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AGENCY FOR INTERNATIONAL DEVELOPMENT

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7. PROJECT TITLE (Maximum 40 characters): On-Farm Water Management - Colorado

8. ESTIMATED FY OF PROJECT COMPLETION: FY 80

9. ESTIMATED DATE OF OBLIGATION (Extension): A. INITIAL FY 77; B. QUARTER 2 (Enter 1, 2, 3, or 4); C. FINAL FY 79

10. ESTIMATED COSTS ($000 OR EQUIVALENT $1 - N/A) For New Three Year Contract

A. FUNDING SOURCE	FIRST FY 77 B. FX	C. L/C	D. TOTAL	LIFE OF PROJECT E. FX	F. L/C	G. TOTAL
AID APPROPRIATED TOTAL	$1,750	-	$1,750	$2,700	-	$2,700
(GRANT)	($1,750)	(-)	($1,750)	($2,700)	(-)	($2,700)
(LOAN)	( )	( )	( )	( )	( )	( )
OTHER U.S. 1.						
OTHER U.S. 2.						
HOST COUNTRY						
OTHER DONOR(S)						
TOTALS	$1,750	-	$1,750	$2,700	-	$2,700

11. PROPOSED BUDGET APPROPRIATED FUNDS ($000)

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	PRIMARY TECH. CODE C. GRANT	D. LOAN	E. Thru 09-30/76 F. GRANT	G. LOAN	H. 1st FY 77 I. GRANT	J. LOAN	K. 2nd FY 78 L. GRANT	M. LOAN
(1) FN	141 J	953	-	$3,879	-	$1,750	-	-	-
(2)									
(3)									
(4)									
			TOTALS	$3,879	-	$1,750	-	-	-

A. APPROPRIATION	N. 3rd FY 79 O. GRANT	P. LOAN	Q. 4th FY 80 R. GRANT	S. LOAN	LIFE OF PROJECT T. GRANT	U. LOAN
(1) FN	$950	-	-	-	$6,579	-
(2)						
(3)						
(4)						
TOTALS	$950	-	-	-	$6,579	-

12. IN-DEPTH EVALUATION SCHEDULED: MM 01 YY 79

13. DATA CHANGE INDICATOR. WERE CHANGES MADE IN THE PID FACESHEET DATA, BLOCKS 12, 13, 14, OR 15 OR IN PRP FACESHEET DATA, BLOCK 12? IF YES, ATTACH CHANGED PID FACESHEET.

1 (1 = NO, 2 = YES)

14. ORIGINATING OFFICE CLEARANCE

SIGNATURE: Leon F. Hesser *Leon F. Hesser*

TITLE: Director, Office of Agriculture, TAB

DATE SIGNED: MM 01 DD 07 YY 77

15. DATE DOCUMENT RECEIVED IN AID/W, OR FOR AID/W DOCUMENTS, DATE OF DISTRIBUTION: MM DD YY

AID 1330-4 (3-76)

BEST AVAILABLE

RESEARCH PROJECT STATEMENT

A. Project Summary

1. Statistical

	Improving Irrigation Water Management on Farms
Contractor:	Colorado State University
Status:	Revision of AID/ta-C-1100
Total Estimated Cost:	Through AID/ta-C-1100 $5,144,000 Revision: 1st year -- 850,000 2nd year -- 900,000 3rd year -- 950,000 Total revision -- $2,700,000
Principal Investigators:	Dr. W. D. Kemper, Agronomist and Dr. Gaylord Skogerboe, Agricultural Engineer, Department of Agricultural Engineering, Colorado State University, Fort Collins, Colorado 80523 (303) - 491-8217
Project Manager:	Gilbert L. Corey, TA/AGR/SWM

2. Narrative Summary:

This project addresses through irrigation system improvement and rehabilitation the general problem of per capita food production and small farmer income. In part, the importance of this undertaking has as its foundation the need for irrigation or supplemental water to produce more of the worlds food. Its further importance is due to the fact that to get the most from improved seeds and from fertilizers, water correctly applied is essential. And, lastly, irrigation renovation and development is the key to widely dispersed quantum increases in food production. Development of improved irrigation systems and water management schemes are, therefore, basic to moving food production forward on a sufficiently wide front and to raising the standard of living of the small farmer.

This proposal is a complementary combination of research, training, and technical assistance directed to improving irrigation water management on farms. To achieve this objective, water delivery, water utilization cropping systems, and drainage are looked at together as the "unit" of production. In a systems sense, each of the irrigation system components is made up of a number of interrelated parts. Measures of overall efficiency include yields, unit costs and returns, and efficiencies of water delivery and drainage. These factors and relationships, considered as a total package, constitute the research outlined in the proposal.

Although huge investments have been made in irrigation systems, there is no systematic means to evaluate the efficiency and effectiveness with which these systems deliver water in response to plant needs, to diagnose weaknesses and failures in the system and to test and prescribe technologies for improvement. This project addresses that void.

Over the past five (5) years the Colorado State water management research and development activity in Pakistan has concentrated on water management improvement technology with direct farmer application. This has included rehabilitation of delivery systems (channels and operational rules and regulations) which transport water from a governmental managed system (main canal, well(s), and/or storage facility) to and among farms and fields; the physical network and problems associated with moving water and uniformly spreading it within cropped fields; improved agronomic practices that will result in better crop stands, increased crop yields, and more effective use of fertilizers; and the operational ules and regulations and pricing structure that are needed to manage the system for optimal use of resources. Implementation of proven water management practices on farmer's fields in Pakistan has and will remain one of the most pressing problems to be dealt with in successfully concluding the research program.

Thus far, the project has through field experimentation a) developed a reliable, inexpensive, farmer acceptable and farmer constructed method of improving the water delivery system among and on-farms; b) demonstrated the value of small water control structures; c) determined the benefits of land leveling and demonstrated its effectiveness in increasing production and reducing water waste; d) described the traditional farmer constraints to acceptance of improved management; e) created an awareness among the government of Pakistan and donor agencies of the potential impact of water management improvement on food production and farmer income; and f) given assistance to indigenous research organizations resulting in more attention being paid to water management research in Pakistan.

The technologies of water delivery channel improvement, land leveling, and field reshaping have been demonstrated to increase the water availability to the farmer by at least sixty percent. Improved crop husbandry, fertilization, weed control, and precision planting result in at least a doubling of crop production when coupled with the increased available water.

Several technical publications have been prepared under the project. The irrigation system in Pakistan has been thoroughly described. The farmer water management problems have been delineated as well as his own perception of these problems. Several papers describe various technologies for improved water use including an analysis of water user associations, water use by specific crops, water measure-

ment and control, fertilizer water interactions, and irrigation water control structures. In total some forty-five publications have been developed under the project.

This project extension will continue to package the results of this work into documents for effective utilization, both in and outside Pakistan. Principal outputs intended are:

a) The description of a systematic approach (model) for developing countries to use in analyzing and diagnosing the inefficiencies of their irrigation water management systems, and selecting appropriate remedial measures, and identifying the processes of implementation.

b) The completion of a series of technical publications describing water management related technologies, organizations, and activities which have or will have been proven effective.

c) Some technical assistance in the form of TDY by project personnel to Missions who are identifying on-farm water management problems, developing programs for potential solutions and evaluating water management programs.

Water management improvement with its biological, physical, socio-economic, physical and political components is a highly complex development process. It is one which historically has been approached by single factor analysis. This project has, however, evolved through an interdisciplinary approach which considers all aspects. These products therefore are not mere descriptions of separate technologies which may or may not fit singly or jointly into a given situation. They will include a synthesis of training needs and methods, institutional requirements; social, economic and environmental impacts; as well as the detailed technical description of the physical processes and the suggested diagnostic and remedial measures.

The laboratory for this project includes three field sites in Pakistan where "pilot" studies are being conducted. Local currency funding is provided by the Mission and Pakistani institutions are directly cooperating. These studies involve direct application, analysis, and evaluation of the development processes under normal farmer conditions and constraints. The recently implemented AID "On farm Water Management" loan program is an important vehicle for evaluation and development of various components of this research. This project is a five year pilot program to establish capability within government agencies, private contractors and farmer groups in planning and carrying out activities necessary for efficient on-farm water management. Research findings, from this contract, and new management procedures will be used to improve watercourses, level farm fields and to improve farmers crop and water management practices. The field research team will carefully monitor key aspects and will be directly

involved with development, testing, evaluation and refinement of the various training and institutional requirements necessary for successful implementation and maintenance of improved water management programs.

The on-campus component of the research will include the development of the information transfer process ((a) above) and the packaging of technologies into a readily useable format. Experiences, data, and the expertise of the Utah State research contract and the Consortium for International Development (CID), will also be utilized through workshops and data exchange to take advantage of all the research and development experience at AID's disposal.

Since this requested extension is focused toward "packaging" the project outputs for utilization elsewhere, it will be necessary for project personnel to become familiar with on-farm water management situations in other LDC's. Project funds will therefore be utilized to provide technical TDY assistance to missions developing and/or evaluating on-farm water management improvements projects.

Selected LDC officials will be brought to Pakistan, as early as winter 1977, for an introduction to the project and an analysis of what the on-farm water management process involves. This step will be helpful for later utilization of research results since there are several items such as pricing, governmental organization, and farmer constraints which need to be analyzed on site before an implementation of the technology can successfully be undertaken. The selection of the LDCs to be involved will be accomplished through Regional Bureau, Mission, and TAB discussions in order that those most likely needing this development will be involved.

B. Research Purpose and Expected Products

1. The purpose of this project is to develop and evaluate guidelines for efficient control and effective irrigation water utilization measures considering physical, economic, social and institutional constraints confronting farmers. Project accomplishments thus far include: (a) documentation of farmer water management problems which led to an awareness of their serious nature and the potential effect food production of developing remedial measures; (b) development, testing and evaluating several technologies for improving water management such as watercourse renovation, land leveling, water measurement and control with simple low-cost structures, fertilizer - soil - water interactions, cropping patterns as related to water use and availability, small tubewell operation techniques; and (c) an evaluation of the problems associated with institutionalizing and orchestrating an integrated improvement program into the socio-economic environment of the farmer.

   Yet to be accomplished is the completion of the evaluation of these technologies and information into a delivery, utilization, cropping and water management system which includes the farmer as an individual

manager and as an institutional representative. The implementation and maintenance requirements for the entire development process need to be analyzed and developed into an information transfer process useful to LDC's. An integral key component will involve the training requirements necessary for successful problem diagnosis, project development and implementation.

2. This project renewal fulfills the following two use objectives:

   a. To meet the desire of AID to be responsive to water management problem identification, technical and economic assessment, and technical and financial "packaging" world-wide.

   b. To help identify and provide technical, research and training support to Pakistan agricultural development systems based upon or geared to water management - in both a decision and action dimension.

   An evolvement of the project is development of an "information transfer" mechanism of an applied nature which can be generalized. The mechanism will describe how a country systematically: discovers the factors responsible for ineffective water management; quantified them and shows their major relationships with each other and with other production and management factors; and organizes to lessen the limiting inefficiencies. The methodology will include a problem identification and decision model covering (a) building and maintaining effective, economical water channels and on-farms; (b) developing and maintaining the on-farm irrigation system; and (3) utilizing the saved water to increase production or to reduce the design quantity of flow into the system.

   It should be recognized that the description of the transfer process and the improvement technologies relating thereto also includes an description of the training requirements necessary to properly accomplish the development process. This refers to training requirements, techniques and materials necessary for LDC personnel to diagnose their problems, as well as to build and maintain a improved irrigation system. Elements needing various forms of training include farmers, extension specialists, program implementors, and key governmental planners and decision makers.

C. Significance and Rationale for the Research

LDC's and donor agencies have placed emphasis on improvement of irrigation water management as a means to increase food production throughout the world. The sixteen(16) donor countries making up the Organization for Economic Cooperation of Development committed almost 20 percent of their agricultural development funds in 1973, and over 30 percent in 1974, to

water development. This amounted to about $360 million in 1973, and $855 million in 1974. AID's 1976 budget submissions contain over $100 million dollars committed to water management related projects.

Even though large financial resources are being directed to solving the problem of water management, no systematic approach to evaluate irrigation systems, analyze weaknesses and failures, and prescribe technologies for improvement has been developed. Instead, each system becomes a case study where improvement programs are developed within a very short period of time, utilizing little more than the experience of the project developer, which most frequently has resulted in capital-intensive "hardware" projects that treat the symptoms rather than the real problem(s). This approach generally ignores the farmer, his attitudes, knowledge, and constraints. This project directly addresses this problem in a total development sense.

The central focus of the water management research activities in Pakistan has been the development of an innovative research process which has helped formulate relevant technical and socio-economic specifications in four major areas: 1) on-farm water management problems and farmer involvement; 2) policy-planning decisions on water and farm production questions; 3) training and institution building; and 4) information transfer processes for other LDC's where irrigation is a required input for crop production. Pakistan has been and will continue to be a laboratory and a learning experience for improving the "state of the art" on knowledge and techniques required for improvement of on-farm water management systems.

Pilot programs have demonstrated that with precise land leveling, rearrangement of farm fields, and betterment of the canal, farm watercourses losses can be halved. These improvements are economic and farmers are enthusiastic. The Government of Pakistan and donor agencies are developing programs to extend the research findings. Agency for International Development's loan program will extend the technology to 60,000 farms and a World Bank program will develop a strategy to improve the entire 25 million acres within the system.

The project impact on Pakistan is impressive, but the possibility of transfer of the research, training, and implementation process to other countries is tremendous. Presently, the Mission in Egypt is awaiting approval of an On-Farm Water Management project to essentially replicate the Pakistan experience. Given the experience gained in the Pakistan field laboratory, a data base and methodologies have been developed which, given certain refinements to be made in the next three years, can advance on-farm water management research and development in all irrigated regions of Pakistan and other LDC's. The refinement and formalization of this research and development process into a general framework is now required.

D. Plans to Coordinate and Link Research

This water management research program has resulted in a keen interest in Pakistan among the government and farmers in developing improved irrigation water management practices. The USAID Mission in Pakistan has

developed an On-Farm Water Management loan to put to practice some of the results of the research. An important outgrowth, also, is the implementation of an extensive watercourse survey by the Water and Power Development Authority (WAPDA), financed by the World Bank, and UNDP, which extends the watercourse surveys developed under this project. Intensive data will be collected on water losses, cropping patterns, water requirements, water scheduling, farmer practices, attitudes and constraints. A great deal of training of local technicians will be required on both the AID and World Bank studies. The Colorado State University field team will be directly involved because of their familiarity with needs but also the experience is necessary for their development of training requirements, techniques, and materials. Also, the evaluation and refinement of appropriate technologies and the implementation process under the AID loan program will be utilized in conjunction with the results of the expanded watercourse surveys in developing a strategy for extending improved water management practices throughout Pakistan.

Development of the transfer model will require utilization of data bases and experiences from other projects. Colorado State University will need to coordinate with the Utah State research project which has collected much data in Latin America. The Consortium for International Development (CID) state of the art water management studies will also provide an input. The water management improvement project in Egypt will be closely monitored since in a sense it is a replication of some of the research and development aspects of this project. And finally, the research team will be involved in development of water management improvement projects for AID. Specific projects to be included will be selected by TAB, Regional Bureaus and Missions through a study of on-going and proposed projects.

E. Plan to Facilitate Utilization of Research Results

Extension of project development to a world-wide basis is now required. There are many countries where similar large-scale rehabilitation of watercourses and improved on-farm irrigation water management practices can greatly increase the food production potential.

During the proposed three-year period of development, refinement, and articulation of the required development process, the research methodology will be directed to utilization. The project is at a point where the worth of the technologies have been demonstrated, and, now, the utilization methods become the major thrust.

Water management and its improvement involves a complicated set of parameters. Social and economic factors could outweigh the technical ones. Farmers must make decisions before change is made and these are not mere on/off decisions of use or not use. They are management decisions involving the physical system, association with fellow farmers, and relationships with governmental institutions. Therefore, utilization

cannot be achieved by mere presentation of a technology e.g., a seed, a bag of fertilizer, a machine. A management process is involved. This research project is, however, proving that given proper time for maturing of correct techniques, enthusiastic utilization is possible.

The following project activities relate directly to utilization:

a. Manuals (handbooks) will be developed for LDC technicians and water management planners. These will include a description of the entire development process from problem identification, technology development, testing and implementation (the transfer model), as well as the by-product outputs described under B. above.

b. The training of LDC technicians is essential for implementation and/or utilization. The process of development of training requirements, materials and techniques will involve actual scheduled training sessions. These sessions will be for the Pakistani personnel who will be key implementors of the AID loan program and the IBRD watercourse studies. Colorado State University project personnel involvement will include training trainers, developing training materials, specifying training needs, and generalizing requirements for other LDC situations. Where applicable, needed, and timely, other than Pakistani technicians can take advantage of training workshops in Pakistan. A good example might be the Egyptian study where technician training will be necessary by mid-77 while developing the training capacity in Pakistan, Colorado State University will evaluate the possibility and feasibility of creating a regional or international training capacity in Pakistan.

c. Colorado State University has a technical assistance capacity resulting from personnel closely involved with the project. This expertise will be sorely needed to produce the outputs of this project; however, limited technical assistance to AID in project development (this was done on the Egypt project) will be available through this project since project development experience is necessary to develop the transfer model. The Consortium for International Development (CID) will familiarize several key scientists with the project so that related project development assistance undertaken by CID for AID will be capable of utilizing the outputs of this project.

d. Near the end of the first year a workshop will be held in Pakistan. LDC officials from countries either presently involved in water management programs or where such programs are contemplated will attend. The country selections will result from an analysis made by Regional Bureaus and TAB with appropriate Mission concurrence. Participants will be presented the technical aspects, potential benefits from the technology, and a general scope of work necessary to implement a program in a specific place. A working textbook will be developed for this activity.

An international seminar will be held near the end of the project to present all developed project materials to the development community.

F. Management Considerations

1. Management responsibilities: The Soil and Water Division of TA/AGR will be responsible for overall project management in AID. The project officer will play a key role in coordinating the activity, providing a technical input, and assisting with work plans, annual reports, and publication reviews. The annual work plans will be developed in detail approximately three months prior to the start of the contract year. They will be developed with host government and Mission cooperation and approved by the Mission, the contractor, and TA/AGR.

2. Non-contract project funding: - The Mission in Pakistan has been cooperating actively with the project from the outset. All contract housing, office, local hire, transportation, and local purchase support has been furnished by the Mission. In addition, field research studies have been financed locally through Project Agreements with the Ministries of Fuel and Power and Agriculture. Total local currency support to the project averages approximately $400,000 annually with the logistical support to contract personnel accounting for approximately one-fourth of that total. This support is expected to continue.

   The AID loan program in Pakistan and the IBRD watercourse evaluation project although not a part of this research project, provide excellent opportunities to test techniques under actual implementation conditions. The contract researchers are expected to work closely with these two programs.

3. Evaluation concept: - Annual evaluations will be made just prior to development of the annual work plan. These evaluations will be conducted by TA/ACR, and the Mission, with Regional Bureau representation. They are to be considered as tools for better communication and guidance for development of the annual work plan.

   A comprehensive formal evaluation will be held between the 18th and 24th month of the contract. This will be done by a team of experts who will intensively review field and campus activities to make recommendations on progress and any special needs for completing the outputs. An evaluation will be made at that time regarding the need for further TAB inputs relative to the utilization of this project on a global scale.

4. Special clearance and information distribution requirements:

   - The Contractor will be required to make requests for TDY assignments at least one month in advance of proposed travel. The request will contain the detailed itinerary, biodata, and a explanation of what the traveler is to accomplish and how it fits into the work plan. Reports prepared after completion of TDY assignments are to be submitted to TA/AGR, the Mission, and the host government agency involved.

An annual technical report will be prepared containing the details of all activities including data, reports, action, fiscal or other problems and associated activities. This report is considered to be a working document and not to be a replacement for the widely distributed brief annual report presently called for.

5. Contractor selection: - The contractor will be sole source, Colorado State University, obviously since they are in place, have the data bank, the knowledge and the expertise capable of producing the outputs within the contract period.

G. Technical Review

One of the highly desirable and beneficial aspects of irrigated agriculture is the possibility of total control of the water. Plants can be provided needed water at the time and in the amounts needed. Supplemental irrigation systems have, in recent years, been utilized in rainfed agricultural areas to provide additional water when unpredictable natural precipitation is deficient. In many areas, this is economical because of the increased production possible with a reliable source of soil water. Therefore, even though the area of irrigated land, less than 15 percent of the cultivated land in the world, represents a rather small portion of the total agricultural land, the production from it and the increased production from supplemental irrigation systems represent a highly significant food producing potential -- one which should not be ignored.

The amount of irrigation water actually used for crop growth in a given area is usually only a small proportion of the amount of water being diverted into the irrigation system. Irrigation water use efficiency is, even today, low in almost all areas of the world. There are several reasons for this. Seepage and evaporative losses, operational waste and spills from inadequately maintained ditches, undesirable vegetation growing along and in the channel distribution systems, and improperly designed and constructed farm fields all take their toll. The operational rules and regulations under which the farmers operate also can contribute to waste if the water is not available to the farmer when needed. These factors are all related to the water management practices on the farm and among farms and fields.

The physical irrigation system consists of a collection point for the water, which sometimes includes a reservoir, a conveyance system which carries the water from the source to the fields and a system which applies it to crops. The complexity of the entire system is quite variable, depending upon the number of farmers served and the structure of the organization managing the system. Usually, construction and maintenance of the reservoirs, dams, large canals, and diversion structures are handled by an agency of government and present no technical problems. Delivery losses of water through the main canals are mostly confined to seepage losses, which are controlled by lining the cannels with suitable materials.

In most canal systems, especially those in LDCs where individual farms are small, there is, leading from the main canal, a system of smaller channels which carry the water from the canal to the individual farms. These channels are called watercourses or laterals. This "sub-system" is the portion with which the farmer works and over which he usually has control. Often the group served by a watercourse is totally responsible for its construction and maintenance.

This terminus of the irrigation system is where the crops are grown and where the economic benefits of irrigation are realized; and yet it is the portion which is most often neglected by developers and builders of irrigation systems. The losses here include seepage and operational waste from inadequately maintained and constructed ditches. The waste due to leaks and overtopping usually far exceeds the direct seepage losses.

Once the water reaches a given farm there is usually an additional ditch system which carries the water to each individual field. In many cases this also is a rather extensive system since, even on small farms, individual fields (irrigation units) tend to be very small. The individual field itself becomes the last portion of the conveyance unit transporting water from the source to the root zone of the crop. Here, also, there are losses associated with imprecise leveling, over-irrigation, or improper scheduling of the time of application.

The losses of irrigation water which occur from the main canal to the root zone usually far exceed those losses in the main canal itself. This is true of practically all systems throughout the world. It is not unusual for more than one-half of the water supplied by the canal to be lost and therefore not available for plant growth.

Less than 15 percent of the 3 to 4 billion acres of cultivated land in the world depends totally upon irrigation. This might suggest that irrigated agriculture plays a minor role in the world food budget. The President's Science Advisory Committee in its report on the world food problem in May 1967 pointed out that "when distribution of irrigated land and arable land over the world is related to the distribution of world population it becomes apparent that a large fraction of the world's people living mainly in diet-deficient countries are heavily dependent on irrigation for food -- nearly 2/3 of the world population lives in diet-deficient countries having less than 1/2 of the arable land and about 3/4 of the irrigated land."

Irrigated agriculture, with all its benefits, does however possess inherent problems. Water, however pure, added to the soil contains some dissolved salts. Continued application over a prolonged period adds significant amounts of salt to the soil profile unless proper management steps are taken. The preferred practice is to apply somewhat more water (about 10 percent) than is needed for plant growth so that salts are leached down into the soil profile below the root zone. However, in most cases, too much water is applied and the amount of over-irrigation is significantly greater than the necessary leaching requirement of approxi-

mately 10 percent. This excess application can eventually create a problem requiring construction of drainage facilities to remove excess sub-soil water. In areas having flat topography, the drainage works need to be extensive covering most of the irrigated land. The salt (salinity and alkalinity) and the high water table (waterlogging) problems are peculiar to irrigation projects and the severity of these problems are directly related to management of the water. When the conveyance system is improperly constructed and maintained, and the irrigated fields are not precisely leveled nor irrigated at the proper interval, there is a great waste of water. Most of this water finds its way to the body of water living beneath the surface, causing it to rise and hastens the day when waterlogging and salinity cause the area to be abandoned.

The FAO/UNESCO International Source Book on "Irrigation, Drainage, and Salinity" indicates that -- in typical earth channels, under usual conditions, about one-third of the total water diverted will be lost by seepage, operational waste and evaporation. Erie in 1968 found on a cross section of 22 irrigation projects in the U.S. that the overall project use efficiency from the dam to the final irrigation process is 36.1 percent and of the amount delivered to the farm, 42 percent is lost through the irrigation process. It is apparent from these studies that wastage of water within irrigation systems is a common problem throughout the world.

The provision of adequately trained personnel for the management of irrigation systems to overcome the above mentioned problems is required, but will be difficult to accomplish. Much focus must be given to training not only the engineers and technicians, but those who work directly and indirectly with the farmer. Although agricultural experiment stations may exist, there is usually a severe limitation in accomplishing on-farm improvements, because of insufficient adequately trained farm-level advisors capable of transferring applied research results directly to the farmers. In many countries, the components of research and advisory services have never been brought together in a carefully planned relationship.

There is an awareness of the need for improved delivery systems for technology once it has been made available by research. How best can this transfer of technology in water management be made to the end user, the farmer? Some extension system is required which will take the proven findings of research, along with utilizing the knowledge of the social sciences "package" in such a way as to convince the end user to move from the trial to the final adoption stage.

The benefits appear to be so important that a great deal of effort should be placed on trying to solve these water management problems. One of the resolutions proposed by a group of LDCs at the recent World Food Conference addressed itself to the necessity of directing increased attention to this problem. Therefore, there now appears to be a worldwide recognition of the problem. Some of the major benefits that could be realized by successfully implementing improved irrigation water management practices are:

a. Irrigation water saved through proper management is perhaps the greatest source of water available to agriculture -- it is presently in the canal ready for use.

b. Proper management increases production of the acres presently being irrigated, but even more importantly provides additional water for additional acreages.

c. Salinity, alkalinity and waterlogging problems are relieved by good management practices. In fact, these menances cannot be completely controlled without proper management.

d. If proper on-farm management of water can be accomplished by a group of small farmers, it will create a cooperative atmosphere among farmers and between farmers and government. This would have several benefits in other areas where such coordination and cooperation is vital. A successful program involving small farmers would also accelerate the diffusion of these new technologies upward to larger farmers (which would be a correction to the invalid trickle down theory)

e. Equitable distribution of irrigation water will be accomplished with each farmer getting his share of the resource.

f. Development of a management attitude (rather than simply constructing "hardware" facilities) that would permeate the farming community, agricultural service personnel, and government planners.

g. If a transfer mechanism can be accomplished for this technology, the process should be applicable in other situations for other technologies such as soil management for soil water conservation in rainfed agriculture, range management, erosion control and other systems requiring management effort among a group of people.

AID sponsored water management research has accomplished significant results which relate to the proposed direction this project now should take. These accomplishments are summarized below:

Problem Identification: Much of the research effort has dealt with studies to identify the problems of on-farm management problems previously mentioned; i.e., low irrigation application efficiencies, canal seepage, spills and evaporative losses, lack of land leveling, excessively long watercourses and poorly shaped fields, high water tables and salinity hazards, physical, human and institutional constraints, etc. All of these management problems have been thoroughly identified, evaluated, and described by Clyma in the published Field Reports. These studies form the basis of specific research projects currently under investigation. Measurement of 64 individual field cases has shown that application efficiencies ranged from 0 to 100 percent and that the median was an extremely low 20 percent.

Rehabilitation of Watercourses: One watercourse on the Mona Reclamation Experimental Project has been completely lined (25,000 feet) with three experimental linings, one of brick in a rectangular shape, one each of brick and conrete in a trapezoidal shape. The ditch is elevated on a pad so that all conveyed water can be eventually discharged by gravity into the fields served by the watercourse. Performance evaluation of both liners and watercourses is continuing. At Lar, near Multan, another watercourse is partially rehabilitated (2000 feet). Construction after a 5-1/2 month delay in making loan arrangements was completed in one month during June, 1974. Average farm size is 12.5 acres. A demonstration of watercourse rehabilitation, land leveling, relocation and re-shaping of fields on 12 acres of Shadab near Lahore has been highly successful. Wheat production during the winter crop season of '73 - '74 produced 50 maunds (82 lbs, per maund) per acre on newly leveled fields, a yield that is 2.5 times the national average of irrigated wheat in Pakistan.

Precision Land Leveling: Procedures, development of equipment and training of personnel to level small f[illegible] are being accomplished as an integral part of watercouse rehabilitation. The ultimate objective is to complete 2 or 3 pilot operate watercourses that can be evaluated as a completed irrigation system. Direct comparisons of efficiencies and crop production with unaltered benchmark watercourses are planned.

Tubewells: A pilot skimming well has been constructed to determine feasibility of pumping "sweet water" that overlays highly saline water at deeper depths to augment water supplies along watercourses. The facility provides for field validation of skimming well theory. Tests were conducted in February, 1975 and are continuing. Economic evaluation indicates that tubewell discharge should be no more than one c.f.s. for most efficient operation. In fact, studies by Colorado State University are showing that based upon technological, economic and social considerations, emphasis should be placed upon the development of small tubewells having a discharge capacity of less than one c.f.s. This would allow considerable private development and facilitate participation by the small farmer, as well as providing less saline water supplies. (In contrast, the "hardware" approach has led to the construction of larger tubewells having capacities of 2-5 c.f.s.).

Improved Irrigation Structures: Leak resistant turnouts and drop structures have been designed and developed to control release of water from watercourses at each farmer's field. Evaluation and improvements are currently being made. Emphasis is placed upon simplicity of design and availability of materials which farmers can use for on-site construction and installation.

Water Measurement: Cutthroat flumes developed at Colorado State University and being manufactured in Pakistan have been used intensively to measure watercourse seepage losses. This has brought an awareness to

Pakistan administrators and engineers of the potential for increasing water supply through watercourse rehabilitation. These flumes eventually will become an integral part of the rehabilitated watercourse to measure water onto farmers fields.

Irrigation Scheduling: Consumptive use as determined by conventional soil sampling techniques has shown that wheat, berseem, cotton and cereal crops use 22.6, 29.0, 33.9 and 18.5 inches, respectively. Also procedures for calibration and application of the Jensen-Haise evapotranspiration equation to estimate consumptive use of the major crops in Pakistan has been developed. The method utilizes maximum and minimum temperatures, solar radiation and rainfall and crop coefficients developed by Jensen in the USA. The crop coefficients must be checked against soil, crops and climate conditions in Pakistan to develop valid scheduling procedures to satisfy crop and leaching requirements.

Benchmark Surveys: Data related to farm resources, cropping patterns, irrigation practices, farmer constraints, farmer attitudes, crop yields, and cropping patterns are being completed on 4 experimental watercourse and 6 other watercourses to establish the "before" conditions. These factors will be compared to the "after" situation where watercourses have been fully rehabilitated and the irrigation system is complete. Approximately 165 farmers at MONA took part in the survey.

Physical, Human and Institutional Survey: To gain a better insight into just how farmers organize and operate a watercourse, information was gathered on operational procedures, and the complex social, human, political and institutional problems related to the state-of-the-art. This was done on 19 watercourse areas. This should contribute greatly towards the development of procedures and programs to ultimately implement proven soil and water practices on farm fields for more efficient utilization of soil and water resources on small farms. The report on this study will be used to refine the techniques for the state-of-the-art studies called for in this proposed project.

Water User Associations: Pakistan has no institutionalized system of water user associations by 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 solved by providing him an opportunity to formally organize with his neighbors to increase agricultural production by improving water management. The water user association can become the nucleus of mutual on-farm water activities pursuing objectives of equitable distribution of water, resolving disputes, watercourse rehabilitation, irrigation scheduling, assistance in land leveling, augmenting water supplies through tubewells and conservation practices, integrating water quality control through conjunctive use of ground and surface water and proper drainage and collection of fees and assessments. Studies thus far go beyond the context of irrigation in Pakistan and examine a range of organizational possibilities that have significance to ultimately developing a pattern of associations

for Pakistan. The organizational structures of five countries were selected to provide a spectrum of associations at the water user level. These five countries include the United States, Republic of Taiwan, Turkey, Spain and Argentina. The results of this work combined with the survey data cited above will provide the necessary guidelines for implementing water user associations on watercourses.

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II. Research Project Design and Methods

In general, the object of this research is to improve water management and crop production by identifying farmer constraints to improvement and by developing appropriate cost effective technologies which can be effectively utilized in the local environment.

Close working relations have developed with several institutions in Pakistan. Some of the cooperative programs are funded by the Mission, some through PL 480-USDA research funds, and still others by the local agency. The overall program, calling for cooperation among the several agencies has created a national focus on water management improvement which undoubtedly would not be possible by working with only one agency. Cooperative programs are ongoing with the Water and Power Authority (WAPDA), the Agricultural Research Institutes, the Punjab Agriculture Department, Lyallpur Agricultural University, and the Agricultural Research Council. Most importantly, all of the programs involve cooperation with the farmers.

At least ten watercourse areas have, or will be, identified for intensive research, implementing a variety of improvements, and post-evaluation of benefits to the farmers. In addition, an essential improvements program, recently undertaken, will be evaluated and refined; the primary purpose being to identify simple technologies that can be undertaken by the farmer with a minimum of technical assistance -- technologies that are readily acceptable by farmers and can be quickly diffused. AID's On-Farm Water Management Pilot Project will become a field laboratory permitting further study of the transfer process. This project involves a technological "package" which will be implemented on 1500 watercourses (600,000 acres). The package consists of improving watercourse channels, precision land leveling of croplands, improved agronomic practices, and additional extension services by water management advisors. This large-scale "pilot project" will require considerable effort by Colorado State University in developing training materials and training host country trainers, which in turn will train personnel for the variety of functions that compose this integrated package of improvements. An important aspect of this research program will involve efforts in organizing farmers on watercourses to effectively implement an on-farm water management program, as well as insure the continued usefulness of the improvements through effective operation and maintenance procedures in succeeding years. The AID On-Farm Water Management Pilot Project will be continually evaluated and refined in order to define a program that will be highly effective for increasing crop production by small farmers.

A major focus over the 3-year period will be given to several types of economic analyses to determine the cost/benefit ratios of alternative technologies and methods for watercourse improvements, increasing cropping intensities, and improving irrigation and cropping practices. These economic studies are of critical importance for policy makers in planning both short and long term research and development programs on a country-wide basis.

Water Management alternatives will be analyzed using cost-benefit methods to determine the relative value of various combinations of technologies for varying water supply situations over various time periods. These and other data provided the "economic analysis" for the recently approved water management loan project in Pakistan.*

Specific economic studies will focus on the following areas: (1) Economic benchmark studies of ten pilot experimental watercourse areas to document the economic benefit-cost ratios resulting from specific technologies. These studies will document the costs of labor and materials and determine the increases in cropping intensities, crop yields, and net farm income resulting from adaption of technologies; (2) Farm Management studies will ascertain alternative changes in cropping intensities and crop mixes to increase net farm income resulting from the increased water supplies due to reduction of water losses and improved field application practices. Special focus will be given to small and medium sized farms. These studies will provide a better understanding of risks and uncertainties confronting small farmers and the results will be immediately useful for both planners and extension personnel; (3) The costs of production of water from private (both diesel and electric) tubewells will be analyzed. The relationship between degree of utilization and availability and dependability of canal water supplies will also be studied. Data on the productive life of different tubewell and pump components as well as actual pumping rates will be collected and analyzed; (4) An intensive socio-economic benchmark evaluation will be made on a sample of the 1500 watercourse areas under the USAID pilot program and (5) A comprehensive, problem identification, study of 40 watercourse systems in Pakistan has already been accomplished. These studies contain several types of economic analyses and identify major constraints confronting farmers.

These studies, when complete, will provide detailed economic and social information and analyses which can be used to develop sound investment programs. The information will be site specific to Pakistan and the technologies will include only those studied; i.e., improved conveyances and structures, land preparation and improved cropping patterns to match water supplies. However, the methodologies and socio-economic analyses will be specified and documented such that replication of the process with site specific data can be accomplished expeditiously.

The activities an be summarized in broad categories including <u>utilization</u> (description of the improvement process), <u>training</u> (requirements and methods to accomplish the process), and the refinement of the technologies involved in <u>water delivery</u>, <u>water application</u> and <u>water quality</u>. Detailed activity descriptions are presented below. The previous studies in Pakistan have focused on the watercourse command area, which begins at the outlet from the distributary canal, as the focus, for evaluating

*See Echert, Dimick and Clyma, WMR Tech Report No. 43 CSU. "The Economic Analysis of Water Management Alternatives for Pakistan."

the irrigation systems. The watercourse channels, which are a part of the water delivery subsystem, are of critical importance in improving farm water management. The watercourse command area has the advantage of including all four of the subsystems in an irrigation system; namely, water source (e.g., tubewells), water delivery, water use (croplands), and water removal. Thus, the watercourse command area can be viewed as an irrigation substem.

1. Utilization - The major emphasis for the concluding three years of this project is the development of the research results into utilizable products. These outputs must be developed, tested, refined and presented during the life of the project and, or course, will include the various aspects discussed above.

   Activities relating specifically to utilization include:

   a) Evaluation and refinement - the purpose of this activity is to monitor on-going programs. This includes data collection related to: before and after water system losses, before and after cropping relationships, success factors of watercourse improvement projects, long-run changes resulting from watercourse improvements, quality of output of training programs, and institutional relationships for water management programs. These data will be evaluated to measure the direct and indirect benefits of watercourse development schemes. Based on the results obtained, refinements will be recommended to increase the efficiency and effectiveness of the existing programs.

This evaluation and refinement phase is the key link between an agricultural development program derived from research, and the implementation process for such a program. Evaluation and refinement involves not only a continual re-evaluation of the costs of the technologies being implemented, but even more importantly, a continual monitoring of the benefits and beneficiaries of the program. This is an activity largely involving economics, with assistance from the agronomists and agricultural engineers. However, the major output from this activity is refinement of the implementation process, which requires a strong interdisciplinary analysis with the social sciences (sociology and economics) playing leading roles.

In this regard, it is essential that CSU coordinate and cooperate with the Cornell project entitled "Determinants of Developing Country Irrigation Project Problems: A Multifactor Analysis for Improved Irrigation System Operation and Performance." That project will be examining in detail several specific Asian irrigation projects from a social and institutional standpoint. The two projects, CSU and Cornell, must share data, experiences, and methods of analysis in order to improve the outputs of each.

The USAID Water Management Loan Program will be monitored to document its successes (and factures). To accomplish this activity, a number of procedures must be established, which include:

i. Development of a program to gather water loss data on the watercourse before the improvement project and after the project. These data must be collected in a consistent manner and compiled in a standardized format.

ii. Development of a program to gather cropping production and intensity data in order to document benefits/costs directly attributable to the program. These data also must be collected in a consistent manner and compiled in a format amenable to computer analysis.

iii. Collection of data related to success and failure on the different watercourses so that it is possible to pinpoint important prerequisites for success.

iv. Design and implement a program to evaluate the skill acquisition, application of skills, and job performance of the watercourse engineers and water management advisors.

v. Measure the overall success of the watercourse improvements in terms of total number of watercourse improved, utilization of the additional services provided and adoption of improved practices.

vi. Develop the statistical pool capability to take these large masses of data and to rapidly process, analyze and evaluate the results.

vii. To draw conclusions from the data evaluations that can provide direct feedback into the training institutions, water management cells, and USAID to make the refinements necessary to have a successful program.

The data collected will be evaluated and used to produce reports on water loss changes, as well as documenting the costs associated with the watercourse improvements. Benchmark surveys will be published on all pilot projects.

b) Development of the transfer process - in order to transfer the results of this research project to other LC's, considerable effort will be spent in developing the transfer process utilizing the Pakistan experience complemented by technical assistance by project personnel in other countries. This process of problem identification, development of appropriate solutions, and demonstrations on farmers' fields preceding full-scale implementation will be defined in sufficient detail that others could utilize the output in developing and implementing on-farm water management programs.

The development of the information transfer process will begin immediately since it involves the synthesis and articulation of all aspects of the project into a model which can be utilized by others in other places. A preliminary description will be presented to in selected LDCs, and finalized as the research and development phases are concluded and the technological components of the management improvement processes are formalized. The process (model) description will be developed by all disciplines involved in the project with assistance from AID/W and the Mission in Pakistan as representatives of the donor agency.

A by-product of the process itself will be development and refinement of those technologies which prove themselves at the test site in Pakistan. Manuals will be developed which describe in detail the problem identification process; precision land leveling; watercourse construction and maintenance; water user organizations; maintenance of water quality, crop water requirements and cropping patterns, and any other deemed necessary as the research progresses.

c) Technical Assistance and state-of-the-art - the apparent success of this particular program in Pakistan will undoubtedly create renewed interest in irrigation water management programs in other countries. One of the mostiimportant aspects of the water management research experience in Pakistan is determining the degree of transferability of the research results. Although there is considerable confidence that much of the research findings have value in other LDC's, this must be documented by and in other LDC's.

Contractor professionals and in some cases their Pakistani counterparts will provide limited technical assistance to AID for irrigation water management project planning and evaluation. Approximately the equivalent of one full-time professional over the three (3) year period, will be allotted from project funds for this purpose. Specific Mission requests will be reviewed by TAB and the contractor to determine relevance and availability of suitable technicians.

Two purposes will be served by this activity. The Missions will receive needed technical assistance for project development and/or evaluation and Colorado State will gain experience and data valuable in refining the transfer process and determining the transferability of the Pakistan water management project. It will also serve to aquaint project personnel with AID's project development process.

d) Presentation of results - utilization plans and activities begin immediately and become a major activity within this extension. All developed materials will be placed in a working textbook which details what is presently known about the water management improvement process. This "how-to-do" manual will become the means of describing the process to other LDC's. A workshop will be held at the end of the first project year to present this material to selected LDC participants. This activity will initiate a process of planning and development in some LDC's. As further and refined material is develop it will be given to

these LDC's and the final outputs will be presented at an international seminar near the end of the project.

Attachment B presents a visual description of these related activities.

2. Training - The Mission in Pakistan has asked Colorado State University to share with the SCS land leveling team the major responsibility for training materials, methodologies, and training assistance of watercourse engineers on the Water Management Loan Program. Colorado State University's successful attempts in train-water management engineers for previously conducted survey efforts have provided unique experience in the range of related activities.*

Selection of personnel training in an actual field situation, development of training materials, evaluation of training techniques, and training in preliminary data reduction activities and reporting techniques have been the major components of this experience. These experiences have provided some opportunities in testing training methods, design of training materials, and the evaluation of on-the-job trainee performance, as well as organizing programs which will be useful in the training of watercourse improvement engineers.

Another major training component involves the provision of special extension services to help farmers improve their present irrigation and cultural practices. Without competent extension advice and assistance, it is doubtful if the technologies of land leveling and watercourse rehabilitation alone will result in substantial increases in per acre crop yields. Also necessary are sufficient prices for increased produce.

The goal of this activity is to train an extension worker to provide direct assistance to farmers in improving water management and crop production. To achieve this objective, it is necessary to develop, test, and refine a training program and explore means to develop institutional capabilities to administer this program in order to train sufficient numbers of water management extension specialists.

The following guidelines are anticipated in developing the training program for water management advisors; a) at least 60 percent of the intensive training at the "training center" will take place under field conditions on watercourses where improvement programs are underway and interactions with farmers can be practiced; b) classroom training will make much use of visuals, maps, charts, case studies, problem sets, method demonstrations and discussions utilizing project data; c) self-evaluation and other evaluative methods will be a continuous process during the training; d) formal evaluations of all trainees will be done during and at the end of the training period to judge progress and as feedback for improvement of training methods; e) six months of on-the-job training under careful supervision of team leader on watercourse to be improved; f) each trainee

*In the watercourse surveys for problem identification purposes, alone, 15 engineers were trained as well as 20 agricultural assistants and social scientists.

will be provided with a field note-book during training with instructions and guidelines for each task he is required to perform. This notebook will be updated as new materials are developed. This will become a Water Management Extension Field Handbook for water management advisers.

The Colorado State University Field Party will provide personnel assistance in design of the program, development of materials and methodologies for implementation and evaluation. Major inputs will be organization, development of training methods and materials, and training and evaluating trainers. Evaluation and refinement of the program will be major activities during both the classroom and on-the-job training periods.

The entire training project experience will be analyzed and developed into a manual which describes and recommends minimum training requirements for various aspects of the development process. The evaluation will include selection of trainees, methods for training, and content of material to be taught. Throughout the training exercise, the contractor will assay the possibility and feasibility of developing a world-wide or regional training center in the field of water management development.

3. Water Delivery - Watercourses in Pakistan delivery only about half of their supply to the field. Consequently on most watercourses there is a potential for increasing the water supply to the field up to 100 percent by reducing losses. Realization of this potential motivated AID and the Government of Pakistan to develop the Water Management Loan Program, a major component of which is the improvement of watercourses.

Watercourses are being improved using farmer supplied labor for earthen improvements and government supplied control structures, culverts, linings, etc. Selection criteria are being evaluated in terms of the effect of these criteria on achievement of the watercourse improvement.

Expertise and training requirements to achieve the improvement will be defined. Increases in water supply due to the improvement and costs of the inputs will be determined. Improvement components to be evaluated and refined include: control structures, culverts, materials for erosion control, materials for low cost lining, buffalo watering and bathing stations, structures and components to facilitate water measurements, clothes washing and vegetable washing stations, sediment traps, etc.

Two basic programs will be tested as described below:

a. A series of watercourses will be reconstructed with concrete and masonry control devices at every junction and outlet, Existing banks of these watercourses will be removed and the watercourse will be reconstructed to proper channel size and elevation, compacting the earth in the banks by the farmers. These reconstructed watercourses will be designed on the basis of a complete topographic map of the area, measurements of the flow to be handled, the number and position of structures and culverts needed and basic principles of open channel flow. Engineers will be essential in the survey, design, alignment,

and structure installation. Farmers will be encouraged to organize their efforts in a range of informal to formal associations whose effectiveness in providing inputs and carrying out a maintenance program will be evaluated. As each watercourse is completed and evaluated, utilizing benchmark data compared with improved conditions, the lessons will be used to refine guidelines for furture watercourse improvement projects.

b. Since the number of engineers is limited, and there are many competing needs for their services as well as for scarce capital, an "essential improvements" program will be tested which involves minimum engineering and capital outlay. Losses at degraded junctions will be reduced by filling borrowed areas and bringing watercourse banks to proper cross sections. Observable leakage through banks will be stopped by simple core compaction techniques. Degradation and subsequent leakage due to animal traffic will be minimized by designing and constructing compacted earth watering and bathing stations and sediment will be controlled with earthen sediment traps.

One or two major junction will be improved with concrete control structures when the farmers have finished their earthen improvements and farmers will be given cost information in case they decide to invest in more of these structures. The professional services will be provided primarily by extension agents who have had special short course training and supervised field experience in this type of "essential improvement" program. Visual aids will be developed, tested, and used to help extension personnel motivate farmers. The method of taking leading farmers to see improved watercourses for conversations with owners of land on those watercourses will be evaluated, along with field days and other approaches as means for motivating farmers to employ improvements.

If this program has a higher benefit/cost ratio than the "watercourse" program it will be included as a low cost alternative in the water management loan project.

The output that can most easily be measured in the length of improved watercourses. However, this is only a small part of the story and documentation will be provided regarding technological and socio-economic parameters that measure direct and indirect benefits as well as the improved quality of life for farm families.

4. Water Application - Improvement of watercourses will supply increased amounts of water to the fields. One cannot simply assume however, that these increased supplies will authomatically be translated into increased production. Certainly they will not eliminate water shortages and water will still need to be managed as a scarce resources. The management practices which must be changed or instituted to best utilize the increased supplies will be determined. Changes in cropping mixes, criteria for irrigation timing, flexibility of water use and changes in other farm inputs will be required.

Past research has shown the importance of precise land farming as essential to efficient water application. Studies will be continued to determine the maintenance and educational requirements necessary to ensure that properly designed and constructed fields remain in good order.

The program involves research on specific questions of crop water needs in cooperation with research institutions. Obviously, it is not possible to include all crops and related variables in such a program. Therefore, a second phase involves synthesis of cropping recommendations and related cultural practices appropriate to the increased water supplies and field testing these practices with farmer cooperators as well as on research farms.

Experimental sites with irrigation capability have been selected at seven locations throughout Pakistan. Consumptive use values will be determined for major area crops under conditions of varying fertility and moisture stress. Calculations will be based both on measured soil moisture depletion and the Jensen-Haise equation for predicting potential evapo-transpiration.

In addition, by installation of simple hydraulic lysimeters, at one site only, direct measurements of crop evapo-transpiration will be measured and comparison will be made with values predicted by the Jensen-Haise equation. Combinations of such lysimeters will allow direct measurement of crop coefficients.

The required climatic data for the Jensen-Haise equation will be measured at each site. Throughout the life of this project a series of training sessions will be held at each location both to keep personnel updated on methodology and also to evaluate their procedures.

Several research activities in the past have been conducted at local research institutions. These have generally involved water and fertility variables and have generated a great deal of enthusiasm among local research staff for the potential of producing high yielding crops with less water. Cooperative efforts in this area will continue, particularly where the effort increases local capability and has a potential for payoff in practices easily utilizable by the farmer. Research on cultural practices designed to increase water use efficiency, particularly those aimed at improved stand establishment, will continue. Data from on-going and recently conducted fertility, irrigation and water quality research will be analyzed and interpreted in terms of potential benefits and risks to the farmer who might adopt these practices.

Only a relatively small number of crops and variables can be considered in intensive research programs. It is then necessary to formulate production systems based on the information gathered in these and other research projects, along with a knowledge of fundamental crop needs, the physical environment of Pakistan, and the needs and capabilities of the cultivators. The approach is to use water requirements as a focal point. Climatic records are examined and water needs for various crops as a function of time are computed for normal and dry years. Cropping

mix, planting dates, or irrigation practices can then be shifted to best match the available water supply to the needs of the crop. Such programs will be tested on research stations and in farmers cooperators' fields. The research component will consist of documenting the performance of the improved cropping system as compared to previous or unimproved systems.

The PL 480 sponsored consumptive use studies are scheduled for 5 years total (2½ years remaining as of April, 1977). All data will be compiled in an annual report from the PL 480 Coordinator's Office, Agricultural Research Council, Government of Pakistan.

The measurable outputs from the efforts for increasing crop production are: (a) development of consumptive use crop coefficients for use in irrigation scheduling and water use coefficients; (b) development of materials for use by extension personnel that will enable them to predict crop water requirements through the season and advise on cropping changes (these materials will also be used for training water management advisors); (3) three or four major reports are expected; and (d) a number of technical papers will be published.

5. Water Quality - A worldwide problem in irrigated agriculture is the "twin menace" of waterlogging and salinity. Over-irrigation on croplands and seepage losses from watercourses and canals reult in groundwater levels. In many areas, these groundwater levels reach the vicinity of the ground surface (within ten feet), which allows upward soil moisture movement from the groundwater to the soil surface. When this soil moisture reaches the ground surface it evaporates, leaving behind the salts that were in solution. This process of soil salinization results in lower crop yields, and in many cases, to the land becoming unproductive or even barren.

Earlier studies by Colorado State University on campus regarding the solution of gypsum into irrigation water for application onto croplands in order to reduce the sodium-absorption-ration (SAR) have been tested experimentally in Pakistan. These field studies will continue. In addition, field evaluations will be continued regarding the effectiveness of precision land leveling in reducing soil salinization. Also, farm cultural practices for reducing soil moisture salinity in the vicinity of emergency plants will be incorporated into the research program.

The primary mechanism that has been employed in Pakistan for alleviating waterlogging and salinity problems is the construction of tubewells. The tubewells serve a dual purpose a lowering groundwater levels, while at the same time providing additional irrigation water supplies. On-campus research has led to the development of analytical tools for designing tubewells to "skim" the less saline groundwater in the upper level of the groundwater reservoir. These analytical tools are presently being field evaluated in Pakistan.

Under this proposed research, field evaluations will continue of existing tubewells and Persian wheels for obtaining groundwater having satisfactory

quality (salinity) for maintaining agricultural productivity of the irrigated croplands.

I. Budget

Budget and manpower estimates from centrally funded sources as presented in the following table. The outputs requirements are divided into the same activities as discussed under research methods.

The Mission in Pakistan directly supports the project through local currency for field team logistical support and field research costs. The estimated dollar equivalent of this support is approximately $450,000 per year or $1,350,000 for the life of the project extension.

Additionally, the project field team provides technical assistance on consumptive use studies throughout Pakistan which are funded by USDA PL 480 funds in the equivalent amount of $500,000.

J. Environmental Impact

The entire intent of this project is to research and develop techniques for wiser careful management of resources. The problem addressed results in wastage of water, leaching of fertilizers, soil salt buildup, open ponding of water, and silt and weed laden ditches. On the other hand, wise use of the water and land resources reduces erosion, and salinization of soil and eliminates stagnant water collection points.

The activities of this project fall into the area described as "Analyses, studies, academic and investigative research, workshops and meetings" and thereby do not require the filing of an Environmental Impact Statement or the preparation of an Environmental Assessment.

K. Project Statement Evaluation

Attached to this Project Statement are comments received from Regional Bureaus during the review process. All suggestions have been incorporated into this final draft.

OVERALL COST ESTIMATES

INPUTS

	FROM: 04/01/77 TO: 03/31/78	FROM: 04/01/78 TO: 03/31/79	FROM: 04/01/79 TO: 03/31/80	TOTAL
1. Salaries	$432,000	$499,090	$524,000	$1,455,900
2. Consultants	2,500	3,500	4,500	10,500
3. Fringe Benefits	40,300	47,134	51,000	138,434
4. Overhead	171,000	196,000	208,000	575,961
5. Travel and Transport	64,476	27,485	59,025	150,986
6. Allowances	49,177	51,806	42,781	143,764
7. Other Direct Costs	48,897	45,000	41,794	135,691
8. Equipment	20,000	7,500	-	27,500
9. Research Operations	21,650	21,524	18,900	62,074
Total by Inputs	$850,000	$900,000	$950,000	$2,700,000

OUTPUTS	MM	COST	MM	COST	MM	COST	COST
Utilization							
Technical Assistance	14	$42,770	24	$82,740	27	$99,290	$2,248,000
Seminar	3	14,752	10	34,475	18	116,756	165,983
Evaluation	13	51,216	18	70,290	36.5	135,220	256,726
Transfer Process	35	107,071	35.5	121,274	36	131,765	360,110
Training							
Requirements Methods	26	$114,364	22	$89,954	14	$58,704	$263,022
Materials	19.5	85,800	19.5	79,755	12	50,316	215,871
Water Delivery							
Reconstructured Watercourses	53	$154,047	50.5	$159,476	48	$157,178	$470,701
Essential Improvements	20	80,480	19	60,028	16	52,393	192,901
Water Application							
Consumptive Use and Agronomic Practices	30	$104,430	30	$110,580	24	$98,454	$313,464
Land Leveling	10.5	36,539	10.5	38,711	8.5	34,884	110,134
Water Quality							
Skimming Wells	10	$41,810	10	$37,655	2	$7,520	$86,985
Soil Amendments	4	16,721	4	15,062	2	7,520	39,303
TOTAL	238	$850,000	253	$900,000	244	$950,000	$2,700,000

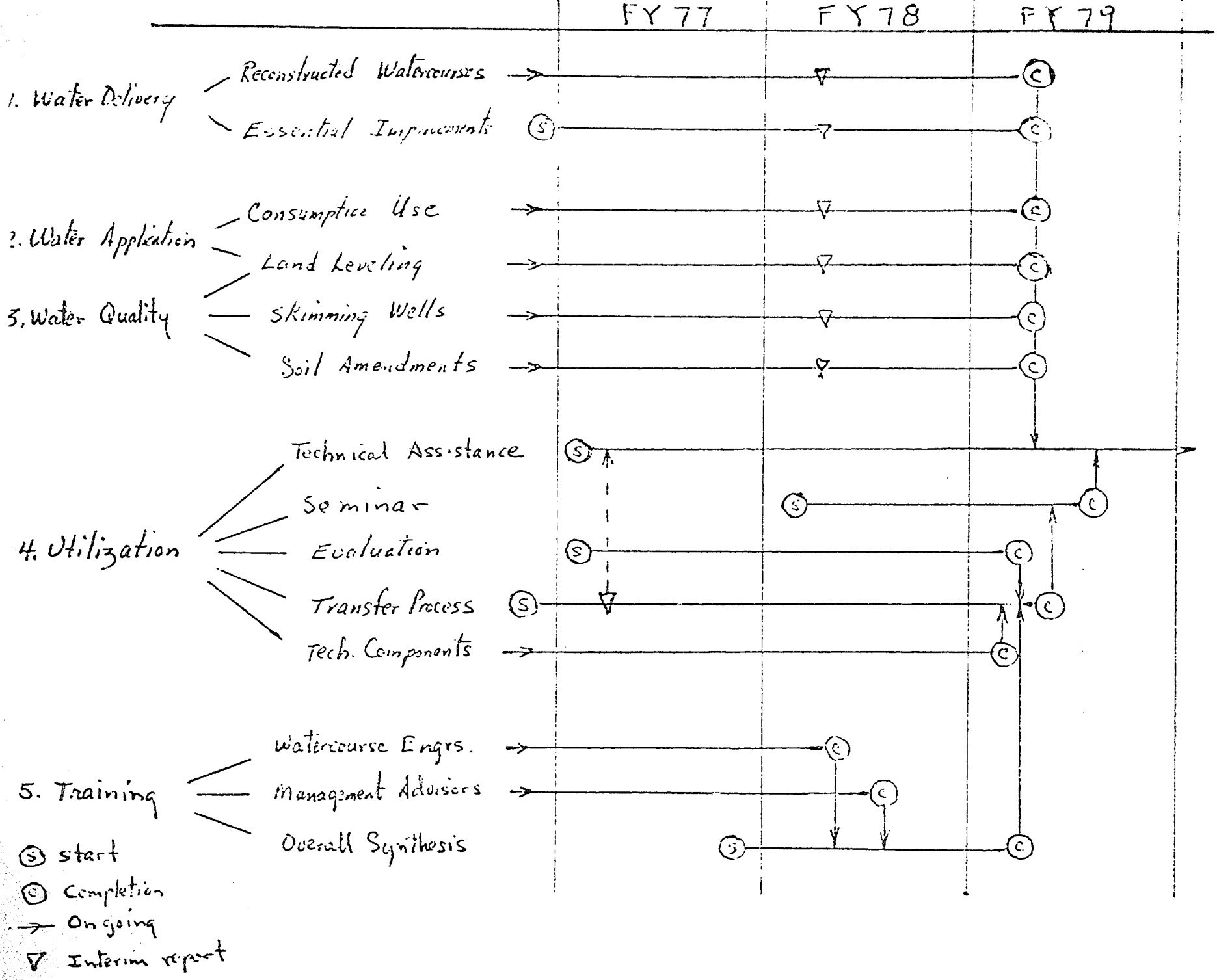
AID 1020-28 (1-72)

PROJECT DESIGN SUMMARY
LOGICAL FRAMEWORK

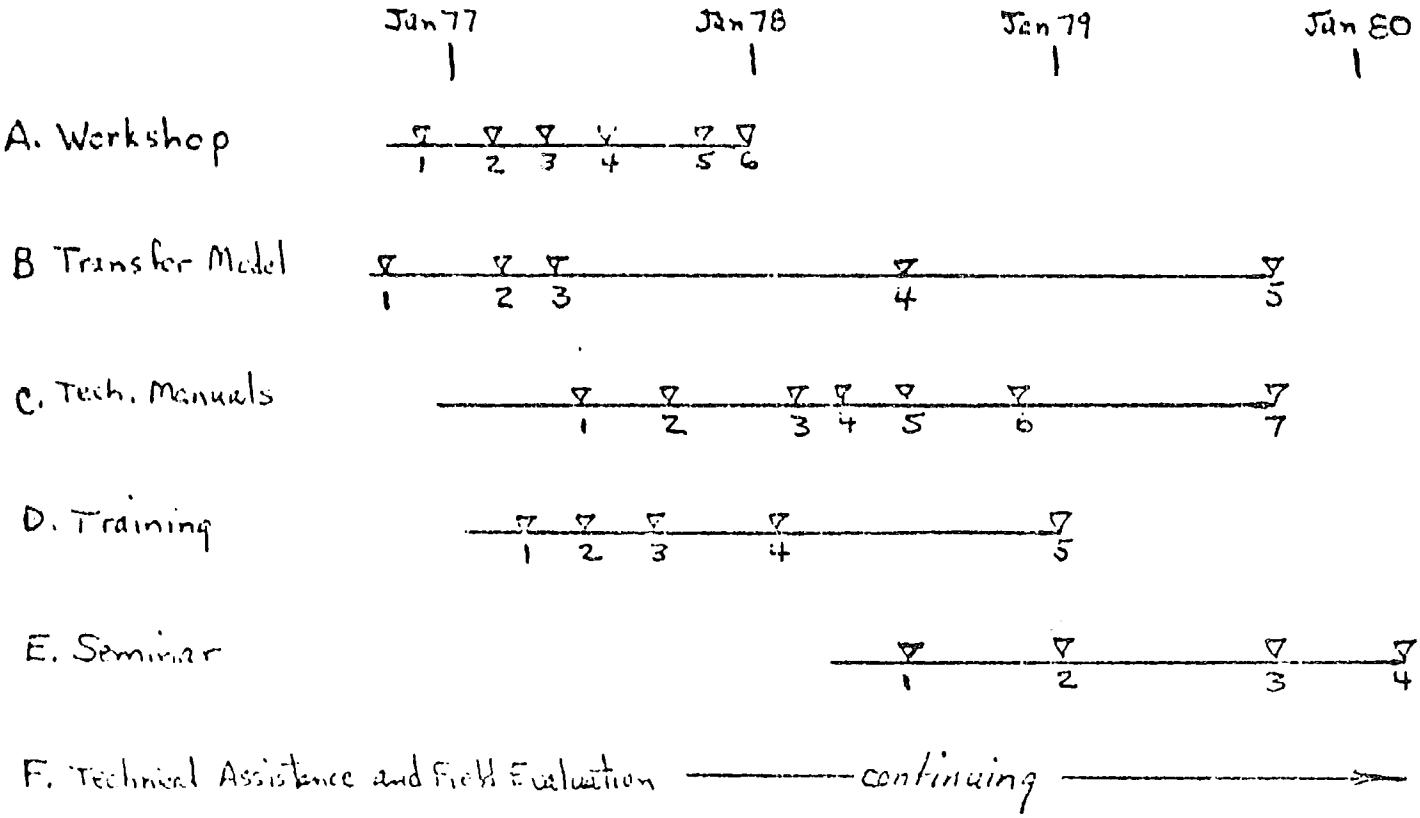
Life of Project: from FY 68 to FY 76
Total U.S. Funding $3,879,000
Date Prepared 22 May 1976

Project Title & Number: On-Farm Water Management AID/ta-C-1100

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Program or Sector Goal: The broader objectives to which this project contributes Increased food production focusing on improvement of level of living of rural families. Sub Goal: Elimination of water waste within irrigation systems.	Measures of Goal Achievement Increase in per capita food production in irrigated agriculture. Increased acreage cropped per unit of water.	Production and population statistics (GOP, Foreign Agricultural Service estimates, IMPs)	Assumptions for achieving goal targets LDC's will attempt to increase food production through on-farm irrigation water management programs.
Project Purpose Develop and evaluate design and implementation guidelines for technologies to identify and solve major physical, economic and institutional constraints confronting farmers in the efficient control and effective utilization of irrigation water.	Conditions that will indicate purpose has been achieved: End of project status 1. Cropping intensity increased 50 percent in pilot test areas. 2. Water wastage reduced 40 percent in pilot test areas. 3. Guidelines utilized in Pakistan. 4. Guidelines accepted by at least 2 additional countries.	1, 2. Pakistan IMP, GOP reports, contractors annual reports. 3, 4, 5. Contractor publications and AID/W documents.	Assumptions for achieving purpose: 1. Incentives sufficient to create farmer desire to utilize developed technology. 2. Government of Pakistan will provide needed professionals.
Outputs: 1. Proven techniques for: a) identifying farmer physical and socio-economic constraints, b) building and maintaining effective canal/farm and on-farm water channels, c) developing and maintaining efficient on-farm irrigation systems, and d) utilizing extra water supply to increase production. 2. Methodology to integrate water management technology into social and economic environment of LDC's. 3. Trained LDC agronomists, economists and engineers.	Magnitude of Outputs: 1. Three pilot test watercourse areas with all farmers participating. 2. At least 8 "how to do" documents published. 3. At least twenty trained personnel. Two training manuals indicating requirements and teaching technique.	1. Contractor reports. 2. Contractor reports, Mission records and reports, field reviews. 3. Contractor reports, field evaluation.	Assumptions for achieving outputs: Project inputs required of LDC will be timely. Host government personnel available.
Inputs 1. Farmer owned land and water supply. 2. LDC technicians (agronomists, economists, engineers) and farmers. 3. Professional personnel from agronomy, agri. engineering, economics sociology and extension. 5. AID funding and guidance.	Implementation Target (Type and Quantity) 1. Three watercourse areas with at least 10 farmers and 100 acres each. 2. At least 15 technicians and all farmers in test areas. 3. Eighty-four man months in field plus campus backup. 4. Approximately $600,000 annually, central and mission funds. 5. Annual work plan - jointly prepared by contractor and AID.	1, 2. AID/W and USAID records, Annual reports. 3. Field evaluation, annual reports. 4. AID/W records, field evaluation 5. AID/W records.	Assumptions for providing inputs: Government of Pakistan will maintain present enthusiasm. AID can supply timely funding and adequate project management support.


FY 77
FY 78
FY 79
1. Water Delivery
Reconstructed Watercourses
Essential Improvements
2. Water Application
Consumptive Use
Land Leveling
3. Water Quality
Skimming Wells
Soil Amendments
4. Utilization
Technical Assistance
Seminar
Evaluation
Transfer Process
Tech. Components
5. Training
Watercourse Engrs.
Management Advisors
Overall Synthesis
S start
C Completion
On going
Interim report

UTILIZATION PLAN SCHEDULE



A. WORKSHOP

1. Meeting with Regional Bureaus
2. Selection of LDC
3. Notification to Missions
4. Working textbook outlined
5. Working textbook printed
6. Workshop

B. TRANSFER MODEL

1. Initial outline
2. Provisional draft
3. First revision
4. Second revision
5. Final draft

C. TECH MANUALS

1. Complete abstract of present meet.
2. Watercourse manual draft
3. Problem ident. process draft
4. Land leveling manual draft
5. Farmer organization draft
6. Crop culture draft
7. Tech. manuals finalized

D. TRAINING

1. Initial discussions-regional ctr.
2. Evaluation of requirements
3. Plans developed
4. Materials drafted
5. Materials finalized

E. SEMINAR

1. Initial plan for review
2. Materials selected
3. Materials finalized
4. Seminar

COUNTRY	PROJECT NO.	PROJECT TITLE	DATE		APPROVED
TA/Bureau	931-0489	On-Farm Water Management - Colorado	12/22/76	XX ORIGINAL * REVISION # ____	

PROJECT PURPOSE (FROM PRP FACESHEET)

To develop and evaluate design and implementation guidelines or technologies to identify and solve water management problems at the farm level.

PRIOR ACTION: Seven years of Research in Pakistan (CSU-AID)

CPI DESCRIPTION

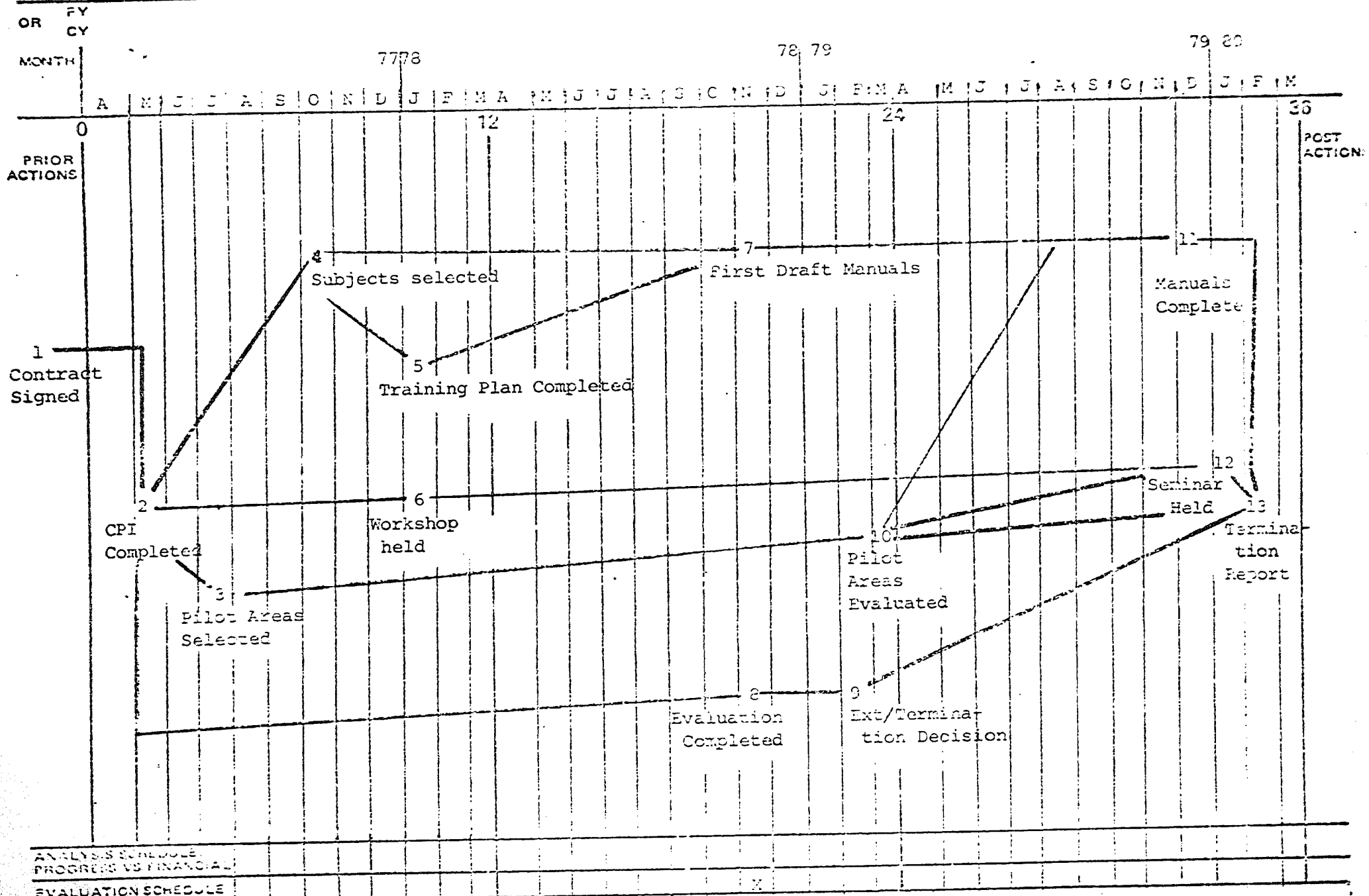
1. 03/77 Contract signed (CSU - AID/TA/AGR, PPU, SER/COM)
2. 05/77 Revised CPI network completed (CSU - AID/TA/AGR).
3. 07/77 Pilot Areas Selected (CSU)
4. 10/77 Subjects for Manuals Selected (CSU)
5. 01/78 Training Plan Complete (CSU)
6. 02/78 Workshop Held (CSU)
7. 11/78 First draft Manuals (CSU)
8. 12/78 Comprehensive Evaluation Completed (AID/TA/AGR)
9. 02/79 Extension/Termination Decision (AID/TA/AGR)
10. 03/79 Pilot Areas Evaluated (CSU)
11. 12/79 Set of Manuals Complete (CSU)
12. 01/80 Seminar Held (CSU)
13. 02/80 Termination Report Complete (CSU)

POST ACTION: Dissemination of Result/Manuals etc. (AID/TA/AGR)

CRITICAL PERFORMANCE INDICATOR (CPI) DESCRIPTION

*Tentative/Pre-Contract

COUNTRY	PROJECT NO.	PROJECT TITLE	DATE	ORIGINAL * / REVISION #	APPROVED
TA/Bureau	931-0489	On-Farm Water Management - Colorado	12/22/76		



CRITICAL PERFORMANCE INDICATOR (CPI) NETWORK *Tentative/Pre Contract

AID 1020-35 (6-76)

AGENCY FOR INTERNATIONAL DEVELOPMENT

PROJECT AUTHORIZATION AND REQUEST FOR ALLOTMENT OF FUNDS PART I

1. TRANSACTION CODE: A (A ADD, C CHANGE, D DELETE)

PAF

2. DOCUMENT CODE: 5

3. COUNTRY ENTITY: TA/AGR RDA-4

Type a. Research

4. DOCUMENT REVISION NUMBER: - Original

5. PROJECT NUMBER (7 digits): 931-0489 A

6. BUREAU/OFFICE: A. SYMBOL: TAB; B. CODE: 08

7. PROJECT TITLE (Maximum 49 characters): On-Farm Water Management - Colorado

8. PROJECT APPROVAL DECISION — ACTION TAKEN: A (A APPROVED, D DISAPPROVED, DL DEAUTHORIZED)

9. EST. PERIOD OF IMPLEMENTATION: Extension

YRS 0 3 QTRS 0

10. APPROVED BUDGET AID APPROPRIATED FUNDS ($000)

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	PRIMARY TECH. CODE C. GRANT	PRIMARY TECH. CODE D. LOAN	E. Thru 09/30/76 F. GRANT	E. Thru 09/30/76 G. LOAN	H. 1st FY 77 I. GRANT	H. 1st FY 77 J. LOAN	K. 2nd FY 78 L. GRANT	K. 2nd FY 78 M. LOAN
(1) FN	141 J	953	—	$3,879	-	$1,750	-	-	-
(2)									
(3)									
(4)									
TOTALS				$3,879	-	$1,750	-	-	-

A. APPROPRIATION	N. 3rd FY 79 O. GRANT	N. 3rd FY 79 P. LOAN	Q. 4th FY 80 R. GRANT	Q. 4th FY 80 S. LOAN	LIFE OF PROJECT T. GRANT	LIFE OF PROJECT U. LOAN
(1) FN	$950	-	-	-	$6,579	-
(2)						
(3)						
(4)						
TOTALS	$950	-	-	-	$6,579	-

11. PROJECT FUNDING AUTHORIZED (ENTER APPROPRIATE CODE(S)) 1 LIFE OF PROJECT 2 - INCREMENTAL, LIFE OF PROJECT: A. GRANT 2; B. LOAN

C. PROJECT FUNDING AUTHORIZED THRU FY 7 9

12. INITIAL PROJECT FUNDING ALLOTMENT REQUESTED ($000): B. ALLOTMENT REQUEST NO. ____

A. APPROPRIATION N/A	C. GRANT	D. LOAN
(1)		
(2)		
(3)		
(4)		
TOTALS		

13. FUNDS RESERVED FOR ALLOTMENT: N/A

TYPED NAME (Chief, SER/FM/FSD)

SIGNATURE

DATE

14. SOURCE/ORIGIN OF GOODS AND SERVICES: [X] 000 [ ] 941 [ ] LOCAL [ ] OTHER ____

15. FOR AMENDMENTS, NATURE OF CHANGE PROPOSED

N/A

FOR PPC/PIAS USE ONLY	16. AUTHORIZING OFFICE SYMBOL	17. ACTION DATE MM DD YY	18. ACTION REFERENCE (Optional) N/A	ACTION REFERENCE DATE MM DD YY

AID 1880-8 (7-76)

PROJECT AUTHORIZATION AND REQUEST FOR ALLOTMENT OF FUNDS
PART II

ENTITY : TA/Bureau

PROJECT : On-Farm Water Management - Colorado

PROJECT NUMBER: 931-0489

1. I hereby authorize grant funds not to exceed $2,700,000 for a three year contract to be negotiated with Colorado State University for research on "On-Farm Water Management." This project is a complementary combination of research, training and technical assistance to improve irrigation water management on small farms in the LDCs. Over the past five years, Colorado State University has conducted AID funded research and development activities in Pakistan to improve water management technology through direct participation of farmers. Pakistani officials and donor agencies are incorporating the research results into future comprehensive irrigation development projects. Egypt and Sri Lanka are also planning projects which will duplicate techniques developed in Pakistan. This project authorization will permit Colorado State to: (a) conclude on-going research activities and continue assistance to implement sound water management practices in Pakistan; (b) develop the technologies resulting from the research into useable manuals for training of and use by other LDCs and donor agencies; and (c) provide technical assistance for the design and/or evaluation of irrigation programs in other LDCs.

2. This project will be incrementally funded with $1,750,000 in FY 77 for the first two contract years and $950,000 in FY 79 depending on the availability of funds.

3. This project was reviewed and endorsed by R&DC during its meeting in September 1976 and RAC at its December 1976 meeting. The Research Project Statement has been revised in accordance with RAC's provisions.

Curtis Farrar
Assistant Administrator for
Technical Assistance

Date: Curtis Farrar
JAN 25 1977

Clearances:
TA/AGR/SWM:GCorey draft DC
TA/AGR/SWM:DPeterson draft DC
TA/AGR:GBaird draft DC
TA/AGR:LHesser draft DC
TA/RES:MRechcigl draft DC
TA/PPU:JGunning