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New Mexico Water Resources Research Institute

P. O. BOX 3167 NEW MEXICO STATE UNIVERSITY

LAS CRUCES, NEW MEXICO 88001

WATER IN LAND USE PLANNING

PROCEEDINGS OF THE

SEVENTEENTH ANNUAL NEW MEXICO WATER CONFERENCE

NEW MEXICO STATE UNIVERSITY

LAS CRUCES, NEW MEXICO

1972

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PREFACE

The Seventeenth Annual New Mexico Water Conference was held at the New Mexico State University on April 6-7 for the purpose of exchanging information pertaining to water resources.

The success of the Conference hinged upon the generous cooperation of the several state and federal agencies and private individuals represented on the Advisory Committee.

The Institute is deeply indebted to the authors, whose papers made the Conference interesting and worthwhile; to the distinguished persons who presided over the various sessions; and to all those who lent support through their participation.

The information presented at the Conference is conveyed to the public through these proceedings. All of the papers presented at the Conference are reproduced herein.

The papers are reproduced in the same form as that in which they were received and were not subjected to editorial correction.

Funds required for publication of the Proceedings were provided by registration fees and by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Act of 1964.

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CONTENTS

WATER IN LAND USE PLANNING

Norman A. Evans*

If you fly over the mountains of Colorado, looking toward the ground you see -- everywhere -- patterns of streets laid out through trees: subdivisions! An all-too-common story is the developer who bought a section in southwest Colorado, divided it into one-acre tracts with a grid of streets -- not compatible with erosion, drainage, or topography -- and advertised nationally, but not in Colorado:

> "You can own an acre of Colorado with pine trees and blue sky and nearby waters for $2,500. You can take not one, but two, trailers or campers onto this lot. We don't have any water supply; no public sewer. You haul your water in and haul your waste out; but you'll have an acre of Colorado."

This is a bargain, no doubt; but is it right? It's land use at its worst. Not only ecologically and environmentally bad -- more often than not the purchaser is misled into costly disappointments and water is usually one of them.

But this "land rush" phenomenon is not unique to my state; it's happening in your state as well.

Yes, we do have much in common. Besides land use trends and problems, there's the Rio Grande river -- for example. I was amused at the reference in last year's conference proceedings to a sign in your State Engineer Office:

> "The Rio Grande: Colorado has the water; Texas wants it, so where does that leave us?"

I realize that Colorado hasn't always been able to deliver as it should under the Rio Grande Compact, but I checked with Clarence Kuiper, our State Engineer, just before I came, and I am happy to report that Colorado is current in its water delivery to New Mexico. Furthermore, the outlook is excellent that we will be able to meet the Compact requirement again this year.

Land use planning is perhaps the most important environmental issue remaining to be addressed as a matter of public policy at all levels of government -- national, state, and local. Jurisdictional disputes between agencies within government, between the several levels of government, must be ironed out before progress on policy can be made. The question is, "who gets the major slice of the action?"

* Director, Environmental Resources Center, Colorado State University.

Let us assume the jurisdictional problems were solved. We would still face the question of how to accomplish the tasks. Certainly all the tools available to public decision makers will have to be used: rules and regulations, persuasion, economic incentives, and others. As this conference theme suggests, water too may be a tool in land use planning.

I approach my task as Keynoter in the traditional engineering fashion -- break the problem into its parts, examine each, and finally synthesize toward a solution from what has been learned. Water, Land, and Planning are the three parts: water in land use planning.

The American Dream sprang from the hunger for land so deeply felt in the hearts and minds of European immigrants. It was that hunger which brought most of them to this country. The prospect of possessing land was, to them, almost beyond belief. It was a prospect of independence impossible to achieve in Europe.

My friend Norman Wengert, the political scientist, has described the American scene at the time as reflected in Jefferson's philosophy: "Those who labor in the earth are the chosen people of God. While we have land to labor, then, let us never wish to see our citizens occupied at workbench or twirling distaff."(1) To Jefferson the vast unoccupied public domain provided the opportunity for an agrarian independent life as well as insurance that the United States would never be plagued by landless mobs, such as were overrunning great cities of Europe. To him the family farm was a socio-political concept, not an economic one. To him land ownership made possible political independence and economic security. To achieve this goal, Jefferson provided in his draft of the proposed Virginia Constitution of 1776 a grant of 50 acres to every adult in full and absolute dominion. In his first inaugural address, he spoke of the United States as a "chosen country, with room enough for our descendents to the thousandth generation."

Equally important to the Jeffersonian land ethic, but not at all recognized at the time, was the equal opportunity for full and free land disposal. This right needs special emphasis because Jefferson and other agrarian leaders did not envision the conflict which was later to arise between the right to dispose of land and the stable community of which they dreamed. In their frame of reference, land transfer would occur only at death.

But a quite different pattern in land ownership has developed, one not at all stable. Unquestionably, the ease with which land can be transferred contributes to population mobility as we see it today. The stable community Jefferson envisioned could have been created only by making land transfers unattractive. But this was and still is politically unacceptable.

New Mexico and Colorado share very much a common heritage in their land settlement and development patterns. The Homestead Act, the Carey Act, and the Reclamation Act made settlement possible. Dr. Ira G. Clark, Professor of History here at New Mexico State University, summarized the impact of these federal programs in his paper at your conference last year.

Both states are characterized by large acreages of public land, and it was toward this land that the traditional concepts of land use planning and management have been directed. There evolved a great volume of federal legislation on public lands which became known as the doctrine of protection and preservation of the land as a national heritage, and concomitantly the doctrine of development of natural resources for the greatest good of the greatest number of people.

Today the concept of public land management is changing. A new concept is evolving which might be described as the doctrine of environmental protection.

Professor Lyn Caldwell described the ecosystems approach to public land planning and management in a paper at the Western Resources Conference in 1968.(2) He pointed out that we should consider land not in small parcels, but rather in natural ecological units. But if land planning and management by whole ecosystem units becomes public policy, all land becomes to some degree public. It is this fact which we are coming to recognize and which is shaping statutory changes in every state. It is a far cry from the view of the Jeffersonian immigrants and indeed a far cry from the views held by some (not all) land speculators, subdivision developers, and the like. But change is coming rapidly, and more and more of the various segments of society are adjusting to the new doctrine.

When man's technology was simple and his demands on nature were modest, he did not cause massive and sudden changes in the ecosystem. Many of his impacts healed themselves -- some did not (e.g. salinization of the Tigris-Euphrates River Valley). Some changes, like forest clearing in western Europe, substituted a new stable ecosystem for the original. But the science and technological explosion coupled with the population explosion of the modern era have put the matter in a new and more serious light. Ecological stability becomes an imperative.

Regardless of historical distinctions between public and private land, the exercise of eminent domain, land use zoning, and tax delinquency sales remind us that there is public jurisdiction over land, and it is not confined to land only in public ownership.

To adjust our land use policies to ecological stability will force a complete transformation in the U.S. political economy. Land owners will lose some rights, but gain some protections. Controversies over land use will be settled on ecological facts as much as on statutory facts.

The application of ecological concepts to land use forces major adjustments in the philosophy of land as a commodity. Private possession of land under ecological ground rules is possible, but the freedom to buy, sell, or transfer land must be somewhat compromised. Traditional land economics, so deeply rooted in American life, are becoming increasingly inconsistent with the interests of a large majority of citizens who live in cities, own no land, and do not, therefore, now hold sacred the tradition of full and unconditioned land ownership.

So much for land; now let me turn your attention toward water for a moment.

It's truly amazing how rapidly concepts change. Only twelve years ago at the Western Resources Conference in 1960, Ted Schad spoke about water resource policy.(3) At the time he was Staff Director of the Senate Select Committee on Water. At the present time he is Executive Director of the National Water Commission, busily engaged in preparing a final report on the nation's water problems and goals as identified by the Commission. He said, in 1960, "One aim of water management which has been accepted as a Federal responsibility is reduction of loss of life and property caused by recurring floods... So long as human encroachment on the natural flood plains continues to increase the flood hazard, engineering works alone cannot be effective, and, therefore, present programs need to be supplemented by other public action." Clearly flood plain regulation was a first step toward comprehensive public control over land use. I doubt if widespread, serious thought was given to using water as a tool to control land use in 1960.

But in 1969 Dr. Ernest Engelbert told the Third Western Interstate Water Conference that water is an important vehicle for planning and guiding the course of physical and economic change.(4) "At present water is too narrowly viewed as a facilitative resource for making growth possible--whether it be for the purpose of adding acres of unneeded crops, of increasing population in metropolitan areas already suffering congestion, or of building additional structures on a stream which is overbuilt. This is a philosophy which lets unplanned growth determine the course of development, when what is really needed is a system of water development that results in planned growth."

It is painfully clear to us in New Mexico and Colorado that water has a crucial impact on growth, on distribution of population and industry. People go where the water is, or if they over-expand beyond available water, they import it. That is our experience in Colorado where the eastern front range strip centering on Denver has virtually outgrown its water supply. Long ago the people reached across the Continental Divide to the Colorado River for new water. The population trend forecasted by the Colorado Environmental Commission in its final report to the Legislature, dated March 1972, suggests that urbanization in the front range will capture 90% of the State population, 60% being located within the Denver metropolitan area, and the balance north to Fort Collins and south to Pueblo.(5) The reasons why this compaction of population into a small area occurs are complex and not fully clear to me. It has something to do with the desire of people to live in that particular region and also something to do with economic opportunities and amenities of life. Whatever the reasons, growth is clearly made possible by availability of water. It is logical to ask, then, could not concentrated growth be discouraged, if not prevented, by unavailability of water?

Now a very brief word about planning.

The lessons of recent years have shown us that water development and management need to be planned in the context of a total system. Entire basins have to be planned and managed as integrated units taking account of both ground water and surface water. Efficiency in water use and recycling are becoming standard guidelines to an optimized plan. The most difficult planning task of all, however, is to educate and persuade the public to make policy decisions in a systems framework parallel to the management system. Legal, institutional, and traditional barriers exist which have to be breached. We have to be more creative in the methods which are employed to present complex water issues to the public for citizen decision making.

Citizen participation in decision making has come to be a subject of intensive thought and discussion. Perhaps no group has been more cognizant of this issue than the League of Women Voters. Speaking at the 1969 Western Resources Conferences, Mrs. Donald Clusen, who is with us today and will speak later, listed several characteristics of good water planning which would insure citizen participation and especially consideration of social benefits during the decision making process.(6) She emphasized attention to alternatives for consideration by the public and the importance of generating public interest in the alternatives. People should have the opportunity to discuss the choices and voice their preferences before final decisions are made. She correctly pointed out that public participation can be possible only if planners place before citizens the choices to be made, the objectives to be reached, and the results of the alternative actions long before any decisions are made.

Now, having examined our conference theme by its parts -- Land, Water and Planning, can we synthesize toward a conclusion about water in land use planning? I have tried, and I must confess that I cannot. I just do not know enough about the interactions which would occur when the three parts are brought together. But I don't feel too badly because I have not found that others have succeeded in such a synthesis either.

So, I turn to experience. What lessons are to be found in my own limited experience?

In my own city of Fort Collins, in the 1950's, city policy was to refuse water service outside its limits. By 1960 rural service districts were being formed and requested the City to provide treatment and delivery. They were rejected. The City attitude was that a rural district couldn't successfully be organized. But they were, because water was available. Five districts now surround the city; when the city limit expands into these districts, it means no end of trouble.

Denver tried a blue line concept long ago -- the result was an awesome array of governmental entities surrounding the city and endless intergovernmental conflict. Again, water was available.

Boulder, in recent years, has combined a blue line concept with a determined county zoning policy and a strong system of building permits to control land use. This combination seems to be working reasonably well.

Experience -- yes, sad experience -- is leading toward statutory provisions which add water into land use controls.

The Colorado General Assembly is right now considering two subdivision acts which attempt to identify and clarify subdivision control responsibility at various levels of government and use water and sewage as tools. Further, there is an attempt to limit ground water extraction in subdivisions because the accumulating effect of many domestic wells is damaging existing water rights. If these measures are passed, new domestic wells will require a permit and State Engineer review. These bills are very much like your SB 39, which I understand failed to pass the New Mexico Senate recently.

These experiences and observations all point toward water as one of the tools available in the construction of orderly land use practices and policies. Just how that tool best can be used remains to be seen. Perhaps this Conference will shed further light on that question. It deserves the most serious attention of all of us: water user, environmentalist, water planner and manager, natural resource professional, and layman citizen alike.

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PROJECT SKYWATER - A PROGRESS REPORT

Archie M. Kahan*

The Bureau of Reclamation's program of Atmospheric Water Resources Management, known as Project Skywater, was begun in 1961. At that time Congress made an appropriation of $100,000 and gave the Bureau authorization to conduct research "on increasing rainfall by cloud seeding." Support of the program has grown to the extent that funding in FY 1972 is almost $6.8 million. A map which depicts the location of Project Skywater contractors is given as Figure 1.

Though many questions regarding weather modification remain unanswered and a large amount of research must yet be done, progress has been made and present planning now reflects changing emphasis within Project Skywater. We are now beginning a period of transition in emphasis from winter to summer research, because many key problems remain in summer cumulus seeding and there is an apparent rapid increase in public interest in summer seeding. However, the continuing goal is that of enhancement of water supplies and crop moisture by developing operational cloud seeding techniques which can be used in a beneficial and socially acceptable manner.

The most significant progress has been with regard to development of techniques for seeding winter storm systems. With the conclusion of on-going winter research projects in Montana, Utah, Colorado, and here in the Jemez Mountains of New Mexico, initial but practical techniques will be available for beneficially increasing mountain snowpack. Yet a continuing need exists for the engineering of these techniques towards a more effective system to improve performance and results.

Project Skywater's largest mountain winter seeding program is the Colorado River Basin Pilot Project (CRBPP) in the San Juan Mountains of southwestern Colorado. The project is now concluding the second of four winters' seedings. From 20 to 40 percent of the winter storms have been found favorable for seeding with increases per storm estimated to be in the order of 50 to 100 percent. Preliminary evaluation of the first winter's seeding has confirmed the estimated increases. A contract is now under negotiation which will engage a group, not previously involved in the project, to perform an independent and unbiased comprehensive evaluation of project results including water production/cost analysis. Figure 2 shows the current project status and points out the need for a decision, by about 1975, based on the evaluation report, related findings, and planning results on whether an operational project should be initiated.

* Chief, Division of Atmospheric Water Resources Management, Engineering and Research Center, Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado.

FIGURE 1

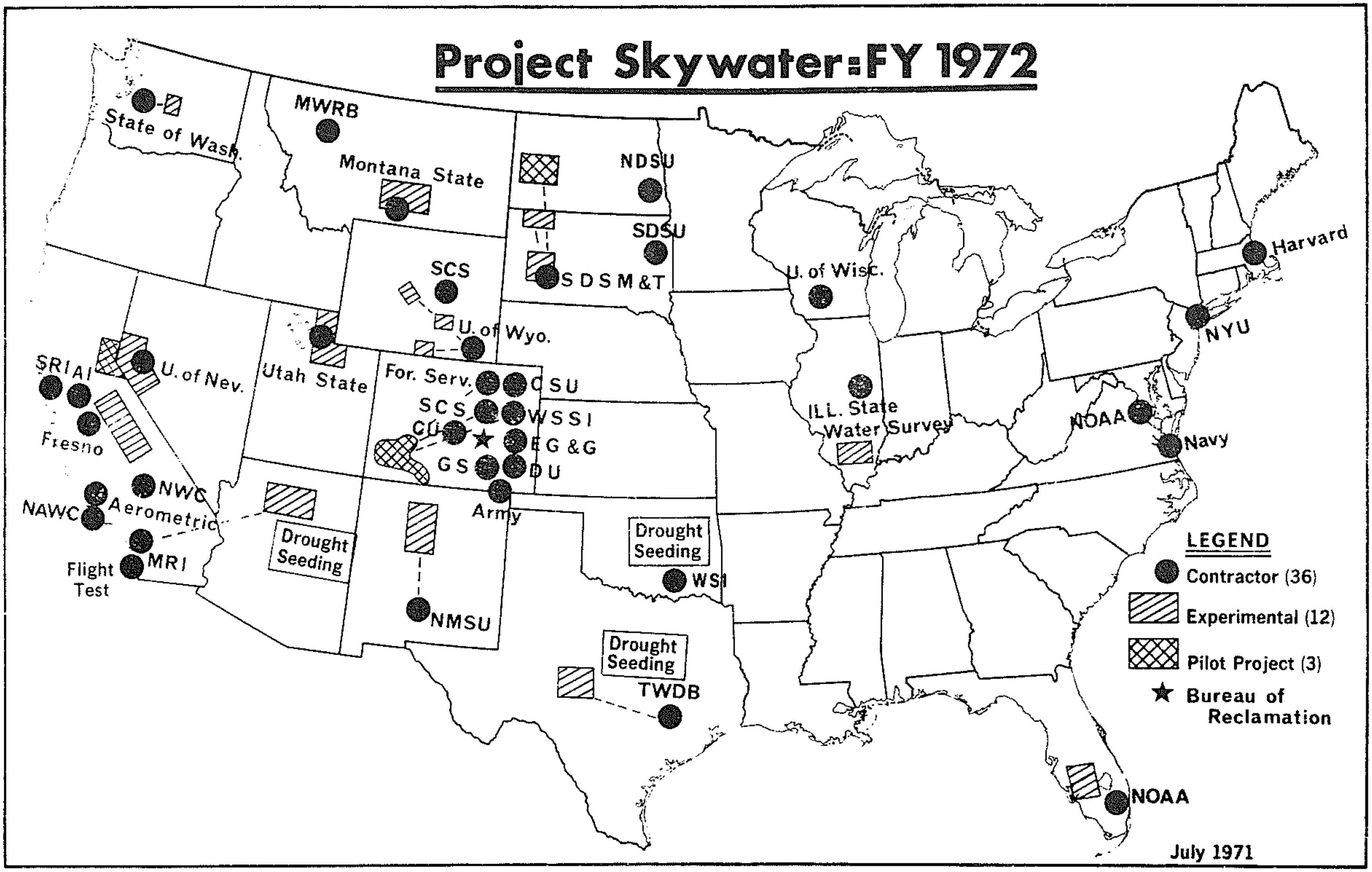
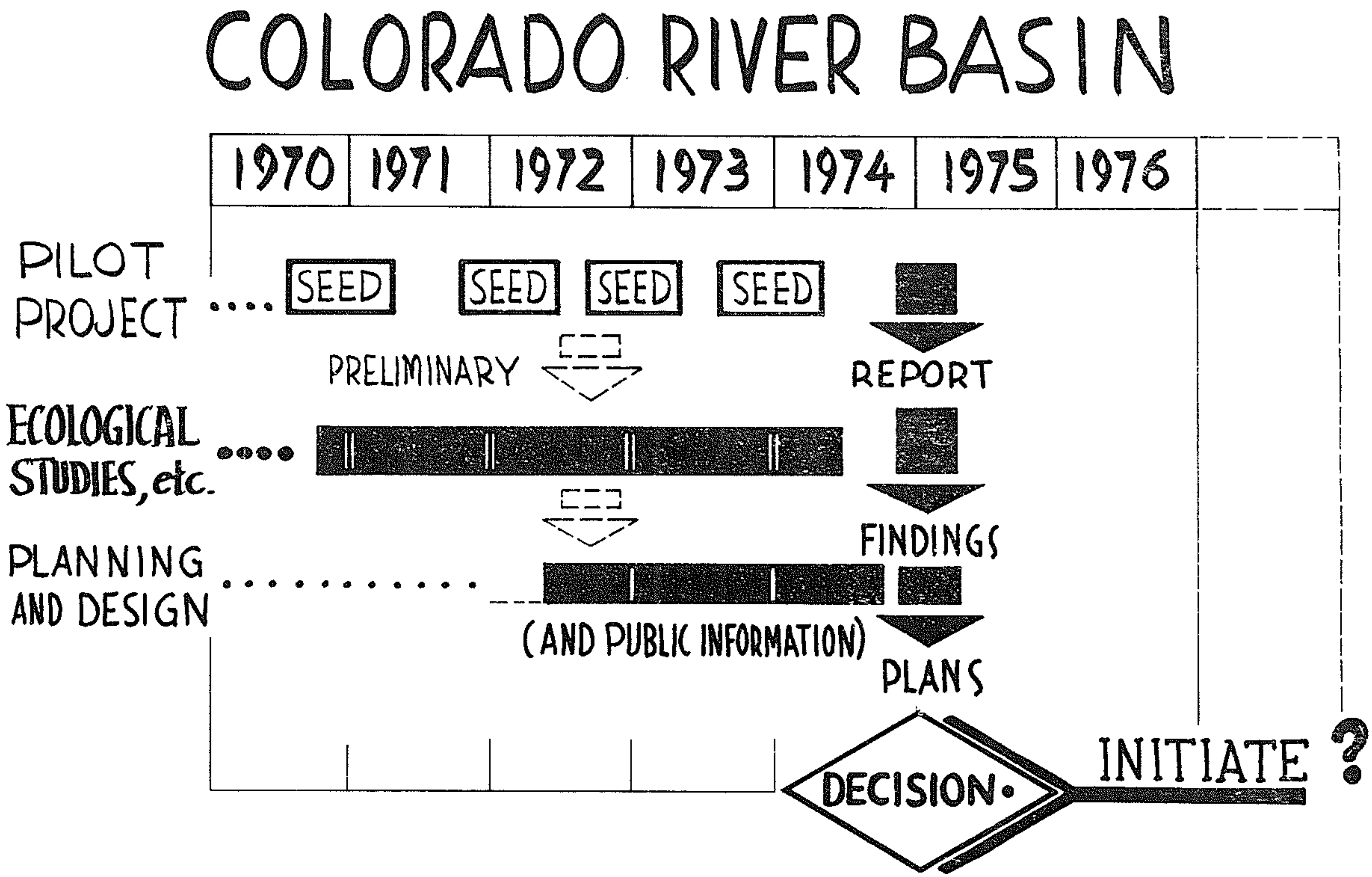

Project Skywater: FY 1972
State of Wash.
MWRB
Montana State
NDSU
SDSU
SDSM&T
SCS
U. of Wyo.
SRI
AI
U. of Nev.
Fresno
Utah State
For. Serv.
CSU
SCS
WSSI
CU
EG&G
GS
DU
Army
NWC
NAWC
Aerometric
MRI
Flight Test
Drought Seeding
NMSU
Drought Seeding
WSI
Drought Seeding
TWDB
U. of Wisc.
ILL. State Water Survey
Harvard
NYU
NOAA
Navy
NOAA
LEGEND
Contractor (36)
Experimental (12)
Pilot Project (3)
Bureau of Reclamation
July 1971

FIGURE 2

(9)


COLORADO RIVER BASIN
1970
1971
1972
1973
1974
1975
1976
PILOT PROJECT
SEED
SEED
SEED
SEED
PRELIMINARY
REPORT
ECOLOGICAL STUDIES, etc.
FINDINGS
PLANNING AND DESIGN
(AND PUBLIC INFORMATION)
PLANS
DECISION
INITIATE ?

A short film about seeding operations in the San Juans, called "Mountain Skywater," was completed just this past February. The film deals in an easily understandable way with cloud seeding, how it is done, avalanche research, and related ecological studies.

Research in seeding summer cumulus, under Project Skywater, has been far less extensive than the winter research. The Institute of Atmospheric Sciences at South Dakota School of Mines and Technology (SDSM&T) is continuing a large randomized seeding field experiment near Rapid City to clarify how salt and silver iodide aircraft seeding influences the precipitation processes in summer convective clouds.

Current planning for a Northern Plains Region is based on the research being done by SDSM&T on the Northern Great Plains Pilot Project in western North Dakota. This pilot project was the subject of Skywater Conference VII held in Denver on March 2-3, 1972. The conference was the latest in the series held by the Bureau to both inform the scientific community and obtain insight about major efforts within Project Skywater. General agreement was reached at the conference that a regional basis for weather modification coordination should be established, but emphasis was placed on having as much local control as practicable. The trend that appears to be developing is for strong locally- and state-supported programs with some as yet undeveloped form of interstate coordination and Federal assistance.

The San Angelo Cumulus Project near San Angelo, Texas, is a 3-year program, initiated in 1971. The project is designed to develop procedures for increasing precipitation from cold clouds by ice-phase seeding and from warm clouds through technology only presently being developed. Hygroscopic seeding materials are used to increase rainfall from warm clouds. This new technique holds great promise for augmenting moisture in the Southern Plains and Southwestern states.

Another Skywater project involved in summer seeding research is a feasibility study of year-around seeding to increase rainfall in Illinois. The study was begun in 1971 by research scientists of the Illinois State Water Survey and will be concluded in 1975. The program is unique in that it will be the first United States project to place primary emphasis on modifying frontal and squall-line storms (the major source of Midwestern precipitation). No actual seeding will take place during this phase of the study. However, if the results provide the justification, a second phase could be an experimental operation. Findings from this research are expected to be an important part of completing the technology for summer seeding.

During the summer of 1971 the Bureau of Reclamation, through Project Skywater, cooperated with the President's Office of Emergency Preparedness and the Governors of Texas, Arizona, and Oklahoma in conducting drought-relief cloud seeding operations in those states. Conditions were favorable for seeding in each of the areas and substantial rainfall did occur. Estimates of the increases attributed to seeding have been made for each of the operations as shown on the following table. However, due to the short-term nature of the programs, the collection of only limited amounts of data for evaluation was possible. The results do give strong evidence that further research and development in this field can result in large scale benefits.

State	Cost	Increase
Texas	$ 92,400*	10-15%
Arizona	150,000	15%
Oklahoma	296,000	95,000 a.f.

*plus cost of U.S. Air Force aircraft operations

The drought-relief operations in Texas and Arizona were each for 1-month periods in June and during late July to early August, respectively, while the Oklahoma operation was conducted for 2 months beginning on August 15, 1971. Two contractors operated in Oklahoma, one using light aircraft for silver iodide seeding and the other performing hygroscopic seeding from a C-97. Each contractor has now completed a report on his operations and the estimated results. Hygroscopic seeding is credited with an additional 70,000 acre-feet of rainfall and the data indicate an addition of 25,000 acre-feet from silver iodide seeding. However, the amount credited to seeding is only a small part of the total rain which fell during the 2-month project. An all-time high of 10.04 inches of recorded rainfall occurred during September at Altus, Oklahoma, located within the project area.

The relative success of last summer's projects by both Project Skywater and by NOAA in Florida has provided the basis for cloud seeding becoming a major consideration for further use in drought-stricken areas. While the Bureau is willing to provide planning and scientific assistance when official requests are made, the program's charter from Congress is limited to performing research. The future operational application of weather modification by the Bureau or other Federal agencies is dependent upon appropriate new legislation which would provide authority and funding, while recognizing the need for continuing the necessary supporting research.

Another important study which will be started this month is a comprehensive evaluation of potential increases from the seeding of winter orographic cloud systems in a number of Western river basins. The increases in precipitation and corresponding streamflow which could have resulted from the use of presently known weather modification techniques over the past 20 years will be determined. The results of the study will become a part of the Western U.S. Water Plan and be made available for future operational planning. One of the major river basins with a high priority to be analyzed in this study is the Rio Grande River Basin here in New Mexico.

Because of the continuing water problems in the Rio Grande Basin and the favorable indications of seeding feasibility from the New Mexico State University and other winter research, the Bureau has included funds in the FY 1973 budget to begin planning for expanded cloud seeding activities in New Mexico.

Although I have made no attempt to bring you up to date on all phases of Project Skywater, I have touched on those items which appear to be of major current interest. In way of summarizing our overall program, the following list separates areas of major interest and some of the participating contractors:

I. Development of Cloud Seeding Technology
   A. Winter Research
      1. Sierra Range - Fresno State College
      2. Bridger Range - Montana State University
      3. Reno Area - University of Nevada
      4. Jemez Mountains - New Mexico State University
      5. Wasatch Mountains - Utah State University
      6. Cascade Range - State of Washington
      7. Elk Mountain - University of Wyoming
   B. Summer Research
      1. Flagstaff - Meteorology Research, Inc.
      2. Florida - NOAA
      3. Rapid City - South Dakota School of Mines and Technology
      4. San Angelo - Texas Water Development Board
      5. Illinois - Illinois State Water Survey
   C. General Research and Development
      1. Aerometric Research, Inc.
      2. Colorado State University
      3. University of Denver
      4. Naval Weapons Center
      5. New York University
      6. Western Magnum Corporation

II. Planning Investigations and Other Support
   A. Background Studies and General Planning
      1. Forest Service
      2. Montana Department of Natural Resources and Conservation
      3. North Dakota State University
      4. South Dakota State University
      5. University of Wyoming
      6. Stanford Research Institute
   B. Field Support
      1. Forest Service
      2. Geological Survey
      3. Soil Conservation Service
      4. Meteorology Research, Inc.
   C. Environmental Computer Network
      1. NOAA
      2. Computer Sharing Services
      3. AT&T

III. Adaptation of Techniques
  A. Environmental Effects Projects
    1. Colorado State University
    2. University of Colorado
    3. University of Wyoming
  B. Pilot Projects
    1. Colorado River Basin
      a. EG&G, Inc.
      b. Geological Survey
      c. Soil Conservation Service
      d. Western Scientific Services, Inc.
    2. North Dakota - South Dakota School of Mines and Technology
    3. North Platte
      a. Soil Conservation Service
      b. University of Wyoming
    4. Pyramid Lake - University of Nevada
  C. Special Studies
    1. North American Weather Consultants
    2. South Dakota Weather Control Commission

Project Skywater represents a major effort by the United States in an area where the rewards can be high. Progress in the relatively short period of study to date has been significant and present indications of advancing the technology in the future are exciting. A reasonable balance between operational adaptation and continued research should now be achieved and maintained to both utilize present technology and to insure continued future advances in the understanding and development of weather modification.

A NEW TECHNOLOGY FOR POLLUTION ABATEMENT

John Eichelmann, Jr.*

Robert Fuehring, who has authored a booklet exclusively for Westinghouse simply entitled "Water" has stated various studies show that within the next twenty-eight years this country will need one trillion gallons of fresh water daily. Disregarding the natural geographical distribution of this resource, it has been estimated that there are only about six hundred billion gallons available. Obviously, if we could but reuse the water once, we could effect a two hundred billion gallon surplus instead of a deficit. Dr. Leon Weinberger, past chairman of what was then called the Federal Water Pollution Control Administration, has said in testimony given before a senate sub-committee on water pollution that if we expect to meet the immediate needs for fresh water, particularly in the water-short southwest, it is imperative that we make multiple reuse of this resource.

Water treating and pollution abatement equipment available on the market today, at best, only solves a portion of the problem. Pollutants, generally organic in nature, can be handled effectively with such techniques as filtration, flocculation, and bio-degradation. However, until now, there has been no effective method for the complete removal of concentrated chemical and mineral contaminants from brackish water and effluents resulting from use by industry and municipalities.

Gentlemen, today's presentation describes an actual operating facility and process which is one possible solution to the concentration problem. A fifty thousand gallon per day test facility now in continuous service at an El Paso Natural Gas Company compressor station is reclaiming 99.6 to 99.7 per cent of a cooling tower blow-down water. The returned product water contains less than one part per million total dissolved solids while the resultant concentrate of about four-tenths of a gallon per minute of a twenty-five per cent total salt content is poured on a salt pad. The return of this high quality water for reuse within the industrial installation has had some rather dramatic effects on the water consumption experienced at the station.

Exhibit One is a bar-chart showing an average thirty day load of some nine million one hundred thousand gallons. In order to stabilize the operations, it was necessary to dispose of one million one hundred thousand gallons. Since this water reclamation plant has been in service, it has effected an approximate thirty per cent reduction in the water demand to six million two hundred thousand gallons of water over a thirty-day period of time with a net resultant blow-down not exceeding some twelve thousand gallons for the same thirty-day period. From a water analysis standpoint, the effect of this facility is equally dramatic as expressed in Exhibit Two.

Exhibit Two is an abbreviated water analysis. The first column shows parts per million or pounds of salt per million pounds of water.

* Engineer, El Paso Natural Gas Company, El Paso, Texas.

For example, chlorides as shown in this exhibit are some eight hundred and seventy-seven pounds per million pounds of water and the sulfates are some thirteen hundred pounds per million pounds of water. If you were to add up the weights of all the salts listed here and those not listed, you would find that the feed water coming to the water reclamation plant contains a total salt content of some three thousand four hundred and sixty-eight pounds of salt per million pounds of water. In contrast, the water being returned for reuse, in this case to the cooling towers at the El Paso facility, contains less than eight pounds of salt per million pounds of water.

The Third Exhibit is a color coded isometric drawing of the El Paso Water Reclamation Plant. Going from right to left, we see the blow-down from the cooling towers going to a small storage tank which provides flooded suction to a feed pump which in turn pushes the feed water through to a unique heat exchanger. This heat exchanger is comprised of five individual tube aluminum coils. The feed water entering the heat exchanger at the bottom and spiraling upward absorbs the sensitive heat from the hot condensate which enters at the top of the heat exchanger flowing counter-flow to the direction of the feed water. The condensate leaves the heat exchanger at the bottom and returns to the cooling tower for reuse. This heat exchanger makes an approximate seven and a half degree approach; that is to say, that if the feed temperature entering the heat exchanger is at seventy degrees, then the product water returned to the towers will be in the neighborhood of some seventy-seven degrees.

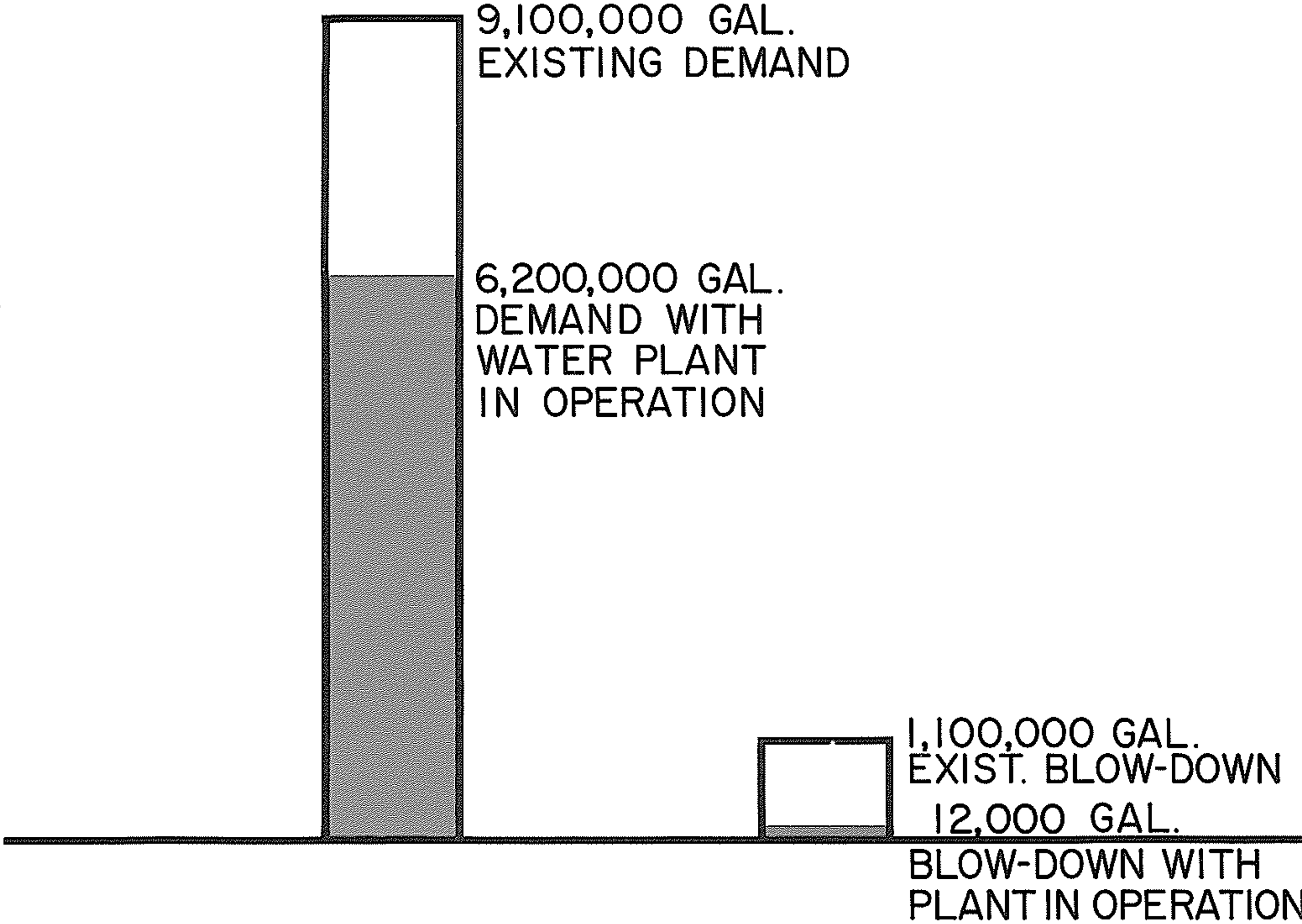
The feed water leaving the heat exchanger passes through a deaerator which allows the absorbed atmospheric gases to be expelled back into the atmosphere. From here the feed water flows by gravity into what we call our first stage evaporator. This is simply an unpretentious rectangular aluminum box with a sloped bottom. We establish a liquid level which provides a flooded suction to recirculating pumps that push what we now call brine to the top of the evaporator. This brine is then allowed to flow over the external surface of what we call aluminum leaves. These panels are approximately three inches thick by eight feet wide and fourteen feet long. To start the process, we activate our heaters and establish a vapor pressure of approximately four inches of water column. At this point we turn on our compressor which compresses the vapor to approximately twenty-seven inches of water column, or about one pound, and inject this steam into the internal side of these aluminum leaves. By compression, we force the vapor to condense on the internal surface of the leaves giving up its heat to vaporization which passes through the thin skin aluminum surface and is reabsorbed by the circulating brine flowing over the external surface. Condensate is accumulated at the bottom of each leaf through a common manifold which flows to a condensate tank that provides the flooded suction to the product pump. From there it goes through the heat exchanger and back into the plant for reuse.

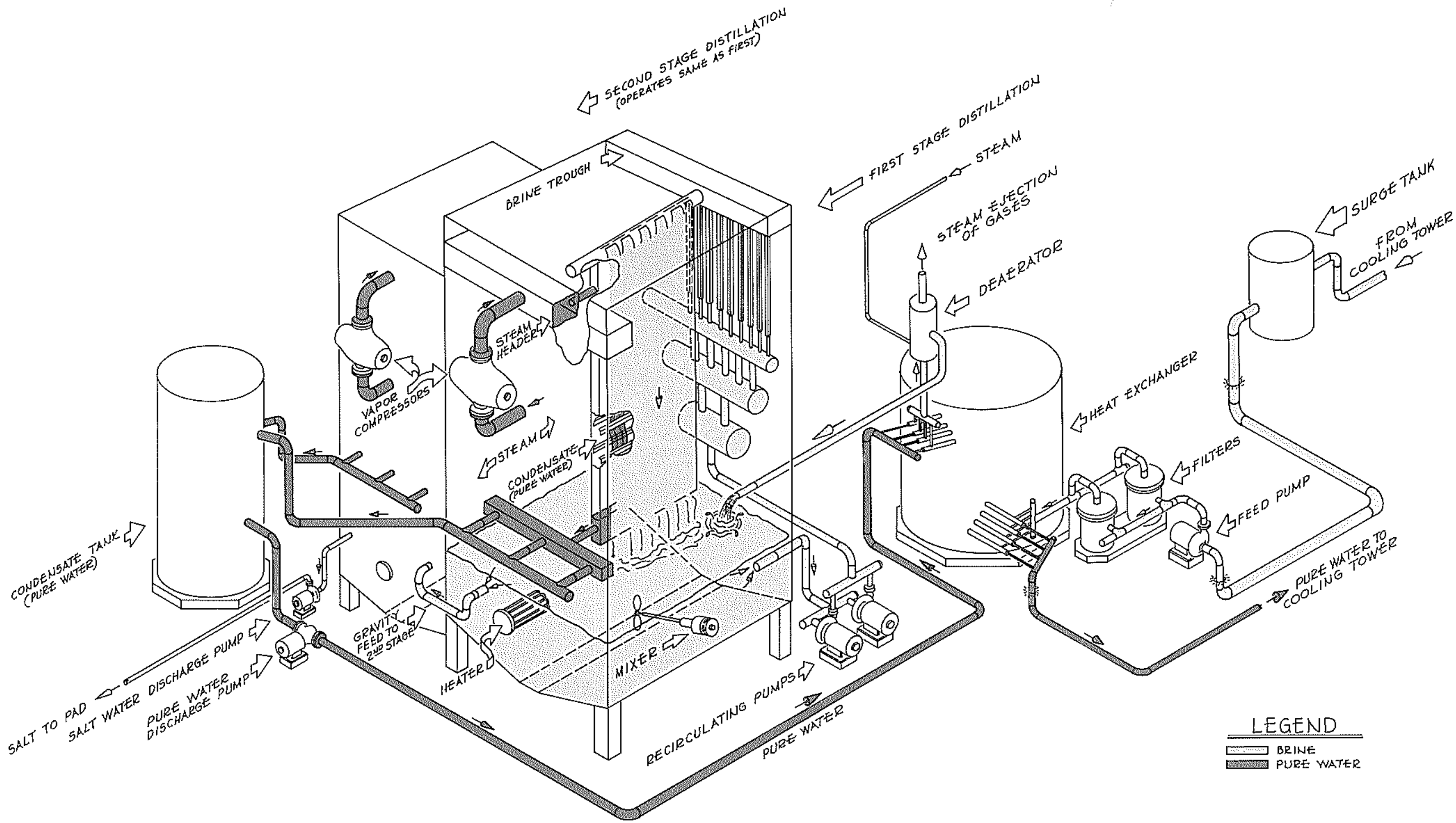
Much like a mulligan stew, we add only enough water initially to establish a liquid level, continuously withdrawing pure water until we have concentrated the initial feed water approximately ten times, or to

WATER ANALYSIS

	PRESENT BLOW-DOWN	PURE WATER RETURN
pH	6.5	5.8
M-ALK	15.0	5.0
CHLORIDES	877	0
SULFATES	1300	0
TOTAL HARDNESS	1048	1
CALCIUM	756	0
SILICA	182	0
NALCO TREATMENT	30	0
TOTAL DISSOLVED SOLIDS	3468	8

30-DAY
ESTIMATED WATER CONSUMPTION
EL PASO STATION





EL PASO WATER RECLAMATION PLANT

1971

THE CITIZEN IN WATER AND LAND USE PLANNING

Mrs. Donald E. Clusen*

I feel rather nostalgic about this invitation to come to New Mexico. Five years, thousands of miles of travel and the width of the State of New Mexico separate me from the circumstances under which I came to Portales in early 1967 to learn about water issues in the Southwest and to become acquainted with New Mexico League members. In 1967 I had been national water chairman for the League of Women Voters only a few months, both the League and the nation thought that the name of the problem was water supply, and a great many Americans were still happily unaware of the true nature of the environmental crisis. In fact, most Americans at that point had never heard of the words "ecology" or "environment" and even among those who had, the real problem seemed to be to have enough clean water for their needs in the right place at the right time. Within the League we were devoting our efforts to river basin planning, to deciding who should pay for a clean stream, and working to create public awareness of the national water crisis.

Now here we are in Las Cruces five years later discussing the interrelationship of water management and land use planning on a much more sophisticated level than would have been possible at that time in the past. During this five years we have had our national attention assaulted by a continuing barrage of bad news about the nation's physical health. We know now that laws are no panacea, that the clean-up of air and water is costly, and that the problem is of immensely greater proportion than we had ever imagined.

Nevertheless there is considerable basis for optimism--in legislative commitment, citizen awareness, and technological progress. The fact that we are together at this conference to look at the effects that one kind of environmental planning or decision has on another facet of the environment is both necessary and reassuring, and I am glad to be a part of it.

One of the current quotations which has been considerably overdone, but which is nonetheless true, is the one which says that everything is related to everything else in the environment. Nowhere is this easier to prove than when we take a look at how water management and land planning are interrelated. Many of you present today are professionals in the field of water resources management--engineers, sanitarians, scientists, researchers, agency personnel, and the like. I am not. I can only tell you how the situation looks to informed laymen and what we think might be done about it.

* Chairman, Environmental Quality Committee, League of Women Voters of the U.S., Green Bay, Wisconsin.

a level of some thirty-five thousand parts per million. This brine level is stabilized by allowing a small portion to flow to the smaller second stage, the function of which is identical as described in the first stage. This is done for energy conservation. The second stage brine is then concentrated to approximately some two hundred and fifty thousand parts per million. This results in a boiling point rise of approximately seven to eight degrees. This brine level is stabilized by allowing a 0.2 to 0.3 per cent of the initial plant feed rate to be poured to a salt pad. A footnote concerning the salts poured to the pad is that at the present time a research program is underway which would indicate that something useful can be made from the accumulated salts.

What makes this process different or unique? First, with pretreatment other than pH control (pH 5.5 to pH 7.5), we are able to exceed the saturation limitations of scale forming minerals without precipitating the scale on the heat transfer surfaces. We account for this success, first because of very low heat fluctuations and second because of Btu per square foot which would reduce the tendency to set scale on our heat transfer surfaces. Secondly we incorporate a feeding technique similar in part to work done by the Russians and funded research programs conducted here in the United States. The theory of seeding is based on the premise that as a particular mineral reaches its satuation limitations in a particular fluid, it would prefer to plate out on a nucleus of its own generic type as opposed to a foreign surface such as the metal in the heat transfer surfaces. The theory in practice is evidently valid, for we do, on initial start-up, charge the brine with seed. This has consistently allowed us to concentrate, through the various saturation zones, without precipitating any scale on the heat transfer surfaces. Once we have reached our design concentration levels, the plant is generating new seed, eliminating the need for continuous seeding.

Another feature of this plant that is of special interest is that -- due in part to the low energy levels, the vapor compressor, and an efficient feed heat exchanger -- we are able to convert a pound of waste water to a pound of pure water for an average of thirty-five BTU per pound.

The conclusions of this four year research program have resulted in a three-way partnership between Reading & Bates Offshore Drilling Company, The Boeing Company, and El Paso Natural Gas Company. Through the efforts of these companies, a subsidiary known as Resources Conservation Company has been formed. Resources Conservation Company is headquartered at the present time in Seattle, Washington.

The most obvious factor in the situation facing land use planners is that the decisions which are made on uses and sites will affect water supply and quality for years to come, perhaps forever. In the Southwest demands upon land use which involve water choices also are primarily those of land for water resource projects, land for farming and grazing, land for urban development--although there are many others as well.

In the report of the Commission on Population Growth, Population and the American Future, we are reminded that "water requirements already exceed available flow in the southwestern U.S." and that "growing population and economic activity will cause the area of water shortage to spread eastward and northward across the country in the decades ahead." This prospect gives great importance to consideration of long and short range effects of water resource projects on air and water quality. We are all aware that dams for water storage and hydroelectric sites, interbasin transfer, straightening of channels, and large scale withdrawal of ground water are some of the more common water resource projects. Unfortunately, not enough attention has been paid to some of the possible effects of these decisions on the rest of the physical world. Impoundment of water by dams can alter water supplies for a region by reducing downstream flows, altering water tables and promoting evaporation of impounded water through increased exposure of the water surface to the atmosphere, especially in arid regions. Dams trap sediments, reducing the effective storage capacity of the impoundment. Dam sites need to be carefully surveyed for subsurface structural ability to withstand great pressures in order to avoid dam failures and damage downstream. They can block fish spawning runs.

Straightening and deepening of natural stream channels may alter water levels and velocity which in turn affects rates of erosion and sedimentation. Interbasin transfer can alter chemical hydrological environments, such as salinity, and possibly other natural patterns of vegetation, climate, etc., depending upon the scale of the project. Large scale withdrawal of ground water can cause saltwater intrusion in coastal areas or subsidence of the land depending on the geologic conditions existing in an area.

Land use for grazing livestock significantly affects the environment. If grazing locations are not carefully chosen and managed, nearby hydroelectric reservoirs can be silted up, reducing water storage and energy output. Loss of covering vegetation can also cause excessive salinity and, removal of other minerals affecting regional water quality.

Use of fertilizers, pesticides, insecticides and herbicides may produce healthy food but not necessarily healthy fish and animals on adjacent lands, and their use may be detrimental to overall water quality. The practice of channelization may cause increased flooding and sedimentation downstream. Use of improved irrigation and drainage techniques is important to prevent salts and plant nutrients from reducing water quality downstream.

Although water quantity is a first consideration in land use planning, water quality needs to be better appraised. Too rapid growth taxes the capacity of community treatment facilities, and industries, subdivisions, and shopping centers discharge untreated wastes into the water with serious effects on health, property, vegetation, and wildlife. Large scale development can have regional effects on water supply--withdrawal of ground water in one state can effect the availability of ground water in another state. In arid and semi-arid areas depletion of stored ground water must be considered every time a land use decision is made. Often the effect of urban development is not fully assessed, and cities and farms compete for the same water. Higher densities and large areas of paving increase urban runoff and simultaneously inhibit ground water recharge--thereby reducing the regional water supply.

One could go on endlessly detailing the need to consider land for open space, land for transportation, land for waste disposal, land for power generation--and in the course of it show that in every demand there is a comparable commitment in terms of water usage.

This is the way things look to the general public and there is grave concern about how these conflicting demands will be adjudicated. Ever since 1965 the League of Women Voters has been the recipient of a technical training grant to conduct conferences for community leaders on land and water issues. In the course of doing this we have sponsored such projects in every section of the country in all or part of 42 states. In fact I have just come here from Cedar Rapids, Iowa, where we have one in progress this week, using the theme, "Agriculture in a Quality Environment." One of the permanent parts of these projects has been a panel of experts which presents the full range of competing demands on uses for the water of the region with due consideration for the related land effects. We have tried to assist community leaders in determining how to decide priorities and preferences for reconciling these competing demands.

How do we tell people to approach these difficult choices? We suggest to them that there are perhaps five basic ingredients which are necessary to reaching wise decisions on good planning for water resources management. We include such things as:

1. Ample information about practical alternatives
2. Evaluation of the demands which various segments of the public place on specific uses
3. An attempt to maintain flexibility for the future
4. Public involvement at every step of the planning process
5. Public discussion and understanding of plans, options, costs, and the environmental impact of the choices.

I very much doubt that there is anything in that list with which anyone here would disagree, but somehow the application of this to a concrete proposal becomes infinitely more difficult. This is especially true when we attempt to use these principles in evaluating water resource projects. It has been the strong desire of League members for many years to have intangible values as a part of the consideration as well as to see the public presented with alternative plans. In fact, back in 1969 in testimony to the National Water Commission, we said:

> "We think the time is ripe for devising new ways to evaluate water resource projects. Economic efficiency is no longer acceptable as the sole measure. The cost/benefit ratio should be only one tool. If it is retained, more value in the cost side should be assigned for benefits foregone and values lost when projects are constructed. Enhancing the nation's material wealth may be of lesser importance than fulfilling the desires of the people of the region; enriching entrepreneurs may be of less importance than preserving irreplaceable values for public enjoyment. Such value judgments must be made by citizens and not by technical experts."

Now the Water Resources Council has completed its Special Task Force Report and is proposing new principles and standards for the preparation of river basin plans and for the formulation and evaluation of federal water and related land resources projects. These were open to comment until March 31, and thus citizens and civic organizations have had a unique opportunity to join with government in shaping new rules. The League of Women Voters reviewed these proposals and submitted a statement for the record, from which I quote:

> "We are glad to see inherent in the Proposed Principles and Standards for water and land resources planning a more tangible and effective route for governmental consideration of benefits other than economic efficiency and cost. Perhaps the greatest step forward in the judgmental process necessary is that of a change in the discount rate to reflect values society places on benefits and costs occurring in the future as compared with the present. We are greatly encouraged by the emphasis on broader basis and more public participation."

It seems to me that the various accounts proposed by the Water Resources Council provide a methodology for consideration of social and economic values in water resources management and that this kind of built-in examination of alternative values and costs is more meaningful than an eyeball-to-eyeball confrontation between developers and environmentalists.

Some years ago I was invited to speak to the Western Interstate Water Conference in Fort Collins, Colorado, on "Improving the Planning Process-Establishing Values," and following this conference I was invited as a representative of the League of Women Voters to become a member of the Advisory Committee for the Westwide Study, which I accepted.

Unfortunately, time, distance, and money have precluded my attendance personally at meetings of the Committee, but I have received all of the information on the Study, and have arranged for a knowledgeable League member from the area in which the meeting is held to be my representative. I tell you this so you will know that League members are not unaware of the stake which the State of New Mexico has in the putting together of the Westwide Plan and the actions which will come after the moratorium. This has been a valuable experience to us, and I hope that, in turn, we can be a channel for public understanding and discussion of the Study and the Plan when the appropriate time comes. I am sure that many of you here have been or will be involved in one way or another with this operation also, and thus my purpose in mentioning it is to put emphasis on the need to be certain that the interrelationships of land and water decisions are a part of the reconnaissance investigations. Obviously this study will be the most comprehensive attempt yet made to gather together all of the information needed for decisions in water use in the West for decades to come. It would be extremely short sighted of us all not to make the most of this opportunity to inject into consideration the impact which land use has on water quantity and quality and vice versa.

In another western state where water problems are of urgent concern, the Director of Water Resources is quoted as saying, "Water quality and regional development are on a collision course." If this is true, and all indications are that it is, then the most important thing we need to consider at this Conference is whether, by rational planning for both land and water, development can accelerate and water quality and supply improve.

In regional planning for water resources we seek the best of all possible worlds--one where planners will resolve the inevitable conflicts between opposing interests, opposing aims, between development and non-development, between wise use and profligate tendencies, between economic necessity and idealistic philosophy. But planners neither can, nor should, make these decisions in a vacuum, neither knowing nor caring what people want. The purpose of comprehensive planning is to devise a pattern for economic and physical development, harmonious and well balanced in its use of land and water. Planners suggest corrective measures for existing problems and recommend priorities for improvement programs in order to guide growth along orderly lines. The master plan is a flexible guide for the making of all developmental decisions, public and private, but it rests on many earlier expressions of community preferences, on many choices between incompatible aspirations, on compromises and adjustments to gain necessary public support.

In recent years there has been increasing acceptance of the idea that planning and management of water and related land resources are best accomplished through some type of organization that cuts across traditional political boundaries and deals with resources in their geographic unity. To put this idea into practice has proved extraordinarily difficult. In the absence of a comprehensive plan, water management and land use programs and policies of separate jurisdictions frequently conflict to the point where plans of one are negated by action or inaction in another. Generally speaking, either a metropolitan area or a watershed would be better served by a unified plan for its water source--by a plan that takes into account the many needs for water and provides for multiple uses. Yet there are few places where such a plan is being applied. All too often water plans are drawn by representatives of vested interests, by professional water and sewer engineers from municipalities, by industrial engineers, rather than by water resource and land use planners whose aim is to find the best utilization of the resource for the entire region.

It seems to me that the first step toward good water-land planning is to develop a truly creative regional plan; the second is to involve the people of the region; and the third is to establish some institutional arrangement, not only for making the plan, but for putting it into effect.

We hear a great deal about comprehensive plans in the present time. Indeed we in the League are very fond of this term. We use it in our statement of position where we say..."In order to meet the present and future water needs of the people of the United States, the League of Women Voters believes: comprehensive planning, development and water management on a regional basis is essential to the optimum development of the nation's water resources."

But can regional planning (and remember a region can be large or small) for water resources be comprehensive if it includes the multiple uses of water but not the general use of land? Clearly the location of industries and recreation areas will affect costs of water supply and waste disposal in cities or the stream's watershed. The effects of land use choices on water management must be evaluated. The evaluation must be given weight in location decisions of industry and in land-use planning by local, state, and regional planning agencies. Stream specialization to provide high quality recreation opportunities, for example, will be impossible without appropriate control of land use.

Any institutional machinery for comprehensive planning will need to deal with both water resources and land use controls and to influence both public and private decision-making where ever the two are interdependent. It seems to me that what we concerned citizens want in regional planning for water resources is a comprehensive plan that gives full consideration to water and related land resources of the area and involves citizens in the decision-making. We want planners to provide us laymen with the information we need to make the hard choices from which there is no turning back. We want to know ahead of time the inconveniences, the regulations, and the costs that are involved. We want to be prepared to pay the price when we commit ourselves to the final goal.

What is required is a value judgment which compares the known risks with the anticipated benefits. No scientific procedure can tell us how much irreversible damage we ought to tolerate and no scientific principle can tell us how to make the choice. The necessary judgments, therefore, are not the responsibility of scientists and technologists, or officials, alone, but of all citizens, and we are all citizens. The League of Women Voters is convinced that people need help in recognizing the possible choices for land and water use and that many people are eager for sound and solid information on which to base value judgments. Those of you in this room who so obviously have the knowledge and experience to help people choose, need to share your expertise with the public and to have the faith that in a democratic society, value judgments should be made by the public through political processes. Upon you and hundreds like you rests the responsibility for a new understanding of political maturity and judgment in which the public accepts, through a series of considered decisions, the responsibility for making its choice for the quality and quantity of the nation's water and land in this generation and along with the pragmatism and the realism on which the League of Women Voters prides itself, we recognize that we need the lift of the spirit which comes with planning for a better future. We want planners to give us this inspiration, to raise our sights. After all it was a planner who first said, "Make no little plans for they have no magic to stir men's souls." To this thought in this day and age when planning has become essential to survival, we can only say, "So be it."

PANEL - WATER IN LAND DEVELOPMENT

David W. King*

Good afternoon. I wish to express my sincere appreciation for the invitation to participate in this Seventeenth Annual New Mexico Water Conference. As State Planning Officer and as a citizen and rancher in New Mexico, I am deeply concerned about the quality and supply of water in our state. The topic "Water in Land Development" is both timely and crucial. As you may know, the governor attempted in the last legislature to pass legislation which would have begun to approach the problems created by growing needs for water. This legislation, after much debate and many revisions, was never passed. Instead the legislature, in its wisdom, created a land-use task force which will report to the Environmental Health Interim Legislative Committee. Hopefully the coming "long" session will have the facts before it and pass strong but reasonable legislation.

Some may not realize the magnitude of the problem and the long-range decisions which must be made soon or they will be made for us. Population projections for the years 1980, 2000, and 2020 indicate that the population of New Mexico should reach between 2.7 and 4.6 million.

If the population increases as projected (and I do not particularly accept these projections), the demands for water for municipal, industrial, domestic, and recreational purposes in New Mexico will greatly increase. Even, if as I hope, the population does not increase at the projected rates, water demands are substantial right now and must be dealt with.

Presently, agricultural depletions account for about 90 percent of all water depleted in the state for beneficial uses. The largest depletions of the water of New Mexico are for agricultural purposes, including the amount needed for livestock. Increasing acreages of irrigated cropland and the development of new agricultural areas in some regions of the state have resulted in increased annual depletions. The acreage of irrigated cropland increased by about 40 percent from 1940 to 1950, increased from 1950 to 1960, and increased from 1960 to 1970. The water resources of the state are almost fully appropriated under the doctrine of prior appropriation under the state water laws. Increases, therefore, in the use of water for municipal, industrial, and recreational purposes must, in general, come from agriculture which in most cases presently has prior rights for irrigation purposes. We must recognize the impact of our water allocation decisions and think long and hard before we allow such a trend to take over. Once it is started, the turning back is painful and sometimes impossible. Many overpopulated states will bear witness to this fact.

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* Director, State Planning Office, Santa Fe, New Mexico.

Over one-third of the total land area of the state is public land held for the use of federal agencies. State lands account for about 12 percent and Indian lands about 10 percent. The land in private ownership accounts for about 44 percent of the total land area of the state. Land ownership is important both from the standpoint of the rights to the use of the land resource as well as the use of water in the state. The management of the land and forage resources affects the quantity and quality of water flowing from those lands available for other uses.

Water import proposals seem to be a long way in the future. However, in 1971, water from the Colorado River Basin started flowing through the canals and tunnels of the San Juan-Chama project into the Rio Grande Basin. The flow through this system will average about 110,000 acre-feet per year under present allocation agreements.

Water, Inc., an organization of citizens in west Texas (Lubbock and Amarillo area) and in the several eastern New Mexico counties, is working with the Bureau of Reclamation and the Corps of Engineers, U.S. Army, on a plan to bring water from the Mississippi River to the high plains of west Texas and eastern New Mexico. A report on this proposal is due to be completed in 1973.

The North American Water and Power Alliance, a development of the Ralph M. Parsons Company, proposes to bring water from Alaska and western Canada to the western United States, including Utah, Arizona, and New Mexico. This proposal has not received very favorable comments from the people in western Canada. They believe it would interfere too much with the timber, mining, power development, recreation, and transportation industries in that area.

The Central North American Project Proposal was developed in concept by Dr. Roy E. Tinney in 1967. This proposal would bring water down through the lakes and rivers to Lake Winnepeg and then into the United States to either the Mississippi or the Missouri rivers, or both. Water would flow down these rivers to about the South Dakota-Nebraska state line before diversions would start to bring this water up to the plains area and then on to the high plains of Texas and New Mexico.

It seems unlikely that either the North American Water and Power Alliance Proposal or the Central North American Project will be developed as a single project. However, there appear to be possibilities for various portions to be developed and ultimately joined together as a more or less coordinated unit in the course of 40 to 50 years.

The surface water use and its relative effect upon ground water brings out another facet of the problem -- water pollution. The pollutants are sewage pollution of both surface and ground water, and industrial pollution of both surface and ground water, sediment pollution of surface water streams and rivers, and salt water encroachment in ground and surface waters. In many areas of the state septic tanks and domestic wells are spaced too close together in subdivisions and trailer parks, resulting in pollution from septic tanks being recycled into domestic wells. Some sewage plants discharge improperly treated wastes into rivers and streams. This is largely due to improperly designed, installed, and operated sewage plants. In many areas the population is increasing faster than sewer facilities are installed.

Many municipalities are faced with shortages of water. Provisions will have to be made to ensure an adequate amount of water for municipal uses in the future. If population increases, there will be increased pressures for more water for municipal and industrial uses and for water-based recreation. New Mexico now has only a small allocation of water for recreational purposes. Water for recreational purposes affects both the enjoyment of activities by New Mexicans and activities by out-of-state tourists. Currently a few new projects are being developed to increase water recreation sites, notably Cochiti Lake, between Albuquerque and Santa Fe.

One means of conserving water is recycling. Recycled water, properly treated, can be used for golf courses, swimming pools, or put back into the municipal water systems. In some systems in the nation, as much as 40 to 50 percent of the city water supply is recycled water. By recycling water, the gross amount of water for city needs -- either surface or ground water -- can be reduced.

With this background in mind, I have several recommendations for state policy.

I recommend:

1. That the State Planning Office be included on the Water Quality Council for long-range resource planning and coordination of State Government Planning to this end.
2. That the Environmental Improvement Agency be given the power to control any dumping into waters of New Mexico.
3. That developers in rural areas be required to provide adequate water and sewage systems for their housing developments.
4. That the current proposed legislation in congress providing for interstate environmental compacts be supported which could provide for regional water quality controls.
5. That immediate attention be given to methods of recycling water.
6. That methods be developed for the orderly transfer of water rights for alternative uses.
7. That the apportionment and control of water in New Mexico by federal agencies be carefully studied to determine the impact.
8. That the production of electrical power and of fuel for that production be related to water quality and water quantity and the affect and long-term impact be determined.

The people of New Mexico must recognize the reality of our water situation and encourage leaders on the local, state, and federal levels to be cognizant of the following:

1. That New Mexico is not seeking a large increase in population. Our number one priority is to establish and maintain a quality of life for all New Mexicans. This quality of life must include both developing a sound economic base and the protection of our uniquely beautiful environment.
2. That protection of our water will step on some powerful toes and will take some decisive leadership to accomplish.
3. That there are no alternatives to the protection of our water supply and water quality and the need for action is immediate. We cannot wait until the situation becomes a health threat.
4. That legislation is the only method of control which will provide a rational and effective approach to the problem.

The State Planning Office will be working with legislators, state agencies, and local units of government to formulate reasonable and comprehensive land use laws. We feel it is crucial for the coming legislature to act in these areas and the State Planning Office will be available to assist in any manner needed. I can assure you that the Governor will be watching the progress of the land-use task force closely. The Governor, along with all the people of New Mexico, will be looking to the legislature for positive action in water and land use problems this session.

As State Planning Officer, I will also be supporting such positive action, and I hope each and every one of you will also. Thank you again for the opportunity to speak today.

PANEL - WATER IN LAND DEVELOPMENT

John R. Wright*

I very much appreciate the opportunity of participating in the 17th Annual New Mexico Water Conference and it is a pleasure to be on the panel with such distinguished persons as David King, Harvey Mudd, and Carter Kirk.

I would like to present my thoughts in two sections. I would like to discuss the overall availability of water within the State of New Mexico and then subsequently relate that to the land resources and the support of the population.

Water Resources of New Mexico, a document compiled by the State Engineer Office in cooperation with New Mexico Interstate Stream Commission and the U. S. Geological Survey published by the State Planning Office in 1967, indicates that, and I quote from that document: "When New Mexico has fully developed her surface-water resources within allowances of the seven interstate water-apportionment compacts to which she is a party, river inflow to the State will approximately equal river outflow; and New Mexico will use about the amount of streamflow that she produces." On the average, it is my understanding, from the same document, that little more than three million acre feet appear annually as stream runoff indicating that our total renewable water resources, excluding groundwater, amounts to three million acre feet annually.

Discounting groundwater mining for a moment, it would appear that New Mexico has three million acre feet of water to put to some use annually into perpetuity should weather conditions remain relatively constant. This amounts to 978 billion gallons annually or 2,680 million gallons per day. It is my understanding that this water resource is presently totally appropriated to beneficial use either through existing uses and projects that are authorized or are under construction. Excluding, for the moment, the finding of a fantastic groundwater resource, present water uses demand New Mexico's total water resource. Therefore, there can be no significant change in water or land use to support an increase in population without the diversion of water from an existing use. In order to put into perspective the 2,680 million gallon a day resource, I would like to develop some figures.

Present surface water resources will support:

1 million people on an	Agricultural Based Economy
8.6 million people on a	Municipal and Industrial Base at 300 gal./capita
26.8 million people for	Municipal Use Only

* Chief, Water Quality Section, New Mexico Environmental Improvement Agency, Santa Fe, New Mexico.

270 million people for	Restricted Household Water Use
10.7 billion people for	Drinking Water Only

Now if we add to the above resources the available groundwater, we can increase the above referenced numbers. Quoting from Water Resources in New Mexico: "Hydrologists and geologists now generally believe that most of the State's large economically usable ground waters have been located and that a future increase in groundwater usage comparable with that of the last quarter century cannot be expected." It is noted that approximately a million acre feet of groundwater was put to beneficial use in 1965. If we assume that we can sustain that usage through a reasonable period of future generations, the above tabulated figures would be increased by about 30%.

We know, of course, that the above water resources are not available equally to the land and people as presently distributed in New Mexico. The Four Corners area of the state is water rich. The Rio Grande is reasonably well-supplied with water while other portions of the State have little water available. Modern day technology, however, would allow for a transport of water resources anywhere within the state provided legal authorities were obtained and the economic bases were such to cover the cost of construction and operation of water transmission facilities.

The land area of New Mexico is approximately 79 million acres. If this land area were totally subdivided into 50 by 100 foot single family dwelling lots, there would be sufficient area for 640 million families or 2.3 billion people, considerably more than the 26.8 million that can be supported by the surface water resource for municipal water supply. There is no question that the water resource is limited in New Mexico and that land resource is sufficient. This statement is made with the understanding that should population pressures be great enough, all land could be developed for human occupancy even our beloved Pecos Wilderness, the Gila Wilderness, and our Indian Reservations.

Having looked at the overall resources, we must now decide how and where to put the resources to use. It is obvious that we can support a great many more people if our water resources are diverted from agricultural to industrial and municipal uses. I would estimate that a realistic figure would be diversion of half of the present agricultural water to municipal and industrial resources indicating that we could support approximately six million people.

Using the six million figure as a hypothesis for discussion, we can see that a great deal of land resources would have to be developed for human occupancy. How these water and land resources are used for support of economy and people will greatly influence the quality of living for future New Mexicans. There is no doubt that we can make a large number of mistakes and survive an ecological crisis for an extended period. For example, in April 1964, Mr. Larry Gordon, then Director of the Albuquerque Health Department and now Director of the New Mexico Environmental Improvement Agency, prepared a report on environmental health problems relating to water in the Albuquerque area. At that time, hard detergents were in wide-spread use and it was noted that concentrations as high as 0.83 ppm were found in the shallow groundwater. The Drinking Water standard is set at 0.5 ppm indicating pollution above the standard. At the time of Mr. Gordon's 1964 report, it was estimated that approximately 15,000 private water supplies and sewage disposal systems were in existence in the Albuquerque Valley area. That estimated figure has now grown to 25,000 just eight years later indicating that we have not yet stemmed the tide of inappropriate land use development and growth, and no crisis has occurred.

The question of how to utilize our land and water resources will be with us, I believe, for an extended period; however, we are beginning to move in the right direction. As a result of my presentation to the New Mexico Health and Social Services Board in August 1970, Mr. Jasper, then Director of Health and Social Services Department, appointed a committee to develop some health related land use regulations. That committee was made up of environmentalists, public health personnel, land developers, State Engineers Office and Planning Office representatives. The committee worked long and hard hours for a number of months and developed a draft set of regulations relating to subdivision development. Mr. Art Trujillo, a planner for the Northern New Mexico Economic Development Administration, prepared a set of model regulations relating to public health aspects as well as other aspects of land use development, and through his diligent efforts and efforts of the Environmental Improvement Agency - Region II personnel, the Counties of Santa Fe, Taos, Mora, and San Miguel have adopted land use regulations substantially in the form prepared by the committee. Bernalillo County and several municipalities throughout the state have also developed comprehensive land use and subdivision regulations.

I believe that it is necessary to develop sufficient regulations, either at the county level on a statewide basis or at the state level covering the entire state, at this time. The main question which always crops up in the development of any such regulation is allowable lot sizes in relation to water and sewer services to be made available. Regulations which are developed cannot be considered solely on the premise of whether or not a septic system will work on a particular lot. It is my position that land development must be properly planned in consort with the resources available and the effect of the development on the quality of the resources. For example, the increase in salinity of groundwater resulting from the domestic use of water which is disposed of through leaching.

A study conducted by EIA indicates that domestic water use adds about 350 ppm of salinity. Using this figure and assuming each home has four people producing 75 gallons each, it can be shown that a non-moving groundwater aquifer of 25 feet thickness and initial concentration of 350 ppm would be polluted in 24 years if there were one house per 1/4 acre. In most instances, the groundwater is moving and it is frequently thicker than 25 feet allowing an extended period to pass before problem conditions manifest themselves. Nature can withstand considerable stress before she retaliates, however, we should not drop our guard simply because there is a storage bank for us to draw on.

I believe that Mr. George Bernard Shaw, one of my favorite authors, has stated the problem quite well in the following quotation: "Nature's way of dealing with unhealthy conditions is unfortunately not one that compels us to conduct a solvent hygiene on a cash basis. She demoralizes us with long credits and reckless over drafts, and then pulls us up cruelly with castastrophic bankruptcies. Take, for example, common domestic sanitation. A whole city generation may neglect it utterly and scandalously, if not without absolute impunity, yet without any evil consequences that anyone thinks of tracing to it. In a hospital two generations of medical students may tolerate dirt and carelessness, and then go into general practice to spread the doctrine that fresh air is a fad, and sanitation an imposture set up to make profits for plumbers. Then suddenly Nature takes her revenge. She strikes at the city with a pestilence and at the hospital with an epidemic of hospital gangrene, slaughtering right and left until the innocent young have paid for the guilty old, and the account is balanced. An then she goes to sleep again and gives another period of credit, with the same result."

I thank you for the opportunity to work with you here today.

PANEL - WATER IN LAND DEVELOPMENT

Harvey Mudd*

The speculative land boom that has so drastically altered the land and social structure of California and Arizona has spread east to New Mexico. Profit-taking on vast tracks of unimproved and often worthless desert real estate is accomplished by the large scale subdividing and high pressure marketing of this land in the centers of urban discontent. While many of the lots sold in New Mexico in this new land rush will never see a homebuilder, and will forever lie useless, thousands of under-an-acre monuments to man's greed and gullibility will be built, and many of the subdivided lots will eventually see their new owners, shovel, hammer, and grass seed in hand.

It has been estimated that already over 1 million acres have been platted for sale. Guessing at densities and sizes of families, we have a potential increase of 2 million people to the state's population. No one knows how many people will actually come. The great degree of environmental and social impact of subdividing will, of course, depend on how many souls respond to the promotional talk of 99% pure water and unlimited opportunity and the photos of well-watered golf courses. There can be no doubt that there will be some impact.

In the arid Southwest, the area of greatest concern should be water. Each new family will consume some .7 acre feet per year. The obvious question should be from where and from whom will the water come. Unfortunately, the way the present water law reads, the water for the new people is likely to belong to an existing water user, and it will be taken from him whether he likes it or not. It is this situation that I will focus on, for it is in urgent need of correction.

The basic tenet of New Mexico water law is the doctrine of prior appropriation. The law says that all the waters of the state belong to the public and may be appropriated for beneficial use. The establishment of a water right is accomplished by putting a quantity of an appropriated water to beneficial use. And in the words of the State Constitution, Section 3, Article 16, "Beneficial use shall be the basis the measure and the limit of the right to use water." The Constitution goes on to say in Section 2, Article 16, "Priority of appropriation shall give the better right." This, in effect, says that the first user of water, the first appropriator, has the better or stronger water right than a later appropriator. The prior appropriation doctrine is essential and an obvious necessity if there is to be any orderly economic development of the state's water resources. Obviously, no capital investment involving water would occur in a situation where a later water user

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could, with impunity, wipe out the viability of an earlier investment. And what capital investment, be it a home, a farm, a factory, or a city, does not involve water?

The language of the Constitution refers to surface waters. The concept was extended statutorily to cover underground waters within those areas declared by the State Engineer to be an underground water basin (Section 75-11-3, NMSA 1959). In addition to the statutory extension of the doctrine, judicial interpretation has, in effect, stated that, "There does not exist one body of substantive law related to appropriation of stream water, and another body of law relating to the appropriation of underground water. The legislature has provided somewhat different administrative procedure whereby appropriators' rights may be secured from the two sources, but the substantive rights, when obtained, are identical." (City of Albuquerque vs. Reynolds, 71 NM 428, 379P, 2d, 73).

The procedures to be followed for the appropriation of underground waters within a declared water basin are set forth in Section 75-11-3. This section states, and I will quote extensively from the section, that:

> "Any person, firm or corporation desiring to appropriate for irrigation or industrial uses any of the waters described in this act . . . shall make application to the state engineer in a form to be prescribed by him . . . .
>
> Upon the filing of such application the state engineer shall cause to be published in a newspaper of general circulation in the county wherein the proposed well will be located . . . a notice of the filing of such application, and that objections to the granting thereof may be filed . . . .
>
> The state engineer shall, if he finds that there are in such underground stream, channel, artesian basin, reservoir or lake, unappropriated waters, or that the proposed appropriation would not impair existing water rights from such source, grant the said application and issue a permit to the applicant to appropriate all or a part of the waters applied for subject to the rights of all prior appropriators from said source.
>
> If objections or protests have been filed with the time prescribed in the notice, of if the state engineer is of the opinion that the permit should not be issued, the state engineer shall notify the applicant of that fact by certified mail . . . . If, after such hearing, it shall appear that there are no unappropriated waters in the designated source, or that the proposed appropriation would impair existing water rights from such source, the application shall be denied."

To summarize the above, Section 75-11-3 states that before an appropriation for irrigation or industrial use may be made there must be public notification of the intention to make the appropriation, opportunity for protest, public hearings, and, quoting again, "if after such hearing, it shall appear that there are no unappropriated waters in the designated source, or the proposed appropriation would impair existing water rights from such source, the application shall be denied."

The principles contained in this section were by judicial interpretation extended to cover appropriations made by a city or municipality, in the case of the City of Albuquerque vs. Reynolds (71NM 428, 379, P, 2d, 73).

The Due Process of Law provisions of Section 75-11-3 and the doctrine of prior appropriation hold for all uses of water in the state. There is one exception. This is the exception or loophole allowed under Section 75-11-1 of the State Code. Quoting from that section:

> "By reason of the varying amounts and time such water is used and the relatively small amounts of water consumed in the watering of livestock, in irrigation of not to exceed one (1) acre of non-commercial trees, lawn or garden; in household or other domestic use, and in prospecting, mining, or constructing of public works . . . application for any such use shall be governed by the following provisions.
>
> Any person, firm or corporation desiring to use any of the waters described in this act for watering livestock, for irrigation of not to exceed one (1) acre of non-commercial trees, lawn, or garden; or for household or other domestic use, shall make application or applications from time to time to the state engineer on a form to be prescibed by him. Upon the filing of each such application, describing the use applied for, the state engineer shall issue a permit to the applicant to so use the waters applied for."

This provision in the State Water Code is the heart of the problem. It, in effect, allows domestic water users to establish a water right of up to 3 acre feet per year without going through any of the due process procedures that are described in Section 75-11-3. It does not require that the State Engineer find that there is some quantity of unappropriated water in the declared water basin, which quantity can then be appropriated by the domestic well. It does not require that the State Engineer first satisfy himself that no existing water right will be impaired by the new use. It is, in effect, an automatic granting of a water right which ignores the protection afforded by Section 75-11-3 and by the basic concept of prior appropriation. When 75-11-1 was enacted in 1953, it was never contemplated that it would be used by large scale land subdividers as the way in which they would provide water to prospective lot purchasers. And yet that is the case today. An examination of the disclosure statements of countless subdivisions, large and small, finds that in many cases, the subdivider provides water service to a small core development area. The majority of the acreage, however, is not serviced by the water system. For the areas not so serviced, the subdivider says in his disclosure statements, and I paraphrase, "New Mexico law allows any individual to drill a domestic well and remove 3 acre feet per year."

If the appropriation of water made through a 75-11-1 well occurs in an already fully appropriated underground water basin, as would be the case in the Rio Grande Basin and in the Roswell Artesian Basin, it means, very simply, that the well is using somebody else's water, without giving the existing water user opportunity to protest the new use and without giving the State Engineer the authority to deny the application. The only protection that is available to the holder of a prior water right is to sue the driller of the 75-11-1 well for damages. The burden of proof would fall on the injured party. This is in direct contrast to the burden of proof under section 75-11-3 where, by judicial interpretation, it has been made very clear that the burden falls on the applicant for a permit to make a new appropriation of waters. (Matthers vs. Texaco, Inc., 77, NM, 239, 421, P, 2d, 71.)

The language of 75-11-1 refers to the ". . . relatively small amounts of water consumed . . . in irrigation of not to exceed one (1) acre of non-commercial trees, lawn or garden; in household or other domestic use . . . ." It is obvious that in referring to the relatively small amounts of water, the drafters of this language never contemplated that a subdivision of 160,000 acres, as exists in Valencia county, for instance, platted in half-, one-, and five-acre lot sizes, would rely on wells under Section 75-11-1 as its source of water. It is obvious that if that subdivision were ever to fill with homes, each one relying on 75-11-1 wells as a source of water, that the quantity of water appropriated and consumed would not be relatively small.

It was this loophole in the state law which the subdivision-water conservation bill introduced in the last legislature attempted to plug. Let me quote to you from the language of that piece of legislation, HB63-SB39, that dealt with appropriations of water inside a declared water basin: "A plat shall not be approved until the owner or subdivider has been issued a permit, other than a permit allowed under 75-11-1 NMSA 1953, by, or has been demonstrated satisfactory arrangements for water supply to the State Engineer for use of water in quantity adequate to fulfill the subdivision's requirements determined under (sic) an earlier paragraph. And for the purposes of this subsection, no water within land subdivisions shall be provided under permits issued under Section 75-11-1 NMSA 1953." This language was an amendment to the State Land Subdivision Act, 70-3-3. It would have in no way affected the uses of 75-11-1 well permit, as intended by the drafters of the original language. The farmer, the sole householder in a remote area, feedlot operator, and the like would still have been granted the permits under 75-11-1. The bill attempted to recognize the fact that land subdivision is a commercial activity and should be regulated in terms of water in the same way agricultural, industrial, or municipal water users are regulated. The fate of this piece of legislation is, I think, well known. It did not pass. And the major objection to it was the closing of the 75-11-1 loophole. It meant, essentially, that subdividers would have been required to subdivide in a direct relationship to a real housing need, to the physical availability of water, to the ability to obtain water rights, to the ability to show that water consumption by the subdivision would not impair existing water rights. This attempt to bring subdivision use of water, both conceptually and economically, within the same framework as other water users in the state was fought vigorously by the speculative land sellers. In light of the magnitude of the land speculation that is occurring in the State of New Mexico at this time, I can think of no greater threat to our water resource and to the property rights of existing water users than this particular loophole in the law. It is my hope that in the coming legislative session, the legislature will see their obligation to the people and correct this matter.

I thank you for your attention.

PANEL - WATER IN LAND DEVELOPMENT

Carter Kirk*

First, I would like to thank the hosts of this conference for inviting me to appear on the panel. I believe it should be made clear that while many of the land subdividers will agree with some of the things I may say, the opinions which I may express, or the position I may take, not all may agree. Therefore, I am prepared to discuss only my own situation.

I believe it important that in any discussion there should be certain common definitions or premises. For example, I suggest that the three areas of land subdivision may well be defined as the local or independent subdivider, meaning those who cut relatively small acreages into various size portions and sell them themselves or through local real estate agencies to persons who most generally visit the sites for sale. Of the larger subdividers, I consider there are two classes - one, such as my operation - which is strictly rural - and other operations which actually afford resort or urban facilities, in many instances including all of the utilities.

Land is acquired for one purpose, in my opinion, and that is use - not use in the strictest sense of the word, but no one acquires land without some intent of use, be it for farming, stock, residential, commercial or investment purposes. Both the intent of the purchaser and the suitability of the land should meet, but regardless of acquisition of land, whether it be within a community or within a subdivision outside of any community, the intent and suitability may not meet.

Being in the land subdivision business is my bag, or thing. Others may elect professional studies, spur movements, accept employment, but in the great, great majority of whatever anyone does as his thing, the ultimate goal is to try to live the good life and, hopefully, leave something for his heirs. I make no apology for my business or my way of life.

Now, insofar as land subdividing is concerned - having chosen a location, having determined that it is suitable for the purpose for which it is intended, it is only natural that the subdivider will use to his benefit any regulation, statute, or lack thereof, that will enable him to recapture his rather substantial investment, pay his extravagant overhead, and hopefully receive some reward. This is as true about the acquisition of a commercial tract within a community. Certainly involved in the selection of the property will be rules, regulations, zoning, utilities, and the myriads of things for consideration.

* President, Select Western Lands, Deming, New Mexico.

So, briefly, if it is assumed that acquisition of land is for use, as outlined by me, then there is no difference between a subdivider and any other acquisitor.

The idea that the subdivider is an unreasoning, conscienceless, land rapist is as full of hot air as those who would so represent him. The subdivider, by the very reason of his substantial investment and continuing overhead, must be responsible and responsive.

Of late, legislation which has been proposed has concerned itself primarily with water. I think this is a realistic thing, except that I feel the water situation should be under full disclosure. I refuse to believe that in my particular area, any of the use of water by the subdividers has denied previous adjudicated rights. I think this situation might occur differently in other areas which, of course, is why it has been my personal opinion that to a large extent, subdivision control should be left at the local level. I submit to you that there is a considerable difference in developing water in Grant County where water is relatively scarce and the cost of drilling is very high, and in the area along the Rio Grande River in Dona Ana County or in my own county of Luna. By the same token, I think it interesting that there are areas where the porosity of the ground is such to make subdivision almost totally impossible, unless sewage systems are to be installed. I recall the rather substantial investment that we made in a ranch because of the water situation, and acted like fools, because we didn't investigate further. As a result we found we were hitting water at 12 feet in a gravelly base. There was no way that we could subdivide without either putting in a water system or a sewer system. We disposed of this particular ranch, frankly at a loss, because this was an area where we just plain didn't pay enough attention in the beginning.

I am advised that the State Engineer has issued within the Mimbres Water Basin or the Extended Basin 300 domestic well permits in the past 5 years. These are not stock watering wells, these are domestic wells. There is no great argument between me and the person wishing to control the amount of water that is permitted under a domestic permit, that people don't use three acre feet of water which is approximately a million gallons a year. I do think that the bill introduced in the 1971 legislature providing for 3/4 acre foot was too limited. Further than that, I felt that the sponsors of the bill were way off first base when they pointed out that a commercial establishment could have 3/4 of an acre foot, but purely for sanitary purposes. In other words, if a man wanted to plant a tree or several plants around the little commercial establishment, he was forbidden to. I think that the amount should be specified, but then the freedom of use other than commercial should be permitted. As stated before I do think that 3/4 of an acre foot was not enough, but I would be most acceptable to 1 1/2 acre feet, even though I don't think the people are using it. I base this on the fact people ultimately moving to our great state to avoid the chaos of rigid urban living may anticipate a small orchard or garden or something and I think they should be permitted to utilize that.

At any rate these 300 residences using an acre foot apiece would have only taken the water from a 100 acres of irrigated land and I submit to you that they are not even in the same aquifer. We calculated that if we allowed 150 gallons per day per person for 3 1/2 persons in a family that in order to move into 10% of the allocated water use for irrigation in Luna County, we would have to build two new residences a year for the next 20 years. If this happened you can imagine what these people are going to get for their water rights because economy dictates that sooner or later as the area grows, private water systems are going to have to be constructed. I can foresee a day in the future when the son or grandson of some farmer who is trying to make both ends meet can get $5,000, $6,000, or $7,000 an acre for water rights.

I would also like to point out that I think there is a greater constituency who want, with reasonable controls, the freedom for their own decisions on land than has been contemplated by persons attacking land subdivisions on the basis of water.

I assume that I am here to discuss my feelings on water in land subdivision. It is my own personal opinion that land use planning should be the first thing we get accomplished. I think this should happen in every county, and I am very much in hopes that the current bills in the Federal Congress will pass permitting funding in counties which just can't afford it at the moment. In the interim, I think most land subdividers are more than willing to meet reasonable controls based on the fact that following the land use planning, we can arrive at definitive and more rigid control.

I will be happy to answer any questions that I can.

PRELIMINARY GROUND-WATER MODEL
OF THE MESILLA VALLEY

Gary L. Richardson and Thomas G. Gebhard, Jr.*

Introduction

The Mesilla Valley is located along the Rio Grande in southern New Mexico and west Texas. Figure 1 shows the location of the area which was modeled. The study area extends along the Rio Grande Valley from the El Paso Narrows on the south to Radium Springs on the north.

Agriculture is the principal user of ground-water in the Mesilla Valley. Since the drought of the mid- 1950's the ground-water resources of the valley have been developed extensively as a supplemental supply of irrigation water.

A mathematical ground-water model would be beneficial in helping to guide the future development of the Mesilla Valley ground-water basin. The central objective of this study of the Mesilla Valley ground-water conditions was to develop and verify a mathematical model of the Mesilla Valley ground-water basin. The modeling was accomplished by incorporating all available geologic and hydrologic data into a computer program that was developed by Dr. Willem Brutsaert of New Mexico Institute of Mining and Technology. The model was calibrated by adjusting the storativity of the aquifer until the computer generated data closely duplicated existing computer generated data on water table fluctuations.

Development of Model

The Mesilla Valley ground-water system was modeled by using a digital computer (IBM 360-50) to solve the mathematical equations which describe ground-water flow. Equation 1,

$$\frac{\partial}{\partial x}\left(K_x h \, \Delta y \, \frac{\partial H}{\partial x}\right) \Delta x + \frac{\partial}{\partial y}\left(K_y h \, \Delta x \, \frac{\partial H}{\partial y}\right) \Delta y = S \, \Delta x \, \Delta y \, \frac{\partial H}{\partial t} + q \ , \qquad [1]$$

is the differential equation which describes incompressible, two-dimensional, saturated, unconfined ground-water flow. Equation 1 can be derived from Darcy's law and the mass-continuity equation using the differential element of Figure 2.

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* Formerly graduate student, Civil Engineering Department, New Mexico State University, currently with Soil Conservation Services, Albuquerque, New Mexico; and Associate Professor of Civil Engineering, New Mexico State University, respectively.

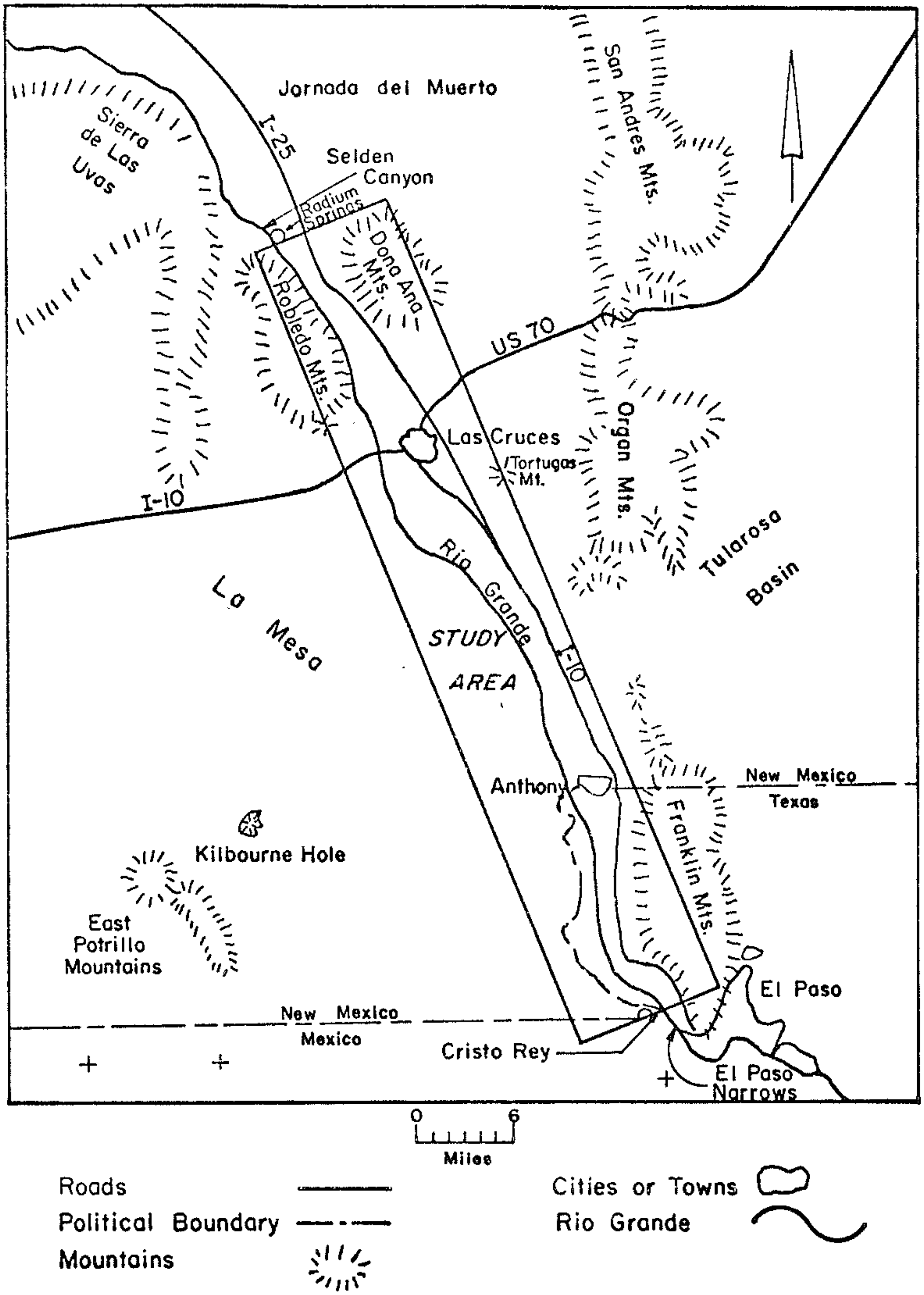


Figure 1. Index Map

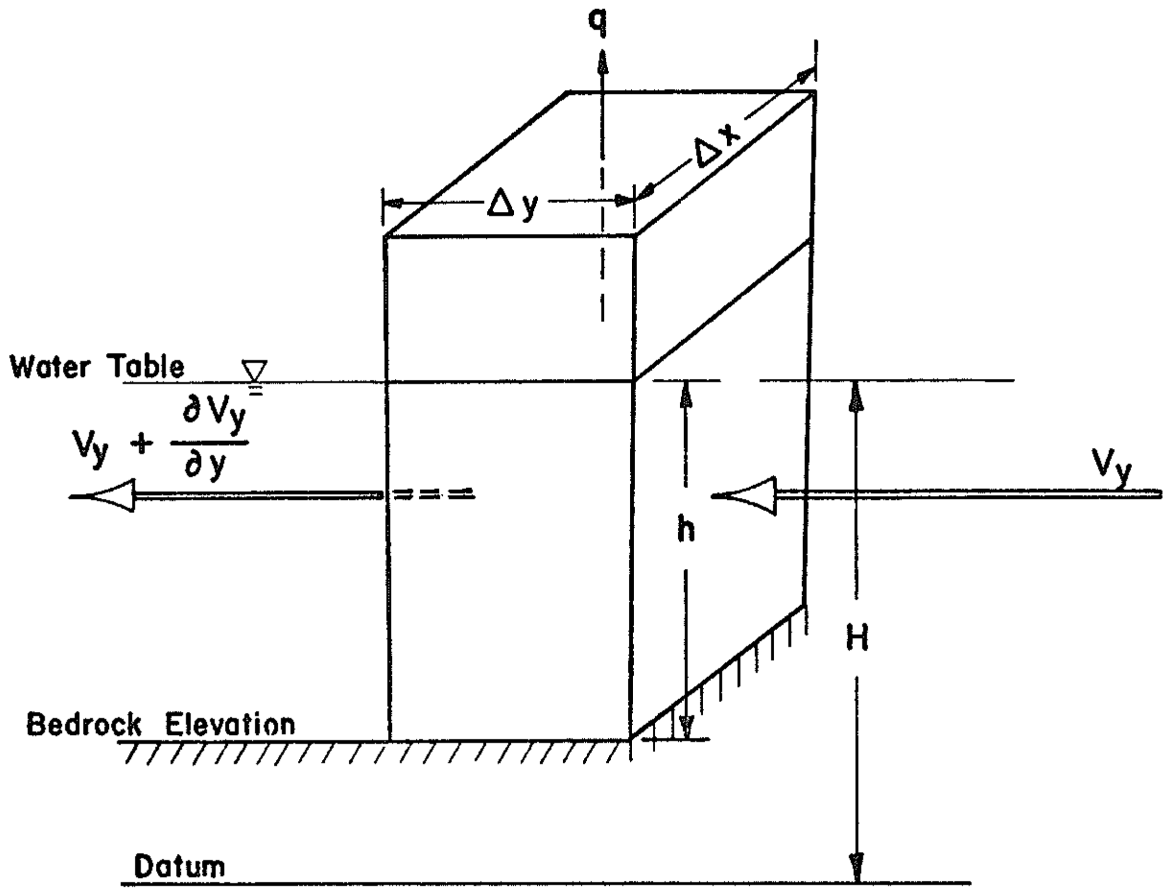


Figure 2. Differential Element of an Unconfined Aquifer

Since equation 1 does not have an exact solution a finite difference approximation is used to determine an approximate solution. The application of the finite difference technique requires that the study area be divided into a system of rectangular grid blocks. Figure 3 shows the 12 x 47 grid system that was superimposed on the study area. It is a uniform system with each grid block being 4000 feet in the Y-direction and 6000 feet in the X-direction. Using an implicit, central finite difference form, a nodal point equation was developed which describes the ground-water flow between adjacent grid blocks.

The digital computer program, which was developed by Dr. Brutsaert, writes a nodal point equation for each grid block in the study area. The entire set of equations is then solved simultaneously, by the computer, to determine the predicted water table elevations for each grid block in the study area at a succeeding time level. The new water table elevations are then used as the initial values for the next time step, and the entire process is repeated.

Input Data

The technique of modeling ground-water basins by the use of a digital computer is becoming increasingly popular in geohydrologic studies. The ability to simulate time dependent water table fluctuations is proving to be very valuable in ground-water basin management. The development of the Mesilla Valley ground-water model took place in four major steps. These steps were as follows:

1. determination of the extent of the ground-water basin,
2. determination of the aquifer constants,
3. quantification of the components of the water budget, and
4. determination of initial water table elevations.

All available geologic information was used in establishing the boundaries of the study area. The study area boundaries were placed such that underflow into and out of the study area would be as small as possible. To aid in locating geologic boundaries within the Mesilla Valley study area, a set of geologic cross-sections of the valley were constructed. These cross-sections (Figures 4, 5, 6, and 7) were constructed with the aid of gravity data, well logs and the personal knowledge of Dr. John W. Hawley of the U.S.D.A. Soil Conservation Service, and who was formerly assigned to the Agronomy Department at New Mexico State University. As can be seen by the geologic cross-sections the northern and southern boundaries were located in positions where the valley is narrowed by bedrock outcrops. The eastern boundary passes through the Franklin Mountains on the south, through Tortugas Mountain and through the Dona Ana Mountains on the north. Boundary flow is not excluded along the southern portion of the western boundary by any geologic formations, however. There is only a small amount of boundary flow in this area because the gradient of the water table is parallel to the boundary.

The total saturated thickness of the shallow ground-water aquifer in the Mesilla Valley is not known. Therefore, an effective base of the aquifer was assumed. North of Anthony the aquifer was assumed to be

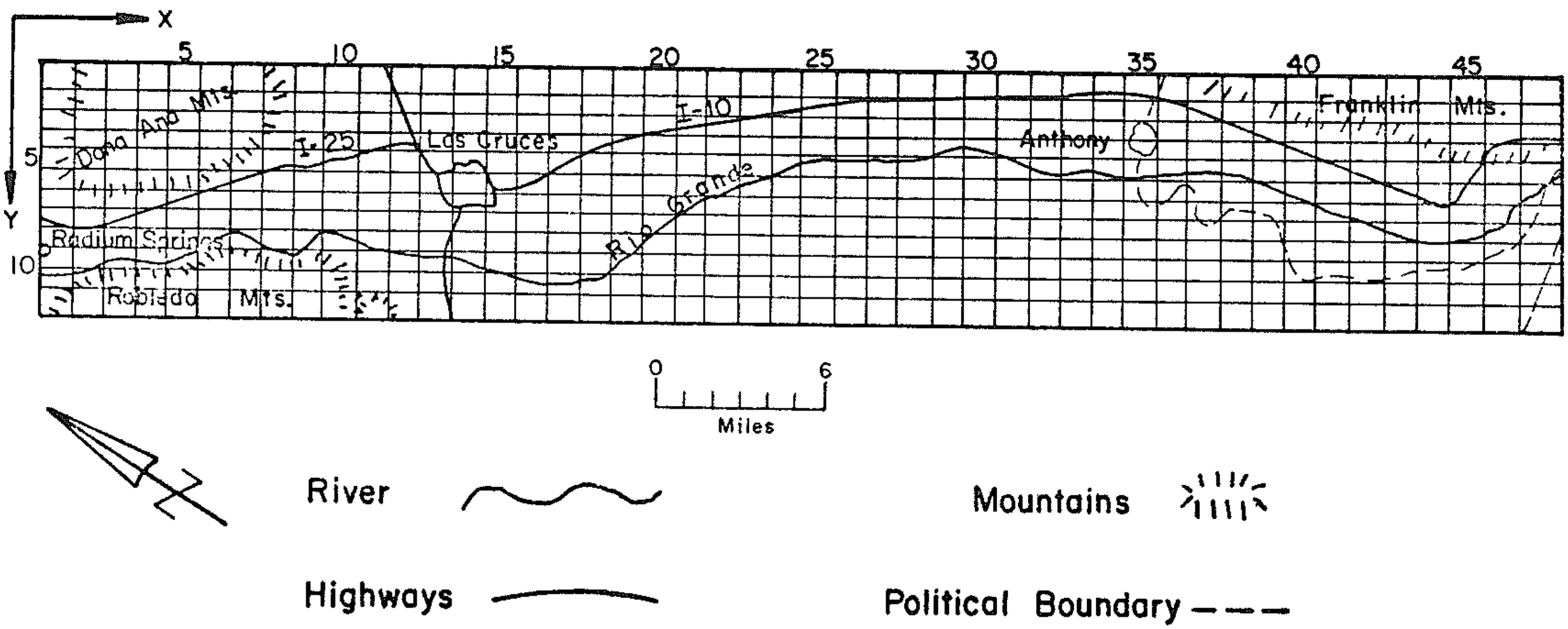
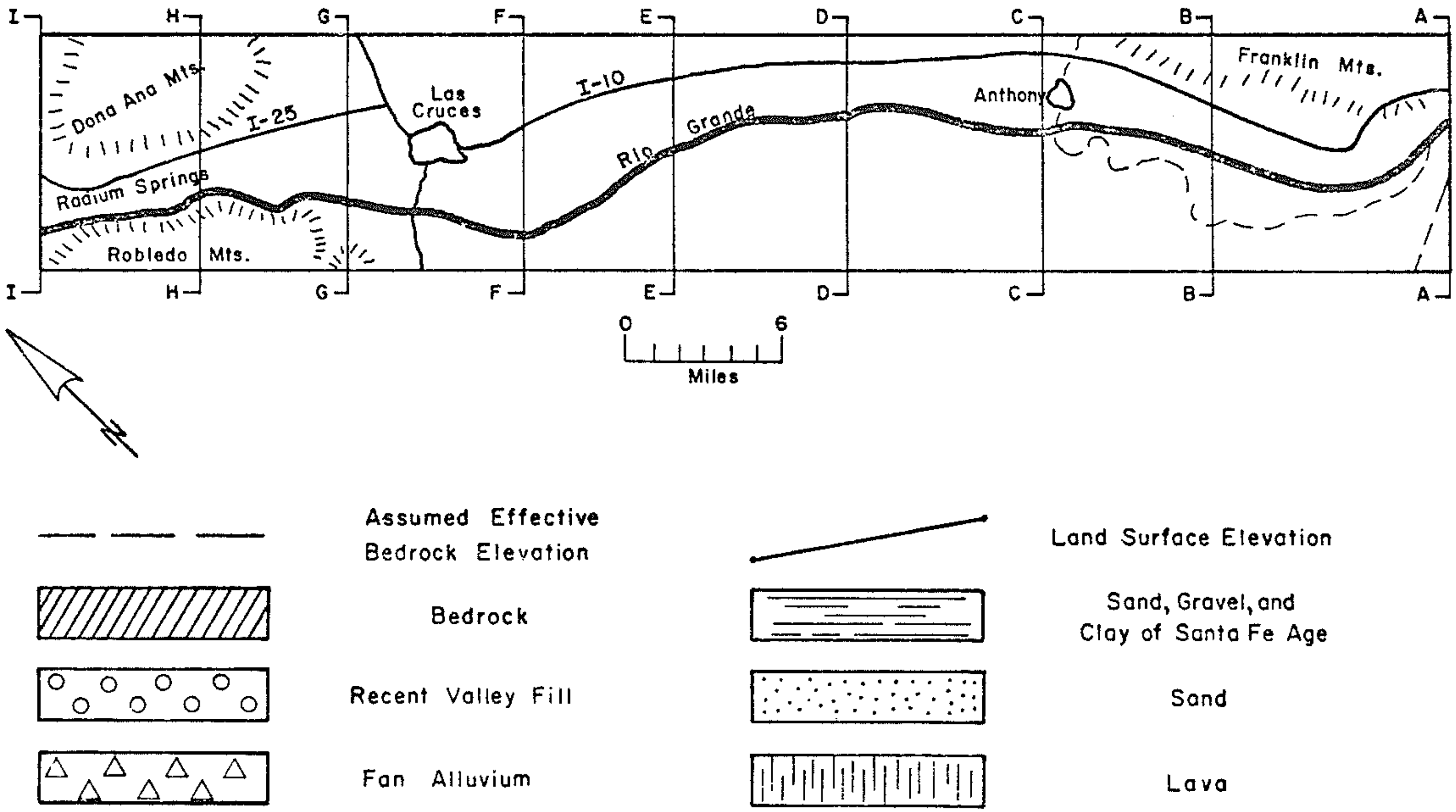


Figure 3. Grid System of Study Area

Figure 4.

LOCATION OF GEOLOGIC CROSS SECTIONS



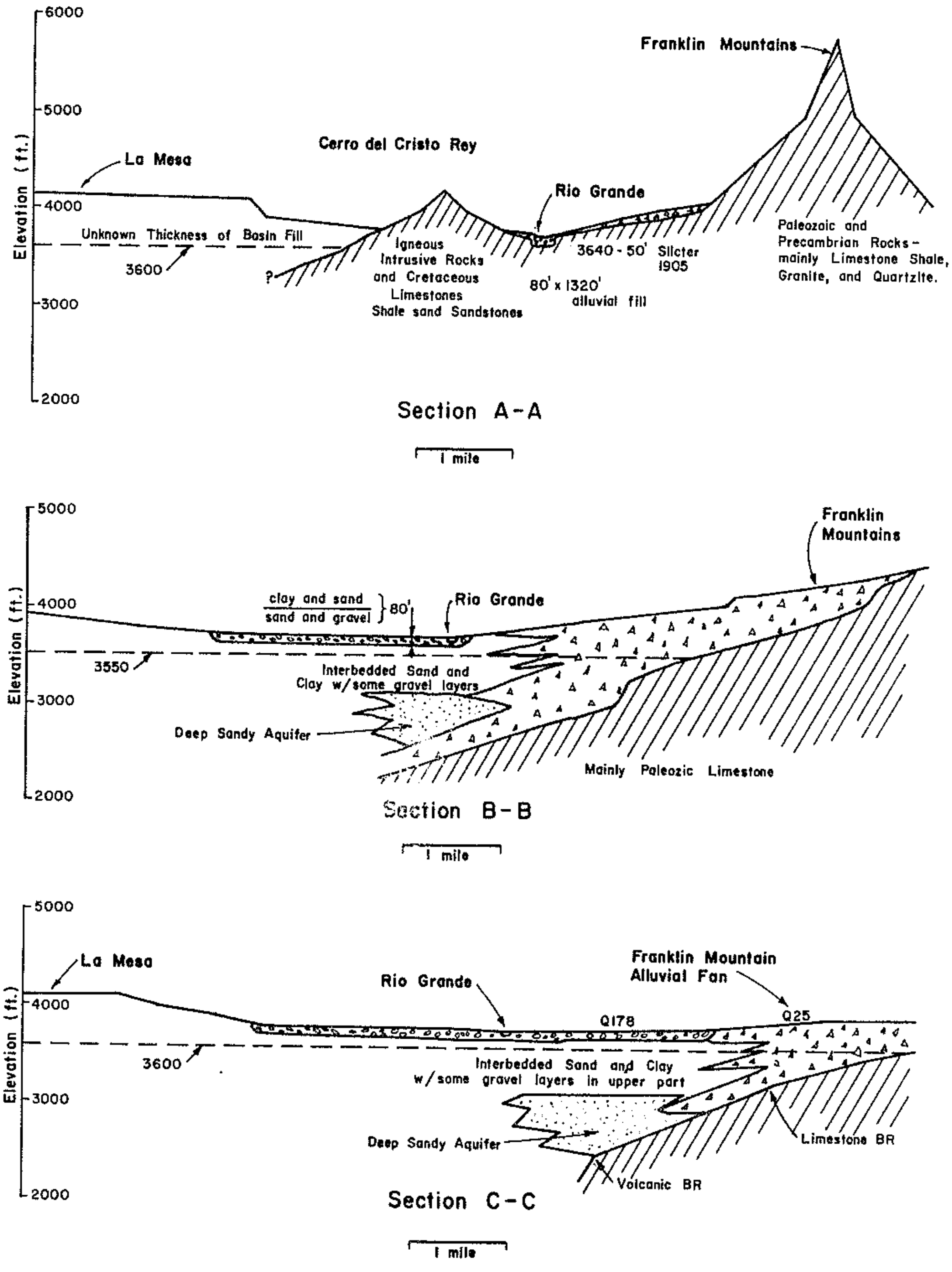

6000
5000
4000
3000
2000
Elevation (ft.)
Franklin Mountains
Cerro del Cristo Rey
La Mesa
Rio Grande
Unknown Thickness of Basin Fill
3600
?
Igneous Intrusive Rocks and Cretaceous Limestones Shale sand Sandstones
3640 - 50' Slicter 1905
80' x 1320' alluvial fill
Paleozoic and Precambrian Rocks - mainly Limestone Shale, Granite, and Quartzite.
Section A-A
1 mile
5000
4000
3000
2000
Elevation (ft.)
Franklin Mountains
clay and sand
sand and gravel
80'
Rio Grande
3550
Interbedded Sand and Clay w/some gravel layers
Deep Sandy Aquifer
Mainly Paleozoic Limestone
Section B-B
1 mile
5000
4000
3000
2000
Elevation (ft.)
La Mesa
Rio Grande
Franklin Mountain Alluvial Fan
Q178
Q25
3600
Interbedded Sand and Clay w/some gravel layers in upper part
Deep Sandy Aquifer
Limestone BR
Volcanic BR
Section C-C
1 mile

Figure 5.

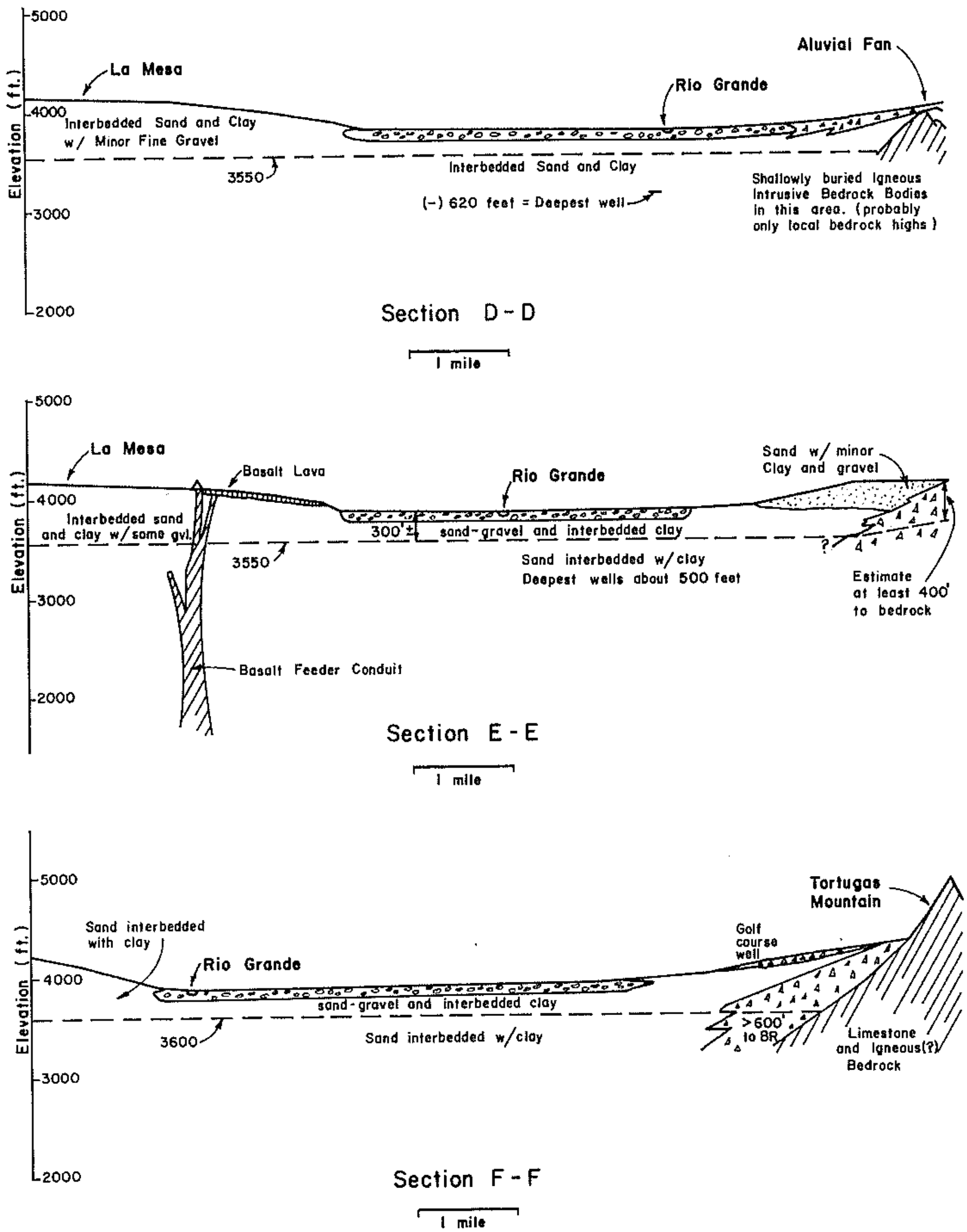

5000
4000
3000
2000
Elevation (ft.)
La Mesa
Aluvial Fan
Rio Grande
Interbedded Sand and Clay w/ Minor Fine Gravel
Interbedded Sand and Clay
3550
(−) 620 feet = Deepest well
Shallowly buried Igneous Intrusive Bedrock Bodies in this area. (probably only local bedrock highs)
Section D - D
1 mile
La Mesa
Basalt Lava
Rio Grande
Sand w/ minor Clay and gravel
Interbedded sand and clay w/ some gvl.
300'±
sand-gravel and interbedded clay
3550
Sand interbedded w/clay
Deepest wells about 500 feet
Estimate at least 400' to bedrock
Basalt Feeder Conduit
Section E - E
1 mile
Tortugas Mountain
Sand interbedded with clay
Rio Grande
Golf course well
sand-gravel and interbedded clay
>600' to BR
3600
Sand interbedded w/clay
Limestone and Igneous(?) Bedrock
Section F - F
1 mile

Figure 6.

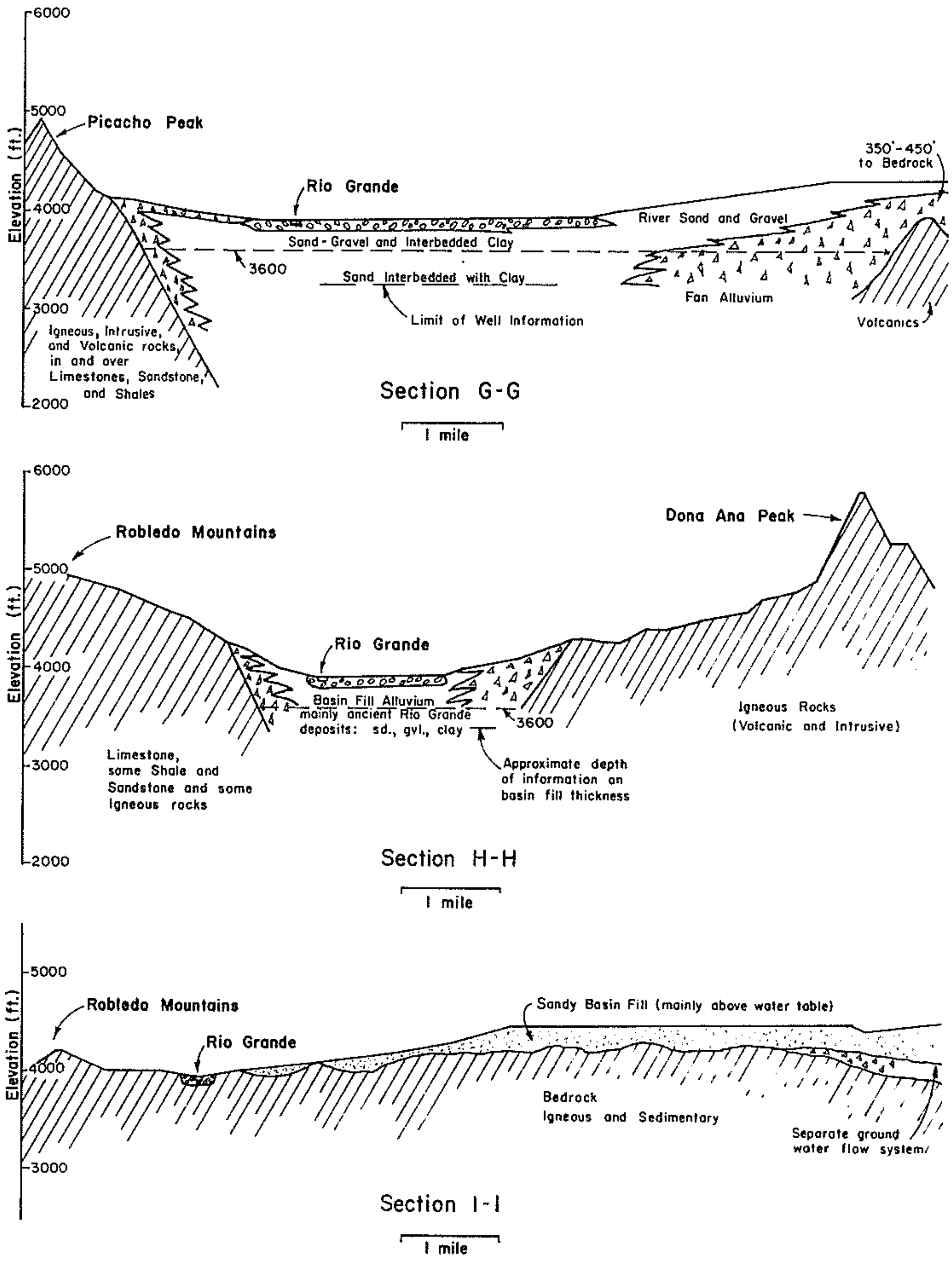

6000
5000
4000
3000
2000
Elevation (ft.)
Picacho Peak
Rio Grande
350'-450' to Bedrock
River Sand and Gravel
Sand-Gravel and Interbedded Clay
3600
Sand Interbedded with Clay
Fan Alluvium
Limit of Well Information
Volcanics
Igneous, Intrusive, and Volcanic rocks, in and over Limestones, Sandstone, and Shales
Section G-G
1 mile
6000
5000
4000
3000
2000
Elevation (ft.)
Robledo Mountains
Dona Ana Peak
Rio Grande
Basin Fill Alluvium
mainly ancient Rio Grande deposits: sd., gvl., clay
3600
Igneous Rocks
(Volcanic and Intrusive)
Limestone, some Shale and Sandstone and some Igneous rocks
Approximate depth of information on basin fill thickness
Section H-H
1 mile
5000
4000
3000
Elevation (ft.)
Robledo Mountains
Sandy Basin Fill (mainly above water table)
Rio Grande
Bedrock
Igneous and Sedimentary
Separate ground water flow system
Section I-I
1 mile

Figure 7.

about 300 feet thick, and south of Anthony it was assumed to be about 200 feet thick. South of Anthony clay lenses become predominant enough, at a depth of about 200 feet, to effectively segregate the shallow aquifer from the medium and deep aquifers.

The two aquifer constants, transmissivity and storativity, are the parameters which define the behavior of ground-water in an aquifer. The transmissivity is a measure of the rate at which water flows through an aquifer, and the storativity relates the drawdown of the water table with the quantity of water removed from the aquifer. Considering all of the available pumping tests, which are shown in Table 1 , and some work done by Conover (1954) correlating water table slopes near drain ditches and flows in the ditches, an average transmissivity of 75,000 gpd per foot was programmed into the model. Values for the storativity of the shallow aquifer in the Mesilla Valley are not available. However, Conover (1954) estimated that the storativity of the shallow aquifer probably averaged about 25 percent. A uniform storativity of 25 percent was used as an initial estimate for the model. The major means of calibrating the model was varying the storativity because of the lack of confidence in this value and because of its influence between volumes removed and drawdown.

In effect, computer ground-water modeling is obtaining a hydrologic balance for each grid block in the study area for each time step. The computer accounts for the flow between grid blocks, while any inflows to or outflows from each block must be included as input data to the computer. Figure 8 illustrates the components of the water budget which were accounted for in the Mesilla Valley ground-water model. The agricultural water budget, which is illustrated in Figure 9, is the major source of inflow to and outflow from the Mesilla Valley ground-water basin. As can be seen from Figure 9, there are four major components affecting the ground-water basin which are connected with agricultural water usage. Estimates of all four components of the agricultural water budget are combined and read into the model as the net irrigation pumpage. The determination of the net irrigation pumpage for 1964 is illustrated in Table 2.

The basic time step used in the modeling was one month. As a result the components of the water budget were read into the model in acre-feet per year with a corresponding monthly distribution factor. The last column in Table 2 and Table 3 illustrate examples of monthly distribution factors used in the model. The other components of the water budget that were accounted for in the model are municipal pumpage, industrial pumpage, exchange between the Rio Grande and the ground-water basin, flow into the drain ditches, phreatophyte consumptive usage, infiltration of rainfall and boundary flow.

In order to model a ground-water basin, an initial water table elevation must be determined for each grid block. All available water level records for January 1967 were gathered and a water table contour map was plotted for that date. Figure 10 shows the water table map. The 12 x 47 grid system was then overlain on the water map, and the

Table 1.

AVAILABLE PUMPING TEST RESULTS FOR THE MESILLA VALLEY

Well Location	Transmissivity (gpd/ft.)	Pumping Rate (gpm)	Specific Capacity (gpm/ft.)	Depth to SWL (ft.)	Depth of Well (ft.)	Source of Data	Approximate Date of Test	Remarks
23.1E.13.244	91,000	64	16	15	83	Con.	1946	A.T. & S.F. Ry.
23.2E.08.434	73,000	250	21	186	300	Con.	1946	L.C. #5
23.2E.29.143	116,000	1270	98	13	50	Con.	1946	N.M.S.U.
27.3E.14.433	---	600	6.6	17.3	200	E.P.	1964	E.P. Well No. 115
27.3E.14.433	---	700	5.25	17.3	200	E.P.	1964	E.P. Well No. 115
27.3E.23.114	---	1200	13.0	12.6	218	E.P.	1964	E.P. Well No. 117
27.3E.23.213	---	825	6.3	16.8	220	E.P.	1964	E.P. Well No. 116
27.3E.23.433	158,000	---	---	5.5	152	LL&H	1956	Q-82
27.3E.26.112	121,000	---	---	4.9	170	LL&H	1956	Q-165
27.3E.26.132	104,000	---	---	6.0	194	LL&H	1956	Q-166
27.3E.26.231	145,000	---	---	5.0	160	LL&H	1956	Q-83
27.3E.26.414	110,000	---	---	4.3	122	LL&H	1952	Q-84
27.3E.26.432	155,000	---	---	---	---	LL&H	1956	Q-86
27.3E.27.222	140,000	---	---	5.2	160	LL&H	1956	Q-90
27.3E.27.242	150,000	---	---	6.2	202	LL&H	1956	Q-91
27.3E.35.212	---	1065	10.7	17.7	209	E.P.	1964	E.P. Well No. 118

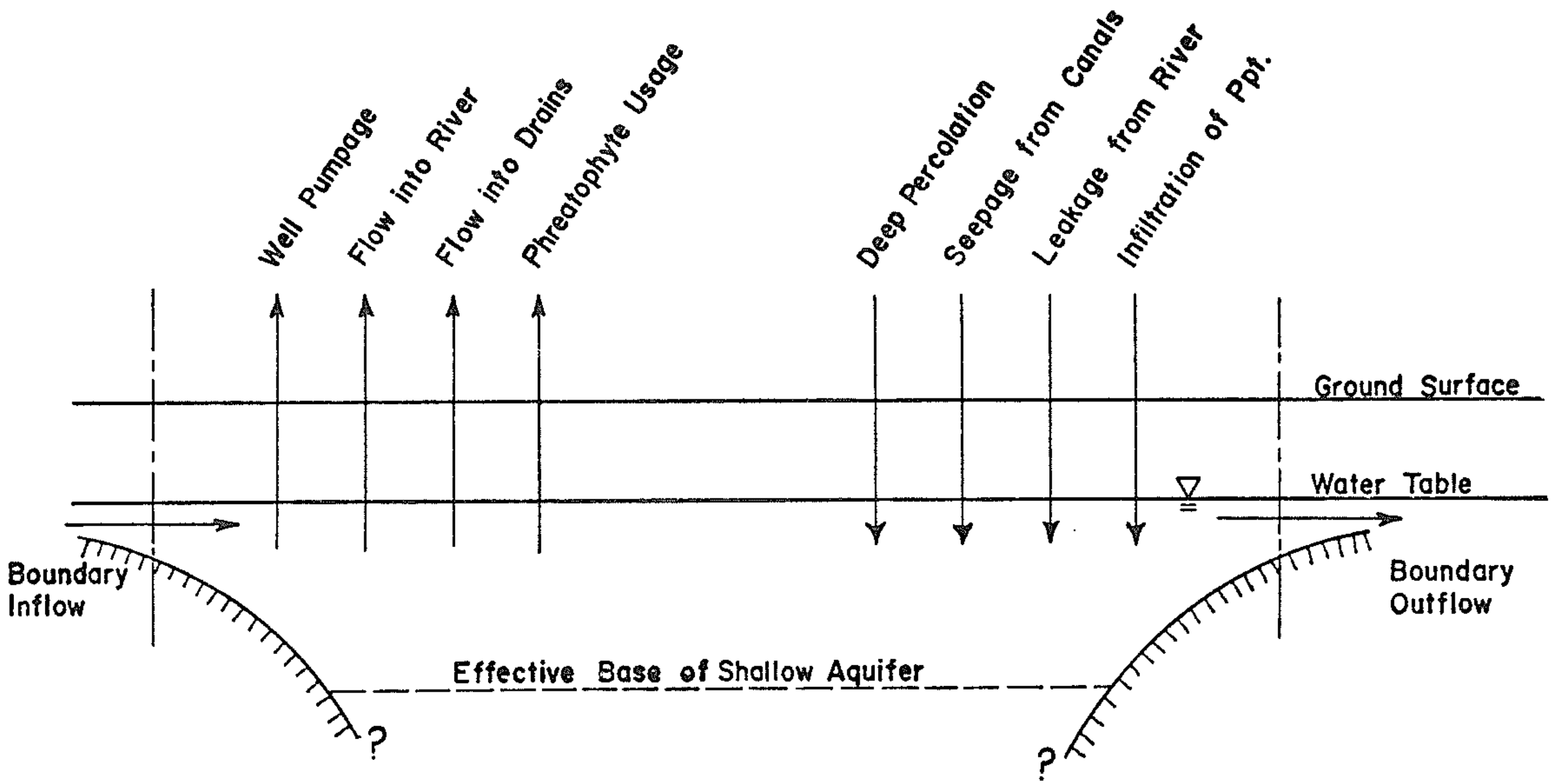


Figure 8. Water Budget for the Mesilla Valley Ground-Water Basin

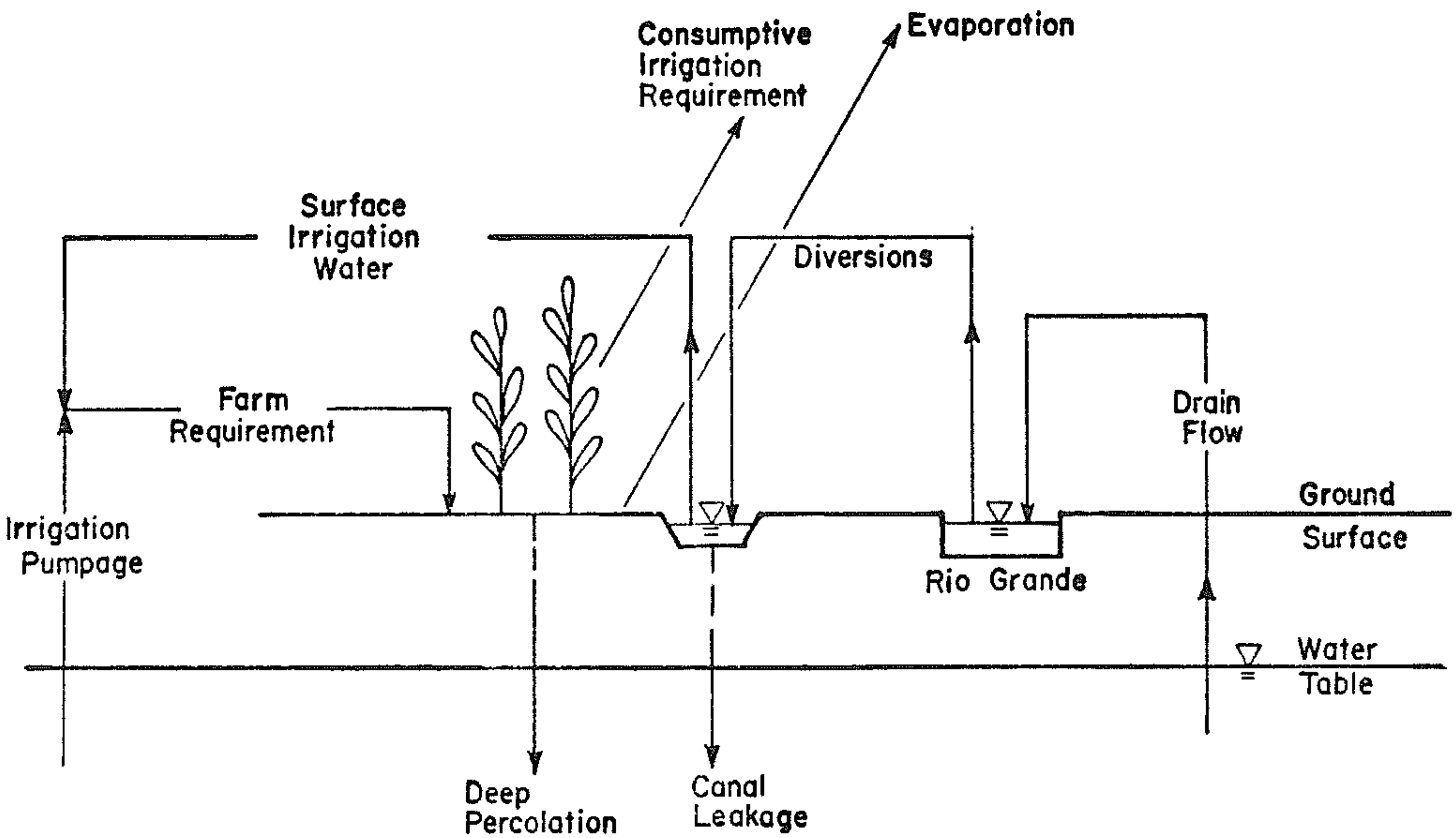


Figure 9. Agricultural Water Budget for the Mesilla Valley

Table 2

Monthly Distribution of

Net Irrigation Pumpage

for

1964

Month	Gross Irrigation Pumpage (Ac-ft/Ac) +	Drain Flows (Ac-ft/AC) +	Deep Percolation (Ac-ft/Ac) -	Canal Leakage (Ac-ft/Ac) -	Net Irrigation Pumpage (Ac-ft/Ac)	Monthly Distribution of Net Pumpage (%)
Jan	-	0.058	-	-	0.058	3.9
Feb	-	0.041	-	-	0.041	2.8
Mar	0.37	0.039	0.140	0.034	0.235	15.9
Apr	0.36	0.044	0.159	0.102	0.143	9.7
May	0.22	0.027	0.077	-	0.170	11.5
Jun	0.39	0.019	0.148	0.034	0.227	15.3
Jul	0.50	0.021	0.196	0.068	0.257	17.3
Aug	0.57	0.017	0.229	0.090	0.268	18.1
Sep	0.26	0.019	0.126	0.112	0.041	2.8
Oct	0.02	0.011	0.005	-	0.026	1.7
Nov	-	0.007	-	-	0.007	0.5
Dec	-	0.007	-	-	0.007	0.5
Total	+2.69	+0.31	-1.08	-0.44	+1.48	-100.0

Note: - indicates recharge
+ indicates discharge

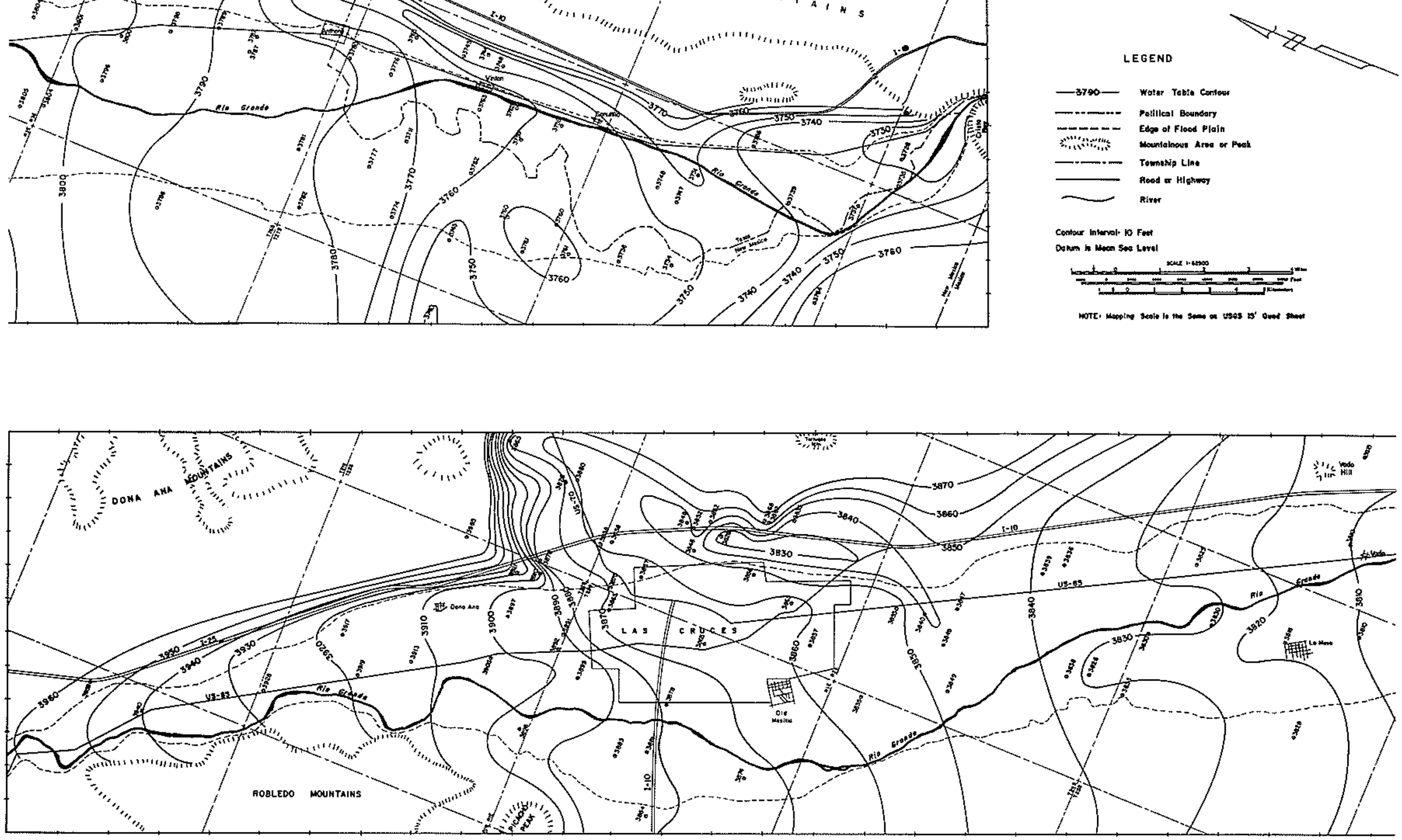
TABLE 3

MONTHLY DISTRIBUTION OF MUNICIPAL PUMPAGE
FROM LAS CRUCES CITY WELLS

MONTH	% OF TOTAL 1960-1969 AVERAGE	1964
January	4.7	4.9
February	4.7	4.5
March	6.5	5.9
April	8.7	7.5
May	11.4	11.3
June	12.1	12.7
July	12.3	12.8
August	11.4	12.4
September	8.8	9.5
October	7.2	7.9
November	7.5	5.9
December	4.7	4.7
TOTAL	100.0%	100.0%

NOTE: From production data provided by the City of Las Cruces.

FIGURE 10. WATER TABLE CONTOURS IN THE MESILLA VALLEY FOR JANUARY 1967
by GARY L. RICHARDSON



water table elevation was determined for the center of each grid block. These elevations were then read into the computer to provide the initial water table conditions for the model.

Calibration

Calibration of the Mesilla Valley ground-water model consisted of adjusting the storativity until the best simulation of historic fluctuations for 1962 and 1964 was accomplished. The years 1962 and 1964 were chosen for calibrating because they are good and bad surface water years respectively. Figures 11 , 12 , and 13 illustrate the calibration process. A storativity of 20% was determined to be a good average value for the Mesilla Valley. Although it is known that the storativity is not constant throughout the valley, data is not presently available to warrant making judgments as to more accurate values.

Following the calibration the sensitivity of the model to changes in several of the input parameters was studied. As an example Figure 14 illustrates the sensitivity of the model to changes in the exchange between the Rio Grande and the shallow aquifer.

Conclusions

The good correlation between the computer generated water table fluctuations and the historic fluctuations strongly indicates that most of the presently available geologic and hydrologic information concerning ground-water conditions in the Mesilla Valley is basically correct. It was concluded from this investigation that no unknown variables exist within the Mesilla Valley which affect the response of the water table. It is felt that for short term predictions of a few years in duration the ground-water model developed as part of this study would be sufficiently accurate. As more new and comprehensive data becomes available, the data can be verified in the model and can be used to refine the model to the point to which reliable long range predictions can be made with it.

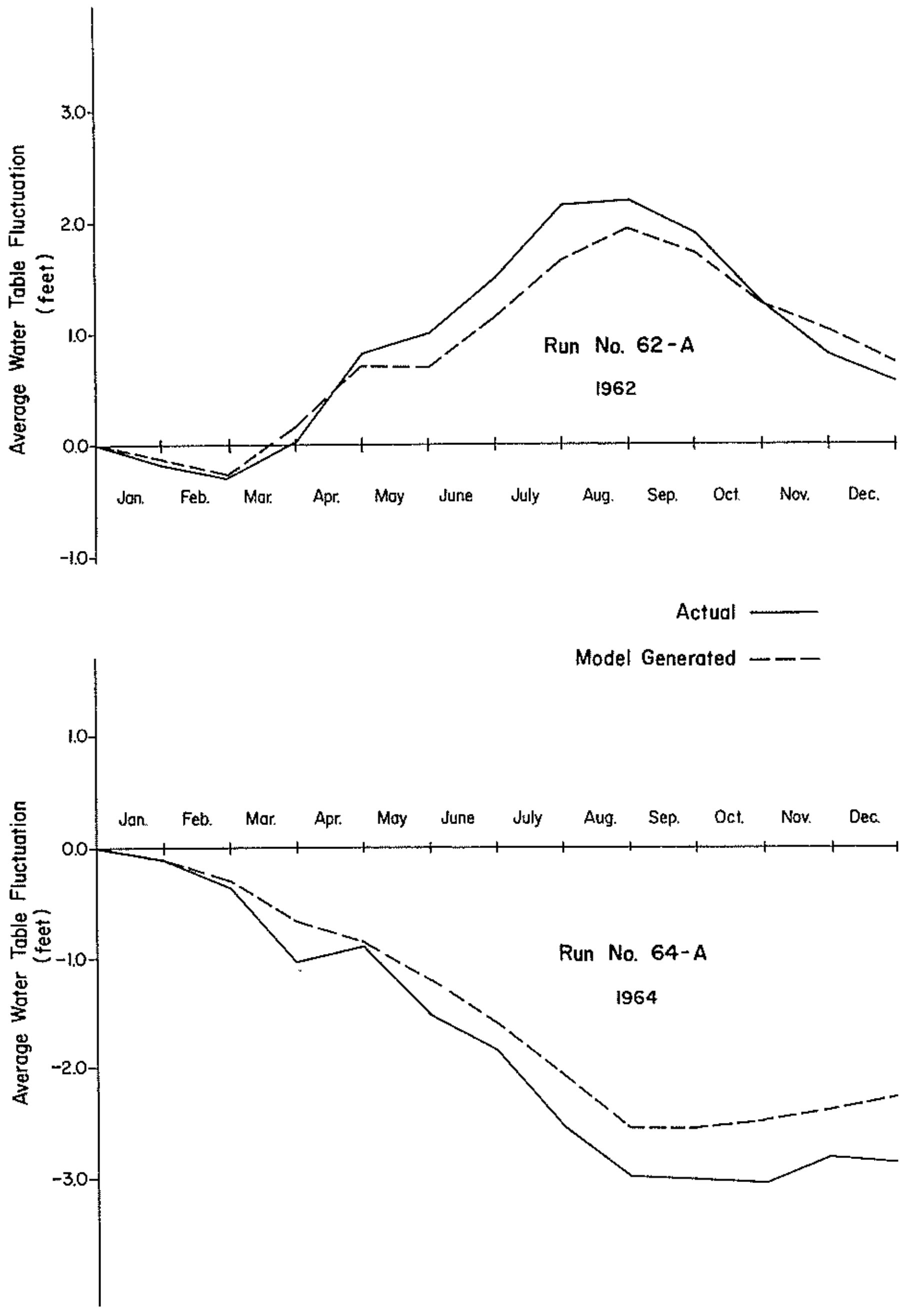


Figure 11. Storativity = 0.25

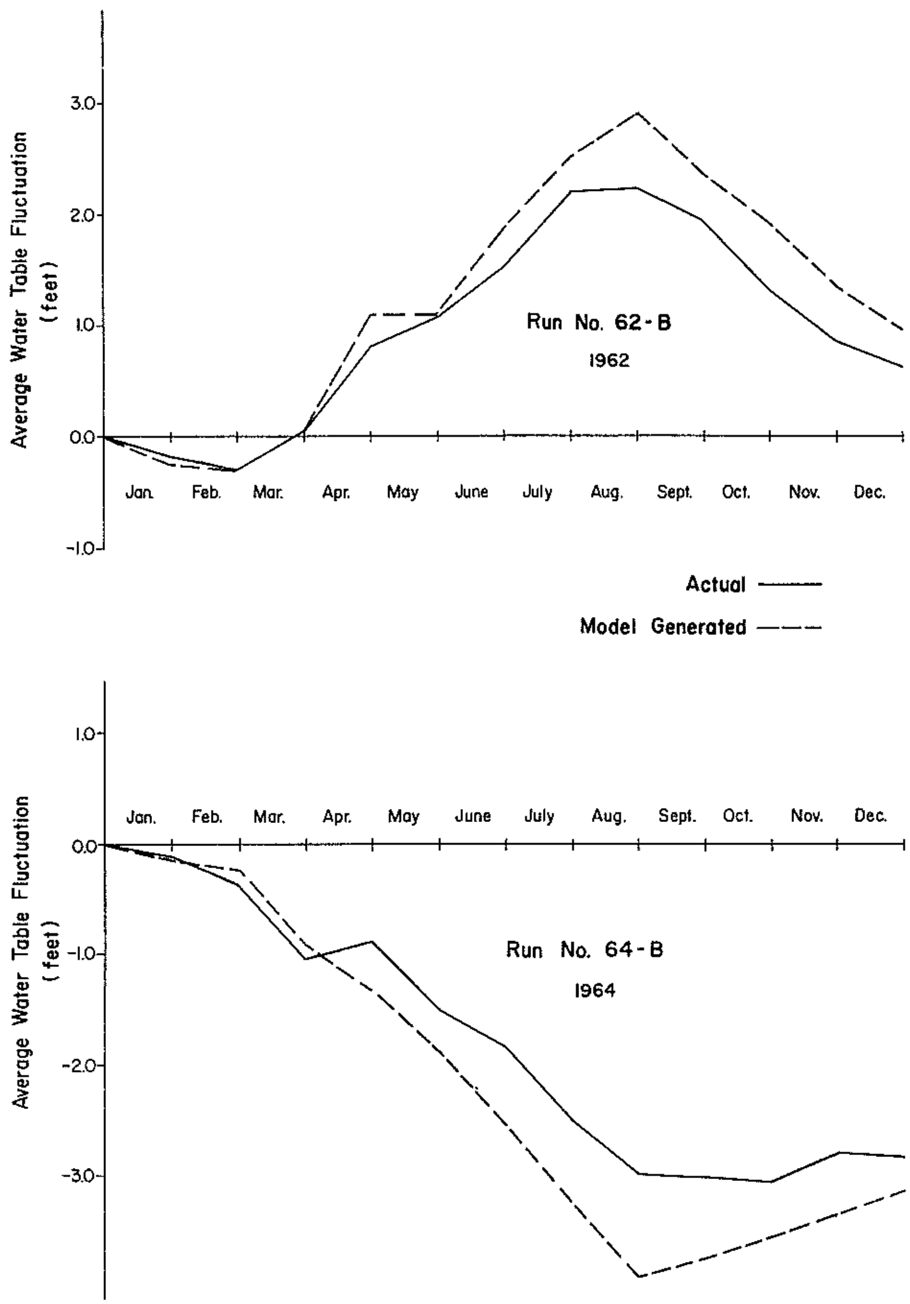


Figure 12. Storativity = 0.15

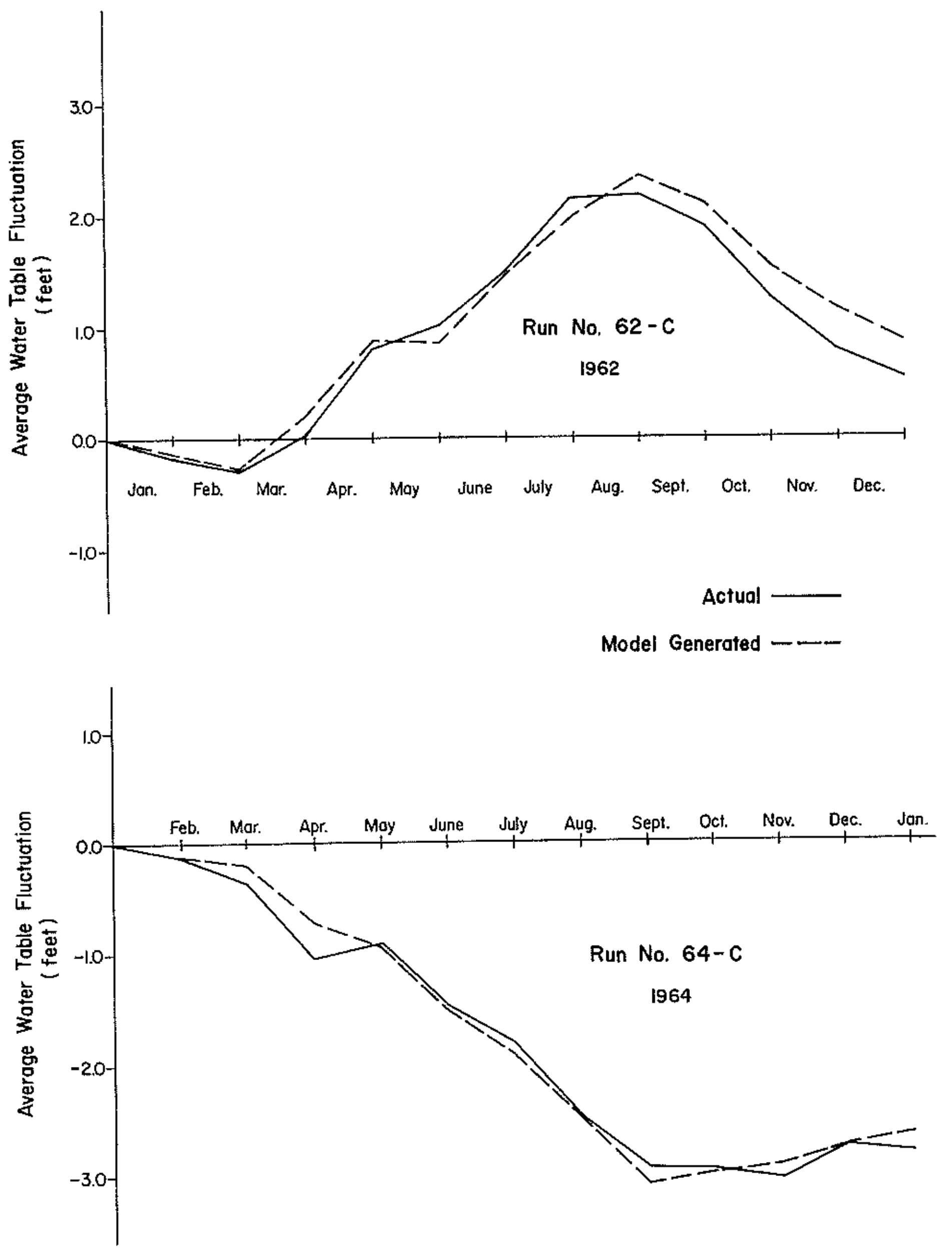


Figure 13. Storativity = 0.20

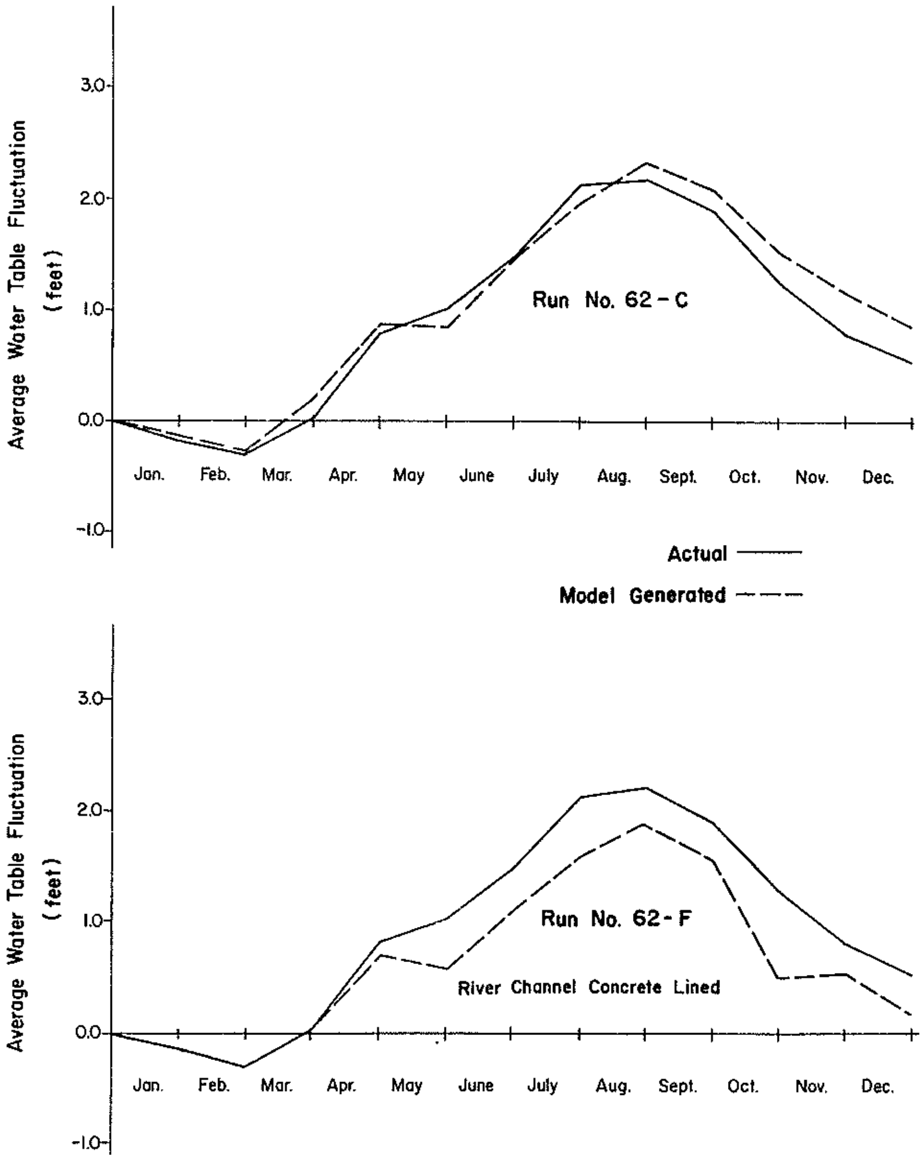


Figure 14. Sensitivity of Model to Changes in the Exchange Between the Rio Grande and the Shallow Aquifer

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AN INTERPRETATION OF WATER USE DATA FOR THE RIO GRANDE IN NEW MEXICO

Fred Roach and S. Ben-David*

Introduction to the Rio Grande Project

For the past several years, three state universities have been involved in a water resources research project[1] centered on and around the Rio Grande River Basin. Within this study several academic disciplines are represented, thus making the analysis and evaluation one of the larger interdisciplinary projects currently being undertaken within the state.

Dr. Robert Lansford (Agricultural Economist) and Bobby Creel (Asst. to the Director, WRRI) from New Mexico State University are pursuing research into the agricultural uses of water. For this purpose land and water use information was collected and evaluated. Cropping patterns and acreage of each crop, CIR's (consumptive irrigation requirements), and diversion efficiencies are only a few of the items that have been collected and analyzed. Most of this effort has been pursued in conjunction with the State Engineer's Office.

Hydrology of the Basin, both in the surface and ground waters, has been tackled by Dr. Thomas Gebhard (Civil Engineer) at New Mexico State University and Dr. Willem Brutsaert (Hydrologist) at New Mexico Institute for Mining and Technology. Items such as the relationship between surface and ground water basins, the applicable transfer mechanisms and efficiencies between ground and surface water, and estimates of the availability and changes in these availability relationships through time have thus far been pursued by this arm of the project.

The economic evaluation has been our responsibility. Recreation demand and supply, production and its associated water use, economic relationships between transfers of surface and ground waters, and changes in future water demand with increased growth are only a few of the areas that have so far been pursued at UNM.

The study has proceeded under the auspices and leadership of all three state universities, NMSU, NMIMT, and UNM. No portion of this study is meant to stand alone, but rather to be complemented as well as to complement the other portions. A general model has been developed with all parties supplying basic data and then sharing in the interpretation and evaluation of the results.

One quick example should portray more vividly this interaction among the disciplines and the universities. A model of the economy of the Rio Grande

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* Research Assistant completing requirements for the Ph.D and Associate Professor, respectively, in the Department of Economics at the University of New Mexico.

1 An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico.

River Basin has been developed. Economic data, constraints, and growth projections were developed at UNM. From NMSU and NMIMT came the agricultural and hydrological information needed to make the model operational. If now we economists project growth and changes in water demand such that agriculture decreases its portion of water use within the Basin, the agricultural economists will relate to us the basic feasibility of this, as well as the types of agriculture that could accordingly be expected to decrease their production. Additional information in the form of the marginal crops in terms of consumptive water use, the capital immobility factor (sales and transfers of unutilized resources), and the future agricultural demand in specific commodities will be derived from their evaluation of the economists' results.

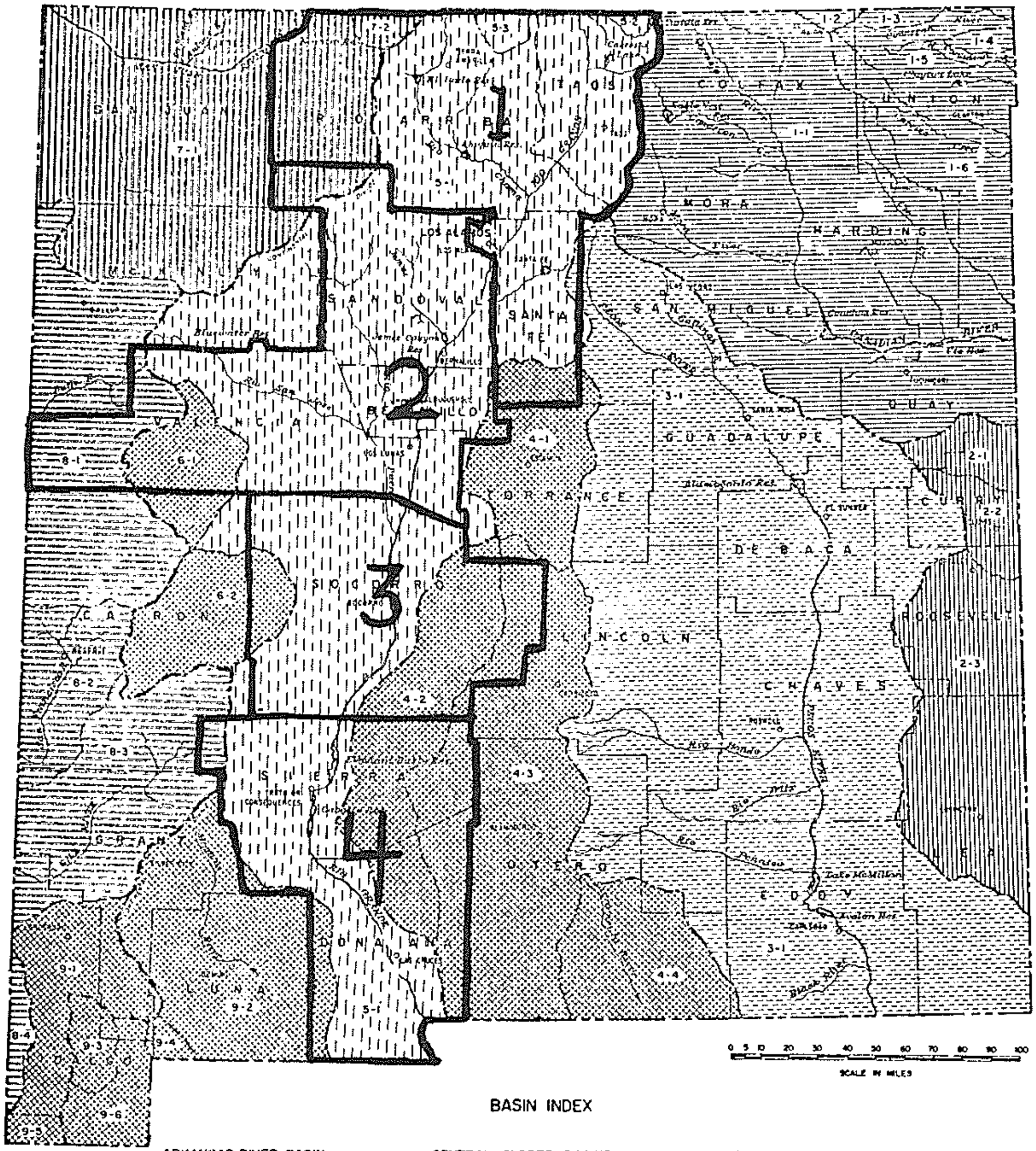
Purpose of the Paper

This paper will briefly present some of the economic interpretations thus far developed for the model, with some further evaluation concerned primarily with water use and its relationship to output, income, value-added, and employment in the Basin area itself. Some of the types of tools and methods currently in vogue will be used to evaluate and interpret the use of water and its associated data within the Rio Grande River Basin. Principally, the amount of new water intake (diversions) in the production processes will be examined. Much of the information presented in the paper is used directly as an input into the model and larger study, while the remaining evaluation presented will complement some of the results thus far derived. But first a brief view of the subject area, the Rio Grande River Basin itself.

Physical Description of the Rio Grande River Basin

The Rio Grande River enters New Mexico from Colorado near Labatos, flows southerly through the state for 430 miles to Texas and Mexico, where it then forms their border until it empties into the Gulf of Mexico. Within New Mexico the Rio Grande drains an area of 25,690 square miles or approximately 20% of the state's land area. Major tributaries include the Red River, Rio Chama, Embudo Creek, Jemez Creek, and the Rio Puerco. As can be seen from the placement of the main tributaries, the major portion of the water addition in New Mexico to the Rio Grande takes place in the northern part of the Basin.

The following map shows the major drainage areas (hydrologic definition) of the state. Outlined in black are the regions used in the present study. For this paper, the four regions were aggregated into one category, the Rio Grande River Basin (RGRB) whenever possible. As can be seen, the county definitions don't always conform to the hydrologic boundaries. Due to the methodology of reporting most types of economic data, the county definition had to be used. In almost all counties the concentrations of population and economic activity is within the hydrologic boundaries. The major user of water, agriculture, is certainly located within the confines of the hydrologic boundaries; except in Santa Fe county where a significant portion of the irrigated agriculture takes place in the Estancia Basin, part of the Central Closed Basin.



BASIN INDEX

ARKANSAS RIVER BASIN
1-1, CANADIAN RIVER
1-2, PURGATOIRE RIVER
1-3, CIMARRON RIVER
1-4, CARRIZOZO CREEK
1-5, NORTH CANADIAN RIVER
1-6, CARRIZO CREEK

SOUTHERN HIGH PLAINS
2-1, RED RIVER
2-2, BRAZOS RIVER
2-3, LEA PLATEAU

PECOS RIVER BASIN
3-1, PECOS RIVER

CENTRAL CLOSED BASINS
4-1, ESTANCIA BASIN
4-2, JORNADA DEL MUERTO BASIN
4-3, TULAROSA BASIN
4-4, SALT BASIN

RIO GRANDE BASIN
5-1, RIO GRANDE
5-2, COSTILLA CREEK
5-3, RIO SAN ANTONIO

WESTERN CLOSED BASINS
6-1, NORTH PLAINS
6-2, SAN AUGUSTIN PLAINS

SAN JUAN RIVER BASIN
7-1, SAN JUAN RIVER
7-2, NAVAJO RIVER

LOWER COLORADO RIVER BASIN
8-1, LITTLE COLORADO RIVER
8-2, SAN FRANCISCO RIVER
8-3, GILA RIVER
8-4, SAN SIMON CREEK

SOUTHWESTERN CLOSED BASINS
9-1, ANIMAS BASIN
9-2, MIMBRES BASIN
9-3, PLAYAS BASIN
9-4, WAMEL BASIN
9-5, SAN LUIS BASIN
9-6, HACHITA BASIN

Drainage basins of New Mexico

Following is a county definition of the regions and the associated names used within the major study and this paper:

Definition of Regions

Region	Sub-Basin Name	Counties
1	Upper Rio Grande	Taos Rio Arriba Santa Fe Los Alamos
2	Middle Rio Grande	Bernalillo Sandoval Valencia
3	Socorro	Socorro
4	Lower Rio Grande	Dona Ana Sierra
5	Rest of State	Remaining twenty-two counties

Economic Description of the Rio Grande River Basin

The basic importance of the Rio Grande and its associated ground water basin to the economy of New Mexico can be illustrated by looking at some basic economic data. Table 1 presents the census year population estimates for both the state as a whole and the Rio Grande River Basin.[2] Today the Basin area is approximately 75% urban in make-up. The urban group within the Basin comprises over 60% of the total urban population within the state. The greatest growth occurred in the 50's for the Basin as a whole, with an apparent slowing down of the growth rate in the 60's. However, several selected areas within the Basin (primarily Albuquerque) continued to show a marked increase in growth during the previous decade.

In 1967, with slightly over half of the state's population residing within the ten counties of the Basin (county definition), over 58% of the total state income was accounted for within the RGRB. In 1970 the percent of total income increased to over 59%.[3] The Basin had a per capita income average of over $2,500, approximately $100 above the state average.

Table 2 presents ESC employment data for the years 1960 and 1970. In all reported categories, except agriculture, the Basin has increased its portion of the total employment in the state; thus further pointing out the growing economic importance of this area in the preceding decade.

[2] County definition.

[3] Unpublished information from the Bureau of Business Research, UNM.

Table 1

Population for New Mexico and the Rio Grande Basin

	Urban	Percent of* Total	Rural	Percent of Total	Total	Percent Change from 1960 Census
1950						
New Mexico	341,889	50.2	339,298	49.8	681,187	28.1
Rio Grande Basin	175,230	53.5(51.3)	152,557	47.2(45.0)	327,787	(A)
Rest of State	166,659	47.2(48.7)	186,741	52.8(55.0)	353,400	(A)
1960						
New Mexico	626,479	65.9	324,544	34.1	951,023	39.6
Rio Grande Basin	318,553	57.2(50.8)	237,948	42.8(73.3)	556,501	70.0
Rest of State	307,926	78.0(49.2)	86,544	22.0(26.7)	394,522	11.6
1970						
New Mexico	708,775	69.8	307,225	30.2	1,016,000	6.8
Rio Grande Basin	427,440	74.7(60.3)	144,730	25.3(47.1)	572,170	2.8
Rest of State	281,335	63.4(39.7)	162,495	36.6(52.9)	443,830	12.5

* The percentsin parentheses represent the two regions' portion of urban and rural population respectively, on a state-wide basis.

(A) Los Alamos county did not exist in 1940; percentage change therefore not calculable.

Table 2

Employment[1] for New Mexico and the Rio Grande River Basin[2]

Classification	1960 Rio Grande River Basin	% of Total	Rest of State	% of Total	Total	1970 Rio Grande River Basin	% of Total	Rest of State	% of Total	Total
Total Civilian Work Force	170,391	52.26	155,609	47.73	326,000	214,608	57.39	159,292	42.60	373,900
Unemployment	9,650	53.02	8,550	45.16	18,200	12,907	54.45	10,793	45.54	23,700
Rate	5.7		5.5			6.0		6.7		
Non-Ag. Wage & Salary	131,691	55.73	104,609	44.26	236,300	175,053	60.36	114,947	39.63	290,000
Manufacturing	10,146	60.75	6,554	39.24	16,700	12,727	60.03	8,473	39.96	21,200
Mining	1,761	8.63	18,639	91.36	20,400	1,620	9.58	15,280	90.41	16,900
Contract Construction	10,521	55.96	8,279	44.03	18,800	10,870	68.36	5,030	31.63	15,900
Public Utilities, Transportation, & Communications	10,091	48.98	10,509	51.01	20,600	10,254	51.01	9,846	48.98	20,100
Wholesale & Retail Trade	26,750	54.14	22,650	45.85	49,400	37,829	62.01	23,171	37.98	61,000
Real Estate, Finance, & Insurance	6,391	66.57	3,209	33.42	9,600	8,639	69.66	3,761	30.33	12,400
Services & Misc.	25,437	68.19	11,863	31.80	37,300	37,236	69.60	16,264	30.40	53,500
Government	40,272	63.45	23,205	36.55	63,477	56,640	63.56	32,460	36.43	89,100
All Other Non-Ag.	21,121	46.62	24,179	53.37	45,300	19,952	50.13	19,848	49.86	39,800
Agriculture	7,897	43.19	10,384	56.80	18,281	6,126	30.32	14,074	69.67	20,200

[1] Based on ESC data.

[2] County definition.

Previous Studies

The states of Arizona, Utah, and California (as well as several others) have done some work in the area of relating water use to production. We have attempted to follow their lead and develop some relationships for the different sectors of the economy within New Mexico, and more specifically, for the Rio Grande River Basin and its related sub-basins or regions. Typically, intake use, consumptive use, and total water use (gross water use) have been examined by previous studies. For the purpose of this paper, however, water intake was the prime area of concern. There exists very little data on gross water use (although we suspect it is very close to water intake in most industries) in New Mexico; and little detailed information on the scale necessary for accurate consumptive use calculation. Therefore, the bulk of interpretation and the subsequent analysis deals primarily with new water intake and its relationships to the economy.

Definition of the Economic Sectors

The economy of New Mexico is made up of many processing or production sectors. From the 1960 I-O Table constructed by the Bureau of Business Research (BBR)[4], a total of twenty-four industries (after aggregation) was used for the study, with the result that not all of the sub-basins (regions) would be represented by each and every "industry." Cotton production is a good example. Regions 1 and 2 of course don't have any acreage devoted to cotton (for various reasons), and therefore no dollar production in this particular "industry." The sector definitions, SIC code classifications, and relationship to the 1960 I-O study are presented on the following page.

Diversion and Depletions

For the purpose of this paper an estimate was made of the major beneficial diversions and depletions for each region from initial results of the model. In Tables 3 and 4 these estimates are summarized for basic "sector" classifications. Of course, agriculture is by far the largest user of water within the Basin; but it should be noted that in Region 2, the middle valley area, other users do compose a significant percentage of the total. It should be kept in mind that both diversions and depletions within the RGRB in the agriculture sector are primarily from surface water supplies (with the remaining supplies of course being ground water). The remaining users are supplied almost entirely from ground water. For ground water sources, only a small portion of the difference between diversion (pumpage) and depletion is returned to the ground water aquifer in the immediate area; whereas the agricultural sectors return their unused portion (after non-beneficial depletions have been considered) of surface water diversions to the streams and drainage ditches. Thus for surface water users, the consumptive use (both beneficial and non-beneficial) is the more appropriate measure of water use within the Basin. For ground water users, the pumpage is probably the

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[4] "A Preview of the Input-Output Study," BBR, October 1965, reprint from *New Mexico Business*.

Sector Definitions

No.	Classification	Description	1960 I-O Study[1]	Major SIC Codes
1	Ag1	Meat Animals, Farm, Dairy Products and Poultry	1,2	
2	Ag2	Food Grains and Feed Crops	3	
3	Ag3	Cotton and Cottonseed	4	
4	Ag4	Vegetables, Fruits and Nut Trees, Miscellaneous Farm Products	5	
5	Ag5	Agricultural Services	6	7
6	Min1	Metals and Non-Metals	7,8,11,12	10,12,14
7	Min2	Crude Petroleum and Natural Gas Oil and Gas Field Services	9,10	13
8	Man1	Meat Packing and Other Meat Products	13	201
9	Man2	Dairy Products	14	202
10	Man3	Grain Mill and Bakery	15	204,205
11	Man4	Miscellaneous Food Products	16	remainder of 20
12	Man5	Lumber and Wood Products, Concrete and Stone Products	17,21	24,25,32
13	Man6	Chemicals, and Petroleum Refining	19,20	28,29
14	Man7	Electrical Machinery and Equipment Fabricated Metal Products and Scientific Instruments	22,23	19,34,35 38 36,371-72-73
15	Man8	Printing and Publishing, Miscellaneous Manufacturing	18,24	22,23,27 31,39
16	TCU1	Railroads and all other Transportation	25,26	40,41,42,45,47
17	TCU2	Gas and Oil Pipelines	27	46,4924
18	TCU3	Communications,Electric and Gas Utilities	28,29,30	48,49
19	Tr1	Wholesale Trade and Most Retail Trade	31,34	56,57,59,50,52, 53,54
20	Tr2	Retail Auto Dealers and Gas Stations Eating and Drinking Places	32,33	55,58
21	FIRE1	Finance, Insurance, and Real Estate	35,36	65,66,67,60,61,62, 63,64
22	Ser1	Hotels, Motels, Personal Services, Business Services	37,38,39,40	70,72,73,75, 76,78,79
23	Ser2	Medical and Professional Services, Research Development	41,42	80,81,82,88, 89,37(P)
24	CON1	Contract Construction	47	15,16,17

[1] Refers to "A Preview of the Input-Output Study," Bureau of Business Research, 1965, a reprint from New Mexico Business.

Table 3

Estimated Total Diversions[1] by Major Sectors in Each Region

Major Sector	Region 1	Region 2	Region 3	Region 4	R.G.R.B.[2]
1. Agriculture[3]	197,000	253,000	100,000	647,000	1,197,000
a. Surface	188,000	238,000	81,000	560,000	1,067,000
b. Ground	9,000	15,000	19,000	87,000	130,000
2. Mining, Oil and Gas	7,100	3,750	300	300	11,450
3. Industrial	2,250	14,850	300	875	18,275
4. Commercial Trade and Services	10,500	34,250	500	4,775	50,025
5. Municipal[4]	7,100	51,150	825	8,725	67,800
6. Rural	3,400	4,200	350	1,750	9,700
Total	227,350	361,200	102,275	663,425	1,354,250

Percentage of the Regional Total

Major Sector	Region 1	Region 2	Region 3	Region 4	R.G.R.B.[2]
1. Agriculture[3]	86.65	70.04	97.77	97.52	88.38
2. Mining, Oil and Gas	3.11	1.03	0.29	0.04	0.84
3. Industrial	1.00	4.11	0.29	0.13	1.34
4. Commercial Trade and Services	4.61	9.48	0.48	0.71	3.69
5. Municipal[4]	3.10	14.16	0.80	1.31	5.00
6. Rural	1.49	1.16	0.34	0.26	0.71
Total	100.00	100.00	100.00	100.00	100.00

[1] Diversions estimated by using information from NMSU, the State Engineer's Office, as well as from several other states. The diversions are in acre-feet.

[2] Total of the four regions.

[3] Includes stock pond evaporation and irrigated pasture - first number is total of ground and surface.

[4] Includes the public and governmental sectors.

Table 4

Estimated Total Depletions[1] by Major Sectors in Each Region

Major Sector	Region 1	Region 2	Region 3	Region 4	R.G.R.B.[2]
1. Agriculture[3]	80,000	105,000	43,000	278,000	506,000
a. Surface	75,000	95,000	32,000	225,000	427,000
b. Ground	5,000	10,000	11,000	53,000	79,000
2. Mining, Oil and Gas	3,030	1,500	150	150	4,730
3. Industrial	250	1,500	25	100	1,875
4. Commercial Trade and Services	4,200	13,700	200	1,900	20,000
5. Municipal[4]	3,550	28,600	400	5,250	37,800
6. Rural	2,050	2,550	200	1,050	5,650
Total	93,080	152,850	43,975	286,450	576,155

Percentage of the Regional Total

Major Sector	Region 1	Region 2	Region 3	Region 4	R.G.R.B.[2]
1. Agriculture[3]	85.94	68.69	97.78	97.05	87.82
2. Mining, Oil and Gas	3.25	0.97	0.34	0.05	0.83
3. Industrial	0.26	0.98	0.05	0.03	0.32
4. Commercial Trade and Services	4.51	8.96	0.45	0.66	3.47
5. Municipal[4]	3.81	18.71	0.90	1.83	6.56
6. Rural	2.20	1.66	0.45	0.36	0.98
Total	100.00	100.00	100.00	100.00	100.00

[1]Depletions estimated by utilizing depletion to diversion ratios and by using information from the State Engineer's Office, as well as from several other states in the Southwest. The depletions are in acre-feet.

[2]Total of the four regions.

[3]Includes stock pond evaporation and irrigated pasture - first number is total of ground and surface.

[4]Includes the public and governmental sectors.

better measure of use for the ground waters in the Basin. Part of pumpage from the ground water basin is drawn from the river. Therefore, in actuality, surface water use is somewhat more than the estimates presented in the tables. [Although the question of actual amounts of surface water flow into the ground water aquifer has been studied considerably by hydrologists and the State Engineer's Office, their findings (with their tendency to revise the surface and ground waters estimated relationships through time) were not considered in this paper. The larger study and model do however require these findings and estimates of the associated relationships. Again, this paper is concerned with primarily new water intake, whether it be surface or ground supplies.]

Agriculture accounts for approximately 88% of the consumptive uses of water within the Basin. Most of the remainder goes to the municipal and commercial sectors. Again, in Region 2 these sectors do account for a significant portion of consumptive water use. About 75% of the consumptive use is from surface supplies, while the remainder comes from the ground water basin. (This does not take into account equilibrium questions and the portion of ground water that is actually derived from surface water supplies. In the Albuquerque area, for example, approximately 70% of the ground water is in reality from the stream flow itself.)

Production and New Water Use by the Rio Grande River Basin

The next table presents water intake use by each of the twenty-four production sectors within the Basin. An estimate was first made of the dollar value of output in each of these "industries" for each region and then summed to arrive at an aggregate total for the RGRB. (Information from all four regions is used in the larger study.) This appears in column 2 of Table 5, along with their relative ranks in column 3. As can be seen, the trade and commercial sectors as a whole rank above the agricultural sectors. Figure 1 illustrates pictorially the magnitudes involved for all these sectors.

An estimate of a water-intake coefficient was derived next from various sources.[5] This coefficient tells us how much new water is needed to produce a million dollars of final product in a specific industry. These estimates appear in column 4 of Table 5 along with their relative rankings in column 5. Again, it should be remembered that presently the majority of agricultural water intake is from surface supplies, while the remaining sectors' intake is from ground waters. However, in the future it should be noted that any additional water intake by the agricultural sectors will have to come from the ground water basin due to the present full appropriation of surface water rights (once again ignoring the interdependent relationship of the two "water basins"). Figure 2 presents these estimates in graphical form. By way of comparison, agriculture uses water (intake) in quantities of ten to two-hundred times as great as that for all other users in the production of a million-dollar unit of final product. This points out even further the well recognized fact of the tremendous amount of water needed to keep agriculture production at the present level it enjoys today.

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[5] Information and data was used from previous studies in the states of Arizona, California, and Utah; national manufacturing censuses and studies; and from published and unpublished material of the New Mexico State Engineer's Office.

Table 5

Production and New Water Use by New Mexico (Regional) Sectors

Rio Grande River Basin

Sectors	Output in[1] Dollars	Rank	Water Intake[2] Coefficient	Rank	Estimated[3] Total Use	Rank
Ag1	39.452511	13	3,782.34	4	149,223	3
Ag2	9.271483	22	56,459.90	1	523,467	1
Ag3	10.781332	21	39,770.23	2	428,776	2
Ag4	23.967717	16	5,238.92	3	125,565	4
Ag5	5.368773	24	6.00	24	31	24
Min1	81.784277	9	90.96	10	7,439	9
Min2	26.276066	14	151.62	7	3,984	13
Man1	20.651193	17	30.07	15	621	21
Man2	25.948143	15	42.66	12	1,107	19
Man3	14.197216	18	14.09	19	200	22
Man4	13.069654	20	144.46	8	1,888	15
Man5	56.157858	11	152.00	6	8,536	7
Man6	7.924270	23	374.04	5	2,964	14
Man7	70.344963	10	22.23	18	1,564	16
Man8	50.457791	12	27.21	16	1,373	17
TCU1	109.912530	6	6.23	22	685	20
TCU2	13.498663	19	6.22	23	84	23
TCU3	104.965017	7	106.86	9	11,217	6
Tr1	325.237252	2	12.28	21	3,993	12
Tr2	98.320701	8	13.62	20	1,339	18
FIRE1	177.372787	3	24.54	17	4,352	11
Ser1	151.552051	5	32.02	13	4,852	10
Ser2	517.959649	1	30.74	14	15,921	5
Con1	172.461980	4	44.04	11	7,596	8

[1] Estimated for 1967 in million-dollar units.

[2] The amount of new water in acre-foot units needed to produce one million dollars in final product.

[3] In acre-foot units.

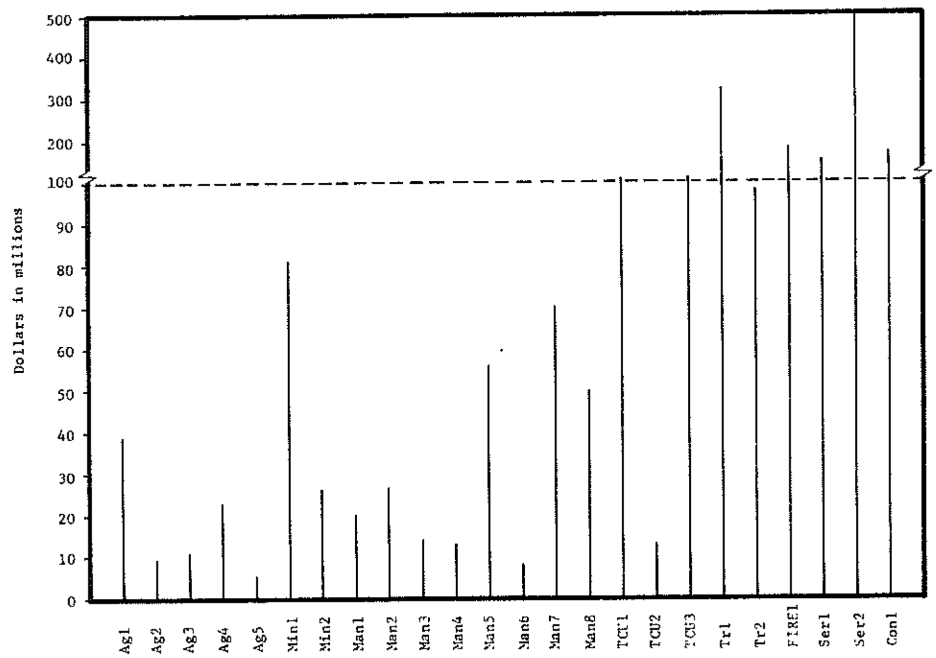

Figure 1. Output in million dollar units for the RGRB.

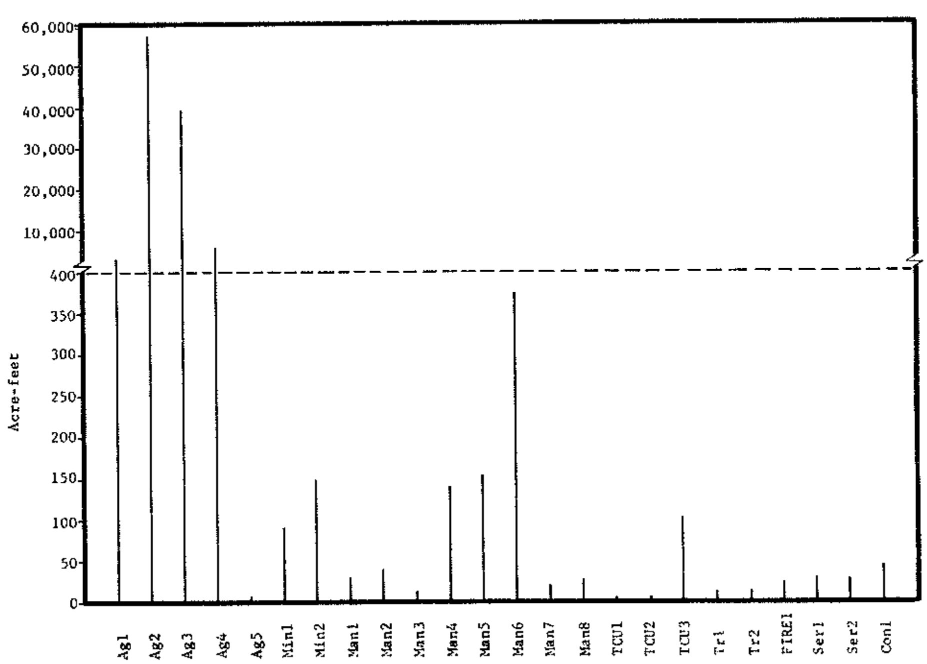

Figure 2. New water intake coefficient per million dollars of input for the RGRB.

By taking the output estimates (column 2) and multiplying by the estimated water intake coefficient (column 4), an estimate for total use was derived. These estimates appear in column 6 of Table 5 along with their relative rankings in column 7. Once again, a tremendous gap in magnitude exists between the agricultural sectors and the remaining production "industries." Figure 3 illustrates, by way of the line graph, these differences.

[It should be pointed out at this time that all of the information in this paper has been estimated from many primary and secondary sources. Even though many of the estimated numbers have several decimal places attached to them, they should not be construed as a presentation of the accuracy of any of these estimates themselves. But rather, they are used in order to point out the differences in magnitudes. These estimates of the coefficients and multipliers should serve as tools in the planning process of future water use and evaluation, as well as helping to point out the economic direction future water use should take.]

Output per Acre-Foot of New Water Intake

Table 6 presents the preceding material, as well as several other estimates, in a slightly different manner. Column 2 is the amount of final product per acre-foot of new water intake within the Rio Grande River Basin.[6] In column 3 appear the relative rankings of each of the sectors. Notice here that agriculture is of considerable magnitude below the other sectors. Care should be taken here in the interpretation of this information for policy formulation. According to this table, agricultural services (Ag5), transportation (TCU1), and oil and gas pipelines (TCU2) seem to be the logical choices for additional water allocation due to their high output to water ratios. It must always be kept in mind that many other factors play a role in the determination of the best economic use of additional water supplies. The demand for the final product here would dictate that unless production increased in certain other sectors at first, there would be no additional demand for agricultural services or transportation and pipeline industries. Figure 4 pictures the relative magnitudes of the estimates involved in column 2.

Income and Value-Added per Acre-Foot of New Water Intake

In addition to the output per acre-foot estimate, two more estimates were made in Table 6. The first, income per acre-foot of new water intake (column 4) was derived by calculating the household income to final product ratio for each sector and then using this ratio to calculate the income coefficient. The relative rankings (column 5) remain pretty much the same as for output to water, except in several cases. Thus, the estimates appearing in column 4 represent the amount of income (average) accruing to the population of the Basin from each acre-foot of new water intake in that particular sector. Columns 6 and 7 contain the dollar value-added per acre-foot of new water intake and their associated relative rankings. Value-added not only includes the income paid to households, but also taxes paid to all forms of government, plus depreciation and capital consumption. Figures 5 and 6 pictorially present both of the "coefficients." It should be noticed that

[6] Derived by using weighted averages from the four regions or sub-basins.

Table 6

Output, Income, and Value-Added per Acre-Foot of New Water Intake

Rio Grande River Basin[1]

Sector	Output in[2] Dollars	Rank	Income in[2] Dollars	Rank	Value Added[2] in Dollars	Rank
Ag1	380.41	21	120.19	22	130.51	22
Ag2	17.83	24	10.95	24	11.60	24
Ag3	25.16	23	14.66	23	15.44	23
Ag4	224.76	22	171.69	21	177.42	21
Ag5	173,341.07	1	103,192.76	1	107,439.27	1
Min1	11,686.29	15	6,069.38	14	7,473.69	13
Min2	6,595.62	19	3,663.67	17	4,782.24	17
Man1	33,256.11	10	5,338.42	15	5,891.58	16
Man2	23,440.57	13	6,073.22	13	6,139.52	15
Man3	72,890.73	6	19,994.20	6	21,386.47	7
Man4	7,095.99	17	2,570.01	19	2,663.78	19
Man5	7,041.83	18	3,062.43	18	3,354.61	18
Man6	2,673.51	20	540.96	20	590.44	20
Man7	45,297.58	7	17,390.35	8	19,064.94	9
Man8	38,652.83	9	18,825.69	7	20,440.49	8
TCU1	160,456.69	3	73,635.13	3	106,486.49	8
TCU2	160,700.27	2	92,152.68	2	110,813.71	2
TCU3	9,565.44	16	4,429.40	16	6,214.95	14
Tr1	81,443.99	4	48,725.91	4	53,710.21	4
Tr2	73,437.31	5	48,086.77	5	52,285.30	5
FIRE1	40,756.62	8	8,230.14	12	30,212.04	6
Ser1	31,321.14	12	16,724.22	10	18,267.85	10
Ser2	32,533.13	11	17,033.51	9	18,000.11	11
Con1	22,704.32	14	8,820.67	11	9,431.16	12

[1] Total of all ten counties within the county definition of the Rio Grande River Basin.

[2] These numbers represent weighted averages of all four regions within the county definition of the Basin.

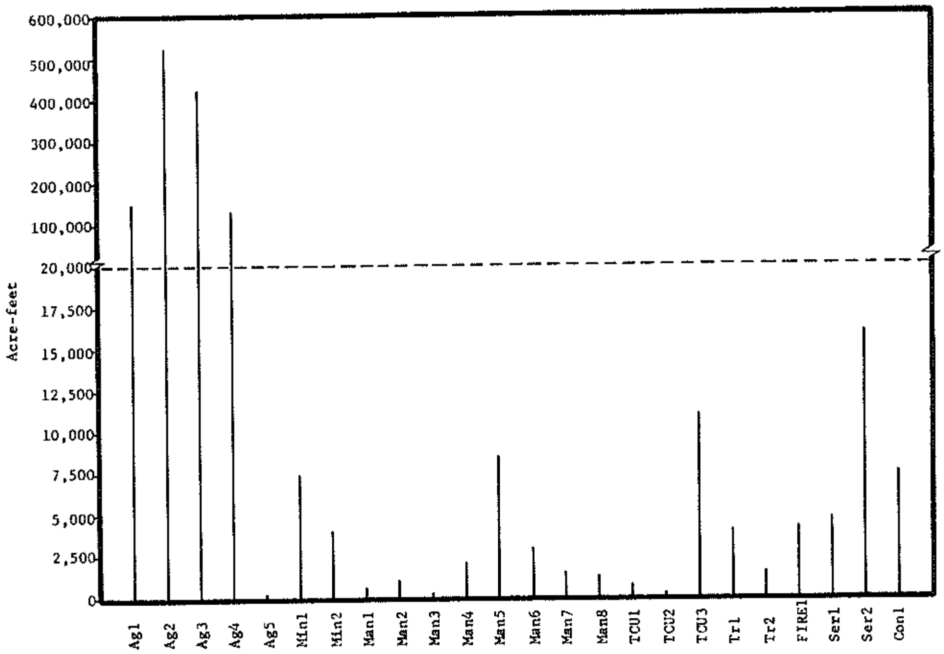

Figure 3. Total estimated new water intake for the RGRB.

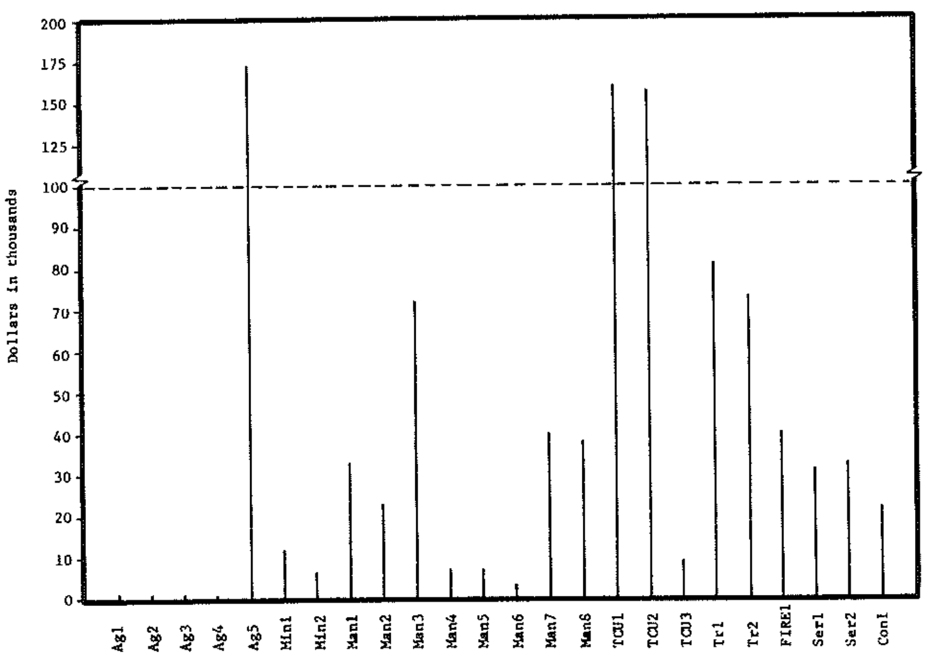

Figure 4. Output per acre-foot of new water intake in the RGRB.

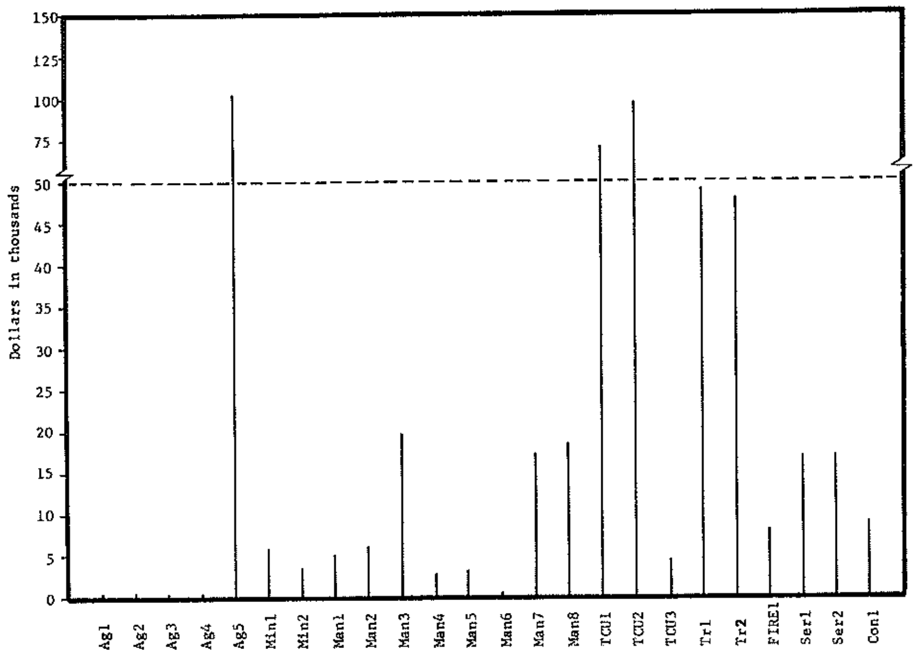

Figure 5. Income per acre-foot of new water intake in the RGRB.

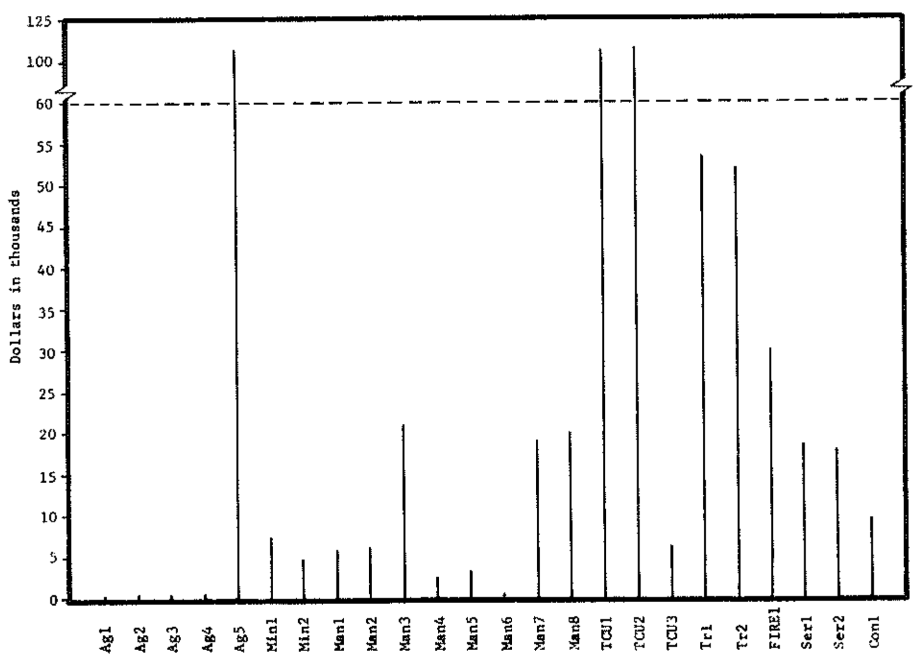

Figure 6. Value-added per acre-foot of new water intake in the RGRB.

the commercial and trade sectors are as a whole significantly above the manufacturing industries; and both of these major areas are substantially greater than the agricultural "sector."

Employment and Direct Employment per Acre-Foot of New Water Intake

Table 7 contains the estimated direct employment totals[7] and coefficients per acre-foot of new water intake for each sector within the RGRB. Columns 2 and 3 summarize the estimates on covered production employment, with column 3 containing the relative rankings. Here a different pattern is noticed. The commercial and trade sectors are employing considerably more people than the remaining sectors, but now the agricultural sectors rank above the manufacturing sectors. However, when looking at the employment per acre-foot of new water intake estimate (column 4), the familiar pattern re-emerges: the commercial and trade "sectors" are greater than manufacturing, which in turn is substantially greater than the agriculture "sector." Column 5 lists the relative rankings of the coefficient. Figures 7 and 8 again pictorially represent the two sets of estimates.

Direct and Indirect New Water Intake Requirements

The next table (Table 8 - a separate table was derived from information on the entire Basin for each region - only Region 2 is used in this paper) begins to throw a little more light on the total use of water within the production process. [Due to the set-up of the inter-dependences and the basin matrix of transactions, it is impossible to arrive at a representative average for the entire Rio Grande River Basin (RGRB), as was done in the previous tables.] Each industry buys from and sells to the other industries within the region. Not every sector needs to buy from and sell to each and every other sector, but it is enough just to have some of the interconnections within and between the regions to change the concept of total water requirements. Column 2 of Table 8, the direct and indirect requirement, gives us the total amount of new water intake required to produce one-million dollars of the product for final demand in that sector. This takes into account all of the water used by the industries it purchases its inputs from to produce one-million dollars. Figure 9 illustrates the relative differences among the sectors.

Perhaps an example may help to clarify this concept. The retail and wholesale sector purchases inputs from many firms in order to be able to sell commodities; such as from the serivce sector to package and merchandise the product, transportation sectors to deliver the inputs and final commodities, the manufacturing sectors from where the inputs are purchased in either finished or semi-finished form, and so on. Now these inputs required water for their production. These inputs in turn required raw materials as well as other semi-processed resources in their production process which required water for their initial production. In other words, the direct and indirect

[7] Estimated from ESC data on covered wage and salary employees. The total employment for all twenty-four production sectors represent only a portion of total estimated employment in all categories. The production sectors exclude government, self-employed, and non-covered workers.

Table 7

Total Employment[1] and Direct Employment per Acre-Foot of New Water Intake

Rio Grande River Basin

Sector	Employment[1]	Rank	Employment[2] per Acre-Foot	Rank
Ag1	2,055	13	0.0137	22
Ag2	1,223	14	0.0023	23
Ag3	542	16	0.0012	24
Ag4	3,366	10	0.0268	21
Ag5	503	20	16.2266	1
Min1	1,136	15	0.1542	18
Min2	302	21	0.0758	19
Man1	273	22	0.4397	14
Man2	505	19	0.4565	13
Man3	535	18	2.6772	7
Man4	539	17	0.2866	16
Man5	2,329	11	0.2728	17
Man6	109	24	0.0368	20
Man7	4,019	9	2.5697	8
Man8	2,139	12	1.5595	10
TCU1	5,007	7	7.3116	3
TCU2	267	23	3.2051	5
TCU3	4,520	8	0.4030	15
Tr1	22,070	1	5.5272	4
Tr2	11,301	4	8.4435	2
FIRE1	7,233	6	1.6634	9
Ser1	13,169	3	2.7141	6
Ser2	17,474	2	1.0975	12
Con1	9,558	5	1.2583	11

1 As estimated from ESC data on covered wage and salary workers contained within each sector's SIC codes.

2 A weighted average of the four regions.

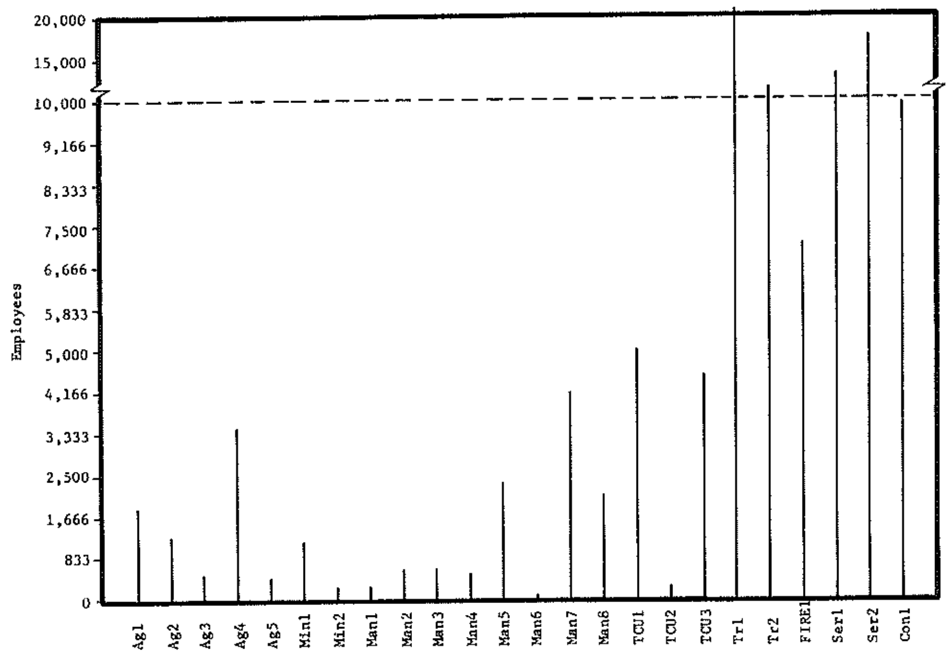

Figure 7. Total employment[1] by sector in the RGRB.

[1] ESC covered 2-digit SIC codes.

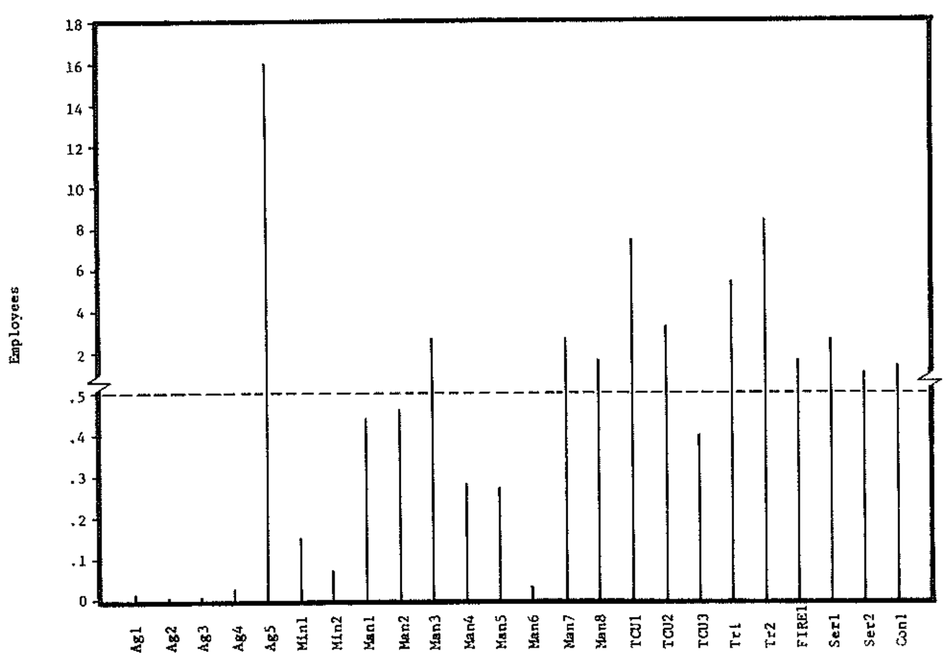

Figure 8. Employment[1] per acre-foot of new water intake in the RGRB.

[1] Estimated from ESC data.

Table 8

Direct and Indirect New Water Intake Requirements,*
Water Multiplier and Weighted Water Multiplier*

Region 2

Sector	Direct and Indirect Req.[1]	Rank	Multiplier[2]	Rank	Weighted Multiplier[3]	Rank
Ag1	2,751.92	7	1.0181	21	872.60	13
Ag2	60,057.51	1	1.0119	22	2,763.01	9
Ag3	0.0		0.0		0.0	
Ag4	22,748.19	2	1.0005	23	1,382.09	10
Ag5	19,581.15	3	3,263.5300	1	2,920.65	8
Min1	83.09	21	1.1591	19	298.61	18
Min2	213.84	17	1.4251	17	117.03	21
Man1	43.82	23	1.4568	16	87.29	23
Man2	56.79	22	1.3306	18	116.78	22
Man3	722.23	11	53.2618	6	885.41	11
Man4	163.91	18	1.1436	20	137.94	20
Man5	603.99	12	3.9537	14	785.76	15
Man6	1,094.98	10	2.9270	15	566.58	17
Man7	147.75	20	6.4917	13	797.07	16
Man8	357.65	14	15.3104	11	874.16	12
TCU1	155.98	19	25.0771	8	866.92	14
TCU2	328.92	15	52.8810	7	207.60	19
TCU3	2,388.78	9	24.7337	9	10,681.05	6
Tr1	6,809.77	5	554.5651	2	154,909.89	1
Tr2	2,444.84	8	179.6356	4	15,141.43	5
FIRE1	9,579.92	4	390.3798	3	79,394.15	2
Ser1	4,256.24	6	135.3766	5	29,266.13	3
Ser2	609.77	13	19.8364	10	19,969.92	4
Con1	295.27	16	6.7046	12	3,469.38	7

* In acre-foot units.

1 The amount of new water intake, both indirect and indirect, per million-dollar unit increase in final demand output by this particular sector.

2 The direct and indirect new water intake requirement divided by the direct new water intake.

3 Based upon a 10% change in final demand multiplied by the direct and indirect new water intake requirement.

Table 5

Production and New Water Use by New Mexico (Regional) Sectors

Region 2

Sectors	Output in Dollars[1]	Rank	Water Intake Coefficient[2]	Rank	Estimated Total Use[3]	Rank
Ag1	13.973370	16	2,720.91	3	38,020	2
Ag2	3.433238	22	59,348.92	1	203,759	1
Ag3	0.0		0.0		0	
Ag4	0.684840	23	22,736.26	2	15,571	3
Ag5	3.580411	21	6.00	23	21	23
Min1	38.522670	11	71.77	9	2,764	12
Min2	6.569016	20	150.05	6	986	15
Man1	20.370050	14	30.08	14	613	19
Man2	22.287410	13	42.68	11	951	16
Man3	14.011440	15	13.56	19	190	21
Man4	9.547336	17	142.70	7	1,362	14
Man5	41.793230	10	156.08	5	6,523	6
Man6	7.924270	19	374.10	4	2,964	11
Man7	63.856710	8	22.76	17	1,453	13
Man8	34.139190	12	23.36	16	797	18
TCU1	62.469580	9	6.22	21	389	20
TCU2	8.979109	18	6.22	22	56	22
TCU3	73.617620	6	96.58	8	7,110	5
Tr1	260.460500	2	12.28	20	3,198	9
Tr2	68.974120	7	13.61	18	939	17
FIRE1	138.893800	3	24.54	15	3,408	8
Ser1	98.213680	5	31.44	12	3,088	10
Ser2	345.814600	1	30.74	13	10,630	4
Con1	123.627500	4	44.04	10	5,445	7

[1] Estimated for 1967 in million-dollar units.

[2] The amount of new water in acre-foot units needed to produce one million dollars of final product.

[3] In acre-foot units.

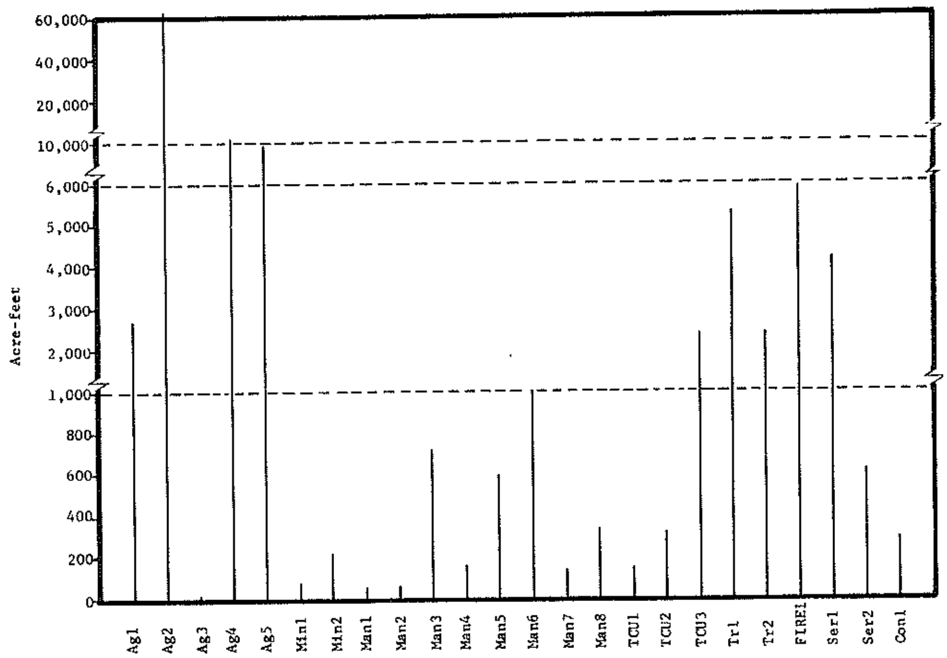

Figure 9. The direct and indirect new water intake per million dollars of output for final demand - Region 2, RGRB.

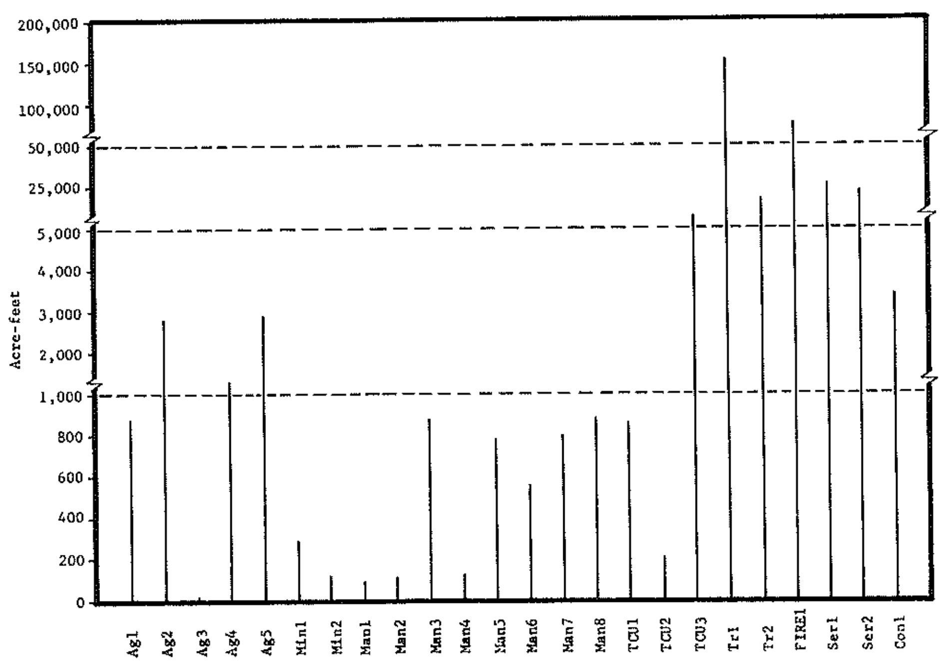

Figure 10. Weighted Multiplier: Based on 10% change in final demand - Region 2, RGRB.

water requirement tells us how much water was used by all the input and raw materials sectors, plus the amount of water needed to do a million dollars worth of business for final demand in that sector.

The relative rankings of the coefficients of direct and indirect water use are listed in column 3 of Table 8. A comparison can be made with the direct water requirements from Table 5 for Region 2 (this follows Table 8 so that a comparison can be made). By subtracting column 4 of Table 5 - the direct new water intake coefficient - from Column 2 of Table 8 - the direct and indirect new water intake requirement - the amount of indirect water use by all the required inputs can be calculated.

Multiplier

Another method of comparison is shown in column 4 of Table 8, the multiplier. This number is actually a ratio, derived by dividing the total direct and indirect requirements by just the direct coefficient. The name multiplier means that if one wanted to increase production in a particular sector, the total required additional water to the system (in this case Region 2) could be calculated by taking the product of the multiplier and the direct new water intake coefficient. The higher the multiplier, the more new water will be needed by the entire system to produce a given increase in a specific sector in comparison to just the water needed by the initiating sector. The relative rankings are presented in column 5 of Table 8.

Weighted Multiplier

Column 6 of Table 8 lists the amount of total water (both direct and indirect) required to meet a ten percent (10%) increase in final demand for that particular sector. Final demand is in many cases substantially less than output in any sector, and represents household and government consumption plus exports of the final product. Of the total output, only a portion is supplied to final demand, the remainder goes to supply the production processes of other industries as inputs; i.e., the metal sector delivers much of its product to other industries as input into their production. Thus when we are speaking of final demand this implies final consumption and export.

A ten percent increase in final demand is probably a better test of changes in future demand. In this case, by using a ten percent change to weight the change in water demand, we present a more reasonable picture of what might take place. Generally speaking, a percent change in exports or consumption is used when measuring future growth possibilities. For example the "weighted multiplier" of column 6 tells us what happens to water intake for a given 10% change in exports of that product. The "weighted multiplier" represents the total new water intake needed by the system (region here) to meet this increase in exports. Column 7 gives the relative rankings of this "weighted multiplier."

[The "weighted multiplier" gives a more realistic picture of possible future new water intake than the direct and indirect water requirements do. As remembered, this later requirement was calculated for a change in total final demand - a million dollars worth. Certain sectors have more potential than others for growth. Certainly in the short run, not all sectors could be expected to increase its final demand output by a million dollars, but at the same time other sectors could be expected to increase their final demand output by substantially more (a much larger production base). In addition, with percentage decreases in final demand for various sectors, the "weighted water multipliers" will tell us the amount of additional water that would then be made available to the system (region) from the decrease in production.]

Two different effects are inherent in the calculations of the "weighted multiplier." First, the amount of direct and indirect water intake per unit of final demand output shows up in the agricultural sectors very vividly (looking at the direct and indirect requirements). However, this effect is dampened considerably because a ten percent change in final demand is much less than the other sectors in these cases. On the other hand, by viewing the commercial and trade "sector," we get the opposite result, a low (relatively) direct and indirect effect, but a substantial effect from the ten percent change in final demand output. Figure 10 illustrates the major magnitudes involved for Region 2.

Direct and Indirect a) Income and b) Employment per Direct and Indirect Acre-Foot of New Water Intake

Table 9 presents possibly the most comprehensive method of analyzing water from an economic point of view. Every production sector generates income payments to households in terms of wages, salaries, profits, etc. Of course, each "industry" or sector doesn't produce the same percent of income per unit of production. At the same time, with each sector purchasing inputs from other sectors, it is responsible for generating some indirect income - income paid to households by the input sectors from their sales to the purchasing sector. Column 2 presents the estimates of generated income from allowing an increased acre-foot water intake to the initiating sector. This water is actually water to the system, with the initiating sector taking a portion of it to increase its production, while the remainder is used by the other "inputting" sectors to supply the initiating sector. Column 3 lists the relative rankings.

[Only Region 2's table is presented for this paper. Again, as in Table 8, due to the construction of the model and analysis, it is impossible to form an aggregate table for the RGRB as a whole, or, to use any efficient weighting mechanism to arrive at an average. Due to the interdependencies implicit in an input-output table, the whole table must be used as a unique unit in this type of evaluation and interpretation of the information. The four regions formed only a portion of the total I-O matrix developed for the state of New Mexico. The forthcoming interdisciplinary study will give a much fuller explanation.]

In addition to income generated to the households, the production process also generates employment. Table 7 presented estimates of employment for each sector. By taking these estimates and dividing them into total output, an employee coefficient per unit of output is derived. The coefficient

Table 9

Direct and Indirect a) Income and b) Employment Effects per Acre-Foot of Direct and Indirect Water Intake by the Initiating Sector

Region 2

Sector	Income Change[1]	Rank	Employment Change[2]	Rank[3]	Adjusted Employment Change[4]
Ag1	153.78	20	0.0342	15	0.0420
Ag2	11.48	23	0.0009	23	0.0011
Ag3	0.0		0.0		0.0
Ag4	33.68	22	0.0048	22	0.0059
Ag5	47.07	21	0.0061	21	0.0075
Min1	6,700.46	1	0.2060	6	0.2533
Min2	2,698109	6	0.0284	16	0.0349
Man1	3,681.50	4	0.3133	4	0.3853
Man2	5,113.70	2	0.3825	3	0.4704
Man3	474.94	13	0.0640	12	0.0787
Man4	2,313.93	7	0.2604	5	0.3202
Man5	1.077.73	12	0.1155	9	0.1420
Man6	219.36	16	0.0164	20	0.0201
Man7	3,318.36	5	0.4404	2	0.5416
Man8	1,596.35	9	0.1450	8	0.1783
TCU1	3,971.11	3	0.4714	1	0.5798
TCU2	1,964.36	8	0.0642	11	0.0789
TCU3	327.51	14	0.0342	14	0.0420
Tr1	166.43	19	0.0203	18	0.0249
Tr2	312.75	15	0.0523	13	0.0643
FIRE1	167.49	18	0.0170	19	0.0209
Ser1	209.41	17	0.0276	17	0.0339
Ser2	1,244.99	11	0.0981	10	0.1206
Con1	1,512.55	10	0.2044	7	0.2514

[1]In dollars.

[2]This column only presents the changes based upon ESC 2-digit covered wage and salary employment for each sector.

[3]Ranks remain the same for both employment changes.

[4]This column presents the total expected change in employment - which includes those in 2 plus those categories not covered by ESC 202 data, such as individual proprietors, partnerships, etc., (excluding government) but estimated as total employment.

then is used to develop the next water related concept, total employment[8] change per acre-foot of direct and indirect water intake. The explanation of direct and indirect employment per total delivered acre-foot of water intake to the system (region) paralells the above discussion on income. Column 4 presents the estimated total change in ESC (2 digit SIC code) covered wage and salaried employment per acre-foot of direct and indirect water intake. This means that if one-hundred acre-feet of water is added to the system and the mining sector (Min1) initiated the production increase (and thus increasing its inputs), that over twenty additional persons would be employed, some in the mining sector, and the remainder in the sectors that supply the inputs.

This employment change doesn't take into account any change in government employment, self-employed persons, and all of the remaining non-covered employment estimated by the ESC. Column 6 lists the estimated total direct and indirect employment from an acre-foot increase in water intake, given the assumption that government employment doesn't change, but that other non-covered employment increases for all sectors at a constant percentage. This assumption is, of course, fairly unrealistic (agriculture doesn't generate the same amount of secondary or spin-off employment as does manufacturing, thus the percentage changes will be different when referring to this category for anticipated increases or decreases); but due to the method of reporting ESC data, and the numerous disclosure rules, it is impossible at this time to develop an efficient method for calculating the different increases that would be appropriate for secondary employment. This estimate does, however, present a little better picture of the actual amount of employment that could be expected per acre-foot in direct and indirect water to a particular sector initiating an increase in production. Column 5 presents the relative rankings of column 4 and 6.

Figures 11 and 12 illustrate the above estimates of the direct and indirect income and employment effects in a little different manner. The horizontal axis of both figures represents the change in acre-feet (in thousands) of new water intake. The vertical axis of Figure 11 is the increase in income that could be expected given the change in new water intake to Region 2, while the vertical axis of Figure 12 is the increase in employment[9] that could be expected. With the increase in income and employment in Region 2, both the direct to the initiating sector and indirect to the remaining interdependent sectors are incorporated into the vertical axis presentation.

An example may help to illustrate the use of Figures 11 and 12. By looking at the sector Man2 in Figure 11, we can see that if an additional 50,000 acre-feet of water was in some form added to the available supplies in Region 2 for the increased production in Man2, that an additional 260 million dollars of income would be generated within Region 2. This income comes not only from the increased sales of Man2, but also from the increased sales of the suppliers of inputs to Man2.

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[8] ESC covered 2 digit SIC data for column 4 of Table 9: column 6 represents this amount plus the estimated non-covered employment less the government sector.

[9] Only ESC 2 digit SIC covered wage and salaried employment.

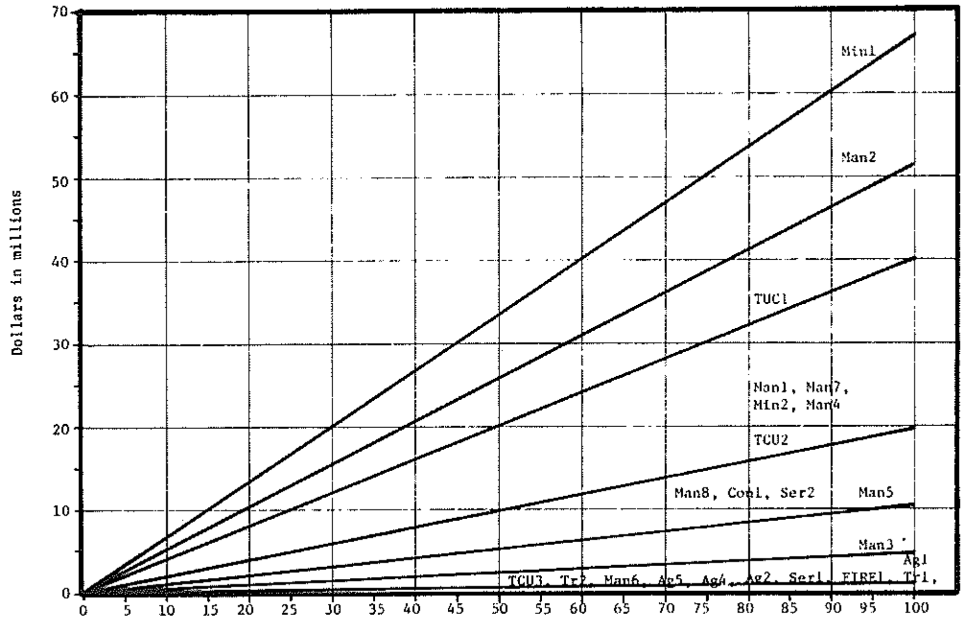

Figure 11. Total direct and indirect income per acre-foot of direct and indirect new water intake - Region 2, RGRB.

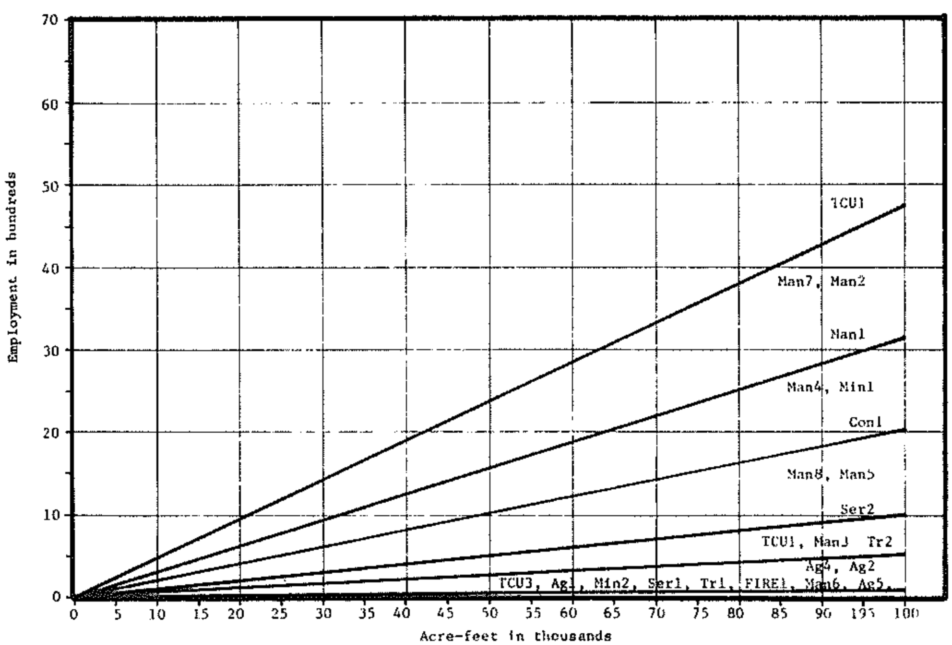

Figure 12. Total direct and indirect employment[1] per acre-foot of direct and indirect new water intake - Region 2, RGRB.

Or, if one wanted to generate a specific employment increase (limited definition), Figure 12 could be used. If one-thousand additional employees were desired, by reading across to the initiating sector one could determine the amount of new water needed in Region 2. Given that TCU1 was initiating an increase in its production to account for the 1,000 increase in employment (both direct in TCU1 and indirect in the remaining sectors), an additional 21,000 of new water would be required (a portion of which goes to TCU1 and the remainder to its suppliers). However, if Ser2 was initiating the increase, an additional 100,000 acre-feet would be needed.

The two preceding figures should be used with care. Some of the higher ranked sectors (in regards to increasing income and employment to the region when they are initiating the process) are also the same sectors that economic information tells us are the least likely to increase their production (primarily from increased export demand) autonomously. In other words, any increase in these sectors will come from increased demands for their products and services by other production sectors. TCU1 is an excellent example of this. It is the sector with the third highest income potential and the highest employment potential, but being that TCU1 is primarily the transportation industry it is highly unlikely that this sector will or could increase its production without first an increase in the business activities of Region 2. Tr2, however, is a good counter-example. Trade is influenced by a variety of economic variables and conditions and could very easily be expected to increase its production autonomously (an example would be the eating and drinking places from increased tourist trade). It ranks much lower in income and employment generation capabilities, but appears on the surface to be much more plausible when looking at future growth possibilities.

Conclusion

This paper has been an attempt at an economic analysis of water use (new water intake) within the Rio Grande River Basin. It is hoped that in the near future the same type of methodology can be applied to the consumptive use of water by the production sectors of the RGRB. By proper and careful use of the various estimates arrived at in this paper, one may begin to formulate future growth criteria based upon the premise that the water supplies will become increasingly scarcer through time.

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ENVIRONMENTAL TRITIUM AS HYDROLOGIC TOOL - ROSWELL ARTESIAN BASIN

D. Dan Rabinowitz and G. W. Gross*

Introduction

Tritium content of precipitation in the vicinity of Socorro, New Mexico, has been measured since 1956 by the tritium laboratory of New Mexico Institute of Mining and Technology. Well waters from the Roswell artesian basin were collected for the purpose of monitoring variations in tritium concentrations with time. This sampling program was carried out for seven wells from 1961 to 1968. Figure 1 is a map of New Mexico showing the locations of precipitation collection stations (of which tritium content was measured) and precipitation recording stations around the study area. The groundwater sampling sites are located in the vicinity of Roswell (Fig. 2). All of these wells are completed in the San Andres limestone aquifer. This report is concerned with the presentation of background material and some of the observed variations in tritium concentration of precipitation and well water. The possibilities of new contributions to the hydrologic knowledge of the Roswell artesian basin by the tritium tracing techniques are discussed. A detailed report of the study and its results will soon be completed.

Properties and Occurence of Tritium

Natural tritium was first identified by its radioactivity in rain water. Its detection in all forms of natural water became possible, and it was evident that tritiated water would be a useful tool in following the path of groundwater movement.

Tritium is usually designated by the symbol T or by the chemical symbol, ${}_1H^3$. Tritium has a half-life of 12.3 years and emits low energy beta particles with a maximum energy of 0.018 Mev, and, thus, produces a stable helium isotope of mass three. Tritium is produced naturally in the upper atmosphere by bombardment of nitrogen molecules with cosmic rays. From the atmosphere, it finds its way into the hydrologic cycle. Another source of tritium is nuclear fusion reactions. Such reactions, generated by nuclear explosions in the atmosphere, caused concentration peaks in natural waters several orders of magnitude larger than the natural concentrations. The content of tritium in water is expressed in tritium units (T.U.). T.U. has the dimensions of concentration and is defined as

$$1 \text{ T.U.} = \frac{1 \text{ Tritium atom}}{10^{18} \text{ Hydrogen atoms}}$$

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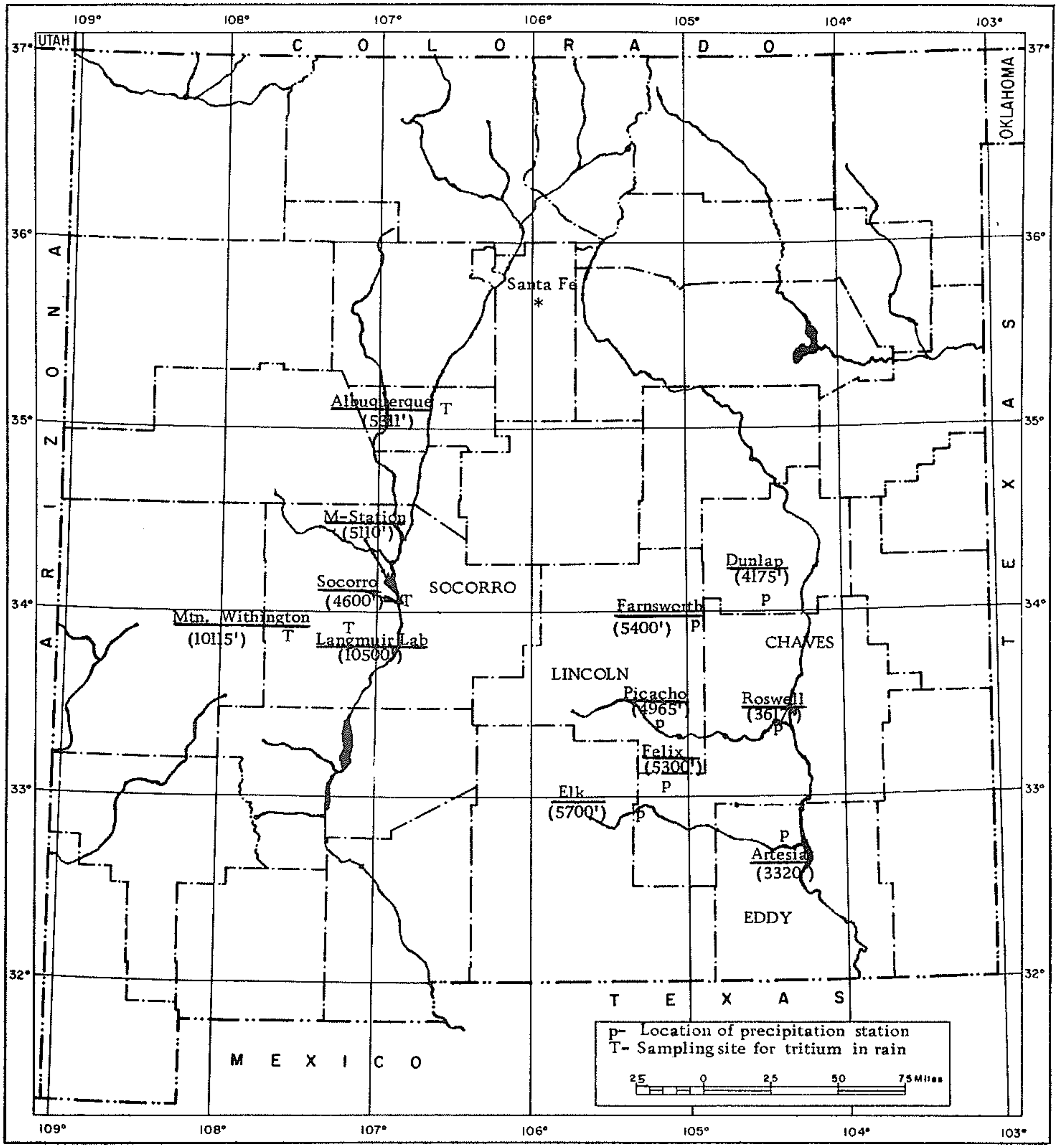

Figure 1. Map of New Mexico with precipitation measuring stations and tritium monitoring stations.

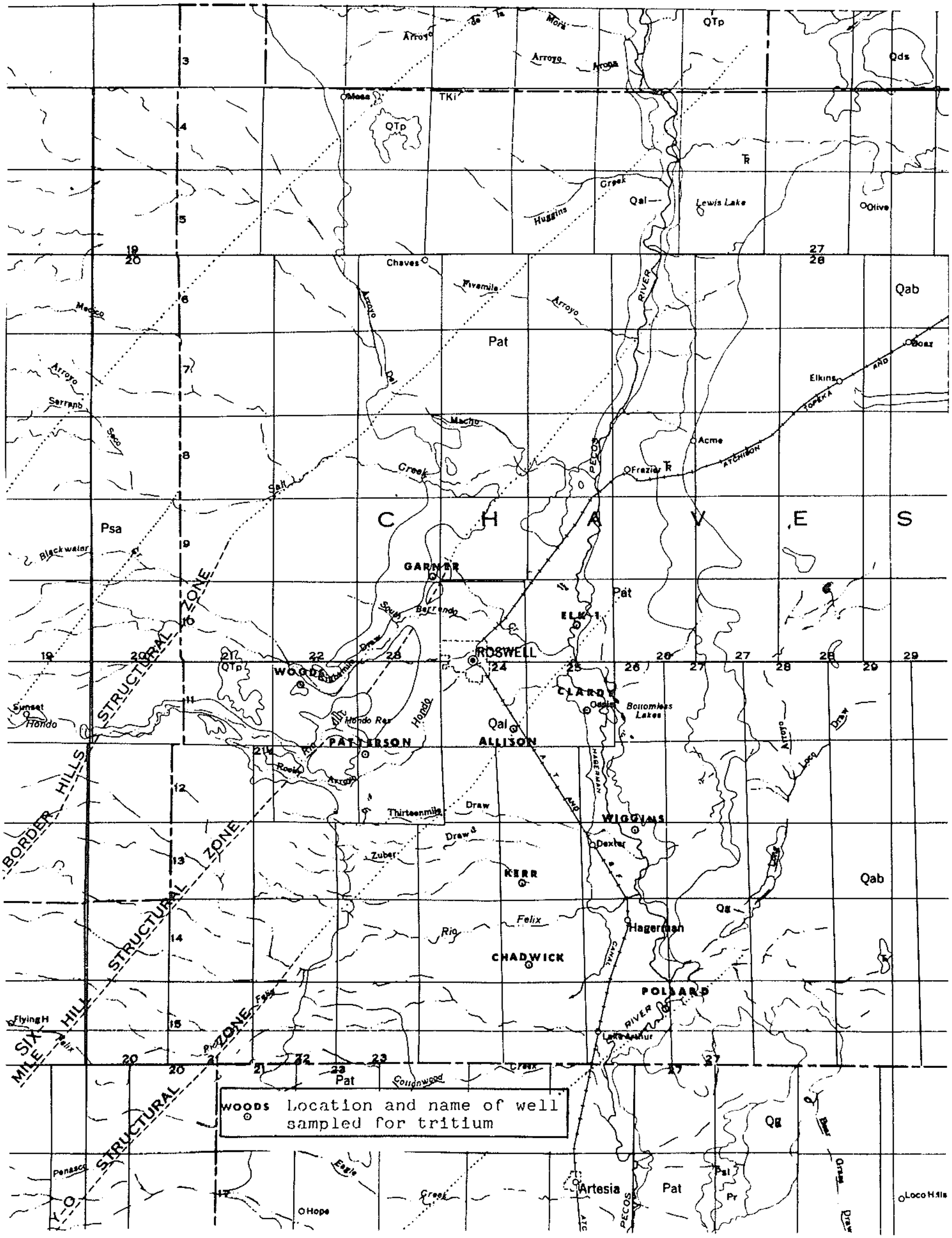

Figure 2. Locations of wells sampled for tritium in the Roswell artesian basin.

In more conventional radiation units the T.U. is defined as follows:

$$1 \text{ T.U.} = 3.24 \times 10^{-15} \text{ Ci/ml}$$

Before 1952, the date of the first atmospheric nuclear bomb explosion, the steady state level of tritium in rain water was about 10 T.U. The maximum concentration of tritium observed in New Mexico rains was about 12,000 T.U. in June 1963. It is these peaks of artificially produced tritium that prove useful in hydrologic studies. As such a peak slowly travels through the aquifer and decays, it can provide valuable clues about residence time, flow patterns, and recharge in an aquifer.

The present study is concerned with the interpretation of such data.

Presentation and Discussion of Data

The variations of tritium concentrations in precipitation as measured in the vicinity of Socorro are presented in Figure 3. For orientation, the history of thermonuclear atmospheric testing is outlined on Figure 3. Following the second period of atmospheric testing (September 1961-December 1962) tritium wash-out was slower than the one following the 1958 moratorium. This is indicative of the amount of tritium injected into the stratosphere during these periods. Figure 3 is a comparison between tritium observations in Socorro and Ottawa, Canada (Environmental Isotope Data: World Survey of Isotope Concentration in Precipitation, International Atomic Energy Agency, Vienna, 1969-1971). Each point represents a monthly average of up to 10 samples (during the summer months). It is clear that some correlation of high and low tritium values exists between the two locations. In a study of this nature it is important to know the variations of tritium concentrations of precipitation a few years before the beginning of groundwater sampling. Since the measurements at Socorro did not start until late 1956, the Ottawa record is used for the period 1953 - 1956.

Figure 3 also shows tri-monthly (seasonal) mean rainfall values at Roswell. The two periods that should be noticed are 1958 - 1960 and 1963 - 1966 which are wet and dry, respectively. Although there are seven precipitation recording stations around the basin, the trend in rainfall at Roswell is representative only of the northern stations. From 1953 to 1968, the annual rainfall at Elk, Felix, and Picacho (Fig. 2) was quite regular with small deviations from one year to the next.

The observed variations of tritium concentrations in groundwater are presented in Figure 4 - 8 as moving averages of 3 months. This smoothing procedure was used in order to eliminate some background variations in the individual data points. Some variations are due to an excessive summer pumpage which may draw water from greater depths of the aquifer. A few vertical profiles, constructed from water samples taken at different depths, indicated tritium stratification,

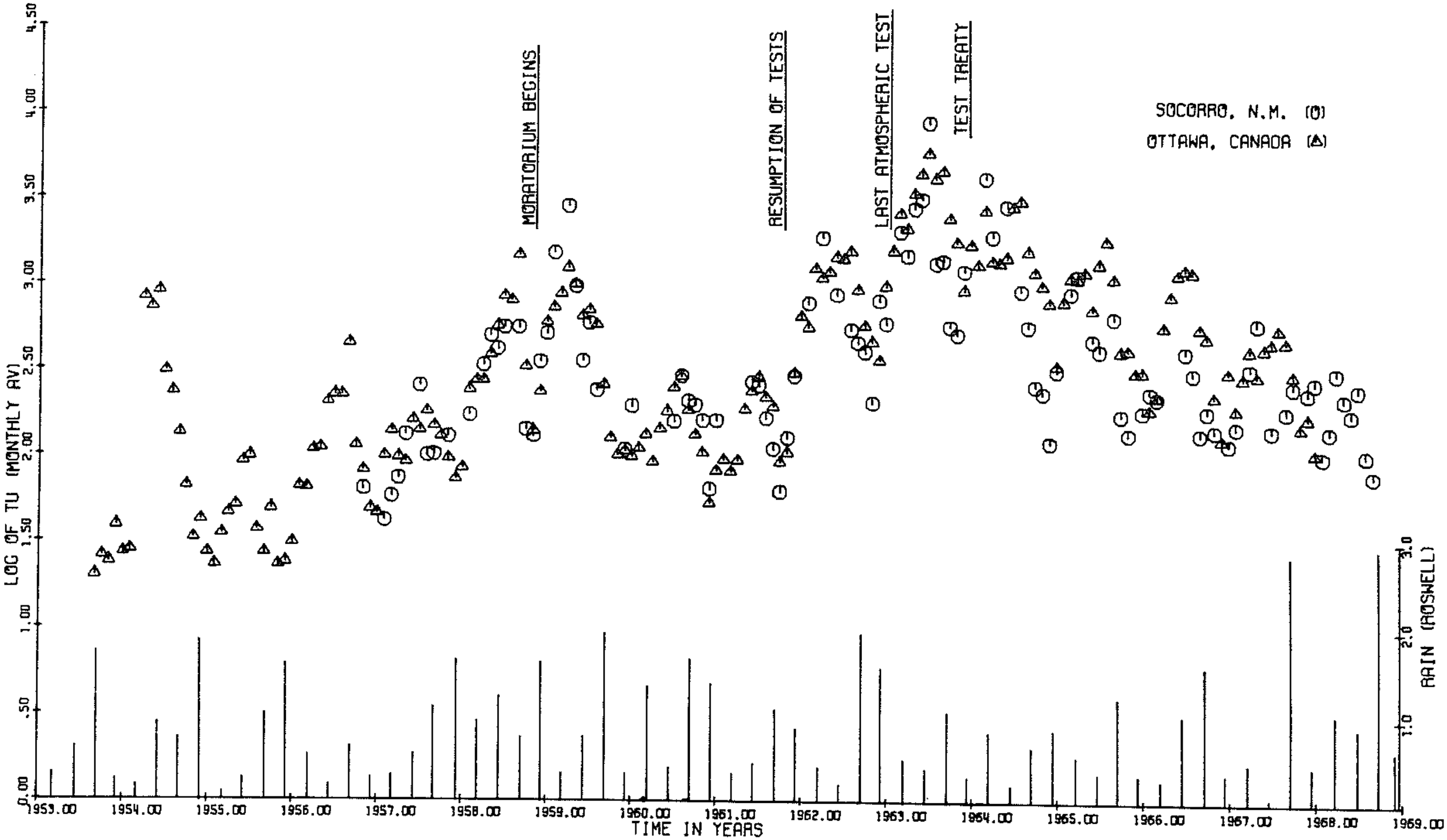

Figure 3. Variations of tritium concentrations in precipitation (Socorro, New Mexico, and Ottawa, Canada). Superposed is the mean tri-monthly rainfall in Roswell.

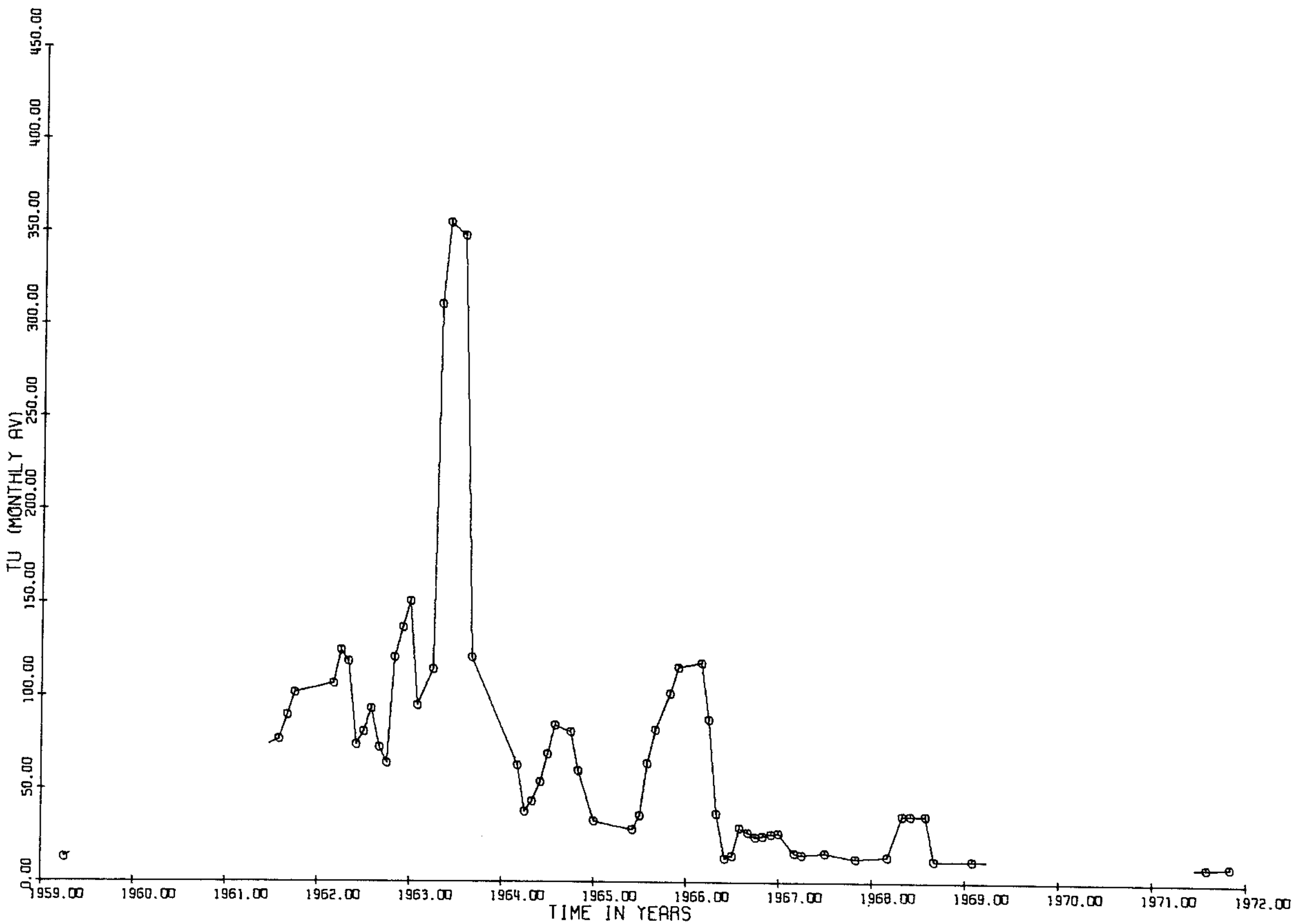

Figure 4. Tritium concentrations in Woods well (11.22. 9. 321).

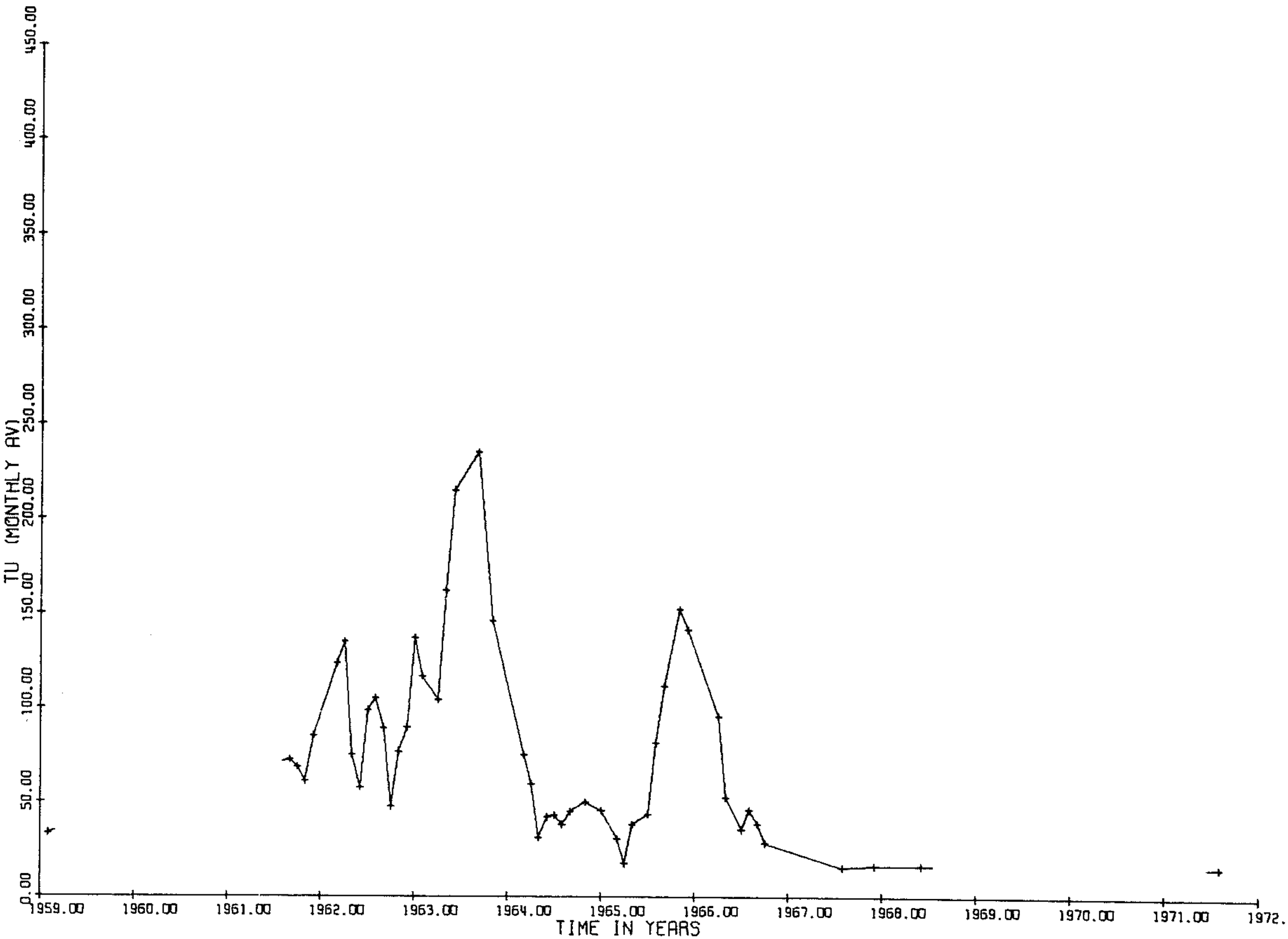

Figure 5. Tritium concentrations in Allison well (11.24.25.341).

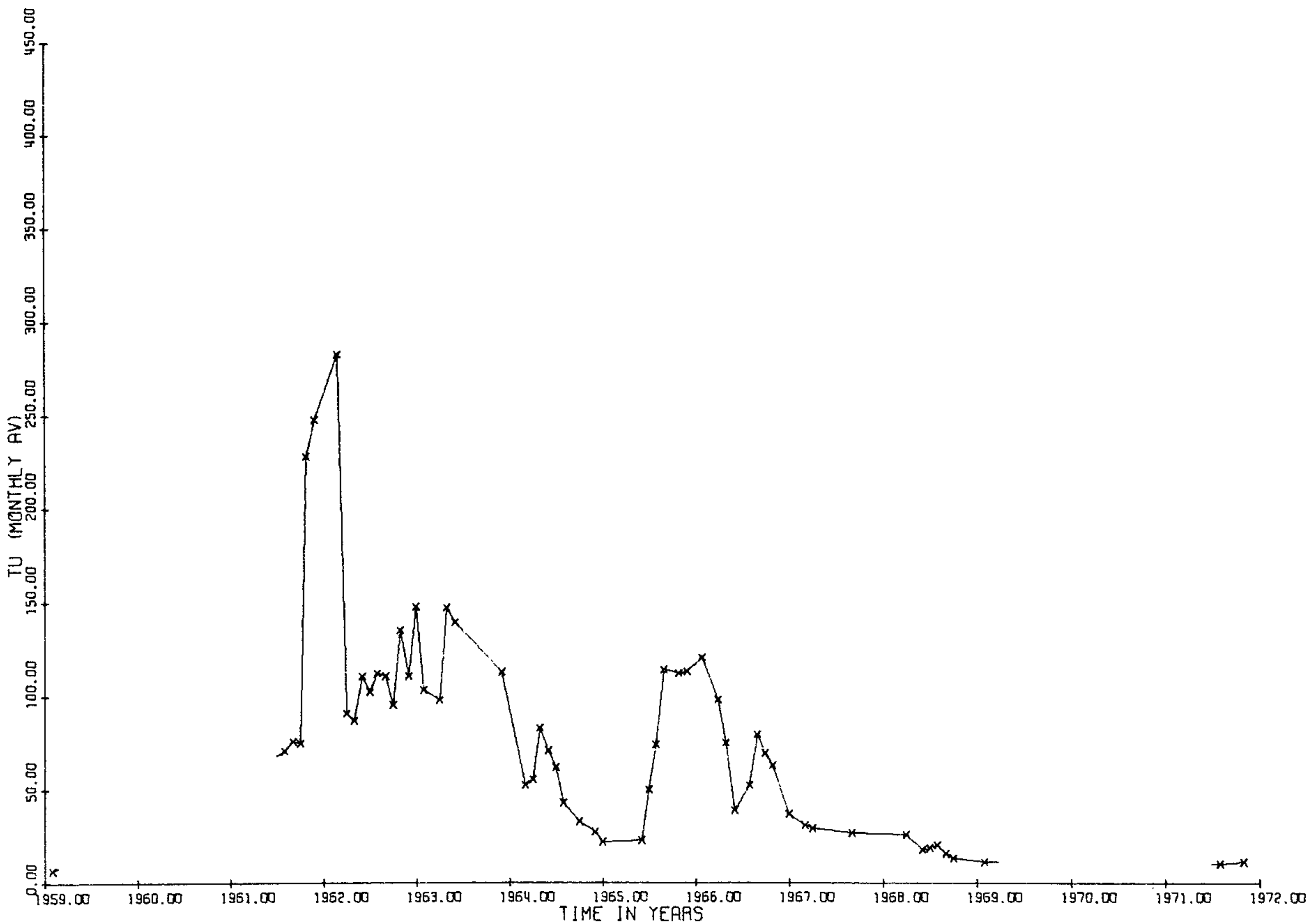

Figure 6. Tritium concentrations in Clardy well (11.25.15.343.).

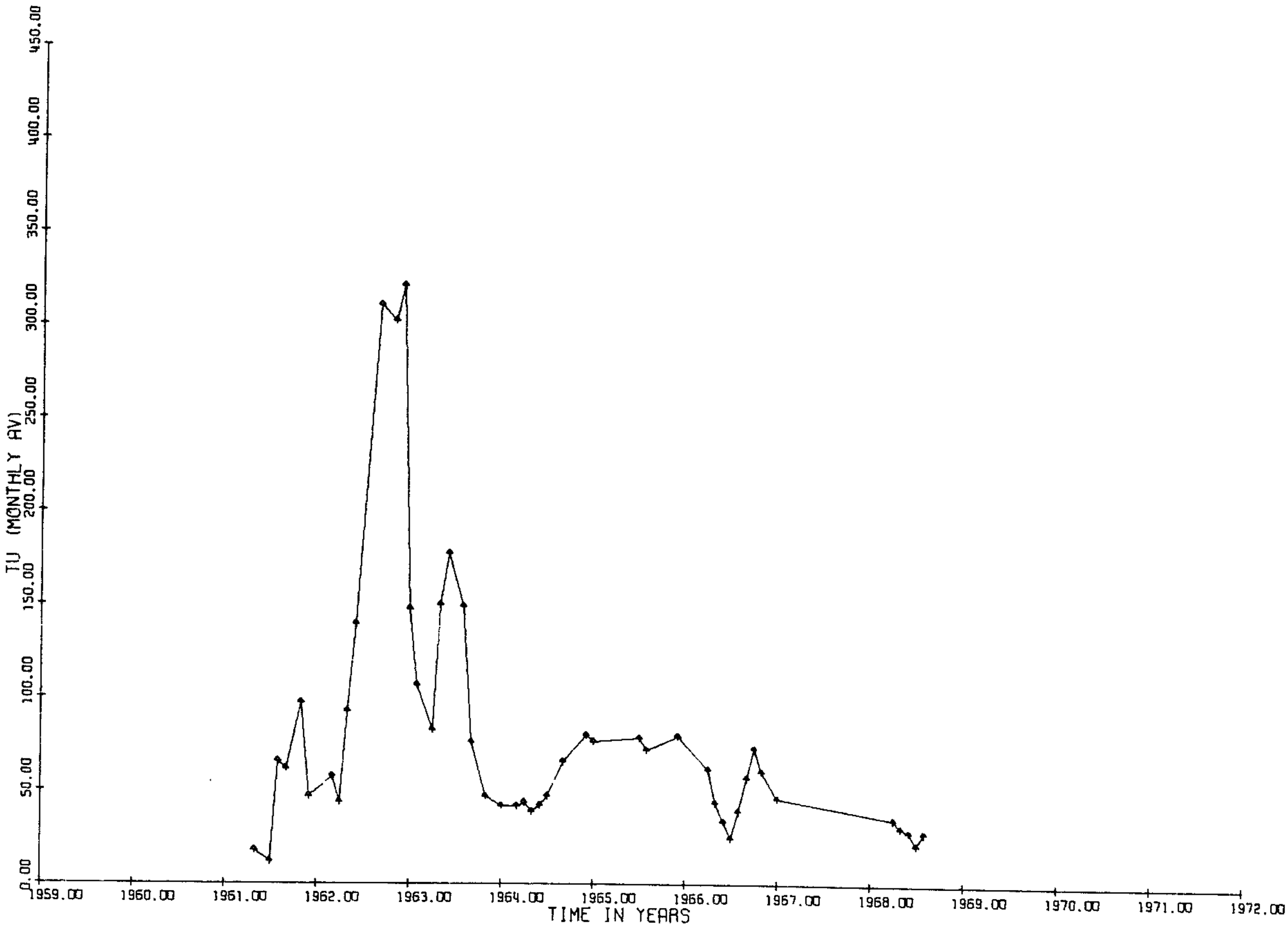

Figure 7. Tritium concentrations in Wiggins well (13.25. 3.114).

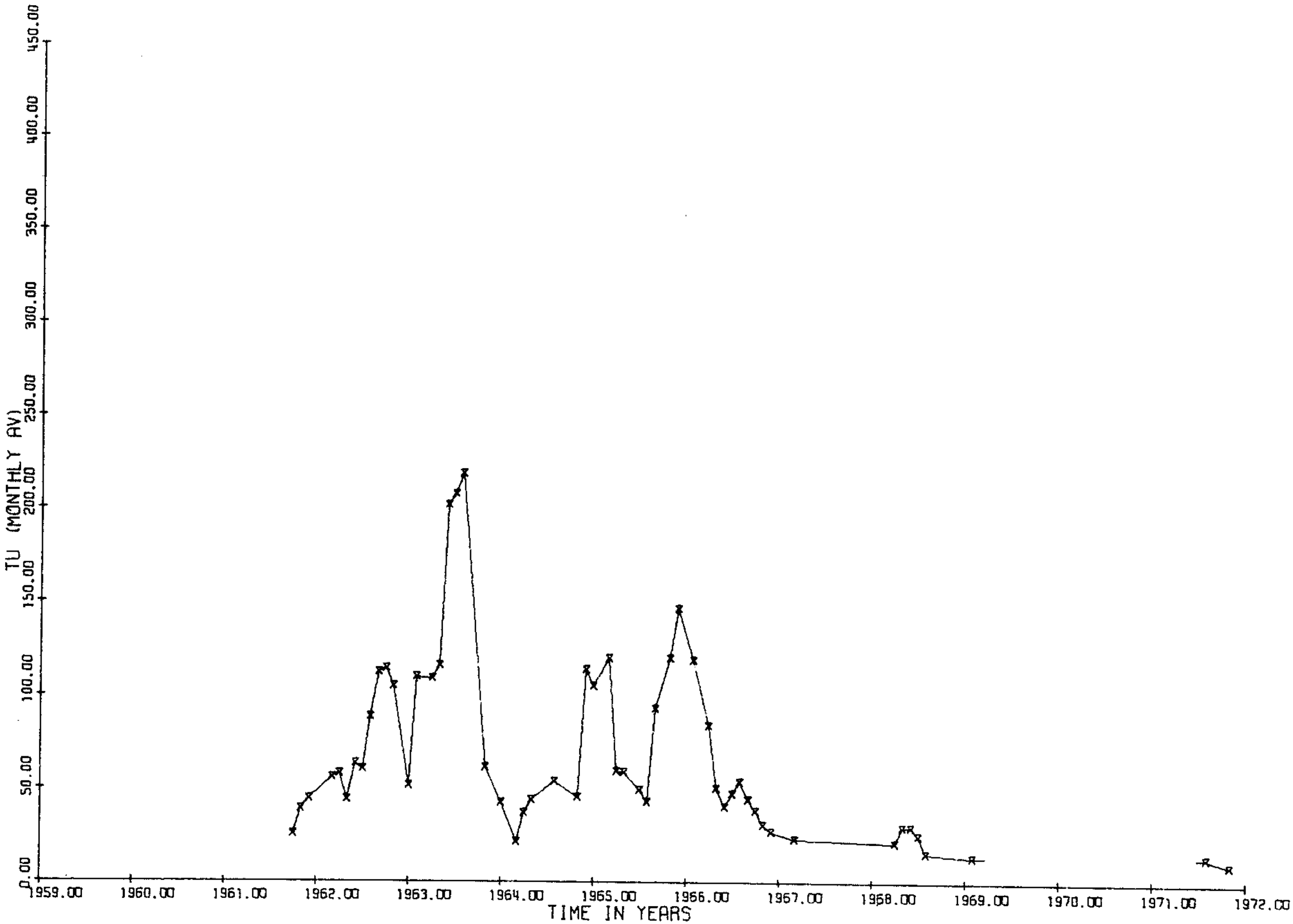

Figure 8. Tritium concentrations in Pollard well (15.26.13.121).

with the older water below. The similarity in the variations of tritium concentrations with time is striking. The main feature of the concentration variations is the rapid increase from the middle of 1961 to about 1964, followed by a sharp decrease, with two or three moderate peaks in 1965 and 1966. During 1961 - 1964, concentrations varied from about 50 to 350 T.U. The peaks in 1965 and 1966 were of the order of 100 T.U. Three of the wells (Woods, Clardy, and Allison) were sampled at the beginning of 1959. Tritium concentrations at that time were already above the natural levels. Sampling during 1971 revealed relatively low levels of tritium, though higher than the natural levels.

Interpretation

The starting point for a meaningful interpretation of this type of data must be an examination of precipitation trends. Without taking into account the variations of recharge per unit precipitation near the study area, any attempt of direct correlation between the variations of tritium concentration in precipitation and groundwater must fail. The size of a tritium peak in groundwater depends not only on the concentration of tritium in precipitation but also on the amount and intensity of the precipitation itself. This is especially true in the semi-arid region of southeastern New Mexico, where large variations of precipitation are the rule rather than the exception.

The correlation was done through a tritium input profile, defined as the product of the monthly average tritium concentration in precipitation and the amount of precipitation during that month. This product is the tritium fallout (in Ci/square mile) at the surface, of which only a certain amount will actually reach the groundwater system. This fraction varies with precipitation. It was found that the best correlation between precipitation tritium and the observed groundwater tritium was through precipitation that was measured at Dunlap and Farnsworth Ranch. The observed rise in tritium concentrations in the wells between 1961 and 1964 is the result of rainfalls during 1958, 1959, and 1960, the tritium levels in precipitation were lower than 1958 or 1963. However, consistently wet months increased the amount of recharge as indicated by the observed tritium content of groundwater. Little mixing between the recharging water and the native water of the aquifer is characteristically shown by the sharp tritium peaks. From the delay time between precipitation (1958) and first arrival at the wells (1962), a residence time of about four years is deduced. From the distance between the wells along the Pecos River and the exposure of the San Andres limestone west of Roswell, a groundwater velocity of about 65 feet per day is calculated.

A "BIG PICTURE" FOR RESOURCE MANAGEMENT
A VIEW OF EARTH FROM SPACE

R. Bryan Erb*

It is indeed an honor to visit with you here in Las Cruces and to participate in the 17th Annual New Mexico Water Conference. The importance of water can hardly be overemphasized as this conference bears witness. Man's endeavors in the development of water resources have been exciting events in the history of technology. The irrigation system of the Sumerians, dating from 4000 B.C., and the aqueducts of Rome at the start of the Christian Era were early milestones in a quest that today reaches for water from the sky and for water from the sea.

And still another phase is beginning with a new vantage point provided in the search for resources. The new vantage point is provided by a view of the Earth from Space. I would like to spend a few minutes this morning describing the NASA Earth Observations Program. This program, while perhaps less dramatic than the lunar landings, represents a major attempt by NASA to bring space technology to bear on earth problems and to provide new data sources to those responsible for management of earth resources.

Let us look now at man's management of his resources and environment. His activities have changed the environment in the past and will continue to do so for the foreseeable future. The results of these efforts are mixed; some ways man has managed his resources have been serious failures while others seem good. We have only to recall the creation of the dust bowl of the 1930's as an example of a serious failure. Many changes appear good, at least for the present. The conversion of forests to farmland in both the United States and in Europe, and the reclamation of land from the sea as carried out by the Dutch appear to be useful environmental modifications without bad side-effects. However, the time over which we judge success is short and history may render a different verdict.

The technology of our age, however, has added a new dimension--the power to make larger and faster changes to our environment than ever before. The changes we initiate could conceivably tip natural systems beyond the capacity of the natural control mechanisms. The point I would like to draw from all this is the following:

As our ability to perturb our environment expands so must our ability be extended to monitor the environment and to predict the consequences of our actions upon it.

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Now gathering information upon which to base resource development or environmental decisions is certainly nothing new. Whether we are talking about a search for gold with a pick and a pack mule, a search for water with a willow twig, or a search for oil with an airborne magnetometer, the approach is the same -- you take some sensing device, place it in or near some part of the earth and make an observation. What the Earth Observations program is attempting is simply an extension of coverage and an extension of sensitivity.

Let me deal with coverage. That is, how much of the earth can we survey with a given technique? A man standing on the ground can examine only a few square yards at a time. The well-developed techniques of standard aerial photography can provide images which include a square mile in a single frame. Certainly this is some improvement, but it takes a lot of such photos to cover New Mexico. Suppose we utilize high altitude aircraft, however. Now, typically an area 14 miles on a side can be surveyed -- or about 200 square miles in a single frame. With such a technique a statewide survey in a few days is quite feasible. Let us, however, go higher still and view the earth from a spacecraft. Now a scene some 100 miles on a side can be captured -- 10,000 square miles on a single exposure. At last we have the basis for rapid surveys at a regional or national level.

Now you will say, "This is all very well, but you can't see as much from so high up." Yes - and - No. If we gathered, over an area of 10,000 square miles, all the data which could be seen by the man on the ground, the mass of data would be indigestible. Low level sampling is always possible for spot checks anyway. What is added by the high level coverage is the broad or synoptic view in which features, unsuspected from close view, are often detected.

A good example of this was noted during the Gemini program. A photograph, which I will show you presently, was obtained over Lake Titicaca on the border between Bolivia and Peru. This photo showed a huge volcano not identified on the most recent map. It showed also a shoreline shape quite different from the maps. This example points out how surface observations alone can be incomplete. Another point which can be made is that remote locations and high mountains are no obstacle to observation by satellite.

Next let us consider sensitivity. Our eyes and conventional films are sensitive only to the narrow "visible" portion of the electromagnetic spectrum. Many important characteristics of the earth are not revealed by the way in which the surface reflects sunlight which is all that our eye or the camera sees. For example, the temperature of a body determines the emission of energy in the infrared. By sensing at wavelengths of 8-14 microns one can, with a knowledge of its emissive properties, determine the temperature of the surface being observed. Another class of information can be obtained in the microwave region. This can be done either by sensing natural emissions or by irradiating the scene purposely as with radar.

For a number of years now effort has been applied to developing sensors to detect emissions in these various wavelengths. In addition to sensors operating at specific wavelengths, such as the infrared, another class of sensor has been developed to detect emissions simultaneously in many wavelengths. These devices are termed multispectral sensors. Such devices and high altitude platforms or satellites provide the basic technology for remote observations of the earth with wide coverage and with unprecedented sensitivity.

Now the first step in utilizing this new technology was to determine just what could be sensed by the various instruments. For several years the Manned Spacecraft Center was involved with numerous University and Government scientists in exploring this basic question. Let me cite two examples in the area of hydrology:

1. Shallow ground water aquifers in glacial drift affect the local surface temperature distribution. The cool areas associated with such aquifers could be located by sensing in the thermal infrared (8-14 microns).
2. Vigorous plant growth reflects strongly in the near infrared (.9 to 1.1 microns). Using color infrared film it was possible to determine the volume of saltcedar plant material in the flood plain of the Gila River. Many other investigations in geology, geography, oceanography, and other disciplines showed similarly promising results. Such research efforts have been sufficiently succesful to indicate that practical applications could be made.

At the Manned Spacecraft Center we have been working for about a year now to develop such applications in conjunction with user agencies. The objectives of this activity are twofold: First, we want to develop experimental applications of this remote sensing technology, and second, we want to develop and test a method for making such applications. The approach is simple in concept. We choose to work in concert with duly constituted operating agencies. This helps to assure the implementation of the results if some success is achieved. We picked a small number of specific problems, each problem concerned with some decision required by the agency.

For convenience, our initial efforts are being pursued in the region around Houston, NASA Test Site 175. This area covers some 15,700 square miles of the Texas coast, an area about the size of Switzerland. For our purposes it offers a very reasonable selection of targets. Each application is pursued by an interdisciplinary, interagency team. We consider it of utmost importance to work applications as joint ventures and involve representatives of the user agency.

I will conclude with a series of slides that will show you some of the types of data gathered in our program, and the areas where we are working to develop applications.

POTENTIAL APPLICATIONS OF AEROSPACE EARTH OBSERVATIONS TECHNOLOGY TO THE PROBLEMS OF THE RIO GRANDE

R. B. Munson*

Abstract

Long range land use planning can only be done, in arid regions like New Mexico, when there is a fairly comprehensive accounting of the area's water resources and current water use practices. This in turn implies a large scale model of the area's water basin, with reasonable understanding of inflows, outflows, losses to evaporation and phreatophytes, and exchange with underground sources.

Large scale modeling, such as is being attempted with the Susquehanna river basin, requires large amounts of data to produce a significant predictive result. As is typical of most of the Western states, New Mexico is limited in the manpower and financial resources required to obtain and process this base data.

NASA's Earth Observation programs are now developing techniques for the acquisition of data from airborne and spaceborne imagery. In the long range land and water use planning, which the Rio Grande Regional Environmental Program (RGREP) is initiating, some of these techniques may be found to provide new or more rapidly obtained data sources. To that end, the NASA Manned Spacecraft Center has furnished RGREP with examples of imagery taken in the Rio Grande area in conjunction with other NASA missions and experiments.

Examples of this imagery, which include color, color-infrared, and other multispectral photography obtained from space and earth observation aircraft missions, are shown and briefly described.

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Scope of the Problem

The Upper Rio Grande basin may be defined as the portion of the Rio Grande river from the headwaters in the state of Colorado to a heavily faulted area, south of El Paso, Texas, (where the river essentially goes underground) where the old Frontier Fort Quitman was located. (Figure I). This portion of the Rio Grande watershed is, in area, about 32,035 square miles. It has a population of nearly 2,000,000, concentrated in two urban areas, Albuquerque and El Paso-Juarez. Its economy is based upon Federal Government Activity (Aerospace and nuclear energy R&D, military installations, and other agencies) agriculture, tourism, and light industrial manufacturing, in about that order. The only basic productivity, in agriculture, comes from irrigated lands and, to a much lesser extent, from rangeland stock grazing. Both of these activities are, of course, water-limited. There are those who predict that ranching, as an economic way of life, is about doomed in this generation; and the gradual salinization of the irrigated lands coupled with the known limits of water available seems to indicate a gradual decline in that activity as well. It is therefore fitting that those of you who are charged with the responsibility of allocating precious water resources should be seeking new methods of assessing our future in terms of water and land use planning.

The U.S. Water Resources Council, in their publication The Nation's Water Resources, stated that "... the water resources of the (Rio Grande) Region are fully appropriated and insufficient to meet present needs." The Council summarizes the water situation in this Region as follows:

> "The Rio Grande Region is confronted by five major water problems:
> 1. in nearly every part of the Region, the available water is not sufficient in quantity;
> 2. a significant amount of water is of poor quality because of high salinity;
> 3. heavy sediment loads are common in many tributaries;
> 4. excessive nonbeneficial consumptive use of water occurs; and
> 5. floods cause frequent and extensive damage to property and threats to human life."

Formation of the Rio Grande Regional Environmental Project (RGREP)

Recognition of this range of problems has been the driving factor in the organization of RGREP, currently under the impetus of the Bureau of Reclamation. The Governors of Texas and New Mexico have strongly endorsed this approach, and directed the Rio Grande Compact Commissioners and the appropriate state agencies and universities to participate. The project is still in the formative stages. A prospectus has been prepared and is available for review at the New Mexico Water Resources Research Institute.

FIGURE I. UPPER RIO GRANDE WATERSHED.

RGREP is presently composed of an executive body and a multi-disciplinary multi-agency advisory board. James Kirby of the Bureau of Reclamation is currently serving as Executive Director of RGREP. The scope, composition, membership, level of activity and funding, are all now in the process of being further defined.

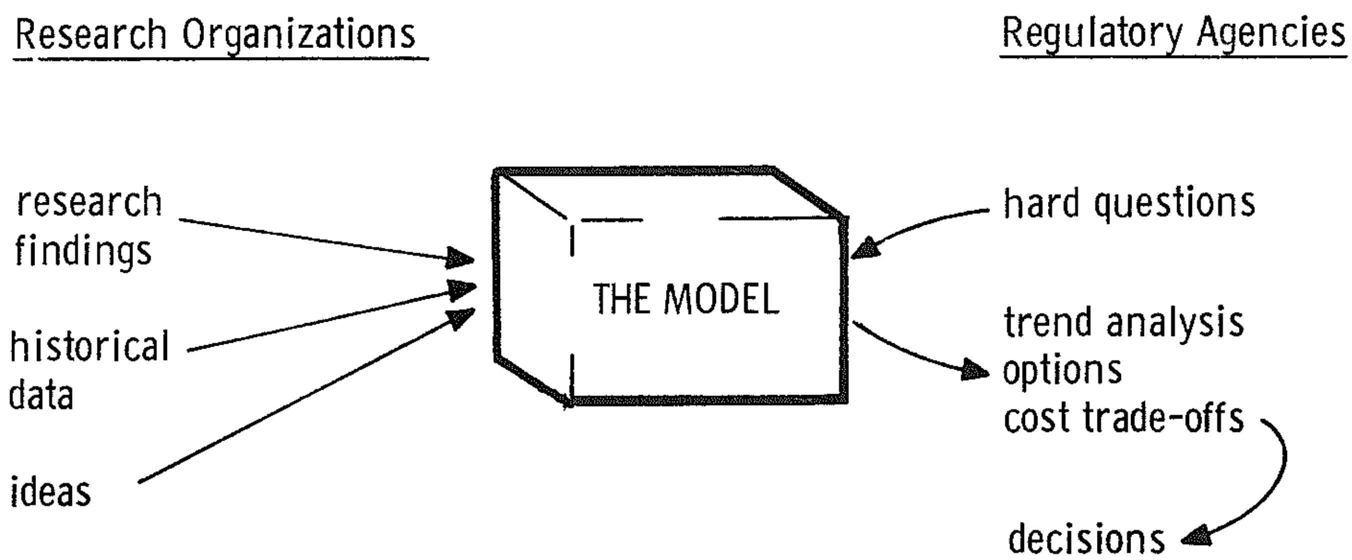
RGREP's Discussions with NASA-What technology is available and how could it be applied?

In November, 1971, after some preliminary discussions with the NASA, White Sands Test Facility, Mr. Jess Gilmer, Rio Grande Compact Commissioner, Mr. Kirby, and the heads of the three local Irrigation Districts, journeyed to the Manned Spacecraft Center at Houston for the puspose of discussing with the NASA the current techniques which NASA has developed in Earth Resources investigations. They were fortunate in their timing: The NASA is currently in the process of defining methods of applying the research techniques developed during the last decade in earth observations technology, and RGREP has the potential of being a very attractive applications program.

I should be very careful to stress, at this point, that the NASA has made no commitments in the ongoing support to RGREP. However, the NASA engineers in Houston were very interested in the RGREP problem, and arranged briefings for RGREP personnel of some of the NASA Earth Observations program activities. Finding some time available on one of the NASA Earth Resources aircraft, a specially-equipped RB-57, one flight was made to obtain some baseline photo coverage of the RGREP area. We will look at samples of this imagery later in the presentation. At the present time, NASA is continuing informal discussions with the RGREP director in the definition of RGREP's eventual program.

Approach: Large Scale Modeling

One of the most useful techniques, in any scientific investigation, is the development of a "model" of the phenomena to be investigated. A "model" can be a fairly simple description of a thing or a process, or an attempt to explain complex relationships not otherwise easily understood. The old "phlogiston theory" was a model in this sense. Once it was proposed, it was found to be inadequate. But, it was a necessary "first step" in the process of understanding combustion and other thermodynamic relationships because it served as a method of communication. Nowdays most large and complex investigations use models in the same sense, for communication, but they are most generally devised to be manipulated by analog or digital computer techniques. Computer-based modeling is largely mathematical in its techniques. It is sufficient here to consider the process as taking place in a "black box." (Figure II) Two basic different interests can be supported by the right "black box." The research community is interested in being able to test its findings against the model, and to communicate those findings to each other. Regulatory agencies, on the other hand, are looking for information in terms of trends, costs, and decision options, because they are called upon to answer hard questions and make far-reaching de-



The model as a "Black Box"

FIGURE II.

cisions. Let me give one example of a question which RGREP may be asked: "How many people, at what standard of living can be supported in the upper Rio Grande basin, based upon the known water limits?" The basic data needed to answer that question may already exist, but at present there is no way to get at it. Even if it does exist, it is not collected and formatted in such a way as to be able to demonstrate the problems which we all know, intuitively, are coming.

Long range land use and other economic planning can only be done in arid regions like ours, when there is a fairly comprehensive accounting of the area's water resources and current water use practices. This in turn implies a large scale model of the area's water basin, with reasonable understanding of inflows, outflows, losses to evaporation and phreatophytes, and exchange with underground resources. A large scale of the water resources then becomes a subset of a larger model of the region's economy, and relationships can be described between these models (Figure III).

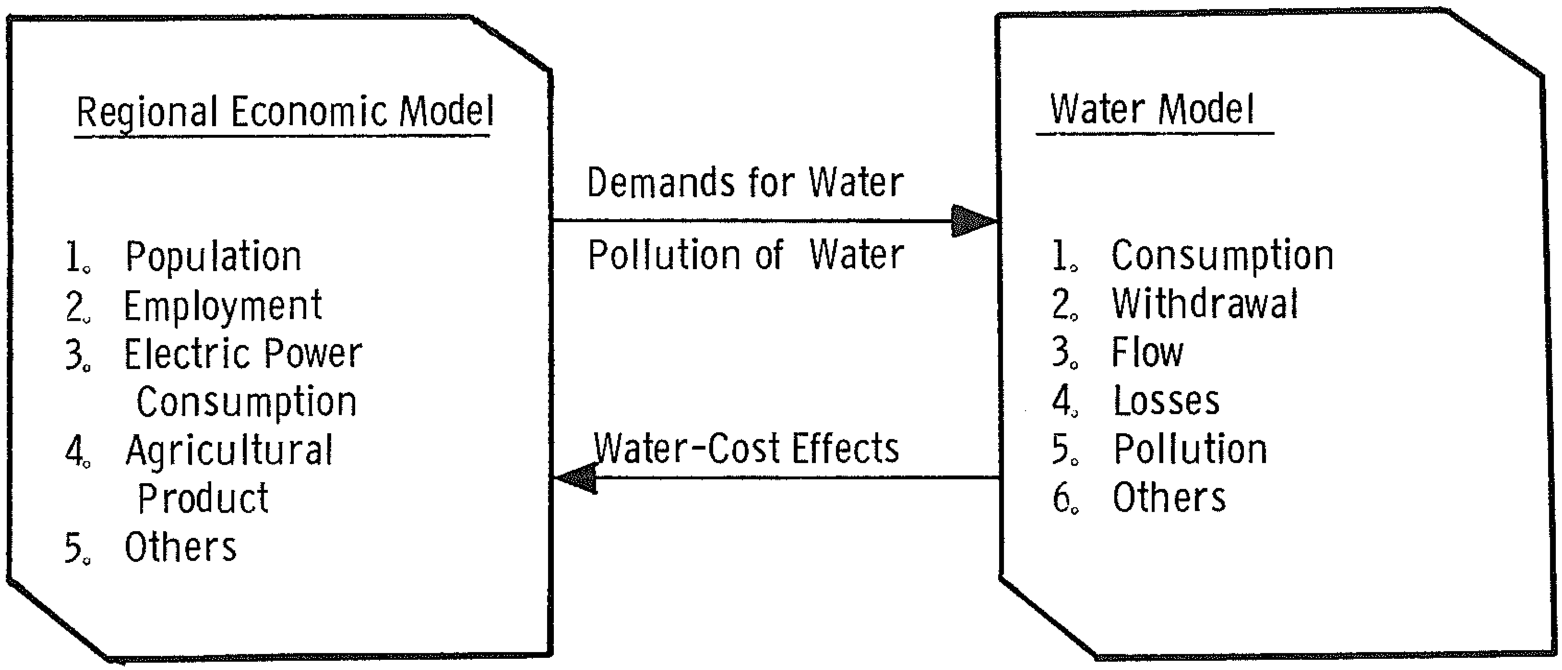
Without getting too detailed, it should be mentioned that even these sector models, such as the water sector model, are composites of submodels of discrete regions (Figure IV).

The upper Rio Grande basin might thus be described in three, four, or five submodels, depending on the physical geometry of the river and how the engineers and scientists choose to define the model.

Large scale modeling, such as has been attempted with the Susquehanna river basin, the lower Mississippi, and other rivers, requires large amounts of data, generally gathered by hand measurements, field trips, etc., in order to produce a significant predictive result. Here in the Southwest, we are limited in the manpower and money required to obtain and process this base data. NASA's Earth Observations programs are now developing techniques for the acquisition of data from airborne and spaceborne sensors, both remote instruments telemetering data to central data collection points, and with multispectral (photographic, infrared sensing, microwave) imagery. Both the data gatherings and the data reduction are evolving into semi-automated procedures. These techniques, then, become attractive to any large modeling program in the Southwest. In the long range land and water use planning envisioned by RGREP, there may well develop some significant applications of this aerospace technology.

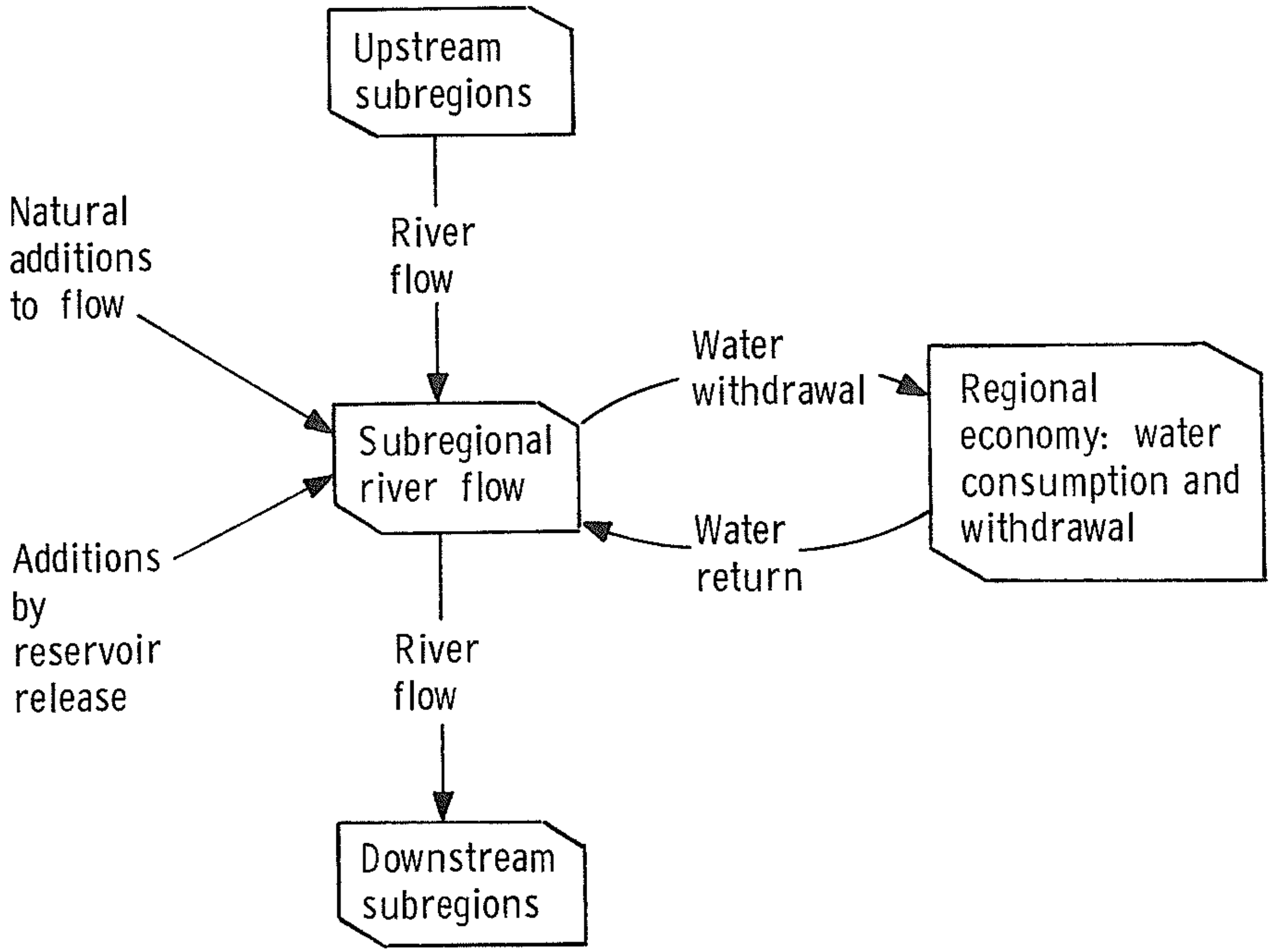
A Closer Look at RGREP

In Figure V, I have taken some liberties with the RGREP organization, to show the approach to the problem now under development. The lists of interested regulatory agencies and participating research agencies are not yet complete. There well may be more and different players in the game. This chart does, however, show the relationships required, and the use of the model as a communications device. The sketch shows a list of the submodels probably required (water, air, land use, economic, and population submodels), and, for illustration, the



Feedback between Models

FIGURE III.



<u>Simplified Water Submodel</u>

FIGURE IV.

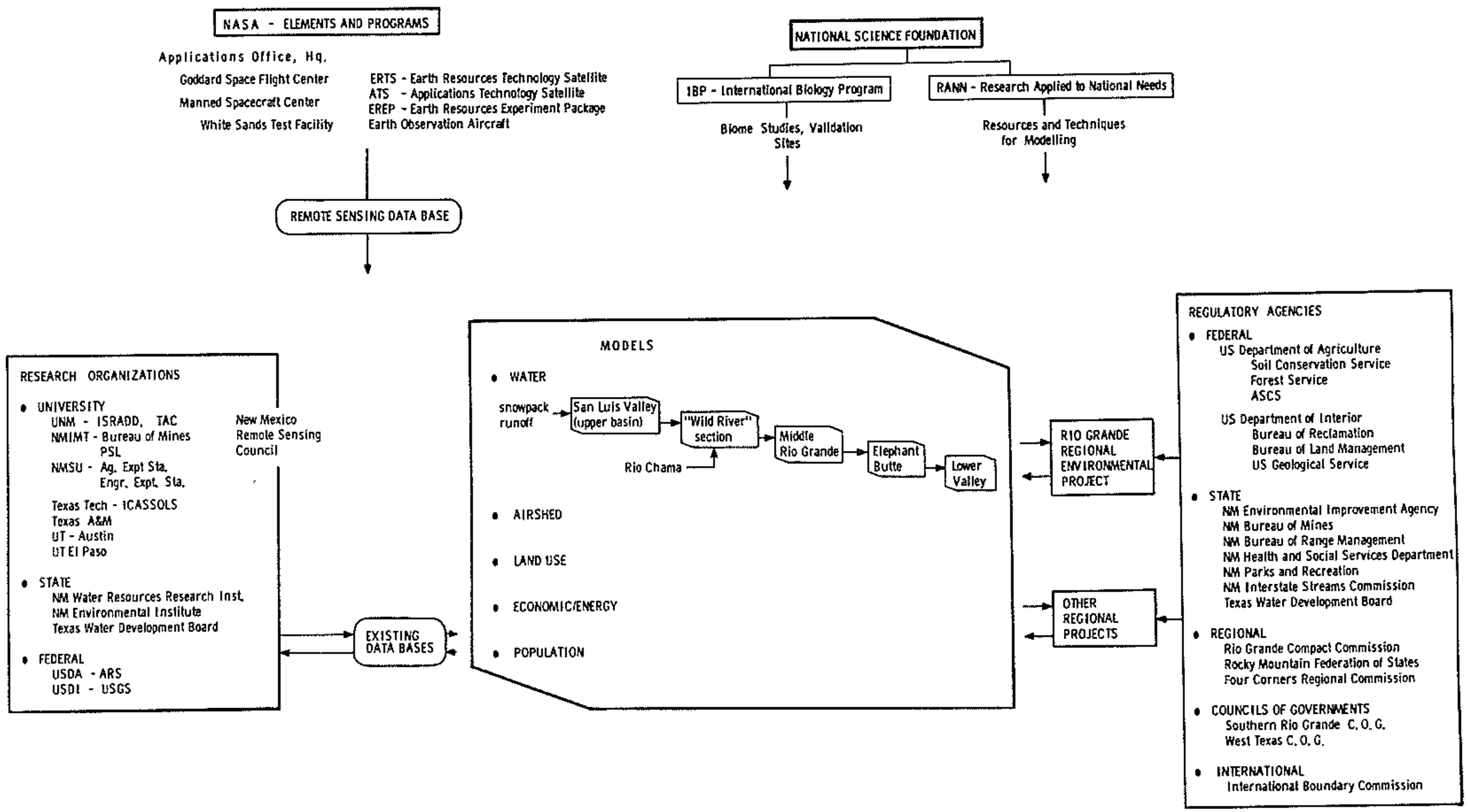

NASA - ELEMENTS AND PROGRAMS
Applications Office, Hq.
Goddard Space Flight Center
Manned Spacecraft Center
White Sands Test Facility
ERTS - Earth Resources Technology Satellite
ATS - Applications Technology Satellite
EREP - Earth Resources Experiment Package
Earth Observation Aircraft
REMOTE SENSING DATA BASE
NATIONAL SCIENCE FOUNDATION
IBP - International Biology Program
Biome Studies, Validation Sites
RANN - Research Applied to National Needs
Resources and Techniques for Modelling
RESEARCH ORGANIZATIONS
• UNIVERSITY
UNM - ISRADD, TAC
NMIMT - Bureau of Mines
PSL
NMSU - Ag. Expt Sta.
Engr. Expt. Sta.
New Mexico Remote Sensing Council
Texas Tech - ICASSOLS
Texas A&M
UT - Austin
UT El Paso
• STATE
NM Water Resources Research Inst.
NM Environmental Institute
Texas Water Development Board
• FEDERAL
USDA - ARS
USDI - USGS
EXISTING DATA BASES
MODELS
• WATER
snowpack runoff
San Luis Valley (upper basin)
"Wild River" section
Rio Chama
Middle Rio Grande
Elephant Butte
Lower Valley
• AIRSHED
• LAND USE
• ECONOMIC/ENERGY
• POPULATION
RIO GRANDE REGIONAL ENVIRONMENTAL PROJECT
OTHER REGIONAL PROJECTS
REGULATORY AGENCIES
• FEDERAL
US Department of Agriculture
Soil Conservation Service
Forest Service
ASCS
US Department of Interior
Bureau of Reclamation
Bureau of Land Management
US Geological Service
• STATE
NM Environmental Improvement Agency
NM Bureau of Mines
NM Bureau of Range Management
NM Health and Social Services Department
NM Parks and Recreation
NM Interstate Streams Commission
Texas Water Development Board
• REGIONAL
Rio Grande Compact Commission
Rocky Mountain Federation of States
Four Corners Regional Commission
• COUNCILS OF GOVERNMENTS
Southern Rio Grande C. O. G.
West Texas C. O. G.
• INTERNATIONAL
International Boundary Commission

FIGURE V.

division of one submodel into sub-region "sub-sub-models". In addition, the figure shows the anticipated participation of two agencies

- the NASA for support in its areas of expertise; and,
- the National Science Foundation, for support in the areas of large scale modeling, under the aegis of the Research Applied to National Needs program (RANN).

Direct participation with NASA would probably involve cooperative study of the following items:

WATER

1. Periodic evaluation of snowpack - October through May.
2. Atmospheric meteorology for melt and for run-off prediction.
3. Periodic evaluation of streamflow conditions in Rio Grande and tributaries.
4. Periodic assessment of water stored in reservoirs, reservoir capacities, silting, etc.
5. Periodic assessment of soil moisture conditions, via microwave techniques.

LAND

1. Assist in preparing a comprehensive report on the physical geology of the area.
2. Assist in preparing a comprehensive study of the geohydrology of the area.
3. Assist in monitoring the fluvial morphology of the Rio Grande and tributaries.
4. Assist in geothermal explorations.
5. Assist in evaluating the progressive sedimentation of storage and flood control reservoirs.
6. Establish land use maps and revise periodically to monitor changes.
7. Participate in studies for the evaluation of the effects on land and water by estimates of biomass, grasslands, phreatophytes, pinon-juniper highlands, and forested areas.
8. Assist with soil studies to determine soil types and particularly soil salinity.
9. Assist with irrigation efficiency studies.
10. Assist with agricultural studies and evaluations covering a broad range of applications by assessing plant pathology, and correlating use of insecticides with water pollutants.

AIR

1. Assist with studies to identify and assess sources of air pollution emanating from the RGREP area and pollutants entering the RGREP area from contiguous areas.
2. Assist with the improvement in weather forecasting, both long and short range.

ENERGY

1. Assist with the evaluation of the area as a potential prime source of solar energy.
   : Geothermal energy
   : Conversion of saline waters

HUMAN

1. Provide basic data and assist with the assessment of the entire human resource of the area.

Involvement in the above programs would necessitate cooperative efforts from a multitude of Federal, State, and other agencies.

Imagery Now On Hand of the RGREP Area

In the course of a number of experiments conducted from spacecraft and Earth Resources aircraft over the last several years, there have been some photographs taken of the RGREP area. This data is already available for viewing at the NASA Manned Spacecraft Center's Earth Observations Research Data Facility at Houston. Copies of most of the photographs, particularly those from space, are available at a nominal charge from the University of New Mexico's Technology Applications Center. One set of imagery, from the most recent aircraft flight, which I mentioned earlier, is available for viewing at the New Mexico Water Resources Research Institute at NMSU. In general, the best imagery from space of the RGREP area was obtained from the flights of Apollo 6 and Apollo 7 (Figure VI): the coverage available that has been taken by the NASA aircraft is shown in Figures VII and VIII, the latter Figure showing the coverage provided to RGREP for initial survey purposes.

(To those attending the 17th Annual Water Conference, I would like to give a brief tour of the Rio Grande Valley, from Bernalillo to Ft. Quitman, as seen in the infra-red. Sixteen selected slides, covering Albuquerque, the Socorro area, Elephant Butte and Caballo, the Rincon Valley, Mesilla Valley, El Paso, and the Lower Valley below El Paso, will be shown.)

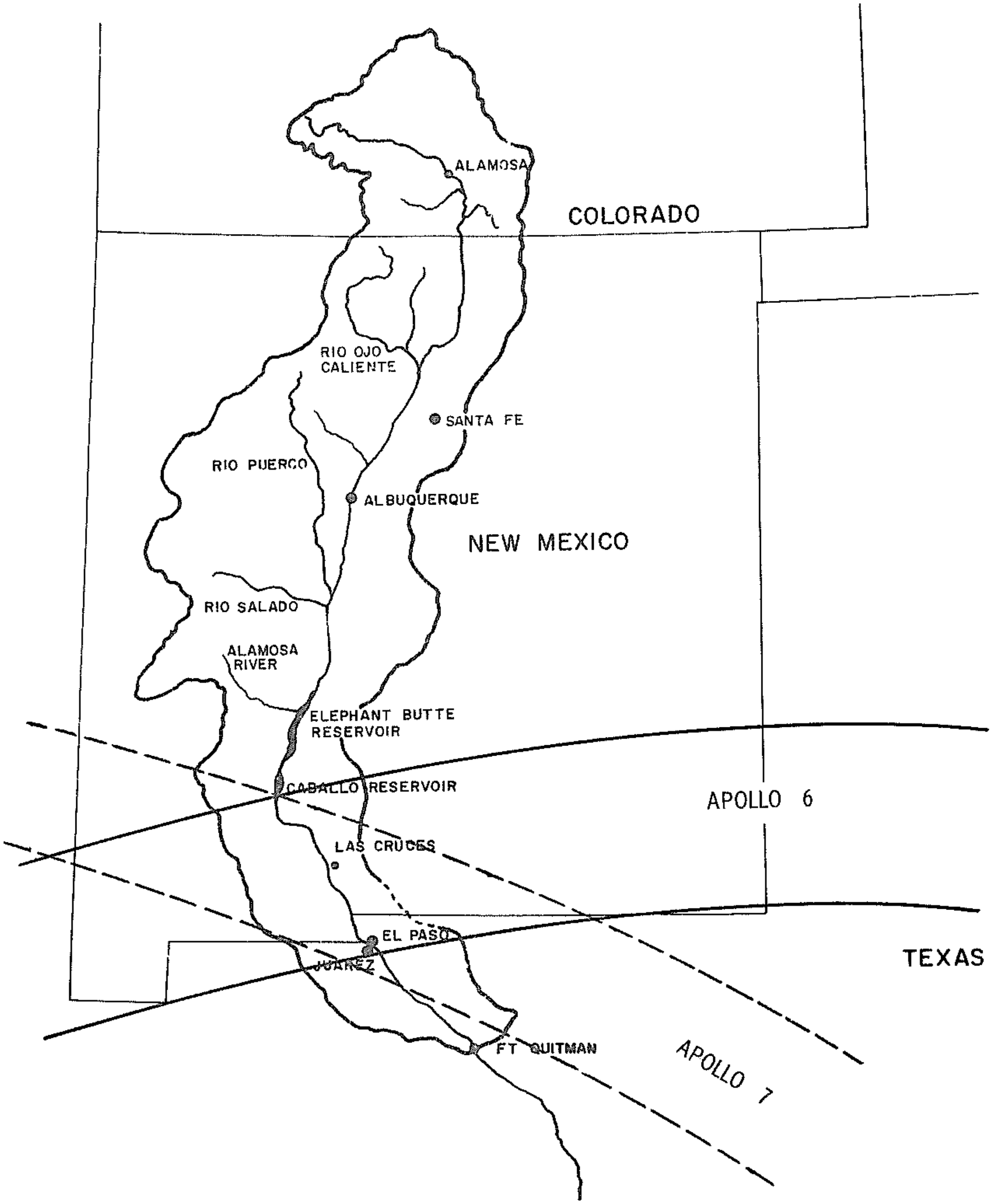


FIGURE VI. PHOTOGRAPHY FROM SPACE.

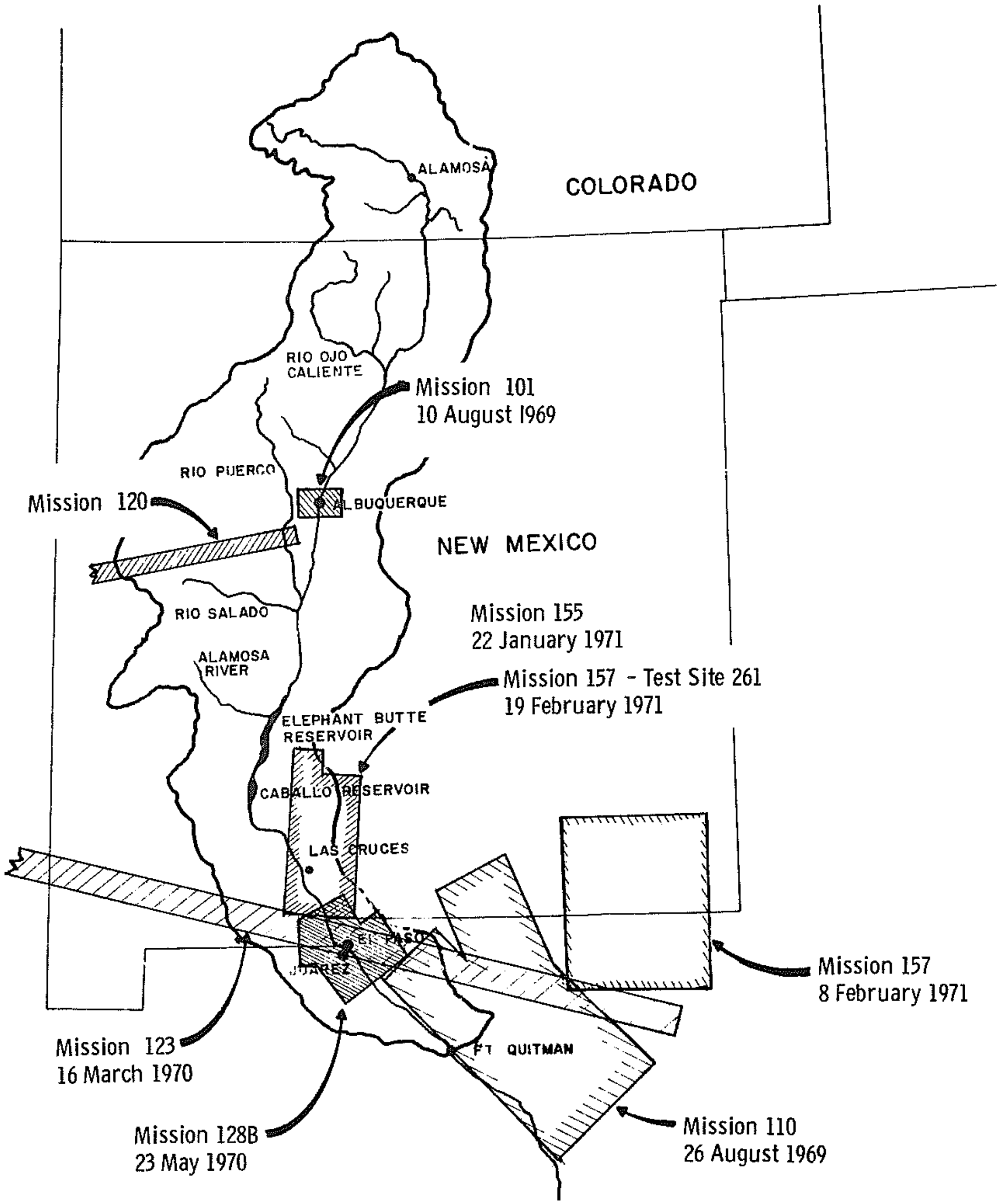


FIGURE VII. PHOTOGRAPHY FROM NASA'S EARTH OBSERVATIONS AIRCRAFT.

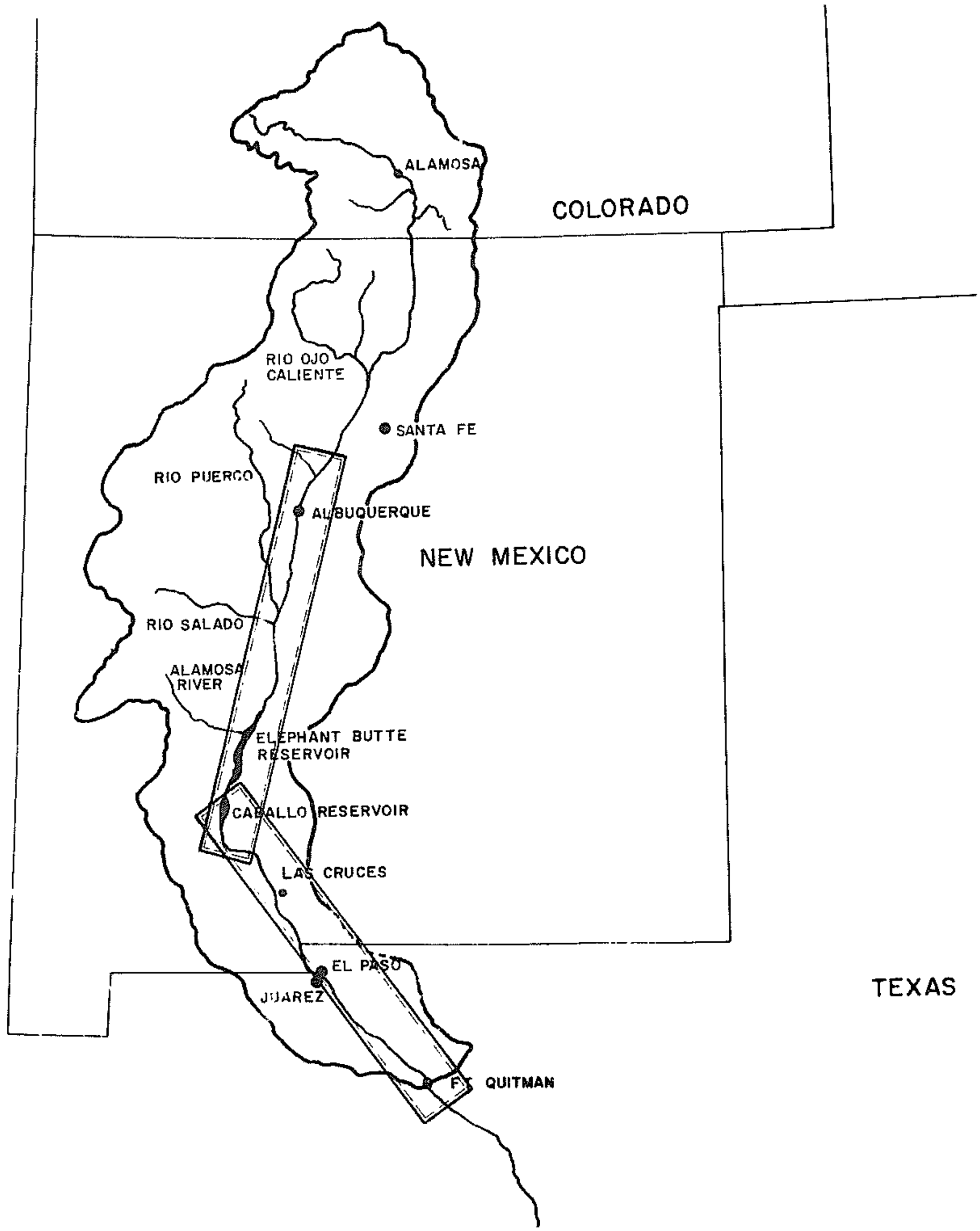


FIGURE VIII. PHOTOGRAPHY FROM NASA'S EARTH OBSERVATIONS AIRCRAFT - MISSION 191 - RGREP AREA.

PANEL - CITIZENS WATER CONFERENCES

Robert R. Lansford*

Introduction

New Mexico's 10 major water problems were identified and ranked in importance during a series of area and statewide meetings held in 1971. Representatives of all sections of the State discussed the over-all situation in detail, considered problems of specific areas, and then recommended a course of action. Since the present and the future of New Mexico are so closely allied to water supplies, the identified problems, recommendations regarding them, and the manner in which such recommendations were arrived at all bear significance for New Mexicans in general and their leaders in particular.

Purpose of the Conferences

The primary purposes of these conferences were:

1. To provide an opportunity for a wide cross-section of citizens interested in water to discuss some of the most pressing water situations and problems of their communities and of the State of New Mexico.

2. To have those attending the Citizen's Water Conferences make suggestions and recommendations about which problems they believe to be the most important in their areas and in the state, and what they believe might be done to solve these problems.

Participation

A request was mailed to each county extension agent in New Mexico asking for a list of up to 25 persons in the county who had an interest in water and who, as a group, would represent a cross-section of various water users. A list was received from every county, and letters and questionnaires were then mailed to the approximately 700 names submitted. Usable questionnaires were received from 211 persons.

Area Conferences

Two Citizens' Conferences on Water were held in each area. The first was to discuss the general water situation in the area and to develop a list of the water problems which those attending felt were the most important in their area. The second was held about two weeks

* Chairman, Associate Professor, Department of Agricultural Economics, New Mexico State University.

later. During the period between the meetings, many persons talked with their neighbors and gathered information which was brought back to the second meeting. At the second meeting the area water problems were ranked in order of importance by the group, and further discussion followed this ranking. At each conference those attending were assembled in small discussion groups to permit everyone to participate. Extensive notes were taken in these discussion sessions and in the general discussion. At the end of the second meeting two delegates were elected by the group to attend a State Citizens' Conference on Water and present the problems for their areas. Two hundred and six individuals attended the conferences.

State Meeting

The 16 area delegates met together for one-half day and discussed the recommendations from each of the eight areas. They then met for one and one-half days with the Advisory Committee of the Water Resources Research Institute. Also attending the state meeting were the leaders of the several research units in the state and five county extension agents.

Our Most Important Water Problems

Out of the many extensive analytical sessions came the identification of New Mexico's most pressing problems in the area of water supply and use. The 10, ranked in order of degree of significance assigned them by the delegates and their consultants, are these:

1. Declining ground-water table and diminishing surface-water supply.
2. Need for improved irrigation systems and water-use management in irrigated agriculture.
3. Water pollution
4. Need for knowledge of present and future supplies and demands of water.
5. Shortage of water for industrial, recreational, and municipal uses.
6. Need for equitable adjudication of water rights.
7. Necessity of improvement of water laws.
8. Salinity of water and its effects on human and plant life.
9. Reuse of water whereever practical by recycling.
10. Establishment of land and water planning and zoning.

Ground-Water Table and Surface-Water Supply

Large-scale pumping of ground water for irrigated acreage and increasing requirements for industrial and municipal uses of water have caused the lowering of the water table in many areas of New Mexico. Considerable ground-water mining is carried on in many parts of the State and may limit the future development of New Mexico. About 58 per cent of the irrigated land is now supplied from ground-water sources (747,450 acres), and an additional 14 per cent (174,310 acres) receives both surface and ground water. Almost all of our municipal and industrial water comes from ground-water sources.

Full appropriation and court decrees limit surface-water development in this state. As a result, many areas have experienced shortages of such water for agricultural and some municipal and industrial uses.

Irrigation

In certain sections of northern New Mexico only 20 to 30 per cent of the water diverted from rivers and streams reaches croplands needing irrigation. Small, obsolete, poorly designed and constructed ditches lacking adequate maintenance cause transportation and excessive seepage losses. They also become silted by flow from arroyos and streams. These small ditches need to be consolidated into larger, better designed conveyance ditches in order to conserve and deliver adequate irrigation water to cropland. Many instances of over-irrigation were cited as present in most areas of the State. On-farm management of ground water could be made more efficient by the lining of ditches, by changes in field layout, and/or through use of better irrigation systems such as sprinklers, trickle irrigation, or subsurface irrigation.

Meters are now used on irrigation wells in the Roswell Artesian Basin and in the Gila and San Francisco drainages to the Colorado River. If irrigation efficiency were increased by only 10 per cent, a large amount of water currently used for agricultural purposes could be made available for industries, municipalities, and recreation, or it could be used for additional irrigated land.

Pollution

Among the forms of pollution mentioned during the conferences were sewage and industrial pollution of both surface and ground water and sediment pollution of surface-water streams and rivers. Many subdivisions and trailer parks have placed tanks and domestic wells too close together, thus causing pollution from septic tanks to be recycled into the domestic wells. Largely because of improperly designed, installed, and operated sewage plants, some inadequately treated wastes are being discharged into rivers and streams. Also, the population is increasing faster in many areas than sewer developments are installed; consequently, delegates recommended that developers in rural areas be required to provide adequate water and sewage systems for housing developments.

Discussions pointed out that sediment can be controlled by proper range and watershed management which can help hold the soil in place, and flood-control dams can reduce the silt and sediment reaching our major streams and rivers.

Present and Future Supplies and Demands

Only incomplete information is available on conditions and amounts of water actually on hand in many New Mexico areas. Studies of ground-water hydrology are lacking for almost all sections, and this lack restricts planning by communities and state agencies. Information is badly needed about both ground water and surface water and about the relationships between the two. Also needed are projections as to expected future requirements of water for agricultural, industrial, municipal, and other uses. Such projections are basic to any long-range planning on a realistic basis.

Industrial, Recreational, and Municipal Shortages

Many New Mexico municipalities are faced with water shortages, and, as the population increases, pressures for more water will also increase--water for municipal and industrial operations and for water-based recreation. Provisions should be developed as rapidly as possible for an orderly transfer of water rights between or among alternative uses. New Mexico has only a small allocation of water for recreational purposes, but a few new projects--notably, Cochiti Lake between Albuquerque and Santa Fe--are now being developed to alleviate this situation.

Adjudication of Water Rights

Many of the people attending the State Citizens' Conference shared the opinion that all claims for water rights in New Mexico should be fairly and equitably adjudicated. Most streams in the State were originally over-appropriated. Adjudications have been completed in several areas, and others are now in process. Adjudication is a court procedure through which each claimant is asked to present his claim for water, following which the court determines and records the amount of water declared to be the "right" for each claimant.

Provision should be made to transfer the financial burden of adjudication from water-right owners to the State of New Mexico. Such provision would help to stabilize the agricultural, municipal, industrial, and recreational uses dependent on such rights.

Water Laws

Topics making up the conference discussions of the improvement of New Mexico's water laws included the following five items:

1. Possible re-evaluation of river compacts to permit larger storage facilities to control flooding and silting and to provide additional recreational facilities.
2. Interstate compacts for ground-water basins.
3. Uniform water-right laws between states.
4. More control by the State Engineer over New Mexico's water resources.
5. Provisions of facilities for an orderly transfer of water rights among uses and within a single use and for the protection of existing rights.

Effects of the Salinity of Water

The general quality of both surface and ground water is decreasing in this State. Part of the problem in surface water arises from increased sewage flows where ground water is the original source of water, from leaching of salts from the soil and their original source of water, from increasing use and reuse of water, and from industrial wastes being dumped into streams and rivers.

The encroachment of salt water into ground water comes primarily from declining water tables caused by overdrafts. Other sources listed included abandoned livestock and irrigation wells in high salt areas, and salt pollution from oilfield brines and from leaky oil-well casings.

Recycling of Water

Recycled water, properly treated, can be used for golf courses, swimming pools, or municipal water systems. In some cities in the nation as much as 40 to 50 per cent of the city's water supply is such recycled water for city needs--either surface or ground water--could be substantially reduced.

Planning and Zoning

Adequate planning and zoning of land and water can serve to anticipate water needs before problems become acute. Ground- and surface-water pollution can be better controlled through such policies. For example, housing and trailer-park developments can be more closely supervised and controlled than when such zoning is absent, and the probability of ground-water pollution is thereby considerably lessened.

State Water Plan

A State Water Plan for New Mexico is being prepared under the leadership of the Bureau of Reclamation, U.S. Department of Interior, and the New Mexico Interstate Stream Commission. In connection with the Plan, a statement prepared April 1, 1971, by Rowland W. Fife, Bureau of Reclamation Area Engineer, Albuquerque, was read at each of the eight area Citizens' Conferences on Water. The consensus of the conferences was that wide citizen-understanding of the Plan while it is yet in its formative stages is vital to its success. Private citizens, businessmen, industrial leaders, ranchers and farmers, personnel of government agencies--all these people will have many occasions to refer to the Plan for years to come.

The Questionnaire

Two hundred and eleven persons completed questionnaires composed of 34 questions designed to determine interest in water resources, the manner in which information on such resources is obtained, and personal feelings on the vital water problems in specific areas. Included among the informants were participants in the conferences.

Respondents were fairly uniformly distributed throughout the State. About half of the 211 were involved in agriculture, but a cross section of occupations was represented. Respondents included housewives, industrialists, public servants, and professional people.

Answers to some of the more important questions are summarized here. (A few were not answered; therefore, responses may not have added up to 100 per cent.) To begin with, interest in water resources is high throughout New Mexico. Almost 70 per cent of the returns indicated high personal interest, and about 25 per cent suggested moderate interest. More than 80 per cent of persons replying stated that they are concerned about our water resources and do want to see improvement achieved. However, they are not sure as to how such improvement can be brought about. The need for additional information was expressed, and many persons felt that most people in their area shared a desire for such added information. The question eliciting such responses was "Would you say that there is a need for additional water-resources information to meet the needs of local citizens?" Replies totaled 89.6 per cent "Yes"; 3.3 per cent "No"; 6.6 per cent "Not sure."

More than 70 per cent of the respondents said that they had themselves requested information on water-related problems from appropriate agencies. The five agencies most often supplying such information (in order of frequency of response) were the Soil Conservation Service, the State Engineer Office, the New Mexico Cooperative Extension Service, the Bureau of Reclamation, and the Water Resources Research Institute. Most information was received through personal contacts, meetings, and bulletins.

PANEL - CITIZENS' WATER CONFERENCES

J. T. McMillen*

I want you all to know I am a New Mexico chauvinist. I take pleasure in the achievements of this State and of its citizens. I point with pride to athletes such as George Young, world class runner and a classmate of mine in Silver City, and Tommy McDonald, football player from Albuquerque and Jal's Kathy Whitworth, the best lady golfer in the world. I talk about Ed Mitchell who at least was born in New Mexico even if he did leave at an early age, and Harrison Schmitt, another one of my classmates in Silver City, both of whom are astronauts and after next December will both have walked on the moon.

In many, many ways New Mexico and New Mexicans are leaders in this Nation and in the world. We are not perfect by any means and we will never be perfect. But in many areas we are way ahead.

One of the places we are ahead is in the field of water and water law. Way back before this State was even a State, the Territorial Legislature wrote the laws which still largely govern our use and development of water. In 1931, ground water uses were made a part of our law.

At the present time New Mexico is continuing its leadership in water. We are developing a State Water Plan which will provide the guidelines for water use in the future.

This State Water Plan is being developed, as it should be, by professionals. Working under the leadership of the Interstate Stream Commission and the Bureau of Reclamation, numerous agencies and individuals are striving to assure our State it will have water in quantity and in quality in the future.

But this is not all. Our great State through the efforts of Drs. H. R. Stucky and John Clark and their associates at the Water Resources Research Institute have made it possible for the individual citizen of New Mexico to voice his opinions about water and the State Water Plan. The Citizens' Conferences on Water was their method of doing this. Once again, New Mexico is proven a leader.

Delegates to the State meeting were polled as to what they considered the ten most important water problems in New Mexico. Their answers were as follows:

1. Declining groundwater table and diminishing surface water supply;

* Rancher, Silver City, New Mexico

2. Need for improved irrigation systems and water-use management in irrigated agriculture;
3. Water pollution;
4. Need for knowledge of present and future supplies and demands of water;
5. Shortage of water for industrial, recreational and municipal uses;
6. Adjudication of water rights;
7. Improvement of water laws;
8. Salinity of water and its effect on human and plant life;
9. Reuse of water, where practical, by recycling; and
10. Land and water planning and zoning.

We also discussed a number of other topics. Some of these were: A continuous and orderly supply of water through the construction of adequate storage facilities; Flood control; Importation of water; Desalinization; Evaporation control; Improved methods of transporting water: Priorities of water use where supply is limited; Reducing seepage from tanks and reservoirs; Nonbeneficial uses; Need for public awareness of water problems; Need for continuity of programs within agencies and governmental bodies; and Need for more public participation in water resources planning and management.

We particularly discussed the matter of unlimited drilling for water by subdividers and/or those purchasing lots within subdivisions.

Steve Reynolds, State Engineer, and Rowland Fife, Area Engineer, Bureau of Reclamation, and many other state and federal officials discussed with us the State Water Plan and other matters. Likewise, several people from New Mexico State University reported on developments relating to water in their particular specialties.

There are three matters in relation to water use and the State Water Plan that were brought up at the Citizens' Conferences on Water that did not get heavy attention there but which are particularly appropriate to the theme of this Conference (Water in Land Use Planning).

I am speaking of preferential use of water for agriculture, population control and weather modification. These are areas in which New Mexico and New Mexicans are uniquely suited to once again be leaders.

I regret to report that the first of these Annual Water Conferences I attended shocked me, an agriculturist, to the very soles of my boots. The unofficial theme of that meeting seemed to be that agriculture is so nonproductive economically that it was a waste of water to grow crops or raise livestock. The industrialists pointed with pride to how many times they could recycle their water and how many people they gave employment to, and the recreationists assured us they didn't use up any water at all and their economic returns were therefore infinite.

Since that Conference, I have been to many other meetings in which it was pointed out that even as agriculture used by far the greatest amount of water, agriculture returned the fewest dollars per acre foot.

I concede these facts. There is no doubt that a larger proportion of this States's water must be and will be used for purposes other than agriculture. Also it is true that we agriculturists are perhaps wasting water.

But is it not also true that there are thousands of acres of land in this State whose best and possibly only use is agriculture and if we do not have the water to use them then where is the waste?

A continuing theme of many of the younger people in our country today is; "Economic return is not the only criteria." I do not claim to agree with everything these people propose but they are right when they say, "You cannot eat dollars."

Clearly the best use of any resource is multiple use whenever reasonably possible. Clearly the choice between human consumption and any other use of water is no choice at all. But ladies and gentlemen, where multiple use of water is not feasible and where the choice is not humans versus agriculture, the choice should normally be in favor of agriculture and it should be so written in our State Water Plan.

The State Water Plan should also carry guidelines to control the growth of population to that which the water available will support. This is true not only on a statewide but also on a local basis. No community or state should allow the introduction into its environs of businesses, subdivisions or whatever would produce demands upon its water supply greater than that supply can meet.

New Mexico because of its present population distribution and because of its small total population is uniquely qualified to lead this effort.

New Mexico is also uniquely qualified to lead efforts in the field of weather modification. Steve Reynolds, our State Engineer, when he was at New Mexico Tech in Socorro was one of the pioneers in rain making.

Senator Clinton Anderson of New Mexico was a leader in the establishment of water research in the United States. The Water Resources Research Institute here at New Mexico State was the first established under his bill. Researchers here at New Mexico State are making great progress in weather modification in northern New Mexico. New Mexico is highly qualified to lead in this field.

More than that, because of New Mexico's low rainfall and high evaporation rates we must lead in this field. Our eventual survival depends on it.

PANEL - CITIZENS' WATER CONFERENCES

John R. Hakanson*

I would like to thank Prof. Clark and Dr. Lansford for the invitation to speak to this fine audience. I feel rather insignificant in the fact that I am taking the place of a gentleman who is probably one of the leaders with the most expertise in regard to water importation for industrial use in the State of New Mexico. I understand that Mr. Foster very much wanted to be here but the call of his business dictated other arrangements. I hope that I can, at least, give you an idea of some of the points Mr. Foster might make, but with your complete understanding that they will be my words, modified by my thoughts.

In a time when mediocrity gains more coverage on a subject than the experts, when emotionalism far outweighs rational and cogent arguments, the land industry, like all industries, has come under fire from the irrational, self-denying populous, who either have made or inherited their fortunes and have no other outlets for their energy, or situated in a civil service job which suffers no repercussion from the free market system.

Joining these organized choirs of doom are many of the subsidized industries who do not have to compete in a supply-demand market. Yet, ironically enough, these are the industries that are doing the damage to the resources now that they accuse me of doing, hypothetically, 50 to 60 years from now.

Water, like any resource, gets values only through use. We find that water has its greatest value in heavy industry and its least dollar value in agriculture. This figure, however, is misleading in my opinion, since some of the water used in agriculture is also used in recreation, which places a high dollar value on water, consequently, giving us another factor for consideration.

In my opinion, one of the highest dollar values on water is residential consumption and corollary uses. Besides the dollar value, I believe that residential consumption also returns more water to the aquifers and ground water supply, and is reused beneficially at a later date. This means less depletion to this resource than from industry, recreation, or agriculture.

The uses of water, like all products, will be modified by the market place. Mr. Steve Reynolds, probably the foremost expert on water in New Mexico, stated in October 1970, "Judgement and our [State Engineers Office] experience thus far suggests that economics will effectively control this

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situation," referring to depletion of ground water. He further suggested that when the density of a subdivision reaches a certain level, the economics would dictate the purchase of existing water rights for community supply.

Considerable credence is given to this assertion of Mr. Reynolds by the action of individuals, pressure groups and politicians in our last legislature. An appeal was made for stifling State control of subdivision on the pretext of protecting the "Green Belt." This proposed legislation immediately created a market for water rights from farms where the entrepreneur was looking for a marketable "out," and had hopefully been granted it through Governmental legislation. This, then, was not protecting the "Green Belt" or anything else, but, in fact, doing just the opposite--in this case, giving the entrepreneur who was banking on land appreciation or its equivalent, in this instance water rights, the opportunity to enjoy the fruits of his labor and make an elusive profit on legislated appreciation. In Luna County, subdivision has been openly accused of depleting the water table. It is a contributing factor, but to say that the industry is the cause is to completely ignore the true facts.

In 1960, there were 37,000 acres of irrigated crop land. In 1970 there were 68,460 acres, nearly double in ten years. If all of the families that located in our subdivision used their 3 acre feet of water, that would only be .6 of 1% of the water being used on the increased acreage put in production in the last 10 years.

To blame subdivision for the drop in the water table is asinine. The increase in producible acreage in an arid region when thousands upon thousands of acres are taken out of production in water abundant areas at an extravagant cost to the American consumer and tax payer is also asinine. In this context, it is ridiculous to ask for local or State land use planning if land for agriculture is left unproductive in water abundant areas. To virtually throw tax money out the window in this fashion is another mistake. To massively support a Federal land use plan is imperative. After we move the Federal government off of its dead center no action bureaucracy, then we can make an effective land use policy state-wide, and, consequently, region or county-wide, which will and should include the complete inventory of our water resources.

Now the question comes to subdivision regulation--we need it. The industry says we need it. We need sound, sensible, workable legislation that will require full disclosure as required by the Federal Government without creating another State bureaucratic agency to waste the tax dollar. We need to have every county require that the property meets the requirements of the county, state and federal health agencies. But to have legislation that is stifling of an industry and ancillary industries, or that can tell a property owner, whether corporation or individual, what may or may not be done with his possession, strikes me as being alien to our culture and best interests. This is especially true in light of the fact that on March 2, 1972, the U.S. Senate passed the Housing and Urban Development Act of 1972 by a vote of 80 to 1. Much of this Act dealt with rural housing development.

Large land developers have to meet stringent Federal and State regulations now. The "rocking chair" subdivider does not. In Luna County there are 79 platted subdivisions of which 3 are the property of Select Western Lands Inc. Of these 79, only three are registered with the Federal Government, two of these belong to Select. As far as our records show, only two of the 79 are registered with the Consumer Division of the Attorney General's office of the State of New Mexico and only two are registered with other State agencies--both the property of Select Western Lands Inc.

Even in the light of these facts for Luna County, the Harpies of the irresponsible environmentalists will tell you that the legislation that was proposed in 1972 would stop unbridled subdivision. It, in fact, would only stop large land developments that are already restricted with meeting the requirements of HUD, New Mexico and other Governmental agencies.

We have chosen the free enterprise system to make the good life. If we do not let every person have the chance to take a chance, then we must restructure our complete system of society, economics and government. We must make a different set of priorities for future generations, but we cannot stand the irresponsible rhetoric of doom that causes unjust reaction. When the media and all concerned act with integrity instead of searching for the elusive freedoms, then the problem of water resources will be solved to the benefit of all segments of society.