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PART II

UNIVERSITY OF ARIZONA

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2457

May 1972

TABLE OF CONTENTS

211(d) Annual Report

Date April 17, 1973

Title: Optimum Utilization of Water Resources for Agriculture: With Special Emphasis on Systems Analysis of Watershed Management Under Conditions Characteristic of Less Developed Countries

Grantee: University of Arizona

Director: David B. Thorud

A. Statistical Summary:

Period of Grant: July 1, 1969 to June 30, 1974 Amount of Grant $350,000
Expenditures for Report Year $76,620 Accumulated $230,922
Anticipated for next year $67,300

B. Narrative Summary:

The University of Arizona's overall competency in the area of watershed management utilizing systems analysis as applied to developing countries has been materially strengthened by the 211(d) Grant. As a member of 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 has concentrated its activities on those concerned with the source of the water supply. Operators of water resource systems are faced with increasingly difficult decisions to overcome the physical, economic and social problems which characterizes man's never-ending battle against aridity, flood, drouth and pollution. The planners and designers of water resource systems must often choose among

a number of alternative plans for location and design of water control structures, operation of water management systems and institutional arrangements for effecting an acceptable plan. Systems analysis techniques with its inherent computer-based methods are employed as an aid in the decision-making process as it combines quantitative analysis and economic concepts into system design and evaluation. Involved in these techniques are predictions and testing to suggest objectives and possible courses of action.

To be in a better position for providing assistance to emerging nations in developing and operating water supply systems for agriculture, the University of Arizona has expanded its program of applied research and teaching in the area of systems analysis in watershed management.

The increased research competency in the utilization of systems analysis techniques has been channeled into two general activities. Hydrologic model building is one while modeling the decision-making process itself is the other. Simulation of a watershed's behavior as a means for determining the effect of man's intervention is an important aspect in water resources decision making. Projects under the hydrologic modeling activity which involve six faculty members include:

Development of stochastic models of precipitation and streamflow.

Computer simulation of the hydrologic behavior of watersheds.

Runoff farming in semi-arid areas.

Water use efficiency of selected crops.

The above projects are inputs into the management activity which is devoted to developing decision-making models for the optimal utilization of a watershed's resources.

A total of four graduate students have obtained their master's degrees (two this past year) working on the above projects. In addition, two doctoral candidates should complete their dissertations within the forthcoming year.

The enhanced instructional phase of the program has the dual function of training U.S. students interested in the development of emerging nations and the development of teaching aids for all students. Three new courses in World Soils, in Hydrologic Modeling and in Environmental Quality and Agriculture have been added, the latter this past year, to those that have been applicable to developing countries.

Since inception of the 211(d) Grant, considerable effort has been directed towards the development of a computer-oriented instruction facility (CARES: Computer Assisted Resource Educational System) and an Electric Analog Watershed Model. Computer-assisted instruction (CAI) is ideally suited for this activity because of the computer requirements of many systems analysis techniques. Thus, instruction is conducted using the very same device as is employed in an operational situation. The Electric Analog Watershed Model facilitates training as students can "visualize" the hydrologic response of watersheds. Two graduate students have been instrumental in developing these training aids and

should finish their dissertations within the next year. With the 211(d) Grant supporting approximately two faculty man-years in the area of systems analysis in watershed management, additional opportunities for providing consulting services to developing countries are available. Some six faculty members (three in the Watershed Management Dept.) consulted on Grant-related activities in Latin America and Near East countries.

Plans have been made to locate within the Department of Watershed Management a library that will contain information pertaining to developing countries. Bibliographies and abstracts have been prepared on specific subjects, such as the one accomplished last year on snow hydrology. In cooperation with other University departments (Hydrology and Water Resources and Systems and Industrial Engineering), the Watershed Management Department is involved in the planning for an international symposium on Uncertainties in Hydrologic and Water Resource Systems to be held next year on the University of Arizona campus.

The Grant has stimulated an awareness on the problems of developing countries within the College of Agriculture. Students,both foreign and U.S. with an interest in foreign relations, have been attracted to the program.

In most cases, the research supported by the Grant will have direct applications to developing countries. The models being developed to describe the hydrologic and decision-making processes have as their goal, the optimum utilization of water resources for agriculture. These models are of the universal type in that their only requirement for making them usable in developing countries is an estimate of parameters obtained from an appraisal of local conditions. Since knowledge so gained must be transferred to be of value, a mechanism for accomplishing this is the international symposium such as the one being planned to be held next year on the University of Arizona campus. The development of special instructional techniques for training and the dissemination of information of complex water management systems is also relevant to developing countries. Finally, U.S. students can focus their attentions on the classes of problems found in developing countries with the aid of a library of readily available information that pertains to these countries.

Cooperation with departments outside the College of Agriculture has also increased the University's capability of involving other faculty members in Grant-related activities. These activities were instrumental in obtaining additional support such as from the Office of Water Resources Research, the U.S. Forest Service and the Bureau of Land Management.

To increase linkages with other countries, plans were made for a faculty member to visit several South American countries to examine first-hand watershed management problems and situations and to establish contacts with foreign scientists working on these problems.

C. Detailed Report

I. General Background and Purpose of Grant

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.

Water management in agriculture can be viewed as the development, processing, storage, transportation and utilization of a raw material, water for increasing food production. Producing a lasting and efficient system for accomplishing this overall objective requires that all segments of water-based activities be integrated into a common plan. Thus, CUSUSWASH has developed a coordinated program in water management for agriculture production. While Utah State University looks at the practices involving the utilization of water, Colorado State University delves into the problems relating

to the storage and transportation of water. At the same time, the University of Arizona is concerned with the development, processing and storage of this vital resource, or the watershed management phase of the system.

Watershed management is generally defined as the management of the natural resources of a drainage basin primarily for the production and protection of water supplies and water-based resources, including the control of erosion and floods, and the protection of esthetic values associated with water. The University of Arizona is one of only a few institutions in the world that has attempted to develop a coordinated effort in the management of this important natural resource. 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. Watershed Management is a complex art that is decidely inter-disciplinary in nature. It involves the development and use of hydrologic simulation models, establishing functional relationships between land management methods and hydrologic processes, and also the techniques of systems analysis which seek to integrate the power of quantitative analysis with the concepts of economic theory. With water management systems becoming increasingly complex, so are the procedures which address themselves to the fundamental issue of design and management,

that of specifying how men, money and material should be combined to achieve a larger purpose. This is an area where the Grant is having a large impact, that is, in the area of watershed management with special emphasis on the science and methodology of applying systems analyses techniques to problems of less developed countries.

II. Objectives of the Grant

1. Objectives restated

The University of Arizona through 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 systems. Specifically, the objectives of the University of Arizona program are:

a. Expand its professional staff in Watershed Management with faculty members who are specifically involved in hydrologic modeling and the utilization of systems analysis techniques in watershed management activities.

b. Expand the graduate student research training program and activities related to the needs of developing countries.

c. Expand and modify course offerings concerned with water management in agriculture especially as related to emerging nations.

d. Expand and initiate special activities such as seminars, exchange programs, institutes, conferences, publications and other programs of interaction which will help establish continuous and effective lines of communication between the University of Arizona and the less developed countries.

e. Strengthen its capability to serve in advisory and consulting capacity through foreign travel and study by faculty members.

f. Improve its understanding of the type of problems encountered in the less developed countries, including the socio-politico aspects relating to the development and management of watershed systems.

2. Review of Objectives

While the objectives of the Grant have, in general, remained as stated above, certain activities have been emphasized. These activities are listed under the objectives which have been re-grouped as follows:

a. Improvement of Research Capability

The objectives included are:

(1) Hydrologic Model Building: the development, modification and quantification of relationships that describe the hydrologic processes occurring on watersheds and predict the effects of land management practices on the watershed system.

(2) Decision-Making Models: the adaptation of relevant management techniques to actual problems encountered in the management of natural resources.

b. Improvement of Teaching Capability

(1) Computer Assisted Resource Education System (CARES): to instruct in the area of watershed management utilizing systems analysis techniques, computer-based methods are essential not only to reduce the computational burdens, but also to provide the manager with freedom to exercise his creative abilities. The development of a computer-assisted instruction (CAI) program is a logical extension of the University of Arizona's effort to increase its research and teaching capability.

(2) Electric Analog Watershed Model: another training aid that is being developed to assist in the instruction of resource management is a Passive Electronic Watershed Model.

(3) Course Development: new courses have been added and existing ones have been re-structured to incorporate the aims of the Grant.

c. Increase Consulting Competence

Foreign travel and study is the principal activity in which the University of Arizona improves its consulting capability.

d. Expansion of Special Activities

These activities may include the organization of seminars, institutes, conferences, exchange program or other programs that stimulate interaction between the University of Arizona and

developing nations. The development of a library which will include bibliographies and abstracts as well as the acquisition of pertinent publications will be a major activity reported in this section.

III. Accomplishment

1. Improvement of Research Capability

a. Hydrologic Model Building

During the past year, support in this area was given to one doctoral and three master's degree candidates. The subject of their projects are:

Development of an overland flow hydrologic model for semi-arid watersheds.

Optimizing parameters in hydrologic models.

Determination of consumptive water-use efficiency for selected crops.

Development of a rainfall multiplication process for dryland farming in semi-arid areas.

There are six faculty members in three College of Agriculture Departments (Watershed Management, Soils, Water and Engineering and Agronomy and Plant Genetics) that are involved in the above activity whose related projects include:

Development of stochastic models of precipitation and runoff.

Prediction of snowpack water balance by means of a seasonal energy balance.

Remote sensing of hydrologic parameters.

Development and testing of transpiration retardants.

Papers prepared on the above subjects during the 1972 year include:

A stochastic model of runoff-producing rainfall for summer type storms.

Elevation effects on rainfall: a stochastic model.

Analysis of ephemeral flow in aridlands.

Choosing hydrologic models for changing watersheds.

An event-based stochastic model of winter rainfall.

Antitranspirant effects on the transpiration and physiology of tamarisk.

Two theoretical models of radiation heat transfer between forest trees and snowpacks.

b. Decision-Making Models

The Grant supported one doctoral dissertation in the 1972 fiscal year dealing with the subject--Optimizing production of range resources through systems analyses on operations research techniques. Completion of this work is anticipated next year.

Dr. Lucien Duckstein of the Systems and Industrial Engineering Dept. was supported by the Grant for one month to consult with

various faculty members on the use of systems analysis techniques in natural resource management. He also presented two lectures on this subject at a Bureau of Land Management short course, a two-week instructional program held annually at the University of Arizona by the Department of Watershed Management.

The following are papers presented this past year that pertain to this activity:

Evaluation of the effects of water yield management.

Systems Analysis: a decision-making tool for arid land development.

2. Improving Teaching Capability

   a. CARES

   Partial support was granted to two students working in the field of developing a computer-oriented instruction program, the second year for this activity. One, a doctoral candidate is working on a computer language for use with this system. The other has just completed an M.S. in which he prepared a professional paper which presents four lessons of computer-assisted instruction (CAI) designed to introduce the concepts and utility of linear programming.

   To assist such projects as the above, Grant funds have been expended towards developing a completely interfaced hydrologic

data acquisition-analysis system. The small computer utilized in this system was used in the above CAI program. In addition to the computer, the facility includes software and hardware for working with live telemetered data and has provisions for rapid recall of data and programs from a magnetic tape library. While primarily intended for improving teaching methods, the facility can also be used for research. This particular activity has been a major effort since initiation of the Grant.

b. Electronic Analog Model of a Watershed

The development of a direct passive electrical analog model of a watershed has essentially been completed by a doctoral candidate supported with Grant funds. All that remains is Graduate College acceptance of the final copy of the dissertation entitled, "Analysis and Application of a Passive Electronic Analog Model to the Hydrologic Regime of a Watershed".

A representative of the Food and Agricultural Organization (FAO) of the United Nations has expressed interest in this model as a teaching and research device.

c. Course Development

This past year the services of Dr. Lucien Duckstein were used to help reorganize a course entitled, "Advanced Watershed Management." Incorporated in the course are such techniques as linear and dynamic programming, simulation devices, sensitivity analysis and

other concepts that are involved in the investigation of a broad range of alternatives and in consideration of the economic and social constraints of natural resources management system.

The College of Agriculture has added a new course, "Environmental Quality and Agriculture", which deals in large part with world food production requirements and problems. Like the above course, it will be offered for the first time in the following fiscal year. This course has direct implications of a current topic of concern to developing countries. The development and management of water resources to increase food production is a major effort in many emerging nations. While the environment for producing more food is greatly enhanced by such projects, these efforts can also have deleterious effects on other parts of the environment. A striking example is the Aswan Dam in Egypt. Linked to this project has been the increased incidence of a dread disease and a reduction of fish production in the Mediterranean Sea.

In the first two years of the Grant, a review of all water-related courses in the College of Agriculture was made in an attempt to increase their relevancy to problems encountered in

developing countries. Two new courses were added, one dealing with world soils and the other with the hydrologic modeling of natural watersheds. Several other courses were revised to incorporate the objectives of the Grant.

3. Development of Increased Consulting Competance

The University of Arizona continues to encourage faculty members to serve in an advisory or consulting capacity to developing countries. Dr. E. L. Smith, formerly supported under 211(d), has been designated as Chief of Party of the University's AID Mission Program in Northeast Brazil. Also spending time in Brazil consulting with University of Ceara personnel was Dr. P. R. Ogden, Professor of Range Management. Dr. Martin Fogel attended a CENTO Seminar in Agricultural Aspects of Arid and Semi-Arid Zones held in Tehran, Iran. He presented a paper on the use of systems analysis in agricultural management.

4. Expansion of Special Activities

a. Library Development

Plans have been made to locate a library within the Department of Watershed Management that will contain information pertinent to developing countries. The library will be organized by a professional librarian and will be maintained indefinitely. It will have a computer access capability compatible with the computer retrieval system being developed by the Office of Arid Land Studies

in conjunction with the University Library. As part of this effort last year, an expanded bibliography on snow hydrology and management was prepared. In previous years, abstracts were obtained in such subject matter areas pertaining to arid watersheds as range management, climatology, hydrology, water quality and irrigation. These categories constitute the basis for developing mathematical models to determine streamflow, soil moisture content, salt accumulation or a variety of other parameters that characterize watershed processes. A bibliography on one of these processes, interception, was also prepared in past years.

b. International Symposium

The Department of Watershed Management is cooperating with the Departments of Hydrology and Water Resources, Systems and Industrial Engineering and Mathematics in sponsoring an International Symposium on Uncertainties in Hydrologic and Water Resource Systems. It has been endorsed by four international societies as well as leading American organizations.

IV. Impact of Grant in Developing Institutional Capabilities

The approach to solving the problems of water management in agriculture must be integrated to consider all policy levels from the system planner to the controller and finally to the user. Watershed Management for the most part, relates to the first two phases. It is concerned with such

specific technical topics as economic evaluation for optimal use of water and land, analysis of hydrologic regimes, and simulations for predicting the water supply. To assist the planner and operator of watershed systems in utilizing the more sophisticated but generally accepted techniques requires the development of procedures that will aid him in understanding these techniques. Computer-assisted instruction (CAI) is a tool that can be used for training in natural resources management.

Procedures for its utilization are currently being developed within the Department of Watershed Management. As a result of this activity, interest in CAI has expanded to other University departments, Geosciences, Physics and Education.

The development of systems analysis or operations research techniques in the field of watershed management has provided the opportunity for collaboration with other University departments, namely Systems and Industrial Engineering and Hydrology and Water Resources. These multi-disciplinary efforts have resulted in the University receiving a three-year grant from the U.S. Department of Interior for studying decision-making processes in natural resources management..

The Grant has stimulated an awareness within the College of Agriculture of the agricultural problems that developing countries are facing. It has helped attract students with an interest in international relations

such as two former Peace Corps members now graduate students in the Department of Watershed Management. These students are considered prime candidates for this program; they have the experience of working with the watershed management problems in developing nations, they are proficient with at least one foreign language, and they have a high technical capability. With further training, they should become excellent candidates for further foreign service. We hope to obtain more students with this kind of background.

With its increased competency in watershed modelling of hydrologic systems, the Watershed Management Department has received financial support from the Arizona Water Commission and the U.S. Forest Service.

V. Utilization of Institutional Resources in Development

The University of Arizona has made a concerted effort in providing faculty time, office space, library facilities, equipment, materials, etc., to meet the objectives of the Grant. Most of the faculty associated with the program are state supported.

Three faculty members from the Department of Watershed Management (B. N. Freeman, P. R. Ogden and E. L. Smith) made two visits to a new livestock and range experimental station in northern Mexico. They were consulted on the implications of adopting various land use management practices.

Since the inception of the Grant, a total of 16 foreign students have completed work in the Watershed Management Department, with 9 coming from emerging African nations and 7 from Latin American countries. Several U.S. students have enlisted in the Peace Corps while two former members have enrolled in the department for graduate work.

The College of Agriculture continues to be heavily engaged in development through its USAID/Brazil contract.

VI. Other Resources for Grant-Related Activities

A major input in the University's program in Watershed Management is the National Science Foundation supported International Biological Program (IBP) - Analysis of Ecosystems. This organization has contributed to the hydrologic data acquisition - analysis system which includes CARES. Another large contributor to Grant-related activities in the USDA through its Hatch, Regional Research and Forest Service programs. The first two programs are involved in the development of specific watershed and precipitation models, while the Forest Service projects are concerned with the installation of experimental watersheds to validate watershed models.

VII. Next Year's Plan of Work and Anticipated Expenditures

While no new activities are planned for the 1972-73 year, there will be some shifting of emphasis. It is planned that consulting activities will increase as will special activities including library development and

co-sponsoring an international symposium. A reduction in research and teaching activities, primarily in connection with the nearly completed electric analog watershed model, will compensate for the expanded activities.

Table I

Distribution of 211 (d) Grant Funds and Contributions From Other Sources of Funding*

Review Period July 1, 1971 to June 30, 1972

List of all grant related activities	211 (d) Expenditures				Non 211 (d) Funding Amount- Period Under Review
	Period Under Review	Cumulative Total	Projected Next Year	Projected to end of Grant	
Research					
Hydrologic Modeling	32,000	115,000	20,500	160,000	35,000
Decision Making	9,000	25,000	12,000	45,000	15,000
Teaching					
Computer Assisted Inst.	16,000	42,000	10,000	59,000	5,000
Electrical AnalogDev.	8,000	25,000	2,000	27,000	4,000
Course Development	1,000	2,000	3,000	6,000	15,000
Libraries	2,000	4,000	3,000	10,000	2,000
Consultation	3,000	7,000	10,000	22,000	1,000
Other	620	1,140	800	4,000	2,000
CUSUSWASH	5,000	5,000	6,000	17,000	
Publication (incl. Above)					
TOTAL	76,620	226,140	67,300	350,000	79,000

*These figures are our best estimates

Table II

Expenditure Report

(Actual and Projected)

Under Institutional Grant #AID/csd - 2457

Review Period July 1, 1971 to June 30, 1972

	Expenditures to Date		Projected expenditures Year		Total
	Period Under Review	Cumulative Total	4	5	
Salaries	37,265	123,599	23,000	25,000	171,599
Wages	7,090	20,535	10,000	3,060	33,595
Fringe Benefits	3,800	12,463	2,300	2,500	17,263
Sub Total	48,155	156,597	35,300	30,560	222,457
Stipends [1]	13,513	29,366	10,000	8,000	47,366
Travel					
Foreign [2]	415	3,035	6,000	5,000	14,035
Domestic	3,090	9,711	3,000	1,000	13,711
Equipment	3,880	10,559	3,500	3,500	17,559
Computer	410	1,858	2,000	1,000	4,858
Operations [3]	2,157	10,014	1,500	1,500	13,014
CUSUSWASH	5,000	5,000	6,000	6,000	17,000
TOTAL	76,620	226,140	67,300	56,560	350,000

[1] See Table 3 for detailed breakdown of this category.

[2] B. N. Freeman, P. R. Ogden and E. L. Smith trips to Mexico to evaluate and consult with Mexican resource managers on range watershed conditions.

[3] See Table 4 for detailed breakdown of this category.

Table III

Expenditure Report Continued

Under Institutional Grant #AID/csd - 2457

Review Period July 1, 1971 to June 30, 1972

Students Supported Wholly or in Part by 211(d) Stipends and Salaries[1/]

Student	Title	Degree Objective	Level of 211(d) Support (dollars)
Bartlett, E.T.	Instructor-Research Assoc.	Ph.D.	2000
Rasmussen, W.O.	Grad. Assoc.	Ph.D.	1200
Tinlin, R.M.	Instructor-Research Assoc.	Ph.D.	9600
Welch, T.G.	Grad. Assoc.	Ph.D.	2100
Cunningham, R.O.	Grad. Assist.	M.S.	1750
Morin, G.C.A.	Grad. Assist.	M.S.	3300
Wilhelm, W.W.	Grad. Assist.	M.S.	3600
		Total	23550

[1/] In addition, a combination of four undergraduates and graduate students were supported on wages totalling $2,210.

Table IV

Expenditure Report Continued

Under Institutional Grant #AID/csd - 2457

Review Period July 1, 1971 to June 30, 1972

Detailed Breakdown of Operations Expenditures

	Category	Amount Expended (dollars)
(1)	Maintenance and Repair of Equipment	119
(2)	Office, laboratory and field supplies (forms, stationery, computer cards, expendible tools, paint, lumber, small hardware items such as nails and bolts, chemicals, laboratory materials)	1203
(3)	Painting and Audio-visual Services	135
(4)	Telephone (long distance calls)	160
(5)	Freight charges	20
(6)	Equipment rental (typewriter, equipment for field watershed installations)	510
(7)	Subscription	10
	Total	2157

APPENDIX A

Abstracts of Publications Related to 211(d) Grant Activities

1. Point Rainfall Frequencies in Convective Storms

ABSTRACT

An exponential relation was developed to describe the spatial distribution of convective storm rainfall in southwestern United States. Given that a storm center has occurred, a geometric distribution was used to describe the frequencies of point rainfall depths. A Poisson distribution was assumed to represent the probability of at least one storm center occurring over a given area a specified number of times during a season. Assuming that the two probability distributions are independent and uncorrelated, maximal and minimal distributions of point rainfall depths were derived. The minimal distribution indicates that with a very high certainty a single rain gage will miss at least one convective storm a year. When compared with frequencies determined from long-term historical records, the maximal distribution exhibits a similar mean, a greater variance, and lower recurrence intervals for the higher rainfall depths.

REFERENCE. Fogel, Martin M. and Lucien Duckstein. Point rainfall frequencies in convective storms. Water Resources Res. 5(6):1229-1237. 1969.

2. A Passive Direct Electric Analog of a Watershed

ABSTRACT

A passive electric analog has been developed that has a direct physical correspondence to the processes taking place on a typical watershed. The usual procedure in surface water electronic analog models is the use of active elements such as operational amplifiers or in the case of surface water routing models, R-C networks combined with slow speed switching devices. Modern technology has made available numerous semiconductor elements which allow us to build passive electric analogs that modify an electrical input function in manner of marked similarity to the way rainfall input is modified by the watershed storage parameters as it traverses through the watershed.

The model discussed in this paper is designed as an instructive tool for student or scientist in investigating the use of electrical components in analog modeling; and also serves as an excellent means of studying most of the major hydrologic processes of a watershed and their interrelationships.

REFERENCE. Tinlin, R. M. and J. L. Thames. A passive direct electric analog of a watershed. Paper presented in Amer. Geophys. Union Sect. of Hydrol. Fall National Meeting, San Francisco, December 1969.

3. Prediction of Convective Storm Runoff in Semiarid Regions

ABSTRACT

Analysis of 14 years of data taken on the Atterbury Experimental Watershed located near Tucson, Arizona, USA has led to a procedure for predicting semiarid basin runoff from convective storms. The record event for small catchments is usually the result of these localized, high-intensity, short-duration storms.

A general runoff equation was developed based on the mass curves of infiltration and runoff. The relationship included a runoff coefficient defined as the ratio of runoff to effective rainfall (storm total less initial abstractions). Multiple regression techniques indicated that for very small areas (less than two square kilometers), this coefficient remains essentially constant for a given basin. However, for catchments ranging in size up to 20 or 25 square kilometers, additional information can be obtained by characterizing the time distribution of storm rainfall.

Using the storm's maximum 15-minute intensity as the time distribution parameter, it was shown that the runoff coefficient was a function of this parameter. Thus, the probability of equalling or exceeding a given volume of runoff is an event that can be determined by a joint probability. The results from a previously developed model that describes the spatial distribution and frequency of occurrence of convective storm rainfall were combined with the frequency distribution of the storm's intensity to define the joint probability function.

An extreme-value distribution was found to adequately describe the annual maximum series of runoff volumes. Using selected return periods, results from this analysis were compared to runoff predicted from rainfall data. The comparison was favorable, especially for the longer return periods.

Antecedent rainfall and the location of the point of maximum rainfall on the relatively small watersheds had no significant effect, statistically, on runoff.

REFERENCE. Fogel, Martin M. and Lucien Duckstein, Prediction of convective storm runoff in semiarid regions. Int. Assoc. Sci. Hydrol. Pub. No. 96:465-478. 1970.

4. Computerized Hydrologic Data Acquisition System - A Facility for Upgrading Instruction in Watershed Management

ABSTRACT

Technological explosion, population expansion, urban sprawl, changing patterns of land and water use and increasing emphasis on environmental quality control are presenting vast new challenges to natural resource scientists and land managers. To successfully meet these challenges, colleges and universities need to produce graduates with new kinds of training and skills. Land managers of the future must have a wide understanding and have a technical training much better than ever before. Familiarity with the computer, for example, is no longer so much an advantage as a necessity. Similarly, skill in interpreting remote satellite data for land management purposes may be required in the very near future. Accordingly, the Department of Watershed Management in the College of Agriculture of the University of Arizona has an extensive program of upgrading its curriculum and improving teaching methods. The purpose of this paper is to describe a teaching-research facility which provides an innovation in instruction techniques for one facet of the program.

The facility is a completely interfaced hydrologic data acquisition processing system. It goes somewhat beyond the definition of SCI and CDI as described by Borden.[1] In addition to a small, laboratory computer and the services of a remote time shared terminal to the large CDC 6400 computer, the facility also includes both software and hardware for working with live telemetered data. Provisions are also made for the rapid recall of past data from a magnetic tape library.

REFERENCE. 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 Teachers in Agric. 14(1):3-4. 1970.

5. A Computer Automated System for Hydrologic Data Acquisition and Analysis

ABSTRACT

This report discusses a state-of-the-art computer controlled telemetered data acquisition system operated by the Department of Watershed Management, University of Arizona for the past two years. The purpose of the system is to provide an accurate time and space history of the variations of hydrometeorological parameters.

A computer is incorporated into the system which processes the raw data on-line, producing finished answers in any format desired. It also affords the user total control of the data taking process--varying the sample rate in relation to input changes, real time, etc. All output is recorded on tape but may also be displayed on a teleprinter for visual inspection.

The system consists of the computer controlled central station on campus with software for data reduction and analysis, a VHF and landline telemetry link, and two remote field stations within a radius of 40 miles. The field stations consist of an array of hydrometeorological sensors, a memory unit, signal conditioning unit, and telemetry transmitter.

The central station 8-K-16bit digital computer is the heart of the system. Accessory central station equipment consists of a teleprinter, digital clock, magnetic tape unit, and the radio and landline communications links.

REFERENCE. Thames, J. L. and R. M. Tinlin. A computerized automated system for hydrologic data acquisition and analysis. Proc. Int. Symp. on Hydrometry, Koblenz, September 1970.

6. Systems Analysis in Natural Resources Management

ABSTRACT

This paper discusses the applications of systems analysis as a tool for decision making in the management of natural resources. The use of systems analysis in decision making is briefly discussed and contrasted with the empiracism used by natural resource managers. By using this technique, a meaningful transition from inventories to decisions is provided which enables the manager to base his programs on a quantified interpretation of basic inventory data. The technique brings together the past knowledge and experience of managers and scientists as well as economics, physical relationships of the natural systems and the ecological and social constraints. An example of a decision making model which employs a combination of linear and dynamic programming is presented. The example, although simplified by assumptions, illustrates the determination of optimal investment for watershed development, considering the distributed nature of model parameters.

REFERENCE. Bartlett, E. T. Systems analysis in natural resources management. 1971 New Mexico Water Conference, New Mexico State Univ., Las Cruces, New Mex., March 1971.

7. Space - Time Validation of a Thunderstorm Rainfall Model

ABSTRACT

A probability model for predicting the occurrence and magnitude of thunderstorm rainfall developed in the southwestern United States was tested in the metropolitan Chicago area with reasonable success, especially for the moderate to the extreme runoff-producing events. The model requires the estimation of two parameters, the mean number of events per year and the conditional probability of rain given that an event has occurred. To tie in the data from more than

one gage in an area, an event can be defined in several ways, such as the areal mean rainfall exceeding 0.50 inch and at least one gage receiving more than 1.0 inch. This type of definition allows both of the model parameters to be obtained from daily warm-season rainfall records. Regardless of the definition used a Poisson distribution adequately described the number of events per season. A negative binomial distribution was derived as representing the frequency density function for rainfall where several gages are employed in defining a storm. Chicago data fit both distributions very well at events with relatively high return periods. The results indicate the possibility of using the model on a regional basis where limited amount of data may be used to estimate parameters for extensive areas. (KEY WORDS: thunderstorm rainfall model; frequency analysis; probability distributions; parameter estimation)

REFERENCE. 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.

8. Antitranspirant Effects on the Transpiration and Physiology of Tamarisk

ABSTRACT

Five-stamen tamarisk, an important phreatophyte in the southwestern United States, is difficult to eradicate for water salvage. There also is increasing opposition to its eradication because this species provides cover for wildlife and greenery in the environment. The application of nontoxic antitranspirant sprays to reduce tamarisk transpiration may be an alternative to eradication. We tested several antitranspirants, including a combination of the monomethyl and monoglyceryl esters of n-decenylsuccinic acid (MDSA-GDSA), 8-hydroxyquinoline sulfate (8-HQS), and phenylmercuric acetate (PMA), on tamarisk in greenhouse and field environments. PMA was toxic at a concentration of 0.001 M and was therefore not considered in the evaluation described below. The effects of MDSA-GDSA and 8-HQS on transpiration, growth, net photosynthesis, dark respiration, relative stomatal apertures, chlorophyll and protein contents, and foliage

temperature were evaluated. Transpiration rates of plants treated with MDSA-GDSA and 8-HQS were 25-35% less than those of control plants for 20 days in the greenhouse and for at least 5 days in the field. Growth was reduced for 2-3 weeks, and net photosynthesis for less than 1 week. The other physiological factors were not changed substantially. Foliage temperatures increased 2°-3°C for 3 days following treatment in the field. Further study for possible management application is suggested.

REFERENCE. Brooks, Kenneth B. and David B. Thorud. Antitranspirant effects on the transpiration and physiology of tamarisk. Water Resources Res. 7(3):499-510. 1971.

9. Analysis of Ephemeral Flow in Aridlands

ABSTRACT

A framework has been presented for the analysis and modeling of streamflows in aridlands. The basic event series of streamflows as observed in nature is found to be more informative than monthly and annual series. The frequency of occurrence of summer and winter events at the Tucson Arroyo gaging station are described, respectively, by a negative binomial distribution and a geometric distribution. Meteorologically this result is explained in terms of the temporal and spatial independence of summer thunderstorms and the persistence of winter cyclonic storms. The negative binomial distribution also describes the duration of flow per event in both winter and summer.

Meriting further exploration in the study of ephemeral flows but not considered herein are the following: (1) Zero-crossing theory (30); (2) theory of forecasting (4); (3) extreme value theory for a random number of random variables (34); (4) multivariate time series models to allow for inclusion of other causal variables

that influence flow prediction; (5) a decision-theoretic approach to estimation of parameters in deterministic and stochastic models (8); and (6) the study of time series of ground-water level fluctuations in wells adjacent to aridland channels periodically recharging the unconfined aquifer.

REFERENCE. Kisiel, C. C., L. Duckstein and M. M. Fogel. Analysis of ephemeral flow in aridlands. J. Hydraul. Div., ASCE, 97(HY10):1699-1717. 1971.

10. Evaluating the Effects of Water Yield Management

ABSTRACT

Research that presents the quantitative analysis of watershed management practices to increase water yields is reviewed. A methodology is suggested for evaluating these practices in light of the entire water supply, storage and delivery system. The procedure includes utilizing a synthetic time series of precipitation as input into a watershed model with streamflow and sediment yields as outputs. A storage - yield function is used to obtain the net yield increase for a given storage reservoir system.

REFERENCE. Fogel, Martin M. Evaluating effects of water yield management. Proc. Third Mt. Symp. for Hydrol. Prof. , Purdue Univ. June 1971.

11. Systems Analysis: A Decision-Making Tool for Arid Land Development

ABSTRACT

Systems analysis is a tool that can permit a view of the entire problem. It takes into account means and ends, choices and alternatives. It makes use of prediction and advanced testing to suggest objectives and courses of

action. It provides a method for more thorough consideration of alternatives.

Systems analysis may be viewed as a formalization of interactions. It contains few new concepts; it makes use of newly developed tools. Its application is by no means restricted to the planning of large-scale water resource management schemes. It can have a significant role in the decision-making processes of individual farmers.

While systems analysis may be a powerful tool, the tools of operations research as applied to water resources systems can only assist the decision-making process. In addition, by itself systems analysis is useless; a knowledge of water resources systems is essential. The purpose of this discussion is to take a brief look at selected examples in which some form of systems analysis may be used to advantage.

REFERENCE. Fogel, Martin M. Systems analysis: a decision-making tool for arid land development. CENTO Seminar on Agricultural Aspects of Arid and Semi-arid Zones, Tehran, September 1971.

12. A Stochastic Model of Runoff-Producing Rainfall for Summer Type Storms

ABSTRACT

Modification of watersheds occurs either through natural processes, such as erosion, or human influences, such as urbanization. In either case the rainfall input must be properly modeled before the runoff output can be predicted as the modifications take place. The paper considers runoff-producing summer precipitation of short duration and high spatial variability as an intermittent stochastic phenomenon. The probability distribution of seasonal total point or areal rainfall is obtained by convoluting a Poisson number of events with a geometric or negative binomial probability of rainfall amount. Close agreement with the experimental data is found. Next the probability of various combinations of rainfall amounts, given the seasonal total and the number of events, is computed. With these

results, the theoretical seasonal water yield distribution can be obtained by using a simple rainfall-runoff relationship, such as the Soil Conservation Service formula. The possibility of using regional input parameters to study the distribution of the output of poorly gaged small watersheds is discussed. In particular, extreme total flows can be computed.

REFERENCE. Duckstein, Lucien, Martin M. Fogel and Chester C. Kisiel. A stochastic model of runoff-producing rainfall for summer type storms. Water Resources Res. 8(2): 410-421. 1972.

13. Choosing Hydrologic Models for Management of Changing Watersheds

ABSTRACT

Changes in the hydrologic behavior of watersheds can be voluntary, indirect, inadvertent or in any combination. Many of these changes will require environmental impact statements to reflect both beneficial and adverse effects. Man-made changes are planned to meet a particular goal. To choose the most appropriate hydrologic model for predicting these modifications, the standardized cost-effectiveness analysis is recommended. In this methodology, the following steps are included: definition of goals, identification of specifications for realization of goals, development of alternative models to achieve goals, establish measures of effectiveness for evaluation of alternative models, determine capabilities and analyze merits of models and perform sensitivity analysis on goals, specifications and measures of effectiveness. For predicting changes on ungaged watersheds, many hydrologic models encounter calibration, validation or extrapolation problems. It is possible, however, to obtain an approximation of these changes with the use of simple models of the rainfall-runoff process. Two such models are compared in determining the effect of urbanization on the return period of a flood of given magnitude.

REFERENCE. Fogel, Martin M., Lucien Duckstein and Chester C. Kisiel. Choosing hydrologic models for management of changing watersheds. Proc. Amer. Water Res. Assoc. Symp., Watersheds in Transition, Ft. Collins, June 1972.

14. Elevation Effects on Rainfall: A Stochastic Model

ABSTRACT

The variation in point precipitation with elevation is investigated using an event-based stochastic model of thunderstorm rainfall and empirical data. Parameters of the model correspond to the number of events per unit of time and the depth of rainfall per event. An increase in precipitation with elevation may be due to an increase in the number of events, in the amount of rainfall per event or to some combination of both possibilities. The distribution of the number of events per season is assumed to be a Poisson variate while the distribution of point rainfall depths may be taken as geometric. The summation of a random number of random variables is used to represent seasonal point precipitation. Assuming that the two parameters of the model increase linearly with elevation, then total seasonal rainfall increases as a quadratic polynomial with elevation. The use of the model allows one to obtain the return period of storm rainfall of a given magnitude despite a short historical record. An independent set of data was used to verify the procedure.

REFERENCE. Duckstein, Lucien, Martin M. Fogel and John L. Thames. Elevation effects on rainfall: a stochastic model. Paper accepted for publication in J. of Hydrology, 1972.

15. Two Theoretical Models of Radiation Heat Transfer Between Forest Trees and Snowpacks

ABSTRACT

Two simple theoretical models have been developed to describe the effect of forest cover on radiation transfer to a snowpack.

Model 1, which describes the effect of varying canopy

closure on the net radiation received by an interior snowpack, suggests that the net radiation may increase or decrease monotonically as the canopy closure increases from zero to 100%, or may exhibit a maximum at a non-zero canopy closure depending upon whether or not certain conditions are satisfied. These conditions involve the values of the albedos and radiant fluxes. This perhaps surprising result was due to the combined effect of long-wave radiation emitted from the canopy to the snowpack and multiple reflections of solar radiation between the snowpack and canopy.

Model 2 predicts the spatial variation of the long-wave radiation flux from the bole and crown of an individual tree to the surrounding snowpack. This model may partially explain melt rates which appear to be higher near the boles of trees than at more distant points. Calculations with assumed data showed an intensification of the long-wave radiation flux to the snowpack as the bole is approached. According to this model, a horizontal snow surface receives negligible amounts of long-wave radiation from the tree at distances from the bole that are greater than two to three times the crown radius.

REFERENCE. Bohren, Craig C. and David B. Thorud. Two theoretical models of radiation heat transfer between forest trees and snowpacks. Agric. Meteor. (in press) 1972.

16. Development of Management Guidelines for Increasing Snowpack Water Yields from Ponderosa Pine Forests in Arizona

ABSTRACT

Snowmelt on the Salt-Verde River Basin in Arizona yields a major portion (possibly 50 percent or more) of the annual surface runoff that supplies six reservoirs. These reservoirs provide municipal, industrial, and agricultural water for the Phoenix metropolitan and nearby areas. About 30 percent of

the Basin (2 1/2 million acres) is within the ponderosa pine forest zone, where much of the snowmelt runoff originates. Therefore, initial work in the development of forest management guidelines for increasing snowpack water yields is concentrated in this zone. These guidelines, to be effective, must be developed in a context that considers the constraints imposed by management objectives involving the other products and uses (e.g., timber, forage, wildlife, recreation opportunities, etc.) of the land.

REFERENCE. Thorud, David B. and Peter F. Ffolliott. Development of management guidelines for increasing snowpack water yields from ponderosa pine forests in Arizona. Proc. Am. Water Resource Assoc. Symp., Watersheds in Transition, Ft. Collins, 1972.

APPENDIX B

PUBLICATIONS ANNEX

UNIVERSITY OF ARIZONA

3 rd ANNUAL REPORT

(Having Significant 211 (d) input)

October 31, 1972

1. Fish, E. B. and E. L. Smith. 1971. Remote sensing for inventory of desert shrub vegetation in southeastern Arizona. Paper presented at Annual Meeting of Rocky Mt. Sec. AAAS and Ariz. Acad. Sci., Phoenix, Ariz.

2. Fish, E. B. and E. L. Smith. 1971. Application of remote sensing for watershed inventories. Paper presented at ARETS Symposium on applied Remote Sensing of Earth Resources. Tucson, Ariz.

*3. Fogel, M. M. and L. Duckstein. 1969. Point rainfall frequencies in convective storms. Water Resources Research. (December, 1969) pp. 1229-1237.

*4. Fogel, M. M. 1969. The effect of storm rainfall variability on runoff from small semiarid watersheds. Trans. Am. Soc. Agric. Eng., 12 (Nov.-Dec., 1969) pp. 808-812.

5. Fogel, Martin M. and L. Duckstein. 1970. 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, 465-478.

6. Fogel, Martin M., L. Duckstein and C. C. Kisiel. 1971. Space-time validation of a thunderstorm rainfall model. Water Resources Bulletin 7(2): 309-316.

7. Fogel, Martin M., C. C. Kisiel, L. Duckstein. 1971. Analysis of ephemeral flow in arid lands. J. Hyd. Div., Proc. Am. Soc. Civ. Eng. 97(HY10): 1699-1717.

8. Fogel, Martin M., L. Duckstein, C. C. Kisiel. 1971. A stochastic model of runoff-producing rainfall for summer type storms. Paper presented at 52nd Annual Meeting, AGU Washington, D.C. Accepted for publication in Water Resources Research.

9. Fogel, Martin M. 1971. Evaluating the effects of water yield management. Paper presented at Third International Seminar for Hydrology Professors, IHD, Purdue Univ., Lafayette, Indiana.

10. Fogel, Martin M. 1971. Systems analysis: A decision-making tool for arid land development. Paper presented at the CENTO Seminar on Agricultural Aspects of Arid and Semi-arid Zones, Tehran, Iran.

11. Fogel, Martin M., L. Duckstrin, C. C. Kisiel, 1972. Choosing hydrologic models for management of changing watersheds. Proc. National Symposium on Watersheds in Transition, Fort Collins, Colo. June 1972.

12. King, David A. 1972. Towards more effective natural resources planning. Paper presented at 37th North American Wildlife and Natural Resources Conference, Mexico City.

13. Matlock, W. G. and P. R. Davis. 1970. Desert strip Farming: A modified dry farming method using rainfall multiplication. Paper presented at Annual Meeting American Society of Agricultural Engineers, Minneapolis, Minnesota.

14. Thames, J. L. and J. H. Kitchen. 1969. Application of a computer model to a desert watershed, Prog. Agric. in Arizona, 21(1): 12-19.

15. Tinlin, R. and J. L. Thames. 1969. A direct passive electrical analog model of a watershed. Abstract, annual meeting of American Geophysical Union, San Francisco. (Not available) (See Professional Paper-Tinlin).

16. Thames, J. L. and R. Tinlin. 1970. A computer a tomated hydrologic data acquisition system. Proceedings, International Symposium on Hydrometry. Koblenze, Germany.

17. Thames, J. L. and R. Tinlin. 1970. Computerized hydrologic data acquisition system: a facility for up-grading instruction in watershed management. Journal, National Association of Colleges and Teachers in Agriculture, 24(1): 3-5.

18. Thorud, David B., E. S. Simpson, I. Friedman. 1970. Distinguishing seasonal recharge to groundwater by deuterium analysis in southern Arizona. Proc., Reading Symposium. International Assoc. of Scientific Hydrology. p. 112-121.

19. Thorud, David B., R. S. Cunningham. 1971. Antitranspirants: a possible alternative to the eradication of saltcedar thickets. Proc. New Mexico Water Conference, Las Cruces, New Mexico, pp. 101-109.

20. Thorud, David B., P. F. Ffolliott. 1971. Progress in developing forest management guidelines for increasing snowpack water yields. Hydrology and Water Resources in Arizona and the Southwest. Proc. of American Water Resources Assoc. (Ariz. Section) and the Arizona Academy of Science (Hydrology Section) pp 291-300.

21. Thorud, David B., K. N. Brooks. Antitranpirant effects on the transpiration and physiology of tamarisk. Water Resources Research 7(3): 499-510.

22. Thourd, David B., P. F. Ffolliott. 1972. Use of forest attributes in snowpack inventory-prediction relationships. Jour. Soil and Water Conservation. In press.

23. Zwolinski, Malcolm J. 1971. "Effects of Fire on Water Infiltration Rates in a Ponderosa Pine Stand". Proceedings, Arizona Academy of Science and Arizona Section, AWRA. April 22-23, 1971, Tempe, Arizona. pp. 107-112.

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