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OPTIMUM UTILIZATION OF WATER FOR AGRICULTURE  
WITH EMPHASIS ON  
WATERSHED MANAGEMENT

REPORT NO. VI

GRANT NO. AID/csd - 2457

UNIVERSITY OF ARIZONA

TUCSON, ARIZONA

December 1975

211 (d) Annual Report

Date Due December 1975

Date December 1975

Grant Title: OPTIMUM UTILIZATION OF WATER RESOURCES  
FOR AGRICULTURE: WITH SPECIAL EMPHASIS  
ON WATERSHED MANAGEMENT UNDER CONDITIONS  
CHARACTERISTIC OF LESS DEVELOPED COUNTRIES.

Grantee: University of Arizona

Grant Program Director: David B. Thorud

AID Sponsoring Technical Office: TA/Agric.

Statistical Summary: Period of Grant: May 23, 1969 to June 30, 1975  
Amount of Grant: \$665,000  
Expenditures for Report Year: \$77,065  
Accumulated: \$427,065  
Anticipated for next year: \$118,000

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## I. NARRATIVE SUMMARY

### A. Principal Accomplishments for Reporting Year

As a result of the comprehensive review by AID, the University of Arizona stressed activities involving utilization of its enhanced competency in Watershed Management. Evidence of this is the nearly two-man years of effort by the university in providing technical assistance to developing countries. The Sahelian countries of Africa received considerable attention this past year with Latin American and Asian countries also receiving technical assistance for the University of Arizona. At the request of CID, plans have been initiated in conceptualizing and organizing a multidimensional information network among universities involved in AID programs. Involving the faculty from other CID universities, the University of Arizona organized and held a week-long watershed management short course in Saltillo, Mexico to serve as a base for the development of a set of materials which can be utilized in LDCs as teaching aids on management of small watersheds. Several research papers have been published or presented that will be of value in the development of state-of-the-art studies, field guidelines and other materials of use to LDCs. Examples of areas in which the knowledge base is being expanded are procedures for predicting available water supply and flood-producing events in the face of limited data, managing irrigation water supplies for optimal return, techniques for augmenting surface water supplies and methods for preventing deterioration of watersheds. Established linkages with FAO and Iran have resulted in the enrollment of five Iranian students in Watershed Management.

### B. Accumulative Accomplishments

Up to this year, the University of Arizona was in position of developing a competency in watershed management that would enable it to respond to requests for technical assistance to LDCs. To accomplish this, six new courses have been added and several others restructured to make the education and training program more relevant to developing countries. Research was expanded to emphasize hydrologic modeling of water resource systems and natural resource management techniques. During the life of the grant, thirteen graduate degrees were given and over 40 publications were prepared on above subjects as a direct result of the grant's funding. This represents about 30 percent of the whole program in this area at the University of Arizona. LDC enrollment in watershed management has more than doubled in this period. Linkages have been established with such multinational organizations as FAO, Ford Foundation, Peace Corps, United Nations (other than FAO) and international research centers in addition to AID, CID and LDCs. The University of Arizona developed a watershed management information system which is the link connecting documents with users who are in need of these documents. The system is essentially a computerized information storage and retrieval process.

## II. DETAILED REPORT

### A. General Background and Description of Problem

A firmly established concept states that improved water management is an essential element for increasing the agricultural productivity throughout the world. Reports have shown that 60 percent of the world's arable lands are deficient in soil moisture during all or some part of the growing season. A large share of the remainder suffer from floods and lack of drainage.

In an effort to provide a coordinated program of assistance to developing countries in water management for agriculture, the Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas (CUSUSWASH), since retitled the Council for International Development (CID), was formed several years ago with three western land-grant universities as members. Water management in agriculture can be viewed as the development, processing, storage, transportation and utilization of a raw material, e.g., water for increasing food production. Thus, while Utah State University looks at the practices involving the utilization of on-farm water, Colorado State delves into the problems relating to the storage and conveyance of water to the farm. At the same time, the University of Arizona is concerned with the development, processing and storage of this vital natural resource, or the watershed management phase of the system.

To enlarge the scope of the expertise, the University of California joined the consortium which is now incorporated as a non-profit organization directed by a board of member university representatives. The most recent additions to CID are the universities of Oregon State and Texas Tech.

Watershed management is essentially the management of land for the conservation and production of renewable resources such as water and vegetation. It represents the link in the overall system between the agricultural sector and the water source area. It is concerned with relationships between the management of soil and vegetation and the production of water for both on-site and downstream use. The outputs of watershed management, in addition to water, such as the production of timber, forage, fish and wildlife, and the protection or enhancement of scenic values and recreation environments are inextricably linked with water. Creation of a system that considers only one element or one step in the travels of this transient resource from its source to its disposition can lead to serious consequences in these days of concern for the environment.

The University of Arizona is one of only a few institutions in the world that has attempted to develop a coordinated, multidisciplinary effort in the management of renewable natural resources. A little more than a decade ago, the Department of Watershed Management was

established to bring together programs with a common interest in the management of water on the non-cultivated areas, the lands which supply the adjacent agricultural lands with a major portion of its water.

About the time the Department of Watershed Management was being formed, two other departments evolved into eminent status throughout the professional world which had a marked effect on the initial orientation of the grant. The Departments of Hydrology and Water Resources and Systems and Industrial Engineering cooperating with the Department of Watershed Management collaborated in attacking the general problem of optimum utilization of water resources for agriculture. Special emphasis was given to the use of systems analysis in watershed management under conditions characteristic of less developed countries.

While the University of Arizona has focused on the systems approach in the development of methodologies for helping solve watershed management problems, the University - in particular the Department of Watershed Management - became intimately involved with the development and evaluation of land management practices that affect hydrologic regimes of watersheds. These practices are concerned with the protection and rehabilitation of soil and plant resources and the management of watershed resources to modify the quantity and the distribution of water production. Results of such studies are used as inputs into decision making models. Although a relatively new field, systems analysis can be viewed as a coordinated set of procedures for planning, designing and managing substantive systems. It is a powerful group of tools which at its simplest could be the quantitative study of the possible ways to achieve certain goals or to use available resources. Systems analysis identifies the important issues and alternatives and relates the costs and benefits of each alternative in a way that is meaningful to a person responsible for approving a program. This individual may range from a farmer who needs to know the number of acres to plant and the crops to grow with respect to an available supply of water and fertilizer to a decision-maker at some government level who has to decide on the distribution of land uses and resources.

The logic of systems analysis forces decision makers to look at an entire system, at a number of alternatives to achieve a stated goal and at the consequences of implementing the alternatives. The era of environmentalism has erupted throughout the world because the development process has neglected the principles suggested by systems analysis.

As a result of AID's Comprehensive Review in April 1974, the University of Arizona began addressing its program more directly to food production and nutrition. Soaring population growth and the concomitant need for adequate food, income, employment and social services provide the basic



justification for the application of modern technology to agricultural production. A crucial consideration in many developing countries is the declining land/man ratio, the result not only of population growth but also of the increasing scarcity of good land reserves.

In this connection, then, the development and conservation of natural resources for agriculture must be given a very high priority. The approach to obtaining a solution to the problem should incorporate and emphasize the dynamic aspects of the controlled and planned exploitation of resources to increase productivity in farming, forestry and fisheries. The avoidance of waste will also serve to reduce the pollution problem.

While the introduction of irrigation dramatically increases agricultural production, sustained irrigation systems are not adapted to many of the agricultural lands in developing countries because of limited water supply or unsuitability of the lands to irrigation. The solution to the problem of raising the agricultural productivity of these lands lies not in any spectacular breakthrough, but rather in a continued and concerted multidisciplinary effort to develop and utilize better adapted species, to consider relatively minor improvements to the environment through cultivation and soil and water conservation, through closer integration of crops and livestock, etc.

#### B. Purpose of the Grant

The purpose of the original five-year grant was to increase the overall competency of the University of Arizona in the area of watershed management utilizing systems analysis in a manner that could be applied in developing countries. As a member of CID, a consortium of U. S. universities dedicated to providing assistance for increasing world food production through optimum utilization of water resources for agriculture, the University of Arizona concentrated its activities on the uncertainty of the water supply and on decision making to optimally utilize this variable supply.

Following the Comprehensive Review, the purpose of the grant was modified to focus and sustain an institutional response capability in watershed development and management with emphasis on problem analysis and small watersheds in both arid and humid environments.

The major change is the increased attention to be given to methodologies, practices and, in general, activities of direct concern to the individuals located within small watersheds. A large effort of the increased capability generated by the grant will be devoted to aiding the small farmer or pastoralist improve his personal situation by providing him with the tools for increasing his income. Thus, through income redistribution at a minimum ecological impact, through means

which allows the individual to determine his own destiny and through other means of humanitarian assistance, his quality of life becomes enhanced.

Envisioned here are practices that will increase agricultural productivity by intensification (better range management practices, closer integration of crops and livestock, reafforestation, etc.) and by increasing yields through conservation of available moisture, erosion control and other land improvement methods. Included also will be the investigation of procedures for developing small water supplies for aquaculture, individual irrigation systems, livestock and domestic use.

### C. Objectives of the Grant

#### 1. Objectives Restated

The University of Arizona, under the leadership of the Department of Watershed Management, in cooperation with supporting departments in the Colleges of Agriculture, Earth Sciences and Engineering contains a nucleus upon which to build an increased competency in research, education and consultation within its area of responsibility, namely, watershed management. The major objectives/outputs designed to integrate these aspects into an effective means of information transfer to developing countries are identified as:

- a. Watershed Management Information Center
- b. Education and Training
- c. Expanded Knowledge Base
- d. Advisory Capacity
- e. Linkages and Networks

#### 2. Review of Critical Assumptions

One of the most important assumptions upon which the University of Arizona deems necessary to make the grant a successful endeavor is that AID will work closely with the university in carrying out the mutually agreed upon objectives of the grant. Included in this assumption is the provision for obtaining supplementary funding for projects approved by AID but falling outside the scope of the 211(d) grant. Funding of this type may be provided directly or through CID by a Basic Ordering Agreement, purchase order, contract or other appropriate mechanism. It is also assumed that AID will assist the university in making appropriate contacts with LDCs, international research centers and others for the purpose of utilizing the university's capacity in advisory services, research projects, training programs, short courses and similar activities.

Other assumptions which are inherent in achieving the purpose of the grant include:

- Outputs will result in purpose achievement, i.e., a viable institutional capacity.
- Creation of additional capacity will result in gradual increase in utilization.
- Utilization will provide at least partial support of necessary core staff and support.

Assumptions for achieving outputs include the following:

- Demand (both U. S. and LDC) for information pertaining to watershed management subject matter will exist.
- AID and other donors will assist in locating and financing LDC students.
- Effective help from AID and other agencies in conducting research, identifying needs, etc.
- AID and donor agencies are willing and able to provide inputs and utilize information services.
- AID assistance and support in developing a network of linkages which will provide an effective basis for utilization of institutional capacity.

### III. Accomplishments

The material that follows relates to University of Arizona accomplishments on an output by output basis for both the sixth year and the cumulative life-span of the 211(d) grant. Included for each output are discussions on relationship to original work plan, means of verification and critical assumptions.

#### A. Objective/Output #1 - Watershed Management Information Center

##### 1. Description, Criteria and Assumptions

This particular output concerns the development of a capability to collect, evaluate, store, retrieve and disseminate information relating to LDC land and water management problems. The principal target for this reporting year was to continue the development of an information storage and retrieval system. Verification of this output would be by on-site observation and reports. The critical assumption for achieving this output is that LDCs and donor agencies are willing and able to provide inputs and utilize information services.

## 2. Accomplishments for Reporting Year

Activities for establishing the University of Arizona as a center of competence in watershed management included the continued development of an information system which is the link connecting documents with users who are in need of these documents. The system is essentially a computerized information storage and retrieval process for information concerned with the management of arid land watersheds. An important use of this system was made in connection with a major effort by various faculty members of the Department of Watershed Management in making a state-of-the-art study of evaluating the potentials for increasing the available water supply for Arizona through vegetation management. Such an analysis, which included studies on the management of all renewable natural resources in addition to water, will serve as a useful guide for similar evaluations in the less developed countries.

In addition to the above activity, the accumulation of a specialized library on pertinent watershed management reference material is a continuing process.

Plans have been initiated on behalf of CID in conceptualizing and organizing a multidimensional information network among universities involved in AID programs. As a result of interest shown by grantees and agencies at the October 1974 AID workshop on Methodology, Techniques and Innovations in Information Networking, the University of Arizona assumed the leadership in developing an operational information network. A workshop for CID and Soils Consortium Universities is in the process of being developed.

## 3. Summary of Accumulated Accomplishments

With the exception of the proposed information network initiated this year, all other activities are on a continuing basis.

## B. Objective/Output #2 - Education and Training

### 1. Description, Criteria and Assumptions

Education and training programs specifically addressed to LDC problems has been the goal of this objective. Scheduled were follow-ups on previously made contacts to attract LDC students and development and revision of certain relevant courses. One criteria for satisfactory achievement is number of students from LDCs enrolled in a watershed management or related

curriculum as well as students taking individual courses. Out of context, such information may be misleading. It is assumed that the demand (both U.S. and LDC) will continue to exist and that AID and other donors will assist in locating and finding LDC students.

## 2. Accomplishments for Reporting Year

As a result of previous contacts with FAO and the Ministry of Agriculture and Natural Resources in Iran, five students have enrolled in a watershed management program with the likelihood that others will follow.

A watershed management short course was organized and held in Saltillo, Mexico which involved the faculty from other CID universities. Topics included hydrometeorological data collection and analysis, range management practice to improve watersheds, watershed rehabilitation through cultural and mechanical techniques, surface water development through small dams and water harvesting techniques and water conservation through seepage and evaporation control. An objective of this course will be the development of a set of materials which can be utilized in LDCs as teaching aids on management of small watersheds.

Also held in Mexico was a Pan American Health Organization sponsored short course for Mexican planners concerned with water quality problems.

Members of the Watershed Management Department are cooperating with other CID universities in assisting FAO with the preparation of Watershed Management Field Guidelines which should be of unmeasurable value to LDCs.

The Department of Watershed Management has assisted the Department of Hydrology and Water Resources in a Ford Foundation - University of Arizona contract to provide training in water basin planning for five students from the Philippines.

## 3. Summary of Accumulated Accomplishments

Increasing the instructional capability of the University of Arizona has in the past been directed towards three activities, e.g. addition and re-structuring of courses, development of a computer-oriented instruction program in resource management and the development of an electric analog model of watershed hydrology.

A total of six courses, one this year, pertinent to the grant have been added or are in the process of being added to the College of Agriculture curriculum. Titles of these courses are:

Modeling Small Watershed Hydrology  
 World Soils  
 Environmental Quality and Agriculture  
 Management of Renewable Natural Resources  
 Land Rehabilitation  
 International Rural Economic Development

In addition, several other courses have been re-structured to increase their relevancy to problems encountered in developing countries.

Partial support was granted to two students for the purpose of developing a computer-oriented teaching program in watershed management. A doctoral dissertation and a professional paper for a master's degree have been completed. To instruct in the area of watershed management using systems analysis techniques, computer-based methods are essential not only to reduce the computational burden, but also to provide the manager with freedom to exercise his creative ability. The development of a program of computer-assisted instruction was a logical extension for increasing the University's research and teaching capability.

In conjunction with the above, 211(d) Grant funds have been used in developing a completely interfaced hydrologic data acquisition-analysis system. The facility includes a small computer and the necessary software and hardware for working with live telemetered data. The unit has the capability for handling data and programs from a magnetic tape library.

To facilitate in the instruction of complex hydrologic processes occurring on a watershed, a passive electrical analog model of a watershed has been developed by a doctoral candidate supported in part by 211(d) funds.

#### C. Objective/Output #3 - Expanded Knowledge Base

##### Description, Criteria and Assumptions

1. Of concern here is the performance of state-of-the-art studies and research pertaining to procedures, techniques and policies for managing renewable natural resources to optimize food production and economic development of small watersheds in LDCs located within semi-arid and sub-humid zones.

One means for assessing the accomplishments of this objective is by the number of state-of-the-art studies and research papers produced. Some measure of quality and applicability of these works is also needed. A critical assumption in this regard concerns the need to disseminate information obtained from these activities. Assistance will be needed to perform this function.

## 2. Accomplishments for Reporting Year

As in the past, research efforts have centered around two broad categories, namely, modeling of hydrologic systems and the development of management techniques applicable to water and other natural resources.

A total of six faculty members in three Colleges of Agriculture Departments (Watershed Management; Soils, Water and Engineering; Agronomy and Plant Genetics) and in the Departments of Hydrology and Water Resources and Systems and Industrial Engineering have been involved in related hydrologic modeling projects. One subject matter area that received considerable attention was the development of stochastic models of precipitation and streamflow. Operating irrigation projects or other water resources systems requires the best estimates of an available water supply and associated risks if the demands are not met. Another goal is to improve on methods for extrapolating point source data to areas where data is limited or unavailable.

Another subject matter area includes projects concerned with maximizing efficiency of water use in both irrigated and rainfed agriculture. Specific topics included determination of consumptive water-use efficiency for selected crops and development of a rainfall multiplication process for dryland farming in semi-arid regions.

Receiving considerable attention this reporting year was the effort to model the effect of land modifications on the hydrologic environment. Another project of importance is the intensive study devoted to evaluating the potential of vegetation management for increasing Arizona's water yield. The study resulted in a report of significant impact to the state of Arizona.

Fundamental to the development and management of the land and water resources of a region is a means for identifying, appraising and monitoring these resources and associated environmental processes. Realizing that remote sensing has a great potential in this area, the Department of Watershed Management has initiated and is continuing to develop a Remote Sensing Laboratory which will be equipped to handle a wide variety of activities from routine aerial photo work to automatic data processing for analyzing satellite imagery.

The management of water resources is fraught with uncertainties, in meteorologic inputs, in input-output relations and in parameter estimation. Management techniques are needed that will reduce doubt and uncertainty regarding the consequences of alternative courses of action. In conjunction with faculty members in the Departments of Systems and Industrial Engineering and Hydrology and Water Resources, a major research effort in the Department of Watershed Management has been concerned with the decision making process in the management of natural resources. A nearly completed doctoral dissertation has been investigating the use of systems analysis to arrive at the optimal investment for watershed development considering ecological and social constraints. Research on the use of Bayesian decision analysis has also received consideration. This effort has implications in the design and operation of water control systems under risk and uncertainty such as where hydrologic data are inadequate which is often the case in developing nations.

Historically, decision-making has been viewed as a process which aims at satisfying a single objective or attaining a single goal. Consequently, analytical tools such as benefit-cost analysis have been oriented towards this view. However, most water resources projects are undertaken for a variety of social, environmental, military or other objectives in addition to the economic ones. Many of these objectives cannot be quantified. An analysis that concentrates on only one objective generally results in less than overall optimal programs. The use of multi-objective techniques and cost-effectiveness methodology to evaluate water resources systems in developing countries is currently being explored.

Noting the similarity between American Indians and LDCs insofar as economic development is concerned, a study was initiated and was completed on range improvement potentials on Indian lands. This work reflects the change in direction the University of Arizona is taking in making a greater emphasis on small watershed development.

### 3. Summary of Accumulated Accomplishments

A total of 13 graduate students have been supported in the first six years of the 211(d) Grant in this subject matter area. Of this number, 3 have completed the requirements for a Ph.D. and 7 for a master's degree. In addition to dissertation and theses, the above efforts have resulted in 21 research papers on a variety of subjects pertaining to hydrologic modeling.

Two Ph. D. dissertations are involved in the subject matter area of resource management, one completed while the other is scheduled for completion within a year. Eight research papers concerned with management techniques have been prepared.



D. Objective/Output # 4 - Advisory Capacity

1. Description, Criteria and Assumptions

The development of a University of Arizona capability to provide consultant and advisory services to LDCs, AID and other donor agencies is the product of this particular objective. A measure of effectiveness may be the number of requests for assistance and the number or percentage to which the university responded. The quality of the effort is once again ignored under these circumstances. Peer review may be the best means of verification of activities designed to produce this output. A critical assumption is that the demand for these services will continue to exist.

2. Accomplishments for Reporting Year

University of Arizona faculty responded to an increasing number of requests for consulting services to LDCs and donors. African countries were by far the largest recipient of such services due in large part to the much-publicized Sahelian drought. Latin American and Asian countries also initiated request for technical assistance from the University of Arizona. Table III-A in the Appendix presents the requests for assistance by whom, for what purpose and the outcome.

3. Summary of Accumulated Accomplishments

While relatively few in number, the University of Arizona has always responded quickly and satisfactorily to all requests for assistance regardless of the agency making the request.

E. Objective/Output # 5 - Linkages and Networks

1. Description, Criteria and Assumptions

The goal of this objective is to develop a worldwide network of linkages with institutions concerned with the management of land and water resources of small watersheds. The assumption here is that linkages will ultimately result in utilization of the University of Arizona's increased capability.

2. Accomplishments for Reporting Year

In addition to donor agencies, the University of Arizona has established linkage with the following LDC institutions primarily as a result of advisory services.

- Brazilian National Research Council
- Ghana Council for Scientific and Industrial Research
- Ministries of Agriculture in Kenya, Senegal, Mali and Upper Volta.

Through a FAO Fellowship, a promising linkage has been made with Syed Manzoor Hussain Bokhari, Joint Secretary in the Economic Affairs Division of the Government of Pakistan. Mr. Bokhari is currently on leave at the University of Arizona, upon return to Pakistan, he will help promote linkages with both governmental agencies and research and training institutions.

### 3. Summary of Accumulated Accomplishments

In addition to the above, LDC institutions with whom linkages have been established include:

- University of Ceara - Brasil
- University of Sonora - Mexico
- University of Coahuila - Mexico
- CNIZA - Mexico
- Recursos Hidraulicos - Mexico
- Ministry of Agriculture & Natural Resources - Iran
- Ministry of Agriculture & Water - Saudi Arabia
- Ministry of Agriculture - Turkey

The purpose of these linkages is to provide LDCs with a source of knowledge on land and water management problems, to train technical staff, to perform consulting services and to exchange ideas and research results.

Linkages, in addition to AID and CID, have also been established with Peace Corps, Ford Foundation, FAO, United Nations and international research centers. In addition, contact has been made with the staff at the International Center for Aquaculture at Auburn University to cooperate in providing a research capability in the development of economic, environmentally-sound watershed management systems for fish and livestock production.

## IV. Impact of Grant Supported Activities in Achieving Grant Purpose

The grant has made a considerable impact on the University of Arizona by helping to bring together a critical mass of scientists, engineers, and students to attack the problems facing many emerging nations. i.e., the need to increase food production and to stimulate economic development based on agriculture. Under the leadership of the Department of Watershed Management, linkages have been developed with other departments in the Colleges of Agriculture, Engineering and Earth Science in a multidisciplinary effort to determine the optimum utilization of water resources for agriculture with special emphasis on employing systems analysis techniques in watershed management. This example of an interdisciplinary approach has made the University of Arizona more attractive to all students both American and foreign.

The first five years of the 211(d) Grant have strengthened the University's competency by supporting additional faculty members and students, by contributing to broadened and revised curricula which give them greater relevancy to problems of emerging nations, and by stimulating and supporting pertinent research. In addition, the Grant has helped the University of Arizona become aware of the role that concerned U. S. educational institutions must play in helping AID meet obligations to developing countries, primarily by means of increased involvement in international programs.

In an effort to strengthen the University of Arizona's capability to perform consulting services, the University has initiated lines of communication with countries in such geographic centers as Latin America, the Near East and Africa. The assumption here is that these linkages will result in utilization.

Summarizing, the grant has allowed the University of Arizona to focus and strengthen its capability in all phases (research, teaching and service) within the general subject matter area of watershed management. While the utilization of this increased capability has been low, the University has responded to all known requests. Also the initial phases of the grant have been devoted to development rather than to utilization as is the intent for the next phase. For this phase, it is envisioned that some emphasis will switch from watershed systems analysis studies to activities related to assisting the small farmer or pastoralist improve his personal situation by providing him with the knowledge for increasing his income.

#### V. Other Resources for Grant-Related Activities

The 211(d) grant has provided the necessary foundation from which it has been possible to entrain other resources into the University of Arizona's watershed management program. A direct outgrowth of the AID grant is the involvement of the Watershed Management Department with the Peace Corps' Environmental Program in Latin America.

Six U. S. universities, including the University of Arizona, are providing technical assistance to at least 10 Latin American countries in watershed management and related environmental programs. Specific topics emphasized include air and water pollution; watershed, forest, fisheries and wildlife management; and regional planning. The objectives of the program include (1) assisting Peace Corps Country Directors, their staffs and host institutions in defining specific program objectives for volunteers, (2) providing technical support services for in-country staff in charge of Peace Corps Volunteer environmental programs and (3) reviewing and assessing current technical achievements of Peace Corps watershed and associated environmental programs. At least six faculty members from the Department of Watershed Management and possibly others are or will be involved in making trips to Brazil and Ecuador, the countries assigned to the University of Arizona.

To meet the objectives of the 211(d) Grant in developing the use of system analysis techniques in watershed management, a multi-disciplinary team involving the Departments of Watershed Management, Hydrology and Water Resources and Systems and Industrial Engineering has been brought together. This relationship has resulted in obtaining additional support for related activities. The 1972-73 period was the initial year of operation under a three year grant from the Office of Water Resources Research (OWRR) of the U. S. Department of Interior entitled "Decision Analysis for Watershed Management Alternatives." The following year, the group received another OWRR grant "Practical Uses of Decision Theory to Assess Uncertainties About Actions Affecting the Environment." Another such activity is a National Science Foundation sponsored cooperative research program between the University of Arizona and the Water Resources Center, VIKOZ, of Hungary. The title of the project, a three year program, is "Cooperative Research on Decision-Making Under Uncertainty in Hydrologic and Other Resource Systems."

The increased competency in watershed modeling of hydrologic systems generated by the 211(d) Grant has resulted in the Watershed Management Department receiving additional support from such diverse sources as the U. S. Forest Service, the Arizona Water Resources Research Center, the Salt River Water Users' Association, the Arizona Water Commission, and Peabody Coal Company.

In general, the Grant has been highly instrumental in putting together a group of scientists, engineers and students that is making an impact in the management of natural resources. Not only will the results of these efforts be applicable to developing countries, but to the state of Arizona's problems as well. A rapidly expanding population is placing a continuing strain on Arizona's resources. Solutions to these problems (water shortages, pollution, etc.) can utilize the same techniques being applied to developing countries.

Table I summarizes the distribution of 211(d) grant funds and from other sources of funding according to grant objectives/outputs.

## VI. Utilization of Institutional Response Capability

### A. Requests for Assistance

Table I reports the requests for assistance during the reporting period. All requests were attended.

### B. Miscellaneous Activities (Graduate students, visitors, etc.)

1. As of October 31, 1974, there were 926 foreign students enrolled at the University of Arizona. Last year's record enrollment was 778. Most of them are men and most are undergraduates, according

to records released by the registrar's office. The totals are 525 undergraduates and 401 graduate students, or 671 men students and 255 women. The largest number of students come from neighboring countries, 174 from Mexico and 65 from Canada. The students come from 90 countries. Other countries with 20 or more students at the UA are Brazil 35, China 41, Hong Kong 44, India 23, Iran 46, Japan 39, Kuwait 27, Saudia Arabia 51 and Thailand 21. The graduate college claims the most foreign students, 401, with liberal arts next with 142 and engineering next with 113. There are 74 students in business and public administration. Total on campus enrollment for this semester was 29,123 making nearly one out of every 30 a foreign student.

2. LDC graduate students studying at the University of Arizona in subject matter areas related to the grant are 25 in number and come from the following countries:

Iran	Mexico
Libya	Taiwan
Iraq	Sudan
Brazil	Philippines
Saudi Arabia	Pakistan

3. Number of visitors or on-campus consultations: 50

C. Progress Report in Establishing Linkages

Relationships with domestic, multilateral and LDC organizations have been established for the purpose of collaborating in a joint problem-solving approach, developing cooperative research, initiating faculty exchange and becoming involved in information exchange and dissemination. The University of Arizona is in the process of evaluating these tentative linkages to ultimately strengthen them or develop new ones.

D. Utilization of Institutional Response Capacity for Problem Solving

The University of Arizona proposes to continue to concentrate on the following problem areas:

1. Watershed management practices to enhance rainfed agriculture, fish production and limited irrigated agriculture. Such practices revolve around moisture conservation, water harvesting and control of erosion and sedimentation. By adhering to sound principles of watershed management, the production of food on upland watersheds can be measurably increased.

2. Range management practices to increase livestock production. Selection of land management practices for improving the amount of forage for livestock consumption must be consistent with the overall goals for watershed development. Basically, increased forage production is obtained through making better use of available precipitation, by controlling erosion in conjunction with proper livestock management.
3. Water resources development and management for irrigated agriculture and human consumption. Efficient management must take place at all levels of control from the farmer to the project manager of large-scale water projects. Since land management practices affect both the quantity and quality of water yielded by watersheds, they must be accomplished in a manner that protects the watersheds and maintains the productivity of the water source areas.

Table I

Requests for Assistance Received During Reporting Period May 23, 1974 to June 30, 1975

## A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance?	Who Funded Assistance?	Size of Effort Dollar	Man Days	Results of Assistance.
The prime objective is the development of a precise scope of work for a pre-investment study of the agricultural potential of marginal and semi-arid lands in Kenya which will serve as the actionable document for authorization by AID of funding for the study.	AID Kenya	AID Kenya	AID/Wash and 211(d)	\$9000	138 (3 UA Faculty)	Report - A proposal for Design of an Agricultural/Social/Economic System for Medium-Potential Lands of Kenya and possible linkage
To evaluate environmental/natural resource program of Ecuador, opportunities for placement of Peace Corps Volunteers and qualifications needed for such volunteers.	Ecuador	Ecuador	Peace Corps and 211(d)	\$3000	18 (2 UA Faculty)	Report and placement of at least 5 PCV's in related programs
To participate in a seminar on Science and Technology for the Development of Agriculture in the semi-arid tropics.	Brazil	Brazil	U.S. Natl. Academy of Science and Brazilian Research Council	\$3000	20 (2 UA Faculty)	Report on research probabilities and priorities

Table I - (Continued)

Requests for Assistance Received During Reporting Period May 23, 1974 to June 30, 1975

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance?	Who Funded Assistance?	Size of Effort Dollar	Man Days	Results of Assistance
To design a multi-disciplinary project for the purpose of conducting research relating to the problem of agricultural land degradation in North-east Ghana.	Ghana council for scientific and industrial Research	AID	211(d) and Ghana	\$5000	23	Report submitted to AID/Ghana
To observe conditions of agricultural production in five West African countries and investigate potential for CID involvement in designed projects.	AID/CWR	AID	211(d) and CID	\$4000	24	Report submitted by CID team
To assess water resources potential of the Upper Pampanga River Project in the Philippines.	Philippines	Philippines	211(d) and Ford Foundation	\$4000	30	Report



Table I - (Continued)

Requests for Assistance Received During Reporting Period May 23, 1974 to June 30, 1975

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance?	Who Funded Assistance?	Size of Effort Dollar Man Days		Results of Assistance
To evaluate and locate potential agricultural water development projects in Southwestern Saudi Arabia.	Asir Directorate of Agriculture and Water, Saudi Arabia	Saudi Arabia	Saudi Arabia	\$6000	45	Report submitted to Saudi Arabian Ministry of Agriculture and Water
To develop, prepare and deliver a watershed management short course in Saltillo, Mexico.	University of Coahuila and CNIZA of Mexico	Univ. of Coahuila	211(d) and CNIZA	\$4000	50 (5 UA Faculty)	Presented material will be published
To present a short course for Mexican planners concerned with water quality problems.	Recursos Hidraulicos, Mexico	Recursos Hidraulicos	Pan American Health Organization	\$2000	10 (2 UA Faculty)	Report

## VII. NEXT YEAR'S PLAN OF WORK AND ANTICIPATED EXPENDITURES

The extension of this grant, and hence this work plan is for the period May 23, 1975 to June 30, 1977. As presented the work plan is structured to indicate the specific outputs to be developed and the associated time and cost schedules.

### A. Objective/Output # 1 - Watershed Management Information Center

1. The Watershed Management Information System (WAMIS) will be expanded to include international sources and information on humid watersheds. The present system has some documents of international scope, but not enough. During the extension period documents of international interest will be banked into the system. The base subject areas of WAMIS will be expanded to include special emphasis on erosion processes, erosion control, watershed rehabilitation and related subjects. These documents plus those added to the Office of Arid Lands information systems (ALIS) will greatly expand the depth and breadth of the information available for users. WAMIS is a subsystem of ALIS. During the extension period, WAMIS will be further advertised to potential users, and in response to requests from abroad and locally, the system will be searched for relevant documents. A printout will be supplied to users, and assistance will be provided in the acquisition of needed documents when not otherwise available to users.

By June 30, 1976, 800 additional documents will be abstracted and processed on to magnetic tapes in WAMIS. By June 30, 1977 an additional 800 documents will likewise be added. The total cost for inputting 1600 documents and responding to the search requests of users of the system is estimated at \$26,000 over the extension period. A total of twenty man-months are required.

2. An international newsletter and/or brochure for explaining the use of WAMIS will be prepared and ready for distribution by December 1975.
3. A workshop on information networking among CID and Tropical Soils Consortium Universities will be organized and held at the University of Arizona in early fall, 1975 (see prospectus - Attachment #1). The University will assume responsibility for CID in organizing and coordinating the workshop. Representatives from CID and Tropical Soils Consortium Universities along with other invited specialists who work

with information networks and information dissemination, including representation from AID and the USDA, will meet for one week to develop an information network among these organizations. Activities that will be investigated as a part of the network development include:

- (1) talent bank exchange, involving the standardization of the questionnaire and indexing words;
- (2) acquisition of or access to existing data bases;
- (3) development of centers of specialization, perhaps based on the state-of-the-art reports being written;
- (4) preparation of materials for processing into one bibliographic data base, with work being divided up by subject area, publisher source, or date;
- (5) document copy distribution;
- (6) performance of combinations of manual and machine literature searches, based upon user requests; and
- (7) sharing of hardware.

A manual for the networking system will be prepared. Other details are presented in the attached prospectus.

Periodically, after this initial meeting, other meetings will be required to improve the network and to keep it current. The CID office will provide logistical and support assistance in the development and maintenance of the network. The cost to the University of Arizona 211(d) Grant (hereafter referred to as the Grant) to organize the workshop and to participate in subsequent meetings is estimated at \$12,000. A total of four man-months are required.

#### B. Objective/Output #2 - Education and Training

1. A short course in watershed management will be developed for presentation in an LDC, and will involve faculty resources from CID universities and representatives from the host country. AID missions, bureaus and TAB will be asked for information on problems in LDCs and for general input in the development and testing of the course. The University of Arizona will assume primary responsibility for organizing the short course on behalf of CID. The course will be developed for land use decision-makers and policy-makers in LDC countries including, for example, representatives from the Ministry of Agriculture,

Minister of the Economy, Ministry of Natural Resources, the private sector and other organizations when appropriate. The purpose of the course is to help the participants understand watershed management and how it relates to agricultural production and the small farmer.

The course will be developed on a pilot basis for testing and refinement, with the ultimate goal being widespread use in LDCs, subject to local modification in objectives and approach as the need dictates. When appropriate, competence developed at the University as a result of the 211(d) Grant in Natural Resources Management and Planning will be utilized in the course. The course will be evaluated for its effectiveness as a teaching tool.

The course will be ready for testing and refinement possibly in the Philippines or Pakistan by June 30, 1977, and hopefully sooner. The total cost to the Grant for coordinating the course is estimated at \$20,000. A total of 11 man-months will be required. The actual testing of the course may require additional funding.

2. Another short course in watershed management, which has already been pilot-tested, will be reorganized as need be for application in LDCs on demand. Faculty resources will be drawn from CID universities and the host country in response to requests for the course to be given. The University of Arizona will assume leadership for publicizing the course and for organizing it in response to requests. The course is aimed at land managers and researchers in government, universities and elsewhere. General topics include the measurement and analysis of precipitation, streamflow and water quality data; principles of erosion; cultural and mechanical techniques of erosion control; estimating runoff from limited precipitation data; estimating water requirements; soil and water conservation practices including water harvesting techniques, methods for controlling evaporation and seepage, and cultural practices that increase water-use efficiency. This core combination of subjects can be appropriately used in a wide variety of LDCs with generally minor modifications.

The course will be ready for additional use by December 1976. The cost to the Grant for the reorganization of this course is \$7,000. A total of 3 man-months will be required. Funding for actual presentation of the course will require funding from outside donors.

3. The University will also assist, in a secondary capacity, in the development of short courses under the primary leadership of Colorado State University (CSU) and Utah State University (USU). The course being developed by CSU is entitled "Irrigation Water Delivery and Removal Systems" and that by USU "Practical Aspects of On-farm Water Development." The cost to the Grant for this participation will be \$6,000. A total of 3 man-months and travel time will be required.
4. Three new courses will be taught in 1975-76 with content directly and expressively aimed at the needs of LDCs as well as the U.S. One course is concerned with the rehabilitation of disturbed watershed-range lands, another with erosion processes and control in arid and semi-arid regions, and the third is a graduate and faculty level seminar course pertaining to the characteristics and problems of LDCs. The total cost to the Grant for preparing and teaching these courses is estimated at \$8,000 and will require a total of 4 man-months.

C. Objective/Output #3 - Expanded Knowledge Base

Emphasis will be placed on state-of-the-art and applicable research that will solve problems of the very poor farmers in developing countries. To identify areas where existing as well as new technology and principles can be brought to bear on the development and management of small watersheds, state-of-the-art studies will be initiated for both arid and humid environments. These studies involve an analytical review of the knowledge accumulated by research and practice, setting forth the established principles, how and where they can be used, and identifying the gaps in knowledge needing research for establishment of better principles and practices.

1. The University will provide leadership for CID and the tropical soils consortium in developing state-of-the-art report on soil and water management for erosion control aimed at the needs of LDCs. This report will be concerned with the present status of research and knowledge, and will include a review of management practices and a consideration of the problems associated with erosion control technology in the small watershed. Although the specific scope of the analysis has not yet been determined, it is anticipated that a wide spectrum of land use will be considered including agricultural, range, forest and disturbed lands in LDCs. This general topic was selected because it is critical to many LDCs, and because it will provide a mechanism for bringing CID and tropical soils consortium universities together in a joint problem solving effort.

The initial cost for the erosion control analysis is estimated at \$30,000 and will require 16 man-months.

The following schedule will be used to develop the state-of-the-art report pertaining to erosion control. This approximate schedule will also apply to other state-of-the-art reports involving University of Arizona leadership or participation.

- |  |                 |
|--|-----------------|
| 1. Subject selection   | April, 1975     |
| 2. Methodology conference  | May, 1975       |
| 3. CID meeting on methodology  | June, 1975      |
| 4. Development Plan  |                 |
| a. Assignment of staff and duties  | Sept., 1975     |
| b. Location of work, cost estimates  |                 |
| 5. Begin preliminary work  | Nov., 1975      |
| 6. CID/AID review - decisions on continuation of funding, priorities, etc. | Jan.-Feb., 1975 |

Item 6 above is included because it is recognized that all suggested state-of-the-art studies cannot be completed under the limited funding provided by the grants. Consequently, the proposed work plan was designed to allow CID to systematically study each topic and in about one year make a decision as to the disposition of each.

The primary mechanism for carrying out the state-of-the-art analyses will include appropriately staffed committees and task forces consisting of faculty expertise from CID, the tropical soils consortium and other universities, consultants from other organizations and agencies, and appropriate participants from AID and elsewhere as required to properly consider the needs of LDCs.

2. Another state-of-the-art study and document will be developed on the subject of efficient water harvest, use, and control in the total watershed system with emphasis on water supply for agricultural applications. The report will review presently used practices and also ancient systems of harvest with an analysis of each suitable for agricultural, forest and rangeland manager use in developing nations. This report will be prepared by October 1, 1976. The total cost is estimated at \$15,000 and five man-months will be required.
3. A state-of-the-art analysis will be initiated on some aspect of small watershed management problems in the humid tropics to determine the need and direction for more in-depth analysis. This will be a feasibility study leading to more comprehensive proposals for detailed analyses. A preliminary report will be prepared by June 30, 1976. The total cost is estimated at \$10,000, and seven man-months will be required.

4. The University of Arizona will also cooperate with CID universities in the preparation of other state-of-the-art analyses for which they are assuming primary leadership. The projected subjects for analysis and leadership assignments are as follows:

- a) Methods of Irrigation (USU)
- b) Water oriented food production technology (USU)
- c) Water logging and alinity (CSU)
- d) Sediment control in delivery systems (CSU)
- e) Water delivery rules and procedures (CSU)

The estimated cost for this cooperation is \$10,000 and the time requirement is six man-months.

These state-of-the-art studies will be a continuing process involving literature reviews, consultations with appropriate LDCs, AID Washington and field personnel, international organizations, and cooperation with sister universities, and will result in a thorough review of all available sources of information and experience. The reports and results of these analyses will provide information for LDCs and will help define gaps in knowledge and the appropriate associated research and training needs. The documents will be widely distributed, and will effectively involve senior faculty and graduate students in work relevant to the Grant purpose and, in the process, produce products useful to them, AID, other donors, and the LDCs.

#### D. Objective/Output #4 - Advisory Capability

1. Three faculty members will be funded to assist in the advisory demands relating to the 211(d) Grant. These faculty members can be directly involved in consulting, but will more usually help take over the courses, research programs and other assignments of other more senior faculty who are called away on advisory assignments in response to requests from the field or in relation to grant objectives. Thus, the Grant, in effect, provides release time for a wide range of faculty expertise present on the campus as a result of other funding sources. This range of talent could not possibly be supported by the Grant alone. Attachment #2 provides an index of faculty resources by specialty and function. The cost of faculty members actually funded by the Grant is estimated to total \$40,000 and will involve 20 man-months. These faculty members will be funded in the program by October, 1975.
2. In addition, \$10,000 will be allocated for consultancy time to be provided in emergency situations where individuals are needed on very short notice and when other instruments cannot be used without causing unacceptable delay. This provision will require three man-months of effort.

3. Working with CID, AID and other organizations, the university will analyze present faculty and staff expertise with the goal of identifying functions that need strengthening. By seminars, short courses, and other appropriate mechanisms, faculty members will receive training to fill knowledge gaps which will lead to an improved overall institutional response capability for CID and each of the member universities. The functions to be included in this self-analysis and improvement program include: 1) problem identification and analysis, 2) program and project design, 3) operations (research, education and training), and 4) project evaluation. It is anticipated that AID or other personnel will be available to help present short courses to be attended by CID university personnel. A supplemental appropriation may be requested for this activity once the courses and sites at which the courses are to be taught are identified. The first course is expected to be presented in April, 1976.

The grant will provide \$9,000 and three man-months of effort for this evaluation and training process.

#### E. Objective/Output #5 - Linkages and Networks

1. The Grant will continue to provide a basis for linkage with the CID network. Many of the outputs described above are total CID products and will require coordination from CID central offices. To assist CID in carrying out these functions, a maximum of \$24,000 including two man-months of University of Arizona faculty time will be provided by the Grant.
2. The university will also establish and maintain linkages with other than CID organizations, including the tropical soils consortium, FAO, other world-wide and regional agricultural organizations and LDCs as necessary to meet the conditions of this Grant. The Grant provides \$2,000 and two man-months for this purpose.
3. As a result of preliminary assessment, the university wishes to establish a linkage with the University of the Philippines and other appropriate agencies and organizations in the Philippines. This assessment indicated several conditions that favor such a linkage as follows:
  - a) Small watershed management problems are prevalent in the Philippines.
  - b) A forestry faculty member from the University of the Philippines is completing his Ph.D. in watershed management at the University of Arizona and is anxious for further long-term cooperative effort.
  - c) The AID review team which reviewed Arizona's 211(d) Grant recommended that the University develop a competence in watershed management problems of the humid tropics.
  - d) The AID mission in the Philippines expressed interest in Arizona's possible involvement in the Philippines.



Consequently, \$2,000, including three man-months of effort, have been allocated from the Grant for purposes of further exploring this possible linkage.

- D. Auburn University has developed a competence in fisheries technology that could be complementary to the watershed management competence developed at the University of Arizona through the 211(d) Grant program. Preliminary contact with Auburn has indicated that a combination of Arizona and Auburn talent could lead to productive cooperative programs in the utilization of water for irrigation of crops, range production for livestock, timber production and in the development of fisheries resources, with specific reference to the needs of LDCs. Such cooperation could lead to effective short courses, joint research programming and other activities relating to Grant objectives. Consequently, \$2,000, including one man-month, are allocated for this purpose.

TABLE II.  
University of Arizona Faculty Consultants

<u>Name</u>	<u>Field of Interest</u>	<u>Function</u>
Barnes, Kenneth K.	Agricultural engineering and irrigation	1,2,3,5,6,7
Day, John C.	Agricultural and natural resources economics	1,2,3,5,6
Evans, Daniel D.	Hydrology and soil physics	1,3,5,6,7
Fischer, John L.	Agricultural economics	1,2,3,5,6,7
Fogel, Martin M.	Watershed management hydrology, agricultural engineering and irrigation	1,2,3,4,5,6,7
Ince, Simon	Hydrology and water resources development	1,3,5,6
Jacoby, Peter W.	Range management	1,3,4,5
Jordan, Gilbert L.	Range management	1,3,5,6
Matlock, W. Gerald	Groundwater hydrology and agricultural engineering	1,3,5,6,7
Ogden, Phil R.	Range management	1,3,4,5,6,7
Resnick, Sol D.	Hydrology and water resources development	1,2,3,5,6,7
Smith, Edwin Lamar	Range management	1,3,5,6,7
Stroehlein, Jack L.	Soil fertility and soil management	1,3,5,6
Thames, John L.	Watershed management and hydrology	1,3,5,6,7
Thorud, David B.	Watershed management and hydrology	1,3,5,6,7

\*Numbers under the heading function refer to the following:

- 1 - Problem identification and analysis
- 2 - Program or project design
- 3 - Education and training
- 4 - Extension
- 5 - Advisory capacity and professional backstopping
- 6 - Research
- 7 - Evaluation of mission program

VIII. Involvement of Minority Personnel and Women

As an equal opportunity employer, the University of Arizona conscientiously adhered to this policy insofar as the grant is concerned. While no minority personnel were hired, one woman was added to the professional staff. Located in close proximity to Mexico, the Grant Director is continually on the look-out for Spanish speaking faculty, staff or graduate students in an effort to improve communications between the USA and Latin America.

IX. Report of Expenditures

Expenditures for this reporting period and cumulative totals are shown in Tables III, IV and V.

Table III  
Distribution of 211(d) Grant Funds and Contributions  
from Other Sources of Funding

Reporting Period May 23, 1974 to June 30, 1975

Grant Objectives	211(d) Expenditures			Non 211(d) Funding
	Period Under Review	Cumulative Total	Projected Next Year	
Center for information	\$10,000	\$23,000	\$15,000	\$10,000
Education and training	21,000	120,000	27,000	40,000
Adaptive research	27,000	223,000	45,000	110,000
Advisory service	11,000	32,500	15,000	10,000
Network of linkages	8,000	28,500	12,000	10,000
	<hr/>	<hr/>	<hr/>	<hr/>
	\$77,000	\$352,000	\$118,000	\$180,000

Table IV - A  
 211(d) Expenditure Report  
 Actual and Projected Summary  
 Under Institutional Grant #AID/csd-2457  
 Reporting Period May 23, 1974 to June 30, 1975

	Expenditures to Date		Projected Expenditures	
	Reporting Period	Cumulative Total	1975-76	1976-77
Salaries - academic	37,961	207,930	57,000	65,000
Wages - non-prof.	2,140	35,193	6,000	6,000
Fringe benefits	4,618	23,203	7,000	8,000
Student support	6,947	56,767	14,000	14,000
Consultants	400	400	3,000	2,000
Travel	12,849	37,198	12,000	14,000
Equipment	1,908	18,710	3,000	2,000
Library	660	3,860	4,000	3,000
Publication	818	6,618	3,000	2,000
Other operations	2,754	14,186	3,000	3,000
CUSUSWASH	6,000	23,000	6,000	6,000
<b>Total</b>	<b>77,065</b>	<b>427,065</b>	<b>118,000</b>	<b>125,000</b>

Table V - B  
 211(d) Expenditure Report  
 Reporting Year Detail  
 Under Institutional Grant #AID/csd - 2457  
 Reporting Period May 23, 1974 to June 30, 1975

	<u>% Time</u>	<u>Amount</u>
1. A. Salaries - Professional		
Martin M. Fogel	60	\$13,535
William O. Rasmussen	30	5,433
Robert L. Beschta	35	5,138
Ruben N. Weiss	15	2,500
Walter U. Gartska	15	3,200
Linda M. White	40	4,297
Robin B. Clark	40	3,858
		<u>\$37,961</u>
B. Salaries & Wages - Clerical, other non prof.		
Noel Boardman		\$ 968
Drucilla Castro		220
Sandra Tapia		174
Marge Melton		778
		<u>\$2,140</u>
C. Fringe Benefits		\$4,618
II. Student Support		
<u>Name</u>	<u>Country of Origin</u>	<u>Amount</u>
Paul Gregory	USA	\$ 638
William Darling	USA	982
Larry Rovey	USA	470
Moshe Baradon	Egypt	1,500
Maurya Smith	USA	486
Charles Kral	USA	378
Barbara Furer	USA	528
Severo Saplaco	Philippines	625
Mark Lee	USA	1,350
		<u>\$6,957</u>

Table V - B (Continued)

III. A. Consultants	(None)		
B. Guest Lecturers	(None)		
IV. Travel			
		<u>No. of Trips</u>	<u>Amount</u>
A. Domestic		16	\$ 6,305
B. Foreign		10	6,544
V. Equipment			1,908
VI. Library Acquisitions			660
VII. Publications			818
VIII. Other operations			2,754
IX. CUSUSWASH			6,000
TOTAL			<u>\$77,065</u>

## APPENDICES



Table 1a. University of Arizona 211(d) PROJECT DESIGN DETAIL

Appendix A

Project Title: Watershed Management

May 1975

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
<p><b>Project Purpose:</b></p> <p>To focus and sustain an institutional response capability at U.A. in arid and humid watershed development and management with emphasis on problem analysis and small watersheds. In cooperation with CID to focus on problems of water delivery and removal systems and on-farm water management.</p>	<p>Conditions that will indicate purpose has been achieved: End of project status</p> <p>a) The University of Arizona is recognized as a center of excellence within the U.S. for information, expertise and research and development related to watershed management in LDCs.</p> <p>b) Continuous and significant involvement on LDC problems.</p> <p>c) Adequate financing available.</p> <p>d) Linkages and networks with other significant institutions working on food production problems in the LDCs.</p>	<p>a) Peer evaluation by other institutions and individuals having knowledge of watershed management research and training.</p> <p>b) Utilization record by LDCs.</p> <p>c) Annual report, university budget.</p>	<p>Assumptions for achieving purpose:</p> <ul style="list-style-type: none"> <li>• A major key to increasing food production, improving nutrition and increasing income in developing countries is better land and water management which in turn will enhance the quality of life for the small farmer in RLDCs.</li> <li>• Linkages will eventually result in utilization.</li> <li>• Creation of additional response capacity will result in a gradual increase in utilization.</li> <li>• Utilization will provide at least partial financing of necessary core staff and support.</li> <li>• AID and other donors will cooperate in problem identification and in generation of requests for assistance.</li> <li>• CID will perform an effective coordinating and supporting role.</li> </ul>

Table 1b. University of Arizona 211(d) PROJECT DESIGN DETAIL

Appendix A - Continued

Project Title: Watershed Management

May 1975

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Outputs:	Magnitude of Outputs:		Assumptions for Achieving Outputs:
<u>OUTPUT No. 1</u> Capability to collect, evaluate, store, retrieve and disseminate information relating to LDC land and water management problems.	<u>OUTPUT No. 1</u> a) Expanded Watershed Management Information System to include international sources and information on humid watersheds.  b) Dissemination system established by 1976 to include an international newsletter and/or brochure for explaining use of Watershed Management Information System.  c) Beginning of information network among CID universities and other cooperators.	<u>OUTPUT No. 1</u> a) On-site observation and annual report.  b) Annual report.  c) Workshop to initiate network, and an operating manual.	<u>OUTPUT No.1</u> •LDCs and donor agencies are willing and able to provide inputs and utilize information services      •Cooperation from CID, AID and other appropriate participants.

Table 1b. (Continued). University of Arizona 211(d) PROJECT DESIGN DETAIL.

Project Title: Watershed Management

May 1975

Appendix A - Continued

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Outputs:	Magnitude of Outputs:		Assumptions for Achieving Outputs:
<u>OUTPUT No. 2</u> Education and training program specifically addressed to problems of LDCs. Short courses will be developed for use in LDCs and new courses aimed at LDCs will be taught on campus.	<u>OUTPUT No. 2</u> a) Development of short courses and training sessions on watershed management as it pertains to the needs of the small farmer. b) Development and revision of on-campus courses. c) Increase of graduate students from LDCs.	<u>OUTPUT No. 2</u> a) Course materials and manuals developed for short courses, on-site observation and annual report. b) On-site observation and annual report. c) On-site observation and annual report.	<u>OUTPUT No. 2</u> • There is a need and demand in the LDCs for the training and education so that funds will be provided for students to participate in the training. • LDC institutions will cooperate in the training and education programs. • AID and other donors will assist in the financing of short courses and will help locate suitable sites for the short courses.

Table 1b. (Continued). University of Arizona 211(d) PROJECT DESIGN DETAIL.  
 Project Title: Watershed Management  
 May 1975

Appendix A - Continued

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
<b>Outputs:</b>  <u>OUTPUT No. 3</u> Expanded knowledge base. Emphasis will be placed on state-of-the-art and problem identification relating to small farmers in LDCs concerning procedures, techniques and policies for managing renewable natural resources to optimize food production and economic development of small watersheds with special emphasis on those of the semi-arid and sub-humid zones.	<b>Magnitude of Outputs:</b>  <u>OUTPUT No. 3</u> a) Identification and evaluation of land and water management practices suitable for use by LDCs located in both arid and humid environment. b) Development of a state-of-the-art analysis of soil and water management for erosion control in cooperation with CID and the Tropical Soils Consortium. c) Development of a state-of-the-art report on efficient water harvest, use, and control in the total watershed system with emphasis on water supply for agricultural applications in cooperation with CID. d) Initial development of a state-of-the-art analysis on watershed management problems of the humid tropics.	<u>OUTPUT No. 3</u> Application to LDC problems, on-site observation and annual report b) State-of-the-art reports, annual report, on-site review. c) State-of-the-art report, annual report, on-site review. d) Preliminary state-of-the-art analysis in report form, annual report, on-site review.	<b>Assumptions for Achieving Outputs:</b> <u>OUTPUT No. 3</u> •Effective help from AID and other U.S. agencies in conducting research, identifying needs, etc. •CID and the Tropical Soils Consortium will cooperate and supplementary funding as may be needed will be forthcoming from AID and other donors for completing state-of-the-art analyses and reports.

Table 1b. (Continued). University of Arizona 211(d) PROJECT DESIGN DETAIL.  
 Project Title: Watershed Management  
 May 1975

Appendix A - Continued

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
<p>Outputs:</p> <p><u>OUTPUT No. 4</u></p> <p>Advisory and consulting capability for AID, LDCs, consulting firms, World Bank and other donors. Provide release time, allow faculty to respond quickly to a consulting request.</p>	<p>Magnitude of Outputs:</p> <p><u>OUTPUT No. 4</u></p> <p>a) Over 30 faculty are available for consulting on optimum water management and watershed management for improved crop production. These are in the fields of watershed hydrology, soils, water, and engineering, agricultural economics, range management, irrigation engineering, agronomy and others.</p> <p>b) Development of seminars and workshops for increasing faculty competence in problem identification and analysis, program and project design, research, education and training and project evaluation.</p>	<p><u>OUTPUT No. 4</u></p> <p>a) Annual report documenting requests for consultants, trip reports, final project reports, donor recommendations.</p> <p>b) Annual reports, on-site review and participation by AID.</p>	<p>Assumption for Achieving Outputs:</p> <p><u>OUTPUT No. 4</u></p> <ul style="list-style-type: none"> <li>• There is a need for these consulting services.</li> <li>• The availability and talent at the University of Arizona is known by the potential users.</li> <li>• CID, AID and other appropriate organizations will help provide staff for faculty improvement training conferences.</li> </ul>

Table 1b. (Continued). University of Arizona 211(d) PROJECT DESIGN DETAIL.

Appendix A - Continued

Project Title: Watershed Management

May 1975

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
<b>Outputs:</b>  <u>OUTPUT No. 5</u> A worldwide network of linkages with institutions concerned with the management of land and water resources of small watersheds with emphasis on food production.	<b>Magnitude of Outputs:</b>  <u>OUTPUT No. 5</u> a) Strengthen our linkage with CID and its participating members. b) Establish or strengthen linkages with institutions working in water for food production in Africa, Near East, Pakistan or India, Latin America, and Asia. c) Sustain and strengthen close working relationship with other 211(d) directors in the water chain. d) Establish and sustain linkages with centers and consortiums working to increase food production by the small farmer.	<u>OUTPUT No. 5</u> a) Annual report and joint programs, seminars and training sessions developed with CID universities. b) Annual report, on-site review, actual utilization. c) Annual report and joint programming. d) Annual report.	<b>Assumptions for Achieving Outputs:</b>  <u>OUTPUT No. 5</u> •AID assistance and support. •The cooperation of the other institutions. •Linkages and networks provide an effective basis for utilization of institutional capacity.

UNIVERSITY OF ARIZONA  
LIST OF PUBLICATIONS HAVING SIGNIFICANT 211(d) INPUT  
(Revised - Dec. 1975)

1969

- 69-1 Fogel, M. M. and L. Duckstein. Point rainfall frequencies in convective storms. Water Resources Res. 5(6): 1229-1237. 1969.
- 69-2 Tinlin, R. M. and J. L. Thames. A passive direct electric analog of a watershed. Paper presented at Fall National Meeting AGU, San Francisco. 1969.
- 69-3 Thames, J. L. and J. H. Kitchen. Application of a computer model to a desert watershed, Prog. Agric. in Arizona, 21(1): 12-19. 1969.
- 69-4 Fogel, M. M. The effect of storm rainfall variability on runoff from small semiarid watersheds. Transactions of the ASAE 12(6): 808-812. 1969.

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- 70-1 Thames, J. L. and R. M. Tinlin. Computerized hydrologic data acquisition system--a facility for upgrading instruction in Watershed Management. J. Natl. Assoc. of Coll. and Tchrs. in Agric. 14(1): 3-4. 1970.
- 70-2 Thames, J. L. and R. M. Tinlin. A computerized automated system for hydrologic data acquisition and analysis. Proc. Int. Symp. on Hydrometry, Koblenz. 1970.
- 70-3 Matlock, W. G. and P. R. Davis. Desert strip farming: A modified dry farming method using rainfall multiplication. Paper presented at annual meeting Amer. Soc. Agric. Engineers. Minneapolis. 1970.
- 70-4 Thorud, D. B., E. S. Simpson and I. Friedman. Distinguishing seasonal recharge to groundwater by deuterium analysis in southern Arizona. Proc., Reading Symposium. International Assoc. of Scientific Hydrology. 112-121. 1970.
- 70-5 Kisiel, C. C. and L. Duckstein. Operations research study of water resources. Part I: Methodology and problems in an urbanized environment. Water Res. Bul. 6(5): 737-745. 1970.
- 70-6 Fogel, M. M. and L. Duckstein. Prediction of convective storm runoff in semi-arid regions. Proceedings Symposium on Representative and Experimental Watersheds, International Association of Scientific Hydrology, New Zealand, Publication No. 96, p. 456-478. 1970.

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- 71-1 Bartlett, E. T. Systems analysis in natural resources management. 1971 New Mexico Water Conference, New Mexico State Univ., Las Cruces, New Mexico, p. 66-71. 1971.
- 71-2 Fogel, M. M., L. Duckstein and C. C. Kisiel. Space-time validation of a thunderstorm rainfall model. Water Resources Bul. 7(2): 309-316. 1971.
- 71-3 Brooks, Kenneth B. and David B. Thorud. Antitranspirant effects on the transpiration and physiology of tamarisk. Water Resources Res. 7(3): 499-510. 1971.
- 71-4 Kisiel, C. C., L. Duckstein and M. M. Fogel. Analysis of ephemeral flow in aridlands. J. Hydraul. Div., ASCE, 97(HY10): 1699-1717. 1971.
- 71-5 Fogel, Martin M. Evaluating effects of water yield management. Proc. Third Intl. Symp. for Hydrol. Prof., Purdue Univ. p. 303-314. 1971.
- 71-6 Fogel, Martin M. Systems analysis: a decision-making tool for arid land development. Proc. CENTO Seminar on Agricultural Aspects of Arid and Semi-arid Zones, Tehran. p. 268-277. 1971.
- 71-7 Duckstein, L. and C. C. Kisiel. Collective utility: A systems approach to water pricing policy. Proc. Intl. Symp. on Math. Models in Hydrol. Warsaw. p. 881-888. 1971.
- 71-8 Duckstein, L. and C. C. Kisiel. Efficiency of hydrologic data collection systems--Role of type I and type II errors. Water Res. Bul. 7(3): 592-604. 1971.
- 71-9 Davis, D. R. and W. M. Dvoranchik. Evaluation of the worth of additional data. Water Res. Bul. 7(4): 700-707. 1971.
- 71-10 Thorud, D. B. and R. S. Cunningham. Antitranspirants: a possible alternative to the eradication of saltcedar thickets. Proc. New Mexico Water Conference, Las Cruces, New Mexico, p. 101-109. 1971.
- 71-11 Kao, S. E., L. Duckstein and M. M. Fogel. A probabilistic model of winter rainfall. Paper presented at Fall National Meeting AGU, San Francisco. 1971.



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- 72-1 Duckstein, L., M. M. Fogel and C. C. Kisiel. A stochastic model of runoff-producing rainfall for summer type storms. *Water Resources Res.* 8(2): 410-421. 1972.
- 72-2 Fogel, M. M., L. Duckstein and C. C. Kisiel. Choosing hydrologic models for management of changing watersheds. *Proc. Amer. Water Res. Assoc. Symp., Watersheds in Transition, Ft. Collins.* p. 118-123. 1972.
- 72-3 Davis, D. R., C. C. Kisiel and L. Duckstein. Bayesian decision theory applied to design in hydrology. *Water Resour. Res.* 8(1): 33-41. 1972.
- 72-4 Chaemsaitong, K., L. Duckstein and C. C. Kisiel. Cost effectiveness of water resources systems in developing countries: Case of the Lower Mekong. *Proc. Intl. Symp. on the Planning of Water Resources.* Mexico City. 1972.
- 72-5 Davis, D., L. Duckstein, C. Kisiel and M. Fogel. Uncertainty in the return period of maximum events: A Bayesian approach. *Proc. Intl. Symp. on Uncertainties in Hydrologic and Water Resource Systems.* Univ. of Ariz., Tucson, Ariz. p. 853-862. 1972.
- 72-6 O'Hayre, A. H. Parameter optimization for simulating semiarid watershed hydrology. Unpublished master's thesis in Watershed Management. Univ. of Arizona. 74 pp. 1972.
- 72-7 Tinlin, R. M. Analysis and application of a passive electronic analog model to the hydrologic regime of a watershed. Unpublished Ph.D. dissertation in Watershed Management. Univ. of Arizona. 109 pp. 1972.
- 72-8 Ffolliott, P. F., and D. B. Thorud. Use of forest attributes in snowpack inventory-prediction relationships. *Jour. Soil and Water Conservation*, 27(3): 109-111. 1972.
- 72-9 Kisiel, C. C. and L. Duckstein. Economics of hydrologic modelling: A cost-effectiveness approach. *Proc. Intl. Symp. on Modelling of Water Resource Systems.* Ottawa, Canada. p. 319-330. 1972.
- 72-10 Tinlin, R. M. and J. L. Thames. The analysis and application of a digitally simulated electronic watershed analog. *Proc. Amer. Water Res. Assoc. Symp. Watersheds in Transition, Ft. Collins.* p. 138-144. 1972.

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- 73-1 Davis, D., L. Duckstein, C. Kisiel and M. Fogel. A decision-theoretic approach to uncertainty in the return period of maximum flow volumes using rainfall data. Proc. UNESCO Symp. on Design of Water Resource Projects with Inadequate Data. Madrid, Spain. 1973.
- 73-2 Duckstein, L., D. Monarchi and C. Kisiel. Interactive multiobjective decision making under uncertainty. Proc. NATO Conf. on the Role and Effectiveness of Decision Theories in Practice. Luxemburg. 1973.
- 73-3 Fogel, M. M., L. Duckstein and C. C. Kisiel. A stochastic snow model to evaluate reservoir operation. Paper presented at AGU Natl. Meeting. Washington, D.C. 1973.
- 73-4 Fogel, M. M., L. Duckstein and C. C. Kisiel. Predicting the hydrologic effect of land modifications. Paper presented at ASAE Natl. Meeting Lexington, Ky. 1973.
- 73-5 Fogel, M. M., L. Duckstein and C. C. Kisiel. Optimum control of irrigation water application. Proc. IFAC Symp. on Automatic Control of Water Resources Systems. Haifa, Israel. 1973.
- 73-6 Morin, G. C. A. and A. W. Warrick. Steady-stage seepage in a hillside. SSSA Proc. 37: 346-351. 1973.
- 73-7 Rasmussen, W. O. A CAI language for mini-computers with sample dialogue and problems relating to physics and wildland hydrology. Unpublished Ph.D. dissertation in Watershed Management. Univ. of Arizona. 151 pp. 1973.
- 73-8 Morin, G., D. Parsons, W. Matlock and D. Fangmeier. Desert strip farming-- A way to make the desert green. Progressive Agriculture in Arizona, Univ. of Arizona. 25(4): 4-8, 1973.

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- 74-1 Bartlett, E. T. A decision-aiding model for planning optimal resource allocation of water basins. Unpublished Ph.D. dissertation in Range Management, University of Arizona. 132 pp. 1974.
- 74-2 Nnaji, S., D. Davis and M. Fogel. Uncertainty in predictions from a deterministic watershed model. Presented at National Meeting, American Geophysical Union, Washington, D. C. April 1974.
- 74-3 Cary, L. E., V. K. Gupta and M. M. Fogel. A stochastic model of snow accumulation and ablation. Presented at National Meeting, American Geophysical Union, Washington, D.C., April 1974.
- 74-4 Fogel, M. M., L. Duckstein and J. L. Sanders. An event-based stochastic model of areal rainfall and runoff. USDA agr. Res. Serv. Misc. Pub. No. 1275, pp. 247-261. June 1974.
- 74-5 Nnaji, S., D. R. Davis and M. M. Fogel. A deterministic model for semi-arid catchments. Proc. Hydrol. and Water Resource in Ariz. and Southwest. Vol. 4, pp. 163-175. 1974.
- 74-6 Smith, J. H., M. Fogel and L. Duckstein. Uncertainty in sediment yield from a semi-arid watershed. Proc. Hydrol and Water Resourc. in Ariz. and Southwest, Vol. 4, pp. 258-267. 1974.
- 74-7 Ffolliott, P.F. and D. B. Thorud. Vegetation management for increased water yield in Arizona. Univ. of Ariz. Agr. Exp. Sta. Tech. Bul. 215. 38 p. 1974.
- 74-8 Fogel, M. M., J. L. Thames and L. Duckstein. Probabilistic model of rare hydrologic events. Presented at Annual Meeting Amer. Soc. Agric. Engrs., Stillwater Okla., June 1974.
- 74-9 Smith, E. L. Opapel de manejo de pastagens nativas no Brasil. Invited paper presented at XI Reuniao Anual da Sociedade Brasileira de Zootecnia. Fortaleza, Brazil. 1974.
- 74-10 Fogel, M. M., L. Duckstein and C. C. Kisiel. Modeling the hydrologic effects of land modifications. Transactions of the Amer. Soc. Agr. Engrs. 17(6): 1006-1010. 1974.
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