by Colorado State University faculty and graduate students in cooperation with personnel in the Department of Administrative Science, University of Punjab. Likewise, much of the work necessary for the publication of already existing papers on water management in West Pakistan has already been done and will be completed in cooperation with Pakistani scholars at the University of The Punjab and elsewhere.

The case studies of the SCARP projects and of the Irrigation Department and WAPDA will be continued in cooperation with Pakistani scholars at the University of The Punjab and elsewhere. The necessary onsite interviewing will be done under the direction of Dr. M. Afzal, Head of the Department of Administrative Science, University of The Punjab. Additionally, data will be obtained via cooperative work with Pakistani scholars who are to be brought to Colorado State University.

The study of water law and water allocation processes will begin in 1970 with the collection, examination and analysis of books, articles, the United Nations, USAID, Government of Pakistan and other materials available to us on campus at Colorado State University. In late 1970 and in 1971 this work will be extended through the procurement of additional printed materials and through personal interviews conducted in Pakistan.

In cooperation with Dr. Garth N. Jones and in consultation with USAID/Pakistan, three Pakistani scholars (most likely trained in the United States) will be selected to spend three months (one academic quarter) at Colorado State University to work with the faculty and staff of the Political Science Department in the specific execution of the research herein proposed.

The possibility will be explored of conducting a conference in West Pakistan on the subject of water management. This conference would bring together in one place Pakistani scholars and administrators concerned with water management, and Colorado State University faculty associated with this project. This conference would permit the exchange of ideas and information quickly and inexpensively.

VIII. Qualifications of Research Personnel.

The Department of Political Science at Colorado State University has perhaps the largest and most distinguished faculty in the nation in the field of public administration of water resources.

In addition to proposed project personnel, the following Political Science faculty have had extended research experience and/or have held responsible management positions in water administration: Dr. Duane W. Hill, Dr. Roy L. Meek, Dr. Daniel M. Ogden and Dr. Norman I. Wengert. They will all be available for informal consultation on this project.

Sociological Research on On-Farm
Water Management in West Pakistan

I. Objective:

To collaborate in the investigation of sources of resistance to, and inducement for, village farmer construction of satisfactory watercourses required to convey tubewell water to field distribution ditches.

II. Justification:

A. West Pakistan Water and Power Development Authority (WAPDA) has installed several thousand tubewells for irrigation and land reclamation purposes. These tubewells can contribute greatly to increased agricultural production.

B. A major problem has developed in many areas which is preventing optimal application of the tubewell water. Watercourses must be constructed to convey tubewell water to field distribution systems. Village farmers, for whom the tubewell water is intended to benefit, have been lagging in the construction of the necessary watercourses. Resistance to the construction of watercourses is significantly limiting the potential of tubewell water for agricultural production.

III. Location: SCARP II A -- Approximately 65 miles N.W. of Lyallpur to nearest boundary.

SCARP II A includes approximately 1000 villages, 100,000 farm families, and 1300 publicly owned tubewells. Of the total 1,052,000 acres in the project area, about 751,000 acres are under irrigation.

IV. Duration: Three years for initial work; five years total.

V. Phasing of Research:

A. First year: Instrument construction, pre-test, and survey data collection;

B. Second year: Model construction and testing;

C. Third year: Initial model application in control and experimental villages;

D. Fourth and fifth year: Controlled experimental innovation.

VI. Proposed Collaborators: (At West Pakistan Agricultural University, Lyallpur)

Dr. Haider Ali Chaudhari -- Ph.D. Missouri

Dr. Muhammad Rafique Raza -- Ph.D. Cornell

Mr. Abdur Rehaman Rizwani -- M.A. Cornell

VII. Proposed Research Personnel:

- A. Two CSU Sociology faculty and two GRA's
- B. Three WPAU faculty and two GRA's
- C. Six permanent Pakistani field investigators with village backgrounds and M.A. degrees in Economics or Sociology.

APPENDIX B

**Proposed Sub-Project Descriptions
for
Project Agreement**

1. Title: Water Control and Land Preparation (Agricultural Engineering)

Agricultural production can be increased significantly by proper management of water already available. The first step in this management is to get the water completely under control so that it can be placed exactly where it is wanted, in the quantity that is wanted, and at the time it is wanted. This requires a combination of proper land preparation by careful leveling and control and measuring structures which provide the necessary flexibility.

Data in Pakistan exist which indicate that crop production is seriously reduced by improper leveling and preparation of the ground and by improper quantities and timing of irrigation water.

Purpose

For the foregoing reasons, a research project is proposed to determine the amount of the increased production which results from various alternative methods of land forming and primary tillages and water application. Such data should provide the basis for more extensive demonstration projects in the future and economic determinations for maximizing return on investment. It will also show the effect of combining improved irrigation practices with mechanized farming.

Procedure

Field experiments will be conducted on land which has been carefully leveled by appropriate land leveling equipment and also on nearby land which has been leveled by conventional methods. Some of the leveled land will be deep chiseled to break up existing plow-sole layers and permit better penetration of roots and moisture. Different slopes of land surface will be used as appropriate for natural conditions and available water. The length of run will be varied at least to some extent as a basis for determining the optimum length of run. Different heads (to simulate variable supplies and canal and tubewell combinations) and rates of water application will be used along with different methods of irrigation (such as border and furrow methods). Crops will be grown on the land to test effects of treatments.

As much as possible, the optimum amount of water and the optimum fertilizer and pesticide treatment will be used.

Action Responsibilities

The Department of Agriculture will provide field space, irrigation water and distribution system, and plant protection and weed control measures necessary to obtain precise experimental results. This includes timely irrigation application, timely plant protection, timely cultivation, and timely weed control. USAID land leveling specialists will assist in leveling the land to specifications before the

experiments are initiated. The Pakistan Officers and USAID consultants will be responsible for designing and conducting the experiments.

Equipment and Services Needed

a. Farm equipment

1. Tractor
2. Subsoiler
3. Plow
4. Disk
5. Planters
6. Grain drill
7. Row crop cultivator
8. Crop sprayer
9. Border disk
10. Harrow
11. Harvesting equipment

b. Land leveling equipment (scraper and land plane)

c. Irrigation water and water measuring devices

d. Weather instruments

e. Soil moisture measuring equipment and instruments

f. Laboratory space for soil moisture and other analyses.

1. Title: Utilization of Saline Groundwater for Irrigation (Agronomy)

Procedure

Studies of the effects of using high salt, high sodium, and high bicarbonate waters for irrigation of various crop rotations are already underway in lysimeters and small plots at the Land Reclamation Directorate. Equipment to instrument future studies and studies now underway will be obtained to furnish vital information such as soil moisture content and salt and sodium content and distribution in the soil during irrigation cycles. Analytic instruments to update soil and water analysis also will be obtained. Future studies concerning limitations of waters of variable quality will be based upon the outcome of studies in progress and will be added as space becomes available. Studies of improving the soil physical properties of soils undergoing deterioration due to the high sodium and bicarbonate waters will be initiated. These studies will include such treatments as the application of gypsum, incorporation of plant residues, and cultivation. Also, long-term field studies will be undertaken to study the effects of irrigating with tubewells of selected qualities on soil properties and crop growth under farmer management.

All data will be made available to Pakistan and USAID economists for inclusion in economic analysis studies.

Action Responsibilities

The Director of the Land Reclamation Directorate attached to the Department of Irrigation and Power will provide lysimeter and small plots and laboratory facilities for experiments. The Pakistan Officer and USAID consultants assigned will be responsible for designing and carrying out experiments which will provide information on the limitations of and for the optimum utilization of ground waters for irrigation.

Equipment and Services Needed

- a. Lysimeters
- b. Tanks
- c. Small plot areas
- d. Analytical instruments for soil and water analysis
- e. Soil moisture measuring devices
- f. Salinity meter and sensors
- g. Soil and water analysis

CSU Contributions

- a. Short-term consultants
- b. Services of consultant stationed full-time in Pakistan
- c. On campus studies relating to water management in Pakistan
- d. Miscellaneous replacement items for laboratory instruments
- e. Moisture monitoring and sampling equipment
- f. Soil salinity sensors and meter (if commercially available)
- g. Hellometer
- h. Miscellaneous chemical reagents

2. Title; Management as Related to Water Quality and Field Cultural Practices (Agronomy)

Procedure

Experimental results and recommendations concerning water quality and cultural practices derived from lysimeter and small plot studies must be tested under field conditions. Therefore, field experiments will be conducted in the experimental area at Ayub Research Institute and at various substations controlled by the Institute. The treatment variables to be included in the experiments are: subsoil tillage, water quality, rate and frequency of irrigation, and alternate use of waters of different quality. Data to be taken to evaluate the treatment effects include: water infiltration, water storage, root penetration and distribution, the salt and sodium balance in the soil, and crop yields. Crop water requirements and moisture use efficiency for high fertility levels will be determined. Land leveling, crop rotation, fertility, plant protection, and weed control will be optimized.

Data will be made available to Pakistan and USAID economists for inclusion in economic analysis studies.

Action Responsibilities

The Director of Ayub Research Institute will provide field space, tillage and cultivation implements and tractor, irrigation water and distribution system, plant protection and weed control measures necessary to obtain precise experimental results. This includes timely irrigation application, timely plant protection, timely cultivation, and timely weed control. USAID land leveling specialists will assist in leveling the land to specifications before experiments are initiated. The Pakistan Officers and USAID consultants assigned will be responsible for designing and carrying out experiments which will determine optimum water use efficiency.

Equipment and Services Needed

a. Farm equipment Needed

1. Tractor
2. Subsoiler
3. Plow
4. Disk
5. Planters, 2 or 4 flex with fertilizer attachment
6. Grain drill with fertilizer attachment
7. Row crop cultivator, rear mounted, 2 or 4 row
8. Crop sprayer
9. Border disk
10. Harrow - spike tooth
11. Miscellaneous harvesting equipment

- b. Land leveling equipment
- c. Irrigation waters of varying quality
- d. Lysimeters - 5 x 5 pneumatic (new), 12 concrete (existing facility)
- e. Weather instruments - pan-evaporimeter, anemometer, heliometer, recording raingage, etc.
- f. Moisture monitoring sampling devices - tensiometers, resistance blocks, extraction cups
- g. Salinity sensors and salinity meter (if commercially available)
- h. Soil sampling equipment and preparation room
- i. Laboratory space for soil analyses (possibly)
- j. Measuring tanks and water distribution system (existing facility)

3. Title: Characterization and Classification of Irrigation Water and Soils (Agronomy)

Procedure

Soil and water analysis to characterize the soils and waters used at Ayub Research Institute and its substations will be made by WPAU. Field experiments also will be conducted with a variety of water qualities to determine different irrigation practices necessary to use a specific water in a specific situation. Examples of specific situations which occur: ground water as the only source, ground water mixed with canal water, ground water used only during canal water shortage (seasonal), ground water applied at advancing stages of crop development, and ground water applied between scheduled canal water runs (intermittent).

This along with the studies at Ayub Research Institute will be aimed at providing farmers more specific information on the use or limitations of waters of marginal or inferior quality. The overall studies will be aimed at developing specific management recommendations for using a given water for a given crop in a specific situation.

Special studies needed to answer some facets of the experiments will be suggested as thesis problems for graduate students.

Action Responsibilities

The Vice-Chancellor of WPAU attached to the Department of Education will provide laboratory facilities for soil and water analysis, tractor, tillage and cultivation implements, irrigation water and distribution system, plant protection, and weed control. USAID land leveling specialists will assist in leveling the land to specifications on land where experiments are conducted. The Pakistan Officers and USAID assigned to the project will be responsible for designing and carrying out experiments which will develop a more flexible water quality classification scheme based on soil, water, crop and climatic conditions.

Equipment and Services Needed

- a. Farm equipment (existing)
- b. Irrigation waters of varying quality, mixing facilities, and distribution systems and field space
- c. Laboratory facilities and soil and water analysis (existing)
- d. Chemical reagents, miscellaneous glassware, certain laboratory instruments, and miscellaneous replacement items for laboratory instruments

- e. Field moisture monitoring and sampling equipment - tensiometers, moisture blocks, moisture extraction cups
- f. Soil salinity sensors and salinity meter (if commercially available)
- g. Vehicle and travel expense

CSU Contributions

- a. Short-term consultants
- b. Services of consultant stationed full-time in Pakistan
- c. On-campus studies relating to water management in Pakistan
- d. Chemical reagents, miscellaneous glassware, certain laboratory instruments and miscellaneous replacement items for laboratory instruments
- e. Field moisture monitoring and sampling equipment
- f. Soil salinity sensors and meter (if commercially available)

Department of Sociology
Pakistan Research Proposal (West Pakistan Agriculture University)

1. Title: Social Inducements and Constraints Affecting Village Farmer Optimization of Water (Sociology)

a. Research Components:

1) The general sociological research theme, "Social Factors in On-Farm Water Management", is much too inclusive to be effectively approached as a whole. The general theme is, therefore, broken into specific components which constitute particular aspects of the problem of on-farm application of water.

2) The increased availability of water, and the consequent increase of food and fibre production, is interdependent with social/institutional change in a wide range of areas including the family and kinship system, leadership structures, credit and marketing arrangements, consumption and investments patterns, informal communication, formal mass-media patterns, and population shifts.* Investigation of any of the above constitute an important component related to the central theme of on-farm water application.

b. Specific Research Component One: Village leadership structure and social inducements and constraints in farmer water course construction.

1) Objective: To investigate sources of resistance to, and inducement for, village farmer construction of satisfactory water courses required to convey tubewell water to distribution ditches and fields.

2) Justification:

a) West Pakistan Water and Power Development Authority (WAPDA) has installed several thousand tube-wells for irrigation and land reclamation purposes. Tens of thousands of private tubewells have also been installed in recent years.

b) These tubewells can contribute greatly to increased agricultural production.

*Note: Wherever pertinent, researchers will draw upon the relevant data made available in the Socio-Economic Bench-mark Survey: Mona Project, and Punjabi Rural Social Institutions.

c) A major problem has developed in many areas, however, which is preventing optimal application of the tube-well water on the farm. Water courses must be constructed to convey tubewell water to field distribution systems. Village farmers, whom the additional tubewell water is intended to benefit, have been lagging in the construction of the necessary water courses for tubewells provided by WAPDA.

d) Resistance to the construction of water courses is significantly limiting the potential of tubewell water for agricultural production.

3) Plan of Research:

a) Location: It is proposed to conduct the research in the SCARP IIA area which lies adjacent to the MONA Project area between the upper and lower Jhelum canal and between the southern branch of the lower Jhelum canal and the Chenab river (see map appendix), to approximately 20 miles down river. The area is in Sargodha, Jhang and Gujrat districts.

b) Characteristics of Research Area:

1.1) Size and number of wells: SCARP IIA includes 1,052,000 acres in which WAPDA has installed almost 1300 tubewells, cumulatively discharging over 5,000 cubic feet/second, and eventually making it possible to bring 751,000 acres under irrigation.

1.2) Number of villages and farmers: SCARP IIA includes approximately 1000 villages and 100,000 farmers.

c) Sample:

1.1) A random Stratified sample will be drawn from a small number of selected villages according to : (These are subject to change and modification)

aa) The origin of the village community.

i) Native

ii) Settlers

iii) Refugees

bb) Ownership patterns.

i) Owner

ii) Owner cum tenant

iii) Tenant

cc) Size of land holding

i) Under 5 acres

ii) 5-12.5 acres

iii) 12.5 to 25 acres

iv) Over 25 acres

- dd) Time of tube-well installation
 - i) Less than 6 months past
 - ii) 6-12 months past
 - iii) 12-24 months past
 - iv) Over 24 months past
- ee) Amount of effort to solve problem.
- ff) Kind of Effort (voluntary, Government of Pakistan, Union Council).
- gg) Amount of water course construction.

4) Methods of Data Collection

Data will be collected through a combination of questionnaire, interview, and modified participant-observation techniques.

5) Personnel for data Collection

The proposed collaborators at WPAU have a team of five permanent Field Investigators with village background and M. A. degrees in sociology or economics who are available to obtain data from the villages.

6) Duration of Research

This initial component of the general research theme will be undertaken for a three year period as soon as funds are provided.

- a) Year one: Instrument Development, pretest, and survey data collection;
- b) Year two: Model Development and Initial Application;
- c) Expanded model application in control and experimental villages.

7) Some Research Questions

- a) What is the nature of the formal and informal leadership structures in the village?
- b) What is the level of leadership and nonleadership information about the presence of tubewell water resources?
- c) What are the leadership and nonleadership perceptions as to what groups or agencies should and should not undertake water course construction?
- d) What are the leadership and nonleadership perceptions of what role outside (non village) agencies should take in regard to watercourse construction?

e) What are the leadership and nonleadership perceptions of the **costs** (economic, political, familial, religious) of watercourse construction?

f) What are the leadership and nonleadership perceptions of the **benefits** (economic, political, familial, religious) of watercourse construction?

g) How are the perceptions of item 6 weighted visa via those of item 5?

ADDENDUM I -- THE SOCIOLOGY PROPOSAL

(Item b 6, pp. 18 of Pro-Ag.)

I. Approach to construction of the Research Design.

- A. The research design will be constructed through collaboration of the members of the two faculties;
- B. Although it is not possible to anticipate the final form of the research design to be evolved through the collaboration, it is possible to state the procedure employed to create the design.
- C. The procedure for investigating the sources of resistance to, and inducement for, village farmer construction of satisfactory watercourses will be divided into three stages:
 1. the sample survey stage--to isolate independent variables significant for farmer willingness to undertake construction of satisfactory watercourses;
 2. the field study stage--to discover strength of relationship between the variables isolated in stage 1;
 3. the field experiment stage--the actual manipulation of one or more independent variables to determine something of causal relations and to lay a basis for specific policy recommendations.

II. The Three Stages.

- A. Research Stage One--the Sample Survey (First Year)
 1. A stratified sample of village farmers will be drawn in Scarp II A with a view to establishing potential significant variables for willingness to undertake watercourse construction;
 2. The survey will focus on three kinds of data:
 - a. personal data--individual and social characteristics;
 - b. environmental data--perceptions of circumstances affecting water-

course construction including level of awareness of the problem;

c. behavioral data--actions of respondents regarding watercourse construction;

3. The first full year of the project will be devoted to the design of the sample survey procedures, construction of the necessary instruments, pretest of the instruments to achieve acceptable levels of reliability and validity, collection and analysis of the data.

4. Expected first year result:

a. development of an over-all description of Scarp II A demographic and social features;

b. identification of propensities to engage in water-course construction by social categories;

c. completion of reliable and valid survey instruments, the results of which will have laid a basis for construction of the Field Study research instruments to be employed in stage two.

B. Research Stage Two--the Field Study (Second Year)

1. The field study allows researchers to investigate hypotheses suggested by the stage one survey in depth through study of a small number of selected village communities. The survey data generated in Stage One will serve to suggest hypotheses regarding water course construction behavior which cannot be adequately confirmed, modified, or rejected except through a field study.

2. The primary purpose of this stage of research will be to discover correlation among variables--to look for the most powerful variables associated with willingness to construct satisfactory watercourses;

3. Because a field study allows observation over time, it becomes possible to ascertain the timing of variables. When variables are timed,

it is possible to obtain hypotheses about cause and effect. Such hypotheses will be required for Stage Three--the field experiment;

4. It is expected that a minimum of one year will be required to conduct the field study in a very limited number of villages.
5. Expected Second Year Result:
 - a. Isolation of variables which are powerfully associated with willingness to engage in water-course construction.
 - b. Statements of positive and negative correlation among the variables.

C. Research Stage Three--The Field Experiment (Third Year)

1. The field experiment has, as its primary objective, the planned manipulation of one or more independent variables in order to achieve change on the dependent variable--willingness to construct satisfactory water-courses;
2. Planned manipulation of one or more independent variables in a field setting is, in effect, planned social change. Such planned change requires some hypotheses about what factors must be manipulated in what manner.
3. The data, correlations, and hypotheses generated in Stages One and Two will have provided the basis upon which planned change can be undertaken.
4. Experimental and control groups will be selected and matched as closely as possible on the significant variables;
5. The crucial methodological problem in this stage will be determining a method of manipulating the independent variable(s) in the experimental group in the field setting. The solution to this problem cannot be known until the first two stages of the research are

completed, but it may well be possible to effectively employ the 94 Agricultural Assistants employed in Scarp II (each has a B.S. degree in Agriculture) to manipulate the independent variable(s).

6. It will be necessary to maximize variation in the independent variable(s) so that changes will be recorded even by relatively unrefined instruments. This is one major reason why the survey and field study stages are so crucial--to provide insight into the variables which account for the most variance.
7. Expected Third, Fourth, and Fifth year results: Recommendations for policy. Things to be done, and a sequence for doing them, if watercourse construction is to be maximized.