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B-1

THE UNIVERSITY OF ARIZONA

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SUMMARY OF CONTRIBUTIONS TO THE UNIVERSITY CAPABILITY

General

In the first year of the 211(d) Grant the University, under the leadership of the Watershed Management Department, has made significant progress toward attaining the goals of strengthening its capabilities in teaching, research and service in the area of systems analysis of watershed management with special emphasis on the problems of less developed countries.

The improvements in teaching facilities, new and revised courses, abstract compilations, analyses of research programs and new faculty, as well as the expanded University support have all increased the awareness and interest of professionals and students in the goals and objectives of the Grant. The net effect has greatly increased potential of the University to render services to individuals, government agencies, private companies and students from foreign countries.

Teaching

Teaching competence has been expanded by curricula reviews, seminars, developing new courses and facilities and adding qualified, motivated professional staff in watershed management.

The Grant has motivated the review and restructuring of all water-related courses in several departments and the development of new courses e.g. World Soils and Hydrologic Modeling. The Agricultural Engineering Department organized and presented seminars for professors and students from the Universities of Arizona and Ceara, Brazil. Collections of abstracts and summaries have been made of available knowledge in wildland hydrology that will be of value in systems analysis. These will provide reference to efficient expansion of the knowledge base for ourselves and others in less developed countries.

An active program is underway in the development of teaching aids. A Passive Electronic Watershed Model has been developed which may be particularly useful for instruction in underdeveloped countries because of its portability and low cost. There is an active interplay between model user and the model and foreign visitors have been enthusiastic about its teaching applications. With the support of the Grant, State funds and other programs in the University, the Department of Watershed Management has developed a unique teaching-research facility consisting of a completely interfaced hydrologic data acquisition system. It consists of a small computer, software and hardware for working with live-telemetered data and provides for rapid

recall of past data. A magnetic tape library of modeling programs and subroutines for systems analysis is being assembled for use with the facility.

Dr. Martin M. Fogel, a specialist in hydrologic modeling and systems analysis, and Dr. Edwin Lamar Smith, a specialist in soil-plant-water relations joined the faculty of the Department of Watershed Management as a result of the Grant and have greatly increased the teaching competence of the University in this field. Seven graduate students were partially supported from the grant. One has completed his M.S. degree and accepted a job working for an American firm in Brazil.

Research

Increased research competence is inter-related with increased teaching competence. The new faculty members will teach, conduct research, and direct the work of graduate students. Many of the new graduate students mentioned above are under the direction of the new faculty members, Drs. Fogel and Smith who have had overseas research experience. Interdisciplinary research has been emphasized. For instance, faculty and their graduate students from the Hydrology and Water Resources, Systems Engineering and Watershed Departments are increasing their cooperative efforts in stochastic and parametric modeling of

hydrologic events for prediction of surface runoff and sedimentation and for development of decision-making models for resource planning. The Agricultural Engineering and Agronomy Departments are cooperating in a project of collecting rainfall from larger areas to augment direct rainfall available to crops. These cooperative efforts have greatly increased the University's awareness of and interest in the Grant objectives and goals, as well as the teaching and consultative capabilities.

Consulting and Services

The addition of new faculty teaching facilities, abstract and summary compilations, cooperative research and training, and the increased awareness and interest of personnel in the Grant are resulting in greater capability of the University to offer consulting, advice and services. New faculty added to the University with the assistance of the Grant, have considerable overseas consulting experience and will directly increase the consulting capability of the University.

OBJECTIVES AND SCOPE

The major objective of the Section 211(d) Grant is to strengthen the existing capabilities of the University of Arizona's watershed management program centered in the Department of Watershed Management with special emphasis on the science and methodology of applying systems analysis techniques to problems of less developed countries.

Specifically, the objectives and scope of the University of Arizona program are:

1. Expand its professional staff in Watershed Management who are now and would be specifically involved in systems analysis of watershed management activities related to the needs of the less developed countries.
2. Expand the number of graduate students in Watershed Management from, or interested in, the less developed countries.
3. Expand graduate student research-training programs and activities related to the needs of less developed countries.
4. Expand course offerings in systems analysis of Watershed Management and watershed modeling especially

as related to assistance in solving problems of less developed countries .

5. Expand special activities , and initiate new ones , in the United States and abroad which are related to research , teaching , and service--e.g. seminars , exchange programs , institutes , conferences , and publications which are concerned with the less developed countries .
6. Help to alleviate the critical shortage of qualified professional personnel with international interests , experience , and expertise , and with cross-cultural insights .
7. Expand its capability to serve in advisory and consulting capacity to various individuals , government agencies , industries , business , and other organizations who have an interest in activities abroad (it would be understood , however , that substantial specific services in this area will be funded by AID and any other sponsoring agencies under separate contractual arrangements) .
8. Improve its understanding of the natural resources and nature of societies of less developed countries with

the hope of finding ways and means of better assisting them to resolve crucial problems relating to development and management of their watersheds .

9. Develop an exchange of personnel and publications , and other programs of interaction , which will help to establish steady and effective lines of communication between the University of Arizona and the less developed countries .

The expansion of its full-time professional core staff , course of study , research base , and information sources will enable the University to respond more adequately to requests on watershed management problems from: AID/Washington , USAID country missions , other U.S. federal agencies , other U.S. universities , foreign governmental agencies , institutions and private individuals . Specifically , the University of Arizona , working under other contractual arrangements , will be in a more favorable position to: render greater technical assistance in foreign countries ; provide a higher quality of training for both U.S. and foreign nationals ; do more problem-solving research ; provide more consultation ; and provide generalized prediction models which can be used by less developed countries .

The interrelated teaching, research and informational service competencies will include, but not be limited to, the following subjects:

1. Development and economic evaluation of land management practices for optimizing productivity of watersheds including alternative goals of maximum on-site use of moisture, or maximum water yield for downstream use consistent with stabilization of the site and maintenance of water quality.
2. Developing systems of quantitative analyses for the hydrologic regimes in areas with extended or cyclic dry periods and/or areas with potential flooding. This will include characterization, surface slope and roughness, watershed slope, and cover amount and distribution on the hydrologic regimes.
3. Formulation of simulation models for predicting the time and space distribution of water within watersheds typical of U.S. and other countries. These will provide the basis for the completion of the first objective. Subsequent investigation will be necessary to determine the ability of the models to predict hydrologic behavior under the varying produc-

tivity levels . Special attention would be given to generalized prediction models which , when adapted to specific physical parameters of less developed countries , can be used by land planners , administrators and specialists of foreign countries .

MAJOR ACCOMPLISHMENTS

In the first year of the 211(d) program, the University of Arizona under leadership of the Watershed Management Department has deviated little from its operational plan for building competency in the area of systems analysis of watershed management as related to less developed countries. Accomplishments are presented as a progress report since specific objectives were not expected to be completed within the first year of the grant.

The initial phases of the project have included coordinating on-going programs that have objectives related to those of the 211(d) program. Interdisciplinary aspects have been strengthened through associations with the Departments of Agricultural Engineering, Agronomy, Hydrology and Water Resources and Systems Engineering. Their relationship to the program will be discussed in other sections of the report.

Development of Teaching Competence

Expanding the teaching competence of the University of Arizona has been in the development of new courses and training facilities, restructuring of existing courses and the addition of motivated and qualified professional staff to work in the area

of systems analysis of watershed management.

A review of all water-related courses in the Department of Watershed Management, Agricultural Chemistry and Soils, Agronomy and Agricultural Engineering was made during the year 1969-70. These reviews were made to determine how more international problems could be introduced into these courses to make them more relevant for foreign students and U.S. students interested in foreign service as well as to make all students more aware of the international problems. No new courses were developed in the Agronomy and Agricultural Engineering Departments as a result of the review however individual faculty members have added an international dimension to their courses.

The Agricultural Chemistry and Soils Department added a new course entitled World Soils. In the Watershed Management Department a new course in hydrologic modeling of natural watersheds was developed and will be taught in 1971.

Close cooperation between the Departments of Watershed Management and Hydrology and Water Resources and Systems Engineering on research projects has given the latter two groups a greater understanding of the project needs. In effect, this has added to the total (teaching and research) capability of the Watershed Management Department. Interaction with the above

departments make it possible to draw on the best talents in integrating the techniques of systems analysis and hydrologic modeling in teaching resource management. An advanced Watershed Management course (WSM 345) was restructured to incorporate some of these principles.

In an effort to draw knowledge from the several disciplines that wildland hydrologists must employ, a portion of the text materials for WSM 262 (Watershed Management II) have been prepared. The sections on evapotranspiration and timber production have been completed while others on precipitation interception, snow hydrology, water yield improvement, erosion and watershed modeling will be worked on at a later date.

A collection of abstracts concerned with hydrologic and range research in arid lands has been prepared under the grant with partial support of the Office of Arid Lands (See Appendix A Section I). The abstracts do not all necessarily deal with modeling but may serve to help an investigator to become acquainted with the variables needed for models particular to his needs.

In executing the grant, one of the needs is summaries of the available knowledge in wildland hydrology that could be of value in systems analysis of watershed management. The first in a series of such summaries of hydrologic processes which in-

fluence the routing of water through a watershed is given in Appendix A, Section II. The purpose of these summaries is to provide a reference of literature for our own use, but if it proves useful to others working on hydrologic problems of under-developed countries, it is all to the good. Only studies published in English have been reviewed. A collection of the European work in wildland hydrology is planned for the future. Copies of all papers reviewed except a few that are virtually unobtainable have been catalogued and incorporated into a library for students and faculty.

A Passive Electronic Watershed Model, developed by the Watershed Management Department under the Grant, has proven an extremely useful teaching aid (see Appendix A, Section IV). The approach is to use electrical components in a nearly direct physical correspondence to their field elements. These elements are passive in the sense that they function only in response to an external electrical stimulus. The model is most useful in instructing students from underdeveloped countries because: (1) there is an active interplay between the model user and the model; (2) the model is portable and compact, so that it can be moved anywhere, and the system can be operated completely from battery power and in most any environment; (3) its low cost re-

quires a minimum of funding; and (4) digital computers are generally not available in the underdeveloped countries. The model has been demonstrated to a number of visiting professors from foreign countries and was met with considerable enthusiasm.

With support from this grant and through cooperation with the International Biological Program, Analysis of Ecosystems, the Department is installing a unique teaching-research facility as part of the program for improving curricula and upgrading teaching methods. The facility is a completely interfaced hydrologic data acquisition-analysis system. In addition to a small computer, it also includes software and hardware for working with live-telemetered data. Provisions are also made for the rapid recall of data and programs from a magnetic tape library.

The facility is extremely flexible and unifies the entire process of data collection, compilation and analysis into a single unit. By means of high speed computation it offers the possibility of having data collected, reduced and analyzed in any desired fashion almost immediately and in some cases while the hydrologic event is occurring. The student is able to observe and work with hydrologic processes in the laboratory, at any time and under more inclement conditions.

With this versatility it offers an opportunity to lessen the gap between the publication of research results and their eventual incorporation into classroom instruction. Because of the convenience of having a variety of data immediately at hand and ready for the computer, new developments in hydrologic techniques and research can be tested and demonstrated with the facility as they become pertinent. Teaching efficiency and educational effectiveness are increased by dealing with complex problems in a very practical but dramatic way.

The Department of Agricultural Engineering organized and presented a series of seminars for all University of Arizona personnel who are or have been involved with the Brazil Program, AID Project 1a-145, and professors from the University of Ceara, Fortaleza, Ceara, Brazil who are pursuing advanced degrees at The University of Arizona. The objectives of the seminars were to examine the agricultural problems of the State of Ceara in Northeast Brazil, to encourage the Brazilians to seek solutions to these problems, and to increase the interest and knowledge of the University of Arizona faculty members in international agriculture.

The addition of new faculty, staff and graduate students have enhanced the University's teaching competence in systems

analysis of Watershed Management. Dr. Martin M. Fogel, a specialist in Hydrologic Modeling and Systems Analysis, joined the Department of Watershed Management as Professor of Watershed Hydrology. He is revising the WM 260 course, Watershed Hydrology, and has assisted in the development of a new course in Hydrologic Modeling. Dr. Edwin L. Smith, a specialist in soil-plant-water relations, joined the Department of Watershed Management as Assistant Professor. He has assisted in the revision of two courses in conservation of natural ecosystems which should be of interest to many foreign students.

A new systems analyst and programmer staff position was also added. Seven graduate students, interested in foreign work as careers, received partial support from the grant. One has completed his M.S. degree and accepted a job working for an American firm in Brazil.

Development of Research Competence

Expanding the research competence of the University of Arizona in the area of systems analysis in watershed management has necessarily been interrelated with increased teaching competence. As with teaching, the interdisciplinary approach to research has been emphasized. Personnel from the Departments of Hydrology and Water Resources, Systems Engineering and

Watershed Management have and are continuing to collaborate on such problems as the development of a stochastic precipitation model for use in water management applications, space-time validation of such a model, prediction of surface runoff from rainfall and watershed parameters, and the stochastic analysis of ephemeral flow in arid land channels.

Pertinent research projects primarily within the Watershed Management Department have included the following:

1. A decision-making model for planning optimal resource development.
2. Computer simulation of the hydrologic response of watersheds to precipitation inputs.
3. Prediction of effects of land treatment on sedimentation in small catchment basins.
4. Spatial distribution of watershed infiltration parameters.
5. Prediction of the effect of soil shrinkage and swelling on movement of water into and through soils.
6. Development and testing of transpiration retardants.
7. Prediction of snowpack water balance by means of a seasonal energy balance.

8. Development of electrical analog models of watersheds.
9. Climatological patterns and their effects on agriculture and forestry.

In an effort to update the Watershed Management Department's knowledge of current research in watershed systems and modeling, a tour of major research offices and field installations in four southeastern states was made by John L. Thames and David B. Thorud. Research and management programs of the U.S. Forest Service Tennessee Valley Authority, Oak Ridge National Laboratory and Duke University were reviewed. A detailed report of the trip which was supported by Section 211(d) is contained in Appendix A, Section III.

A compilation of current research in the United States applicable to systems analysis of watershed management has been prepared under the grant (see Appendix A, Section V). Its purpose is to summarize current research projects being carried out by federal and state agencies and universities in the United States that may be pertinent to the "Optimum Utilization of Water Resources for Agriculture with Special Emphasis on Systems Analysis of Watershed Management."

Systems Analysis of watershed management implies integrating hydrologic, ecologic, and economic principles into operational models that will provide quantitative guides for the management of land for the optimum yields of water for: (1) on-site use in the production of timber, forage or crops; (2) use further downstream for irrigation, municipal needs or power production; (3) control of erosion, sedimentation and floods; and (4) all or any combination of these uses.

From more than 1000 research projects in progress, 152 were selected as particularly applicable to these objectives. The science information exchange was the primary source of information supplemented by correspondence, telephone communication and personal visits with the organizations involved.

Partially funded by the Grant, The Agricultural Engineering Department, in cooperation with the Agronomy Department, has inaugurated a project which is attempting to make more beneficial use of the limited rainfall that occurs in semi-arid regions. The possibility of farming relatively small areas of the desert by collecting runoff water from a much larger area to augment the crop's available water supply from direct rainfall is the objective of this project. A more detailed account of this project is found in a paper presented at the 1970 annual meeting of the American

Society of Agricultural Engineers (See Appendix A, Section VI) .

The Department of Agronomy has several programs underway in the general area of water use by crop plants . Although these programs are not funded by the Grant, they do provide expertise, equipment and facilities for two graduate students training under the Grant.

New faculty members, Dr. Martin Fogel and Dr. Edwin L. Smith added as a result of the grant, have substantially increased the research capabilities of the University in system analysis in Watershed Management. These professors will also advise some of the new graduate students assisted by the grant with their research programs . A new systems analyst and programmer staff position was added to assist faculty and graduate students in the development of better research and teaching.

Development of Competence for Consultations and Service

The addition of new faculty, facilities, library holdings, abstract and bibliographical compilations, and the increased awareness and interest of personnel in the Objectives of the Grant have resulted in greater capability of the University to offer consulting advice and services . The new faculty added to the staff with the assistance of the Grant, Drs . Fogel and Smith have more than 5 years total overseas consulting experience. Gradu-

ate students particularly those from less developed countries, working with these faculty will increase the talent available for research and teaching in less developed countries.

A brief listing of the staff and their consulting assignments follows:

Dr. John H. Ehrenreich, June 26 to July 12, 1969 - to Northeast Brazil in connection with the USAID/Brazil Contract with the University of Ceara.

Dr. Martin Massengale, November 22 to December 9, 1969 - to Northeast Brazil in connection with the USAID/Brazil Contract.

Dr. R. E. Dennis, September 20 to September 30, 1969 - To West Pakistan.

Dr. M. H. Schonhorst, September 23 to September 30, 1969 - To Venezuela Private Consulting.

Dr. Martin M. Fogel, November 25 to November 30, 1969 - To Mexico. Private Consulting.

Dr. W. Matlock, July, 1979 - To Brazil in connection with the USAID/Brazil Contract.

Involvement of Other University Resources

An up-to-date and complete library is essential to any teaching or research program. The University has responded to

this and other projects by embarking on an expansion program for the Science Library. State and Federal funds in excess of two million dollars are being used to construct additional space and for acquiring additional reference materials.

The usefulness of the recently completed Computer Center to systems analysis has been greatly enhanced by the University's purchase of a multiplex unit for the CDC 6400. This will make it possible to install terminals which will facilitate the teaching and research concerned with highly complex watershed management problems. The terminal will allow the eventual interfacing between the CDC computer and the hydrologic data acquisition and analysis system referred to on page B-14 of this report.

All personnel added to the project have been funded, at least in part, by other University sources. The time of the Project Director and other closely associated personnel has been paid from University funds.

Associated departments, such as the Department of Agricultural Engineering, Agronomy, Agricultural Chemistry and Soils, Hydrology and Water Resources and Systems Engineering have all made significant contributions to the project. The assistance of the Office of Arid Land Studies has been invaluable in obtaining pertinent abstracts, bibliographies and research summaries.

EXPENDITURES

The approximate expenditures during the year are indicated for the various categories in Table 1. Expenses for professional services were slightly greater than anticipated because of employment of persons to assist in the software package development for the instructional modeling and hydrologic simulation facility and for assistance in installation of electronic instruments for the telemetry phases of the facility.

Travel costs were less than anticipated partly because all foreign travel was financed from other funds. The most significant domestic travel expense was the trip to the East and the Southeast by Drs. John L. Thames (\$552) and David B. Thorud (\$863) to observe experimental and instructional watersheds in more humid vegetation types, to build a backlog of data available for modeling and to aid in course development. A detailed description of their trip and accomplishment appears in Appendix A, Section III.

Equipment costs were less than anticipated because most of the hardware including the modeling and hydrologic instructional facility were obtained from state and other federal sources. The only item costing more than \$100 was a sickle mower

attachment for a garden tractor (\$181.10) to be used in obtaining production data for water use effectiveness modeling problems. Computer costs were also lower than anticipated because the instructional facility has not yet reached a fully operational stage and because additional computer use in courses was financed for the most part with state funds. The general operational expense was very close to anticipated amount.

Table I. Expenditures and Anticipated Expenditures For Fiscal Years 1969-70 through 1973-74

	<u>69-70</u>	<u>70-71</u>	<u>71-72</u>	<u>72-73</u>	<u>73-74</u>	<u>Total</u>
Salaries	38,113	40,000	38,000	37,000	36,000	189,113
Wages	9,430	5,000	5,000	4,000	3,500	26,930
Fringe Benefits	<u>3,771</u>	<u>4,000</u>	<u>4,000</u>	<u>4,000</u>	<u>4,200</u>	<u>19,971</u>
Sub Total	51,314	49,000	47,000	45,000	43,700	236,014
Stipends	6,213	8,500	14,000	10,000	8,500	47,213
Travel						
Foreign	--	4,000	4,000	4,500	3,500	16,000
Domestic	3,368	2,000	2,000	2,000	1,500	10,868
Equipment	2,694	4,000	2,000	2,000	2,000	12,694
Computer	1,348	3,000	3,000	3,000	2,000	12,348
Operations	<u>2,993</u>	<u>3,000</u>	<u>3,000</u>	<u>3,000</u>	<u>2,870</u>	<u>14,863</u>
TOTALS	67,930	73,500	75,000	69,599	64,070	350,000

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WORK PLAN AND BUDGET FORECAST

Many of the activities initiated during the first year will be continued in the forthcoming period. These include:

1. Assemble and analyze existing information devoted to the use of the techniques of systems analysis in the development and management of watersheds in less developed countries.
 - a. Available bibliographies and abstract compilations with reference to the major processes in the hydrologic cycle will be collected and amended if necessary to bring up to date. Additional compilations will be made to include those processes not previously reviewed and published.
 - b. Assemble and catalog a library of research pertinent to the general field of watershed management. A library of computer programs of existing watershed models will be assembled.
2. Develop and analyze computer simulation models that quantitatively characterize the natural hydrologic processes. These models route the precipitation

input through the vegetation-soil complex of the watershed to predict streamflow. Data from actual watersheds will be used to validate the models.

3. Prepare plans for research programs that are concerned with the development and economic evaluation of land management practices for optimizing productivity of watersheds. An example of where such work appears to be needed is in the country of Indonesia. Reports have indicated that serious erosion problems have developed in the up-land areas which have affected downstream water storage facilities. This problem has occurred as a result of people migrating to these upland, water-source areas from the population centers in the valleys. The settling of the people in the predominantly forested regions have altered the vegetation complex in these areas resulting in the erosion problem. Support for these complementary research programs will be sought through CUSUSWASH and other sources.

In addition to the above, broad operational plans have been prepared to meet project objectives. For example, in an effort to

strengthen its competency for consultations, the Watershed Management Department will emphasize this aspect through a systematic investigation of those less developed countries that have serious watershed management problems. Efforts will be made to obtain first-hand familiarity with such areas in an endeavor to assist in finding a solution to these problems.

The Watershed Management Department in conjunction with the Hydrology and Water Resources Department will explore the possibility of holding the Fourth International Seminar for Hydrology Professors, a United States Contribution to the International Hydrological Decade at the University of Arizona during 1972. Based on the subjects that were or will be presented, the theme that suggests the use of systems analyses in watershed management appears to be a logical choice.

Insofar as the budget forecast for the 1970-71 year is concerned, no major changes from the proposal document is contemplated.