ELEVENTH ANNUAL NEW MEXICO WATER CONFERENCE

March 31, and April 1, 1966

THEME:

Water Economics with Limited Supplies and an Increasing Population

Milton Student Center
New Mexico State University
University Park, New Mexico

NEW MEXICO WATER CONFERENCE

Sponsored By

NEW MEXICO STATE UNIVERSITY DIVISIONS

of

Agricultural Experiment Station
Agricultural Extension Service
College of Agriculture

College of Engineering
Engineering Experiment Station
Cooperative Agent, USDA-ARS, SCS

Water Resources Research Institute

and the

WATER CONFERENCE ADVISORY COMMITTEE

Membership New Mexico State University

WATER CONFERENCE COMMITTEE

Dr. John W. Hawley	- Geologist, USDA
Clark D. Leedy	- Resource Development Specialist Extension Service
Dr. Harold E. Dregne	- Agronomy - Soils
Dr. W. P. Stephens	- Assistant Director Agricultural Experiment Station
K. A. Valentine	- Animal Husbandry - Range Management
Dr. N. N. Gunaji	- Civil Engineering
Eldon G. Hanson	- Agricultural Engineering
James F. Cole	- Vice President - Administration
O. F. Baca	- Assistant County Agent Leader Extension Service
Gene O. Ott	- Farm & Business Management Specialist Extension Service
Dr. James R. Gray	- Agricultural Economics
Dr. H. R. Stucky	- Water Resources Research Institute Chairman

Membership of

WATER CONFERENCE ADVISORY COMMITTEE

Willis H. Ellis
University of New Mexico
Albuquerque, New Mexico

S. E. Reynolds
State Engineer
Santa Fe, New Mexico

Rogers Aston
South Spring Foundation
Roswell, New Mexico

Cooper Malone
New Mexico Farm Bureau
Lake Arthur, New Mexico

Claud Tharp, Member
NMSU Board of Regents
Las Cruces, New Mexico

W. E. Bertholf, II
New Mexico Institute of Mining & Technology
Socorro, New Mexico

W. P. Cater, Chairman
State Soil & Water Conservation Committee
Questa, New Mexico

James Anderson, Director
Bureau of Land Management
Santa Fe, New Mexico

Ladd S. Gordon, Director
New Mexico Department of Game & Fish
Santa Fe, New Mexico

E. O. Moore
Production Credit Association
Roswell, New Mexico

Robert J. Hoffman, Director
Department of Development
Albuquerque, New Mexico

Ralph Charles
U. S. Bureau of Reclamation
Albuquerque, New Mexico

W. H. Gary
Interstate Stream Commission
Rincon, New Mexico

Wm. E. Hale, District Chief
U. S. Geological Survey
Albuquerque, New Mexico

Drew Cloud, State Director
Farmer's Home Administration
Albuquerque, New Mexico

Lloyd A. Calhoun
New Mexico Electric Service Co.
Hobbs, New Mexico

William D. Hurst, Regional Forester
Forest Service, USDA
Albuquerque, New Mexico

Einar Roget
Soil Conservation Service
Albuquerque, New Mexico

Fred W. Moxey, Executive Director
New Mexico Oil & Gas Association
Santa Fe, New Mexico

Donald C. Rider, Executive Director
New Mexico Municipal League
Santa Fe, New Mexico

F O R E W O R D

The Eleventh Annual New Mexico Water Conference emphasized the theme: Water Economics with Limited Supplies and an Increasing Population. Many of the papers bring the problem home to New Mexico, that water must be more carefully used and that water will cost more in the near future.

New Mexico population has increased from 423,000 in 1930 to 681,000 in 1950, and 951,000 in 1960, an increase of 528,000 people, or a 125 percent in 30 years. The 1966 New Mexico population is near 1,100,000, or 2.6 times the 1930 population. During this time we have put much of our water resources to better use, but the actual supply has decreased. The decrease has been due to heavy pumping which is depleting the water supplies in several of our groundwater basins. This does not mean that we, as a State, are going to run out of water, and that we do not have water for further economic development. It does mean, however, that we must protect our present supplies from further uneconomic depletion and pollution.

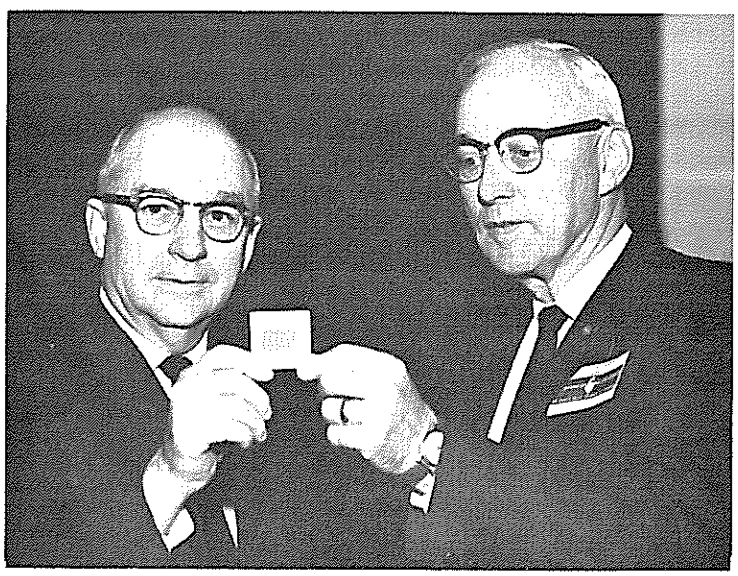
New Mexico State University is proud to have had the opportunity to sponsor the eleven Annual New Mexico Water Conferences and to have had ten of these held on our campus. The Eighth Annual Conference was held July 1 and 2, 1963 in connection with the dedication of the Saline Water Conversion Plant at Roswell. The University is assisted with the planning and conduct of the conferences by a dedicated and progressive Advisory Committee of twenty members, whose names are listed on the inside of the cover page. Also, a University committee assists with the program development and the carrying out of the conferences.

The papers presented appear in this proceedings in the order in which they were presented at the conference. The program which follows will serve as an index to the papers.

H. R. Stucky

H. R. Stucky, Chairman
New Mexico Water Conference, and Director
New Mexico Water Resources Research Institute

Roland P. Kelly of the Ralph M. Parsons Company, Los Angeles (left), and Charles Howe, Resources for the Future, Washington, D. C., receive greetings from Dr. Philip J. Leyendecker, Dean and Director of Agriculture, New Mexico State University, at the opening of the conference.



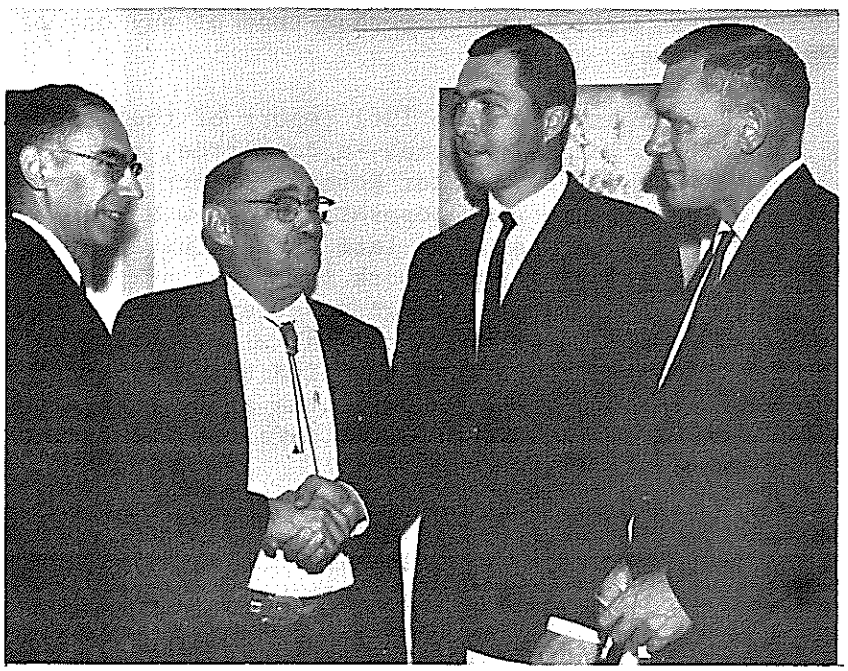
Harry Steele (left) of the Economic Research Service, U.S. Department of Agriculture, Washington, D. C. consults with Dr. H. R. Stucky, director of the Water Resources Research Institute at New Mexico State University, on visual aids for Steele's speech.

NEW MEXICO WATER CONFERENCE

March 31 and April 1, 1966

THEME OF THE CONFERENCE - "WATER ECONOMICS WITH LIMITED SUPPLIES AND AN INCREASING POPULATION"

Abe Zuni (left) of the Bureau of Indian Affairs in Ignacio, Colorado gets acquainted with Clyde Stewart of the Economic Research Service of U.S. Department of Agriculture in Logan, Utah. Stewart was one of the keynote speakers in the two-day New Mexico Water Conference at New Mexico State University.



Edward Triviz (left), Las Cruces Attorney, greets J. L. Gardner, research botanist with the U.S. Department of Agriculture's Agricultural Research Service, Tucson, Arizona; John C. Drissel, engineer with USDA-ARS in Santa Rosa, New Mexico; and Robert Keppel, director of the Southwest Watershed Research Center for USDA-ARS in Tucson. Triviz presented the speech prepared by U.S. Representative Thomas Morris.

NATIONAL WATER LEGISLATION IN THE 89TH CONGRESS

Honorable Thomas G. Morris[1/]

The theme of this year's conference, "Water Economics--with a Short Supply and Increasing Population" summarizes the national water problem as seen by Congress.

In 1966, in the second session of the 89th Congress, we can look back at a record of legislative activity in the field of water resources that has never been equalled in the history of the United States. There have been years of landmark legislation before, as in 1902, when the Federal Reclamation Act became law; 1920, which saw enacted, after many years of effort, the Federal Power Act; 1927 and 1928, which gave us in turn the adoption of the comprehensive flood control project on the Lower Mississippi River and Tributaries and the Boulder Canyon Project which led to the construction of the Hoover Dam, first of the great multiple purpose water development projects in the West; 1936, when under the last of unprecedented floods in the Ohio River basin, Congress adopted a flood control policy for the entire Nation.

But the far-reaching impact of the broad legislation enacted in the past two years, which will be added to before the end of the present session of Congress, will be greater than that of any one of these legislative milestones.

Starting from the benchmark of the 1961 report of the Senate Select Committee on National Water Resources--a committee, you will remember, that was chaired by the late Senator Robert S. Kerr of Oklahoma, with the wholehearted assistance and cooperation of New Mexico's own Senator Clinton P. Anderson and the late Dennis Chavez--the Congress has now laid the legislative groundwork for tackling problems of water economics. This is being done through a series of statutes that will permit necessary action to be taken to deal with water problems far into the future, so that the Nation can find the most efficient way of coping with the situation resulting from the great pressure of growth of population, agriculture, and industry, against the finite limits of natural water supply.

So far, through enactment of the Water Resources Research Act of July 17, 1964, and the Water Resources Planning Act of July 22, 1965, Congress has raised the Nation's sights above the limitations imposed by a project-by-project approach to water resources development, and established the means to find through research, better technical

1/ United States Congressman from New Mexico answers to our various problems, and through improved cooperative arrangements, a way to focus the best efforts of all Federal and State agencies toward the solution of problems of river basin development on a comprehensive basis.

In addition, new legislation to broaden and intensify the program of research and development of economical processes for desalinization of ocean and brackish waters has been enacted to extend this program for another six years, in continuation of the program initiated more than a decade ago under the leadership of the present senior Senator from the State of New Mexico.

It has been my privilege to join Senator Anderson in the co-sponsorship of all of this important legislation. Senator Anderson and I have joined forces again this session to push legislation that will establish a large program of scientific and engineering research, experiments, testing, and operations for increasing the yield of water from atmospheric sources, under the direction of the Secretary of the Interior. We are talking in terms of a program in the magnitude of $35 to $70 million a year over the first three years, to go beyond the meager research programs presently underway under the National Science Foundation and the Bureau of Reclamation.

Other legislation having great importance in our all-out endeavor to surmount the broadening water crisis of our times was enacted as the Water Quality Act of 1965, which for the first time provides for water quality standards in streams receiving the effluent from various sources of pollution.

Other important water resources legislation during the last session includes the Water Projects Recreation Act of July 9, 1965.

As a basis for discussing what we are considering during the current session, let me comment briefly on the programs which have already been enacted.

FIRST THE WATER RESOURCES RESEARCH ACT

This Act authorizes establishment of water resources research institutes at land-grant colleges or other universities or combination thereof in each of the 50 States and Puerto Rico, and provides a contribution of Federal Funds which will eventually amount to $100,000 annually, toward the administrative expenses of the institute.

In addition, matching funds are provided for grants to carry on research on all aspects of water and water-related problems at the institutes. This Act grew directly out of the recommendations of the Kerr Committee for increased research into these aspects of water that are not fully understood by scientists and engineers, as well as into scientific techniques that need to be improved in order to utilize our water resources to the optimum.

In the science of water, as in other scientific fields such as space, meteorology, or astronomy, there has to be a body of basic fact on which plans may be fruitfully made for solving problems. The Water Resources Research Act is modeled after the agricultural experiment stations programs, and it is hoped that these institutes will do as much to solve the Nation's gaps in water knowledge as the agricultural experiment stations have done to solve problems in American agricultural conservation and production. Federal funds are provided to assist in the establishment and administration of the centers, and matching grants will be made for specific research projects orginated by scientists and engineers from within each State. There has been a shortage of well-trained engineers and scientists working in water and water-related problems, and one of the reasons for setting up these research centers in each State is to provide training for scientists and engineers in water and water-related fields. Our water resources research institute in New Mexico is right here at New Mexico State University, under the direction of Dr. H. R. Stucky. I am sure that you will hear more about it during the course of your meeting.

WATER RESOURCES PLANNING ACT

While the water resources research institutes have to do with research, the second landmark in recent water resources legislation has to do with planning. The Water Resources Planning Act of 1965, like the Water Resources Research Act, is based on recommendations made by the Senate Select Committee on National Water Resources. It may be interesting to note that as far back as 1949, when he first came to the United States Senate, there was a proposal by New Mexico's great and practical neighbor, the late Senator Kerr of Oklahoma, for a river basin commission to carry on comprehensive planning for multiple purpose development of the water and related land resources of the Arkansas-White-Red River Basins. His original proposal was modified and the Arkansas-White-Red River study was carried on under authority given to the Corp of Engineers in the Flood Control Act of 1950. Subsequently, there have been many proposals for independent river basin planning commissions which would tie together Federal, State, local, and private interests in the planning for the overall development of the water resources of entire river basins.

With the passage of time, it has become perfectly clear that the water problems of the Nation have been increasing because of our expanding population, our growing economy, and increased leisure time. Solution of these problems requires nothing less than full and complete coordination between Federal, State, and local interests to plan for the most comprehensive and efficient uses of the water resources of all States and regions as well as of the Nation. The Select Committee therefore recommended that coordinated river basin plans be developed in all major river basins and that Federal grants be made to the States to stimulate and help along their efforts in doing this.

The Water Resources Planning Act of 1965 is the culmination of this objective. The Act aims to improve the coordination of planning activities of Federal, State, and local governments, as well as many parts of the private enterprise economy, so as to promote better ways of dealing with water problems now and in future years.

The first part of the Planning Act establishes a Water Resources Council as a cabinet-level coordinating agency in Washington for the many Federal agencies that are involved in water resources development programs. These programs, as you well know, are scattered among many departments and agencies, from the Bureau of Reclamation to the Department of Health, Education and Welfare. The Council is composed of the Secretary of the Interior (appointed chairman by the President), the Secretary of Agriculture, the Secretary of the Army (representing the Corps of Engineers), the Secretary of Health, Education and Welfare, and the Chairman of the Federal Power Commission.

The Council's assignments are to (1) make continuing studies and periodic assessments of the adequacy of water supplies to meet water requirements in the various water resources regions of the country; (2) to maintain a continuing study of the relation of regional or river basin plans or programs to the overall national requirements, including the adequacy of administrative and statutory means for coordination of water and related land resources policies of the several concerned Federal agencies; (3) to appraise the adequacy of existing and proposed policies and programs to meet such requirements; (4) to make recommendations to the President about policies and proposals; (5) to establish, with the President's approval, principles standards and procedures for Federal participation in river basin planning, and for the formulation and evaluation of Federal water and related land resources projects; and (6) to review river basin development plans prepared by Federal-State River Basin Commissions as they are authorized by section II of the Act. The first commission to be established under this Act is to be the New England River Basin Commission. The preliminary steps by the New England States and the Council have been completed and approved, and the New England Commission awaits only the go-ahead of the President and the appointment of the Federal members.

The Water Resources Council will also administer a Federal grant-in-aid program to provide funds to the States, on a matching basis, to assist the States in developing and participating in the development of comprehensive water and related land resources plans. The Council will review river basin plans, or revisions thereof, as they are received from the river basin commissions. In their review, the Council will consider the appropriateness of the plan in achieving optimum use of the water and related land resources in the area involved, and what the broad implications and effects of the plan may be on other programs, as well as on the national economic and social goals. The Council will formulate its own recommendations and transmit them, together with the plan or revision of plan, and all views and comments about them received from Federal agencies, governors, and interstate or international commissions, to the President for review and transmittal to Congress with the President's recommendations as to authorization of Federal projects.

The Water Resources Council does not alter any of the statutory functions of the various Federal agencies operating in water resources, nor does it change Federal or State jurisdiction, responsibility, or rights in this field. It is intended primarily to provide a statutory basis for the conduct of cooperative work among the Federal agencies that has been previously carried out by various interagency commissions. The new Council, in general, has the powers given to an independent government agency.

The second part of the Planning Act provides for river basin commissions--like the New England Basin Commission of which I spoke earlier--to coordinate the efforts of all responsible agencies and interests in preparing and keeping up to date comprehensive plans for the development of water and related resources in each water resource region. These will be Federal-State in makeup, and through them the Federal, State, and local governments and non-governmental groups will be provided a medium for cooperating in planning for the development of the water resources of a river basin. New Mexico may well become a member of such a Commission which is being considered for the Pacific Southwest region, as a part of the authorization for the lower Colorado River Basin now under consideration by Congress.

In the past, the work of some of the States in water resources planning has not always been on the same level as that of the federal agencies, sometimes through lack of coordination of effort and sometimes because of financial needs. The third section of the Planning Act will help to correct the financial problems by matching grants with the States to help them carry on their share of the work that is required if comprehensive and economic development of their water resources is to be fully achieved.

OUTDOOR RECREATION LEGISLATION

Planning for the use of land and water for recreation has become a new imperative in the 1960's. Americans increasingly value their outdoor retreats and they consider planning for recreation as an essential part of good resources management. It is obvious that water-based recreation is of top priority. In 1962, the Outdoor Recreation Resources Commission recommended a Federal program to stimulate and assist the States in stepping up their work in this area. The ORRC said, that while all levels of government have responsibility and interest in meeting outdoor recreation needs, the State governments should have the dominant public responsibility and should play the pivotal role. The Land and Water Conservation Fund Act passed in 1964 was the outcome of that recommendation. The Act aims to coordinate and promote comprehensive planning between the Federal and State agencies and to provide more recreation areas for the American people to enjoy in their leisure hours.

It sets up a $2 billion, 10 year fund to be given to the States on a matching basis so that they may develop more public recreational facilities. The cost of the program is to be met from a combination of sources, including admission and user fees, motorboat fuel taxes, and revenue from the sale of property owned by the United States. Sixty percent of the annual appropriation by the Congress to this Fund will be available to the States as grants-in-aid, while forty percent of the money will go to Federal agencies to purchase other recreational areas and to repay the Treasury for the capital costs of public recreation and fish and wildlife progagation at Federal projects.

Of the States' share of sixty percent, two-fifths will be divided equally among the States, and three-fifths will be apportioned to States according to their needs. When the States receive their portions of the money, they then allocate it to political subdivisions within the State as they see fit.

The States may use their money to prepare statewide outdoor recreation plans; to maintain recreation facilities; to acquire water and land areas where they want to establish recreation areas; and to pay for developing the recreation areas and facilities. After a State builds or develops recreation areas under this Act with the 50-50 matching of monies, it is left up to the State whether it will charge the public for their use. However, no charge may be made for the use of water areas, whether they are lakes, reservoirs, or running streams. Only the developed land areas are subject to user charges or admission fees.

Since the end of World War II, increasing attention has been given by the Corps of Engineers and the Bureau of Reclamation to the need for inclusion of recreation and fish and wildlife facilities in their water projects. This has been accompanied by an almost continual discussion of who is to pay for these features--the Federal government or the States and local bodies.

The Congress came to grips with this controversy in the 89th Congress, last year, in the Federal Water Projects Recreation Act. The Act established standard guidelines to govern allocation of costs and responsibilities for the repayment of recreation and fish and wildlife costs when they are part of Federal multiple purpose water resources projects. The Act provides that the States will be encouraged to develop and operate recreation and fish and wildlife features at Federal water projects. The Federal government will bear all joint costs allocated to these functions and half of the separable costs of construction features specifically for these purposes. An example of a joint cost on such a project would be a share of the cost of a dam that is essential to the functions of all purposes of the project, while a separable cost might include the cost of picnic tables, a boat launching ramp, lands, roads, an extra foot on the height of a dam so as to provide storage capacity for a permanent pool, or building a new water impoundment just for the purpose of recreation or fish and wildlife. The States' part of the costs could be borne either as a cash payment to the government, provision of lands or facilities, or through an agreement to pay the money to the government over a 50-year period out of receipts collected from the users of facilities at the recreation areas.

The prerequisite for eligibility to receive Federal contribution to these projects is that the State or other non-Federal public body must declare its intention to develop and run the recreation facilities in accordance with the overall plan of the project, to bear half of the separable costs of construction, and to bear all costs of operation, maintenance, and replacement

WATER QUALITY-POLLUTION CONTROL

Another important piece of legislation enacted near the end of the last session of Congress was the Water Quality Act of 1965. In this Act, for the first time, Congress provided for the establishment of water quality standards by the States, against which the effects of various types of pollution can be measured. Establishment of such standards forms the next important first step toward eventually cleaning up the rivers of this Nation. The legislation established a new agency, the Federal Water Pollution Control Administration, effective at the beginning of 1966, to marshall the attack on water pollution.

Within the last month, the President sent to the Congress a message on water pollution and related subjects and is proposing several new actions for consideration of the Congress. The first of these calls for an all-out attack on the problems of water pollution through what the President called a "Clean Rivers Demonstration Program" which would include four requirements: (1) The adoption for every part of a river basin of appropriate water quality standards, as they are already authorized by the Water Quality Act of 1965; (2) Comprehensive, practical long-range development plans by States and local communities to achieve water quality standards and to preserve them; (3) The creation of a permanent river basin organization, where it does not already exist, to carry out the plan, to represent the communities and the States, to work closely with the Federal government, and to revise plans as conditions require so that new threats to the quality of the river may be turned back; (4) The contribution of funds by communities for the construction of facilities and the levying of charges for their use in order to maintain, extend, and replace them when needed.

To initiate this program, the President recommended initial expenditures of $50 million for fiscal year 1967. However, the President emphasized that the ultimate goal "to free all of America's rivers from pollution" will be much more costly. Estimates range between $7 and $10 billion as the Federal government's contribution.

NATIONAL WATER COMMISSION

The President is also proposing legislation to establish a National Water Commission to study and report on just the problems that are the subject of this meeting. The President said:

> In no areas of resource management are the problems more complex--or more important--than those involving our Nation's water supplies...I propose the establishment of a National Water Commission to review and advise on the entire range of water resource problems--from methods to conserve and augment existing water supplies to the application of modern technology, such as desalting, to provide more usable water for our cities, our industries, and our farms.
>
> The Commission will be composed of the very best minds in the country. It will judge the quality of our present efforts. It will recommend long-range plans for the future. It will point the way to increased and more effective water resource measures by the Federal Government, working in close cooperation with States, local communities, and private industry.

As an adjunct to these legislative proposals, the President proposes to transfer the Water Pollution Control Administration from the

Department of Health, Education and Welfare to the Department of the Interior, as a step toward a more coordinated approach by the Federal government to water problems.

Consideration of all these proposals will require the continued best efforts of the Congress. From my vantage point, as a member of the Committee on Appropriations, I shall do my part to see that adequate funds are provided for all worthwhile proposals in the field of water resources, and, of course, to see that the interests of the State of New Mexico are not lost sight of, in consideration of overall national problems.

WATER AND LAND RESOURCES--POTENTIALS AND REQUIREMENTS

Harry A. Steele 1/

This paper discusses the relation of land and water resources to economic activity, the magnitude and regional distribution of these resources, and their potentials in relation to projected requirements.

Since management and development of water resources involve long-term decisions--both investment and institutional--the decision makers need projections of long-term economic activity and related water requirements. The decision makers also need information on the effect of water resource development on the growth and location of economic activity. As pointed out by the Water Resources Council in its policies and standards, water policy is also concerned with preservation of the quality of the environment and with the well-being of all the people.(1)

Where conflicts arise, intangible values arising from "preservation" and "well-being" may often be more important than those from economic activity.

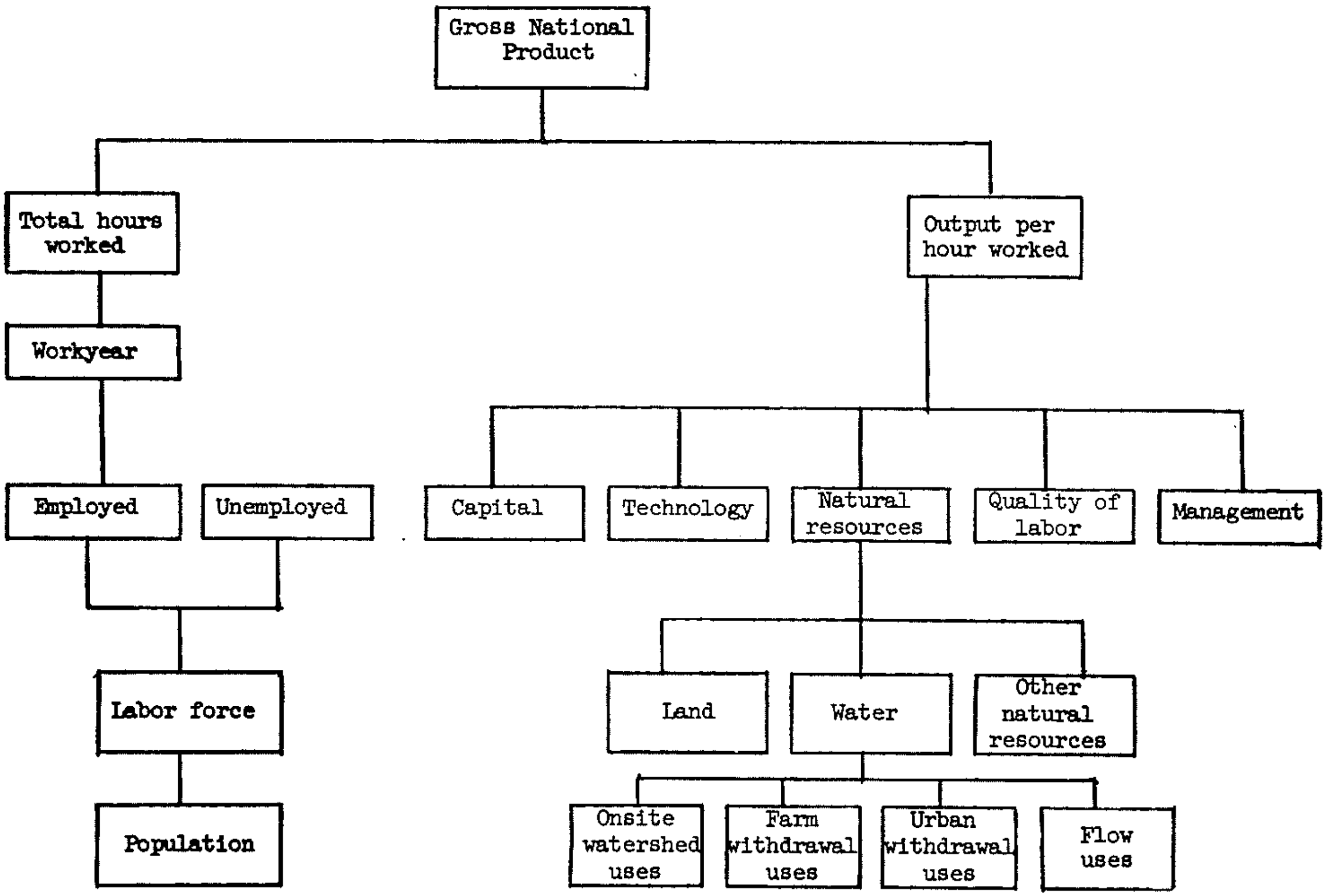
The consideration of any one use of water must be treated as an integral part of an analysis of water requirements for all uses with a common water supply. The shorter or more variable the supply, the more essential the need for taking account of all competing uses. Consideration of the water needs for any particular purpose is but an initial step in approaching the problem of comprehensive planning and multipurpose development.

The Nation is concerned with how variations in the occurrence of water resources--both location and time--can be offset by investment that results in local and regional development and in turn national development. National policy should avoid increasing one region's growth at the expense of other regions or retarding national growth. Here, we may encounter a conflict between national economic efficiency and the well-being of people in a particular region.

Economic growth is usually measured by an increase in the gross national product (GNP) which represents the market value of the national output of goods and services. The skills and knowledge of workers, the levels of management, capital and technology, and the available natural resources are important determinants of productivity and potential regional and national output (fig. 1). In the

1/ Director, National Resource Economics Division, Economic Research Service, U. S. Department of Agriculture, Washington, D. C.

PRODUCTION FACTORS DETERMINING GROSS NATIONAL PRODUCT



U. S. DEPARTMENT OF AGRICULTURE NEG. ERS 2805-64 (4) ECONOMIC RESEARCH SERVICE

Figure 1

long run the quantity and quality of natural resources are basic to the economy and determine the environment in which people live.

Figure 2 shows the relations between population, gross national product, and productivity for the period since World War II, and on a projected basis to the year 2020. (2) The GNP projection for 2020 is over 8½ times 1960. This rate of growth is based on a projected population growth to almost 3 times the 1960 figure and an increase in labor productivity of 4 times the 1960 level. The farm component of the GNP would increase slightly over 2 times. In contrast, the nonfarm component is projected to increase over 9 times. As a result, the rate of increase in water requirements for nonfarm uses will be much greater than for farm uses.

THE NATION'S WATER SUPPLY

Our annual water supply over the 48 mainland States amounts to 4.75 billion acre-feet of precipitation. About 3,380 million acre-feet, or 70 percent, of the total water supply is used by evapotranspiration from watershed lands. (3) (4)

About 1,100 million acre-feet, or 33 percent, of the water used on watershed lands is used for the production of farm crops and pastures. These nonirrigated lands currently account for about 80 percent of the value of the Nation's crop and pasture production. (5) Associated with and influenced by the location of this primary farm activity were agriculturally related industries which make an important contribution to the GNP. It is expected that these nonirrigated lands will continue to be the major source of farm production.

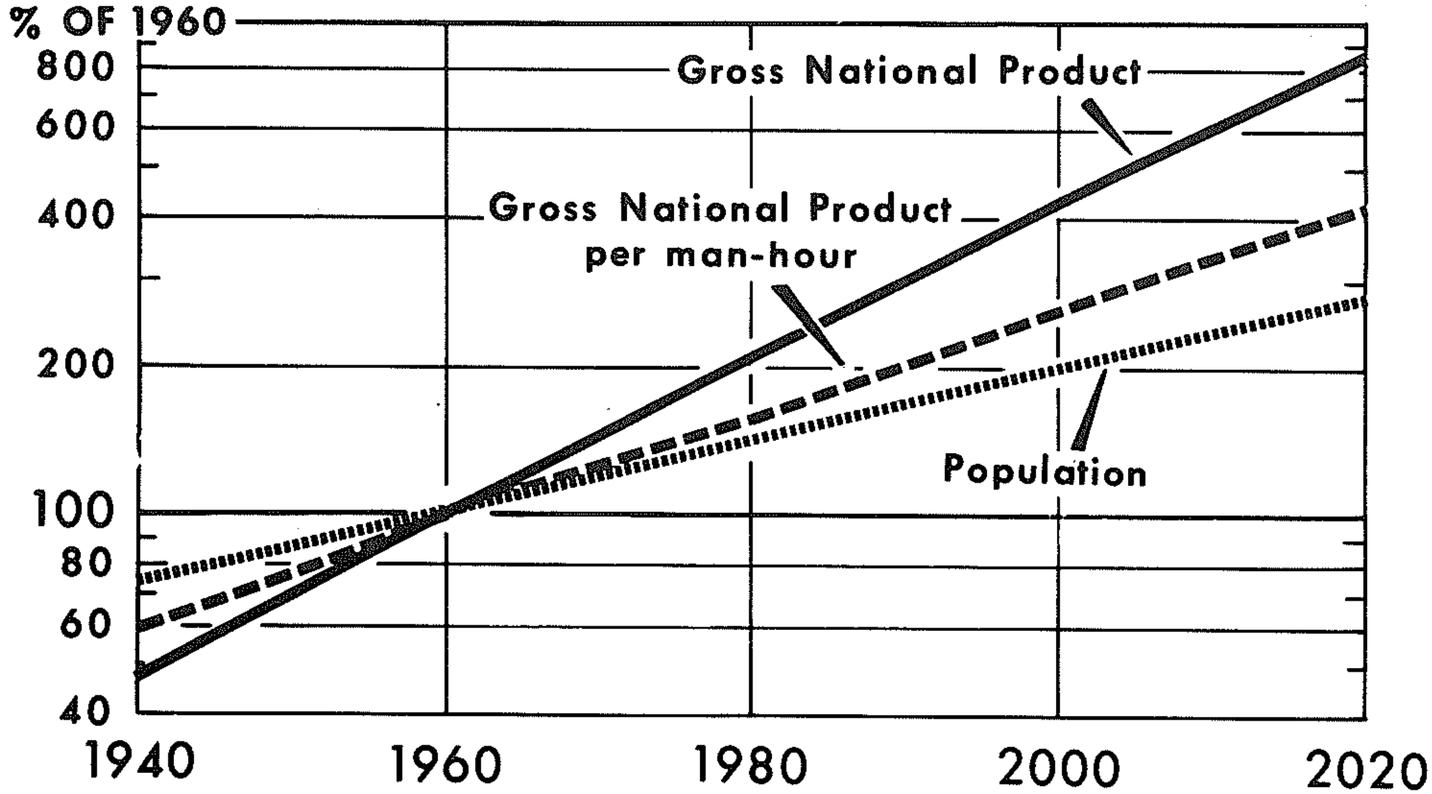
Another 750 million acre-feet, or 22 percent, of the onsite watershed use is used in the production of timber and browse. These lands account for the Nation's timber production and related timber-based economic activities. (6) Forest lands also have value for many other purposes, including recreation and water yield. A substantial portion of the forest land is in public ownership and is managed for multipurposes.

About 1,530 million acre-feet, or 45 percent, of onsite watershed use is on lands supporting vegetation with little, if any, market value. (7) Many of these lands have important scenic, recreation, fish and wildlife or other values, and a large proportion of the lands is in public ownership.

Water-caused erosion is a major problem on a large proportion of our cropland, pasture, and woodlands. Losses from erosion damage to these watershed lands and resulting damages downstream from sedimentation are extensive. (8)

GROSS NATIONAL PRODUCT, POPULATION, AND OUTPUT PER MAN-HOUR

1940, 1960, and Projections to 2020



U. S. DEPARTMENT OF AGRICULTURE NEG. ERS 2804-64 (4) ECONOMIC RESEARCH SERVICE

Figure 2

The manner in which farm, range, forest, and other watershed lands are managed has a direct impact on the potential yield and quality of water. Our ability to manipulate water yield is limited now, but at some future time research may improve our ability to manage watershed land use so as to reduce uneconomic uses of water, to increase the efficiency of onsite water use, and to improve the quantity, quality, and timing of water yield available for downstream economic uses. Since such a large proportion of our total water supply (70 percent) is used on watershed lands, gains in efficiency of water use, water yield, or water quality would be of great significance.

Figure 3 shows how the 30 percent of our precipitation that constitutes our streamflow of 1,370 million acre-feet is used. (9) Examination of data from a number of sources indicates that about 267 million acre-feet, or 20 percent, of streamflow is withdrawn for farm and nonfarm uses. Another 20 million acre-feet is mined from ground water, making a total withdrawal use of 287 million acre-feet. (10) (11) (12) (13)

Farm withdrawal amounts to 107 million acre-feet, of which 60 percent is lost through evapotranspiration and 40 percent returns to streamflow. About 103 million acre-feet is used for irrigation which produces about 20 percent of the value of crop and pasture production. Agriculturally related industries whose location is influenced by the location of irrigation contribute importantly to the GNP. There is considerable evidence that great improvement is possible in the efficiency of water use in irrigation. (14) Lack of economic incentives, legal obstacles, and lack of technical information, however, have hampered adoption of improved practices. Farm uses for irrigation, livestock, and household purposes account for 88 percent of total consumptive use of water withdrawn from the concentrated supply.

Withdrawals for urban uses, including industrial, municipal, and other uses, account for 180 million acre-feet, or 63 percent, of total withdrawal uses. Some industries are much heavier users of water than others. On the average, however, only 5 percent is lost, so 95 percent is estimated to return to the river systems although the quality may be greatly impaired.

If the flow uses such as recreation, fish and wildlife habitat, navigation, and waste dilution are combined with urban withdrawal uses, a large proportion of the Nation's economic activity and a very large component of the GNP would be associated with such uses of our rivers and streams. In addition, much of the Nation's urban development and a substantial part of the farm production takes place on the flood plains of our rivers. Flood flows cause a loss in economic activity. Flood damages exceed $1 billion annually, of which about 40 percent is upstream and about 50 percent downstream. (15)

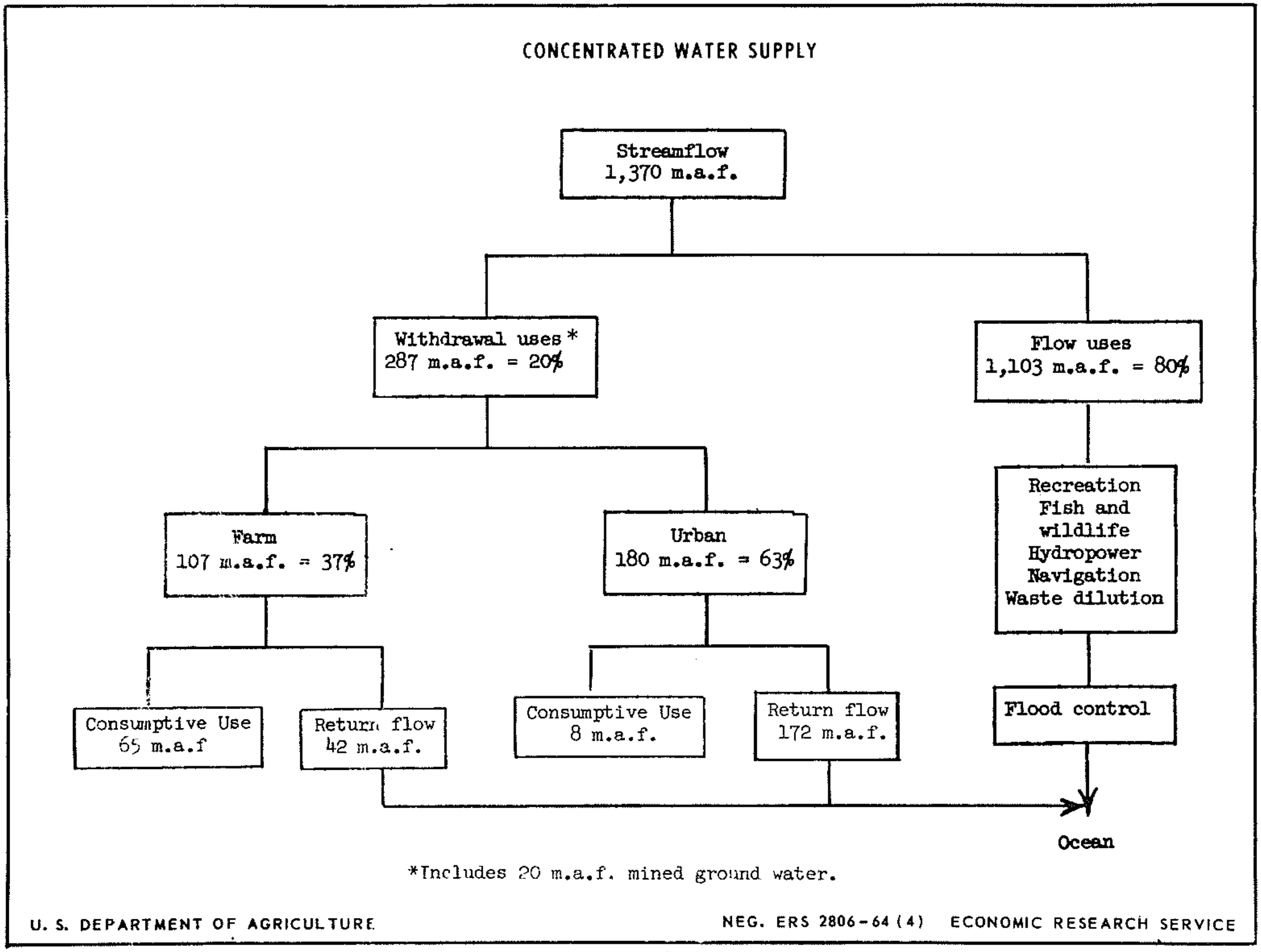

CONCENTRATED WATER SUPPLY
Streamflow
1,370 m.a.f.
Withdrawal uses *
287 m.a.f. = 20%
Flow uses
1,103 m.a.f. = 80%
Farm
107 m.a.f. = 37%
Urban
180 m.a.f. = 63%
Recreation
Fish and wildlife
Hydropower
Navigation
Waste dilution
Consumptive Use
65 m.a.f
Return flow
42 m.a.f.
Consumptive Use
8 m.a.f.
Return flow
172 m.a.f.
Flood control
Ocean
*Includes 20 m.a.f. mined ground water.
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 2806-64 (4)
ECONOMIC RESEARCH SERVICE

Figure 3

These rough indications of the association of water use and economic activity pose some of the strategic questions and issues of water management policy to which an expanded program of research and comprehensive planning should be directed. Providing water management and land use systems for our river basins to meet the present and future needs of our economy for withdrawal and flow uses and to minimize flood damages is a responsibility involving all levels of government as well as private enterprise. Of equal importance to our economy is improving the quality of the water input into the river systems as it runs off watershed lands or is discharged as return flow after being diverted for agricultural and urban uses.

REGIONAL DISTRIBUTION OF WATER RESOURCES

The total annual average water supply of 4.75 billion acre-feet is not distributed uniformly over the country and the requirements for water are not distributed in relation to the available water resources. So the water problem varies according to many local and regional factors.

Figure 4 shows the annual precipitation in acre-feet per square mile for water resource regions; the national average is about 1,600 acre-feet per square mile. As will be seen from this chart, evapotranspiration tends to be high in regions where the precipitation is low. Consequently, usable water supply from runoff in these regions is relatively low when measured on a unit area basis. (16)

Figure 5 shows the amount of water withdrawn or diverted for use by water resource regions. This pattern of water use varies greatly among the regions. For example, the Ohio River region and the Pacific Northwest both had total withdrawals of 27 million acre-feet, but in the Pacific Northwest about 89 percent was used for rural uses such as irrigation, livestock, and domestic purposes while in the Ohio only 1 percent was used for these rural purposes.

This regional variation in the availability and use of water resources is reflected in economic activity in the various regions. The most critical deficiencies in regional water resources are already reflected in the extent of primary economic activity.

For example, seven Western regions (excluding the Pacific Northwest and Central Pacific), with almost 50 percent of the total land area of the conterminous United States, contribute only 23 percent of the value of nonirrigated crop production. These regions have pushed irrigation development and produce 50 percent of the value of irrigated crop production. (17) If we examine employment in principal water-using industries, we find that these seven Western regions have about 10 percent of the U. S. total. (18) These seven regions have about 17 percent of the total population. (19)

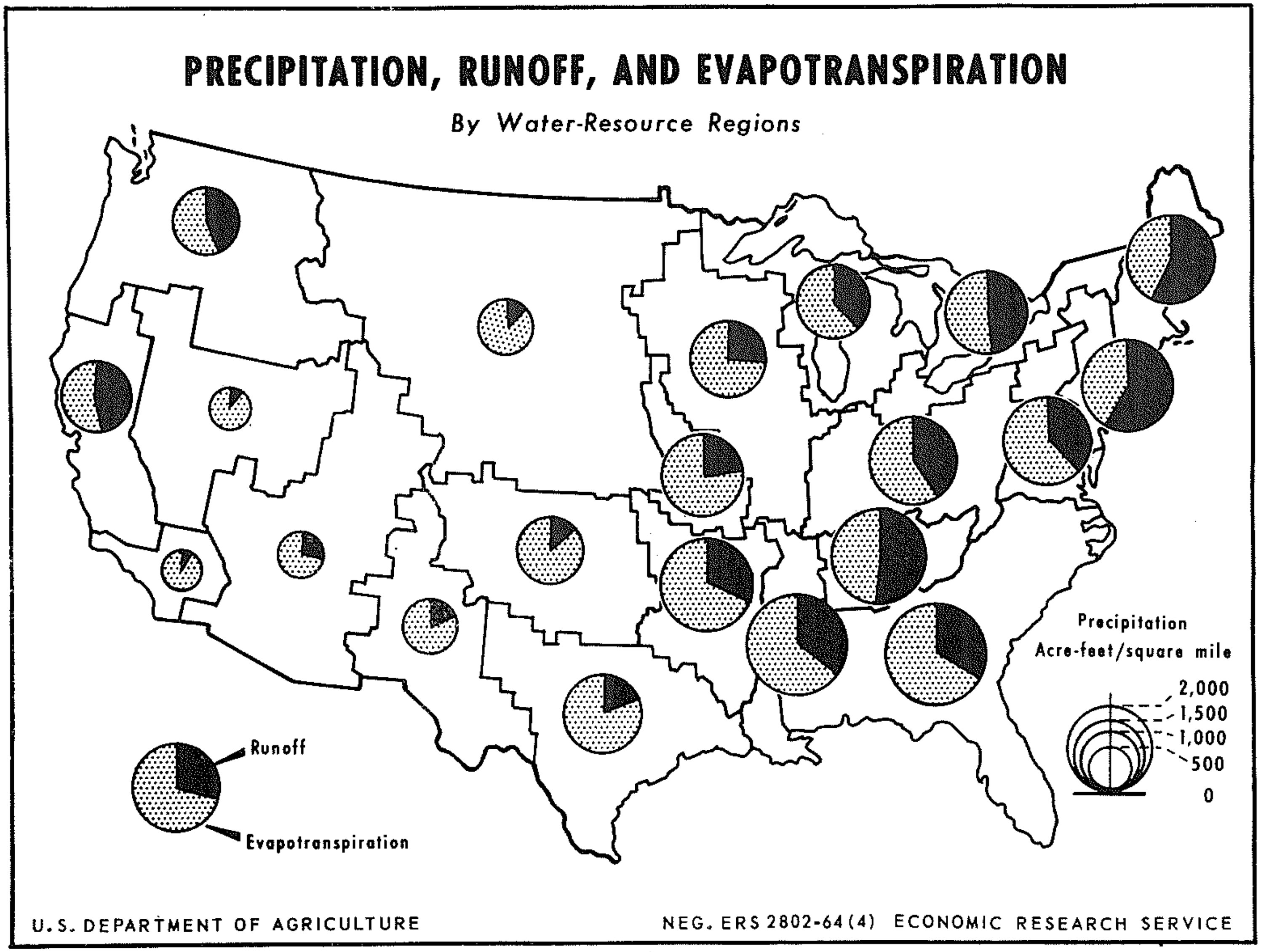

PRECIPITATION, RUNOFF, AND EVAPOTRANSPIRATION
By Water-Resource Regions
Runoff
Evapotranspiration
Precipitation
Acre-feet/square mile
2,000
1,500
1,000
500
0
U.S. DEPARTMENT OF AGRICULTURE
NEG. ERS 2802-64(4) ECONOMIC RESEARCH SERVICE

Figure 4

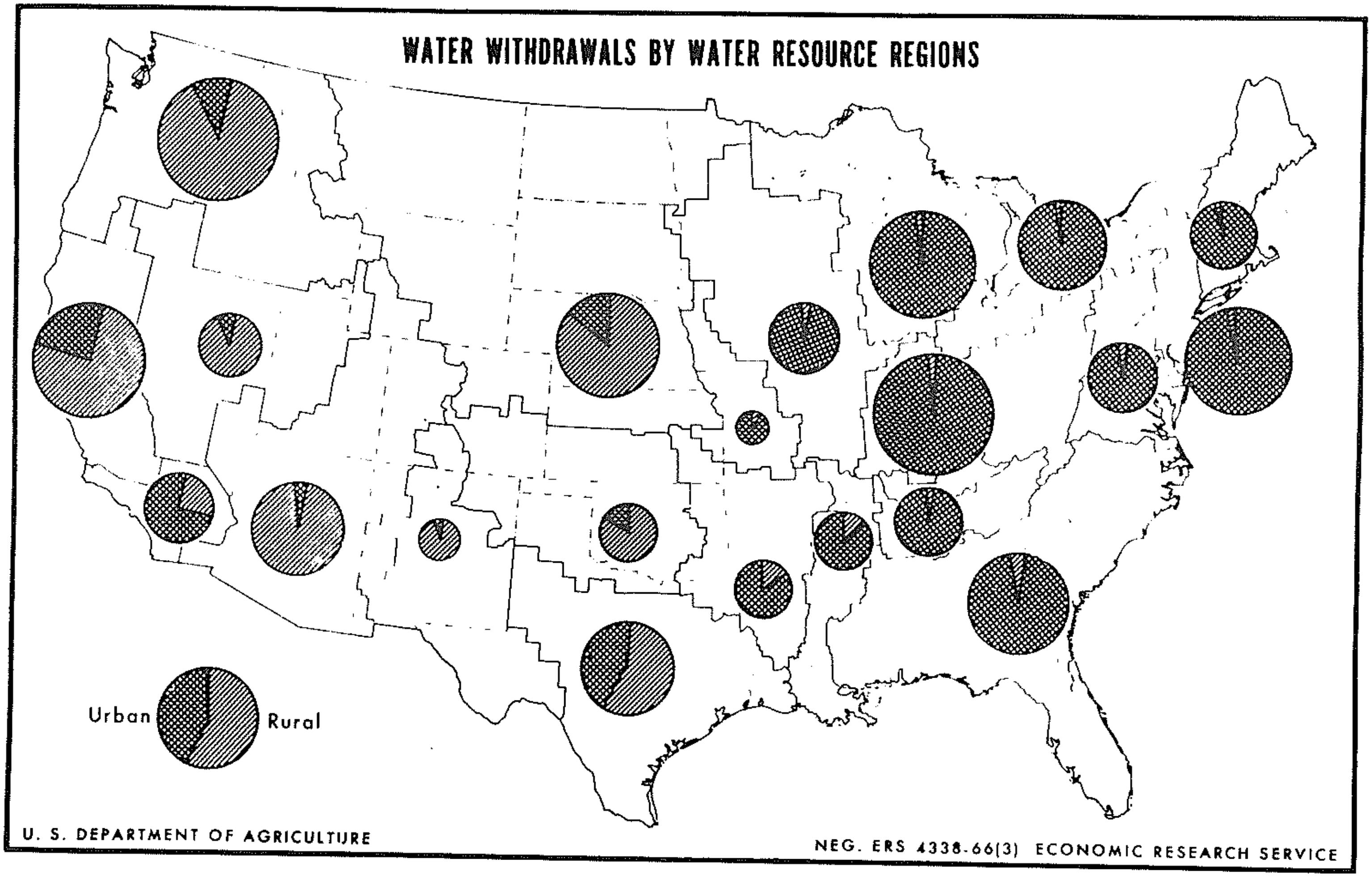

WATER WITHDRAWALS BY WATER RESOURCE REGIONS
Urban
Rural
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 4338-66(3) ECONOMIC RESEARCH SERVICE

Figure 5

Although many factors are involved, there is little doubt that availability of water resources has been a major influence on the type of economic development occurring in these regions.

THE NATION'S LAND RESOURCE

There are 640 million acres of land in capability classes I, II, and III (fig. 6) which are physically suitable for regular cultivation. Currently, about 113 million acres of this land is in pasture and range and could be converted to crop uses if necessary, although some might require draining or other improvements. Clearing and other improvements likewise could make available for crop production about 125 million acres of forested land in these capability classes. (20)

Approximately 169 million acres of class IV land is suited for occasional cultivation at high cost and with intensive conservation treatment. Only about 49 million acres of class IV land is currently used for crops.

Thus, we have about 800 million acres that might be considered potential cropland. A very rough estimate indicates that as much as 600 million acres might be developed for crops by shifts from pasture, forests, and other uses. There would be a wide range in cost of development of these lands for crop use. Some of these lands would be of low productivity. The opportunity costs in terms of loss of timber, production, or increased erosion might be quite high. At present, we are using less than 400 million acres of cropland.

REGIONAL DISTRIBUTION OF LAND RESOURCES

The distribution of potential cropland in relation to total area of each region is shown on figure 7. There is a very uneven distribution of potential cropland among the water resource regions. Much of our cropland potential is concentrated in the Great Plains, North Central and Southern parts of the country.

PRODUCTIVITY

There are many factors that must be estimated or assumed in projecting future requirements for water and land resources. I have discussed projections of population, labor productivity, and the GNP, but another important factor is the productivity of our land and water resources which is increasing rapidly as a result of improvements in technology. One of the most striking illustrations of this is the

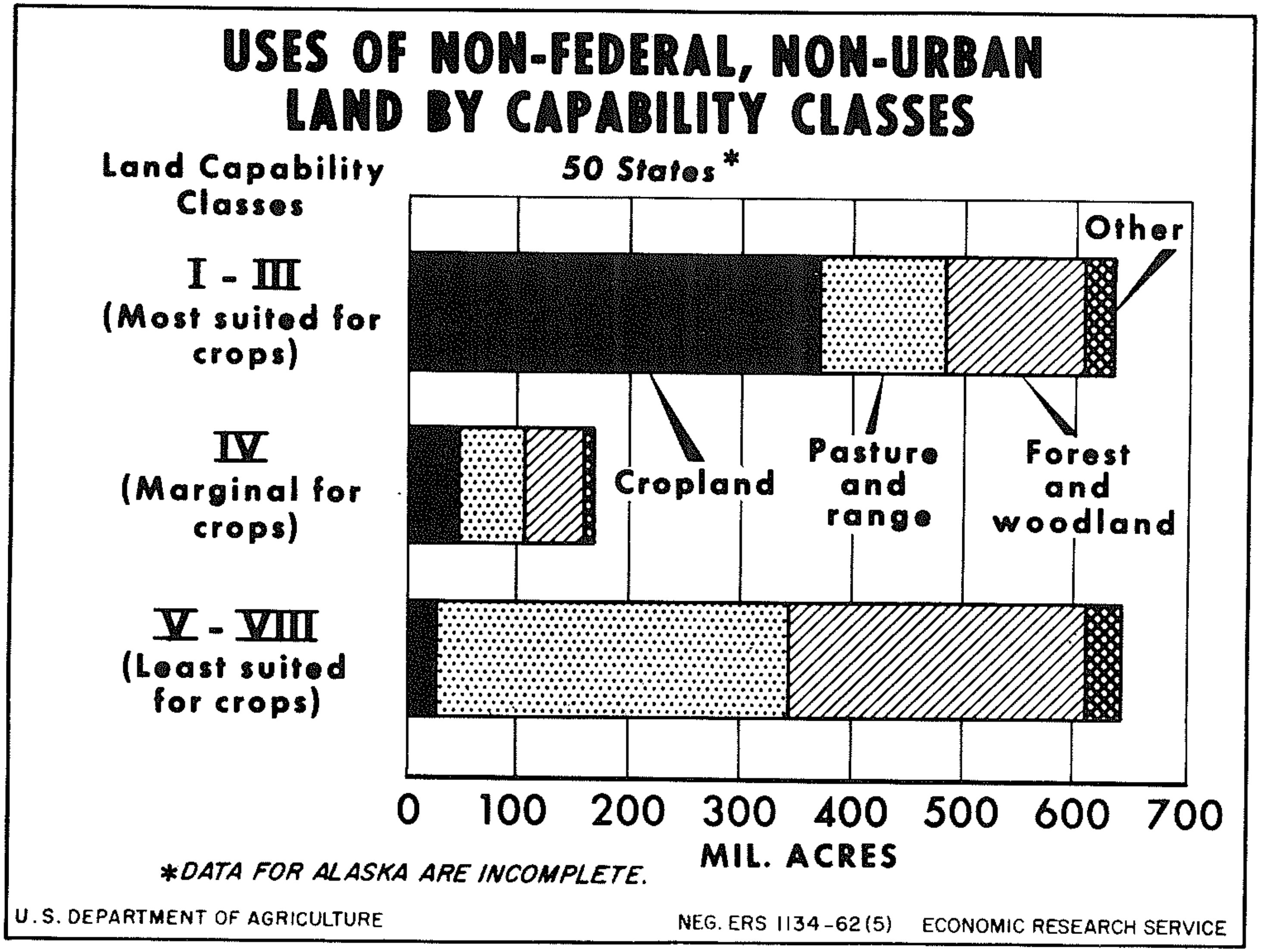

USES OF NON-FEDERAL, NON-URBAN LAND BY CAPABILITY CLASSES
Land Capability Classes
50 States*
I - III
(Most suited for crops)
IV
(Marginal for crops)
V - VIII
(Least suited for crops)
Other
Cropland
Pasture and range
Forest and woodland
0
100
200
300
400
500
600
700
MIL. ACRES
*DATA FOR ALASKA ARE INCOMPLETE.
U.S. DEPARTMENT OF AGRICULTURE
NEG. ERS 1134-62(5)
ECONOMIC RESEARCH SERVICE

Figure 6

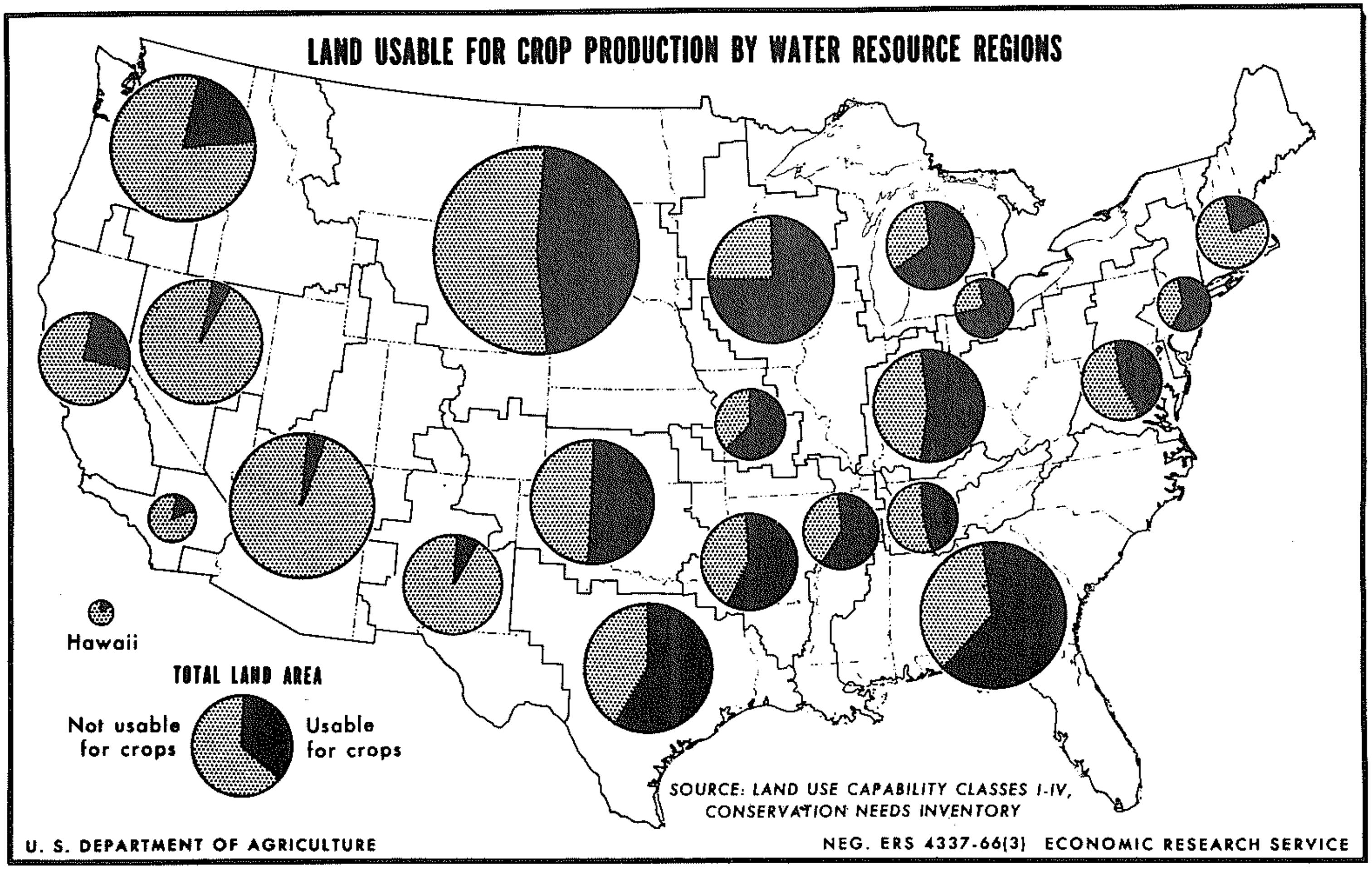

LAND USABLE FOR CROP PRODUCTION BY WATER RESOURCE REGIONS
Hawaii
TOTAL LAND AREA
Not usable for crops
Usable for crops
SOURCE: LAND USE CAPABILITY CLASSES I-IV, CONSERVATION NEEDS INVENTORY
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 4337-66(3) ECONOMIC RESEARCH SERVICE

Figure 7

trend in crop production per acre (fig. 8). Since 1950, crop production per acre has increased 46 percent, more than offsetting the decrease in cropland, with the result that we are producing more on fewer acres.

MODEL FOR PROJECTING REQUIREMENTS

Figure 9 outlines in very simplified form some of the factors involved in projecting future requirements for land and water use. Population growth, consumer income and demand, and foreign trade policy are shown as the principal determinants of demand for land and water resources. The circles on the chart indicate important factors in converting resource use in products and services. Crop and timber yields and the efficiency of feeding livestock or irrigating land are illustrative of these factors.

In 1962, the Department of Agriculture's Land and Water Policy Committee used this model to estimate land use requirements for 1980. (21) Its report indicated that productivity would increase fast enough so that cropland needed in 1980 would be about 50 million acres less than was counted as cropland in the 1959 census. This happened to be about the same acreage as was and still is held out of production by Government programs. In this calculation the Committee assumed that various factors that had been bringing about an increase in crop yields per acre would continue. This included a continuation of the expansion in irrigated acreage. As a result of these considerations, policy was directed toward a continuing program of cropland diversion and a program to expand other rural income-producing possibilities such as recreation.

In 1965, the Committee reviewed its 1962 work and concluded that although there were several changes in the outlook for different factors affecting resource requirements some of these were offsetting and there was no basis to change the conclusions arrived at in 1962.

Now consideration is being given to a Food for Freedom policy that could expand export requirements and thus result in a corresponding requirement for additional crop production. (22) With a model such as I have outlined it is possible to calculate the effect of such policy proposals on land and water use.

In my 30 years of Government service I have seen great shifts in land water requirements from depression to wartime shortages as well as major changes regarding export policy. The look back at past experience as well as this attempt to look ahead indicate the problem of predicting the future with any great degree of certainty and the need for maintaining flexibility in public policy and avoiding irreversible decisions.

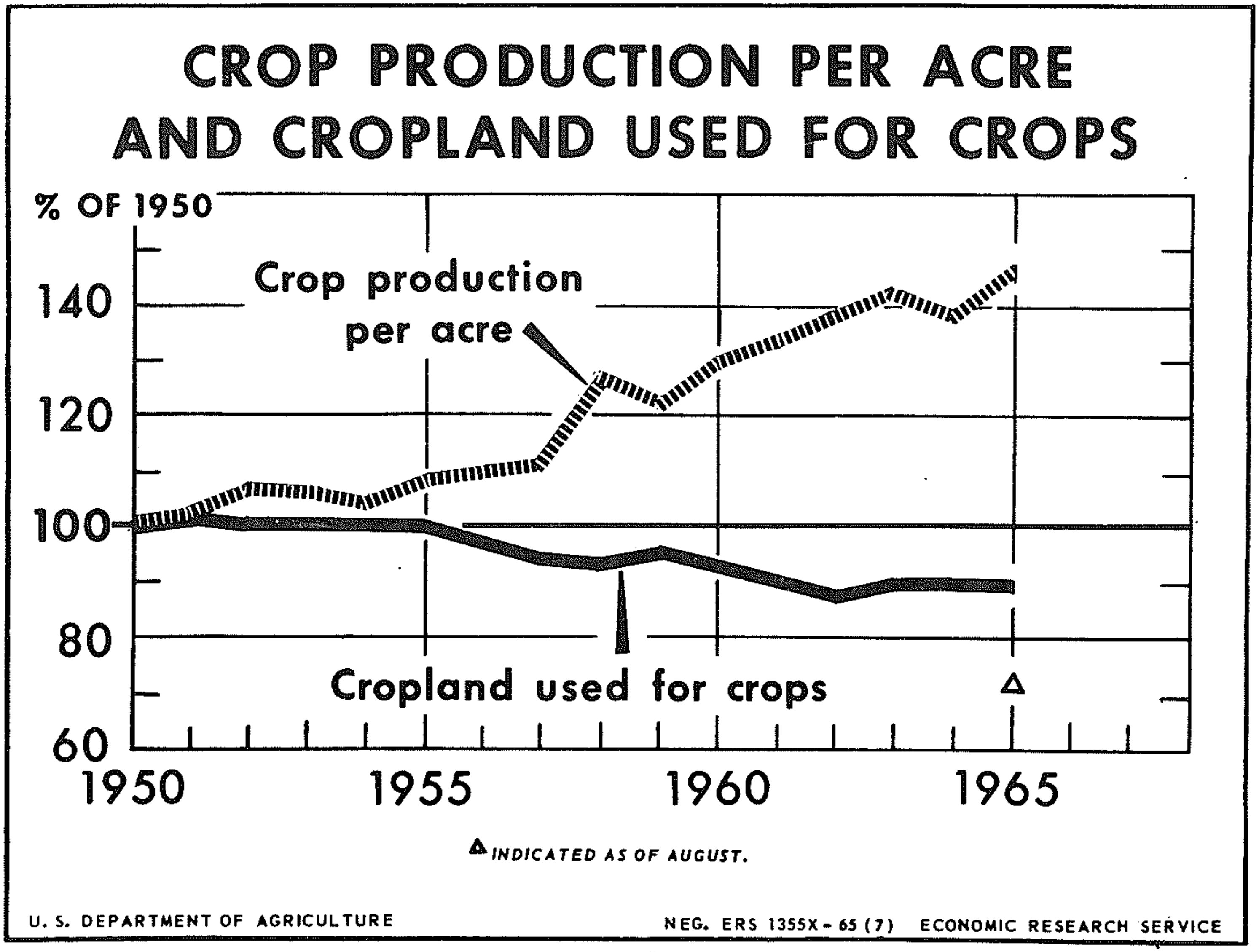

CROP PRODUCTION PER ACRE
AND CROPLAND USED FOR CROPS
% OF 1950
140
120
100
80
60
Crop production
per acre
Cropland used for crops
1950
1955
1960
1965
△ INDICATED AS OF AUGUST.
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 1355X - 65 (7)
ECONOMIC RESEARCH SERVICE

Figure 8

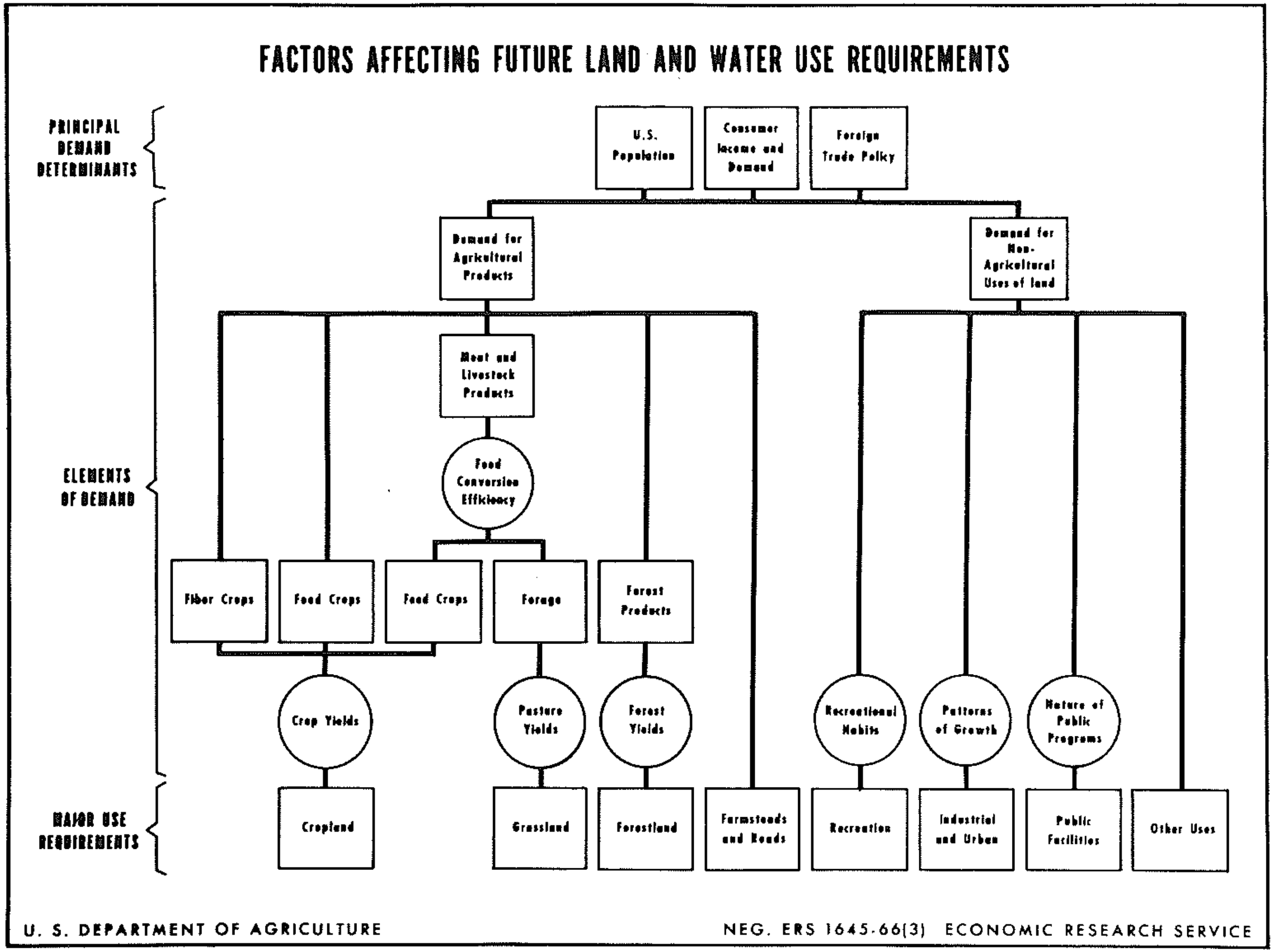

FACTORS AFFECTING FUTURE LAND AND WATER USE REQUIREMENTS
PRINCIPAL DEMAND DETERMINANTS
ELEMENTS OF DEMAND
MAJOR USE REQUIREMENTS
U.S. Population
Consumer Income and Demand
Foreign Trade Policy
Demand for Agricultural Products
Demand for Non-Agricultural Uses of land
Meat and Livestock Products
Feed Conversion Efficiency
Fiber Crops
Food Crops
Feed Crops
Forage
Forest Products
Crop Yields
Pasture Yields
Forest Yields
Recreational Habits
Patterns of Growth
Nature of Public Programs
Cropland
Grassland
Forestland
Farmsteads and Roads
Recreation
Industrial and Urban
Public Facilities
Other Uses
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 1645-66(3) ECONOMIC RESEARCH SERVICE

Figure 9

As a Nation we are fortunate to have such a large cropland potential. Our land and water resources are valuable national assets which must be managed and conserved for the future. The Nation should make provision for adequate land and water reserves which could be shifted to crop use in case of domestic need or to meet international policy objectives.

REFERENCES

1. "Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources," Senate Document No. 97, 87th Congress, 2d Session, May 29, 1962.

2. Preliminary projections by the Economics Task Force of the Water Resources Council, July 1963. There have been minor revisions in these projections by the Task Force.

3. Ackerman, Edward A. and George O. Lof, "Technology in American Water Development," Johns Hopkins Press, 1959. 710 pp.

4. National Academy of Sciences--National Research Council, "Water Resources - A Report to the Committee on Natural Resources," NAS-NRC Pub. 1000-B, Washington, D. C., 1962. 35 pp. (Abel Wolman, Chairman of the Water Resources Study).

5. Select Committee on National Water Resources, "Water Resources Activities in the United States--Land and Water Potentials and Future Requirements for Water," Committee Print No. 12, U. S. Senate, Dec. 1959. 86th Cong., 1st Sess.

6. Hair, Dwight, "The Economic Importance of Timber in the United States," U. S. Dept. Agr., Forest Service, Misc. Pub. 941, July 1963.

7. NAS-NRC Pub. 1000-B, 1962, op. cit.

8. Steele, Harry A., "Research on Water Resources in the U. S. Department of Agriculture," presented at Interstate Conference on Water Problems, Chicago, Illinois, Dec. 1963.

9. NAS-NRC Pub. 1000-B, 1962, op. cit.

10. Ackerman and Lof, op. cit.

11. MacKichan, K. A. and J. C. Kammerer, "Estimated Use of Water in the United States, 1960," U. S. Dept. of the Int., Geological Survey Circular 456, Washington, D. C., 1961.

12. NAS-NRC Pub. 1000-B, 1962, op. cit.

13. Select Committee on National Water Resources, "Water Resources Activities in the United States--Water Supply and Demand," Committee Print No. 32, U. S. Senate, 86th Cong., 2d Sess., August 1960.

14. Select Committee on National Water Resources, Committee Print No. 12, op. cit.

15. Steele, Harry A., "Research on Water Resources in the U. S. Department of Agriculture," op. cit.

16. Select Committee on National Water Resources, "Water Resources Activities in the United States--Estimated Water Requirements for Agricultural Purposes and Their Effects on Water Supplies," Committee Print No. 13, U. S. Senate, 86th Cong., 2d Sess., December 1959.

17. Select Committee on National Water Resources, Committee Print No. 12, op. cit.

18. Select Committee on National Water Resources, "Water Resources Activities in the United States--Future Water Requirements of Principal Water-Using Industries," Committee Print No. 8, U. S. Senate, 86th Cong., 2d Sess., April 1960.

19. Select Committee on National Water Resources, "Water Resources Activities in the United States--Population Projections and Economic Assumptions," Committee Print No. 5, U. S. Senate, 86th Cong., 2d Sess., March 1960.

20. Steele, Harry A. and Norman E. Landgren, "Demands for Land for Agriculture--Past, Present, and Future," address at the Homestead Centennial Symposium, Lincoln, Nebraska, June 12, 1962.

21. The details of this model may be found in "Land and Water Resources: A Policy Guide," U. S. Department of Agriculture, Washington, D. C., September 1962.

22. Daly, R. F. and A. C. Egbert, "A Look Ahead for Food and Agriculture," Agricultural Economics Research, Vol. XVIII, No. 1, January 1966.

CRISIS DECISION-MAKING IN

AMERICAN WATER DEVELOPMENT

Charles W. Howe [1/]

INTRODUCTION

History is replete with examples of the importance of water to the well-being of civilizations. The great civilizations which occupied the valleys of the Tigris and Euphrates Rivers owed their prosperity in large part to their cultivation of the riches of those rivers, and their downfall was at least in part due to neglect of their water resources and changes in the hydrological regime.

North Africa once supplied Rome with agricultural produce far more varied and plentiful than now found there. This is traceable in part to elaborate irrigations systems which had been developed there and which were partly destroyed by war and permitted to decay.

In more recent history, we can observe the demise of the great plain of the Indus River, once the grain basket of the Indian Sub-Continent, but now the home of abject and grinding poverty. An interesting variation of the water story, the plain of the Indus has gradually become water-logged and highly saline with an average of 100,000 acres per year being lost to cultivation in the midst of one of the greatest population explosions in human history.

The Western Hemisphere presents its own examples of economic retardation traceable in part to lack of water. Northeastern Brazil and the high plateaus of Mexico would be examples.

The existence of such examples does not mean that the availability of water is sufficient to guarantee economic growth nor that it would necessarily be worthwhile to incur the expense of bringing water to those regions. Indeed, plentiful water is not, in all cases, even necessary for establishing a thriving economy, as can be seen in the success of Israel in establishing a viable economy in the face of meager water supplies. Even so, it would not be unreasonable to argue that water can and does exert a profound influence on the course of development and well-being of national economies.

1/ Associate Director, Water Resources Program, Resources for the Future, Washington, D. C.

DO WE HAVE A WATER CRISIS?

To relate the foregoing observations to the contemporary U. S. scene, one can observe that, while water availability has been extremely important to the development of several major regions of the United States, the dependence of economic activity on water tends to decrease with advancing wealth and technology. Advanced irrigation farming in the Southwest can substitute investment in lined irrigation canals for water, but a peasant economy could not consider this possibility. A modern beet sugar plan can be designed to withdraw from its water source only 76 gallons per 100 pounds of sugar, whereas the average for older plants is closer to 1200 gallons. Washed coal operations are currently designed to withdraw from 1 to 1,000 gallons of water per ton.

The United States thus has a greater flexibility than ever before in conserving its water resources, greater opportunities for devoting water to the highest value uses, and a vast inventory of technology to reduce required water intake and improve water quality. Yet it is commonly thought that the country faces a water crisis which requires crash programs to avoid dire results! How much content is there in this impression?

The answer to this question might be placed in some perspective by noting that decision-making, particularly in the public sector, frequently takes place in a crisis atmosphere. In 1955 there existed a common impression of a great shortage of engineers and several programs were instituted to promote engineering education and advertise professional opportunities. Sputnik went up and we were suddenly lacking scientists, scientific education, and adequate research.

Eastern railroads declined in service to the public for years, yet it seemed to require the rather spectacular bankruptcy of the New Haven to call this to the public's attention. Social injustices of years' standing went unheeded until the situation assumed crisis proportions. Now we presumably face a crisis in water quantity and quality.

All of these situations have characteristics in common: the underlying problem had existed for some time; experts and informed laymen in each field were very much aware of the problems but the public was not well informed; some particular incident seems to trigger public awareness; those who have long term responsibility for alleviating the problem help to fan the fires of crisis in hope of gaining support to help make up for accumulated inadequacies.

Why do such crises occur? First, the public sector, both local and national, has limited funds to allocate among many programs and political support must be mustered to secure funds. The issues are complex and their understanding frequently requires data, analytical abilities, and time that the average voter cannot easily acquire, making it unlikely that the initiative would come from the public. At the same time, no institutions exist with the time and expertise required to keep particular problem areas under continuing review. Existing institutions which have the potential for so doing frequently get bogged down in day-to-day administration and develop traditional viewpoints which may mask a problem for a time and then magnify it unduly through failure to perceive the whole range of alternative solutions.

Does the United States face a crisis in the water resources area? A crisis must have two elements: there must be a present or impending shortage of water and there must be significant costs which will result from that shortage. The definition of shortage which must be used here is:

> water of the quality desired is not available in the quantity desired under the terms of availability, including price, to which users have become accustomed.

For most commodities, the market is expected to take care of such excesses of demand over supply by inducing increased supply and improved quality and through adjusted prices. It is worth recalling, however, that water has unique characteristics which frequently, though not always, take its provision outside the market place.

1. Water users frequently have impacts on each other's operations. Upstream users affect downstream availability and quality. Groundwater use affects other's pumping costs as well as stream flow.

2. Gross supplies provided by nature are irregular, probabilistic--serving to cloud property rights in the commodity and making market transfers difficult.

3. Supply systems, to be efficient, frequently must be large-scale, basin-wide, frequently requiring legal and administrative powers which are difficult to transfer to private enterprise.

Recognizing that much of our water resource supply and development falls within the scope of public authorities for the above reasons, we must seek the causes of the currently perceived excess of demand over supply and investigate just what is known about the costs of shortages when they are actually experienced.

THE DEMAND FOR WATER: IS IT REASONABLE?

Demand may conveniently be broken down into classes of uses: residential, commercial, industrial, public, and agricultural. Only residential, industrial, and agricultural demands will be mentioned here.

Residential demands represent a small percentage of national total water withdrawals, but in metropolitan areas such demands can represent a large percentage of total system output and can account for very large proportions of total investment. Contemporary urban water problems are of two major types: inadequate distribution system capacity and shortage of basic water supply. However, many of these problems arise through excessive, uneconomic demand.

The urban situations serve to illustrate an important point: uneconomic pricing of water throws a large and unnecessary burden of capital expansion on the water system. The system must stand ready to satisfy all demands without permitting an excessive pressure drop to occur. Thus systems are designed to handle the peak hourly demand rate. The following table gives results of measurements taken in a recent analysis of 34 study areas across the country.

TABLE 1. Per Capita Water Use in 34 Study Areas[1/]

Period	Range	Mean
Average Annual	50 to 530	115 gpcd
Maximum Day	72 to 1450	300 gpcd
Peak Hour	150 to 2750	690 gpcd
Ratios:		
Maximum Day/Average Annual	145 to 500	260%
Peak Hour/Average Annual	260 to 1300	600%

1/ Residential Water Use Research Project, The Johns Hopkins University, Report II, Phase 2, by F. P. Linaweaver, Jr., June 1965.

Nearly all of the excess use above the average annual is accounted for by lawn sprinkling. The "average system" must thus be designed to distribute 6 times the amount that is used on average, and most of this additional investment is attributed to lawn sprinkling.

What does this have to do with pricing? Much of the water is in fact wasted and this waste is induced by uneconomic pricing; that is, prices are set below the actual cost that additional demands impose on the system. The following table illustrates the impact of metering on residential water use.

TABLE 2. Water Use in Metered and Flat-Rate Areas[1/]
(climatically similar areas)

	Metered Areas (10)	Flat-Rate Areas (7)
	(gallons/day per dwelling unit)	
Annual Average		
Leakage and waste	26	32
Household	239	232
Sprinkling	191	520
Total	456	784
Maximum Day	975	2400
Peak Hour	2420	5240
	(Inches of water)	
Annual		
Sprinkling	14.9	47.2
Potential Evapotranspiration	29.7	25.7
Summer		
Sprinkling	7.4	27.3
Potential Evapotranspiration	11.7	15.1

1/ Residential Water Use Research Project, The Johns Hopkins University, Report II, Phase 2, by F. P. Linaweaver, Jr., June 1965.

Metering means that users must pay for each additional unit they use. Whatever may have been the levels of prices paid, the differences of behavior under metering and flat rate are striking.

Some major urban areas which are currently experiencing basic water shortage and distribution bottlenecks still price water on a flat-rate basis. It has been more than ten years since an eminent board of consultants recommended universal metering and extensive system repairs for New York City. Yet most residential users are still not metered and the system losses through leakage amounts variously estimated from 200 to 400 million gallons per day.

One can quote Reno's experience of a few years ago as an indication that residential water usage can be substantially reduced without damage to the community. (1) After lowered lake levels had reduced the Truckee River to a trickle, a program of public information was undertaken to advertise the nature of the shortage and the kinds of steps which households and businesses might undertake to conserve water at minimum inconvenience. The result was a 20 per cent reduction in overall consumption with a great reduction in peak demands. In spite of reduced application, lawns were not adversely affected.

It is my conclusion from this and other evidence that residential demands in many places are excessive relative to what they would be if water were metered at economic prices, with a bit of consumer eudcation thrown in. Not only would short-term reductions follow, but over time more suitable adjustments of lawn acreage, shrub and tree types would be made.

What of industrial demand? The outstanding characteristic of industrial demand is the variablility of gross water use (withdrawal plus recirculation in some cases) per unit of product. The following table summarizes data collected in a survey by the National Association of Manufacturers.

Of course, not only does gross use vary a great deal within a given industry, but consumptive use and water-borne waste load also differ widely.

On the basis of this evidence and a sequence of intensive industry studies being conducted by Resources for the Future, Inc., it is clear that there exists a wide design range for plants in most industries, ranging from heavy water using design to high water conserving design. Conserving water costs money, of course, but with water supply costs continually increasing and with a rational pricing of water, industrial plants can and will adapt to lower water intake.

This adaptablility has been exhibited in new plants in various industries. An excellent example of it, combined with the perils of forecasting without taking technological change and adaptation into account is

TABLE 3. Ranges of Gross Water Use per Unit of Product[1/]

Beet Sugar	76 to 3200 gallons per 100 lb. sugar (withdrawal only)
Salt Production	6 to 640 gallons per ton
Distilling	125 to 167 gallons per proof gallon
Soap	3 to 100 gallons per case
Detergents	33 to 38 gallons per drum
Tanning	0.2 to 64 gallons per sq. ft.
Petroleum Refining	500 to 3247 gallons per bbl. of crude
Pulp and Paper:	
1954 average	66,400 gallons per ton of product
1959 average	57,000 gallons per ton of product
Steel	3544 to 24,798 gallons per net ton
Coal Preparation	1 to 1000 gallons per ton

1/ Water in Industry, National Association of Manufacturers and the Chamber of Commerce of the United States, January 1965.

found in two forecasts for the pulp and paper industry's water withdrawal. The forecasts were made independently by Business and Defense Services Administration and Resources for the Future, Inc. In 1954 when actual withdrawal amounted to 1607 billion gallons, both organizations forecast a 1959 withdrawal of 2140 billion gallons. A Census survey covering 1959 indicated actual use was up only to 1744 bgy, an increase of 8-1/2 percent, in spite of an increase in product output of 30 percent.

The water use projections of the Senate Select Committee on National Water Resources (88th Cong., Aug. 1960) were, for all sections of the country except the West and Southwest, dominated by flow augmentation "requirements" to maintain acceptable stream quality. Combinations of secondary treatment and flow augmentation were assumed. Other quality-improving alternatives, such as in-stream reaeration and waste load redistribution, were not taken into account, nor were the wide possibilities of industrial process change for reducing waste outfall.

The point is that many of the industrial water use forecasts which have contributed to predictions of water shortage by 1980 or 2000 have not taken into account the adaptability of industrial water use in reducing water requirements and waste loads. The success of the Ohio River Sanitation Commission in achieving results in this field is a monumental example of what can be achieved on a voluntary basis.

A final observation on the demand side should be made to cover agriculture. Here I find myself in the embarrassing position of having no particular expertise while addressing experts. Several "safe" points might nonetheless be made. Irrigation represents the largest withdrawal and by the far the largest consumptive use of water in the country. At the same time, irrigation efficiency remains low in many areas. Where small river basins are involved or where groundwater is used, the impact of inefficiency in application may be localized, but in the larger basins the effects may be felt over vast areas. In all cases, inefficient use leads to pressures for the development of new sources such as long distance inter-basin diversion, often long before such needs are economically justified. Clearly there are cases where private rationality diverges from the nationwide interest. If imported water will be provided to an irrigation district at, say, $15 per acre foot while local projects designed to reduce losses will cost $20 per acre foot of water saved, the district can hardly be blamed for voting for imported water. This cannot, however, obscure the fact that currently proposed inter-basin diversions are going to cost the country at least $30 per acre foot, whoever pays the bill.

The national interest requires continuing effort to increase irrigation efficiency. A few percentage points in increased efficiency can represent sufficient water not only to provide for the future economic health of the agricultural sector but to provide water that may be necessary for continued population expansion and industrial growth. Again, a more rational pricing of water would give impetus to increasing efficiency.

The overall conclusions regarding current and prospective demands for water seem to be that:

1. under-pricing or flat-rate pricing lead to excessive use and waste in all sectors of the economy;

2. economic pricing can, over a long period, result in more efficient use through process and systems adaptation;

3. many of the extrapolations of future water requirements have greatly overstated needs by failing to take into account technological change, process and system adaptability, and some important alternatives in handling the water quality problem.

WATER SUPPLY: HAVE WE LOOKED AT THE ALTERNATIVES?

New supplies of water are available to the United States only at increasing cost. In the development of surface supplies, most regions have already utilized the best reservoir sites. The Colorado is so highly controlled that additional reservoirs will reduce reliable flows through evaporation. Imported water from projects which can be executed within the next decade will cost at least $30 per acre-foot, as shown by the reconnaissance estimates below (uncorrected for price increases since originally made):

Snake-Colorado	$31.80*
Modified Snake-Colorado	34.00
Sierra-Cascade	27.00 to $38.00
Yellowstone-Snake-Green	30.00

(*Water Resources Center, UCLA)

These figures represent only the first step of delivery into a major reservoir or other point of the Colorado River.

Desalination is currently receiving a great deal of publicity as a new source of water. Plants have been successfully established on a commercial basis two or three places in the United States and in greater numbers abroad. Costs to date are running $1.00 and up per thousand gallons, but plants now in the engineering stage promise to reduce this to about 30 cents per thousand gallons -- $97.80 per acre-foot. These costs refer to very large scale plants in the 100 to 200 million gallons per day range which require particular circumstances for their viability: sea coast location where intake salt water and brine disposal are cheap, a market for vast amounts of electrical power (400-1500 megawatts) produced jointly with the water, and ability to use the water near at hand. Once plants of this size have been attained, present technology will have been largely exploited, and major breakthroughs appear unlikely. Potential applications of desalting appear limited.

The effective supply schedule of water depends upon water agencies' perceptions of alternatives. New York has long had its "crisis" but is only now turning to the Hudson River for water -- water of a quality far superior to that used by many major cities, including nearby Philadelphia which uses the waters of the Delaware. The last reservoir added to the New York system provides more costly water than the Hudson and, now during extreme draw-down, is providing "black water" of a quality offensive to many users. This point apparently was not anticipated by those who argued that cost differences were justified by quality differences.

Los Angeles will be importing water from Northern California at $45 to $65 per-acre foot (depending upon who does the figuring) while having a vast potential for water reuse and sewage reclamation at almost half the cost. The Whittier Narrows sewage reclamation plant produces potable water from domestic sewage at 5 cents per thousand gallons or $16.50 per-acre foot. The water is used currently as groundwater recharge. This program is capable of vast expansion in Los Angeles, but plans are moving ahead for the desalting plant mentioned earlier -- $98 water.

It seems quite likely that advanced waste treatment processes will be improved and lowered in cost in the near future. A new surge of interest and research, both public and private, is being felt in this field, promising to make water reclamation and reuse even more attractive.

Realistic supply alternatives thus are frequently ignored or given low priority in development in spite of large cost differences.

At the same time, some disadvantages have been overlooked in public discussions of alternatives.

The brine disposal problem in desalting has not been adequately analyzed. A plant producing 100 mgd from sea water will produce 20,000 tons of salt per day -- in the form of brine unless further treated. The disposal of such quantities of brine can cause change in the biological regime of the ocean along the coast. Various forms of plant and fish life were killed in the environs of the Point Loma demonstration plant. Disposal of brine at inland locations will, in some locations, require costly recharge wells which might ultimately feed back into the brackish water supply.

Large-scale importation schemes have the drawbacks of inflexibility, irreversibility and long payout periods. Given the economies of scale in building large diversion systems, it is difficult to keep demand and supply in phase. While it is necessary to build ahead of demand in a growing economy, a balance must be struck between the operating cost economies of larger systems and the premature commitment of capital. A long payout period is not to be deplored in itself, but committing oneself to projects of very long life in the midst of an era of great invention and technological change may not be the best way of handling uncertainty. Not only are there uncertainties about future technological advances, but little is known about environmental and ecological response to withdrawal of large quantities of water from rivers such as the Columbia or Snake or to the flooding of vast mountain valleys as envisioned in NAWAPA. Anyone who has observed a large reservoir gone dry can appreciate the irreversibility of such projects. These points may be summed up in the phrase "the desirability of flexibility" in water resource development.

These observations on the supply situation can be summed up in the following points:

1. additional supplies are going to cost a good deal more than we have been used to paying;

2. how high costs go will depend on our willingness to consider on the basis of cost all alternatives for augmenting supplies;

3. planners should consider the "desirability of flexibility" before committing us to large-scale, irreversible projects.

THE COST OF WATER SHORTAGE

I trust that by now my conclusions are beginning to show: that nationally we have no shortage of water which cannot be eliminated by more efficient, less wasteful use (most easily induced by pricing water at its real national cost) and through additions to supplies from the lowest cost available sources, including water reclamation and reuse. This conclusion holds, in my mind, for all of the major water resource regions, although there may well be smaller areas for which the suggested steps would prove inadequate to maintain the growth of the existing economic structure. For such cases, it is probably worthwhile to give thought to what changes in economic structure might best exploit the natural advantages of the area.

The final step in this analysis will be to state what is known -- or rather, what is not known about the short and long term costs of failing to satisfy the demands for water.

New York provides an illustration of an area which has been forced to restrict water use during the drought. There seem to be two extreme schools of thought (both without support of cost analysis) about this situation: (1) that it is unthinkable and unreasonable to have, in an affluent society, a water system which will <u>ever</u> fall short of meeting all demands; (2) that infrequent extreme events like the drought cannot be guarded against with complete certainty and that the best way of coping may simply be an occasional belt-tightening.

To assume that any water system, particularly systems depending on surface storage, can guarantee meeting all demands with a probability equal to one at a cost anyone would be willing to pay is indeed naive.

The amount which should be invested in increasing the probability of meeting all demands depends upon the costs associated with having to restrict water use. The latter element is simply not known, and, in the absence of that information, both of the above approaches represent naive opinions. The costs imposed on New York by water restrictions have not been compiled, so we cannot tell to what extent the observed shortfall of supply really represents a problem of crisis proportion. If, as one eminent authority feels, the costs have been insifnificant, then the shortage does not imply crisis at all. The real story can only be uncovered through careful research on the problem.

The long-term impact of water shortage is also uncertain. Clearly, agriculture in arid areas requires water and without it such activity must contract. But many arid areas have great potential along lines other than agriculture, as demonstrated by the postwar industrial and commercial growth of the Southwest. It is yet to be demonstrated that water availability, within the range of conditions found in the United States, has any measurable effect on industrial location. A study currently underway at RFF indicates that those U. S. counties adjacent to navigable rivers and inland waterways experienced an average 1950-60 decade growth of 8 percent in employment; those adjacent to the Great Lakes expanded their employment 9 percent; costal areas expanded by 28 percent; while the rest of the country averaged 13 percent. Although there are local deviations from these averages, it is clear that water availability *per se* doesn't guarantee economic growth. (2)

CONCLUSIONS

More rational pricing of our water resources and more efficient use, combined with a fuller exploitation of existing technological alternatives on the supply side can preclude any water crisis in the forseeable future. Effective application of these steps will require revisions in our traditional thinking, from the acceptance of reclaimed water for drinking to a fresh look at the best ways of promoting the continuing economic growth of arid areas.

Public education and the production of larger numbers of broadly educated water managers are needed. Extensive research is needed not only on the technological aspects of water systems, but on the regional economic and social impact of alternative pricing and administrative controls over water. We must study carefully the implications of new legislation relating to water, such as "basins or counties of origin protective statutes" which, while aimed at securing equity, may unduely shackle our use of water resources. Legal ingenuity and creativity must be combined with careful economic analysis to facilitate transfers of water from one use to another when called for by large differences in the value of product or service produced, full account being taken of secondary impacts and the necessity of adequate compensation being paid.

It is in these areas that institutions like New Mexico State, with its Water Resources Institute, can make great contributions both to the regional and national well being. With their continuing contributions to our knowledge of water-related technology, sociology, and economics, and through the establishment and effective use of new institutions such as the River Basin Commissions provided in the Water Resources Act of 1965, we can successfully meet any challenges facing us.

REFERENCES

1. See Noel A. Clark, "The Western States Have Water Supply Problems, Too," Water and Wastes Engineering, 1966, 3, 2.

2. Bower, Blair T., "The Location Decision of Industry and Its Relationship to Water," paper given at the Conference of the Committee on the Economics of Water Resources Development, San Francisco, December 10, 1964. (Another research project on the topic is currently underway at TVA.)

NORTH AMERICAN WATER AND POWER ALLIANCE

Roland P. Kelly[1/]

This oppprtunity to present the North American Water and Power Alliance concept to you is deeply appreciated by The Ralph M. Parsons Company and me, and we sincerely thank New Mexico State University for honoring us with the invitation. It isn't often one has the privilege of addressing such an important group. We are indeed grateful and pleased to be able to do so.

Throughout the world the chief water problems are (1) too much water, (2) too little water, (3) polluted water, and (4) the growth of human demands for water beyond the perfectly normal and once satisfactory supply. Of these, "too little water" is most in the public eye in most parts of the North American Continent. Water, where it is needed, when it is needed, that is pure enough to drink and cheap enough to use in agriculture and industry, is one of the world's most feverishly sought resources.

New York City, and more than 1,000 other American communities, have had to restrict water usage to stretch the supply to meet the demand. In the northeast, there has been a record-shattering drought from New Hampshire to West Virginia. Likewise, the Prairie Provinces of Canada have experienced severe droughts and still have a serious water shortage in many areas.

Near-record snows and heavy spring rains in 1965 in the upper Mississippi Valley spread devastating floods all the way from Minnesota to Missouri. There were also highly destructive floods in northern California. In Canada they have also often felt the effect of too much water in the Thompson, Fraser, Columbia, and Peace rivers to name a few.

In northern Mexico, immediately across the border lies the most fertile agricultural area of that country, yet it is not developed agriculturally and industrially because of a lack of water. Their water shortage is so critical they are planning large desalting plants to provide water for municipal use. They also have the problem of flash flooding from lack of proper flood control facilities.

In the United States, many of our greatest rivers and lakes now suffer chronic pollution. President Johnson, in a recent message to Congress, described the situation by saying that "Every major river

1/ Technical Program Manager, The Ralph M. Parsons Company - Engineers-Constructors, Los Angeles, California.

system is now polluted." The Canadian Minister of Northern Affairs and National Resources, Arthur Laing, referring to President Johnson's statement said, "We in Canada have not yet reached this condition, but we are not far behind, and I think it is a safe statement to make that most major river systems in the populated parts of Canada are polluted to some extent." Of course, almost everyone is aware of the problems -- pollution, decreased navigation, low power production -- being encountered in the Great Lakes because of the low water levels.

What I have been attempting to do with these few examples is not only to highlight the problem but also to illustrate the commonality of the problem. In other words, the water problem is not unique to the United States. This situation exists now, it is real, and it will grow steadily worse until it reaches alarming proportions by 1980.

I say this because our advancing technology and expanding population will make it so. For example, the average demographic projections show that by the turn of the century the population of this continent will double. By 1980 the demands for water will almost double the amount used today, and they will triple by 2000. In the United States we are said to have a potential supply of 515 billion gallons per day. Our consumption is now 340 billion gallons per day. By 1980 we probably will need 600 billion gallons, and the demand will exceed the natural supply. This is approximately 1,700 gallons per person per day. The total river flow in the United States amounts to about 1.8 million cubic feet per second, or a little more than 5,000 gallons per person per day.

Fresh water supplies can be increased through three means: (1) reducing the need for water; (2) making more efficient use of our present water supply, and (3) finding new sources of water. Many plans and methods have been proposed for solving this nation's water problems and the water problems of the Southwest. There is importation of water, desalination of sea water and brackish water; then there is cloud seeding, better methods of conservation, such as evaporation control, reuse, watershed management, et cetera. Actually none is a panacea. What is needed is a good overall water management plan incorporating as many of the methods possible within economic limits. However, in reviewing the situation, one factor is incandescent and that is the shortage of water.

The NAWAPA concept naturally falls into the last category of finding new sources of water. The requirement for such a plan is, we believe, dictated by the continental nature of the need which I have briefly touched upon earlier.

In simple terms, NAWAPA is a concept for collecting a small percent of the water of the high precipitation areas of the northwestern part of the continent and redistributing it to water-scarce areas of Canada, the United States and northern Mexico.

In presenting the NAWAPA concept, we fully recognize it represents but part of the total water management problem - conservation and distribution, although in providing this element it certainly affects many other elements such as flood control, recreation, reclamation, et cetera, quite substantially.

As I mentioned before, we realize the NAWAPA concept poses many problems which must be solved before work can begin. There are first and foremost the political problems. Then, of course, there are engineering problems, legal, sociological, financial, et cetera.

We are making no attempt at this time to offer solutions to these problems, but are merely presenting a concept for utilizing surplus water now flowing unused into the sea. We are trying to solve one of the water management problems, the problem of proper distribution on this continent.

We are often asked how the NAWAPA concept was developed? It was brought to our attention through our Foreign Operations Division which has been actively engaged in water development projects in Taiwan, India, Iran, Iraq, Kuwait, and many other foreign countries. It was this general knowledge of water and mankind's need for water which lead to a study of means of augmenting the supply of water in the United States. Several years ago we started development of the NAWAPA project, then continued to expand it. The concept was developed entirely by The Ralph M. Parsons Company at Company expense. We have worked on this plan strictly as a free enterprise research and development project without contract from the government or any other agency.

As an aside, I would like to point out that we are engineers, not politicians. We have created the NAWAPA concept based on what we believe to be a definite need -- an ever increasing need. We have based our development and findings solely on the requirement to fulfill that need. In doing so, we have not allowed political boundaries to restrict our thinking because we noted at the outset that mother nature did not take political boundaries into consideration when she bestowed her resource treasures upon this earth. This is not to say we do not fully recognize and appreciate the complexity of the political problems that must be solved before such a project can be undertaken; but from an engineering viewpoint, the best solution to the problem can be obtained looking at it from an objective and practical viewpoint.

Total drainage area involved in the primary NAWAPA collection region is approximately 1,300,000 square miles. It has a mean annual precipitation of between 15 to 60 inches. Of an average annual runoff of 663,000,000 acre-feet of water, approximately 110,000,000 acre-feet, or less than 20 percent of the total flows of the basins, would be utilized. In addition, up to 48,000,000 acre-feet per year, as required, of the unused runoff of the eastern slopes of the Rocky Mountains would be used for development of the Canadian prairies and stabilization of the water level of the Great Lakes.

The primary sources of water collection, as shown on Figure 1, are the Susitna, Copper, and Tanana rivers in southeastern Alaska; the Yukon and Stewart rivers in the Yukon Territory; and the Liard, Stewart, Stikine, Fraser, Peace, Kootenai, and Columbia rivers in British Columbia. A series of dams and power stations would provide for pumping this water up to the Rocky Mountain Trench Reservoir at an elevation of 3,000 feet. From the Rocky Mountain Trench Reservoir, water would be pump-lifted to the Sawtooth Reservoir located in central Idaho. From here, water would flow southward by gravity passing the Sawtooth Mountain barrier through a tunnel.

NAWAPA water would be conveyed via canals and tunnels. The canals would be of trapezoidal cross section and concrete lined. The canals would be based upon a velocity varying from 2 to 3 feet per second and would have a slope of approximately 0.2 foot per mile (.04 foot per thousand feet). Tunnels would be concrete lined. Tunnel design would be based upon a velocity varying from 5 feet to 10 feet per second with a slope varying between 1.2 feet per mile (0.22 foot per thousand feet) to 0.76 foot per mile (0.144 foot per thousand feet). The NAWAPA system would include a total of 6,700 miles of water transfer canals and multipurpose water transfer and navigational canals, and 1,800 miles of tunnels.

Lakes and reservoirs would be the primary delivery points for NAWAPA water. Secondary delivery points would be provided by turnouts on the canals connecting storage facilities. The location and size of turnouts would be dependent upon local requirements.

Total installed power generation capacity of the NAWAPA would be approximately 110,000,000 kilowatts. Based upon an overall efficiency of 83 percent, the total power generation would be 876,000,000,000 kilowatt hours per year. Of this amount, approximately 613,200,000,000 kilowatt hours per year would be available for marketing.

Total pumping plant capacity installed in the NAWAPA system would be 53,500,000 horsepower. Pumping requirements of the NAWAPA system would consume 262,800,000,000 kilowatt hours per year of NAWAPA-generated power. Pumping plant capacity and power consumption are based upon an overall efficiency of 83 percent.

NAWAPA water would be surface waters collected over uninhabited, uncultivated catchment areas of sparse vegetation. The principal catchment areas will be above 2,000 feet and 3,000 feet in glacial regions

Figure 1

NORTH AMERICAN WATER AND POWER ALLIANCE
CONCEPTUAL PLAN

and areas subject to snow cover most of the year. NAWAPA water would contain about 50 p.p.m. of total dissolved solids, have a temperature range between 40 degrees F. and 55 degrees F., and in terms of the United States Public Health Service limits, have a color rating of approximately 2 units and a turbidity below 0.5 units.

Estimated construction costs based on 1964 prices and expressed in United States dollars are tabulated below:

Item	Costs in Billions Of United States Dollars
Land Acquisition and Relocation	16.6
Engineering	8.9
Construction	64.5
Contingencies	10.0
Total	100.0

NAWAPA would require about 20 years to complete after resolution of political and international features. The Rocky Mountain Trench Reservoir, Sawtooth Lift, and Sawtooth Tunnel would be the first elements of the system to be constructed. Following completion of these elements, water deliveries could be made into Utah, Nevada, Arizona, California, New Mexico, Texas, and Colorado.

The NAWAPA concept envisions water deliveries into the Pacific Southwest Region about 9 years after initiation of the program and power deliveries about 8 years after go-ahead.

National benefits accruing to Canada, the United States, and Mexico through implementation of the North American Water and Power Alliance would be significant. The physical benefits would be readily manifest through the creation of scenic inland lakes and waterways.

While the physical results of the North American Water and Power Alliance would affect the three nations, directly and indirectly, the impact created by the economic benefits would influence all facets of their industry and society. The average annual increase in the gross national product of each nation would be increased many times and sustain economic development for generations. The impetus provided industrialization and economic growth would foster and encourage national developments consistent with the needs of ever-increasing populations.

Of particular importance would be the creation of an integrated network of facilities which could be utilized for recreational pursuits such as hunting, fishing, boating, water skiing, hiking, swimming, and related activities. Consistent with an expanding economy and increasing population, potential profits from operation of recreation facilities and enterprises would be a significant factor in the national economy of all three nations.

The primary benefits accruing to the United States alone from NAWAPA water and power are:

1. Water

    a. Delivery of approximately 69,000,000 acre-feet of water annually.

    b. Delivery of approximately 11,000,000 acre-feet of water annually to the Great Lakes for municipal and industrial usage and diversions out of the Great Lakes system in the Chicago area for pollution abatement.

    c. Delivery of approximately 37,000,000 acre-feet of water annually to the Great Lakes system for stabilization of lake levels.

2. Power

    a. Make available 30,000,000 kilowatts of electric power.

    b. Increase and stabilize power production of the Niagara hydroelectric complex.

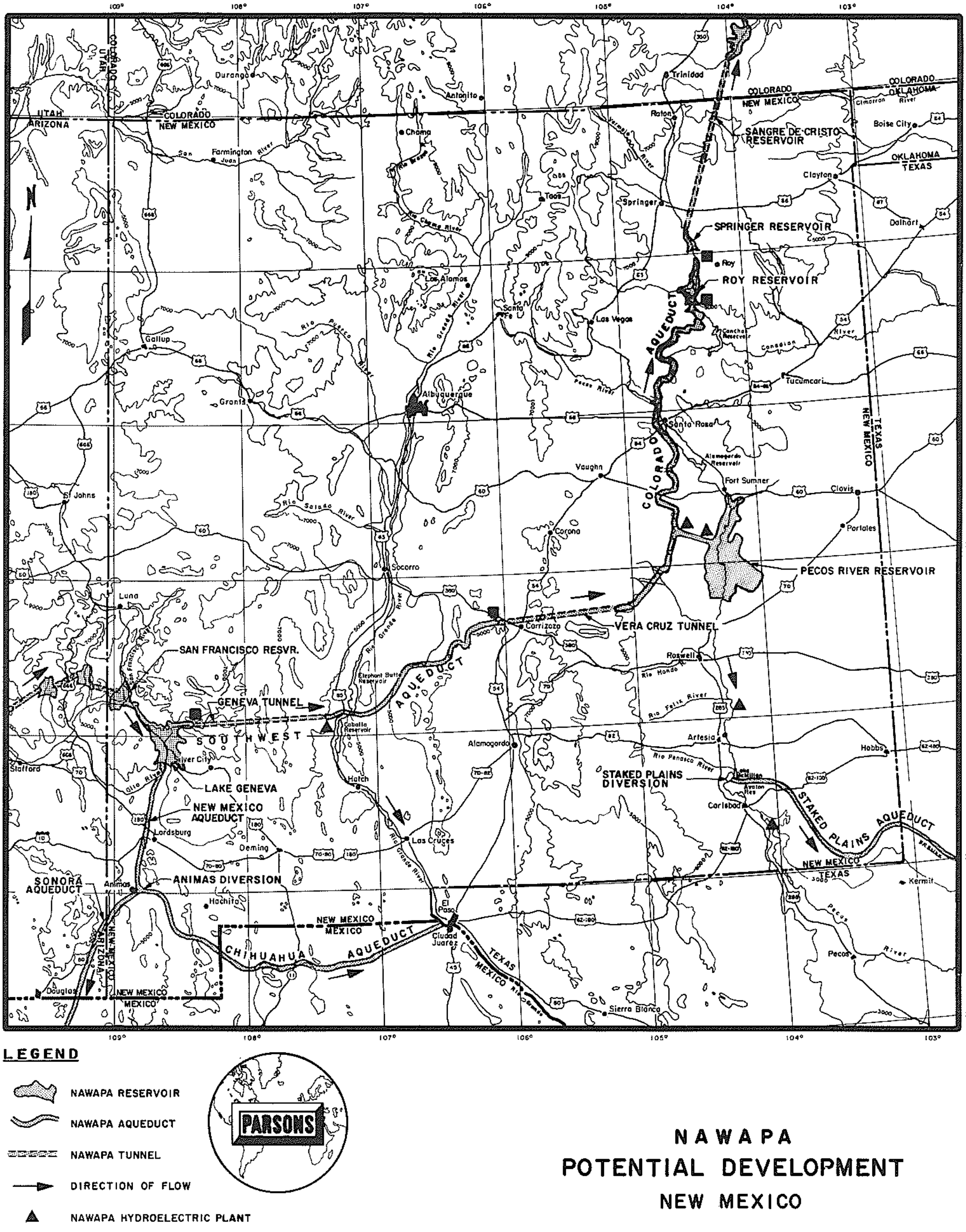
As shown on Figure 2, the North American Water and Power Alliance would entail extensive construction in the State of New Mexico and result in the creation of numerous lakes, reservoirs, and a system of aqueducts crossing the state from west to east and south to north.

NAWAPA water would enter the State of New Mexico in the southwest corner of the state. The Southwest Aqueduct would enter New Mexico from Arizona, north of Reserve, New Mexico, and deliver water into the San Francisco Reservoir. From the San Francisco Reservoir, a continuation of the aqueduct would deliver water into Lake Geneva in west central New Mexico. Lake Geneva, a man-made lake, would be maintained at elevation 4,950 feet above sea level.

Lake Geneva would have two outflows; one to the south designated the New Mexico Aqueduct and one to the east designated the Southwest Aqueduct.

The New Mexico Aqueduct would deliver water into southwestern New Mexico and the northern states of Mexico. North of Animas, New Mexico, at Animas Diversion, water would be diverted into the Rio Grande River via the Chihuahua Aqueduct.

Figure 2


NAWAPA
POTENTIAL DEVELOPMENT
NEW MEXICO
LEGEND
NAWAPA RESERVOIR
NAWAPA AQUEDUCT
NAWAPA TUNNEL
DIRECTION OF FLOW
NAWAPA HYDROELECTRIC PLANT
NAWAPA PUMPING STATION
PARSONS
REFERENCE No. 606-2934
SANGRE DE CRISTO RESERVOIR
SPRINGER RESERVOIR
ROY RESERVOIR
AQUEDUCT
COLORADO
PECOS RIVER RESERVOIR
VERA CRUZ TUNNEL
SAN FRANCISCO RESVR.
GENEVA TUNNEL
SOUTHWEST
AQUEDUCT
LAKE GENEVA
NEW MEXICO AQUEDUCT
STAKED PLAINS DIVERSION
STAKED PLAINS AQUEDUCT
SONORA AQUEDUCT
ANIMAS DIVERSION
CHIHUAHUA AQUEDUCT
COLORADO
UTAH
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
Durango
Farmington
Chama
Taos
Trinidad
Raton
Springer
Clayton
Boise City
Dalhart
Roy
Los Alamos
Santa Fe
Las Vegas
Gallup
Grants
Albuquerque
Tucumcari
Santa Rosa
Vaughn
Fort Sumner
Clovis
Portales
St Johns
Corona
Socorro
Luna
Carrizozo
Roswell
Artesia
Alamogordo
Hobbs
Carlsbad
Silver City
Stafford
Lordsburg
Deming
Hatch
Las Cruces
El Paso
Ciudad Juarez
Animas
Hachita
Douglas
Kermit
Pecos
Sierra Blanca

The Southwest Aqueduct would deliver water to the eastern and northern sections of New Mexico and into Colorado, Texas, and Oklahoma via the Colorado Aqueduct. From Lake Geneva, the Southwest Aqueduct would be routed almost due east. It would cross the Rio Grande River north of Hot Springs, New Mexico, and continue into the Pecos River Reservoir. At Hot Springs, New Mexico, about 5,000 cfs would be diverted into the Rio Grande River. Diversion would be through a power drop which would produce approximately 300 megawatts of hydroelectric power. The aqueduct would drop 1,000 feet into the Pecos River Reservoir. This head would be developed by two hydroelectric plants generating approximately 1,300 megawatts of power. From the Pecos River Reservoir, the Colorado Aqueduct would be routed almost due north terminating in the Colorado Reservoir east of Denver, Colorado. North of Hobbs, New Mexico, water would be diverted into the Staked Plains Aqueduct for delivery of water into Texas.

The added hydroelectric power potential of the Rio Grande and Pecos rivers, which would exist due to the NAWAPA releases into these river systems, has not been evaluated at this time.

The NAWAPA system in the State of New Mexico would include a total of 500 miles of water transfer canals and 180 miles of tunnels. Storage facilities of the NAWAPA system which are located in the State of New Mexico are tabulated below.

Facility	W.S. Elevation/Feet	Storage Capacity/AF
San Francisco Reservoir	4,955	4,600,000
Lake Geneva	4,950	17,100,000
Pecos River Reservoir	4,000	34,800,000
Springer Reservoir	5,200	2,100,000
Roy Reservoir	5,000	600,000

Potential benefits accruing to the State of New Mexico from development of the North American Water and Power Alliance will be physical as well as economic. The benefits listed herein are indicative of the impact that the proposed project would have on the State of New Mexico.

1. Water

   a. Deliver approximately 10,000,000 acre-feet of water annually into all major irrigable districts of New Mexico.

2. Power

   a. Make available for distribution approximately 1,000,000 kilowatts of electric power.

3. Economic

   a. Provide for an increase in agricultural income of approximately $600,000,000 annually.

   b. Provide permanent employment opportunities in construction, manufacturing, and agriculture.

4. Population Growth

   a. Provide for the support of an additional population of approximately 6,000,000.

5. Recreation

   a. Create a large lake in southwestern New Mexico and one in eastern New Mexico of great value for fishing and recreation by visitors.

   b. Increase recreation and wildlife assets throughout New Mexico.

For NAWAPA planning purposes, it has been assumed that the average cost of delivering water from the NAWAPA facilities to farm ditchside would be approximately $7 per acre-foot, and the average price for NAWAPA irrigation water at the NAWAPA aqueduct would be $4 per acre-foot.

This value may initially be considered high because currently average costs to the farmer's fields or ditchside now run $1 to $4 per acre-foot. Some areas today are charging $3 to $8 and $35 per acre-foot. As water becomes more valuable in our economy, it would appear that the historical American attitude to the price of water must recognize increasing prices consistent with economics. For the purposes of the NAWAPA concept, it was assumed that 94,000,000 acre-feet of water would be used in agriculture. At a sales price of $4 per acre-foot, the revenues from irrigation water sales would be 0.38 billion dollars.

About 16,000,000 acre-feet per year of the water from the NAWAPA project is estimated to be purchased by communities and industries. This would be about equal to some 20 projects the size of the Metropolitan Water District in the Southern California area. Considering the other attendant costs, $15 per acre-foot is considered a reasonable average return to expect at the NAWAPA main canal. The revenue at this sales price would be 0.28 billion dollars.

A reasonable and competitive price for NAWAPA power at the generator busses is between 4 to 5 mills per kilowatt hour using an average 5.7 mills per kilowatt hour for steam-generated power as a guide and adding to the NAWAPA power the cost for transmission of power of one (1) mill per kilowatt hour. This is the fee for transmission on the

Missouri River Basin power system. An average net power production of 70,000 megawatts at 4 mills per kilowatt hour yields an annual gross revenue of 2.45 billion dollars; however, in this study the bus bar power costs are varied from 3 to 5 mills per kilowatt hour.

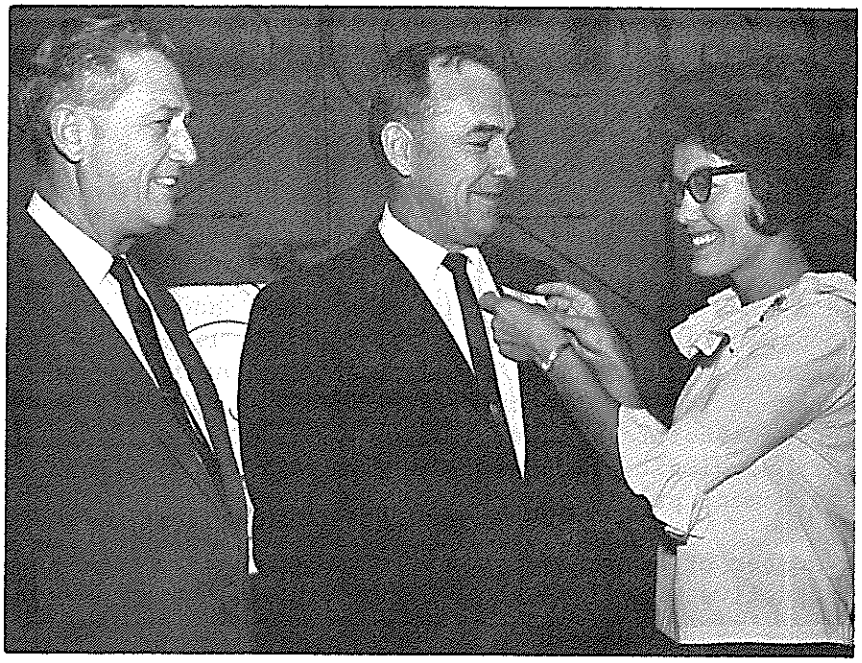
Other revenues, in addition to those from the sale of water and power include the sale of 48 million acre-feet diverted annually to the Great Lakes, of which 12 million acre-feet annually will be designated for water pollution abatement; navigation toll charges for the 2,000 mile Canadian - Great Lakes Waterway; entrance, license, or permit fees obtained from the recreation areas developed; and the lease and/or rentals obtained from land and/or various concessions on the NAWAPA lakes, reservoirs, waterways, and aqueducts. The net annual income for the above revenue is estimated conservatively at one billion dollars for this financial analysis.

Sale prices of NAWAPA water and power do not reflect radical departures from current practices. However, they do indicate that our present approach to pricing water may be in for serious adjustments. The severity of these adjustments will substantially affect the planning and financing of future water projects. The pressing need for pollution abatement and waste reclaiming will no doubt be reflected in these adjustments.

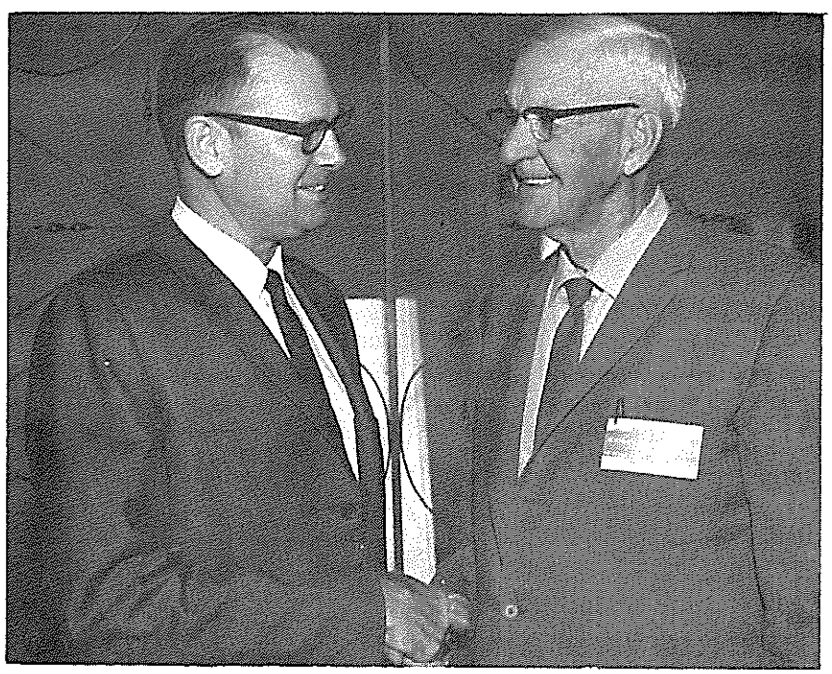
The NAWAPA concept just presented you is one concept for importing water sufficient to meet the needs of areas consistent with anticipated growth and development. It cannot be overemphasized that this concept is <u>one</u> way of accomplishing water deliveries. In itself, it is not <u>the</u> answer to wise and prudent water management. Water management must include not only the importation of water to meet deficiencies, but also pollution abatement to clean our streams, reclamation of waste waters, adequate storage, and flood control

It is well to note that some of the features of water management will be done with or without NAWAPA. We must clean up our rivers. In order to maintain clean rivers, we will have to clean our wastes. Storage must be provided to take care of devastating floods. All these will be done whether the NAWAPA concept is developed or not. We, of The Ralph M. Parsons Company, feel that the NAWAPA concept is one plan that will weld all features of intelligent water management into an integrated system for obtaining maximum use of our waters.

In closing, I would like to reiterate a few salient points concerning NAWAPA. NAWAPA is a concept. The in-house funded studies performed by The Ralph M. Parsons Company to date on NAWAPA indicate that the water is there, the concept is technically feasible, and economically practical. In the past, many projects have been started without due consideration of the sociological, economical, and ecological impact. These should, and must, be considered in the early stages of the NAWAPA program. In each country of this continent, population growth, industrialization, and an increasing economy are placing serious strains on one of the most important natural resources - water - its supply, distribution, and use. Adequate planning is imperative to insure that water resources are managed with foresight and vision.



Helen Molina of the Animal Sciences staff at New Mexico State University greets participants with a smile and a name tag. H. C. Fletcher (left), assistant director of the Rocky Mountain Forest Ranger Experiment Station near Fort Collins, Colorado, and William D. Hurst, regional forester for the U.S. Forest Service, Albuquerque, New Mexico.



Dexter Henderson (left), engineer appraiser for the Federal Land Bank in Wichita, Kansas, gets acquainted with W. H. Gary, well-known farmer from Hatch, New Mexico. Both were program participants.

ECONOMIC EVALUATION OF WATERSHED MANAGEMENT ALTERNATIVES THE BEAVER CREEK WATERSHEDS

David P. Worley[1/]

INTRODUCTION

In semi-arid areas, water for home use, industry, and agriculture is at a premium. Usually, water availability is the limiting factor for continuing economic growth. One possible way to augment water supplies is to change the vegetation on upstream watersheds. Such changes in vegetation, deliberately made to alter the amount of water available to particular hydrologic processes, are included in the category of watershed management practices.

There are a number of options open to a watershed manager to achieve a particular objective. Some of these alternatives require sweeping changes of the plant cover on lands where increased water yields might be expected. Some could jeopardize other land uses and values. Some are "irreversible" in the sense that they can be made easily, but they can't be undone except through long years and at great expense.

Before such practices are conducted on a large scale, then, an economic evaluation is required to estimate the advantages and disadvantages of the alternatives. The economic evaluation is not considered a final answer, but rather as additional information to help managers make a better decision. The evaluation must analyze the effects of the alternatives on other resources as well as direct and indirect benefits and costs of increased water. Comparisons can then provide a basis for deciding on the best course of multiple-use land management.

Such an evaluation is the purpose of the Beaver Creek Pilot Watershed Project in northern Arizona. (1) It involves testing the multiple-use effects of watershed management on an operational scale.

THE DESIGN ANALYSIS

The economic evaluation, within the framework of multiple use and sustain yield, was subjected to a linear program analysis which was used to help design the Beaver Creek project. To do this it was assumed that the project was completed and we had data about the outcomes of watershed management alternatives. We needed this information to

1/ Principal Economist, U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Tempe, Arizona

evaluate the effectiveness of a potential action program. The objective assumed in the design analysis was to maximize benefits, with streamflow increases, timber markets, and costs used as restraints. Restraints as used here specify the levels of these items that must be met for analysis.

The design analysis required us to measure the yields of forest-based products (water, timber, range for livestock, wildlife, and recreation) so that we could determine their responses to each watershed management alternative. We were obliged to collect costs of implementing management changes, and costs of maintaining the watersheds in a treated condition. Also, "outside" costs due to the change in management were needed, as, for example, costs due to possible increases in sediment yields or additional costs of conducting other activities as fire control. Finally, the design required us to estimate appropriate values for watershed multiple-use products.

It was further decided that we should determine product response to management change directly by making before-and-after measurements of production on small watersheds. Thus, these small watersheds will describe what actually happened on the ground rather than form a paper synthesis of what might have happened. We also decided to develop prediction techniques which will enable us to extrapolate results from small watersheds to other similar areas. The design analysis indicated that we should be prepared to make these extensions on other larger watersheds in such a way that we could verify our findings and methods.

The design analysis led to dividing the whole Beaver Creek area into smaller units, and indicated the studies to be undertaken.

THE BEAVER CREEK WATERSHEDS

The entire watershed area, 275,000 acres, contains four different vegetation types, each with a different streamflow potential. Only the three types containing trees--the lower woodland (Utah juniper), upper woodland (alligator juniper), and the Ponderosa pine types--are being considered for testing watershed practices (Figure 1). The smallest watersheds are being treated first, with a single treatment on each. For example, the juniper types are being converted from juniper tree cover to grass, herb, and shrub cover. Pine-covered watersheds, on the other hand, will be subjected to a variety of clearing and thinning treatments.

The larger watersheds--Bar-M Canyon and Woods Canyon--will be used to test combinations of treatments found effective on the smaller watersheds. It is here we will test our findings and methods to see if they can be extended to other areas. Extensive areas have been reserved for operational studies, where techniques are being developed for conducting treatment operations and for determining costs of treatments applied to project-sized areas.

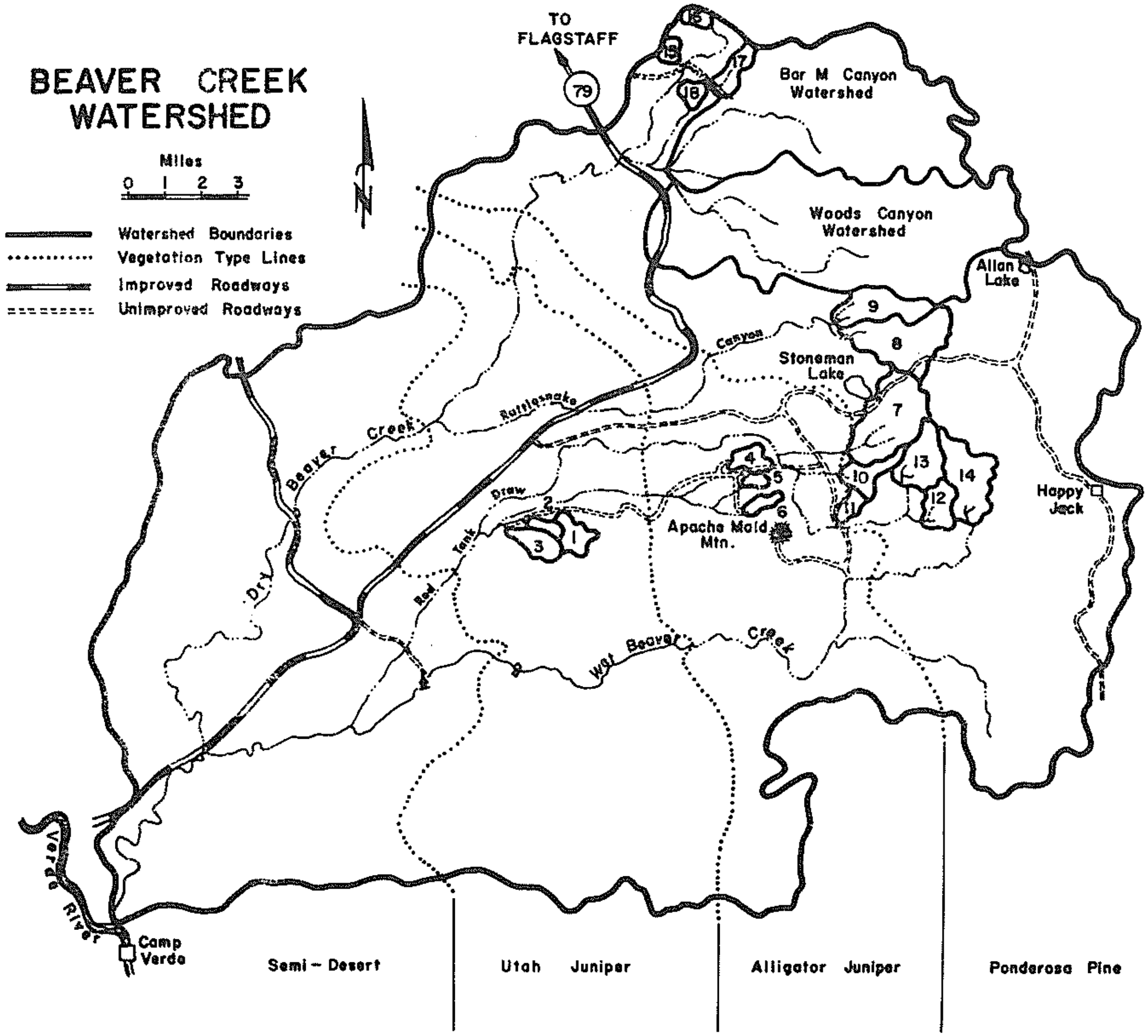


Figure 1. The Beaver Creek Pilot Watersheds in Northern Arizona.

Each of the watersheds shown in Figure 1 has been steamgaged to determine streamflow before and after treatment. Total sediment yield is measured on selected watersheds. Timber growth and quality are measured. Records are kept on forage production and utilization, and on ecological trends. Actual game use is recorded on the watersheds, as well as hunter use, to assess the affects of treatments on this major recreational use.

Special information is being collected to more fully describe the watershed themselves, and to form a basis for extending the data to other areas. A network of rain gages gives us data about the amount, intensity, duration, and form of this basic input to the watershed system. Topographic, geologic, soil, and vegetation maps and data provide us with basic information about some of the hydrologic processes involved. Special studies of watershed hydrographs give use insight into streamflow characteristics. Our timber inventory is designed to answer questions about (1) tree size distribution, (2) physical characteristics of trees, such as sweep, crook, mistletoe infection, dead top, etc., and (3) arrangement of trees on the area. With this information, we can accurately describe the tree cover, and assess suitability of different management practices for the watersheds.

Special studies are conducted to determine multiple-use interrelations to help us extend data to other areas. Other special studies seek to fill gaps in existing information which is needed to satisfy the design analysis.

THE UTILITY OF PILOT WATERSHEDS IN ECONOMIC EVALUATION

Thus far, our development of an economic evaluation has been measuring inputs, outputs, and costs, and making special studies to develop methods for extending the data to other areas. This is a straightforward task conceptually, but the practical, on-the-ground implementation is related to our pilot plant to enable us to understand the physical system.

THE CONTEXT FOR EVALUATION

Multiple-use management involves coordination of the various management functions. In terms of the watershed management function, other functions--timber, range for livestock, wildlife, and recreation--constitute an array of "outside" factors which need to be coordinated with a watershed proposal in a multiple-use framework. These "outside" factors are very important, since they point out that the choice between two watershed management options for a particular watershed can't be determined by general formula, and that each case (watershed in this instance) must be decided on its own merits. While a general formula can be developed for a large area, such as a National Forest or a river basin, its results can only be used to indicate the general direction watershed management should take. Analyses of individual watersheds which make up the larger area and account for the required coordination are necessary for actual management planning.

These evaluation requirements suggest that two sets of background data are required for economic evaluation: (1) data for analyzing a river basin, where watershed management for increased water yield is being seriously contemplated, to estimate the potential of the broad area for accomplishing the objective, to give clues as to its economic worthwhileness, and to suggest the direction which watershed management might take, and (2) data for detailed management planning on individual project-sized watersheds. Finally, of course, the river basin can be reanalyzed by summing the analyses of the individual watersheds.

ECONOMIC CRITERIA AND DATA

To make an economic evaluation of watershed management alternatives, we need to define the criteria which will form a basis for comparing alternatives. The criteria selected will dictate how the physical data will be used, and show what economic data will be required.

Our thinking to date suggests three criteria to form the basis for choice: (1) maximize benefits, (2) maximize returns on investment, and (3) achieve specified physical production goals at least cost. No single alternative is likely to satisfy all three of these criteria at once. It seems important, though, that these solutions should at least be considered in the overall evaluation. They would give decision makers a better picture of the various economic implications of potential courses of watershed management action.

Data required for the first two criteria include values of multiple-use products as well as the physical responses and cost data learned from the small pilot watersheds. Values should be considered for different points of view. For example, on-site values represent a net-benefits point of view. Income flows and employment generation at various stages of processing can be combined to represent local, state, regional, or national points of view. For the cost minimization analysis production goals must be set for the various products. In the real world production goals commonly are derived through the political process. For an analysis, value judgments can be fed back from the benefit maximizing analysis to help establish reasonable goals.

ECONOMIC ANALYSIS

It is anticipated that the economic analyses themselves will be stimulated by linear programs and systems analysis. Early efforts at this are being made currently in consultation with economists at the Pacific Southwest Forest and Range Experiment Station at Berkeley, California. The initial model just completed seeks first to maximize on-site benefits to establish national production goals, and then to minimize the cost of achieving these specific production goals. The analysis is based on a linear program followed by parametric programs. Data requirements for the computer program are estimates of current costs, values, and physical outcomes. All these vary from site to site. The arrangement of conditions is hypothesized on a dummy area of 1,000,000 acres of ponderosa pine-covered watersheds. Potential pine-covered watersheds can thus be ranked according to cost, value, and watershed conditions. At present, it is a static analysis. Later we will make it dynamic by changing projected costs and values. Other changes planned will vary the use levels of different products. Thus, we will take into account sets of circumstances (such as market potentials) which simulate actual multiple-use coordination problems. These circumstances will probably take the form of efficiency factors for making use of the products being produced. Such efficiency factors will then be incorporated into a basic program to show the relative importance of different kinds of tension areas in multiple-use coordination.

Such analyses will be continually refined and updated as experience on the ground and in computer analysis further sharpens the issues to be resolved.

ECONOMIC EVALUATION

The economic evaluation itself, then, will consist of an array of pertinent economic analyses to help decision makers make a better decision. Each individual economic analysis may yield a determinant, one-answer, solution to the problem of selecting a watershed management alternative within the framework of specific assumptions and criteria. A group of such analyses, however, based on different criteria, will result in an array of items for decision makers:

1. Estimates of product yield response associated with the changes in management.

2. Estimates of costs of different management alternatives.

3. Least-cost solutions for different goals of multiple-use production.

4. Net and/or gross benefits to be associated with the range of management alternatives.

5. Investment returns and benefit/cost ratios associated with the alternatives.

6. Pertinent coefficients and incremental ratios associated with the individual analyses.

With such a spectrum of economic relationships, the decision makers should be better able to choose the best course of action.

SUMMARY

The Beaver Creek Pilot Watersheds were established (1) to measure and evaluate the effects of management practices, intended to increase streamflow, upon water supply, sediment, timber and forage production, wildlife populations, and recreational use of watershed lands, and (2) to formulate concepts and processes for economic evaluation of alternative watershed management practices, and develop guides for making multiple-use management decisions.

REFERENCES

1. Worley, David P., "The Beaver Creek Pilot Watershed for Evaluating Multiple-use Effects of Watershed Treatments," U. S. Forest Service Res. Pap. RM-13, 12 pp., illus., 1965. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

SELECTED LIST OF PUBLICATIONS FROM THE BEAVER CREEK PROJECT

Brown, Harry E., "Characteristics of Recession Flows from Small Watersheds in a Semiarid Region of Arizona," Water Resources Research, 1(4): 517-522, illus., 1965.

________, "Preliminary Results of Cabling Utah Juniper, Beaver Creek Watershed Evaluation Project," 9th Annual Arizona Watershed Symp. Proc., pp. 16-21, illus., 1965.

Clary, Warren P., "A Method for Predicting Potential Herbage Yield on the Beaver Creek Pilot Watersheds," Amer. Soc. of Agron., ASA Spec. Publ. 5, pp. 244-250, illus., 1964.

Ffolliott, Peter F., "Determining Growth of Ponderosa Pine in Arizona by Stand Projection," U. S. Forest Service Res. Note RM-52, 4 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

______ and Roland L. Barger, "A Method of Evaluating Multiproduct Potential in Standing Timber," U. S. Forest Service Res. Pap. RM-15, 24 pp. illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

______, Edward A. Hansen and Almer D. Zander, "Snow in Natural Openings and Adjacent Ponderosa Pine Stands on the Beaver Creek Watersheds," U. S. Forest Service Res. Note RM-53, 8 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

______ and David P. Worley, "An Inventory System for Multiple Use Evaluations," U. S. Forest Service Res. Pap. RM-17, 15 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

Kelso, M. M. and Lawrence Mack, "The Value of Additional Surface Water to Agriculture in the Salt River Project," Arizona Watershed Symp. Proc., 11 pp., illus., 1964.

McCulloch, C. Y., O. C. Wallmo, and P. F. Ffolliott, "Acorn Yield of Gambel Oak in Northern Arizona," U. S. Forest Service Res. Note RM-48, 2 pp. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

Worley, David P., "The Beaver Creek Pilot Watershed for Evaluating Multiple-use Effects of Watershed Treatments," U. S. Forest Service Res. Pap. RM-13, 12 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

______ and Robert L. Miller, "A Procedure for Upstream Watershed Economic Evaluation," Arizona Watershed Symp. Proc. pp. 36-38, illus., 1964.

______, Gerald L. Mundell, and Robert M. Williamson, "Gross Job Time Studies--an Efficient Method for Analyzing Forestry Costs," U. S. Forest Service Res. Note RM-54, 8 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1965.

ECONOMICS OF WATER IN RECREATION DEVELOPMENT

James R. Gray[1]

The least expected of the post World War II shortages was the supply of natural resources developed in part or entirely for recreational purposes. The serious outdoor recreational resource supply shortages of the early 1950's caught most resource planners looking the other way. However, early efforts by a few focused attention on the problem. Later, a congressional commission was formed, succeeded shortly by a federal bureau, a multiplicity of state agencies and an awakened press. By the late 1950's, the recreational boom and research bandwagon were picking up speed.

Numerous statistics are available that project our recreational needs for the future. Perhaps the most quoted of these are the consumption estimates developed by the Outdoor Recreation Resources Review Commission (1), Figure 1.

Note the types of recreation that are expected to exceed 500 million occasions each by the year 2000--swimming, driving, outdoor games, walking, sightseeing, picnicking, boating and fishing. In the total of over 12 billion outdoor summer recreation occasions in the United States by 2000, water is a strategic resource in three of the eight major activities, a major element in three others, and perhaps of minor importance in the final two activities--driving and walking.

On what basis were these estimates made of outdoor recreational use 30 to 50 years hence? The estimates are based on a combination of at least four major factors (2). These factors and their combined effects are pictured in Figure 2. Note the accumulation effect of each factor.

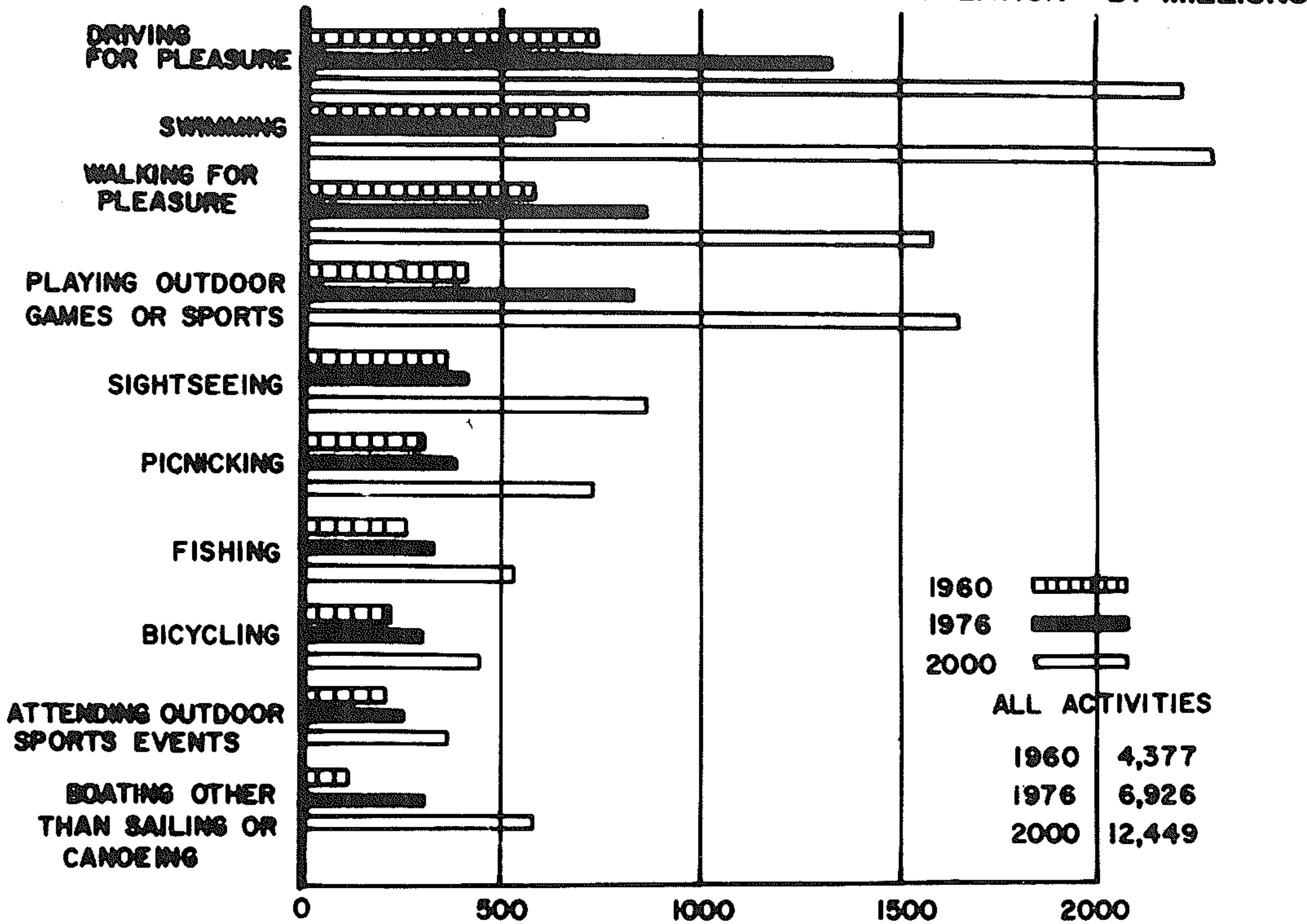
New Mexico is expected to participate at least partially in the recreation boom. The extent to which we will share in the benefits are not known except in a general way. However, some projections of the expected number of recreationists are available for various parts of New Mexico. One projection for the Silver City Area is shown in Figure 3 (3).

Apparently projections beyond 1976 "frightened" these Forest Service planners because their projections ran off the desk after 1968.

As long as outdoor recreation in New Mexico is based on a mix of the natural resources rather than on one or two resources in short supply,

1/ Professor of Agricultural Economics and Agricultural Business, New Mexico State University.

FIGURE I: NUMBER OF OCCASIONS OF PARTICIPATION IN OUTDOOR SUMMER RECREATION--BY MILLIONS



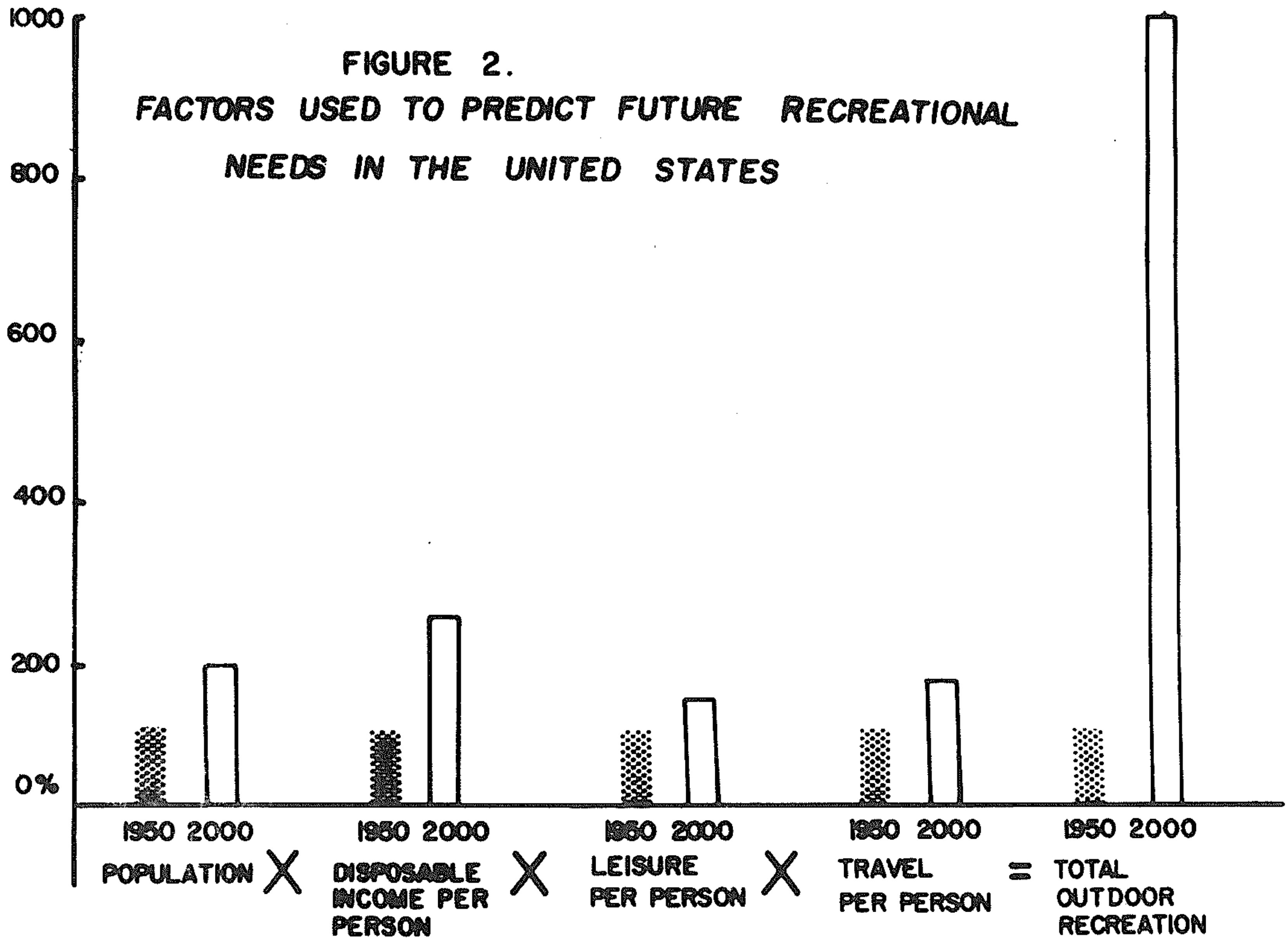
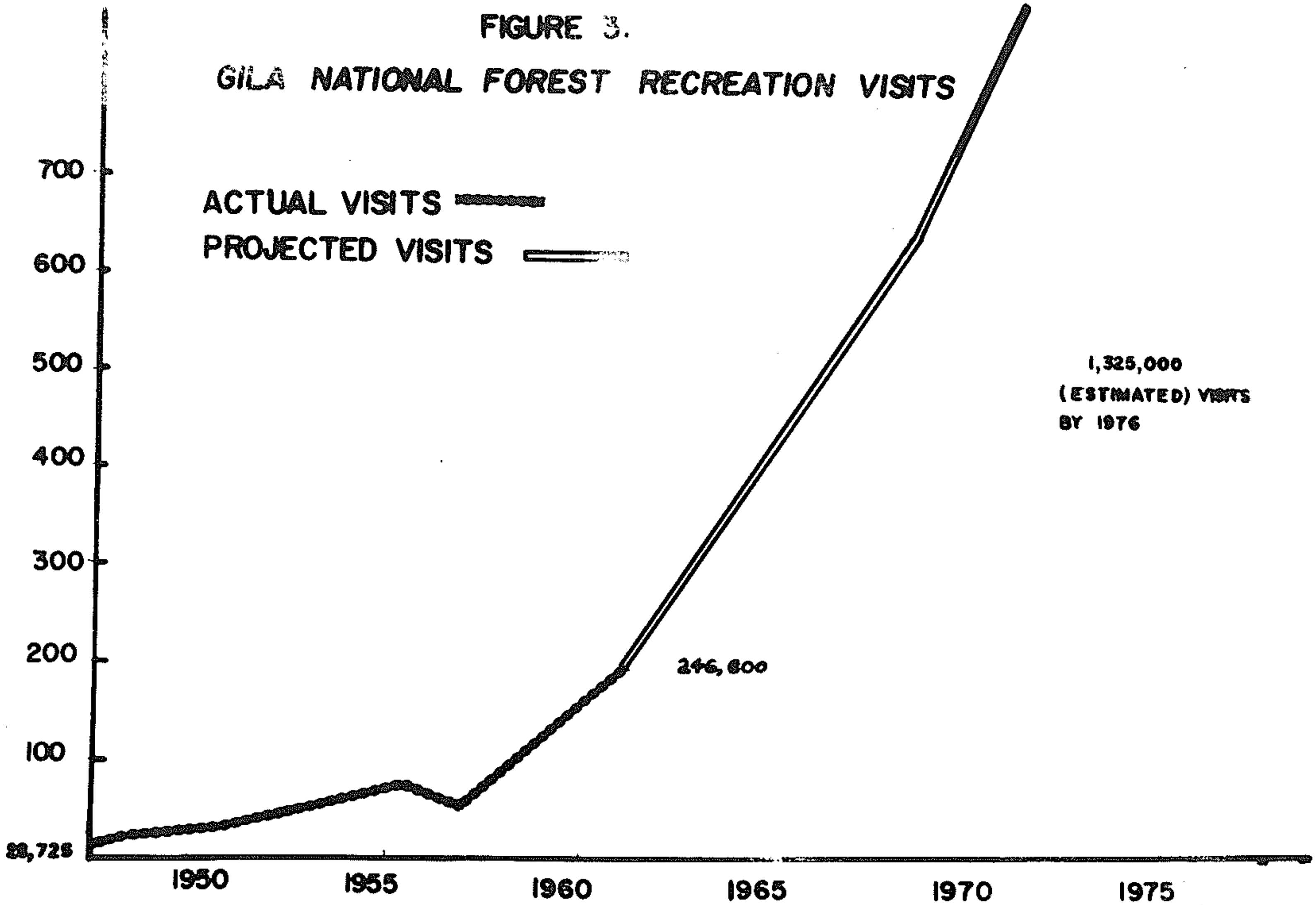


FIGURE 2.
FACTORS USED TO PREDICT FUTURE RECREATIONAL NEEDS IN THE UNITED STATES

FIGURE 3.

GILA NATIONAL FOREST RECREATION VISITS



it might be expected that we can equal or exceed the U. S. projection. But if recreational needs fall heavily on one of our resources in short supply, such as water, we may be in trouble.

A review of various sources indicate that there are approximately 126,000 acres, or 200 square miles, of water surface in the major reservoirs, lakes and rivers in New Mexico. There is a maximum potential of 294 square miles. These amounts are much less than those of any of the other 17 western states. A state with a single lake or reservoir that is 30 miles long by 10 miles wide, or any similar combination of sizes, would have more water surface than the maximum for the entire State of New Mexico. Since water is an essential ingredient in most types of outdoor recreation, water is expected to be our most limiting recreational resource. Presently, our one million residents are limited in their recreational pursuits of swimming, boating, water skiing, fishing and waterfowl hunting by this restricted water surface. If the state's maximum water surfaces were gathered together into the one body of water as represented by a 30-mile-long lake, and if all of the state's population decided to go swimming at one time in this lake, there would be a 5-inch strip of water for each bather. Most of us need at least a foot, and judging by apprearances, some of us might need two or three feet.

An overwhelming majority of the "large" (over 40 acres) water surfaces of the state is contained in four of its reservoirs, Elephant Butte, Navajo, McMillan and Conchas. These reservoirs were constructed mainly to provide irrigation water for agricultural purposes and for flood control. Recreation mainly is a secondary and supplementary use of whatever water happens to be impounded. Reservoir levels fluctuate widely from one season or year to the next, and it is speculated that this fluctuation greatly reduces their recreational values.

Because water is our recreational resource in most limited supply, then it behooves us to plan for and use this water as wisely as possible. To aid in this planning some of the techniques used in measuring the value of recreation to state and local economies should be understood. Knetsch feels that this is a major deficiency of recreational research efforts to date (4).

In this address several of the economic techniques that have been used to measure recreational values will be described. Some of the results of water-based recreational studies in various areas will be shown. Two studies completed in New Mexico will be presented in detail. And finally, the direction of future studies in recreational economics will be indicated.

METHODS OF MEASURING RECREATIONAL VALUES

There are about as many methods used to determine recreational values as there are economists in this research area. Perhaps a very brief review of some of them would be appropriate with the techniques described roughly in ascending order of complexity.

1. The Cost Method. This method uses the cost of providing, operating and maintaining recreational facilities as a direct measure of the benefits. Obviously this technique could grossly underestimate the value of the resource if the facilities are heavily used, as often happens. It might overestimate the value if the developed resource remains unused.

2. The Market Value Method uses either the fees charged at private resorts as the measure of benefits or the costs of the facility adjusted to price level changes if the facility is publicly-owned. Both variations underestimate the value of the resource being used because the fees and costs of the facility usually include only a part of user costs and benefits derived from the recreational resource.

3. The Gross National-, State- of Local Expenditure Method is an estimate of recreational values of resources based on all expenditures by recreationists using the resource. This technique, either on a nationwide, statewide or local basis usually overestimates the value of the resource because expenditures are included that consumers would have made whether or not they engaged in a recreational activity. The four essentials of life are food, clothing, shelter, and recreation. The expenditure method includes the costs of all of these essentials rather than just the additional amounts occurring because of a recreational activity.

4. The Value-Added Method is one that subtracts from gross expenditures the costs of goods and services supplied to recreationists. Several difficulties are encountered that tend to lower the accuracy of this method. Besides the overestimation of value based on gross expenditures, the costs of many goods and services have been approximated, especially when the goods and services are supplied by persons employed by public agencies using resources in public ownership.

5. The Consumer Surplus Method has many variations. Three of the more commonly-used variations are:

   a. The Trice-Wood Method uses as a value of recreation the difference between median travel expense per visitor-day and the travel expense below which 90 percent of the visitor-day travel expenses are found. In other words, the value of recreation is based roughly on the travel expenses of the 10 percent of the recreationists spending the largest amounts per visitor-day. In an area with many recreational developments and a high level of competition between areas, perhaps this method may be helpful. However, the difficulties include an arbitrary selection of the 90 percent level, an unresolved problem of accumulating expenses other than travel without which the value of the resource for recreation is grossly underestimated.

b. The Concentric Travel Zone Method uses as the value of recreation the difference between the weighted average of travel costs to the recreational resource being valued and the travel cost to sites in more distant zones. The major difficulty again is the inclusion of the single expense of travel cost, resulting in an artificially low value. This technique has, with modifications, been adapted and included in more modern techniques.

c. The Travel Cost-Saving Method utilizes the saving in the cost of travel resulting from using one site vs. the cost of using an alternative site. Again only travel costs are used to estimate recreational values, meaning an underestimation of value. This technique also has been useful in developing later models.

5. The Demand Curve Method was developed by Clawson and others and most economists are now using a variety of his method in estimating recreational values (5). In this method a demand curve is computed based on expenditures of different groups of recreationists living at varying distances from the recreational site. The X-axis, or independent variable, is usually expressed as the number of persons using the site per 100,000 of population in the recreationists' home areas. Clawson then combined the demand method with the concentric travel zone and travel cost-saving methods to determine the differences in the two demand curves (the site being studied and a competitive site) as representing the value of the recreational resource.

6. The Monopoly Method. Brown, Singh and Castle used a variation of the Demand Curve Method to estimate the value of salmon and steelhead fishing in Oregon (6). The variation used by these authors was to estimate net economic value of the resource by including a time cost factor, which they label as a "transfer cost." The transfer cost is based somewhat on the concentric travel zone and demand curve methods. Since time is an important factor in most recreationists' vacation plans, this is a reasonable addition. Also these authors distinguished between fixed (durable) and variable costs and used the variable cost category to determine marginal costs. Their net economic value is "their best estimate" of the monetary value which might exist if the resource were owned by a single individual, and a market existed for the opportunity to fish. The reasoning can be reduced to the amount that an owner would be able to charge anglers for the fishing experience. The price is that charged which would maximize the income of the monopolist, with price based on the demand curve of the recreationists. The difficulty with this method, other than its complexity,

is that the net value cannot be compared with alternative uses in a competitive situation. These authors recognized the limitations of their method.

7. The Wennergren Method (for want of a better designation) was devised to determine the value of water resources when they are used for boating (7). Demand curves were constructed based on travel costs plus expenditures at the site. Fixed (durable) and variable costs were determined. The "price" was assumed to be the travel plus on-site costs. The variable used as quantities is the number of trips made by each boater to the site. This quantity is then combined with the "price" to determine value. It was hypothesized that a boater will maximize his satisfaction in boating by equating his costs of repeated boat trips with the value of his satisfaction in boating. One with a low satisfaction will visit the site once. One with a high satisfaction will make repeated trips to the site.

The Wennergren Method leans heavily upon Clawson's demand curve method. Wennergren differs in that he estimates the surplus value, or the difference between the amounts that each of the various boaters paid and the amounts paid by all other boaters who had higher expenses. Boaters near the recreation site pay less than those living at distant points. The difference is accumulated and represents the value of water for boating purposes.

In New Mexico we have used two varieties of methods based partially on those previously mentioned, but unique in themselves. We used a simple demand curve analysis in a low budget study of the Ruidoso Area, utilizing a portion of the surplus value concept as conceived later by Wennergren (8). However, we relied heavily upon simple demand curves. Our study was based on the recreational expenditures of a sample of recreationists, with expenditures limited to those costs above the usual living costs had the recreationists chosen to stay at home. We included travel costs, on-site costs and fixed costs. We estimated the total surplus value of recreationists by simply computing the area under the demand curve. We divided recreationists into local and non-local groups (to permit some isolation of where expenditures might occur) and we tested our demand curves by determining both actual and maximum expenditures. Once recreational values were determined, we then included our result in a static linear programming model along with several kinds of competing uses and with several kinds of resources (9).

Left unanswered except in a general way in the Ruidoso study was the impact that recreationists made on local businesses. To solve this unknown area of recreation economics, we adapted the input-output model to small areas and added a recreational activity for the Reserve Area in west-central New Mexico (10). Briefly, the input-output model as we used it in a compilation of the total value of production of each business in the Reserve Area as well as the total value of products and services sold into the area that were produced elsewhere (final demand) which together are the total outputs of the area. The total value of goods and services used by businesses in the area as well as the value of goods and services imported together are the total inputs. Inputs and outputs are separated among the various groups found in the area. The dependency of each business on each of the other businesses is shown on a flow sheet with dependency being expressed in total dollar amounts.

Using Forest Service estimates of the numbers of recreationists expected when a recreational development is made, the output and inputs change as more recreationists visit the area. The change is considered to be the value of the recreational development.

RESULTS OF ECONOMIC STUDIES IN OTHER AREAS

The results of the study by Brown et al. (6) and Wennergren (7) are interesting because they use the more modern techniques of measuring recreational values, both studies deal with a popular resource use, and water is a strategic resource in the analyses.

The Oregon study indicated that salmon-steelhead sport anglers spent over $9 million annually for durable items (fixed costs) and over $8 million for current expenses (variable costs). The gross value was estimated as $18 million per year. Net economic value, or the estimated value of the resource to a single monopoly owner was estimated at from $2.5 to $3.1 million per year. Projections to 1972 indicated a net value of $4.7 million.

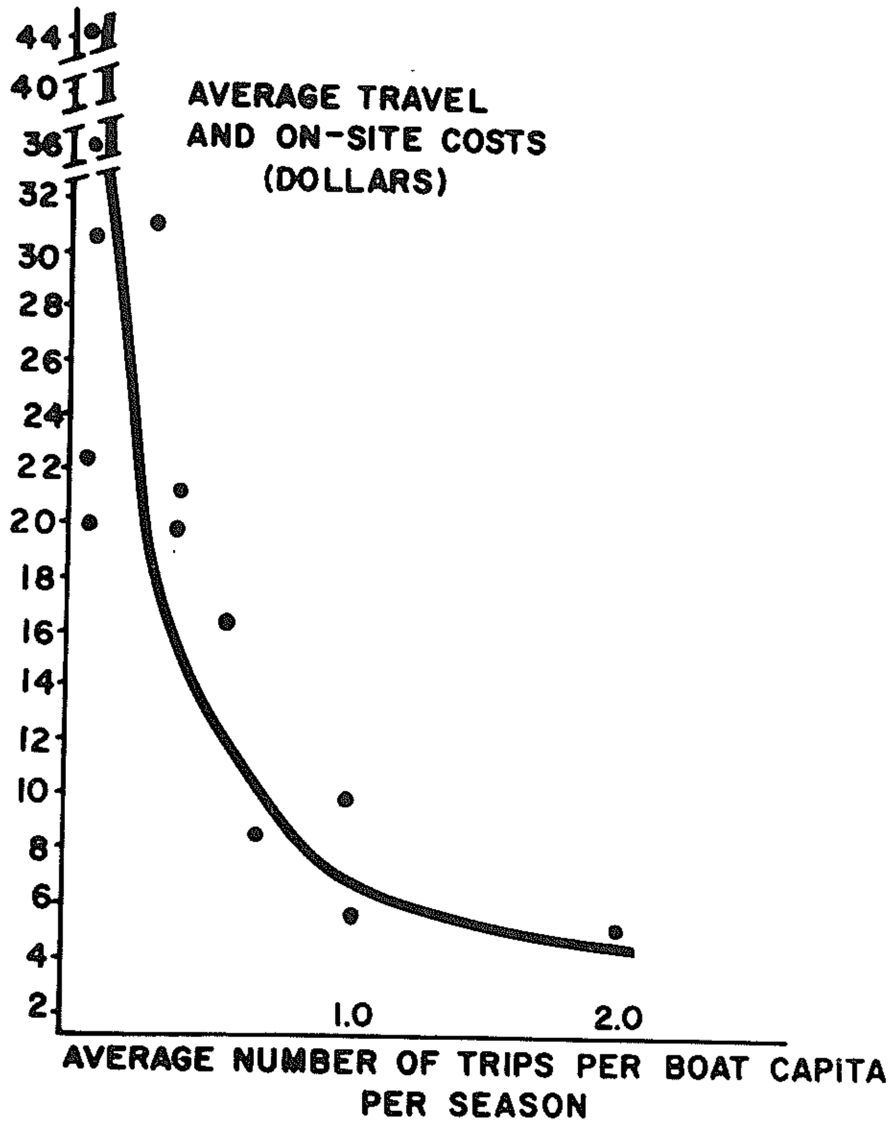
The Utah study reported an annual surplus value of $96,342 for Bear Lake when it was used for boating purposes, a surplus of only $3,433 for Hyrum Reservoir, and $6,635 for Mantua Reservoir. The demand curve computed for Bear Lake and used in the estimation of surplus value is shown in Figure 4.

RESULTS OF ECONOMIC STUDIES IN NEW MEXICO

An early study by Wollman et al. of the recreational value of water in the Rio Grande Basin used the value-added method (11). Wollman's results indicated a value of water for recreational purposes of $212 per acre-foot of Rio Grande water and $185 of diverted San Juan water.

The Ruidoso Study resulted in several sets of demand curves, for those living within 200 miles of Ruidoso and those living beyond 200 miles (8). Additionally, demand curves were constructed for each group based not only on their actual recreational experience expenses, but also on the maximum amounts they would be willing to spend for

FIGURE 4:
DEMAND CURVE
OF BOATERS
AT BEAR LAKE,
UTAH



the experience. These curves are shown in figures 5 and 6. Note the wide spread between the actual and maximum demand curves of local recreationists, and the closeness of the demand curves of actual expenditures of non-local recreationists and the maximum of local recreationists. All of these relationships appear reasonable.

When the total area under the demand curves is computed (expenditures per man day times number of man days), recreationists spent $10.8 million in the Ruidoso District, about $61 per acre in the District, or about $637 per acre-foot of surface and ground water produced in the District when uses are reallocated to their "best" use, with "best" meaning the maximum gross values, recreational values would have increased to $11.9 million per year and only an estimated 44 acre-feet of water would have been used for all camping, picnicking, cabin ownership, hunting, fishing and skiing activities.

If an optimum combination of uses had been made of the resources of the District, including the water resource, net cash receipts would have increased from $4.2 million to $11.5 million, or from $247 per acre-foot of water for all uses of water, to $679 per acre-foot. Let me caution you in using these values. They represent the net cash income of all uses (of which recreation is a large part). The values assume that all benefits accrue solely to the water resource and that recreational uses require a proportionate share of water. The fact that an estimated 16,943 acre-feet of water was used in the area and recreation required only about 44 acre-feet obviously indicates, despite the value of other uses, that the value of $247 and $679 per acre-foot probably is a gross underestimation of the value of water for recreational purposes in the Ruidoso District.

Some of the difficulties encountered in the Ruidoso Study using demand curve analysis and static linear programming were partially overcome in the Reserve Area using the input-output model (10). We did determine how 12 groups of businesses would be affected by a water-based recreational development. And we did determine precisely how much more water each of these groups of businesses would require with different projections of recreational uses into the future.

The intermediate level of recreational use in the Reserve Area anticipates that from the 1963 level of 825 recreationists there will be as many as 75,000 recreationists by 1967, and 151,300 recreationists by the year 2000. Using these projections, the total value of production for the various groups of businesses are shown in Table 1. By the year 2000 and based on the projected increase in the area, farms and ranches will be relatively unaffected, as will also lumber manufacturing, the two major industry groups in the area. The big gainers percentagewise will be the industry groups of real estate rentals; equipment, service and repair; grocery sales; the Forest Service; and restaurants and bars; in that order. All of the other industries will

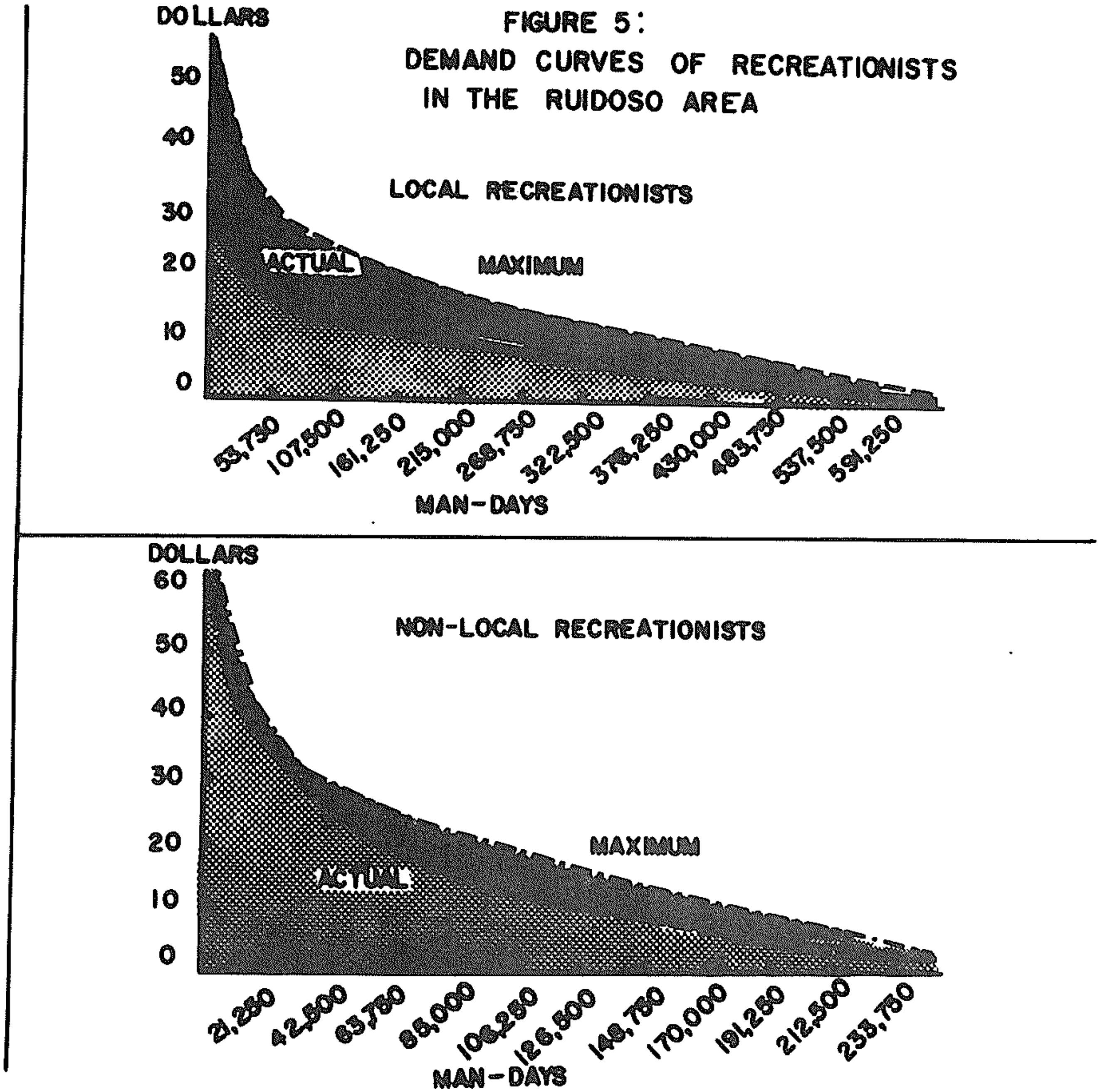


FIGURE 5:
DEMAND CURVES OF RECREATIONISTS
IN THE RUIDOSO AREA

FIGURE 6:

CURVE COMPARISON

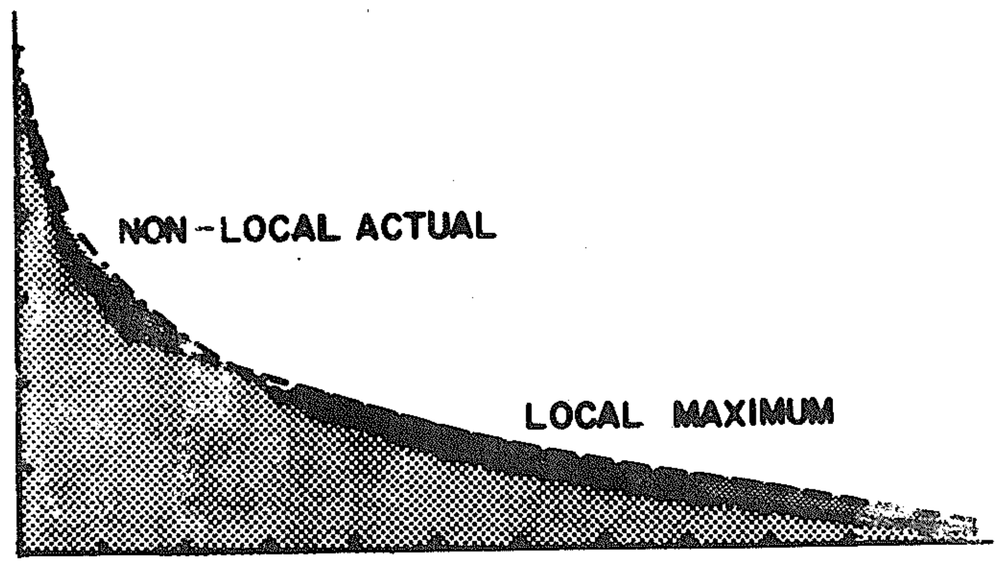


TABLE 1. Total Value of Production with an Intermediate Level Projection of Recreation in the Reserve Area

Major Industry Group	Total Value of Production In: 1963	2000
	Dol.	Dol.
Agriculture	409,301	431,217
Lumber Manufacturing	1,613,150	1,613,885
Utilities	74,820	82,914
Real Estate Rentals	22,731	73,161
Equipment, Service, Repair	110,199	289,766
Restaurants and Bars	108,150	168,898
Personal Service, Drugs	72,221	72,290
Grocery Stores	225,487	460,233
General Merchandise	83,900	88,958
Construction and Maintenance	291,006	299,365
Forest Service	88,485	164,995
Unallocated Services	130,224	134,054
Total	3,229,675	3,879,736

realize a ten percent increase or less in total production. Water requirements for all industries in the area will increase by only 13 percent (by a total of 55 acre-feet) even at the highest projected level of recreational activity. We concluded that in rural areas such as the Reserve Area the gain in local business activity will be modest, only about a half of the industry groups will be affected materially, and those benefiting the most will be industries supplying goods and services that recreationists cannot easily bring in with them.

FUTURE RESEARCH AREAS

One of the major handicaps in economic research dealing with recreational developments has been the popular philosophy that recreation somehow creates a value to consumers that is not readily measurable by economists, or that recreation has extra-market values (12). This philosophy has been attacked by Knetsch in an address to the Great Plains Council (12). According to Knetsch "economic values are measured basically by what people are willing to give. The relevant economic measure of recreation value, therefore, is a willingness to pay on the part of consumers for outdoor recreation services. This set of values is the same as the economic values which are established for other commodities, for it is the willingness to give up income on the part of consumers which establishes values throughout the economy."

This demolishing of the extra-market or esthetic value philosophy of recreation permits economists to push ahead using variations of the demand curve models already developed.

In Texas, a project is being undertaken dealing with an economic analysis of the demand for land and/or water-based outdoor recreation. The objectives are to construct demand functions (curves) and to analyze consumer preferences for outdoor recreation. The project began January 20, 1965. No completion date was included with the project outline.

In New Mexico, a project was initiated on September 1, 1965 to investigate the recreational values of water in the major reservoirs of New Mexico. The objectives of this project are to determine recreational demand schedules and demand price elasticities at Elephant Butte and Navajo reservoirs and to measure the changes in demand schedules for the major recreational activities as reservoir levels change from one season to subsequent seasons. The completion date is two years hence.

Other research currently being conducted include one by Raup in Minnesota which stresses the legal as well as the economic aspects of use, allocation, regulation and pricing of water among competing uses. A division of costs and benefits among competing uses is being attempted. Another study by Helfinstine has one objective of appraising the economic benefits to South Dakota of the non-agricultural uses of water from the Oahe Reservoir. A study of the Colorado River Basin by Therkildsen at the University of New Mexico includes an analysis of recreation in the upper Colorado River Basin.

The direction of future research would seem to indicate that rather than being concerned with methods of analysis and estimation of recreational values for groups of different mixes of natural resources, economists are now concentrating their efforts in attempts to analyze the recreational value of individual kinds of natural resources. Leading the way is research aimed specifically at determining recreational values of water.

REFERENCES

1. Outdoor Recreation Resources Review Commission, "Outdoor Recreation for America," Washington, D. C., January 1962. 246 pp.

2. Clawson, Marion, "The Crisis in Outdoor Recreation." Resources for the Future, Inc. Reprint from American Forests, March 1959 and April 1959.

3. Forest Service, "The Gila National Forest Works for You," U. S. Department of Agriculture, Forest Service, Southwestern Region, 11 pp.

4. Knetsch, Jack L., "Potentials for Water-Based Recreation," in Water Resources and Economic Development in the South. North Carolina State University, Raleigh, August 1965, pp. 43-51.

5. Clawson, Marion, "Methods of Measuring the Demand for and Value of Outdoor Recreation," Reprint No. 10, Resources for the Future, Inc., Washington, D. C., 1959, 36 pp.

6. Brown, William G., Ajmer Singh, and Emery N. Castle, "An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishing," Oregon Agricultural Experiment Station, Corvallis, Bul. 78, September 1964, 47 pp.

7. Wennergren, E. Boyd, "Value of Water for Boating Recreation," Utah Agricultural Experiment Station, Logan, Bul. 453, June 1965, 27 pp.

8. Gray, James R. and L. Wayne Anderson, "Recreation Economics in South-Central New Mexico," New Mexico Agricultural Experiment Station, University Park, Bul. 488, May 1964, 22 pp.

9. Gray, James R. and L. Wayne Anderson, "Use of Natural Resources in the Ruidoso Ranger District," New Mexico Agricultural Experiment Station, University Park, Bul 489, October 1964, 29 pp.

10. Gray, James R. and Garrey E. Carruthers, "Economic Impact of Recreational Developments in the Reserve Area of New Mexico," New Mexico Agricultural Experiment Station, University Park, bulletin manuscript, 51 numbered leaves.

11. Wollman, N., R. L. Edgel, M. E. Farris, H. R. Stucky, and A. J. Thompson, The Value of Water in Alternative Uses, The University of New Mexico Press, Albuquerque, 1962, 448 pp.

12. Gray, James R., "Value of Water for Recreation and Other Uses," in Proceedings of the Fourth Annual New Mexico Water Conference, Water and Water Law, New Mexico State University, University Park, November 5-6, 1959, pp. 61-67.

13. Knetsch, Jack L., "Some Topics of Interest in Outdoor Recreation Research Economics," in Outdoor Recreation Research, Proceedings of a Seminar Sponsored by the Great Plains Resources Economics Committee of the Great Plains Agricultural Council, Texas A. and M. University, College Station, April 5-6, 1965, pp. 8-24.

THE ROLE OF ECONOMICS IN RIVER BASIN SURVEYS

Clyde E. Stewart[1/]

This statement emphasizes economics investigations in river basins by the U. S. Department of Agriculture. Emphasis is given to the general economic and policy features that serve as an environment within which these surveys are made. Special attention is focused on both regional studies involving four Federal departments and smaller area studies that involve primarily the Department of Agriculture and the State where the study area is located. Finally, economic aspects of a survey in the Upper Rio Grande Basin of New Mexico are described in some detail.

The Department of Agriculture participates in river basins investigations under authority of Section 6 of Public Law 566, the Watershed Protection and Flood Prevention Act of 1954, as Amended. This section reads in part, "The Secretary (of Agriculture) is authorized in cooperation with other Federal and with States and local agencies to make investigations and surveys of the watersheds or rivers and other waterways as a basis for the development of coordinated programs." Department participation is comprised of representatives of the Soil Conservation Service, the Forest Service, and the Economic Research Service.

River Basins activities by the Department of Agriculture were initiated in 1955. Two of the first investigations were cooperative with the Corps of Engineers in the Lower Mississippi, and with the Bureau of Reclamation in appraising the direct agricultural benefits on participating irrigation projects in the Upper Colorado River Basin under the Colorado River Storage Project Act.

Seven or 8 years ago, USDA initiated river basins surveys cooperative with the respective states. One of the most recent ones is in the Upper Rio Grande in New Mexico. These kinds of surveys are widely distributed over the country. Currently there are 7 such surveys in the West. Large numbers of applications are pending for new starts. These surveys cooperative between USDA and the States have been identified by the Department as Type IV.

Within the last several years, there has developed a Federal-State program of Comprehensive River Basin Planning which is a large investigative effort in water resources. These investigations are

1/ Leader, Western Resource Group, Natural Resource Economics Division, Economic Research Service, U. S. Department of Agriculture, Logan, Utah.

scheduled to cover the total area of the United States by 1972. The program is a major activity of four Federal Departments--Agriculture, Army, HEW, and Interior.

The summary report (1) of the Senate Select Committee on National Water Resources, published in 1961, included a proposal that the concept of comprehensive development be redefined to include all purposes served by water resources and all measures for meeting prospective demands and that Congress redefine its concept of comprehensive planning along these lines. Further, Congress should request the Executive Branch to submit to Congress a program for preparing comprehensive plans for each of the major river basins or water resource regions, toward the end of providing for the development of plans for all basins, in cooperation with the States. This proposal was approved by the Administration.

In 1962, the ad hoc Water Resources Council, at the request of the President prepared Senate Document 97 (2) on Policies, Standards, and Procedures in formulating and evaluating plans for development of water and related land resources. This document also emphasizes the need for comprehensive basin plans.

The Water Resources Council has been officially established by Federal legislation. The Water Resources Planning Act, PL 89-80, 89th Cong., signed by the President on July 22, 1965, established this Council, authorized the President to establish River Basin Commissions, and authorized financial assistance to the States for comprehensive water resources planning. Among other duties, the Council shall maintain continuing studies of the use and development of water resources.

The Department of Agriculture is now heavily involved in this comprehensive river basin planning program. The Water Resources Council has identified its investigations as Type I or Type II. Type I surveys are regional studies of water resource problems, needs, and general approaches to development; they are referred to as framework studies. Type I surveys comprise five major elements:

1. Studies and projections of economic development.

2. Translations of such projections into needs for water and related land resources.

3. Appraisals of the availability of water supplies both as to quantity and quality.

4. Appraisals of the availability of related land resources.

5. A description of the characteristics of present and future problems and the general approaches that appear appropriate for their solutions.

Type II studies are Type I plus more detailed studies of selected subbasin areas, a major objective of which is to identify projects to satisfy immediate and short-term needs for water developments.

In the West, Type II studies are in progress in the Willamette River Basin in Oregon and in the Puget Sound area of Washington. In order to meet the schedule for completion of Type I investigations, the Council has decided that no new Type II starts will be made at least for several years.

Type I "framework" investigations will be carried out in 16 major water resource regions, embracing the entire area of the 48 states, exclusive of the Tennessee Valley. Comprehensive studies are also proposed for Alaska, Hawaii, Puerto Rico, and the Virgin Islands. Type I studies are currently underway in the Ohio, Upper Mississippi, Missouri, Columbia-North Pacific, and North Atlantic Regions. Plans provide for new starts in fiscal 1967 in the Upper Colorado, Lower Colorado, and California Regions. A type I is scheduled to begin in the Rio Grande in fiscal 1968.

POLICY GUIDES

The following quote from SD 97 (3) is indicative of the policy framework guiding economic investigations by the Department of Agriculture:

1. Reports on proposed plans shall include an analysis of present and projected future economic conditions in the study area and the contribution that comprehensive or project development may be expected to make toward the alleviation of problems and the promotion of economic growth and well-being within the zone of influence. Economic projections will be made to provide a basis for appraisal of conditions to be expected with and without the plans under consideration, and an estimate of the contribution that comprehensive development may make to increased national income and welfare, and regional growth and stability. Such analyses will frequently require a general economic study of the area, a study of all of its resources, an assessment of their functional relationships, their development potentials, possible adverse effects, and the locational situation with reference to resources, markets, transportation, climate, and social factors. Analyses should indicate the significance of the locality and the

region in producing increased goods and services to meet foreseeable needs.

2. These analyses should be as extensive and intensive as is appropriate to the scope of the project being planned. They should provide essential information for identifying both immediate and long-range needs in economic and social terms and these needs should be expressed in a form useful for program formulation. Presentations in reports should identify:

   a) The relationship between development needs and opportunities and potential water and related land resource use and development.

   b) The economic and social consequences of complete or partial failure to satisfy these needs; and

   c) The possible improvements in economic efficiency, alleviation of unemployment, stabilization of production and income, community well-being, and the quality of goods and services that will be forthcoming.

This framework is further emphasized in the responsibilities of the Water Resources Council stated in Section 102 of the Water Resources Planning Act. The Council shall:

a) <u>maintain a continuing study</u> and prepare an assessment biennially, or at such less frequent intervals as the Council may determine, of the <u>adequacy of supplies</u> of water necessary to meet the water requirements in <u>each water resource region</u> in the United States and the national interest therein; and

b) <u>maintain a continuing</u> study of the relation of regional or river basin plans and programs to the requirements of larger regions of the Nation and of the adequacy of administrative and statutory means for the coordination of the water and related land resources policies and programs of the several Federal agencies; it shall appraise the adequacy of existing and proposed policies and programs to meet such requirements; and it shall make recommendations to the President with respect to Federal policies and programs.

Within these guides, the Economic Research Service is concerned directly with rural people, with resources used and needed in the agricultural and forestry industries, and with closely related processing and service industries. However, appraisals of these uses and industries cannot be made independent of other sectors of the economy. Hopefully, the needs for data and analysis of these other sectors will be met by other agencies and investigators. But this is not always the case, so that on occasion, the Economic Research Service may be required to do research, at least to a limited extent, in non-agricultural uses of water and land.

"COMPREHENSIVE" POINT OF VIEW

Senate Document 97, the Water Resources Planning Act, and common usage in water resource agencies of the Federal government, all are oriented to investigational efforts embracing entire river basins or regions. Attention is directed primarily to water and "related land resources". Comprehensive river basin planning has come to include all significant uses of the water and related land resources of a designated region, as well as all purposes of development.

The term "related land" has been a thorny issue in the development of this comprehensive concept. All land is obviously related to water in at least some sense. But with water as a central focus, something less than consideration of all land problems is likely.

The term "comprehensive" also has interesting implications with respect to the economic appraisal of alternative plans. Existing policies and standards for plan formulation provide for full consideration of "<u>all effects</u>, to whomsoever they accrue," both beneficial and adverse; Secondly, plans for water development should reflect full consideration of <u>alternative means</u> of satisfying given markets or needs for products and services obtainable from water resource developments.

Coordinated development of natural resources is feasible only within a common framework of goals, needs, and objectives. If this framework is lacking in terms of definition, understanding, and concensus, "harmonious adjustment or functioning" cannot be achieved.

Possibly a major task in river basins investigations is to achieve a more adequate delineation and description of resource goals for particular regions and the nation and to arrive at somewhat more general agreement about these goals and directions of attainment. Orientation to the point of view identified above as "comprehensive" will facilitate greatly the "coordination" that nearly everyone proclaims.

ECONOMICS OF AGRICULTURE AND FORESTRY IN TYPE I SURVEYS

Within the program of the Department of Agriculture, the Economic Research Service is responsible for:

a. The economic base survey

   1) Analysis and projection of (a) economic activity in the agricultural and related sectors of the economy, (b) other economic activity in rural areas, and (c) the demand for land and water resources in such activities.

   2) Assessment of the current and projected demands for goods and services obtainable from the use of water and related land resources and the translation of such demands into economic needs for development.

b. Studies of problems and needs

   1) Analysis of agricultural and rural water problems as they relate to economic activity in rural areas, specifically to the volume and value of production, employment, and income.

   2) Economic appraisal of agricultural and rural needs for water and related land resource development.

c. Studies of impacts and secondary effects.

   Appraisal of prospective economic impact of development alternatives defined by the survey on the agricultural, rural, and related sectors of the economy and the economic relationship of these alternatives to the coordinated and comprehensive development of the basin.

One major effort in meeting these responsibilities is a program arranged between the Interdepartmental Staff Committee of the Water Resources Council, the Office of Business Economics of the U. S. Department of Commerce, and the Economic Research Service. This program has two major objectives: (1) Development of a system of data storage and retrieval for use of cooperating agencies, and (2) generation of a consistent set of national-regional economic projections for the U. S. for each of 16 regions.

Projections (1980-2000-2020) being developed by the Department of Agriculture for the Council include:

1. Volume of agricultural and forestry output by product groups

2. Employment and income in agriculture

3. Use of rural lands

4. Employment, income, and other measures of economic activity in those trade, service, and processing activities locationally related to the basic agricultural industries.

The initial regional and subregion projections will be appraised and refined, especially at the Field level, in terms of local economies, availability of land and water resources, and alternative means of development to meet regional and national requirements.

DEPARTMENT-STATE SURVEYS

Initially, the Water Resources Council listed three types of investigations--I, II, and III; the Type III designation has been discontinued. However, in order to identify the USDA-State cooperative efforts, the Department of Agriculture attached a Type IV classification and this is the origin of the Type IV designation. It is not part of the Council numbering or classification system.

Wide variations exist among Type IV activities over the country. A common element is formal cooperation between USDA and the respective States. But from this common starting point, variations have arisen because of particular local problems and needs, associated with the fact that personnel and budget available for individual Type IV surveys have dictated that they be something much less than comprehensive in terms of analysis of uses of water and of alternative means to meet needs for goods and services. Basically, Type IV surveys are small-scale Type II surveys. Both types have elements of overall framework analyses (Type I) and both identify prospective projects. Type II studies, of course, involve four Federal Departments, they are large in scope, and they cover a wide range of kinds of projects and developments. Type IV studies involve three agencies in the Department of Agriculture and the State, they are relatively small in terms of budget and personnel, and they are oriented project-wise largely to Department of Agriculture programs, and especially to prospects for PL 566 projects.

Type IV studies are restricted to encompass:

1. Development of short-term economic projections and their implications with respect to the supply of and demand for, water and agricultural and rural lands,

2. Analysis of agricultural water problems (drought, flooding, land drainage, recreation, etc.), adverse effects on the local economy, and potential benefits to be derived from their alleviation, and

3. Basinwide economic appraisal of alternative patterns of water resource use and development.

UPPER RIO GRANDE

As a concluding section, some more specific features of Type IV surveys will be noted using the economics work currently underway in the Upper Rio Grande River Basin for illustrative purposes. These investigations are being made within the general framework outlined above. They are still in preliminary stages.

A Field Advisory Committee has general responsibility. Its members are Einar Roget, Soil Conservation Service, Chairman, Lowell Woods, Forest Service, and Clyde Stewart, Economic Research Service. Steve Reynolds, New Mexico State Engineer, works closely with this committee.

The investigations are actively carried out by a USDA Field Party at Albuquerque. This Party is composed of specialists from the three Services. One economist is assigned to this Field Party by Economic Research Service. Surely sufficient personnel are not available for a comprehensive survey and analysis of this area.

For study purposes, the Upper Rio Grande in New Mexico has been divided into six subbasins. Initially, detailed efforts are in the Chama-Otowi Subbasin, although activities are not restricted to this subbasin where it seems more efficient to carry along other efforts concurrently. A portion of the Upper Rio Grande Basin is in the State of Colorado. The Department has not passed by this situation. A similar USDA Field Party is located at Denver for Type IV investigations in the State of Colorado. In the relatively near future this Party will likely find time to work on the Colorado State portion of the Rio Grande. Specific plans have not been made, however, for these investigations or for merging the two State activities.

Several important features of the upper portion of the Rio Grande area serve both as guides and problems to investigative decisions and efforts. By most economic and income standards, the area is depressed.

Unemployment is high. Land and water resources are few and development opportunities are limited. The institutional obstacles are difficult and in some instances insurmountable within the next several decades. Available data are meagre and collection of needed data extremely difficult. These problems have been recognized further by establishment of a Resource Conservation and Development Project in part of the area, which is being integrated with the river basin activity.

Usually in Type IV investigations, study is made of one or more economic resource problems. Two problems in particular are listed in the Upper Rio Grande Plan of Work that relate specifically to economics: (1) Economic development, and (2) land tenure.

Several special areas of investigation are possible under economic development:

1. Analysis of agricultural water problems--their adverse effects on the local economy and potential benefits from their alleviation;

2. Impacts of resource development on employment and income;

3. Recreation uses of water and land, especially demand aspects;

4. Agricultural processing needs and opportunities.

Other special problems that relate to resource appraisals and projections include:

1. Economic appraisal of alternative hydrologies;

2. Competition among alternative major uses of land and water;

3. Resource availability to meet demands.

In the land tenure field,

1. The Plan of Work notes public-private tenure relationships;

2. Another indicated problem relates to urban "encroachment" on agricultural land and efficiency of water use. Apparently this reference is to areas downstream from Albuquerque.

Three likely problems for special study in the two upper subbasins (Chama-Otowi and Red River-Embudo) in the initial stage of our program are: (1) Impacts of a lumber mill on the local economy, (2) potentials and impacts of recreational development, and (3) appraisals of minimum land and water resources needed to meet various levels of income.

The lumber mill impact study would be an appraisal by Economic Research Service under a cooperative agreement for investigations under the RC&D program. An important element of this agreement is to conduct studies (1) To develop analytical procedures for appraisals of economic impacts in terms of income and employment, and (2) to conduct studies of economic impacts of particular developments, for example, a lumber mill at Espanola. This study will likely be made after construction of the mill and will constitute a before-after analysis.

The local RC&D Project Group several months ago requested that special study be made of the recreation potentials in the area with special emphasis on prospective demand. The decision has been made that the USDA Field Party at Albuquerque will have major responsibility for this assignment. A joint Type IV-RC&D investigation is planned, initially with emphasis on the present supply of recreation facilities, characteristics of present users, and some potentials for development.

Recreation development in the Upper Rio Grande may be one of the best opportunities to improve the economy of that area. Relatively, the agricultural potential does not seem highly promising. The tenure and cultural obstacles constitute an instutional environment within which resource development must be done, rather than try to alter materially. Improvements in agricultural and forestry production can and should be made also. But these adjustments generally will occur slowly in terms of stimulating the local economy, which appears to be a vital need for the near future.

As the Field Party proceeds downstream with its investigations, apparently a look should be taken at the tenure and transition in major land and water uses with respect to their impacts on the economy and on the efficiency with which water is being used. The thesis has been advanced that ownership changes based on anticipated or hoped for adjustments from agricultural to urban uses are resulting in marked inefficiencies in the use of both land and water.

Apparently a substantial need prevails in these upper Basin areas for analysis of water and land resources needed to meet various levels of family incomes. The Department has been asked to make some analysis of these questions, recognizing the dearth of information and the large reliance on informed judgments necessary for this analysis.

Finally, over the period of study, aggregative economic aspects will be analyzed from the standpoint of the total Upper Rio Grande Basin. The national program in connection with Type I investigations should be extremely helpful.

A description of the economic base of the Basin seems essential as a foundation for appraisals, projections, and other purposes. Studies will emphasize agriculture and forestry, but the total economy will need also to be considered, drawing for the most part on analyses accomplished by the Universities, other Federal and State agencies, and others. A description will be needed of present characteristics and trends of the agricultural economy, including farm production, incomes, population, and employment; trade, service, processing, and secondary activities; forests and forest-based industries; and recreational and multiple uses of farm and forest lands.

If present plans materialize, an appraisal of these resources will be made in terms of needs and requirements for goods and services as a basis for suggesting alternative means and kinds of resource development that will help meet these requirements.

At the present level of operations, the Department cannot proceed far in this Type IV study toward accomplishment of these objectives within the next three or four years. But the initial work will likely later merge into a more complete and comprehensive analysis of these problems.

CONCLUSIONS

Comprehensive analysis of water resources gives rise to several major concerns or problems. In closing, two are noted.

Strictly in terms of resource development and of productivity requirements, interregional competition comes into focus. Not only is this a complicated problem analytically, but it poses questions as to the position of regions or areas in terms of needs and developments for their particular localities.

A second major problem confronts economists and others with respect to meeting data needs and to developing an adequate technique or methodology for analyses and appraisals of alternative major uses of water and impacts of development on economic activity. Basically, investigators are looking at single major water uses independently of relations with other major uses. The need still exists for a workable technique for bringing together all uses into an integrated system to examine interrelationships among the various sectors of the economy and to appraise the impacts and constraints of various levels of water quantity and quality and various levels of resource development. The OBE-ERS Interregional Analysis is directed toward this end. Progress is evident but a major challenge remains for physical and social scientists.

REFERENCES

1. Select Committee on National Water Resources, Report with Supplemental and Individual Views. 87th Congress First Session, Report 29. 1961, pp. 45-47.

2. The President's Water Resources Council. Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources. 87th Congress, Second Session, Senate Document 97. 1962.

3. The President's Water Resources Council, op cit., p. 7.

THE CHAMIZAL SETTLEMENT

The Honorable J. F. Friedkin[1/]

On January 14, 1964, President Johnson proclaimed the Treaty between the United States and Mexico for solution of the nearly 100 year old Chamizal boundary dispute between the two countries, at El Paso, Texas and Ciudad Juarez, Chihuahua. The dispute involved less than one square mile. Yet it was as tough and thorny as its namesake - the Chamizo bush which was native to the area.

The story of the dispute and its settlement is one of many interests:

a) The principal is the river - the Rio Grande, flowing in its alluvial bed, and it all started with a relatively simple change in the course of this river.

b) It has a very real human interest - some 5,000 people reside in the disputed area.

c) The settlement will cost an estimated $45 million.

d) Local and state authorities are directly concerned.

e) It involved the question of national sovereignty of two great nations over their lands.

f) At stake was the important principle of arbitration as a means of settlement of disputes between nations.

And so, while in a narrow physical sense the dispute and its settlement may be a small matter, in a larger sense it is a big matter. As perhaps many of you noted, the settlement received national and international news coverage.

I believe the settlement was an outstanding example of the moral strength and character of our Government to do what it believed fair and right - our late President Kennedy and President Johnson - our Senate, Republican and Democrats alike - the Senate Foreign Relations Committee was unanimous in recommending approval. On the floor the Senate voted 79-1 in expressing its advice and consent to the Treaty. The Department of State and particularly your former Ambassador to Mexico, and now Under Secretary of State for Economic Affairs, the

1/ United States Commissioner
International Boundary and Water Commission
United States and Mexico, El Paso, Texas

Honorable Thomas C. Mann, played a leading part. The International Boundary and Water Commission, of which I am a member, played a technical part.

I should like to trace for you this true story of local, national and international significance:

HISTORY OF RIVER CHANGE

It began in 1848 when the Treaty of Guadalupe Hidalgo was signed establishing the Rio Grande as the boundary between the United States and Mexico, starting at a point just above where the City of El Paso, Texas is now situated on the north bank. El Paso was then only a few scattered adobe huts. On the Mexican side, the present city of Juarez was an important community, having been established in the 1600's by early Spanish missionaries.

The Rio Grande in its southward course makes a bend through the two cities, with the United States bank on the convex side - the accretion side; and the Mexican bank on the concave side - the eroding side of the channel. Pursuant to the 1848 Treaty, joint surveys were made in 1853 by engineers for the two Governments, which established definitely the location of the river at that time. In the period 1853 to 1896 the river shifted its course in its alluvial sands to cut into the Mexican bank and effect accretion to the United States bank to the extent of about .75 miles at the maximum point. By 1896, the total land area transferred from the south bank to the north bank was about 630 acres - just under one square mile. This is the land involved in the Chamizal dispute.

MEXICAN CLAIMS

In 1867, Mexico filed its first notice of claim and in 1896 filed an official protest and claim for the Chamizal tract. The claim was referred to the International Boundary Commission for settlement. This was a joint international body consisting of a United States Commissioner and a Mexican Commissioner, established by the two Governments in 1889 with the then primary responsibility of the settlement of boundary disputes incident to changes in the course of the river. It has a record of settlement of 219 cases involving boundary questions incident to river changes, involving more than 27,000 acres. But it was unable to reach agreement on the Chamizal tract - because of differences in views and interpretations of the governing treaty.

THE 1910 ARBITRATION TREATY

On June 24, 1910, the Governments of the United States and of Mexico entered into a Treaty to arbitrate the Chamizal dispute. This Treaty provided for an Arbitration Commission consisting of three members--the United States Commissioner, the Mexican Commissioner of the International Boundary Commission, and the third neutral member--a Canadian jurist selected by the two Governments by common accord. They selected Mr. Eugene LaFleur, one of His Britannic Majesty's Counsel, Doctor of Civil Law, and former professor of International Law at McGill University. He was well recognized internationally for his juridical ability.

The Treaty provided that the Arbitration Commission shall decide whether the international title to the Chamizal tract is in the United States or Mexico. It provided that the decision of the Commission, whether rendered unanimously or by majority vote of the Commissioners, shall be final and conclusive upon both Governments, and without appeal.

The hearings were held in 1911 in El Paso, Texas. The two outstanding questions considered by the arbitrators were:

1) Had the United States of America acquired title to the Chamizal tract by prescription--that is, by its having occupied and exercised jurisdiction over the area. Upon this question, all three Commissioners voted no.

2) The second question related to the manner of movement of the river channel from the time of the initial surveys in 1853 until 1896. On this question the determination of the Commission turned upon the interpretation of the 1884 Treaty between the United States and Mexico which was designed to lay down rules for determination of questions and difficulties which may arise due to natural changes of the channel of the Rio Grande. This Treaty provided that:

> The boundary line shall follow the center of the normal channel of the river, notwithstanding changes in its course provided that such alterations be effected through slow and gradual erosion and deposit of alluvium and not by the abandonment of the existing river channel and the opening of a new one.
>
> Any other change wrought by the force of the current shall produce no change in the dividing lines but that the line shall continue to follow the middle of the bed of the old channel even though it become wholly dry or obstructed by deposits.

And so, the question turned on the character of the movement of the river. The substance of the evidence and arguments presented may be of special interest to those concerned with the mechanics of alluvial rivers.

It was the United States view that there are only two types of river changes, 1) "erosion and accretion" changes where a river shifts its course more or less continuously, and 2) "avulsive" changes where the river suddently abandons an old channel and adopts a new one. Evidence was presented showing that the river did not abandon its old channel, that it did in fact more continuously by erosion and accretion. Therefore, the United States contended that the boundary moved with the river and the entire tract should properly be under the sovereignty of the United States.

The Neutral Arbitrator directed attention to the wording of the Treaty of 1884 - that the boundary changed with the river only when its movement was "slow and gradual." He noted from the testimony that during the 1864 flood, the caving of the Mexican bank was very rapid and at times even violent, and that this could hardly be considered "slow and gradual."

On this basis it was the finding of the majority of the Commission, the Neutral Arbitrator and the Mexican member, that:

1) The river moved by slow and gradual erosion from 1853 until 1864, a year of large floods; that therefore, during this period the boundary moved with the river and hence, the lands north of the 1864 channel belonged to the United States.

2) During the 1864 flood, the river movement was rapid and violent and the changes that took place in that year did not result in a change in the boundary. The old channel before the 1864 flood remained the boundary. Accordingly, the land lying to the south of the 1864 channel belonged to Mexico.

This determination awarded to the United States the northerly approximately one-third of the Chamizal tract and to Mexico the southerly approximately two-thirds of the tract.

UNITED STATES REJECTION

The United States rejected the award on three legal points, taking the view that the findings of the majority of the Commission were outside of the terms of reference of the Arbitration Treaty. Since this rejection by the United States in 1911, the Chamizal dispute has been a most difficult and a most sensitive problem between the two countries.

It is important to note, however, that the United States in its note of rejection, proposed that the two Governments settle the issue by negotiation through diplomatic channels.

EFFORTS TO SETTLE 1910 to 1961

In the years immediately following the arbitration, Mexico was heavily concerned with its internal problems which at times involved armed revolutions. But beginning in the 1920's, each administration in Mexico has approached each administration in the United States for settlement of the Chamizal dispute -- requesting that the United States recognize the arbitration award. In 1925, the Government of Mexico proposed in a note that the legal validity of the award be submitted to the Hague Tribunal for discussion. The United States considered it preferable to negotiate a settlement. And with almost each administration in the United States, Republican and Democratic, instructions have been issued and efforts have been made toward a solution, but without success until the recent effort.

AGREEMENT OF TWO PRESIDENTS IN JUNE 1962

At their meeting in Mexico City in June of 1962, the Mexican President, Lopez Mateos, urged to our President Kennedy, a settlement of the dispute. They agreed at that meeting to instruct their respective executive agencies to recommend a complete solution to this problem which, without prejudice to their juridical positions, takes into account the entire history of this tract.

There followed an intensive study, conferences and discussions with the civic interests of the City of El Paso and with the State of Texas, in an effort to formulate a United States position for a fair and equitable solution to the problem. Probably no treaty has ever been negotiated which took into confidence and worked with the local interests, as was done in the case of the Chamizal negotiations.

CRITERIA AND BASIS FOR SETTLEMENT

The basic criteria for the settlement was to give effect to the 1911 award to the extent practical in today's circumstances, and to reestablish the river channel as the boundary between the two countries.

The first agreement negotiated was to establish the probable location of the 1864 river channel - since this dividing line established by the Arbitration Commission had not been surveyed and was not specifically known. Agreement was reached on the basis of surveys before and after the 1864 flood resulting in the determination that the area south of that channel to be transferred to Mexico amounted to 437 acres.

There were two criteria for relocation of the boundary to effect such transfer:

1) The boundary should be relocated in a manner to minimize insofar as practicable, disturbance to the United States residental and commercial developments which had built up in the Chamizal tract, and

2) The alignment of the new boundary must meet the hydraulic requirements for relocation of the river channel - particularly there should not be excessive curvatures - there should not be excessive head losses.

The new alignment for the boundary and relocation of the river was recommended and approved by the two Presidents as a basis for the settlement. It provides for 4.3 miles of new concrete lined channel - capacity 18,000 c.f.s. It will effect transfer of a gross total of 630 acres from the United States to Mexico; it will effect a transfer of 193 acres from Mexico to the United States; making a net to Mexico of 437 acres.

1963 TREATY

The approved recommendation was the basis for the Treaty signed August 29, 1963. Its preamble states that the "United States of America and the United Mexican States animated by the spirit of good neighborness which has made possible the amicable solution of various problems which have arisen between them and desiring to give a complete solution to the problem of the Chamizal resolved to conclude this Convention."

The relocation of the river will be accomplished jointly by the two Governments through the International Boundary and Water Commission, with the cost of the relocation of the channel and bridges shared equally by the two Governments. The Treaty provides that the new boundary shall not become effective until all the private properties in the United States have been acquired. It provides that the transfer of lands shall not affect the citizenship of people who now reside or who have resided in the area, nor the jurisdiction which

United States authorities have in the past exercised over the area. It provides that while the lands will pass from one country to the other without cost, a Mexican bank shall pay to the United States the value of the improvements which pass intact to Mexico. It provides that the cost of relocating the river and the cost of the new bridges shall be divided equally between the two countries.

THE UNITED STATES ENABLING LEGISLATION

To carry out the United States part of the Treaty will require acquisition of some 800 privately-owned properties. This will include about 650 residential and apartment properties housing some 5,000 people, and 150 business properties. There will be required relocation of schools, railroads and other public facilities. The Congress, at this session, authorized the necessary acquisition and relocation of properties and authorized appropriations therefor, not to exceed the estimated cost of $44.9 million.

Of special note, the legislation contains provisions designed to guard against economic injury or damage to the El Paso residents and businesses of the area. The Congress recognized that this settlement of a dispute with a foreign country should not impose a hardship upon our private interests of the area.

IMPLEMENTATION OF THE CHAMIZAL TREATY

The carrying out of the Chamizal Convention began in January 1965. The first phase of the project is the acquisition of the private properties on lands to pass to Mexico and required for relocation of public facilities on land which pass to Mexico. This phase is about 75% as expected to be practically complete by July 1, 1966. The second phase of the project is the relocation of the public facilities located on the lands to pass to Mexico. These include the United States Port of Entry facilities, railroads, canals, and bridges. This phase is scheduled to be completed within 18 months - by January 1968. The third and last phase - the relocation of the river channel will be completed in 1968.

BENEFITS OF THE SETTLEMENT TO THE CITY OF EL PASO, TEXAS

1) It will remove the cloud of international title to lands in the Chamizal tract remaining in the United States which has retarded their development, and thus permit their improvement.

2) The 193 acre tract of Mexican land which will pass to the United States is strategically most important to El Paso.

3) The new concrete-lined river channel and new bridges will provide a higher degree of flood protection.

4) Relocation and improvement of port of entry facilities and railroads in the area will effect an improvement.

5) The solution of this problem provides opportunity to the City for extensive improvements not otherwise possible.

6) It will make for better local relations between the two border cities.

In addition, the President of the United States has recommended to the Congress the enactment of two complementary projects to assist the people of El Paso in adjusting to the change.

1) Chamizal National Monument to be located on a part of the lands that pass from Mexico to the United States in the settlement. This monument will be a park area with a symbolic monument and a visitors' center designed to depict the history of the boundary between the United States and Mexico.

2) Chamizal Memorial Highway to extend along the bank of the new river channel and southward therefrom along the river, a total distance of about 12 miles.

FROM THE STANDPOINT OF THE FEDERAL GOVERNMENT:

1) The settlement is in the best tradition of the United States in carrying out our commitments with foreign countries.

2) It strengthens our posture before the world in supporting and advocating the peaceful settlement of disputes among nations by negotiation, by arbitration, or international court. This is our position before the United Nations, it is our position before the Organization of American States.

3) It strengthens our position of respect before the world.

I think this is best illustrated by the following quotation by the Secretary of the Organization of American States, Jose A. Mora, upon the signing of the Chamizal Treaty; I quote, "Such a paramount example of international good behavior honors the parties to the settlement and demonstrates to Americans of all latitudes how much can be accomplished when there is goodwill, inspired by the letter and the spirit of the Charter of the Organization of American States."

4) It puts the United States back in a position to arbitrate differences with Mexico, which has not been possible since 1911.

5) The settlement of the Chamizal removes one of the foremost propaganda weapons of the Communists.

THE DEMOCRATIC IDEAL IN OUR POLICY TOWARD LATIN AMERICA

Important as the Chamizal settlement is in itself, it is perhaps most important as one reflector of the democratic ideal in our policy toward Latin America.

And in this respect, I should like to bring to you a few notes from a recent address by the Honorable Thomas C. Mann, now Under Secretary of State for Economic Affairs:

We are, to be sure, now caught up in a shrinking interdependent world in which we have great responsibilities and which progressively become more complex. We can no longer afford to live apart from the rest of the world as if it did not vitally affect our national and individual well being.

In this situation, it is a fundamental in our United States foreign policy that we are firmly and irrevocably committed, as in our own constitution to our own individuals, to the principal that every individual and that every nation no matter in what part of the world has the inalienable right to individual freedom and to individual dignity.

One of the problems of our Latin American foreign policy is the problem of what can we do to bring out a more effective exercise of representative democracy in the western hemisphere - to bring out the individual freedom, the individual dignity of man. What can we do - what are we doing:

1) An example of vigorous representative democracy in our own United States that assures the dignity and respect of our own citizens, will provide strong support for our policy.

2) A policy of consistent persuasion in our discussions with our Latin American friends is another way to help promote democratic progress in the hemisphere.

3) Our basic policy is not one of intervention. We have learned by hard historical experience that unilateral United States interventions in the hemisphere have never succeeded in themselves in restoring constitutional government for any appreciable period of time.

4) Nor do we put ourselves in a doctrinaire straight jacket of nonintervention. Each case must be looked at in the light of its own facts and where the facts warrant, where the circumstances are such as to "outrage the conscience of America" we reserve our freedom to register indignation by refusing to recognize or to continue our economic cooperation, and if necessary to prevent a take over by the Communist, to move in as we did in the Dominican situation until the problem could be taken over by the OAS.

Finally, my fellow engineers, let me emphasize that the central element of our foreign policy toward Latin America is to insist upon for ourselves and for others, dignity and respect, between nations and between individuals. This was the real basis upon which the Chamizal dispute was settled. This recognizes our God given dignity and respect for ourselves and for our neighbors.

It is important that each of us feel and participate in this effort to create a peaceful world.

THE MOST EFFICIENT USE OF WATER AFTER IT HAS BEEN DELIVERED TO THE FARM

E. O. Moore[1/]

For this discussion we will assume that, "delivered to the farm," means delivered to the point of contact with the soil, where the beneficial use of water actually begins.

We will assume also that the following statements are true:

1. Efficient use of water means the most profitable production of useful crops per unit of water.

2. Production of crops is dependent upon soil, air, (or weather,) and water of a quality suitable for irrigation.

3. The use of air or weather consists in adjustment to it.

4. The amount of water available for irrigation will probably not increase and may be considered as the limiting factor.

5. Great improvements in the suitable condition of soil for efficient water use can be obtained by tillage methods, including those calculated to control depth of water penetration; and the proper kind and amount of additives or fertilizing elements. These elements generally consist of:

    a. Commercial fertilizers. These are readily available and their need can be accurately ascertained both as to kind and amount through analysis of the soil.

    b. Humus, which is derived from disintegrated plant material, that is, organic material, either directly or indirectly and must be produced from or by the soil-air-water combination.

6. Quoting from a textbook on soils, (The Nature and Properties of Soils, Lyon-Buckman-Brady) "With a given amount of water, the productivity is dependent upon the low element of soil fertility." Now, since we are dealing with a fixed amount of water, and since the supply of chemical elements is readily available and can easily be brought to the optimum amount, we must look for ways and means of supplying an adequate amount of organic matter, or humus, if we are to improve the soil-water-plant production efficiency.

1/ Production Credit Association,
Roswell, New Mexico

The plowing in of crop residues is almost universally practiced and should be satisfactory when enough plant material is left and time is allowed for disintegration. This will take from one to two years and there is no sales return from the plant growth so used. The growth and plowing in of green manure crops is also satisfactory and the organic material becomes available as humus more quickly, but the amount of water required and the cost involved in the production of a green manure crop are almost as great as in the production of a marketable crop, with no cash return for the green crop. The incorporation of livestock into the farm program offers a way for rapid disintegration of whatever residues the cattle or sheep will eat. This can include field clean up grazing and all forage production, and besides returning to the soil the greatest possible amount of organic material, in the best possible condition for quick integration into plant nutrients, there can be a market return through the sale of the livestock, which should be greater than from the market return for the forage crops sold as such. It is a way of selling the crops and the residues and having their soil improvement benefits in addition.

Referring again to the reports of soil scientists, we are told that it is the amount of organic matter, or humus in the soil which more than all other elements combined, determines the penetration, the distribution and the retention of soil moisture as well as much of the presentation of the plant nutrients to the roots of the plants in an available condition.

Mr. Robert B. Kennedy, Soil Analyst of the Western Soil Laboratory at Roswell, reports that the average organic matter content of the Pecos Valley Soils is 1¼% as determined from the many analyses of Pecos Valley soils in that laboratory. He says that this could and should be brought up to 2¼% and in his opinion the additional 1% of organic matter with suitably balancing commercial fertilizers should increase the water use efficiency by 50% and reduce the amount of water required by 25%, or present production could be maintained with 25% less water.

The course followed by one farm on which it was necessary to try to find the Most Efficient Use of Water After It Was Delivered to the Farm, may be taken as an illustration of <u>one</u> way which met with reasonable success. No claim is made that the greatest possible production was reached, nor that the greatest possible profits were realized, nor that greater production and greater profits might not have been attained with the availability of more water for irrigation, the claim is simply that the farm operation was profitable and was conducted with the limited amount of irrigation water.

On this farm of 320 acres, irrigation was begun in 1934 with water pumped from the shallow sands. About ten years of gradual addition to the cultivated portion was required to bring the entire half section into production, although clean up grazing and full feeding of livestock was begun as early as 1936.

Land leveling was begun about 1945 and was sufficiently completed by 1960 that permanent concrete lined ditches were planned. The farm program of crops was, during the last ten years, about ¼ cotton, ¼ alfalfa and ½ forage crops of various kinds, chiefly silage sorghums with occasional barley or grain sorghum. All the production of this farm was fed to livestock either sheep or cattle and even the cotton was fed, indirectly, through an exchange, by selling the cotton and buying an equal number of dollars worth of feed grain.

During the last eight years, soil samples were taken from each field, each year and according to the analyses the amount and kind of commercial fertilizer to be used was determined. This was not an expense; from the first the amount and kind of commercial fertilizer needed, as shown by the analysis, to be added to what was already <u>in</u> the soil, was either less in total or of a different kind from the estimate, so that the analyzing actually <u>saved</u> money, as compared with the cost of the guess method. Manure from grazing livestock was, of course, naturally dropped on the fields as grazed, and the manure from feedlots was spread as produced. Upon advice of the laboratory, the manure was treated with a nitrate fertilizer in a small amount. This had the effect of making the nutrients in the manure available in good proportion in the year of application; without this nitrate addition the benefit for the first year was slight.

The Western Soil Laboratory was installed in Chaves County in 1954. From that time it was possible to calculate a balanced fertilization program based upon what was in the soil and what was needed to balance with the organic matter. The later analyses show this farm to have built up its organic matter to a level ranging from 1.7% to 2.00% while the average for the general area was 1.25%.

This farm was sold in May of 1961 at which time it was definitely in the best productive condition of any time since 1936 and the meters which had been in continuous operation on the three wells for five years, from 1956 to 1961, showed an average metered pumpage of 2.99 acre-feet per acre per year.

Actual measurement of the water loss by seepage in a half-mile of open ditch on this farm showed a loss of 22% and since the average length of ditch for the whole irrigation system was three fourths of a mile, the estimated loss for all ditches by seepage would be fully up to the engineers and hydrologists estimate of 30% per mile--in this case 33%. This, of course, means that only 67% or less of the pumped water was ever applied to the soil for beneficial use and that the amount of pumped water used for production was actually slightly over 2.09 acre-feet. Since being sold, the new owner has lined almost every foot of ditch and so most of this loss has been eliminated and it should now be possible to have the same production -- a reasonably profitable production with a little over 2 A. F. of pumped water, actually 2,093.

So far as I know, this program of balanced fertilization based on the adequate supply of organic matter, which it seems can best be accomplished through the addition to livestock to the farm program is the best answer to the question, How to Obtain the Most Efficient Use of Water After It Has Been Delivered to the Farm -- a circumstance where you can eat your cake and have it too, in this case the crops are sold through the livestock and the fertilizing elements are kept where they can do the most good.

The question naturally is asked, "If this is so good a program, why have you only twenty eight feedlots on farms with as many as 100 cattle when your county agent gives as his opinion that there ought to be a hundred such feedlots?"

There have been two principal hindrances, both of which are rapidly disappearing; one is the hesitancy on the part of the eligible farmer to borrow the necessary funds for the purchase of the livestock needed; this because he doubts that the necessary credit is available to him. This is being corrected as he learns that credit agencies are not only willing, but anxious to add this part to his farm operating loan. The second is the erroneous information that elaborate feed preparation equipment is a requirement and that to justify this elaborate equipment there must be rather great volume from the start. Both are fallacies. For a safe and sound operation one must start small and grow in numbers as well as in equipment, and in both, additions can be made as needed.

In summary, to reach the Most Efficient Use of Water After It Has Been Delivered to the Farm, we conclude that a program of soil management must be followed, one that is capable of producing the most profitable continuous supply of useful plant growth per unit of water.

EFFICIENT USE OF IRRIGATION WATER

W. H. Gary[1/]

The use of water in irrigation is for the purpose of producing crops. Just that simple at the first glance! So just apply the proper amount to the plot and move on. Yet as we try to determine just what is the proper amount we are confronted with many variable factors that influence its use that we wonder if we have enough known quantities to solve for the unknown.

Among the factors contributing to inefficient use of water is the actual irrigating is generally done by some incompetent workman, who is only on the job for the pay, with the result he either cuts the water off too soon leaving areas half dry or lets it run too long and floods the field. Either way the crop is hurt for too much water at one time is about as harmful as too little. You can add more if too little but you can't do anything about too much after the application. So we suggest it would be most profitable for the farmer to do his own irrigating and if this is not feasible to hire competent irrigators.

Agriculture, whether we like it or not, has been forced into mechanization and the trend is to larger and larger machines to minimize the high cost of labor. Naturally, the longer the irrigations the more efficient is the use of this equipment. Many times other factors are not considered with the result that the production of crops is actually decreased by the excess application of water in certain areas of the plot.

To our mind, the most disturbing of these unknown quantities is the variation of soil textures, ranging from adobe clay which is practically impervious to absorbing more water after it is saturated, to river bed sand which is so permeable it will continue to absorb water as long as the water is poured on it. Of course, some plots have uniform soil and the problem becomes much simpler than in a plot that has various soil textures.

These are only some of the variables, we do not presume to know all of them. So let us consider the ill effects of the application of water to these different types of soils. Our experience has been that the adobe lands are lacking in drainage with the result that excess water dries up by evaporation causing a baked crust. Such a dry, hard crust on top with mud underneath will not germinate seed;

1/ Interstate Stream Commission and farmer,
Rincon, New Mexico

the soil must be pliable. To illustrate, we had such a plot of land with about 18 inches of adobe on top underlaid with silt. As long as we rotated with alfalfa we had their top roots growing through the adobe into the silt which furnished drainage until they sealed up. For years we were not troubled with baked soils. Then the State University recommended rotation with barley in order to minimize the effect of wilt in cotton production. We lost our drainage in time and found it impossible to sprout a stand of healthy cotton plants. We then transfered the adobe on a 100 foot strip across the lower end of the irrigation for silt soil from an adjoining plot. We have had no more trouble getting any seed we plant to germinate. We relieved another block by digging two 10 foot trenches across the end of the irrigation schedule and filled them with river bed sand so that any excess water would drain into the basin below.

On the Salem farm we had the end of an irrigation on some highly permeable soil one foot in depth underlaid with river bed sand. We stockpiled the top soil from a strip 30 feet wide and replaced some six inches of the sand with a like amount of adobe, mixing them with a breaking plow. We continued this procedure across the area replacing the top soil. Originally this area would not pay the expenses of operation but after adding the adobe it has been producing comparable crops to the rest of the field.

On another hundred acre block we originally irrigated from the adjacent lateral toward a drainage ditch. Some of these soils were adobe, some silt fairly tight and some highly permeable. In time we found the production going down fast in the permeable areas so we changed the farm ditches in order to segregate the different soils into shorter irrigations. In two years without any extra fertilization these permeable soils were producing crops equal to the other areas in the field. We were simply leaching the fertility of this area into the basin below. Incidentally, the change cut the amount of water to irrigate the entire field by one third. Plant food to be available to plants must be soluble and the more you leach the soil the less fertility you have available for production.

These are some of the remedies we have used and we are certain there are many others. We would be so bold as to suggest that every farmer study his irrigations and where feasible construct his farm ditches on the tighter soils and if he cannot segregate his plots into uniform soil to recondition the permeable areas so that they will be productive and at the same time use less water. When we consider there is not 10 percent profit in farming we are convinced you cannot support unprofitable acres in any irrigation project.

To show that this leaching process is not confined to just an occasional acreage let us consider some Bureau of Reclamation figures here in the Rio Grande Project because we think the same conditions prevail generally in other river irrigation projects in the state. For that period of years until 1951 when there was ample supply of water in the Elephant Butte Reservoir and no pumping from the underground basin, the Bureau measured some 300,000 acre feet of drain returns to the river yearly. The river bed seepage has been estimated at about 15% of the release from the dam which at that time ranged from 720,000 acre feet upward and in only one year did the release amount to 800,000. So, for the sake of computation let us take an average of 760,000 acre feet release. The river seepage would then be 114,000 acre feet. The distribution losses in the canal are estimated 20% or 152,000 acre feet, but we know all of this is not seepage as a considerable portion was leaky turnouts, growing vegetation such as willows, johnson grass, etc., on the banks. We would estimate about 50% seepage or 76,000 acre feet. Adding this to the river loss we would have 190,000 acre feet, leaving a net seepage through areas in the field of 110,000 acre feet of water. This seeping water hurt production of crops by leaching. If you take the irrigation records of the use of water for all crops at three acre feet per acre this is enough water to have irrigated some 36,666 more acres.

We are sure some of you are thinking of the old quip, "Figures don't lie but liars can figure". He tells us that this water is returned to the river and used again. Where then is the loss? The answer is that during this period of ample water supply the Bureau, in test wells scattered over the project showed the elevation of the water table in the basin to be two feet higher in September at the end of the irrigation season than it was the next March when started again. Then during the drought when wells were operated to supplement the surface irrigations from the canals, and the amount of water that was pumped to produce the crops that were grown, and the effect it had upon the elevation of the water table, gives one a guess that approximately this two foot buildup during the season, draining out each winter, represented 100,000 acre feet of water. So the figures do reconcile within a reasonable degree.

During the drought the Irrigation Board of Directors of the Elephant Butte Irrigation District heard a lot of agitation to concrete the river and canal system to save water. We will admit that it would have made deliveries more prompt and more efficient but not any saving of water. We are afraid the advocates of that approach were only considering the surface supply and overlooking the fact that whether we like it or not the river is going to support this underground basin and if we lowered the water table by removing the seepage from the river and canals we would merely transfer the filling of the resulting void in the basin through the fields. Draining below, evaporating above requires more frequent and heavier irrigations to produce crops with the resulting loss in fertility caused by leaching. This was definitely proven during the drought when our efficiency of delivery dropped from a normal of 65% to 19% one year.

Besides, Colorado has expanded the diversion of water from the Rio Grande River until they have an accumulated debit since 195[illegible] of over 900,000 acre feet with an allowable debit of 100,000 acre feet under the Rio Grande Compact. The State of New Mexico with an allowable debit of 200,000 acre feet has a debit of 450,000 acre feet. The Rio Grande Compact was entered into in 1938 by Colorado, New Mexico and Texas to divide the water of the basin between the three states and therefore is either an enforceable contract or meaningless words. If the latter, then what do we want with concreted river and canals with no water to run in them?

The Carlsbad Irrigation District has a different problem, a fan of salt cedars in front of McMillan Lake estimated to cover some 30,000 acres. The Lake is necessary for terminal storage in order to successfully irrigate the project and if the cedars are removed the Lake will silt up. What is the solution of the problem? The project hasn't sufficient water to support their irrigation and the consumption of water by the salt cedars.

The State of New Mexico in cooperation with the Bureau of Reclamation has eliminated 5,000 acres of salt cedars between Elephant Butte and Caballo lake with an estimated saving of 15,000 acre feet per annum in the transfer of water in this distance of some seventeen miles. The same organizations are now clearing salt cedars from the San Acacia Dam north to Bernado for the conservation of water.

When we look at the record that only about fifty percent of the water entering the streams in this state are beneficially used and half of it escapes in evaporation, growing worthless vegetation, frog ponds, mosquito dens, etc., we believe we should make every effort to reduce this waste in every feasible way. For, with the expanded uses of water and increased population the development of the economy of the state is limited to and by the availability of water for whatever trend the economy may take. Consequently, we should all cooperate and try to be more efficient in the use of the available water whether urban or rural. We farmers should fully realize that if the day comes when the shortage of water forces the price higher the irrigated farming will be the least able to buy.

The State of New Mexico through its agency the Interstate Streams Commission has set the price of water in the Ute Creek Reservoir on the Canadian River at three cents per 1,000 gallons in the lake. That is approximately $10.00 per acre foot. Even farming in the

Mesilla Valley could not pay such a price for water in Elephant Butte Lake. Yet as you from the East side know, the Bureau of Reclamation is making a survey as to the feasibility of a pipeline to make this water available for municipal use in several cities in Eastern New Mexico. Not the price of water but feasibility of the pipeline will determine whether or not it is constructed.

It is evident that the acute problem for both urban and rural areas is the shortage of water, for the economy of any town in a farming area depends upon a profitable agriculture. We sincerely hope we have presented some of the water problems that confront all of us. Also a few helpful suggestions to minimize the inefficient use of water.

WATER AND AGRICULTURE FINANCING

Drew Cloud[1/]

Since the beginning of civilization, agriculture and water have been anonymous. In many areas this creates no great problem. However, in New Mexico it is the abnormal, rather than the normal, year that adequate water for agriculture purposes is available. The term drought is normal and it is only the degree of drought from year to year, or the cycle that we are in at a given time, that is of concern to us.

The establishment of the Farmers Home Administration by the Congress of the United States envisaged an Agency to finance the purchase of farms and ranches of family size. The repayment period would be of sufficient length of time to allow an orderly repayment of the capital investment, plus an adequate cost of living, and the building up of a reserve to meet emergencies that could arise from time to time. With this guideline, the instructions call for a loan to be repaid as rapidly as possible with a maximum repayment period of 40 years. Restrictions were written into the law that when applied in a practical manner, served to identify the people who would be eligible for FHA assistance -- such as:

1. No loan could be made by the Farmers Home Administration when credit was available from a normal lending source (banks, Production Credit Associations, Insurance Companies, Federal Land Banks, private individuals, etc.) at reasonable interest rates and length of repayment periods;

2. That titles must be merchantable after the loan was made and second liens would not be allowed;

3. The maximum real estate debt could not exceed sixty thousand dollars; and

4. The maximum operating debt could not exceed thirty-five thousand dollars or be for a period in excess of seven years.

Other restrictions in the Act have some effect. However, the previous four - when used in a practical manner - have the effect of placing the Farmers Home Administration in a position of being the primary source of credit for young farmers and ranchers just entering the profession. Also, we are the secondary source of credit for those who

1/ State Director, Farmers Home Administration, Albuquerque, New Mexico.

are already in the profession and find themselves in financial difficulty and are unable to get credit from their previous sources. This establishes a "gray area" in the field of agricultural finance. This already high risk of finance now becomes even greater, and compels our agency to give considerable attention to even the smallest detail when deciding if an applicant has a reasonable chance for success.

The individual and his background are important factors to be considered when making a loan. However, when you are considering a final repayment date of the year two thousand and six - it is very evident that other items must receive a higher priority, in order of importance, when the loan is expected to be repaid from the production of agricultural crops over the next 40 years. This is where we get to the most important single item of all factors considered. And, that is the availability of adequate water, both in quantity and quality, to sustain production over this period of time.

In order to give the viewpoint of the Farmers Home Administration on water in New Mexico, we need to identify the agriculture produced and the water needs of the various crops as seen by a financing agency. Agriculture in New Mexico is much more complex than the casual observer might think. It varies from the heavily irrigated crops of cotton and alfalfa in the lower Rio Grande and Pecos River Valleys to the lightly irrigated crops of oats and barley in the extreme northern part of the State, to the dry land grain sorghum areas of the High Plains. Numerous studies have been (and are still being) made as to the amount of water necessary to produce the maximum crop with a minimum amount of water. However, as a financing agency, we do not attempt to innovate new theories as to water use, but tend to rely very heavily upon the Land Grant Colleges (for example, New Mexico State University), the New Mexico State Engineer, and the United States Geological Survey studies to supplement our farm management practices in the State. Decisions on a loan must be made on what the situation could possibly be in the year two thousand and six - or any year in the intervening period of time.

In each county we develop a minimum resources guide which is based upon all of the data available at the present time for each community and agriculture area. We are aware of the net average annual surface water supply of slightly over two million acre-feet per year and the agricultural lands that have a valid water-right that will protect the value of the land and the security of our loans for an indefinite period of time. However, we are not complacent with this situation and it is necessary to keep a careful watch over water legislation on both the State and National level. Reapportioning of the State Legislature will give some idea of our concern as a rural financing agency, since a change in complexion or makeup of our State Legislature will undoubtedly reflect more of the urban and city problems and less of the problems of the farmer. It is too early to make a prediction on how this will effect agricultural financing.

However, we do know that the value of water for uses other than farming is tremendous. Dr. Ralph Stucky, in his report to this conference in 1962, disclosed that the recreational value per acre-feet of water ranged from $198 to $293 and the value per acre-foot of water for municipal and industrial uses was from $1,273 to $3,300, while agricultural value was only from $17 to $18. This, coupled with an anticipated population growth rate of approximately 75 percent in the next two decades, should warn the farmer that competition is going to be very stiff for the limited amounts of surface water that is and will be available and that the agency providing the agricultural financing will, of necessity, have to adjust accordingly.

Areas of New Mexico where no major streams exist and the preponderant majority of irrigation water comes from ground-water storage present a completely different problem, and one that I am sure keeps bankers and other financial agents from sleeping at night. We were extremely interested in the data for Roosevelt, Curry, Lea, Chaves, Eddy, Dona Ana, Otero and Torrance counties printed in a Basic Data Report by Fred E. Busch of the U. S. Geological Survey (Ground-Water Levels in New Mexico, 1964). This report indicates that although there is a rapid recharge in some areas, the water levels are either at, or near, all time lows in all counties, and that we are continuing to mine our underground supplies at an alarming rate. From the viewpoint of an agricultural financing agency, the question that keeps hovering just out of reach is -- "when do we start the countdown of 40, 39, 38, 37, etc...." and limit our loans to this length of time, so there will be enough time left to amortize the debt before the well runs dry. This is a question that we do not dare - nor are we equipped - to answer since we know that the explosion from the farmers and communities involved would be deafening. We would, however, urge a continuous study of this situation and data be kept current so a reasonable time limit of available ground-water reserves can be estimated by all financing agencies.

A 1965 publication entitled "Characteristics of Water Supply in New Mexico," by W. E. Hale, L. J. Reilend, and J. P. Beverage reported the total acreage irrigated in New Mexico in 1954 was estimated to be 880,000 acres, of which about 335,000 were irrigated entirely with surface water; 400,000 acres entirely with groundwater; and 145,000 acres with a combination of ground and surface water. They estimated the irrigated acreage in 1960 to be 959,000, of which about 484,000 acres were irrigated entirely with groundwater and about 140,000 acres with a combination of ground and surface water. There appeared to be no significant change in the acreage irrigated by surface water in the period of 1954-1960.

It seems that where the surface water is visable, and users can see that there is a limited amount, they are concerned and will take action to preserve certain amounts. However, we are more concerned with the limited amounts of groundwater available, and in preserving these reserves for future use. While the total acreage irrigated went up only an estimated 8.43 percent, the amount of land in acres irrigated by groundwater went up an amazing 19.36 percent. If this trend continues, we are going to find our groundwater reserves depleted to a very dangerous level in a relatively short period of time.

The New Mexico State Engineer administers the water rights in our State in accordance with provisions of the Constitution and the Statutes, the terms of interstate water compacts and international treaties, and rules and regulations of the State Engineer's office. In our opinion, Steve Reynolds is doing an excellent job in keeping the people of this State appraised of the water that is available for all purposes, and we would recommend a continuation of the present program.

We are also blessed by having a Congressional delegation that is conscious of our water problems in financing and we who work in this area are facing the future with confidence.

Historically, a banker or financing agent has been referred to as someone with one glass eye, and that the only kindness or sympathy you would receive from him when discussing your problems comes from that "one glass eye!" We would beg to disagree with this.

The Farmers Home Administration now has outstanding in New Mexico approximately 30 million dollars in agricultural loans. We are presently lending at an annual rate of approximately 9 million dollars. We anticipate this annual rate will go higher as we move toward an industrial state and the competition for banking loans increases.

WATER AS A FACTOR IN CREDIT
FROM THE FEDERAL LAND BANK VIEWPOINT

Dexter G. Henderson[1/]

The Federal Land Bank of Wichita was established in 1917 to help meet the long term credit needs of farmers and ranchers in the four state area of New Mexico, Colorado, Kansas and Oklahoma. Next year - 1967 - marks the 50th year of lending activity. Present outstanding loan balance is about $375 million, and current figures indicate that somewhere around $100 million will be loaned to farmers and ranchers in this four state area during 1966.

Funds for lending are obtained through the sale of bonds issued jointly by the twelve land banks in the nation. The bonds are secured by first mortgages as collateral and are not insured, endorsed or guaranteed in any way by the Federal Government. It is important that the bank's lending activity be on a sound basis in order to keep the continued interest of the investment markets of the country.

The land bank has long recognized the importance of irrigation in the economy of agriculture, and has found it advantageous to maintain an engineering section to study the many aspects. This section is charged with the responsibility of investigating the numerous factors involved in the supply, distribution and cost of irrigation water and the organizational structure of the units making delivery of the water as well as such factors as drainage, flood frequencies, etc; and making recommendations to the bank.

With this introduction I would like to outline some of the types of investigations made and how they are used in the appraisal of farms for lending purposes. One of the best ways to estimate or predict what will likely happen in the future is to study what has happened in the past. This applies to a study of an irrigated area whether it be the drainage area of a major stream, a pump irrigated area, or a new irrigation project just being developed below a large reservoir. A review of the available records is usually the starting place for any irrigation study, and usually the longer the period of record, the more accurate the result. In this connection I think it only proper to give credit to state and federal offices such as the State Engineer, Geological Survey, Bureau of Reclamation, Extension Service, etc., as well as universities for the many excellent technical and basic data reports published on the subject of water and its use. Without this information it would be difficult, if not impossible, for an agency like the land bank to be of service in some areas.

1/ Engineer-Appraiser, Federal Land Bank of Wichita, Wichita, Kansas

Let us first consider gravity rights originating from surface streams in Colorado or New Mexico. A series of ditches diverting from a stream may have the same legal status yet have a wide range of values based on the availability during the irrigation season. As a guide to appraisers in the valuation of irrigated land a system of water supply classification has been devised for designating different degrees of adequacy of water supply. These are based on the quantity of irrigation water normally available as related to crop production of the most profitable crops for which the land is adapted. The classifications are designated as Class I, II, III and IV with subdivisions each under Class II and III. In working up a report on a particular district the first step is usually a tabulation of all court decrees granted in the order of their priority. Published stream flow records, diversion records of water commissioners or ditch riders, and ditch company delivery records are studied. The larger ditch companies usually have fairly complete records of diversions and deliveries on which a supply classification can be based. On small private and partnership or community ditches there are seldom sufficient diversion records to gauge a supply classification, and stream flow records supplemented with field observations and experience are used. Under many ditches the element of time the priority is available is the controlling factor rather than the quantity of water delivered. Such factors as return flow to the stream and the location of a ditch on the stream may also influence its classification. Water deliveries are usually shown in acre-feet per acre for land holding the customary right under the system. In the event the water right offered with the security varies from the customary right, the proper delivery per acre or per share can readily be calculated.

The appraiser is provided with information on the normal water supply classification for decreed rights and also with the assessments normally made against the water company stock or ditch to maintain the system. This information is needed in order to make a comprehensive estimate of net returns. A register of land sales is also maintained in each area, and the water supply classifications enable the unit sales value to be broken down into the sale price of land with various adequacy of water supplies. Most of the bank's surface water reports were made some years ago and now we just attempt to update or revise them as changes take place in ditch organizational status or water supply features.

One factor that may alter the classifications established is the number of new Bureau of Reclamation projects organized in Kansas, Colorado and New Mexico within the last few years. Some of these projects provide supplemental water to land that was already irrigated with a short supply and some irrigate new land that was formerly unproductive or farmed as dry land. There is usually a desire on the part of land owners in a new irrigation district for recognition of the potential water supply as early as possible in the development period. The Definite Plan Report on a new project is studied to determine the probable water supply and costs to be expected, and the new project is compared to other projects on which information has been collected. A long period of record is available on such projects as Elephant Butte at Las Cruces, and Grand Valley and Uncompahgre Projects in Colorado, and the lending experience of the land bank has been very favorable. Appraisals can usually be made on a semi-irrigated basis to cover leveling and developing costs as soon as water is available to a farm in a new district. Appraisal levels are then increased during the development period as crop production and water costs become stabilized, and by the end of the time allotted to development full irrigation value can be considered. If the new water provided by the district is supplemental on land already developed and irrigated, the full supply can often be considered as soon as the district becomes operative.

The development of pump irrigation in the many underground water areas in the district has occupied much of our study time for the last 10 or 15 years. The expansion of pump irrigation in western Kansas and Oklahoma and eastern Colorado as well as many areas of New Mexico has been tremendous. There are reported to be three million irrigable acres in western Kansas alone, of which something like one million acres are presently developed for irrigation. Such factors as the modern turbine pump, introduction of natural gas for fuel, aluminum surface pipe and underground pipe to transport water from the well to the place of use have made it feasible to lift water from 300 to 400 feet where previously around 200 feet was considered the economic limit. Another factor that has contributed to the expansion of irrigation has been the shortage of available land accompanied by the steady rise in the price of land. This has been largely a result of the trend toward larger units and greater mechanization. An operator may have 4 to 6 quarter sections of dry farm land or one irrigated quarter with several dry land quarters, and still be able to handle another quarter section or so with little or no additional investment in machinery and equipment. It may be possible to put down a well and develop irrigation on a quarter section already owned rather than to look for additional dry land that may be some distance away from the present operation. The irrigation development can often be completed at less expense than the purchase of the additional land, and at the same time stabilize yields and permit greater diversification. Pump irrigation is even being utilized in areas of eastern Kansas and Oklahoma, where the average rainfall is 40 inches and more, to offset occasional periods of short supply during July and August. The application of possibly a foot of supplemental water during this period stabilizes crop yields and enables full utilization of fertilizer applications.

Studies of irrigation in pump areas involve keeping abreast of cropping trends and yields, water requirements, water efficiencies and cost trends as well as estimating water level declines and future life expectancy of water supplies. As we all know, such yields as 2 to 2½ bales of cotton and 100 bushel corn and grain sorghum per acre have become commonplace, but studies also indicate costs have increased to the point where the margin of profit becomes small with yields much less than these.

In considering a long term loan in an area supplied from underground water, it becomes necessary to make an estimate on the life expectancy of the water supply. This is done by plotting the trend in water level declines based on annual well level measurements made by State and Federal agencies supplemented by measurements that we may make in some areas. In estimating future declines an allowance must then be made for future development. This becomes largely a matter of judgment in areas where there is little control over the number of wells that may be drilled. The problem is made much easier in areas of New Mexico that have been declared as closed basins by the State Engineer. This establishes a limit on the ultimate development in the area and future trends can be projected with better accuracy. In closed basin areas the appraiser is supplied with maps showing the depth to water table and the average declines to be expected based on the trend over the past 10 or 15 years or whatever period of record is available. We also attempt to provide contours showing the remaining thickness of saturated sediment where this may become a factor during the life of a loan. In the Mimbres and Animas Valleys of southwestern New Mexico the depth of valley fill is considerable and the saturated thickness map is not so important; however, in the Portales Valley in eastern New Mexico, where the 'red bed' is rather close to the surface and the saturated thickness is limited, this information becomes important.

The land bank is by its very nature rather conservative in the approach to appraisal levels during the development stages of a new area. After the cropping trends and markets have become fairly stable the area may be approved for limited lending with a 10 to 15 year term. When the area has approached its ultimate development, or has been declared a closed basin, it is usually approved for irrigated lending for a longer term. A 20 year term is usually the maximum term under irrigation where all the water is supplied by pumps.

It appears certain that the expanding trend in irrigation development will continue as the role of agriculture becomes even more important in this age of increasing population. I think we must admit that many problems exist - if this were not the case - there would be little need for our being here for this conference. The limiting factor could well be the life expectancy of that all important commodity - water.

The land bank is constantly making appraisal studies to determine what changes should be made in value levels, loan terms, or other features to better serve farmers and ranchers. We feel we have been quite successful in the evaluation of water rights, and this has been possible only through the close cooperation of the many people involved in the various phases of the water problem.

ELECTRICAL ANALOG MODEL OF THE ROSWELL BASIN - ITS USE IN HYDROLOGIC ANALYSIS

George E. Maddox[1/]

PURPOSE OF THE ANALOG MODEL

Complex ground-water systems, such as the Roswell basin, can best be studied by scaling down the system and looking at it in miniature on a reduced time scale and simulating certain stresses, such as those induced by pumping. These stresses will immediately effect the analog model in a manner that would take many years under natural conditions in the basin. This can be done because an electrical analog model of a ground-water system reacts to changes in the flow of electricity in the same way that a ground-water system reacts to changes in the flow of groundwater. An analysis of the data obtained from an electrical analog model of a ground-water system permits hydrologists to predict the effect of increasing or decreasing pumping and recharge, changes in pumping pattern, and many other factors important to the life and yield of a ground-water system.

DATA USED IN CONSTRUCTING AND PROGRAMMING THE ANALOG MODEL

The most important data used in constructing an electric analog model of a ground-water system are the geological features that limit or bound the ground-water reservoir or reservoirs and the water-transmitting and water-retarding formations in the ground-water system. Several ground-water boundaries and three hydrologic units were modeled into the electric analog of the Roswell basin. The main aquifer is the San Andres Limestone and it is called the "artesian aquifer" Figure 1.

The western boundary of the Roswell basin is where the San Andres becomes an aquifer. This boundary is marked by a rapid decrease in the ground-water gradient and this occurs where the water table in the Glorieta Sandstone and older rocks intersect the base of the San Andres Limestone, Figure 2. Groundwater moves into the permeable limestone from the underlying and less permeable formations because of regional eastward dip of the geologic formations and the slope of the water table. An eastern boundary of groundwater movement in the San Andres lies parallel to, and about 5 miles east of, the Pecos River, Figure 2. The position of this boundary can only be inferred on the basis that oil tests drilled into the San Andres

1/ Geologist, U. S. Geological Survey, Roswell, New Mexico.

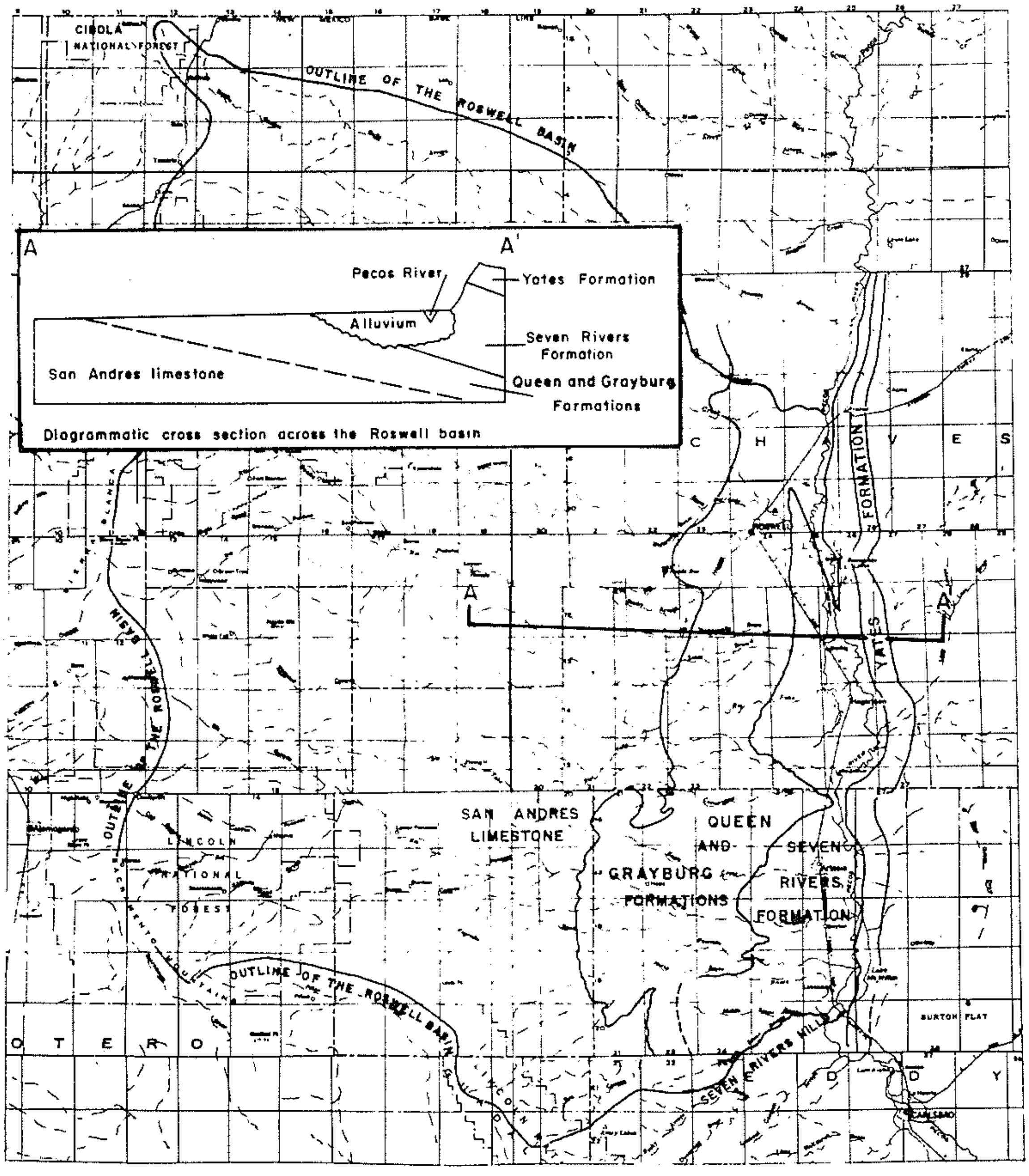


Figure 1.--Subcrops of geologic formations in the Roswell basin.

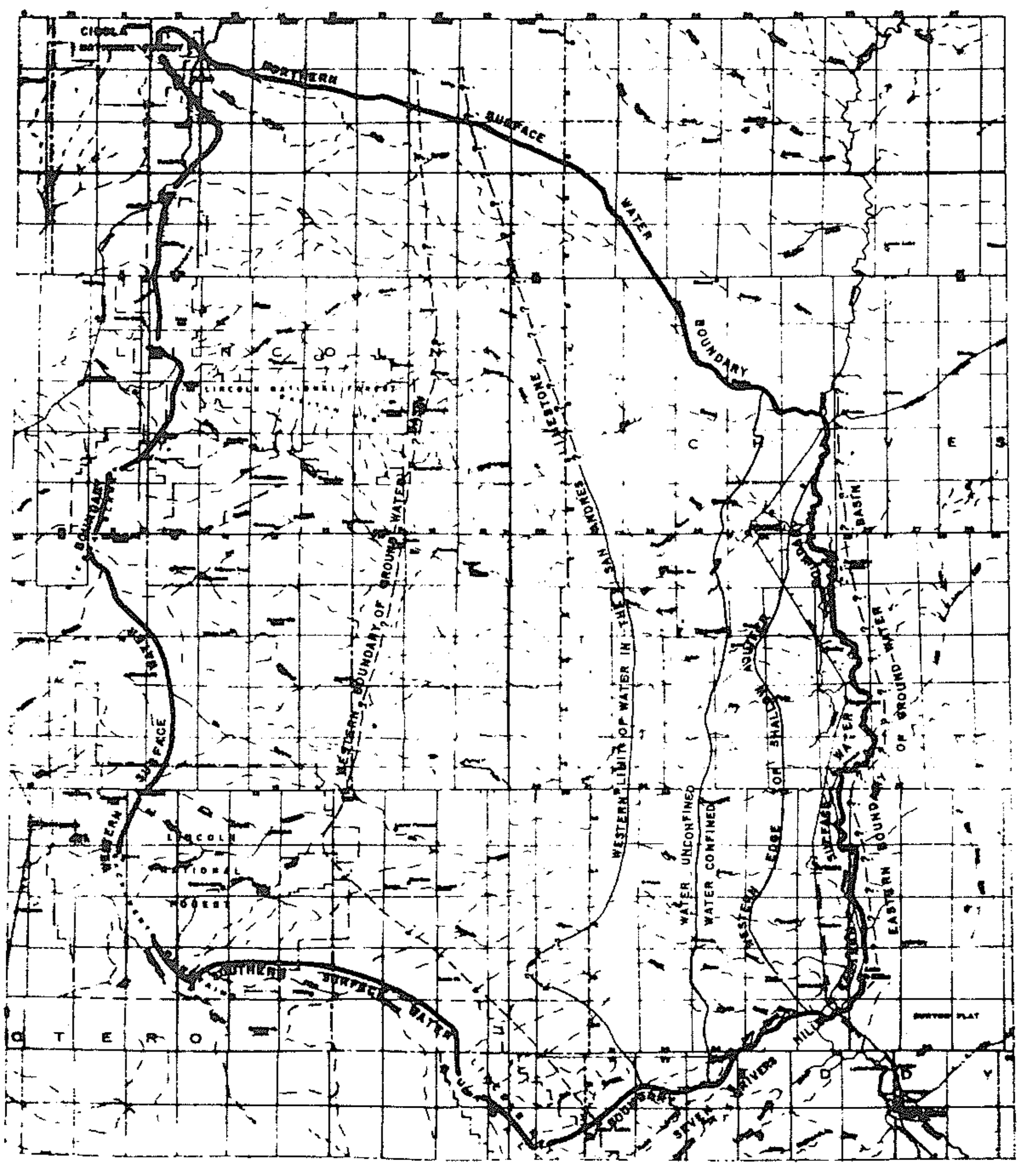


Figure 2.--Ground-water boundaries in the Roswell basin.

several miles east of the Pecos River do not encounter the large flows of groundwater as do wells drilled closer to the river. The presence of such a boundary does not mean that small amounts of water may not continue to flow eastward beyond the boundary; however, in the analog model the boundary has been designated as impermeable, that is, no water will flow eastward beyond this line.

The southern ground-water boundary of the basin is quite complex because the San Andres becomes less permeable and ceases to be an aquifer towards the southern surface-water boundary north of the Seven Rivers Hills, Figure 2. The northern ground-water boundary of the basin is very indefinite and in the analog model was considered as being at an infinite distance from the basin.

The Seven Rivers Formation and alluvium which was deposited by the Pecos River constitute the "shallow aquifer." Its western and northern boundaries are at its interception with the top of the underlying geologic formation, due to regional geologic dip and water-table gradient. Its eastern boundary is the Pecos River, and its southern boundary is the Seven Rivers Hills, Figures 1 and 2.

The Grayburg and Queen Formations lie between the shallow and artesian aquifers, Figure 1. These units are relatively impermeable compared to the San Andres Limestone and tend to confine the groundwater in the San Andres Limestone. Over a large area, however, considerable water can move between the shallow aquifer and the San Andres Limestone depending on the head difference between the two principal aquifers.

Figure 2 shows a boundary where groundwater in the San Andres becomes confined or artesian. West of the boundary, groundwater in the San Andres is unconfined or non-artesian. This boundary moves laterally with time, owing to fluctuating water levels. Its position as shown in Figure 2 is based on water levels measured in 1964 and in the boundary used in the electric analog model.

Hydrologic constants of the ground-water system must be incorporated into the analog model in order to determine the effects of stressing the system. In the Roswell basin, specific capacities of wells, or the yields of wells in gallons per minute per foot of water-level drawdown caused by pumping, were used to determine changes in the property of the artesian aquifer to transmit water, Figure 3. These specific capacities, and other data from a few pumping tests, were used to determine a value -- referred to as the coefficient of transmissibility. The various coefficients were then assigned to the aquifer at the proper geographic locations. In the analog model of the aquifer these various coefficients were simulated by various size resistors that control the flow of electricity in the same manner that transmissibility controls the flow of groundwater.

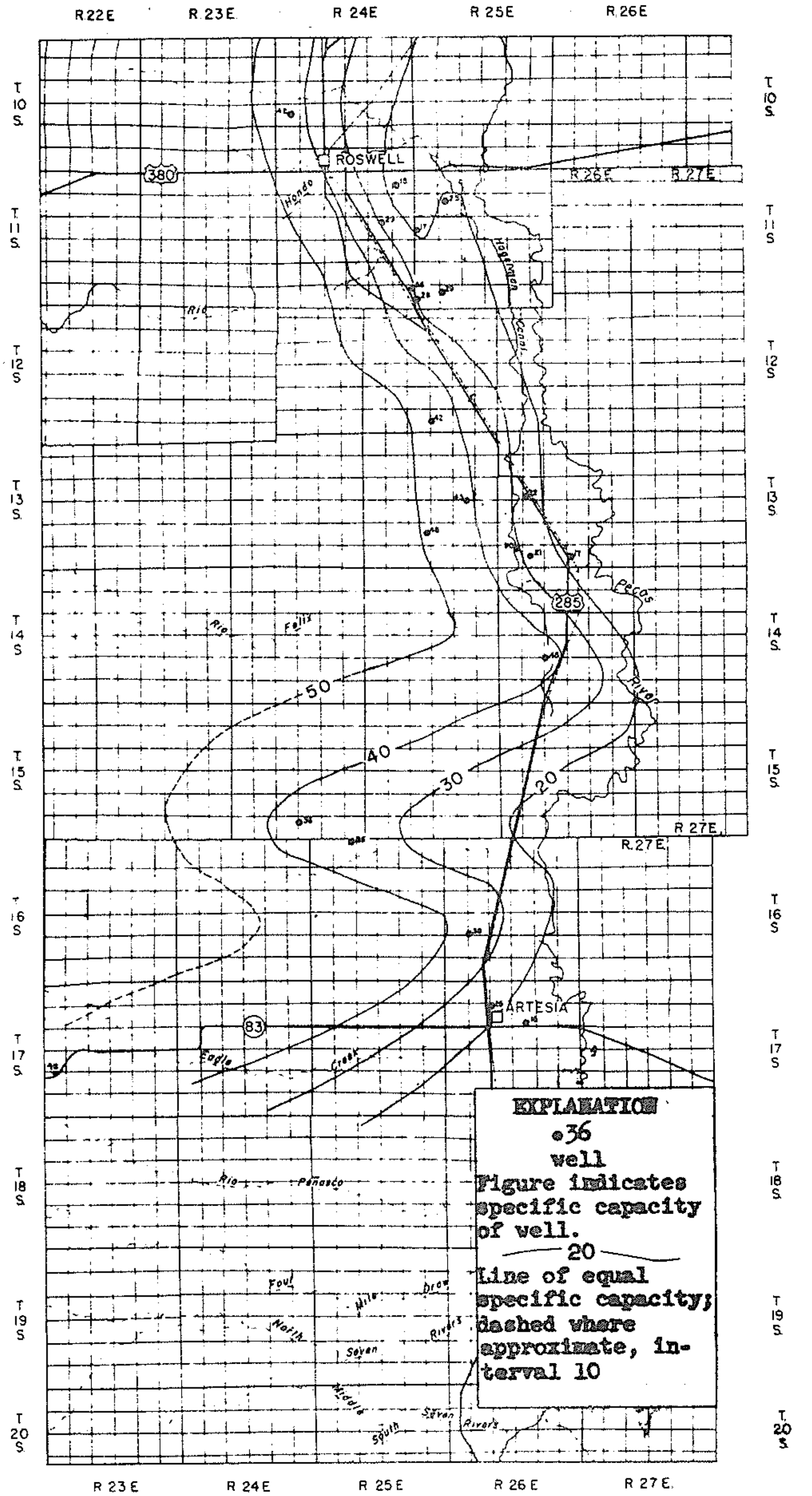


Figure 3.--Specific capacity of wells in the artesian aquifer in the Roswell basin.

The artesian aquifer was assigned a coefficient that indicated its property to take in or release groundwater -- referred to as the coefficient of storage. This feature of the aquifer, the capacity to take in or release water, was simulated in the analog model by using electrical capacitors that store electricity. Different size capacitors were used to indicate changes in the coefficient of storage.

The shallow aquifer was considered to be heterogeneous and to have no definite changes in either its property to transmit water or to store water. Consequently, only one size resistor and one size capacitor were used to represent coefficients of transmissibility and storage in the shallow aquifer. The confining units (Grayburg and Queen Formations) were considered to be heterogeneous; therefore, it too could be modeled using only a single coefficient of transmissibility, which was smaller than those used for either the shallow or artesian aquifers, and a single coefficient of storage, which was larger than those used for either the shallow or artesian aquifers.

A model must be programmed with accurate historic water-level changes in order to predict properly the future water-level fluctuations as a result of pumping or recharge. For the analog model of the Roswell basin, a hydrograph (graph showing water-level fluctuations) was used to determine changes in water levels in the artesian aquifer prior to 1964, Figure 4. Data collected by Fiedler and Nye (1933) in 1926 were used as a base point for determining later water-level changes in the artesian aquifer. It was assumed for the purpose of modeling that the artesian aquifer was in equilibrium in 1926 and that recharge equalied discharge. Water-level changes in the artesian aquifer between 1926 and 1964 were contoured, Figure 5.

Groundwater in the shallow aquifer generally was not developed before the New Mexico State Engineer closed the artesian aquifer to further development in 1933. The best and earliest data available for the shallow aquifer are given by Morgan (1938). Water-level changes in the shallow aquifer were contoured for the period 1938 to 1964, Figure 6.

Groundwater withdrawal by pumpage was computed for each year between 1926 and 1964 for the artesian aquifer and between 1938 and 1964 for the shallow aquifer, Figure 7. In addition, the base flow or the volume of water gained by the Pecos River between Acme and Artesia from 1938 through 1963 was considered to be discharge from the shallow aquifer, Figure 7. River-flow data were taken from a basic data report (Pecos River Commission, 1960) and additional data were obtained through verbal communication with Carl L. Slingerland, a member of the committee.

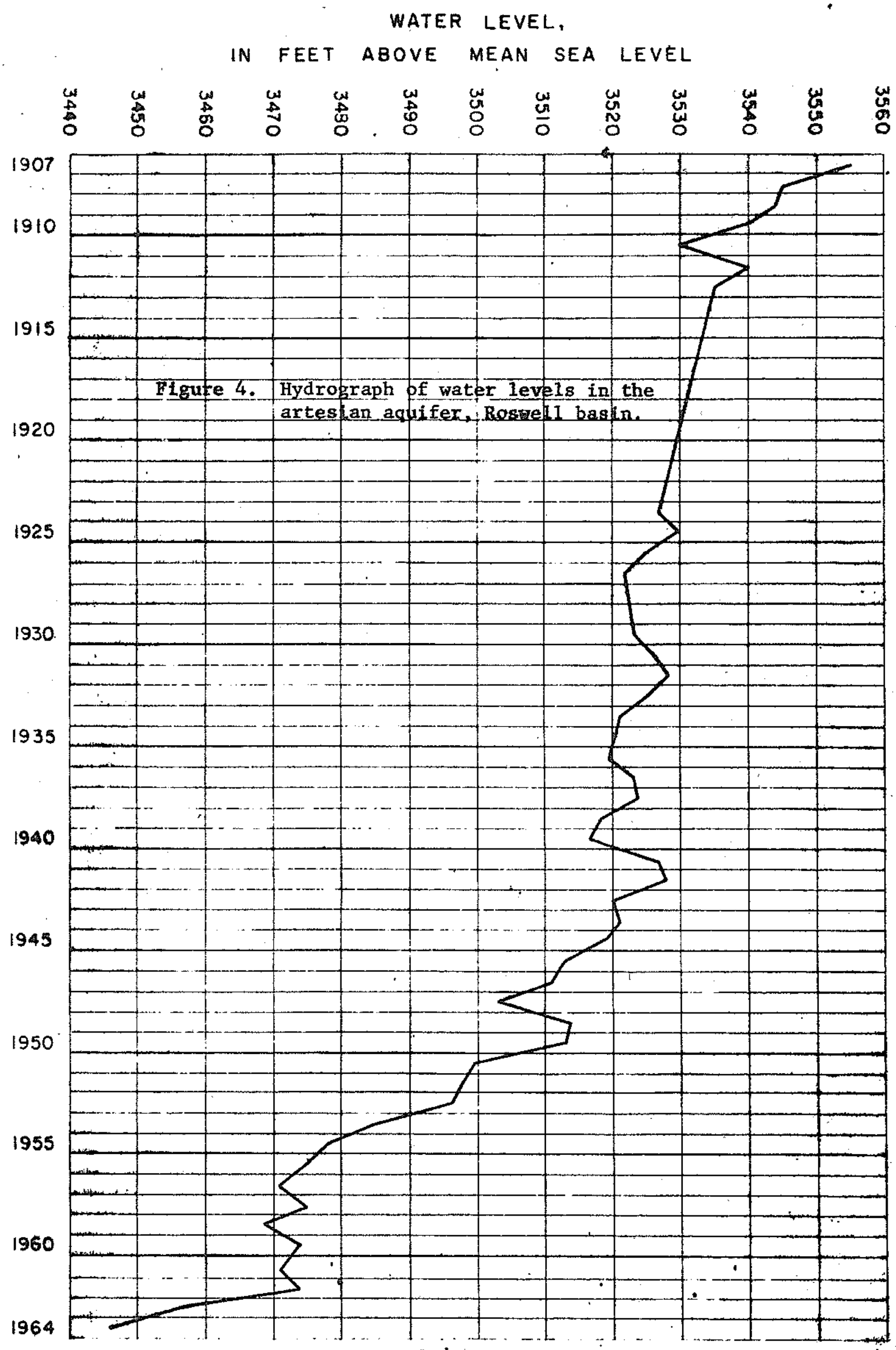


Figure 4. Hydrograph of water levels in the artesian aquifer, Roswell basin.

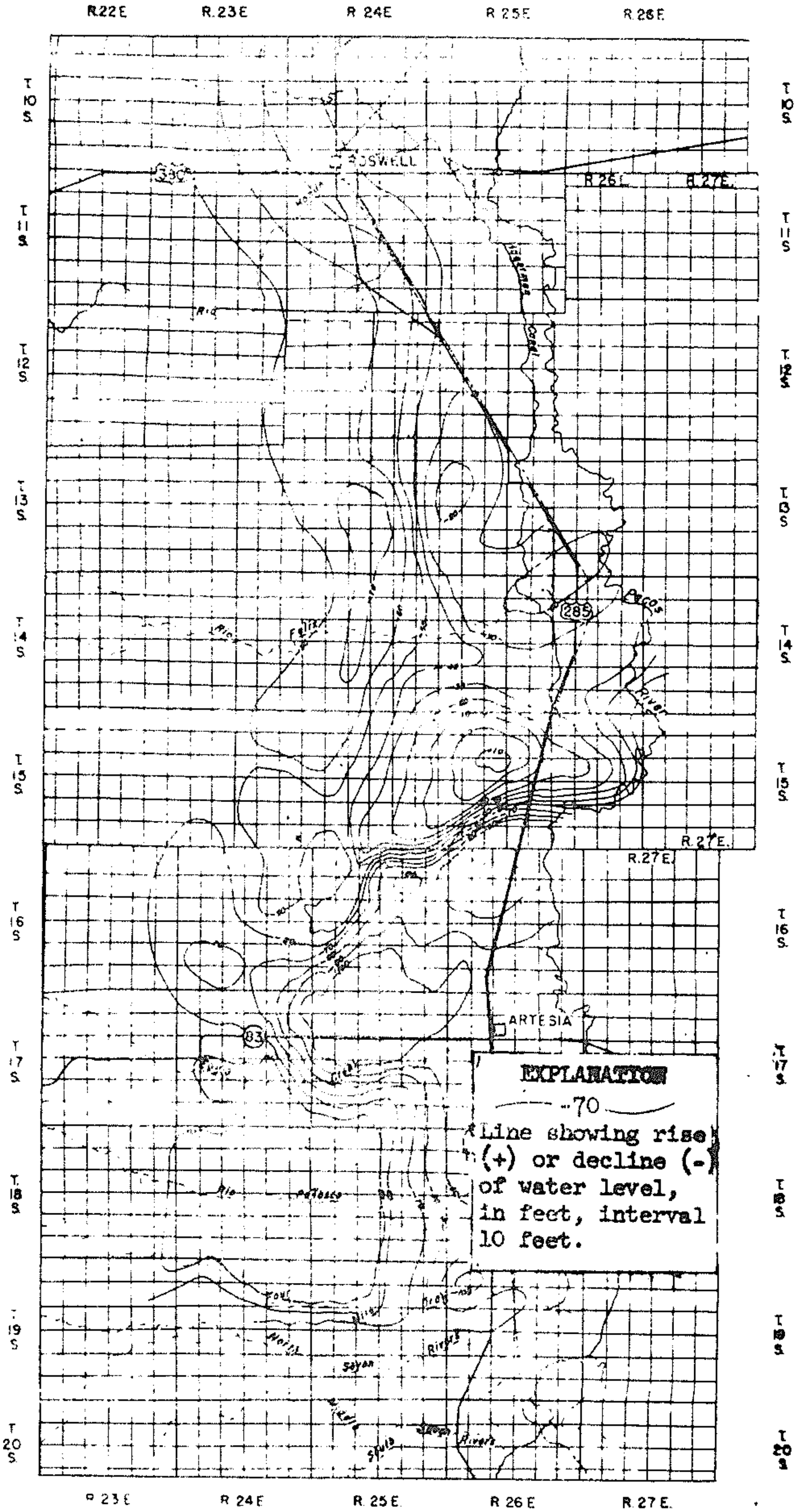


Figure 5.--Change of ground-water level in the artesian aquifer from 1926 to 1964 in the Roswell basin.

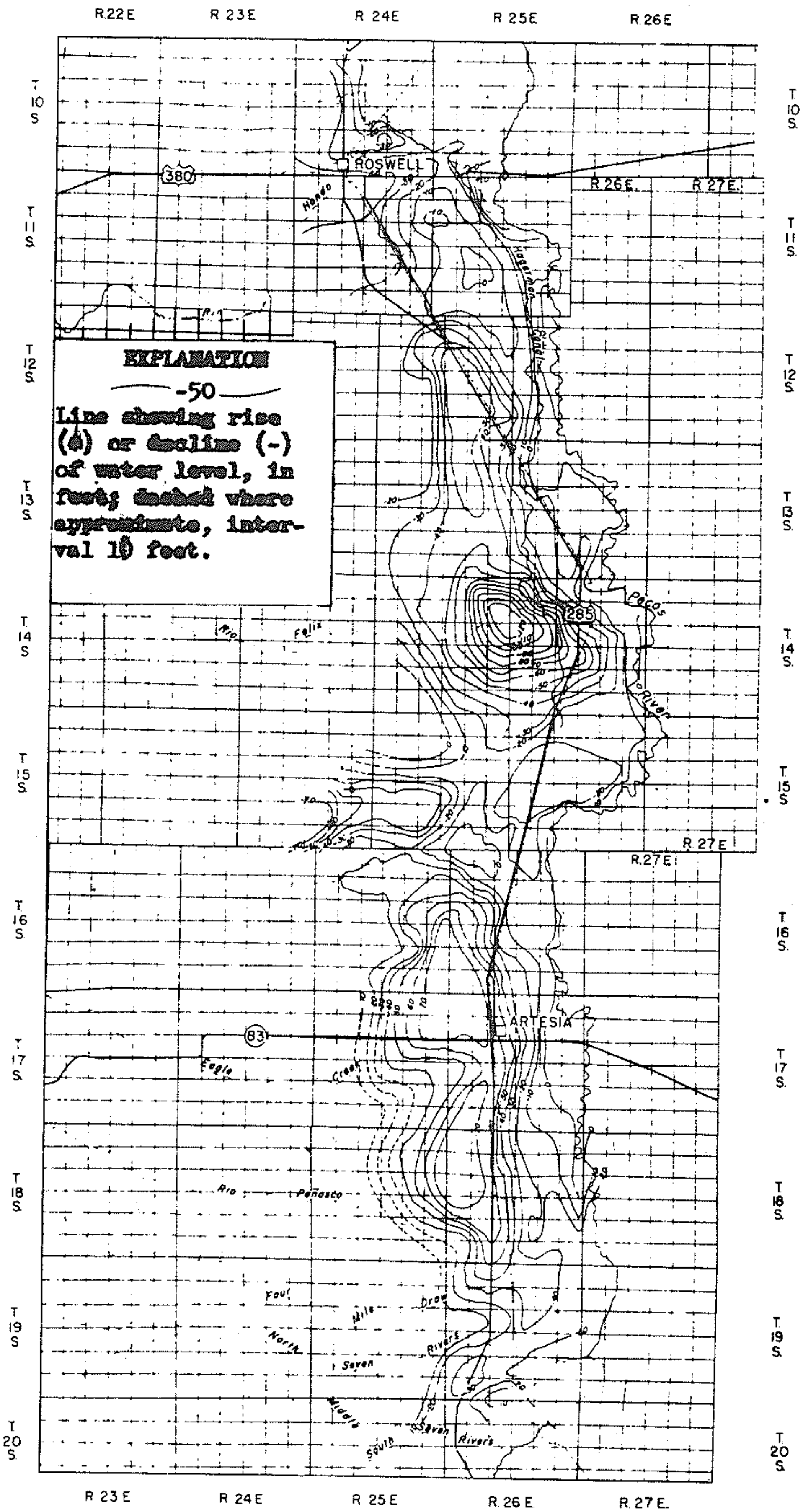


Figure 6.--Change of ground-water level in the shallow aquifer from 1958 to 1964 in the Roswell basin.

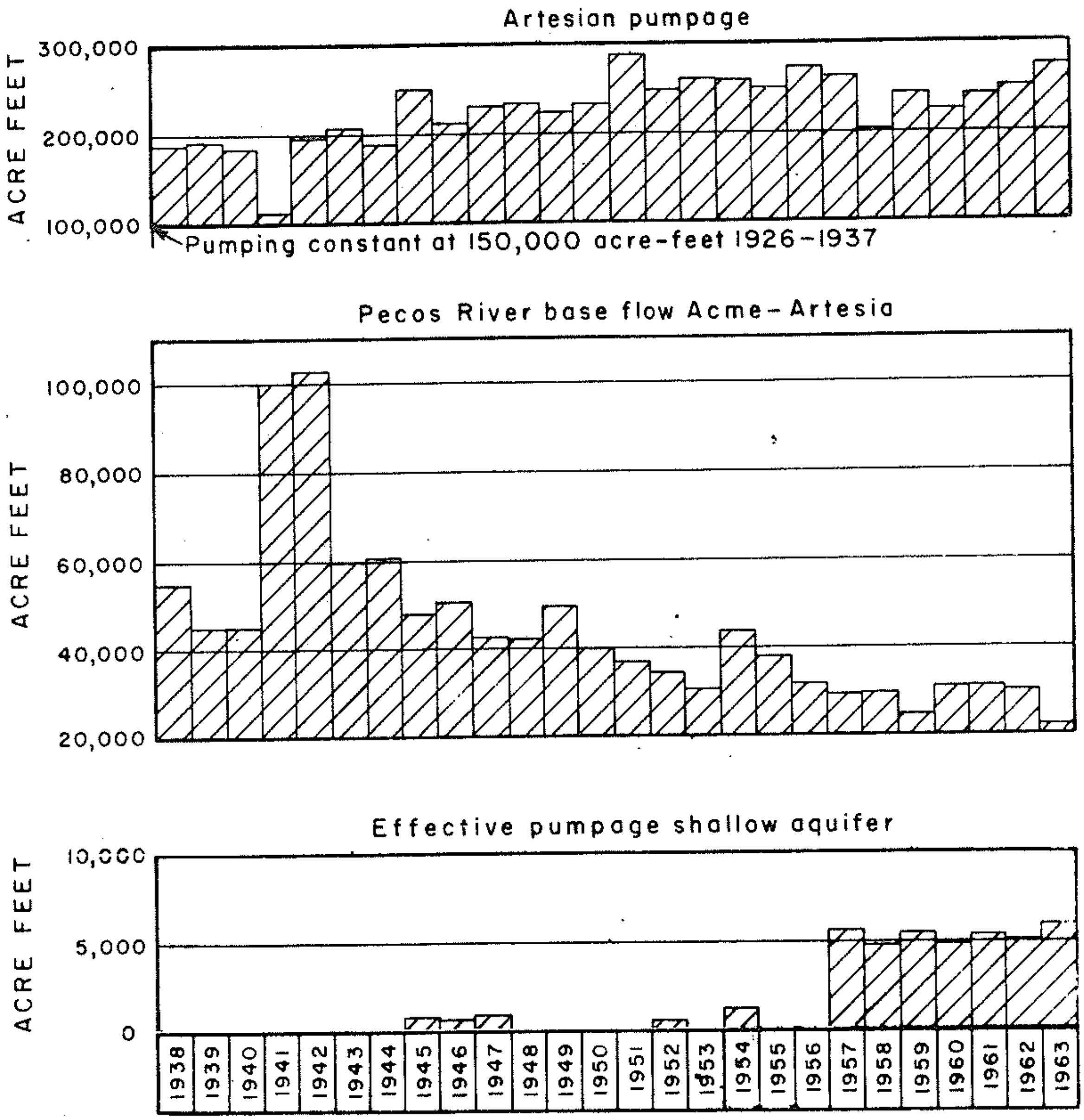


Figure 7.--Graph showing base flow of the Pecos River and ground-water pumpage from the shallow and artesian aquifers that were programmed into the analog model of the Roswell basin.

Owing to the great number of pumping wells in the basin, pumping centers representing the pumpage of surrounding wells were established for each aquifer, Figure 8. The pumping centers were located near major cones of depression in the water surfaces of the appropriate aquifers, and each center represents a percentage of the total groundwater discharged from the appropriate aquifer. The percentage of the total ground-water discharge was based on the calculated volume of groundwater pumped from each township. The volumes were calculated first by Mower (1960 and then through 1963 as part of this study. Pumpage programmed into the shallow and artesian aquifers in the model is shown in Figure 7.

Return flow from irrigation was assumed to recharge only the shallow aquifer. To account for this volume of recharge, shallow groundwater pumpage for any given year was reduced, first by a volume equal to 40 percent of the artesian pumpage for that year, and second by a volume equal to 40 percent of the gross shallow ground-water pumpage for that year.

Total annual recharge to the artesian system was assumed to be 236,500 acre-feet, the volume calculated by Fiedler and Nye (1933). This volume best represents long-term natural recharge to the artesian aquifer.

Vertical leakage from the artesian to the shallow aquifer across the Grayburg-Queen Formations was modeled as 70,000 acre-feet of water per year, the volume calculated by Fiedler and Nye (1933). Comparison of hydrographs of shallow and artesian wells for the period of record indicate vertical leakage to the shallow aquifer probably decreased until 1948, when vertical leakage stopped. Leakage from the artesian aquifer has been modeled as an increasing input to the aquifer since 1948 which reached a maximum of 70,000 acre-feet per year in 1954.

Ground-water discharge by springs discharing from the artesian aquifer around Roswell and Major Johnson Springs at the southern end of the basin was modeled at 166,500 acre-feet per year between 1926 and 1933, when it was assumed that all spring flow stopped. Consequently, as of 1933, 166,500 acre-feet of water per year became an input to the artesian aquifer to account for cessation of flow by the springs.

INTERPRETING THE ANALOG MODEL

The pumping of wells is simulated in the electric analog model by withdrawing electricity from the pumping centers. The simulated decline in the ground-water level caused by the "pumping" of electricity is read on an oscilloscope that measures changes in voltages in the model. The decline in voltage in the model is analogous to

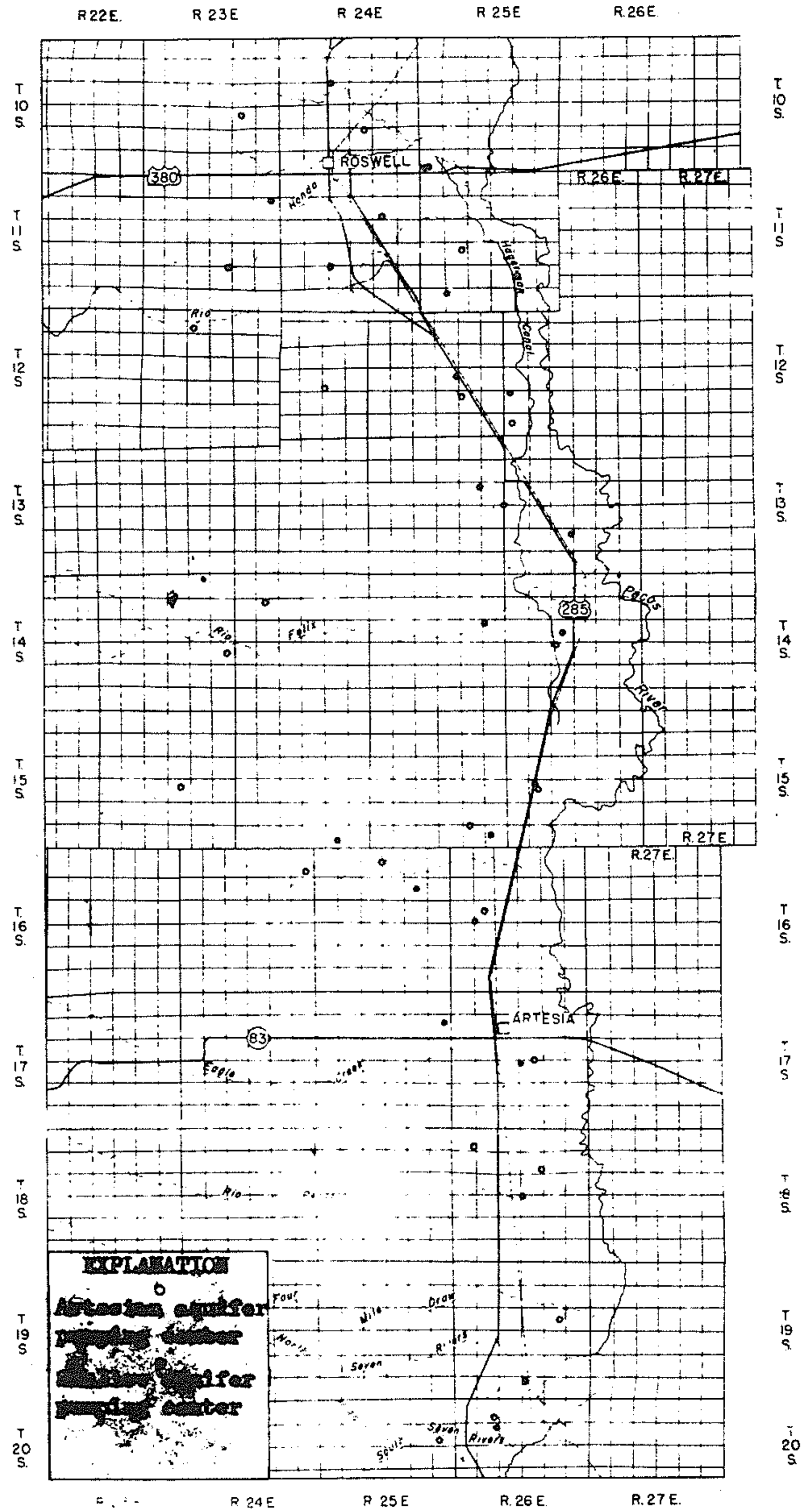


Figure 8.--Pumping centers for the shallow and artesian aquifers in the Roswell basin.

the decline in water level in the ground-water system. The oscilloscope has the scales of a graph on its screen so that feet of change of water level can be read directly for any unit of time desired.

The rates and patterns of past pumpage are programmed into the model by varying the electric current going into the model until it accurately reflects known historical data for the basin. Then various patterns and rates of pumping are also programmed into the model by varying the electric current going into and being taken out of the model. Water-level declines in the model are observed on the oscilloscope at random points and water-level decline maps are drawn. In this manner, the model can be manipulated to show quickly the long-term effects of pumping or recharging the aquifers throughout the Roswell basin.

REFERENCES

1. Fiedler, A. G. and S. S. Nye, 1933, "Geology and Ground-water Resources of the Roswell Artesian Basin, New Mexico," U. S. Geol. Survey Water-Supply Paper 639, 372 p., 46 pls., 37 figs.

2. Morgan, A. M., 1938, "Geology and Shallow-water Resources of the Roswell Artesian Basin, New Mexico," New Mexico State Engineer 12th-13th Bien. Rcpts., 1934-38, p. 155-249, 5 pls., 5 figs., (also published as N. Mex. State Engineer Office Bull. 5, 1938).

3. Mower, R. W., 1960, "Pumpage in the Roswell Basin, Chaves and Eddy Counties, New Mexico," U. S. Geol. Survey open-file rept., 88 p., 21 figs.

4. Pecos River Commission, 1960, Engineering Advisory Committee--Basic Data Report: Pecos River Commission.

SOIL TYPE AND SOIL CONDITION EFFECTS UPON VALUE OF WATER APPLIED FOR CROP PRODUCTION

B. C. Williams[1/]

Plant growth is limited over much of the earth's surface by either too much or too little water in the soil. Much of the water research in agriculture has been aimed at controlling the amounts of water present in the soil during given times of the year. In order to accomplish this, a better and more full understanding of soil-water relations is necessary. The understanding of these relations leads us to look at several conditions which affect the amounts of available water in the soil and its value in crop production. Among these are permeability of the soil, texture of the soil, structure of the soil, depth of the soil, and fertility of the soil - either native or added.

Permeability of the soil to water is essential if the root zone of the plant is to be supplied with water necessary for crop production. Permeability has been shown by Bodman (1) to follow a pattern of decrease upon wetting, then increase with additions of water, and followed by a slow decrease with further water additions. The overall decrease in water permeability of the soil was attributed to salt removal by the water and the subsequent dispersion, and rearrangement of the soil particles. Further work by Christiansen (2) and Greacen and Huon (3) showed that the increase in permeability at stage two was partly the result of removal of air entrapped upon wetting by water passing through the soil. This resulted in freeing pore space for the movement of water which had been blocked with air and gave increased permeability. The decrease in permeability was caused partly by increase in volume of the soil aggregates which is accompanied by a decrease in size of large pores. Also, Allison has shown that microorganism growth can restrict permeability by clogging pores of the soil. Other factors will affect permeability but it will suffice for us to say that permeability of the soil profile must be unrestricted if an adequate supply of water is to enter the root zone to be effective in crop production.

Among these other factors, affecting both permeability and amounts of available moisture retained by the soil, will be both texture and structure of the soil. Coarse textured, very sandy, soils usually are rapid in permeability to water having rates of water movement, called hydraulic conductivity, ranging from 5 to 10 inches per hour. Fine textured soils (heavy clays) range in hydraulic conductivities from .05 to 1/2 inch per hour. Similar hydraulic conductivities can

1/ Associate Professor, Agronomy Department, New Mexico State University.

be associated with very porous well granulated soils and soils with plate like or platy and columnar structures (particle arrangement) respectively.

The amounts of water available to plants as related to texture are shown in Table 1. From this index, it is possible to get some information that is useful to the irrigator in our area. The amounts of water per foot of soil should indicate the need for frequent light irrigations while the inverse is true for the fine textured soils.

In Table 2, the work of Heinonen shows some broad relationships of structure to the amount of available water for plant growth retained by the soil. In the soil groups a to c it was found that the increase in available water was the result of increased clay and silt content. For soil groups d to f the relationship was an increase in available water with a decrease in bulk density. Heinonen associated the decrease in bulk density with an increase in more open granular structure which resulted in greater quantities of available water being held by these soils. Such results have been reported by other research workers and lead to the conclusion that soil management practices such as good crop rotations have a definite effect upon water management practices for subsequent crop production. This effect is a result primarily of the effect of granular structure in the soil.

TABLE 1. A Rating of Available Moisture for Plant Growth by Soil Texture

Rating	Inches of Water/ Foot of Soil	Texture
Very low	$< .6$	Very coarse (coarse sands)
Low	.6 - 1.2	Coarse (loamy fine sand, sandy loam)
Medium	1.2 - 1.8	Medium (loam, fine sandy loam)
High	> 1.8	Fine (clay loam, clay, silt loam)

TABLE 2. Water Retained in the Surface Layer (5-15 cm) of Soils Under Pasture[1/]

Group	Bulk Density	Available Water
	g/cm^3	percent by volume
a	1.26	14.9
b	1.20	19.6
c	1.09	22.4
d	1.07	18.0
e	1.01	16.5
f	.73	23.3

1/ Part of average data of Heinonen, 1954, for 129 Finish soils from Marshall, Relations Between Water and Soil, 1959 (4).

The foregoing factors or conditions can be related to depth of the soil as seen in Figures 1 to 4. Figure 1 shows a soil of sandy loam texture with a depth of 8 to 10 inches over sand. The soil is permeable with a low water holding capacity. Adequately watered and heavily fertilized this soil produced the cotton plant we see in Figure 2. The yield on this crop was one-fourth bale of lint cotton per acre. In Figure 3, the depth of the same soil is seen to be 18 to 24 inches. Other practices with respect to water and fertilizing were the same as stated for the soil and cotton in Figure 1 and 2. This soil produced the cotton plants shown in Figure 4. The yield on this crop was 1.9 bales of lint cotton per acre. It can be noted in Figures 3 and 4 that no roots penetrated the sand beneath the surface soil. The abrupt change in pore space has created a barrier to air, water, and root penetration. This has resulted in restricted root volume and reduced yield of the crop. Similar patterns of crop response have been noted for crops of alfalfa and forage sorghum on this same field. Such findings throughout the world have resulted in a statement that, except for a few shallow rooted crops, the depth of surface soil should be more than 20 inches with no restrictive layers or abrupt breaks in texture if a near normal crop is to be produced. Most of our cultivated crops, when no restrictions are present, will have a root system that extends to 4 to 6 feet in depth.

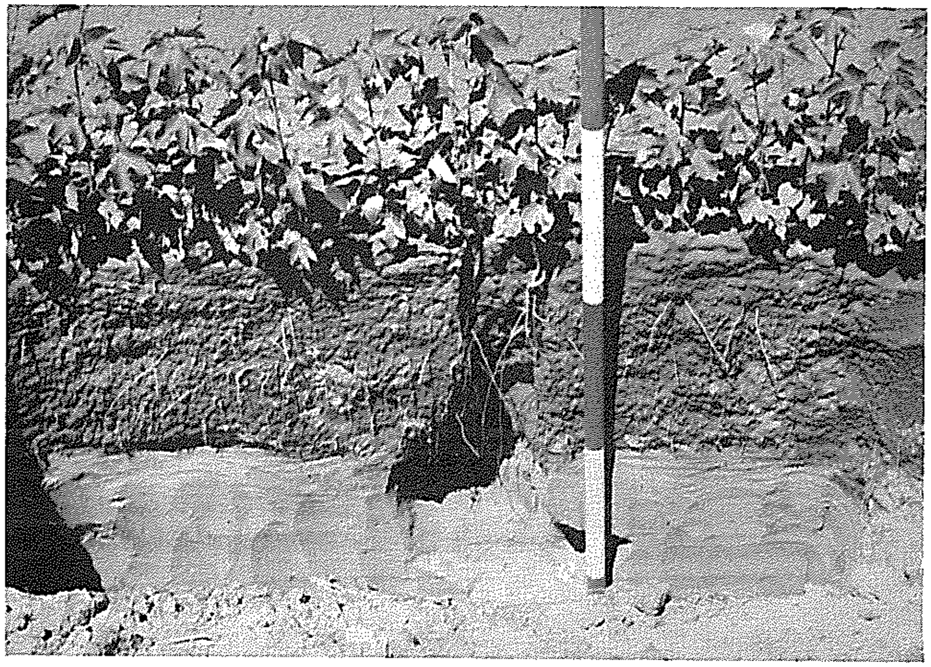


FIGURE 1. Shallow (8 x 10 inches) shallow loam soil over sand.

FIGURE 2. Cotton produced with adequate water and heavy fertilization on shallow sandy loam soil.

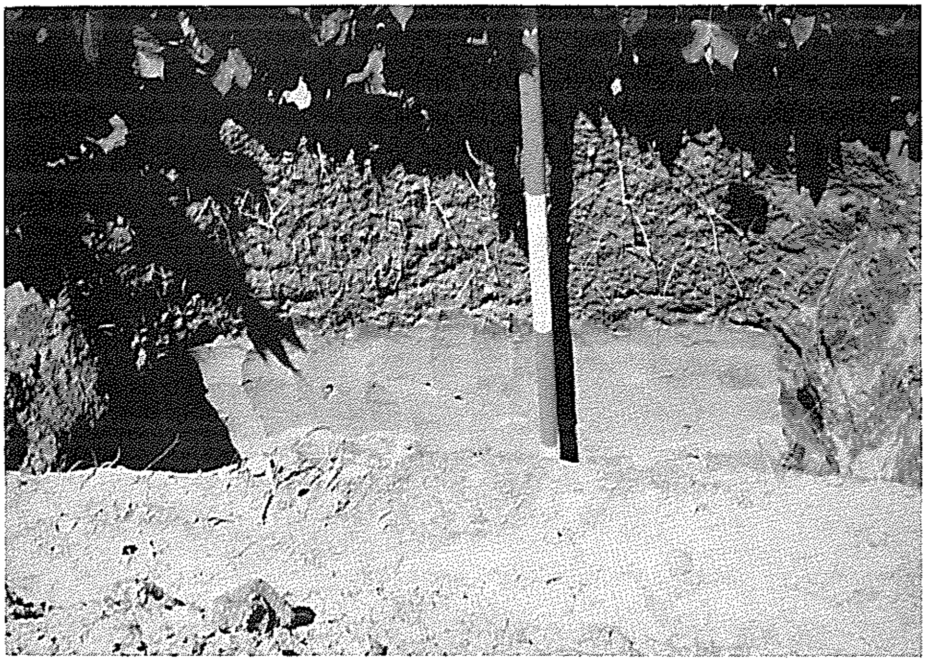


FIGURE 3. Medium depth (18 x 24 inches) sandy loam soil over sand.

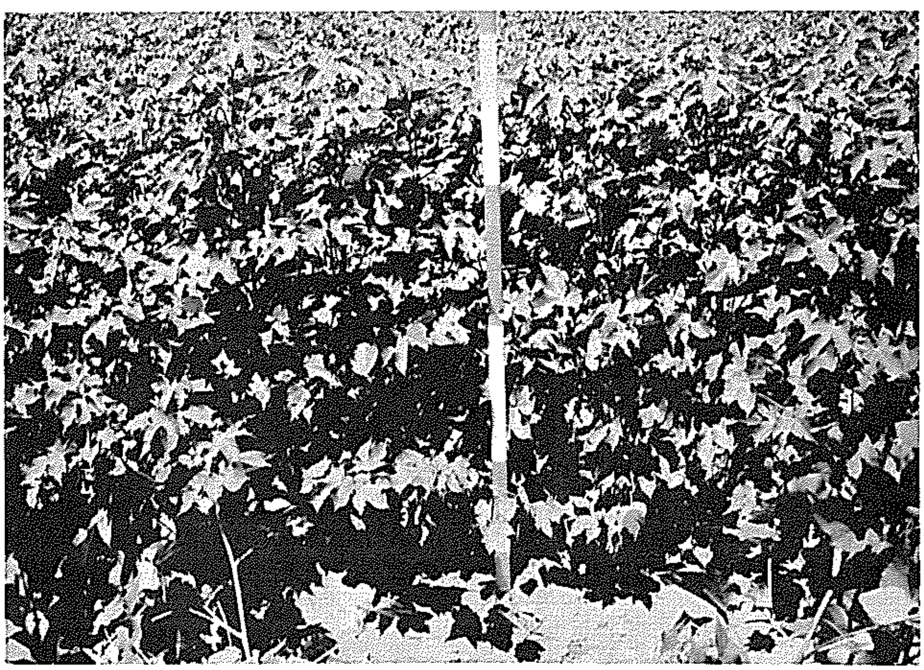


FIGURE 4. Cotton produced with adequate water and heavy fertilization on medium depth sandy loam soil.

On soils having good depth, permeability, medium to fine texture, and good structure several experiments have been conducted to obtain some information about crop response to fertilizers and water.

Table 3 reports work from Yuma, Arizona on alfalfa response to fertilizer and water. Here the data are reported to show the effect that increasing fertility of the soil has upon water use. Wet soils correspond to a suction less than 175 cm at a depth of 12 inches, medium treatment was a suction less than 600 cm at a depth of 18 inches, and dry treatment was a suction less than 800 cm at a depth of 36 inches. This experiment shows increased efficiency in water use by keeping the soil moist and by increasing the fertility level of the soil. These data on moisture treatments are comparable to those of E. G. Hanson at New Mexico State University.

Further effects of fertility on water use by crops can be seen in Table 4. These data show that although crops differ in the amounts of water required to produce a given amount of dry matter per acre they all respond to proper management. One evidence of the response is noted here in the reduction of inches of water required to produce a ton of dry matter when all factors are the same except proper fertilization. The fertilizer applied was 120-60-0, 60-30-0, 200-50-0, and 160-80-0 for barley, wheat, common sweet sudan, and sumac respectively. These rates of available nitrogen and phosphate were the most effective in increasing yield of the respective crops. The yields for the crops were 48 and 92 bushels of barley per acre, check and fertilized respectively; 26 and 47 bushels of wheat per acre, check and fertilized respectively; 39 and 56 tons of sudangrass silage per acre, check and fertilized respectively; and 34 and 48 tons of sumac silage per acre, check and fertilized respectively. These data show that increasing soil fertility increases the efficiency in use of a given quantity of water. The efficiency may double which can mean that proper use of fertilizers may result in nearly double the yield of crop for the same amount of water.

In summary it can be said that for most efficient use of water we need a soil which is deep, with good structure and uniform texture, with good permeability and drainage, with good aeration, with a large fraction of available moisture held at low suction, and having a high fertility level. In such a soil as we see in Figure 5, a plant can produce deep, dense roots which can effectively remove both water and nutrient sufficient to give increased value to the water used. If these conditions are present except for depth as we can see in Figure 6, then the value of water is reduced and agriculture is in trouble.

TABLE 3. The Amount of Water Required to Produce One Ton of Alfalfa Hay for Various Moisture and Fertility Treatments at Yuma, Arizona[1/]

Pounds P_2O_5/A	Inches of Water/Ton of Hay Wet	Medium	Dry
100	10.67	11.60	12.81
200	8.79	9.11	10.49
400	7.45	8.20	8.80
600	6.82	7.45	8.86

1/ Data of Stanberry, Converse, and Haise in Marshall's Relations Between Water and Soil, 1959 (4).

TABLE 4. Effects of Fertility upon Water Used in Crop Production[1/]

	Inches of Water per Ton of Dry Matter			
	Barley	Wheat	Common Sweet Sudangrass	Sumac
No fertilizer	13.0	13.4	7.0	3.9
Fertilized	6.2	6.7	4.2	2.5
Irrigation plus rainfall for growing season	28.45		38.5	

1/ Data of Williams, 1962 and 1963 (5).

SUMMARY

To obtain best value of water use in crop production a soil should be deep, have more than 20 inches of good surface soil; should have good structure; be well drained and aerated; and have high fertility.

Reduced depth of surface usually results in reduced yield with higher amounts of water required for this yield.

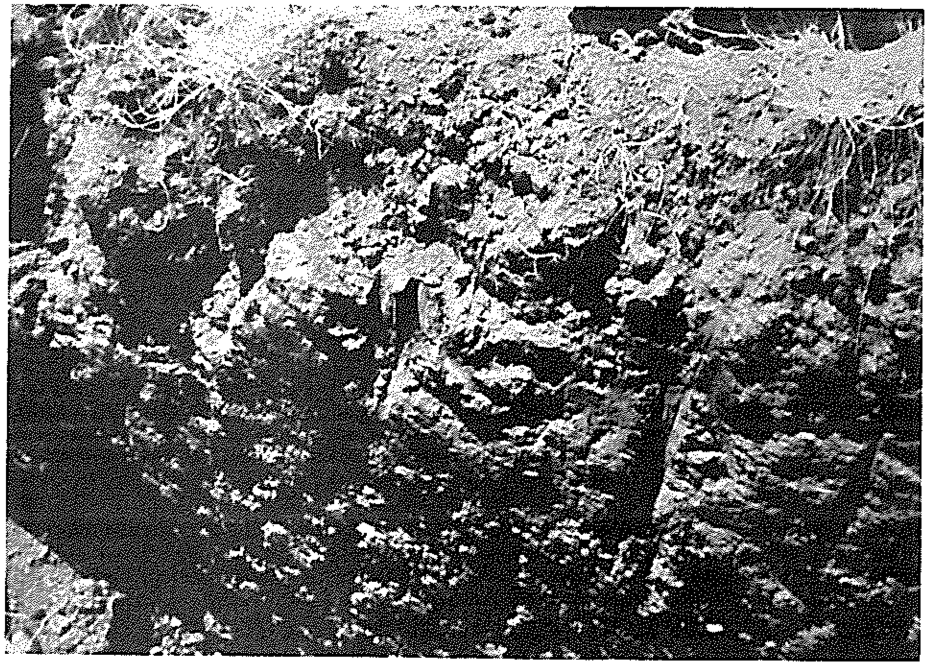


FIGURE 5. Deep, uniform soils such as these are best for deep dense root penetration for effective moisture and nutrient removal by plants.

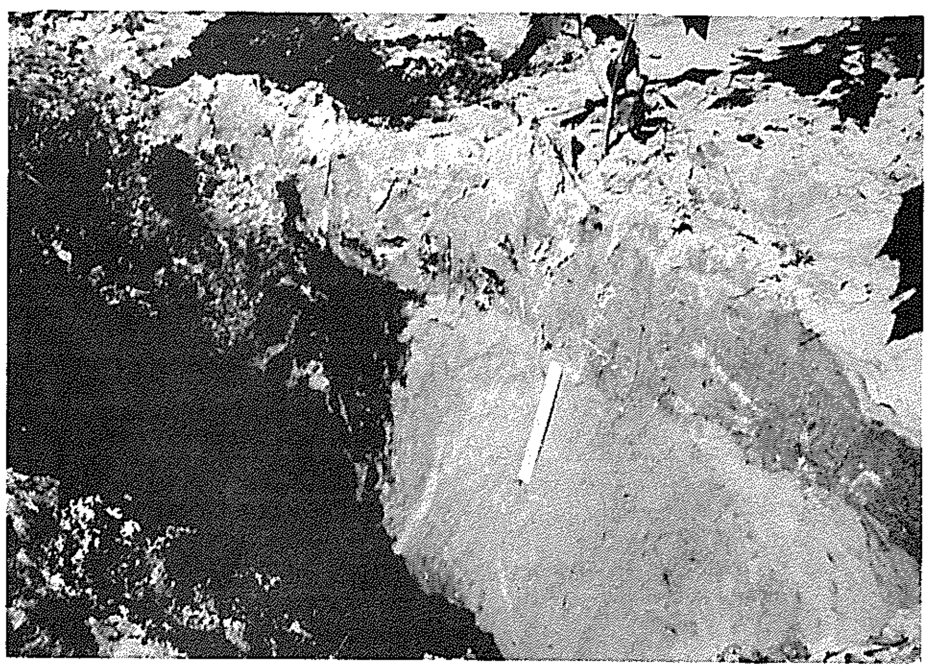


FIGURE 6. Lack of depth in soil prevents efficient use of nutrient and water by plants by restricting root growth.

Poor structure results in poor drainage and aeration with reduction in yields and increased water requirement for this yield.

Increasing fertility level of the soil usually results in decreased water use per given amount of crop produced. This reduction may be as much as one-half. This would mean that proper use of fertilizers can result in twice the yield for the same amount of water.

REFERENCES

1. Bodman, G. B., "The Variability of the Permeability 'Constant' at Low Hydraulic Gradients During Saturated Water Flow in Soils," Soil Sci. Soc. Amer. Proc. 2:45-53, 1938.

2. Christiansen, J. E., "Effect of Entrapped Air Upon Permeability of Soils," Soil Sci. 58:355-365, 1944.

3. Greacen, E. L. and A. N. Huon, "Microscopic Changes in Soil Aggregates During Permeability Tests," Aust. J. Agric. Res. 4:184-192, 1953.

4. Marshall, T. J., "Relations Between Water and Soil," Com. Bur. Soils, Tech. Com. 50, 1959.

5. Williams, B. C., "Rates of Fertilizer for Forage Crops," New Mexico Agric. Exp. Sta. Res. Rpt. 71, 1962.

6. Williams, B. C., "Fertilizer Rates for Spring Barley and Wheat," New Mexico Agric. Exp. Sta. Res. Rpt. 85, 1963.

CROP PLANTS - WATER USE AND SALT TOLERANCE

Arden A. Baltensperger[1]

This is a discussion and presentation of data regarding the amount of water used by crop species and water used by different plants within a species. Salt tolerance among and within crop species is also discussed. Only selected references are used for illustration and therefore many references that relate to this subject are omitted. The inherent plant differences are of primary concern here.

Consumptive use (evapotranspiration) values have been measured and estimated for various crops by several methods. These values give some indication of water needed by various species to maintain growth and development during a growing season. Since these figures include only estimations of evaporation and transpiration losses and do not include other necessary losses, they should be used only as a guide as to which crops need more of less water. Table 1 shows measured consumptive use values for several crops grown at different locations.(2)

These measured consumptive use values provide an indication of the relative water need of some crop plants. However, it would be desirable to have such values for a single location. Computed consumptive use values are available by locations. An example is shown in Table 2. These computed values are considered for Deming, New Mexico and show a relationship of crops to water use similar to Table 1. (3)

Even though these consumptive use values do not include necessary water "loss" such as leaching, conveyance and application, they may help decide the crop to be grown if water is limiting. For more detailed information on consumptive use of water by crops and how this information can be applied to irrigation practices see Blaney and Hanson (3) and Erie, French and Harris (5).

More realistic measurements of actual water necessary to produce high yields are demonstrated by unpublished data from Professor Hanson (6). Alfalfa responded as shown in Table 3 to high, medium, and low irrigation levels. This experiment was conducted on a highly productive soil with adequate fertility for the expression of high yield.

Even though the highest yields were obtained from the high irrigation treatment, it appears very important that pounds of alfalfa

1/ Department Head and Professor, Agronomy Department, New Mexico State University

TABLE 1. Examples of Seasonal Consumptive Use of Water by Various Irrigated Crops as Determined by Field Experiments in Western United States (2)

	Growing Season or Period		Consumptive Use	Location
	Dates		Total Inches	
Alfalfa	4/10	10/31	38.0	State College, N.Mex.
Cotton	4/1	10/31	26.9	State College, N.Mex.
Citrus Trees	4/1	10/31	20.6	Los Angeles, Calif.
Corn	3/15	7/15	20.0	Mercedes, Texas
Potatoes	5/1	9/30	19.9	San Luis Valley, Colo.
Sm. Grain (sp.)	5/25	8/21	16.6	Vernal, Utah
Beans	6/1	9/30	14.4	Davis, California

Note that the consumptive use values shown here consider only the growing season and do not take into account water necessary for maintaining perennial plants during the winter.

TABLE 2. Example of Computation of Seasonal Consumptive Use for Crops Near Deming, New Mexico (3)

Crops	Length of Growing Season or Period		Consumptive Use Amount
			Inches
Alfalfa	4/15	10/29	36.01
Cotton	4/15	10/29	26.27
Corn	6/1	10/15	23.11
Sorghum	6/1	10/15	21.57
Sm. Grain (sp.)	3/10	7/1	15.58
Beans (dry)	6/15	9/15	13.15

TABLE 3. Average Alfalfa Yield by Irrigation Treatments in Relation to Yield per Acre-Inch of Water Applied in 1961, 1963, and 1964 - University Park, New Mexico (6)

Irrigation Treatment	Water Applied*	Yield	Yield/In. of Water Applied
	Inches	Tons/Acre	Pounds
High	89	12.1	272
Medium	82	11.0	268
Low	68	8.8	259

*Including rainfall

produced per inch of water applied is not lower for the medium and low irrigation treatment. Professor Hanson has summarized this as an indication that if water is limiting for alfalfa forage production, it may be advisable to reduce acres rather than attempt to apply a low amount of water to more acres.

More data such as shown in Table 3 for specific crops at several locations are desirable to determine the water necessary to allow a crop variety to express its inherent maximum water use efficiency.

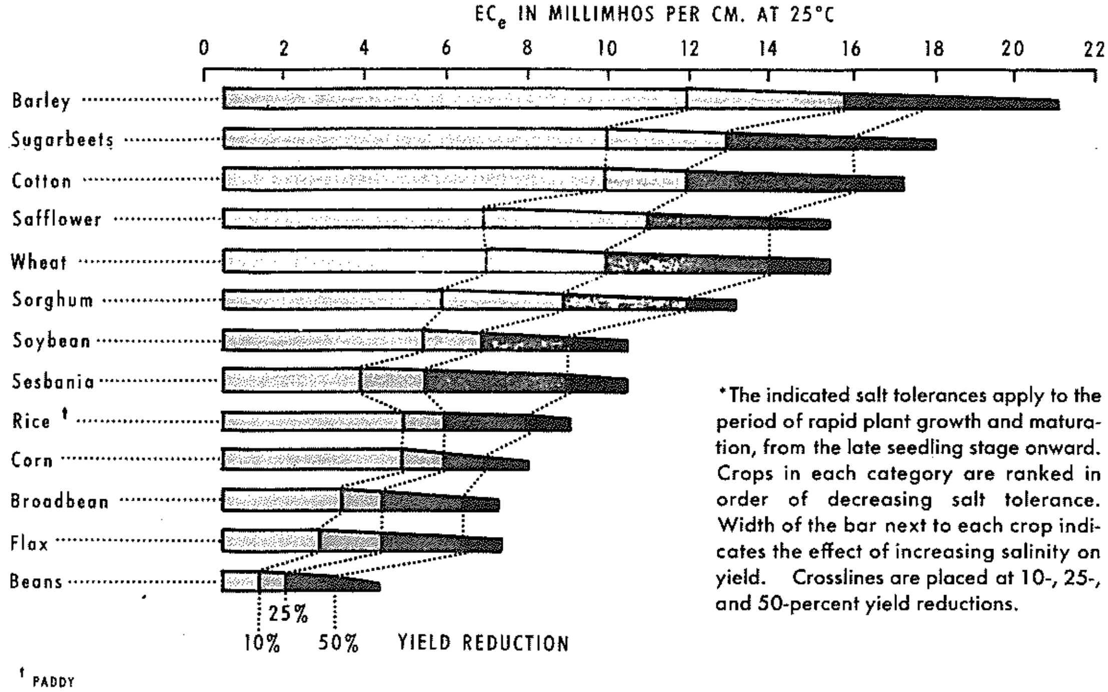
Of less interest to producers, but important to agronomists is - can strains be developed which use water more efficiently? There are indications this is possible simply by breeding for increased yield. Table 4 shows large differences among orchardgrass genotypes for units of water necessary to produce a unit of dry matter (7). This greenhouse experiment showed a high, negative correlation between water requirement and yield. However, as water becomes more valuable, it may be necessary to determine if agronomically desirable strains can be selected for higher water use efficiency without changing yield.

That certain crop plants are less sensitive to high concentrations of soluble salts in the root medium (or salt tolerant) is well known. Tables 5 and 6 graphically show the relative salt tolerance of field crops and vegetable crops respectively (1). Difference among crops are very important to producers contending with high concentrations of soluble salts. However, another point of interest is the inherent differences that may exist among strains or genotypes for salt tolerance. Several workers have measured the response

TABLE 4. The Water Requirement (X/Y), Dry Weight Yield in Grams (Y), and Water Used per Plant in Grams (X). The Data are from 16 Genotypes of Orchardgrass and are Based on 66 days Growth in Gallon Cans (7)

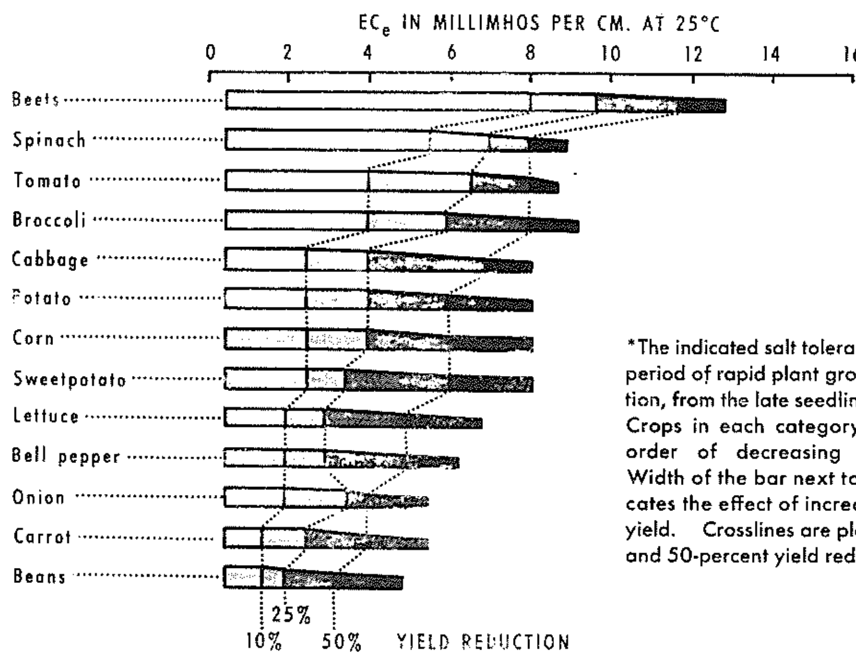
Genotype	Number of Replications	Water Requirement (X/Y)	Yield (Y)	Water Used (X)
8	23	670	5.09	3411
17	24	753	4.35	3272
16	24	764	4.28	3271
7	19	769	3.18	2447
12	22	776	3.60	2798
15	24	792	3.97	3147
10	23	799	3.49	2790
6	24	808	3.50	2827
9	24	835	3.74	3122
5	24	836	3.45	2889
2	23	843	3.44	2899
14	21	891	2.61	2329
1	23	901	3.08	2769
11	22	958	3.01	2887
3	24	995	3.01	2999
4	23	1082	2.79	3016
Mean		842	3.54	2930

TABLE 5. SALT TOLERANCE OF FIELD CROPS* (1)



*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50-percent yield reductions.

TABLE 6. SALT TOLERANCE OF VEGETABLE CROPS*(1)



*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50-percent yield reductions.

of strains within species for tolerance to high salt. For example, Dewey (4) working with wheatgrass and Tromble (8) working with bermudagrass and blue panicgrass found large differences among strains for germination percentage in high salt content solutions. Figure 1 and Figure 2 graphically show the large germination salt tolerance differences found in blue panicgrass and bermudagrass. Similar data has been collected for cotton, alfalfa, and other crops. Such data indicate it should be possible to breed for increased salt tolerance for the germination stage of growth. However, to the author's knowledge, no salt tolerant varieties have been released as a result of concentrated selection for this characteristic. If failure to get a stand under high saline conditions becomes economically more important, it may be necessary to develop varieties with higher germination salt tolerance. Although mature plant salt tolerance may not be highly correlated with germination salt tolerance, there are indications that salt tolerance at the mature plant stage can also be increased by selection.

SUMMARY

Consumptive use measurements are available or can be computed to serve as a guide to relative water use by crop species. However, more research is needed to determine the irrigation level necessary to give the greatest water use efficiency for specific crops grown under specific environments.

Crop response to various concentrations of soluble salts is relatively well known. The performance of strains and genotypes within a species to high concentrations of salts is less well known. However, data now available for several species indicate it should be possible to breed for increased salt tolerance, especially in the germination stage of plant growth.

REFERENCES

1. Berstein, Leon, "Salt Tolerance of Plants," U. S. Department of Agriculture, Inf. Bull. 283, 1964.

2. Blaney, H. E. and W. D. Criddle, "Determining Consumptive Use and Irrigation Water Requirements," U. S. Department of Agriculture, Agriculture Research Service Tech. Bull. 1275, 1962.

3. Blaney, H. E. and E. G. Hanson, "Consumptive Use and Water Requirements in New Mexico," New Mexico State Engineer, Santa Fe, New Mexico, Tech. Rept. 32, 1965.

4. Dewey, D. R., "Salt Tolerance of 25 Strains of Agropyron," Agron. J. 52:631-635, 1960.

Fig. 1. A graphic comparison of the mean adjusted germination percent of each of the 15 accessions of blue panicgrass at three salt concentration levels (8).

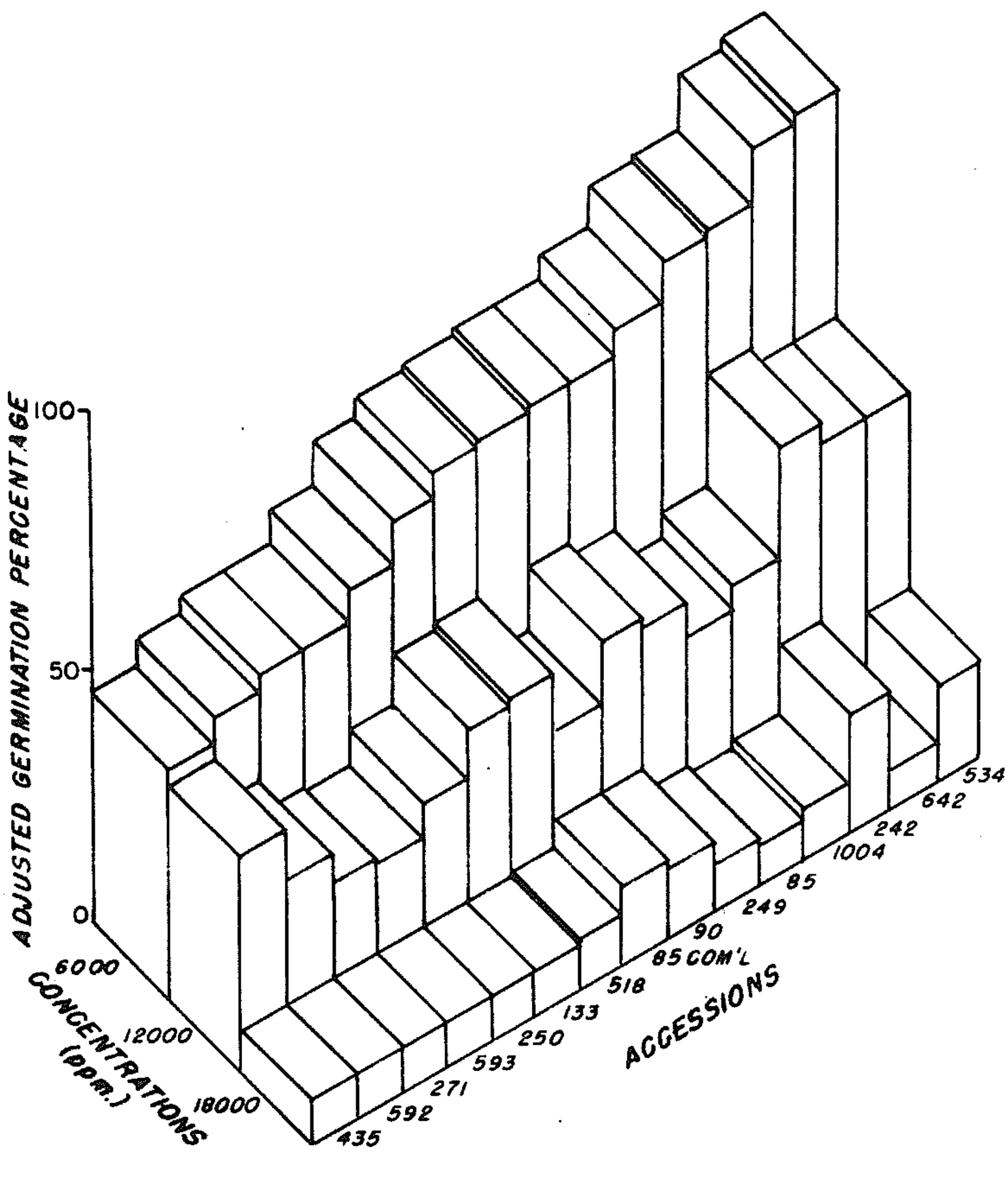
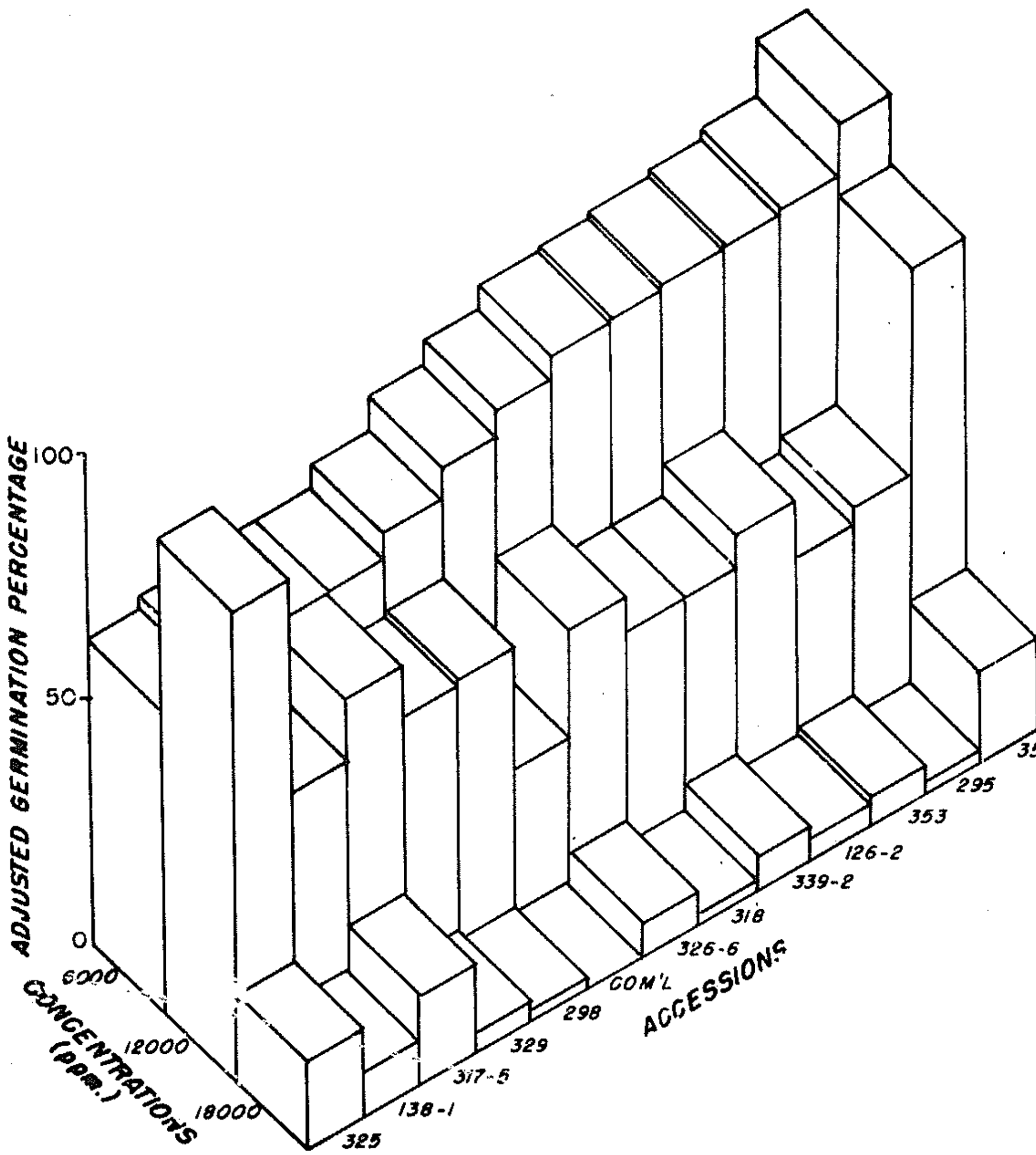


Fig. 2. A graphic comparison of the mean adjusted germination percent of each of the 13 accessions of bermudagrass at three salt concentration levels (8).



5. Erie, L. J., O. F. French, and Karl Harris, "Consumptive Use of Water by Crops in Arizona," Arizona Agricultural Experiment Station Tech. Bull. 169, 1965.

6. Hanson, E. G., "Influence of Irrigation Practices on Alfalfa Yield and Consumptive Use," Manuscript in preparation.

7. Keller, W., "Water Requirement of Selected Genotypes of Orchardgrass, Dactylis glomerata," L. Agron. J. 45:622-625, 1953.

8. Tromble, J. M., "A Seed Germination Study of the Salt Tolerance of Cynodon dactylon, (L.) pers. and Panicum antidotale retz.," University of Arizona Library, 1963.

WATER QUALITIES AND NEEDS IN RELATION TO CROP YIELDS

H. E. Dregne[1/]

Evaluation of water quality from the standpoint of irrigation agriculture frequently has been attempted without regard for soil, crop, climate, and management conditions where the water will be utilized. A natural consequence of this approach has been that standards for salinity, sodium, and boron, the three most important chemical characteristics of irrigation water, have been set at the lowest concentration levels that can be considered safe under the worst combination of conditions. In practice, irrigation waters that do not meet these high-quality standards have been used successfully for decades when other conditions are favorable. Numerous examples of this fact could be cited in the Southwest, alone, and in particular in southern New Mexico and west Texas.

Attempts to develop a water classification that actually reflects the interrelations of water, soils, crops, and climate, and that would be useful to farmers in a local area, have led to the setting of different quality standards in different areas. We have done that for New Mexico by establishing three sets of standards, and the El Paso Valley experiment station has devised another for west Texas. However useful these local standards may be, they are based upon average conditions that may or may not be representative of conditions on an individual farm. The purpose of this paper is to point out some of the factors besides the chemical characteristics of irrigation water that determine whether a water is or is not suitable for continued and successful use.

Table 1 is an example of a conventional set of water quality standards that attempts to show what constitutes "satisfactory" irrigation water. It is patterned after quality standards for potable water, where the underlying assumption is that water coming within the established limits is safe to use under all but exceptional conditions. The principal defect in this type of classification system is that it implies that water exceeding these limits is unsatisfactory, whereas such, frequently, is not the case. If it were true, farmers in the lower Pecos Valley would have been out of business years ago. As with any classification system, the limits set forth in Table 1 must be used with a strong dose of common sense, based upon knowledge of when exceptions can be made safely.

The four remaining tables show some of the soil, crop, climate, and management factors that should enter into the evaluation of water quality.

Professor, Agronomy Department, New Mexico State University.

Two soil conditions are of primary importance in determining whether a salt, sodium, or boron problem will develop when a particular water is used, Table 2. They are soil permeability and depth to a water table. For soil permeability, the desirable condition is one where the permeability to water exceeds one inch per hour. If the permeability is less than that, a problem won't necessarily arise, but it indicates that care should be taken to assure that salts do not accumulate as a result of inadequate leaching. A high-water table is a hazard because water can move up to the soil surface, be evaporated, and leave behind the salts it carried. The likelihood that this will happen is quite small if the water table is more than five feet below the surface.

Plant tolerance to salts, sodium, and boron varies widely among species. Table 2 presents suggested limits for desirable conditions. If an irrigation water contains less salt, sodium, or boron than a plant is capable of tolerating, it means that the chances are good that the water can be used satisfactorily. Cotton, barley, and sugar beets are representative of plants that are included in the "desirable" range of tolerance for salt and sodium; sugar beets and alfalfa are highly tolerant of boron.

An often-overlooked factor affecting suitability of water for irrigation is the climate of the area. Salt problems, as an example, are less serious in cool regions than in hot, dry regions, at the same salt level in the soil. Greater evaporation and transpiration, as well as temperature differences, account for the variation in response. The climatic factor is considered in Table 4 in two ways: evaporation measured from a Weather Bureau pan, and amount of soil leaching by rainfall. Pan evaporation is the resultant of the effect of humidity, temperature, and wind movement, all of which affect plant transpiration, too. Soil leaching by rainfall must be evaluated for those cases, such as in winter rainfall areas of the Pacific Coast, where much or all of the salt that accumulates in the soil in summer is leached out in the winter. When that happens, highly saline water may be able to be used without harmful results.

Other factors, in addition to soil, crop, and climate, are important for water quality evaluation under a particular set of conditions. Three of these are the quantity of water available, the irrigation method, and the completeness of land leveling, Table 5. Water quantity, meaning water supply, determines whether there is enough water for leaching excess salts, sodium, and boron. In a water-deficient area, soil problems can arise rapidly, even when all other conditions are favorable, if a little water must be spread over a lot of land. Among the principal management factors, border irrigation is likely to cause the least increase of salts, double-row beds are less desirable, single-row beds even less desirable, and sprinkler irrigation with saline water is the most hazardous irrigation method. Lastly, land leveling must be evaluated. In the final analyses, whether or not land is properly leveled to avoid high spots may well be the most important factor of all in determining what the odds are for salt problems arising. Certainly, the possibility of using saline water with success on a poorly leveled field is very low.

Putting all these factors together into one water quality classification system has not been done. Some progress is being made, and we hope to have a reasonably satisfactory classification worked out before long. In the meantime, we can use the presently established criteria as rough guides.

TABLE 1. Water Quality Standards for Irrigation

	Satisfactory Water
Salinity, EC x 10^6	less than 750
Sodium-adsorption-ratio	less than 10
Boron, ppm	less than 0.3
Residual sodium carbonate, me/1	less than 1

TABLE 2. Soil Factors of Importance in Water Quality Evaluation

Factor	Desirable Condition
Soil permeability (water)	more than 1.0 inches per hour
Water table	more than 5 feet below soil surface

TABLE 3. Plant Factors of Importance in Water Quality Evaluation

Factor	Desirable Condition
Salt tolerance	tolerates $EC_e \times 10^3$ more than 12
Sodium tolerance	tolerates ESP more than 50
Boron tolerance	tolerates boron concentration in irrigation water of more than 4 ppm

TABLE 4. Climate Factors of Importance in Evaluating Water Quality

Factor	Desirable Condition
Pan evaporation	less than 100 inches per year
Rainfall	sufficient to leach soil to depth of 5 feet

TABLE 5. Other Factors of Importance in Evaluating Water Quality

Factor	Desirable Condition
Quantity of water available	sufficient to meet leaching requirement
Irrigation method	border
Land leveling	no high spots