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Proceedings of the Twenty-Seventh Annual New Mexico Water Conference

"Hope for the High Plains"

New Mexico Water Resources Research Institute

New Mexico State University ● Box 3167, Las Cruces, New Mexico 88003

Telephone (505) 646-4337

Water shortage so[…] sought at conferenc[e]

By Priscilla O'Connor
Asst. Managing Editor

The burden of finding soluti[…] water shortages in th[…] which affects Eastern […] on the shoulders of the […] according to federal o[…] the 27th annual New M[…] ference today.

Once solutions are in […] problem of funding i[…] underlying factor, agre[…] speakers at this morning's […] two-day event.

William Pearson, assis[…] planning for the U.S. Ar[…] Engineers, discussed the p[…] importing water from the M[…] Arkansas rivers to the ar[…] Ogallala aquifer which face w[…] tages.

Sitting on a panel which […] "The View from Here" were Ne[…] State Engineer Steve Reynol[…] Gen. Hugh G. Robinson, comma[…] the Southwest division of the U.S[…] Corps of Engineers, Garrey Carr[…] assistant secretary for Land and […] Resources for the Department […] terior; John Hernandez, deputy […] ministrator for the Environmental […] tection Agency; Harold Brayman, […] Senate Environmental and Public W[…] committee staff member; and Hoyt […] tison, New Mexico state representativ[e].

The initial cost of construction fo[…] water importation system, without […] distribution system, will be between $3[…] and $23.6 billion depending […] routes are […]

$226 and […]

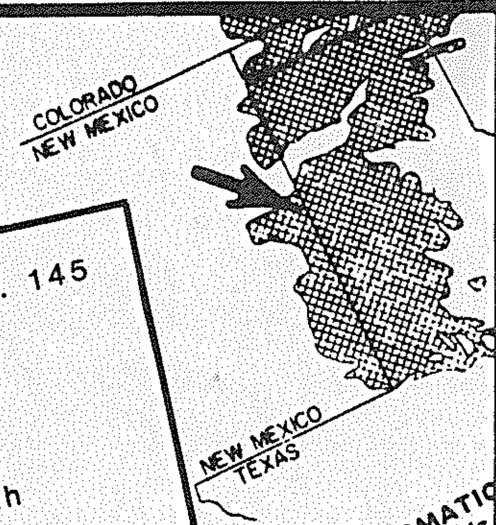
For water woes

Importe[…] no quic[…]

Harvey Banks, project director of the High Plains Water Study Commission, told the 27th annual Ogallala Water Conference today that importation of water for agricultural use is far in the future. Banks, who has headed the six-year $6 million study of underground water in the Ogallala Basin, told the members meeting in Clovis that the political implications would be formidable and that after these […] would take at […]

whether or not the state engineer could reduce the amount of ground water which could be used by a permit holder.

At the conclusion of Banks' presentation, Gerald Thomas, president of New Mexico State University, raised the question "how important is it to maintain the council?" Banks replied "If you want to do anything about it (the water supply) it is absolutley essential." Thomas asked for a show of hands to indicate whether the group present favored the […] mechanism



OGALLALA FORMATI[ON] […] Ogallala Formation, is […] ference scheduled at t[…] approximate location[…]

Water[…]

CLOVIS (AP) — […] ng the 27th annual N[…] Conference here hav[e] […]ution to retain the […]il to study water […]ight-state area se[…] a Aquifer.

The resolution […] the conference […]ruce King and […]ven other state[s] […]gallala Aquife[r] […]urce of irrigat[ion]

The Ogallala […]pic at the co[…]s year is "[…]ains."

Gerald W. […]w Mexico S[…]ference d[…]a would […]ges in the […]rces.

New Mexico

Ogallala Project Looks Doubtful

Federal and […] elected a […]

Oklahoma, western Kansas […] most of Nebraska. The aquifer has been deple[ted] […] quicker than it can be r[…] […]ials have said […] by the c[…]

HOPE FOR THE HIGH PLAINS

PROCEEDINGS OF THE TWENTY-SEVENTH

ANNUAL NEW MEXICO WATER CONFERENCE

New Mexico Water Resources Research Institute

New Mexico State University

Las Cruces, New Mexico

April 1-2, 1982

PREFACE

The 27th annual New Mexico Water Conference was held April 1-2, 1982, in Clovis, the heart of New Mexico's High Plains. The conference theme, "Hope for the High Plains," reflects the statewide concern over the decline of the Ogallala aquifer in this important agricultural region.

The portion of the Ogallala aquifer that lies beneath New Mexico has been an economic blessing for High Plains agriculture. Agricultural producers depend on this vast underground reservoir to irrigate crops that in 1980 were valued at $107 million. However, the aquifer decline threatens to destroy that economic base. The purpose of the conference was to address those problems and generate ideas for solving them.

The conference began with an overview of the recently completed High Plains Study. Congress commissioned the study in 1976 to investigate the extent of ground-water depletion of the Ogallala aquifer and its impacts on six High Plains states. Each conference session focused on aspects of the study that pertained to New Mexico. The panel then encompassed both views with local, state and federal officials discussing the political and economic problems of dealing with the complexities of an aquifer decline affecting six states.

Conference participants also adopted a resolution calling for continuation of the High Plains Study Council to help plan strategies for solving the water resources problems of the Ogallala aquifer region. The adoption of this resoultion refects the commitment of conference participants in seeking these solutions.

Special thanks goes to the speakers and participants who helped make the conference a productive forum for seeking answers to the problems of a declining water supply. The Water Conference Advisory Committee must be recognized also for the guidance essential to the continued success of the annual conferences.

Thomas G. Bahr
Director

Funds required for publication of the Proceedings were provided by registration fees, the United States Department of the Interior, Office of Water Research and Technology, and by state appropriations to the New Mexico Water Resources Research Institute.

RESOLUTION*

WHEREAS, the High Plains Study Council developed and has been actively engaged in the Six State High Plains-Ogallala Aquifer Area Study; and

WHEREAS, the High Plains Study Council represents a grass roots organization to define problems and possible solutions on a regional basis; and

WHEREAS, the need still exists and will become more critical in the future for implementation of the recommendations generated from the study; and

WHEREAS, the High Plains Study Council has developed the knowledge and expertise on the subject area and has established and maintained contacts with potential water supplying states for interbasin transfers; and

WHEREAS, the body of knowledge gained from the study must be maintained at a high visibility level on the state, regional and national scene;

NOW, THEREFORE BE IT RESOLVED, that the High Plains Study Council or comparable entity be maintained for the purpose of ensuring continuity in the planning process in order to assist in the solution of future problems for the Ogallala Aquifer region.

*This resolution has been sent to the governors of the six High Plains states.

27th Annual New Mexico Water Conference

"Hope for the High Plains"

April 1-2, 1982
Holiday Inn
Clovis, NM

Thursday, April 1

SESSION I: LAND OF THE UNDERGROUND RAIN

Moderator: Ralph Finkner, Superintendent, New Mexico State University Plains Branch Agricultural Experiment Station

8:00 - 9:00	Registration: Holiday Inn Lobby
9:00 - 9:15	Conference Opening - Thomas G. Bahr, Director, Water Resources Research Institute Invocation - Lt. Col. David Grosse, Chaplain, Cannon Air Force Base Welcome - Gerald W. Thomas, President, New Mexico State University
9:15 - 9:40	<u>An Overview of the High Plains Study</u> Harvey O. Banks, Project Director, High Plains Associates
9:40 - 9:55	Questions
9:55 - 10:15	Water Break
10:15 - 10:35	<u>Geohydrology of the Ogallala Aquifer</u> Edwin D. Gutentag, Hydrologist, U.S. Geological Survey
10:35 - 10:45	Questions
10:45 - 11:05	<u>The Ogallala in New Mexico</u> Sherman E. Galloway, Water Resources Engineering Specialist, New Mexico State Engineer Office
11:05 - 11:15	Questions

11:15 - 11:35	The Economic Front Robert R. Lansford, Agricultural Economist, NMSU
11:35 - 11:45	Questions
Noon	Luncheon: Holiday Inn

SESSION II: COPING WITH LESS ON THE HIGH PLAINS

Moderator: Wayne Cunningham, Agricultural Policy Analyst, New Mexico Department of Agriculture

1:30 - 2:00	Water Saving Techniques William M. Lyle, Agricultural Engineer, Texas A & M Agricultural Experiment Station
2:00 - 2:10	Questions
2:10 - 2:30	Irrigation Scheduling James R. Gilley, Agricultural Engineer, University of Nebraska
2:30 - 2:40	Questions
2:40 - 2:55	Pump Testing George H. Abernathy, Head, Agricultural Engineering, NMSU
2:55 - 3:15	High Plains Study Recommendations Questionnaire Noel R. Gollehon and B. J. Creel, Agricultural Economists, NMSU
3:15	Pump Test Equipment Demonstration Holiday Inn Patio
5:30	Social Hour: Cannon Air Force Base Officers' Club
6:30	Barbeque: Cannon AFB Officers' Club

Friday, April 2

SESSION III: DO SOMETHING!

Moderator: Hoyt Pattison, State Representative, New Mexico

8:30 - 8:50	<u>Bureau of Reclamation Water Projects</u> Darrell W. Webber, Regional Director, U.S. Bureau of Reclamation, Southwest Region
8:50 - 9:00	Questions
9:00 - 9:20	<u>Conservation Through Crops Research</u> Merle H. Niehaus, Head, Agronomy, NMSU
9:20 - 9:30	Questions
9:30 - 9:50	<u>Water Importation</u> William R. Pearson, Assistant Chief of Planning, U.S. Army Corps of Engineers
9:50 - 10:00	Questions
10:00 - 10:15	Water Break
10:15 - 10:30	<u>Questionnaire Results</u> Noel R. Gollehon and B. J. Creel, Agricultural Economists, NMSU
10:30 - Noon	<u>The View from Here</u> Panel Moderator: Don Frederick, Santa Fe Correspondent, El Paso Times Panel Members: • Harrison Schmitt, U.S. Senator, New Mexico • Hugh G. Robinson, Maj. Gen., Commander, Southwest Division, U.S. Army Corps of Engineers • Garrey Carruthers, Assistant Secretary for Land and Water Resources, Department of the Interior • John Hernandez, Deputy Administrator, Environmental Protection Agency • Harold Brayman, U.S. Senate Environmental and Public Works Committee Staff • Steve Reynolds, New Mexico State Engineer • Hoyt Pattison, State Representative, New Mexico

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William R. Pearson
Maj. Gen. Hugh G. Robinson
Gerald W. Thomas

SESSION I

MEET THE SPEAKERS
27th ANNUAL NEW MEXICO WATER CONFERENCE

SESSION I

Thomas G. Bahr is director of the New Mexico Water Resources Research Institute at NMSU. Before coming to New Mexico he was the director of the Institute of Water Research at Michigan State University. He has held some 17 regional, national and international appointments including the U.S coordinator for the U.S./Mexico Inter-American Conference on Salinity and Water Management. He holds degrees from Michigan State University and the University of Idaho.

Ralph Finkner is superintendent of the Plains Branch Agricultural Experiment Station and professor of agronomy at NMSU. He served as a consulting agronomist to the U.S. AID in Paraguay, Turkey and Egypt. For 13 years he held research positions with the American Crystal Sugar Co. including director of agricultural research. He is a member of several professional organizations including the American Society of Agronomy and the Crop Science Society of America. He holds degrees from Iowa State University and Colorado State University.

Gerald W. Thomas is president of New Mexico State University. He is a nationally recognized authority in agriculture, ecology and resource management. He has served as a consultant to the U.S. Department of Agriculture and has held assignments in Greece, Italy, Africa and South America. He recently returned from China where he headed a delegation that studied agricultural production and human nutrition in that country. He is the author of the book, "Progress and Change in the Agricultural Industry" and co-author of, "Food and Fiber for a Changing World." He was named Man of the Year in Service to Agriculture in 1981. He holds degrees from Texas A&M University and the University of Idaho.

Harvey O. Banks is president of the Water Research Division, Camp Dresser and McKee. His 47 years' experience in planning and resource management includes positions as the California State Engineer and 10 years as Director of California Water Resources. He is an honorary member of the American Society of Engineers and a member of the National Academy of Engineering. He has a B.S.C.E. from Syracuse University and a master's degree from Stanford University.

Edwin D. Gutentag is a hydrologist with the Water Resources Division of the U.S. Geological Survey. In 1960 he began conducting studies on the Ogallala and associated aquifers in Kansas where irrigation was being started. He was author or co-author of 24 reports during the 18-year assignment. In 1978 he transferred to Colorado to study the geohydrology of the High Plains aquifer for the High Plains Regional Aquifer-Systems Analysis. He has a master's and a bachelor's degree in geology.

Sherman E. Galloway is the water resources engineering specialist for the New Mexico State Engineer Office. With more than 30 years' experience in water resources, he has investigated areas such as the source, occurance and quantities of ground water available for development statewide. He is a registered professional engineer and is a member of the Association of Engineering Geologists and Sigma Gamma Epsilon. He holds degrees from the University of New Mexico.

Robert R. Lansford is professor of agricultural economics and agricultural business at NMSU. He was project coordinator for the New Mexico state-level research on the High Plains Ogallala Aquifer Study. He is a delegate to the Universities Council on Water Resources, an alternate to the High Plains Study Council and a member of the Great Plains Natural Resource Economics Committee and the Great Plains Council on Energy Committee. He holds degrees from the University of Minnesota and from NMSU.

CONFERENCE WELCOME

Dr. Gerald W. Thomas
President, New Mexico State University

Thank you very much, Tom. It's a special privilege for me to welcome this group to the 27th Annual Water Conference sponsored by our Water Resources Research Institute. I'm glad to see so many people out. This is a good crowd, but it's still not big enough because the topic is of utmost importance to every individual in New Mexico and particularly in the High Plains of New Mexico and Texas. I knew the room wouldn't hold them, but I had hoped we would have 500 or 1,000 or even 10,000 people here because we've put together a fantastic program on a topic of vital interest to everyone in this area of the United States.

I'm glad to be here myself because, as Tom mentioned, I started the year in the People's Republic of China with a team from Texas Tech, New Mexico State, and Colorado State. Dr. Merle Niehaus, head of our agronomy department, was also part of that team. As we looked at agriculture in China, we looked also at their water resources and the interaction between water, energy and land. All three resources are of vital concern to the people in that part of the world.

We particularly looked at irrigated agriculture because much of the hope for feeding the billion people in China rests on irrigated agriculture. We looked at one installation for irrigation that was constructed 2,400 years ago -- 2,400 years ago -- and is still in operation in China. If you think our challenges are great in this country, imagine the challenges in China as they try to feed a billion people on a total land area only slightly larger than that of the United States. Actually, the cultivated land area in China is considerably less than that of the United States.

Their dependence on irrigated agriculture and new technology is awesome. Awesome, to say the least. We learned that China had 17.5 million biodigesters, more than any other country in the world. Their technology in the utilization of wastes is far superior to our own. We have commercial alcohol plants and some experimental units utilizing grain as the major fuel source in the United States. But in China, biodigesters run primarily on pig manure since they produce more swine than any other country in the world. China cannot afford to use any food resources for the direct conversion to fuel. They must depend on waste. We could learn much from them, and I think we'll learn a lot more from them as time goes on. China, after all, has a per capita income of only about $300 per year and they are heavily dependent on the water base, the land base, and energy which comes primarily from the process of photosynthesis. They don't depend so much on depletable resources, although coal is heavily used in China. So, again we see the interrelationships between energy, land and water.

From China I returned to face the New Mexico legislature with a different kind of a challenge as we tried to defend our budget. We tried again to get more support for water resources research in the state of New Mexico. We were not successful. NMSU received a maintenance budget for our Water Resources Research Institute even though we know the federal government is withdrawing federal support for institutes in the various states.

After the legislative session, I went to Egypt where I spent a week reviewing our $47 million project. The goal for that project is to increase cereal grain production by 25 percent in a four-year period. That is a major challenge -- also related to land, water and energy. I met with the Minister of Agriculture for Egypt, and also the head of the National Academy of Sciences in Egypt. We talked about the agricultural program which is funded through USAID with matching monies from the country of Egypt. We also talked about a joint effort among New Mexico State University, Israel and Egypt on a water project to conserve the fresh water resource by diluting the fresh water with saline water. The people in Egypt also recognize the importance of water. The same kind of project we were unable to get funded in New Mexico, we may be able to support in Egypt through economic assistance that's directed toward trying to stabilize the political situation between Egypt and Israel. This research would help create a better and more stable economic situation in the Middle East. Research directed toward economic development and better utilization of the fresh water resource may have both direct and indirect benefits to this part of the nation as well.

And finally this week I was privileged to join Sen. Harrison Schmitt, Gov. King, and many others to observe the landing of the Space Shuttle at White Sands. The next morning I interacted with Gen. Nord as we outlined the many activities in which NMSU supports the space effort at White Sands -- working with NASA, the Army, the Air Force, and the Navy. Our university is tenth in the nation in national defense contracts. Just a couple weeks ago we delivered to White Sands a package called "HELDAPS," which is High Energy Laser Data Acquisition System. It is the most sophisticated computer program in the world for looking at the potential use for lasers.

So, it was an exciting week. Yesterday afternoon I flew to Artesia to review our agricultural research and meet with some people to talk about the challenging problems we're facing on the High Plains of New Mexico.

I welcome you here today because I think it's important that you look to the future with hope -- "Hope for the High Plains" -- as was so well brought out in the invocation this morning. The positive approach is the approach that we must take.

We are facing some real challenges in water research. We see the loss of federal funding. We see more dependence upon the state to pick up a bigger share of the responsibility for their own problems and to look at their own opportunities for the future. And, we see more dependence upon private industry. I think it is important that private industry now move in and accept a greater share of the research and development activities that traditionally have been covered by state and federal agencies.

We especially think this conference will be of significant benefit to the people in this region. When you look at the statistics on the New Mexico High Plains, the profile that's in your program, it reflects a situation worldwide. You'll find statements made such as this: "In the last decade, roughly 40 percent of all increases in food production worldwide has come from expanding irrigation and more effective use of water as a supplement to sporadic rainfall." The statistics are there. The handwriting is on the wall. The challenge has never been greater. It would be a grave mistake to ignore the statistics. But, it also would be a grave mistake to look at these data and not look to the opportunities and build on that base through the focus on "hope for the future." You and I will hear of our options in the next two days as we concentrate on the High Plains Study.

I have a proclamation from Gov. King I would like to read to this group. Gov. King, as you know, served as the chairman of the High Plains Governors' Committee last year for the six states in the High Plains Study. We're hoping we can keep that core of states together even though the funding for the High Plains Study is coming to an end. Harvey Banks will talk to you about that later. So I'll read this proclamation:

> WHEREAS, water is vital to all things living; and
>
> WHEREAS, as a continued source of good quality water is crucial to the citizens of the state of New Mexico; and
>
> WHEREAS, the state's High Plains is a valuable contributor to the well being of New Mexico; and
>
> WHEREAS, the 1982 New Mexico Water Conference focuses on water resources problems in the High Plains and seeks innovative ways to solve these problems;
>
> NOW, THEREFORE, I, BRUCE KING, Governor of the State of New Mexico, hereby proclaim the week of March 28 - April 2 as:
>
> "WATER FOR THE HIGH PLAINS WEEK"
>
> and urge all citizens to pay special recognition to this week and the significance of water to the State of New Mexico.

It's signed by Gov. Bruce King, and I would like for Ralph Finkner, who heads our local agricultural research center here to accept this on behalf of Gov. King. Thank you all for coming to this annual water conference.

SIX-STATE HIGH PLAINS-OGALLALA AQUIFER REGIONAL RESOURCES STUDY AN OVERVIEW

Harvey O. Banks, Study Director
President, Water Resources Division
Camp Dresser & McKee Inc.

INTRODUCTION

The purpose of this overview of the Six-State High Plains-Ogallala Aquifer Regional Resources Study, now drawing to a close, is to serve as background for the papers and discussion to follow. The history of the study, its objectives, how and by whom it has been conducted, the current status and what remains to be done will be discussed. Economic results will not be presented; this is left to the others who will follow. The policy issues to be resolved by the High Plains interests, the states and the Congress and the legal/institutional change that might be required for effective actions will be presented.

LEGISLATION

The Congress, concerned over the declining water levels in the Ogallala Aquifer, the decreasing oil and gas resources, the potential effects on the state, regional and national economies, and on national food supplies, authorized the study by Public Law 94-587, Sec. 193, in October 1976. Six million dollars were authorized and subsequently appropriated for the study. The full text of Sec. 193 is on page 25.

THE HIGH PLAINS REGION

The region encompassed by the Six-State High Plains-Ogallala Aquifer Regional Resources Study as shown in Figure 1 (p. 10) comprises some 180 counties. This area of about 220,000 square miles, wholly or partly overlying the Ogallala Aquifer, is the principal source of water supply for irrigation and other uses. Counties formed the areal base for the study since most economic data are available by counties. The aquifer extends from the High Plains area of west Texas and eastern New Mexico, north under the panhandle area of Oklahoma, western Kansas and eastern Colorado, and the central and western parts of Nebraska. It extends north into South Dakota and northwest into Wyoming, but these extensions were not included in the authorizing legislation.

The region is one of the most heavily irrigated areas in the United States, comprising some 20 percent of the national total. About 40 percent of the fed beef for American consumers is fattened within the region from the grain grown there. Rapid expansion of irrigation began after World War II and will expand further in those areas where ground water continues to remain available within economic pumping limits. About 16 million acres are currently under irrigation out of a total of 35-40 million potential irrigable acres.

The region has been and still is an important source of oil and gas, a significant sector of the regional economy.

The Ogallala Aquifer is one of the most extensive and important interstate aquifers in the country. It varies widely in hydrologic and hydraulic characteristics, amount of recharge, lateral extent and depth, and remaining saturated thickness. It is severely overdrawn. The overdraft is increasing as irrigation expands. The degree of overdraft also varies widely being much less in Nebraska than in west Texas and eastern New Mexico. The aquifer is now subject to planned management only to a very limited degree.

For purposes of the study, the region has been subdivided into 21 subregions, each having approximately similar soils, climate, water resource availability and economic characteristics. Study results have been aggregated by each state, by north (Colorado, Kansas and Nebraska) and south (New Mexico, Oklahoma and Texas) subregions, and for the entire region.

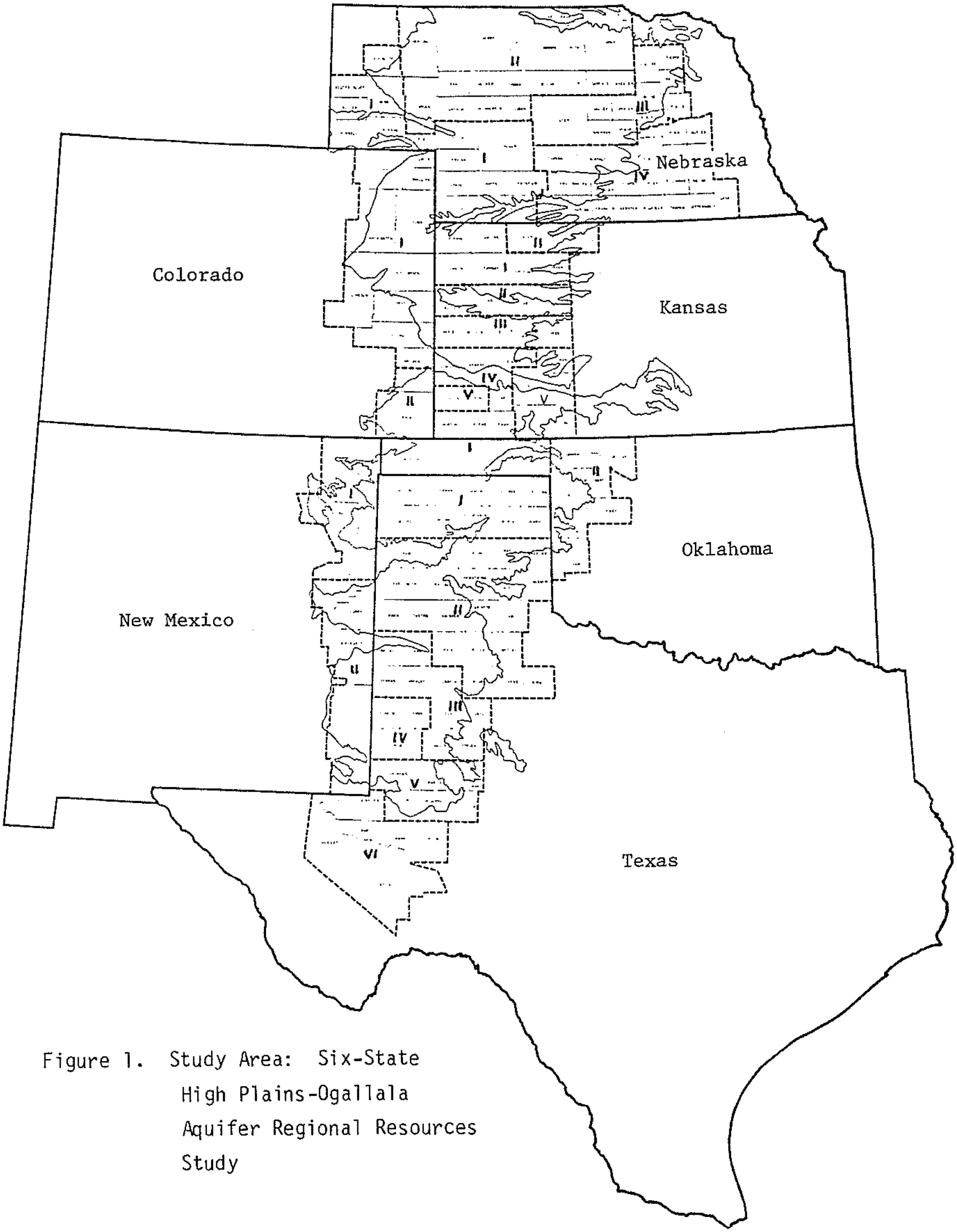

Figure 1. Study Area: Six-State High Plains-Ogallala Aquifer Regional Resources Study

STUDY ORGANIZATION

The U.S. Department of Commerce, Economic Development Administration (EDA), is the responsible federal agency. The study has been directed by the High Plains Study Council, composed of the governor of each of the six states and three interested citizens designated by the governor, and a representative of the EDA. The council was formed in 1977 at the insistence of the states after an initial plan of study, federally oriented, had been formulated by Resources for the Future under a contract with the EDA. The council then developed the plan of study which has been followed and will prepare the final conclusions and recommendations for submittal to the Secretary of Commerce and the Congress.

The regional study has been conducted for the EDA under a contract executed in September 1978 by the High Plains Associates, the general contractor. The consulting group is composed of:

Camp Dresser & McKee Inc. (CDM); Austin, Texas, the prime contractor
Arthur D. Little, Inc. (ADL); Cambridge, Mass.
Black & Veatch (B & V); Kansas City, Mo.

CDM has been responsible for the overall management of the study; the conservation, water resource, environmental and legal/institutional aspects; and the final report to the High Plains Study Council and the EDA. ADL has conducted the agricultural, economic and social studies. B & V has been responsible for the energy studies. The role of the general contractor has been to develop and evaluate alternative action programs for the future of the High Plains region. The general contractor will not draw any conclusions or make any recommendations; that is the responsibility of the High Plains Study Council.

Each of the six states, under subcontract with CDM, has assembled relevant data for that state and has conducted research on the economic, environmental and social effects of various alternative courses of action in the state. Results of the state research have been used by the general contractor in the regional analysis and evaluations.

The U.S. Army Corps of Engineers, under separate contract with the EDA, has studied the possibilities of importing water -- sources, points of diversion, amounts, conveyance routings, storage and costs -- from adjacent areas, particularly the Missouri River, the Arkansas River and other streams in Arkansas.

The U.S. Geological Survey, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Department of Agriculture, and other federal agencies have cooperated in the study.

The general contractor has been advised by a consulting panel of 12 internationally recognized authorities in various aspects of the study. The study organization is shown in Figure 2.

The $6 million appropriated was allocated approximately as follows: general contractor, $3.2 million; High Plains Study Council and the states, $2.0 million; and the U.S. Army Corps of Engineers, $775,000.

STUDY ORGANIZATION

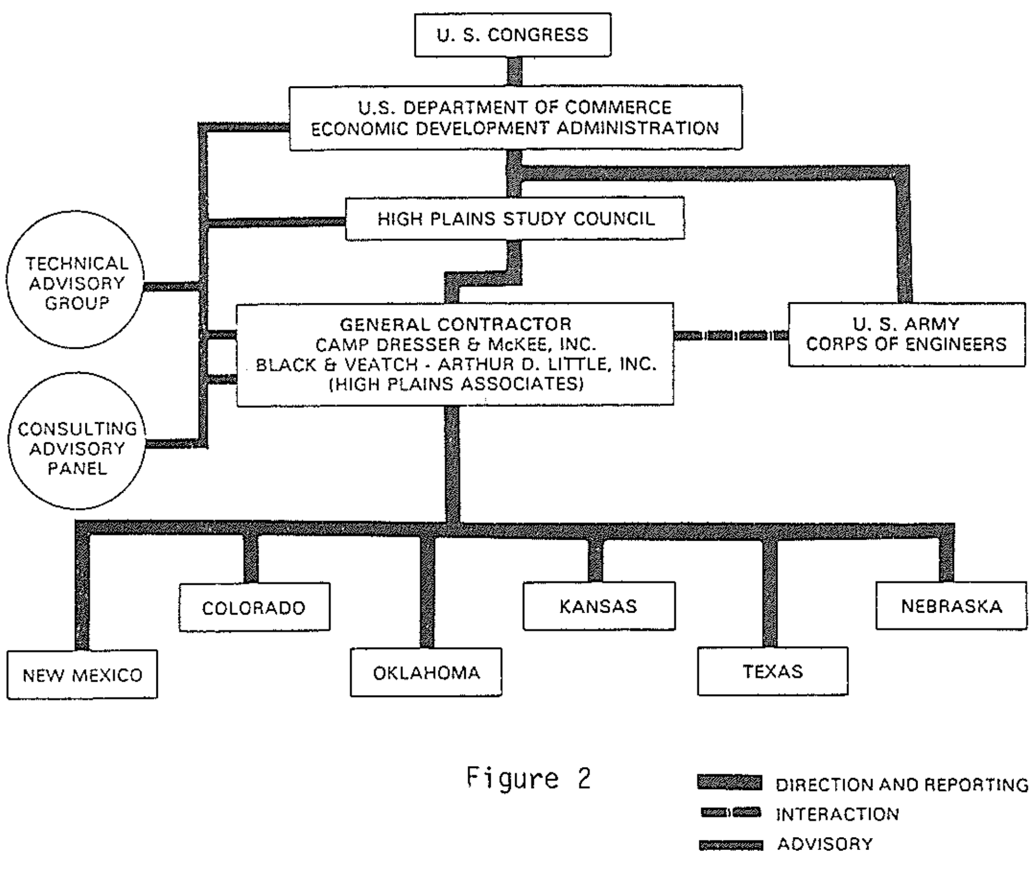

Figure 2

STUDY OBJECTIVES

P.L. 94-587, Sec. 193 (excerpted)

-- Assure adequate water supplies to the area,

-- assure an adequate supply of food to the nation,

-- promote economic vitality of the High Plains region,

-- develop plans to increase water supplies in the area, and

-- assure continued growth and vitality of the region.

High Plains Study Council

-- Determine potential development alternatives for the High Plains region,

-- identify and describe the policies and actions required to carry out promising development strategies, and

-- evaluate the local, state and national implications of these alternative development strategies.

STUDY PROGRAM

Water is the key resource involved in meeting the study objectives. Therefore, the study has been conducted by analyzing and evaluating the economic, environmental and social impacts on the states, the region and the nation, and the costs and the legal/institutional changes that would be required for implementation of alternative water resource management strategies. The future of the energy sector of the High Plains region and the potential for non-agricultural production economic development also have been evaluated.

The "base" year 1977 was selected because it was the last year for which economic and hydrologic data were available when the study was started. The study period extended to 2020 with projected results presented for 1985, 1990, 2000 and 2020. All projected monetary results are presented in terms of 1977 dollars.

The water management strategies analyzed in the study are:

-- A "baseline" trend projection of currently available water conservation and use technology and practices already in use to some extent, with no new purposeful public policy to intervene with action programs for altering the course of irrigation water consumption (Baseline).

-- A strategy which would stimulate voluntary action to reduce water demands through research, education, demonstration programs and incentives, using technology and practices either not considered in the Baseline analysis or reflected at rates which would be purposefully accelerated (Management Strategy One).

-- A strategy which assumes Strategy One policies and programs, and in addition projects further water demand reduction by mandatory programs of a regulatory nature to control water use (Management Strategy Two).

-- A strategy to add local water supply augmentation actions to demand reduction efforts. These actions could include local practices such as cloud-seeding, local storage, ground water recharge, desalination, and snowpack and vegetation management (Management Strategy Three).

-- A strategy of intrastate surface water interbasin transfers, importing water into the High Plains region in accordance with state water plans of the six High Plains states (Management Strategy Four). The opportunities for such interbasin transfers in New Mexico are limited and such plans are not being considered. Only Nebraska and Oklahoma have considered plans for potential intrastate interbasin transfers.

-- A strategy of interstate surface water transfers, importing surplus water from sources in areas adjacent to the Ogallala region by means of large-scale federal-state or federal projects to restore and maintain irrigation of the acreage that would have reverted to dryland farming by 2020 under Strategy One or Two (Management Strategy Five). Such a transfer could not possibly be operational before 2000. It is important to note that in making its studies of interbasin diversion, the U.S. Army Corps of

Engineers has not made a determination that there would be surplus water available for such imports from any of the sources considered.

For each water management strategy, state-level linear programming (LP) models were used to project crop production, irrigated and dryland crop acreages, value of agricultural production, returns to land and management (plus returns to imported water for Strategy Five), and ground water use and ground water remaining in storage, each for 1985, 1990, 2000 and 2020. State and regional input/output (I/O) models were then used to project industry sector activities, sector employment, total value added, total household income, and state and local tax revenues, each related to the LP projections for the future years.

A special feature of the regional I/O model was its division of outputs by northern (Nebraska, Kansas and Colorado) and southern (Oklahoma, New Mexico and Texas) subregions so as to highlight the probable difference in conditions in the future for these parts of the study region. Projections of energy production, economic effects and prices were incorporated into the LP and I/O models.

Projected trends in energy production and availability are important factors in the regional economy. These projections, however, do not indicate significant differences among the effects for the several water management strategies although a major interstate water diversion project under Strategy Five would impose very large energy production and use requirements. Over the study period to 2020, the decline in crude oil and marketed natural gas production is projected to continue. By 2020, these production levels are projected to be approximately 1/10 the levels at the beginning of the study period. Electricity production, however, is projected to increase, both in installed generating capacity and electric energy production, by approximately threefold over the study period. Some increase is projected in water consumption associated with energy production.

The projected results of each strategy were compared to those projected for the "baseline" condition.

It is emphasized that this has been a comprehensive regional resources study. It is not limited to water resources although that aspect has been given major emphasis since water could be the limiting resource over the long term.

Research Conducted by the States

A-1 State Agriculture and Farm Level Research. Project cropping patterns; agricultural output and output value; inputs and input costs; agricultural employment and income.

A-2 Energy Industry Impacts. Project energy production; energy requirements for irrigation; employment; royalties and other income from energy industry; and water requirements.

A-3 State Water Resources Evaluation and Impacts Research.

A-3a. Evaluate intrastate water resource situation; project intrastate water supplies and demands under alternative management strategies.

A-3b. Project economic adjustments and socioeconomic and environmental impacts at the subregional and state level resulting from changes in land use and changes in supply and uses of water, energy and other sources under each alternative development strategy.

Results of the state research have been used by the general contractor in the regional and national analyses.

Regional Research by the General Contractor

The regional research has assessed and evaluated:

B-1 Interbasin transfers -- in cooperation with U.S. Army Corps of Engineers.

B-2 National and regional changes in commodity prices, shifts in consumer expenditures.

B-3 Effects and costs of applying advanced agricultural and water management technologies to achieve more efficient use of water.

B-4 Environmental impacts.

B-5 Technologies for augmenting locally available water supplies and costs.

B-6 Legal and institutional framework for implementing alternative development strategies.

B-7 Crop price projections, analyses of total revenue and costs for a wide range of commodity and livestock enterprise situations.

B-8 Energy price and technology.

B-9 Impacts of transition to dryland farming.

B-10 Regional potential for non-agricultural production economic development.

B-11 Evaluation of alternative development strategies.

Evaluations of alternative strategies are being reported to the High Plains Study Council for consideration and recommendations to the Secretary of Commerce and the Congress.

LEGAL/INSTITUTIONAL ASPECTS

As noted at the beginning, the economic results of the study will not be presented here. However, the legal/institutional implications will not be covered by the other papers. Since these will be significant for the decisions that must be made on the future of the High Plains region, they are presented in Table 1.

POLICY ISSUES

During the course of the High Plains-Ogallala Aquifer Regional Resources Study, analyses have been made of the resource use alternatives available to the six states and to the nation in the face of depletion of the Ogallala Aquifer and the decline of oil and gas production and reserves.

The alternatives were considered with the recognition that some constraints might hinder their implementation. For example:

-- The Ogallala Aquifer has been intensively mined for irrigation since the years following World War II. Some areas such as in the southern High Plains of Texas are already either out of water or water levels have dropped below economically feasible pumping lifts.

Table 1: INTER-STRATEGY COMPARISONS - LEGAL/INSTITUTIONAL CONSIDERATIONS

STRATEGY	LEGAL/INSTITUTIONAL ASPECTS: LOCAL	STATE	FEDERAL
BASELINE	There is sufficient authority at the local government level in all of the states to carry out many of the voluntary and regulatory water demand reduction and supply augmentation measures now in place or projected for the Baseline.	Each of the six states have water and natural resource agencies to administer programs at state and local levels and provide local assistance to districts and farmers.	Many state resource agencies are now supported to some extent by federal agencies and programs, such as those of the Department of Agriculture and Interior in present ongoing Baseline efforts.
MS-1	Implementation of MS-1 would require little change or realignment of the institutions in the area at local level. Additional funding and staff required.	Implementation of MS-1 would require little change or realignment of the institutions at state government level. Authorization and funding for selected financial incentives required. Additional funding and staff necessary.	Federal agency authorities to support state and local efforts in water demand reduction would need some extension to carry out certain MS-1 programs. Additional funding and some additional staff needed, particularly for research.
MS-2	Some local political subdivisions would need added powers to promulgate rules and regulations, and to enforce restrictions on uses of water. Additional funding and staff might be needed.	Nebraska, New Mexico and Oklahoma appear to have adequate statutory authorities to control ground water use although there may be constitutional questions as to power to reduce use under existing permits. Colorado and Kansas statutes may require broadening. State level agencies in Texas have no statutory authority to control ground water use. Additional funding and staff required.	Enforcement of mandatory restrictions on ground water use would not be a federal responsibility.
MS-5A	Local management agencies would be needed with adequate powers to contract for, receive and distribute imported water, to finance, construct, operate and maintain local facilities, and to levy and collect water charges and taxes to pay local costs and to repay allocated reimbursable costs of import project.	State legislation would be needed to provide necessary authorization for local management agencies, to contract with exporting states for water, to participate with the federal government or with the other states and the federal government in a federal-interstate compact management commission to plan, finance, construct, manage, operate and maintain the import project, and to provide necessary funding for cost-sharing and other costs.	Congressional actions needed to authorize and fund planning and feasibility studies, to provide for participation with the states in a federal-interstate compact management commission, and to authorize and fund federal participation in the import project.
MS-5B	Same as MS-5A	Same as MS-5A	Same as MS-5A

-- The waters of the Missouri River system and the other streams being considered by the U.S. Army Corps of Engineers for interstate interbasin transfers to the High Plains region are already largely developed, mostly by federal projects, and committed. For these interstate streams, available storage has been committed for flood control, hydropower generation, navigation and local consumptive uses even where the water has not yet been fully developed and allocated.

-- Upstream and downstream states are developing state water plans to meet their potential water needs that will have major long-term impacts on the potential availability of water for diversion to the High Plains region.

Under these circumstances, certain public policy questions arise that will determine the mix of alternatives, including the option of no-action, to be implemented. These are not new questions -- they have been raised for many years in various contexts with respect to water and related resource management. Through the results of this study, however, their resolution within the context of the High Plains region may be possible. Experience in the region indicates that the questions to be answered cannot be related singularly to an alternative strategy. Rather, these questions relate to the choices to be made that will tailor alternatives and mixes of alternatives to the physical, social, economic, environmental and institutional conditions to local areas in the High Plains. This will shape the future of the High Plains region.

1. Major changes would occur in production of agricultural commodities (feed grains, food grains, cotton, etc.) as the result of transition in the High Plains from irrigated to dryland farming. Climatic variations make dryland less assured, year to year, than irrigated production. These changes and uncertainties would impact federal policies on agricultural commodity market stability, international trade and balance of payments, inflationary controls, support for agricultural prices and income, and related programs. These impacts would be the basis for considering implementation of all alternative strategies for

the region. Would these impacts justify federal intervention to assure continued levels of agricultural production? How could these impacts be considered quantitatively in analysis of the federal subsidy that probably would be required for interbasin transfers of water? There also would be adverse economic and social impacts on the states. Would state intervention be justified, and if so, in what manner?

2. Should promotion of, or a requirement for, conservation of water and energy in irrigation enterprises be a major federal objective and program? If so, could and should this be built into programs of the Department of the Interior, Environmental Protection Agency, Department of Agriculture, and the U.S. Army Corps of Engineers? Should such promotion include research and development aid to states and local districts, education incentives such as low interest loans, or a mix of these and others built into existing agency programs? What could be the mechanism for getting it underway? If a federal requirement, in what manner should it be implemented? Should it be a major state objective and program? What actions should the states and state agencies take? Should primary responsibility for enforcement of conservation measures be at the local water resources management agency level? If so, what statutory changes would be necessary including source of funds? This would vary among the states as Strategies One, Two, and Three are considered.

3. The economic study results indicate that mandatory water demand management (Management Strategy Two) through laws and regulations controlling the use of Ogallala water, would significantly extend the duration of availability of such water, but would result in decreased annual agricultural production and returns to land and management over the period to 2020. Would it be in the public interest to legally restrict current usage of the ground water with near-term economic detriment in order to prolong the availability of water for far future economic benefit?

4. Should investigation and planning of possible interstate interbasin transfers be continued? Should investigations and planning encompass the basins and states of origin? What institutional mechanism should be established for accomplishment? Should planning for an interstate transfer be integrated with planning for potential intrastate interbasin transfers?
5. Should further study be given to local water supply augmentation measures examined under Strategy Three such as desalting, direct use of brackish and saline waters, water harvesting, water banking, and other innovative approaches to augmentation of local water supplies for the region? By whom? What actions, if any, should the federal agencies and the states take to encourage augmentation of water supplies from local sources?
6. Although the High Plains Study preliminary results indicate that the overall regional irrigation economy could be maintained into the next century, projections of oil and gas reserves indicate that adverse declines would have occurred by that time unless significant new reserves are found. Depletion of the Ogallala by the end of the study period to 2020 would already have occurred in several intrastate subregions, with many other subregions going out of irrigation in the following decade or two. Experience with large-scale water diversions demonstrates that a long time period is needed for the necessary engineering, economic, financial, social and environmental planning and feasibility studies, and to achieve the political consensus required to move such projects to fruition. Is there a federal interest in making a participatory commitment now for that time frame in order to maintain the food and fiber production of the region? Assuming that federal interest, what federal-state mechanism could and should be established to provide continuity of leadership over such an extended time frame?
7. The present administration has emphasized reliance on the states as the responsible cornerstone for water resources planning and

management. It has effectively moved to abolish the Economic Development Act of 1965 Title V Regional Commissions, and the River Basin Commissions. In the case of the six-state High Plains region, action by an individual state could have little significant effect in implementing actions with regional consequences under any mix of alternative strategies. What would be the federal and state interests in:

-- Continuation of a multi-state regional entity such as the High Plains Study Council as a planning and policy body?
-- A new federal-state-local institutional mechanism, a compact or commission for example, for multi-state resource planning, development and management for the High Plains region by itself, or in combination with upstream and downstream states in basins of origin for possible interstate transfers? Would such a mechanism, including states of origin, be of value in gaining support for both intrastate and interstate developments?
-- A federal approach to planning and development for the High Plains region on a regionalized systems basis, including basins of origin?

8. In view of the increasing in-basin demands for consumptive and instream uses, and possible out-of-basin needs, for example the High Plains region, and the competition among the states and with federal reserved and Indian water rights, for the waters of interstate stream systems, should the Congress establish an institution for continued investigations and planning to advise the Congress, states and others as to the proper allocation and reallocation of interstate waters among states, areas and uses?
9. The gains resulting from any regional alternative approach, and in some cases even a subregional approach, to solution of water problems of the High Plains would not be distributed evenly among all those who might achieve some gain. What legal/institutional/financial mechanism(s) might be developed and implemented to achieve equitable distribution of costs and resultant obligation

for repayment? Creation of zones of benefit and variable pumping assessments have been used in similar instances elsewhere.

10. Non-agricultural economic development might alleviate to some extent the adverse impacts on the regional economy of a decline in irrigated agriculture and would have some positive actions for implementation. Should the states or local governments develop and carry out programs to stimulate non-agricultural development? Concentration of the labor force in a few centers might make the High Plains more attractive to industry. However, this would provide no relief for small farm towns where irrigated farming is declining. What tradeoffs are possible and acceptable?

11. Base flows in interstate and intrastate streams have been significantly reduced in the High Plains study area as pumping from the Ogallala has lowered ground water levels. Significant examples of this occur in the northern High Plains area in Nebraska and Kansas. This has had and will have increasing adverse impacts on availability of surface water for diversion for irrigation. This will result in increased costs and greater demands on the groundwater and the aquatic and riparian habitats. In the case of interstate streams, is there need for a mechanism for federal or state intervention or both, to prevent further reduction in base flows? Should the states take action and, if so, what?

12. As water levels in the Ogallala Aquifer continue to decline, and as surface application of pumped water is reduced because of economics, riparian wetland habitat will be increasingly impacted. The High Plains study area is a major flyway for migratory birds. Substantial federal law and policy have been established to protect water critical habitat. Is there a federal interest and appropriate role in intervening to minimize adverse impacts? Is there a state interest and appropriate role?

STUDY STATUS

The general contractor has completed a draft final report. It is now being printed and will be submitted to the High Plains Study Council about April 10, 1982. The next step is up to the council to prepare and submit its conclusions and recommendations to the Secretary of Commerce and the Congress.

The contract of the general contractor with the EDA under which the study has been conducted, terminated March 31, 1982. The council has requested an extension to September 30, 1982, in order to complete its work.

PUBLIC LAW 94-587--OCTOBER 22, 1976 (90 STAT. 2943)

Sec. 193. In order to assure an adequate supply of food to the Nation and to promote the economic vitality of the High Plains Region, the Secretary of Commerce (hereinafter referred to in this section as the "Secretary"), acting through the Economic Development Administration in cooperation with the Secretary of the Army, acting through the Chief of Engineers, and appropriate Federal, State, and local agencies, and the private sector, is authorized and directed to study the depletion of the natural resources of those regions of the States of Colorado, Kansas, New Mexico, Oklahoma, Texas, and Nebraska presently utilizing the declining water resources of the Ogallala aquifer, and to develop plans to increase water supplies in the area and report thereon to Congress, together with any recommendations for further congressional action. In formulating these plans, the Secretary is directed to consider all past and ongoing studies, plans, and work on depleted water resources in the region, and to examine the feasibility of various alternatives to provide adequate water supplies in the area including, but not limited to, the transfer of water from adjacent areas, such portion to be conducted by the Chief of Engineers to assure the continued economic growth and vitality of the region. The Secretary shall report on the costs of reasonably available options, the benefits of various options, and the costs of inaction. If water transfer is found to be a part of a reasonable solution, the Secretary, as part of his study, shall include a recommended plan for allocating and distributing water in an equitable fashion, taking into account existing water rights and the needs for future growth of all affected areas. An interim report, with recommendations, shall be transmitted to the Congress no later than October 1, 1978, and a final report, with recommendations, shall be transmitted to Congress not later than July 1, 1980. A sum of $6,000,000 is authorized to be appropriated for the purposes of carrying out this section.

WATER RESOURCES OF THE HIGH PLAINS

Edwin D. Gutentag
Hydrologist, U.S. Geological Survey

Data for this talk was taken from the following U.S. Geological Survey Reports:

"Water table in the High Plains aquifer in 1978 in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming," by Edwin D. Gutentag and John B. Weeks, U.S. Geological Survey Hydrologic Investigations Atlas HA-642.

"Bedrock geology, altitude of base, and 1980 saturated thickness of the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming," by John B. Weeks and Edwin D. Gutentag, U.S. Geological Survey Hydrologic Investigations Atlas HA-648.

"Water-level and saturated-thickness changes, predevelopment to 1980, in the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming," by Richard R. Luckey, Edwin D. Gutentag, and John B. Weeks, U.S. Geological Survey Hydrologic Investigations Atlas HA-652.

THE WATER SUPPLY AND IRRIGATION DEVELOPMENT OF THE SOUTHERN HIGH PLAINS, NEW MEXICO

Sherman E. Galloway
Water Resource Engineering Specialist
New Mexico State Engineer Office
Roswell, New Mexico

INTRODUCTION

Like most of the southwestern United States, the Southern High Plains area of New Mexico has experienced a phenomenal rate of development since World War II. Hand in hand with this development has come an unprecedented demand for water. Foremost in this demand has been the need for additional water to supply the greater requirements of agriculture that have resulted from the transition from dry farming to irrigation farming that has occurred in this region during the past three decades.

The purpose of this paper is to review briefly the general conditions of ground-water occurrence and the growth of irrigation development in this area.

GEOGRAPHY

The Southern High Plains area of New Mexico occupies parts of Lea, Eddy, Chaves, Roosevelt, Curry, and Quay counties, and comprises the most westerly part of the Llano Estacado or Staked Plains. This in turn is a part of the High Plains Section of the Great Plains Physiographic Province and includes the Lea Plateau and those parts of the drainage basins of the Brazos and Red rivers of Texas that lie in New Mexico.

The Llano Estacado is a large, nearly flat plateau that occupies much of western Texas and eastern New Mexico. Characteristically, it is a grassy, treeless plain that is terminated to the north and west by erosion escarpments which face the valley of the Canadian River to the north and the valley of the Pecos River to the west. These escarpments are very bold and stand as steep faces that are cut by reentrants of short length. Except for a few localities where the edge is somewhat indefinite and marked only by a gradual slope, the escarpments reach heights of 100 to 400 feet.

In general the plain slopes gently to the east and southeast at a gradient of 10 to 15 feet per mile, and with few exceptions is remarkably smooth. The only irregularities in the topography are broad, shallow, nearly circular depressions that occur throughout the area and a few broad shallow valleys that are found for the most part in the northern part of the area.

The depressions range in size from some which are hardly discernable to those having diameters of 1 or 2 miles. In depth, they range from less than 1 foot to nearly 100 feet. In some localities, as a result of these depressions, short canyon-like stream channels have been formed by the headward erosion of drainage tributary to the depression.

In some parts of the area, notably the northern part, several valleys transverse the plain. In general these valleys are very shallow in relation to their width, and with the exception of some short ones on the edge which are tributary to the Pecos River drainage system, all follow the general slope of the plateau. Included among these are the Portales Valley and Blackwater, Running Water, and Frio draws, of which the Portales Valley is the most notable.

Sand dunes are found throughout the area, and several extensive areas of dune development exist that are worthy of mention. One strip of these dunes that is 2 to 5 miles in width lies between the Portales Valley and Blackwater Draw. It completely transverses the area and rises about 50 and 100 feet above Blackwater Draw and the Portales Valley, respectively. Other areas of dune development include a belt north of Blackwater Draw, a small area east of McDonald in Lea County, and large areas in southern Roosevelt County and northern Lea County.

Major centers of population within the area include Hobbs and Lovington in Lea County, Portales in Roosevelt County, and Clovis in Curry County. The major part of the income of the area is derived from stock grazing, irrigation farming, and oil production.

STRATIGRAPHY

Nearly all the Southern High Plains area of New Mexico is underlain by 25 to 500 feet of relatively unconsolidated sediments of Tertiary and Quaternary age. These consist chiefly of clay, sand and gravel that rest unconformably upon a thick sedimentary sequence of pre-Permian, Permian, Triassic and Cretaceous rocks. Triassic and Cretaceous rocks are exposed in the escarpments on the north and west sides of the Llano Estacado and locally in some of the deep arroyos and depressions of the region. Permian rocks are exposed in the valley of the Pecos River to the west.

Pre-Permian Rocks

Pre-Permian rocks are encountered only at relatively great depth throughout the region. These have little bearing on the water supply of the area, hence no further consideration will be given to them in this discussion.

Permian Series

Rocks of Permian age underlie all the Southern High Plains area. The uppermost strata of this series are chiefly brick-red shales and sandstones that are interbedded with gypsum, anhydrite and dolomitic limestone. Below these "red beds" is a thick section that consists chiefly of anhydrite which in turn is underlain by a thick salt series. Total thicknesses of Permian rocks in the area range from slightly less than 5,000 to slightly more than 5,500 feet.

The Permian rocks do not enter directly into the water-supply problems of the area, but when considered indirectly, they assume importance because of the role they have played in the development of the valley of the Pecos River to the west. The gradual removal of soluble strata, which comprise a major part of this series, from areas along and on either side of the Pecos River, over a period of many thousands of years, has been a major factor in the development of the present Pecos

Valley and the resulting complete isolation of the present Llano Estacado from contributory drainage from the mountains to the west.

Triassic System

Rocks of Triassic age in the Southern High Plains area have been assigned to the Dockum Group. They consist of as much as 1,400 feet of red shale and sandstone that rest unconformably upon the Permian Series.

The upper part of this series of rocks consists predominately of a thick shale sequence with minor amounts of sandstone that is unusually purplish-red in color. It attains a maximum thickness of about 1,200 feet. The interval between the base of this shale sequence and the top of the Permian Series is predominately sandstone and has been correlated with the Santa Rosa Sandstone of northern New Mexico.

Cretaceous System

The Cretaceous rocks of the region rest unconformably upon the Triassic "red beds." These rocks are usually present in the subsurface in extreme northern Lea County, and in southern and south-central Roosevelt County, but they are relatively rare throughout the remainder of the Southern High Plains area of New Mexico. Outcrops of these rocks are, in general, both poor and scattered, but when exposed they are seen to consist predominately of gray calcareous clay and sandstone with minor amounts of conglomerate and limestone, all of which change in character rapidly when traced laterally.

Logs of wells and seismic shot holes indicate a maximum thickness of about 125 feet for Cretaceous rocks in this region.

Tertiary System

The Ogallala Formation of late Tertiary age rests unconformably upon the rocks of the Cretaceous System and the Triassic "red beds," and is the principal formation exposed at the surface on the Southern High

Plains of New Mexico. This formation is composed of silt, sand, clay and gravel, and with the exception of the upper 10 to 40 feet, which is usually caliche, it is usually relatively unconsolidated. The upper caliche zone is particularly well exposed at the top of the escarpment on the north and west sides of the Llano Estacado where it is known as the "Caprock." Although the Ogallala Formation is lenticular and its lithology varies widely from place to place, sieve analyses of composite samples from test holes drilled in Lea County indicate that it is composed primarily of fine- to medium-grained sand. The basal part of this formation typically consists of very coarse sand and gravel that ranges from 5 to 20 feet in thickness.

The maximum known thickness of the Ogallala Formation in the Southern High Plains area of New Mexico is about 500 feet.

Quaternary System

Sediments deposited during Pleistocene and Recent times are found throughout the Southern High Plains area of New Mexico. Over much of this area these deposits are virtually inseparable from the underlying Ogallala Formation. In parts of Roosevelt and Curry Counties, however, these deposits assume great importance because of the bearing they have on the ground-water supply of the area.

Quaternary valley fill occurs to depths greater than 100 feet in the Portales Valley and consists of silt, sand and gravel, with the gravel usually being confined to the lowermost 5 to 10 feet of the deposit. The upper part of the valley fill consists of material ranging from silt to medium-sized sand. C. V. Theis, of the U.S. Geological Survey, on the basis of fossil evidence, has attributed these materials to a combination of lake and wind deposition. Logs of wells drilled in the vicinity of Running Water, Frio, and Tierra Blanca draws in Curry County further suggest that significant thicknesses of Quaternary valley fill may also underlie these draws.

Lake deposits are well exposed in the Big and Little Salt lakes in the Portales Valley, and notable occurrences of sand dunes are found on the north and south sides of the Portales Valley and Blackwater Draw, and in some areas of Lea County.

GEOLOGIC STRUCTURE

In general the rocks underlying the Southern High Plains of New Mexico dip gently to the east or east-southeast. This regional dip is interrupted by gentle folds, but these are noted only in the correlation of pre-Cenozoic rocks in the area. The overlying post-Mesozoic sediments apparently did not share in this deformation.

HYDROLOGY

There are no perennial streams on the New Mexico part of the Llano Estacado, and no contributing drainage, hence all of the water supply of the area must be derived from precipitation that falls on the area.

The major part of the precipitation comes during the summer, and typically occurs in the form of local thunder showers, which usually have a very irregular and spotty distribution. In general, annual precipitation decreases from about 18 inches to about 10 inches from north to south.

The rate of evaporation is relatively high throughout the year. During the summer there is in general a decrease in wind, but as the result of relatively high seasonal temperatures, the relative humidity is usually low, except during storms, and the air absorbs moisture readily. The fact that the wet season of the year coincides with the growing season is favorable for agriculture, but since it is also the season when potential evapotranspiration is greatest, it is certainly not favorable for ground-water recharge.

Well developed drainage systems are relatively rare on the New Mexico part of the Llano Estacado, and consist almost exclusively of Running Water, Frio, and Tierra Blanca draws in Curry County, Alamosa Creek in southwestern Quay County, Blackwater Draw in northern Roosevelt County, and two or three unnamed draws in southern Roosevelt County. During and following periods of heavy, sustained precipitation, flow may occur to varying degrees in all of these draws as well as in a few minor incipient draws that exist locally, but as a rule such flow diminishes rapidly due to infiltration and evaporation or drains into one of the numerous depressions in the land surface of the area.

This lack of well developed drainage systems is due to several factors: first, the slope of the surface of the Llano Estacado rarely exceeds 15 feet per mile and, secondly, the usual presence of a relatively well developed mat of vegetation, chiefly grass, tends to retard runoff and thereby protects the existing land surface from erosion. In addition, the usual patterns of precipitation are such that the ground ordinarily becomes relatively dry between periods of precipitation and therefore is usually capable of absorbing moisture readily. Consequently, it is only during periods of heavy sustained precipitation that there is any appreciable runoff.

Runoff that accumulates in the depressions in the land surface of the area is usually lost for the most part to evaporation rather than to seepage, due to the fact that a mantle of poorly permeable, extremely fine-grained sediment, that ranges from a few inches to several feet in thickness, is almost universally present within the perimeters of these natural catchment basins. As a result, the percentage of runoff which accumulates in depressions that becomes ground-water recharge is, for the most part, quite small.

C. V. Theis has presented evidence which indicates that the overall recharge to the ground-water supply of the region averages less than one-half inch per year.

Also to be recognized in considering the long term availability of ground water is the fact that the Llano Estacado extends eastward for 100 miles or more into Texas, and that ground water in amounts essentially equal to annual recharge in New Mexico, flows naturally across the state line into Texas each year.

SURFACE WATER AND SURFACE-WATER DEVELOPMENT

As previously noted, there are no perennial streams on the Southern Plains of New Mexico, hence there is little opportunity for the beneficial utilization of surface water. The only surface-water developments in the area are small retention works that impound runoff for stock, wildlife promulgation, and recreational purposes.

GROUND WATER AND GROUND-WATER DEVELOPMENT

The Southern High Plains of New Mexico, for purposes of discussing "Ground Water and Ground-Water Development," can be conveniently considered to consist of: (1) the Lea County Underground Water Basin, which includes all of central, and part of northern Lea County; (2) the Portales Underground Water Basin, which includes most of northeastern Roosevelt County and part of southwestern Curry County; (3) the Curry County area, which includes most of Curry County and parts of northern Roosevelt and southwestern Quay Counties; and (4) the Causey-Lingo area, in south-central Roosevelt County. The Lea County and Portales Basins are declared basins in which initiation of any new appropriation of ground water, or change in any existing right to appropriate ground water, requires prior approval by the State Engineer. The Curry County and Causey-Lingo areas, in contrast, have not been declared by the State Engineer.

Lea County Underground Water Basin

The Lea County Underground Water Basin, which was initially declared on August 21, 1931, and then extended to encompass additional areas to the south and west on October 1, 1952, occupies the southernmost sector of the Southern High Plains of New Mexico. It is bounded on the west and south sides by the escarpments of the Llano Estacado, and on the east by the Texas-New Mexico state line. Its northern boundary is roughly on an east-west line that might be projected across the Llano Estacado about 10 miles north of Tatum.

The geology and occurrence of ground water in the basin is rather simple. The Ogallala Formation outcrops on the surface over most of the area and is the principal water-bearing formation in the Basin. With only local exceptions, where erosional remnants of Cretaceous rocks existed prior to the deposition of the Ogallala Formation, it rests unconformably upon Triassic "red beds," which for all practical purposes form a barrier to the downward percolation of the ground water. The Cretaceous rocks contain water locally.

The depth to ground water in the basin ranges from about 20 to nearly 300 feet depending on where the well is located. In most of the irrigated area, however, water is obtained within 50 to 60 feet of the surface. The configuration of the water table is, in general, quite similar to the configuration of the land surface and slopes gently to the east-southeast.

The development of irrigation farming in Lea County had its beginning in the 1920s. By the end of 1929, 41 irrigation wells had been drilled. Of these, 17 had either been abandoned or were no longer in use, and 24 were still in use, although not every season. Development proceeded slowly until the end of 1946, at which time it was estimated that about 5,000 acres were being irrigated. The post-war years have brought a rapid increase in development and at the present time it is estimated that irrigation has been practiced on about 120,000 acres of land under rights to water that are recognized by the State Engineer. Approximately 55,000 acres of these lands are now fallow.

Present rates of water-level decline in wells in the Lea County Basin range from zero to slightly more than 2 feet per year. The average annual water-level decline in the vicinity of irrigated lands within the boundaries of this basin is slightly less than 1 foot.

A comparison of the calculated rate of annual flow of ground water from the Lea County Basin across the state line into Texas, under 1952 conditions, with a similarly calculated rate of flow, under 1976 conditions, shows an apparent net <u>decrease</u> in annual flow during this

24-year period of 2,200 acre-feet. Calculated annual rates of flow for the cited years across the subject reach of the state line are 34,260 acre-feet, and 32,040 acre-feet, respectively.

Portales Underground Water Basin

The Portales Underground Water Basin, which was initially declared on May 1, 1950, extended to encompass additional areas to the north, south and west on July 18, 1955, and then revised on November 3, 1955 to exclude part of the area encompassed by the extension of July 18, 1955, is located in northeastern Roosevelt County and southwestern Curry County, and occupies a part of the central portion of the Southern High Plains of New Mexico. The basin includes lands in Township 1 North, Ranges 30 through 37 East; Township 1 South, Ranges 31 through 37 East; Township 2 South, Ranges 32 through 37 East; and Township 3 South, Ranges 34 through 37 East.

Small quantities of water of relatively poor chemical quality are produced locally from the Triassic "red beds," and in some localities water may be derived from the Ogallala Formation or from Cretaceous rocks, but in general most of the water pumped in the area is shallow ground water that occurs in valley fill deposited by an ancient river, that was beheaded by the Pecos River in late Pleistocene time. Apparently this ancient river was a major stream that more or less followed the present course of the Pecos River above Fort Sumner and then continued east-southeastward across the plains, to the present course of the Double Mountain Fork of the Brazos River in Texas.

C. V. Theis, from his work in the area in the early 1930s, concluded that this valley must have had a topography similar to that of the present "Breaks in the Plains," with steep valley slopes facing a broad flat valley on either side, which was cut through the Ogallala Formation and into the underlying Cretaceous and Triassic rocks. He concluded that at least the lower part of the fill was the result of stream deposition, and he attributed the remainder of the fill to deposits of talus that resulted from waste and slump from the side slopes that the captured stream was unable to carry water. The accumulation of this talus and subsequent smoothing by local runoff and wind action have been postulated as the principal factors in the development of the present valley form.

In general, over most of the developed area the average depth to water is about 70 feet. Actual depths to ground water in the valley range from less than 10 feet to more than 170 feet depending on where the well is located. Depths to Triassic "red beds," which underly all of the area and form an effective barrier to the downward percolation of ground water, range from a few feet to slightly more than 300 feet.

Prior to 1910, many of the farmers in the area irrigated small tracts with water pumped by windmills and in a few cases centrifugal pumps powered by gasoline engines had been installed, but it was not until this date that large-scale irrigation was begun.

In 1910, the Portales Irrigation Company was organized by local irrigators who financed the project with mortgages on their irrigated land. An electric-power plant was constructed at Portales and 69 individual pumping plants were served in the present irrigated area. The electric-power plant had sufficient capacity to pump 30,000 acre-feet during the growing season and 10,000 acres were included in the project, but the capacity of the plant was never reached and the planned acreage was never irrigated. It is reported that an average of 4,000 acre-feet of water a year was pumped from 1910 to 1914.

The experiment was unsuccessful because of the lack of irrigation experience on the part of the people involved in the project. Attempts were made to irrigate too much land with one well, suitable crops were not ascertained, no markets were readily available for the produce, and a great deal of dissatisfaction developed among the people because of the restrictions that were imposed to distribute the load on the central power plant. As the result of these and other factors, the project failed and the electric-power plant was dismantled and sold during World War I.

In 1919, the pumping plants were too few to be reported separately by the U.S. Census. In about 1925, however, irrigation farming began to expand again in the area. Irrigation development grew slowly, and by

1929 the U.S. Census reported that 166 pumping plants were in operation and 4,823 acres were irrigated. About 300 irrigation wells were in use in 1931 and about 8,850 acres were under irrigation.

Irrigation development has grown from about 11,000 acres in 1938 to more than 110,000 acres at the present time.

Present rates of water-level decline in wells in the Portales Basin range from zero to more than 3.5 feet per year. The average annual water-level decline in the vicinity of irrigated lands within the boundaries of this basin is about 2 feet.

A comparison of the calculated rate of annual flow of ground water from the Portales Basin across the state line into Texas, under 1962 conditions, with a similarly calculated rate of flow, under 1972 conditions, shows an apparent net decrease in annual flow during this 10-year period of 2,990 acre-feet. Calculated annual rates of flow for the cited years across the subject reach of the state line are 11,270 acre-feet, and 8,280 acre-feet, respectively.

Curry County Area

The Curry County area includes most of Curry County and parts of northern Roosevelt and southwestern Quay counties. It is bounded on the north and west sides by the escarpments of the Llano Estacado, and on the east by the Texas-New Mexico state line. The southern boundary of the area follows roughly a line that might be drawn just north of, and parallel to Blackwater Draw from the Texas-New Mexico state line to the western escarpment of the Llano Estacado. The occurrence of ground water in this area is similar to its occurrence in the Lea County Underground Water Basin and with few exceptions all ground water pumped in the area is obtained from the Ogallala Formation. The saturated part of the Ogallala Formation in this area ranges from zero to slightly more than 200 feet in thickness and the best yields to wells are usually obtained from coarse sediments near the base of the formation. Depths to water in wells in this area range from less than 25 to more than 450 feet below the land surface with the depth to water in most wells being in excess of

250 feet. Pump discharges range from about 500 to nearly 1,000 gallons per minute.

The development of irrigation farming in the Curry County area began in the middle 1930s near the village of House in southwestern Quay County, and until the late 1940s was confined almost exclusively to the valley of Alamosa Creek in the vicinity of that community, where depths to pumping water levels in irrigation wells were ordinarily less than 50 feet. During the late 1940s and early 1950s, and particularly during 1953 and early 1954, however, numerous farmers drilled irrigation wells in southeastern Curry County, where pumping water levels were then, in most cases, in excess of 175 feet, and in some cases, in excess of 300 feet. An estimated 150 wells had been completed, and about 20 new wells were drilled per month in this area as of March 1954. Most of the acreage on which irrigation is now being practiced in the Curry County area was developed with water produced by wells drilled prior to 1960.

Recent cooperative surveys of irrigation in New Mexico by several federal and state agencies indicate that approximately 1,800 wells are now in existence in the Curry County area, and that the lands that have been irrigated with water produced by these wells total about 232,000 acres. During the past 10 years, however, drastic increases in pumping costs, arising in part from increased pumping lifts produced by declining water levels, and in part from rising fuel and/or power costs, have brought about a substantial reduction in the extent to which irrigaton continues to be practiced in this area. Many of the wells that were in use in the area as of the early 1970s now have either been abandoned or are simply no longer in use. Furthermore, many of the wells that are still in use are being pumped only to the extent necessary to sustain crops during extremely dry periods of the growing season.

Present rates of water-level decline in wells in the Curry County area range from zero to more than 6 feet per year. The average annual rate of water-level decline in the vicinity of irrigated lands in this area is about 3 feet.

A comparison of the calculated rate of annual flow of ground water from southeastern Curry County across the state line into Texas, under

1962 conditions, with a similarly calculated rate of flow, under 1972 conditions, shows an appaarent net <u>increase</u> in annual flow during this 10-year period of 6,500 acre-feet. Calculated annual rates of flow for the cited years across the subject reach of the state line are 38,230 acre-feet, and 44,730 acre-feet, respectively.

Causey-Lingo Area

The Causey-Lingo area consists of some 22,000 acres of irrigated land which are more or less confined within an area of less than 150 square miles in the vicinity of the communities of Causey and Lingo, and immediately adjacent to the Texas-New Mexico state line, in south-central Roosevelt County. Irrigation to supplement precipitation was begun on a small scale in this area in about 1945. Most of the wells in this area, however, have been drilled since 1954.

The principal water-bearing formation in the Causey-Lingo area is encountered below the base of the Ogallala Formation, and is composed of relatively unconsolidated sand and gravel of Cretaceous age, which occur for the most part in erosion channels cut into underlying Triassic "red beds."

Irrigation wells in the Causey-Lingo area range in depth from about 100 to about 275 feet and in yield from less than 100 to more than 1,000 gallons per minute. Known thicknesses of saturated material encountered by irrigation wells in the area range from 20 to 100 feet.

Present rates of water-level decline in wells in the Causey-Lingo area range from zero to more than 3 feet per year. The average annual water-level decline in the vicinity of irrigated lands in this area is about 1 foot.

Rates of annual flow of ground water from this area across the state line into Texas have not been calculated.

SUMMARY

Ground water provides the only dependable source of water supply in the Southern High Plains area of New Mexico, and as the result of extensive development of natural resources and irrigation farming during the past three decades, there is now an unprecedented demand for this important and necessary resource throughout the region.

To date, the principal areas of irrigation development have been confined to the Lea County Underground Water Basin in central and northern Lea County, the Portales Underground Water Basin in northeastern Roosevelt County and southwestern Curry County, the Curry County Area, and the Causey-Lingo area in south-central Roosevelt County.

While there are some slight differences in the occurrence of ground water in each of these areas, all are faced with the problem of having limited quantities of ground water in storage and annual withdrawal rates that are far in excess of annual recharge. Since ground water, in amounts essentially equal to annual recharge, flows naturally into Texas from each of these areas each year, it follows that most of the water now being pumped in all of these areas is being "mined" from transient storage. Under such conditions a reasonable approximation of the remaining life expectancy of large-scale irrigation at any particular locality in any of these areas can, in most instances, be obtained from:

$$LE = \frac{m_1 - m_2}{\Delta m}$$

where "LE" is the life expectancy of continued large-scale irrigation farming in years, "m_1" the present thickness of water-yielding materials in feet, "m_2" the thickness of water-yielding materials that will be needed to sustain future economic well yields in feet, and "Δm" the average annual water-level decline in feet.

Comparative analyses of historical changes in ground-water conditions in the vicinity of the Texas-New Mexico state line have shown, in general, that gradients on the regional water table have increased along this line. Further analyses of these data have shown, however, that the

magnitudes of these water-table-gradient increases, when considered in combination with the reductions of cross-sectional areas of the aquifers that occurred in consequence of regional water-level declines, were not sufficient to materially alter annual rates of ground-water movement across the state line.

Previously recited calculated rates of flow of ground water from New Mexico across the state line into Texas are as follows:

Lea County Underground Water Basin

1952 Flow Acre-Feet	1976 Flow Acre-Feet	Change in Flow Acre-Feet/Year
34,260	32,040	-2,220

Portales Underground Water Basin

1962 Flow Acre-Feet	1972 Flow Acre-Feet	Change in Flow Acre-Feet/Year
11,270	8,280	-2,990

Southeastern Curry County

1962 Flow Acre-Feet	1972 Flow Acre-Feet	Change in Flow Acre-Feet/Year
38,230	44,730	+6,500

It is quite interesting to note that the only listed area from which the annual flow of ground water increased across the state line into Texas, i.e., the Curry County area, is the only area of those listed that has not been designated as a declared underground water basin by the State Engineer.

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HIGH PLAINS-OGALLALA AQUIFER STUDY, NEW MEXICO -- ECONOMIC IMPACTS

Robert R. Lansford
Professor, Ag. Econ. and Ag. Business Department
New Mexico State University

INTRODUCTION

A large part of eastern New Mexico is situated in the High Plains, a somewhat homogeneous region extending over large areas of Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Texas (Figure 1). Discovery and subsequent exploitation of extensive groundwater resources in the region, primarily from the Ogallala Formation, has generated dramatic economic growth. This growth has exerted greater and greater demands on groundwater supplies, and water levels have declined and some irrigated areas have gone out of production. As a result, there is a threat to the economic activities in the area that are dependent on irrigated agriculture. If significant areas were to be forced out of irrigated production in the New Mexico High Plains, the economy of the entire state could be adversely affected. In response to these concerns, New Mexico participated with five other states and the High Plains Associates (general contractor) in the Six-State High Plains-Ogallala Aquifer Area Study.

The general purpose of this study was to estimate the economic impacts of several conditions over a 40-year planning horizon. The conditions are: irrigated and dryland cropping patterns, agricultural output, farm income, regional income and employment under alternative sets of assumptions regarding public policy, water and energy costs and availability, and irrigation management practices.

This article presents a brief summary of the on-farm and regional impacts for two sub-regions of the High Plains-Ogallala Aquifer region in New Mexico. The Southern High Plains sub-region included Lea County, Roosevelt County, Curry County, and the southwestern portion of Quay County. The Northern High Plains sub-region included the rest of Quay County, Union and Harding counties.

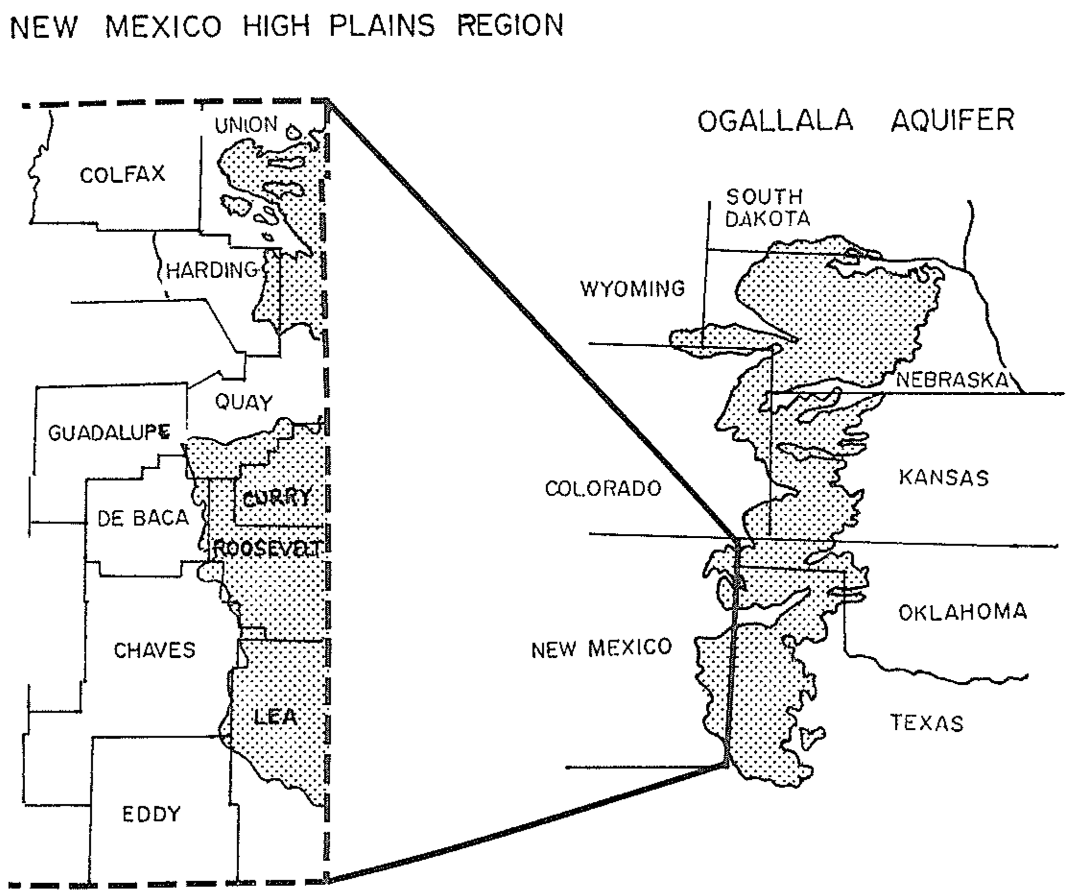


Figure 1. Ogallala Aquifer, Region and New Mexico.

METHODOLOGY

For the New Mexico agricultural production model, the methodology was to develop an aggregate linear programming (LP) model for the High Plains region of New Mexico. The LP model was designed to maximize returns to land and management from crop and livestock enterprises. The LP Model was structured in a diagonal cell framework which enables local conditions and resource requirements (cropping patterns, irrigation technology, etc.) to be met while the model maximized the regional returns. It included costs and returns budgets, a pumping cost model and hydrological data. The initial hydrologic data for 1977 were provided by the New Mexico State Engineer Office. The pumping costs model and hydrologic information also was designed to incorporate local conditions and resource utilization.

Assumptions concerning crop yields, commodity prices, energy prices and input prices were developed cooperatively between the six states and the general contractor. All states used basically the same assumptions for compatability.

An input/output (I/O) model was utilized to evaluate the regional economic impacts resulting from the alternative management strategies. A regional input-output table was developed for the High Plains region from a 1972 national I/O model (Young and Ritz, 1979). The 496-producing sectors national model was aggregated to 55-producing sectors using a location quotient technique. Information on the production functions for the agricultural sections were developed from the on-farm impact.

A second multi-regional socio-economic model developed by Shaul Ben-David and others (1980) generally referred to as the Southwest Water, Energy, Environment, and Population (SWEEP) model was used to project the regional gross total output, employment and population for the baseline and alternative management strategies.

RESULTS

Results are presented for the on-farm impacts by sub-region by management strategy for key resources, followed by regional economic impacts for selected years (1977, 1985, 1990, 2000 and 2020). Results are presented for the baseline and three alternative strategies -- voluntary water demand reduction, mandatory water supply reduction, and water supply augmentation for areas that physically exhaust its water supply.

Crop Acreages

Northern High Plains. Under all management strategies the total cropped acreage is expected to increase steadily over time by county (Figure 2) and strategy. The acreage irrigated in 2020 is expected to be the greatest under the voluntary strategy (127,740 acres) and lowest under the mandatory strategy (108,400 acres). The baseline strategy was estimated to have 155,854 acres irrigated in 2020. Under the baseline and the voluntary management strategy, no acreage is expected to transfer from irrigated to dryland. Under the mandatory strategy, transfers from irrigated acreage to dryland over the study period are expected to be about 19,400 acres, to meet the mandatory water reduction defined for this management strategy. There will be no imported water for the Northern High Plains because no irrigated areas are expected to go out of production due to aquifer exhaustion.

Southern High Plains. The projected acreage of irrigated cropland by county for baseline is presented in Figure 3. By the year 2020, no irrigated cropland is expected in Curry County, nor in the southwestern portion of Quay County. The acreage in Roosevelt will be drastically reduced to about 38 percent of the 1977 acreage by 2020, and no irrigated cropland is expected to be farmed after 2021.

Under all management strategies the total cropped acreage in the Southern High Plains varied only slightly. However, significant shifts from irrigated to dryland production are expected. The baseline strategy

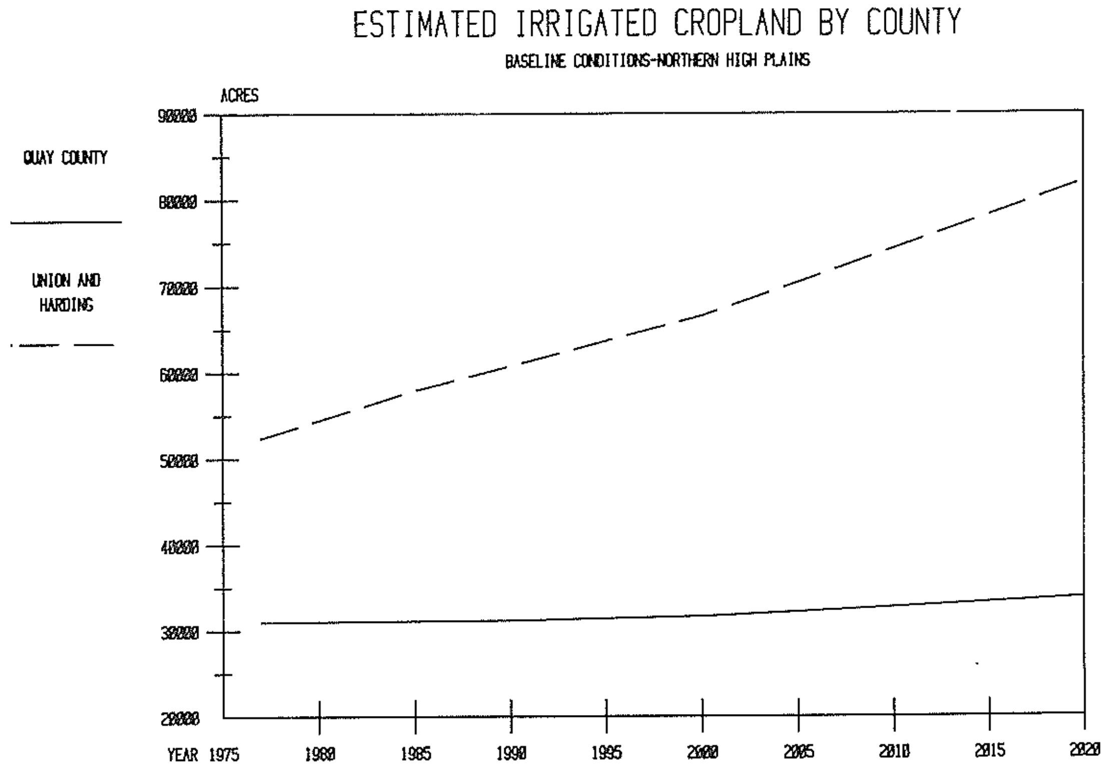


Figure 2

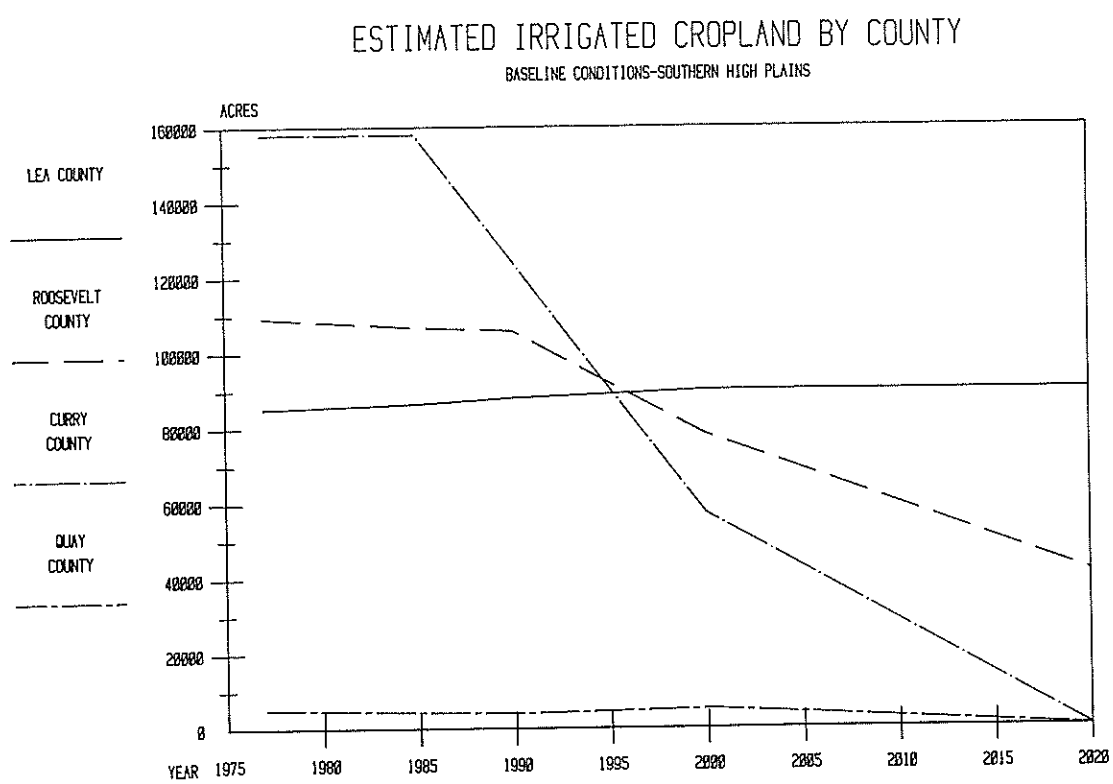


Figure 3

is expected to have the greatest acreage transfer from irrigated to dryland over the period 1977 through 2020. About 37,000 more acres are expected to remain in irrigation under the voluntary strategy than baseline in 2020 due to water conservation. Under the mandatory strategy about the same irrigated acreage as the baseline is expected through 2000, but by 2020 about 75,000 more irrigated acres are expected. The acreage irrigated is expected to be almost constant under the importation strategy, except for a decline in 1990 due to the exhaustion of the water supply in part of Curry County before the imported water becomes available in 2000 (Figure 4).

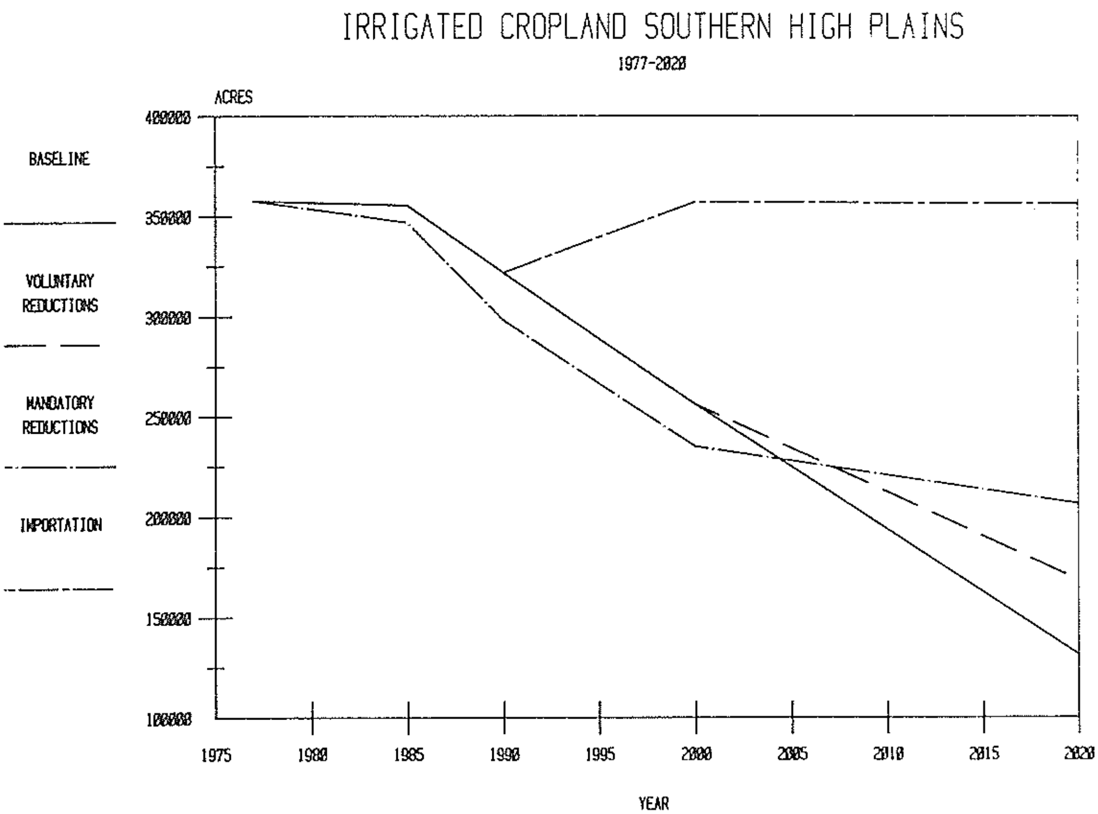


Figure 4

Cropping Pattern

Northern High Plains. Irrigated cropping patterns are affected less in the Northern High Plains than in the Southern High Plains because no area in the Northern High Plains is expected to run out of water. The acreages of corn and wheat are expected to be larger under the baseline, voluntary and importation strategies. Cotton acreage under all management strategies is expected to increase to 2000 then remain constant to 2020. Grain sorghum acreage basically is expected to decline and alfalfa acreage is expected to increase over the study period under all of the management strategies.

Of the dryland crops in the Northern High Plains, wheat and alfalfa follow a generally increasing trend while grain sorghum generally declines. However, there was a large shift from wheat to grain sorghum in 2000 and back to wheat in 2020. There was a slight decrease from baseline to the other management strategies in 2020 in range livestock. This was due to more land being converted from rangeland to irrigated cropland.

Southern High Plains. Generally, irrigated crops produced under the baseline and the voluntary strategy follow similar patterns -- irrigated feed grains and forage crops are expected to initially increase in acreage from 1977 to 1985 or 1990 before significant declines in acreage are expected to occur by 2020. Irrigated small grains and fiber crop acreages are expected generally to decline over time. The importation strategy follows similar patterns to the voluntary strategy until imported water becomes available. After importation, feed grains, forage crops and small grains tend to increase, while cotton tends to decline. Irrigated forage crops under the mandatory strategy are expected to initially increase in acreage in 1985, exhibit significant declines by 2000, then have a tremendous increase by 2020. The fiber crops acreage are expected to fluctuate a great deal, but in the end to be almost the same as they were in 1977. Feed grains and small grains are expected to follow a generally declining trend in acreage.

The dryland crops for all management strategies are expected to follow similar patterns. The dryland small grain acreage is expected to increase under all strategies, and significantly under some strategies. The dryland fiber crops are expected to increase in acreage slightly over time while the dryland feed grain crops are expected to have acreage declines over time. The acreage devoted to range livestock is not expected to change for the baseline, voluntary and importation strategies, but the acreage is expected to increase for the mandatory strategy.

Water Diversions

Northern High Plains. Under all management strategies except mandatory, significant increases in the quantity of irrigation water diversions are expected over the period of the study (Figure 5). Reductions are expected for the mandatory strategy because of the mandatory irrigation water application reductions.

The largest irrigation water diversions are expected to occur under baseline in 2020. They are expected to increase almost steadily from about 193,000 acre-feet in 1977 to 256,000 acre-feet in 2020. The diversions are expected to maintain about a 25/75 percent furrow/sprinkler relationship through 2000, but in 2020 they are expected to be more than 75 percent sprinkler.

Under the voluntary and importation strategies, decreases in water diversions are expected when compared to baseline. There is still an increasing trend in water applications from 1977 to 2020 similar to baseline. However, the flood/sprinkler relationship is expected to change (significantly less furrow irrigation).

The water applications per acre for all crops except pasture are expected to decline for all management strategies over time due to increasing field efficiency. The average water applications per acre are expected to decline 0.49 acre-foot per acre under the voluntary and importation strategies and 0.65 acre-foot per acre under the mandatory strategy due to mandatory supply controls. Despite the reduction in per acre applications the total water applications are expected to increase under the baseline, voluntary and importation strategies due to greater irrigated acreage.

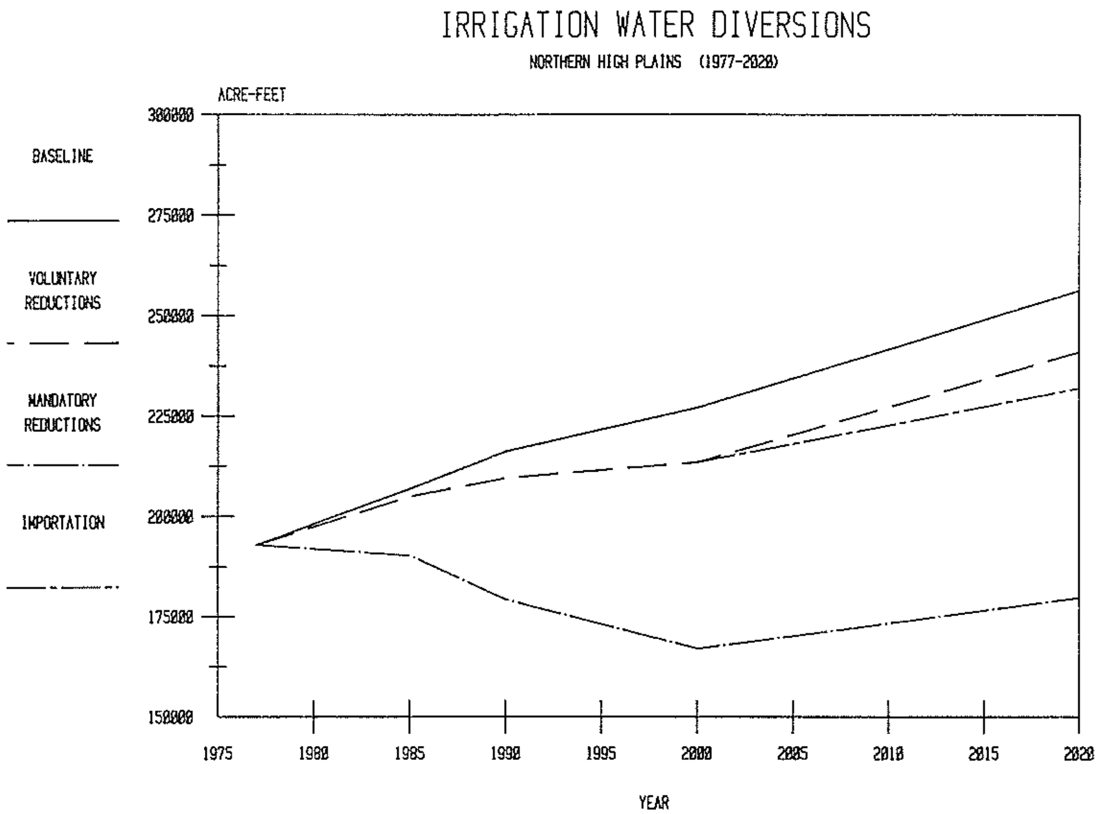


Figure 5

Southern High Plains. Significant reductions are expected in the quantity of irrigation water diversions over the period of the study due to aquifer exhaustion and increases in field irrigation efficiency for all management strategies (Figure 6). The greatest reductions are expected to occur in baseline, followed by the mandatory strategy. In 1985, diversions are expected to exceed 790,000 acre-feet under baseline and then decline to less than 300,000 acre-feet by 2020 due primarily to aquifer exhaustion. In addition to reduction in diversions, there are expected also to be significant changes in the furrow/sprinkler mix. The baseline water diversions maintained about a 50/50 furrow/sprinkler relationship through 2000, but by 2020 the water diversions are expected to be 100 percent sprinkler.

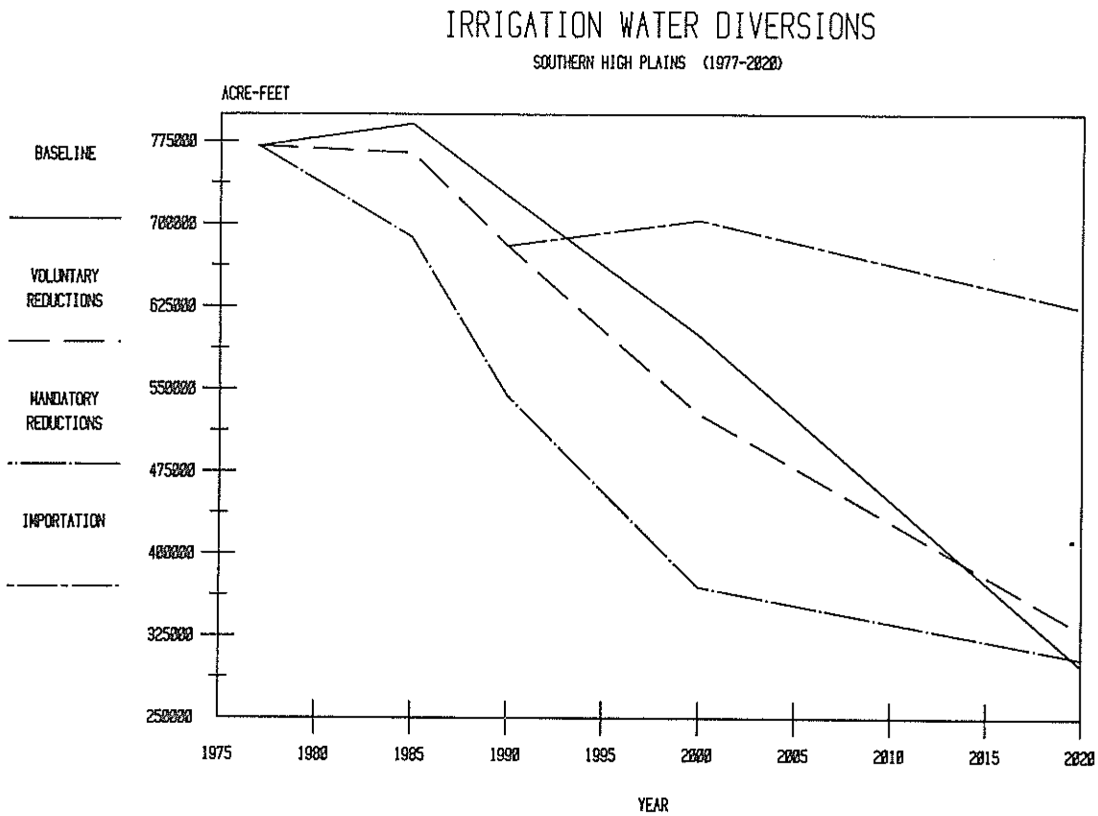


Figure 6

The annual water diversion for the voluntary strategy is expected to be lower than baseline except in 2020, where the diversions are expected to be about 32,000 acre-feet more than under baseline (Figure 6). This was also due to the availability of irrigation water in some areas where the aquifer is expected to be dewatered in baseline. In 2020, the voluntary strategy is expected to have more than 100,000 acre-feet of furrow irrigation due to the improved economic position of furrow relative to sprinkler irrigation.

The irrigation water diversions for the mandatory strategy are expected to be less than the voluntary strategy in all years.

Significant reductions in water diversions are expected under the mandatory strategy through 2000, but in 2020 the diversions are expected to be only about 26,000 acre-feet less than the voluntary strategy due to mandatory irrigation water diversion reductions. Furrow irrigation is also expected to be significantly reduced after 1977 to meet the mandatory water reductions.

The water applications per acre for all crops under all management strategies are expected to decline over the period from 1977 to 2020 due to increasing field efficiency. The greatest per acre water reduction over the study period is expected to occur under the mandatory strategy for all crops but wheat. Even though there was a constant decline in per acre water applications under baseline, the average per acre water applications are expected to increase due to a change in cropping pattern and increased irrigated acreage in some areas. Of the original nine irrigated areas, only three remain in production in 2020 under baseline. These three irrigated areas have a high percentage of alfalfa, corn and peanuts, all significant water-using crops. The average per acre water application for the alternative management strategies declines despite the influence of the high percentage of higher water-use crops. This was due to voluntary or mandatory conservation measures and the influence of some additional areas that remain in production. The average per acre water applications are expected to decline 9 percent under the voluntary, 32 percent under the mandatory, and 19 percent under the importation strategy.

As a part of the High Plains Study, the U.S. Army Corps of Engineers studied, at a reconnaisance level, four importation routes -- two from the Missouri River (routes A & B) and two from tributaries of the Mississippi River (routes C & D) (see William Pearson's presentation). The routes were sized to provide costs for a range of flows. Where possible, routes will be located to minimize environmental impacts.

Route D could provide water to New Mexico and parts of Texas and Oklahoma. Sources of water would be the White River at Clarendon, Ark.; the Arkansas River at Pine Bluff, Ark.; the Ouachita River at Camden, Ark.; the Red River at Fulton Ark.; the Sulphur River at Darden, Texas;

and the Sabine River at Tatum, Texas. These supplies then would route west and northwest across Texas into the panhandle of Texas to terminal storage west of Lubbock, Texas. This route would require a canal about 860 miles long and would have 30 pumping plants to lift the water 2,700 feet along the route.

The water diversions under the importation strategy are expected to be the same as those under the voluntary strategy through 1990. After imported water becomes available in 2000, the water diversions are expected to be significantly increased. The water diversions under the importation strategy in 2020 are expected to be about 300,000 acre-feet more than the voluntary strategy and over 330,000 acre-feet more than baseline. The diversions in 2000 are expected to be more than 50 percent furrow applied under the importation strategy, but by 2020 the diversions are expected to be more than 75 percent sprinkler applied.

Local water supply augmentation and intrastate water transfers will not furnish enough water to alter the time when irrigation goes out of production by more than a year or two.

Surplus water supplies available for interstate transport for the adjacent areas must be determined before any import scheme can be considered. If water supplies were available, a project of this magnitude would require many years to complete. Water from an interstate transport scheme probably would not be available to the High Plains until about 2020. Even if it is determined that surplus water could be brought to New Mexico's High Plains and that political, legal, environmental and other problems could be put to rest, it is unlikely that such a project could be completed in time to save much of the irrigated economy. As indicated below, much of the presently irrigated land in southern Quay, Curry and Roosevelt counties will have gone out of production by 2020.

	Year Irrigation Ceases		
County	Baseline	Voluntary	Mandatory
Union	2060	2060	2100
Harding	2063	2063	2108
Quay (House Area)	2010	2013	2016
Curry	2015	2017	2023
Roosevelt	2021	2027	2041
Lea	2085	2096	2114

Returns

Northern High Plains. The irrigated and total (irrigated, dryland and rangeland) value of production and returns to land and management for the Northern High Plains were calculated for each of the management strategies. The irrigated value of production for baseline is expected to maintain an increasing trend that continues through 2020 when the returns are 3.4 times the 1977 amount. The dryland value of production is expected to increase by 137 percent by 2020. The range livestock value of production is expected to increase by 28 percent. The irrigated returns to land and management are expected to increase from 1977 through 2020. The increase in returns from 1977 to 2020 are expected to be significant, about 835 percent. Dryland returns are expected also to show significant gains in returns over the study period. The dryland returns to land and management in 2020 are expected to be more than 6 times the returns in 1977. The rangeland returns are also expected to be up 44 percent. The total agricultural value of production and total agricultural returns to land and management follow almost identical trends as those for irrigation for all management strategies.

The voluntary strategy follows an almost identical pattern as the baseline except both the value of production and returns to land and management for irrigation are expected to be higher, and rangeland lower, due to more land being in irrigated production in each time period (Figure 7). By more land being retained in irrigation, there is a decrease in rangeland acreage.

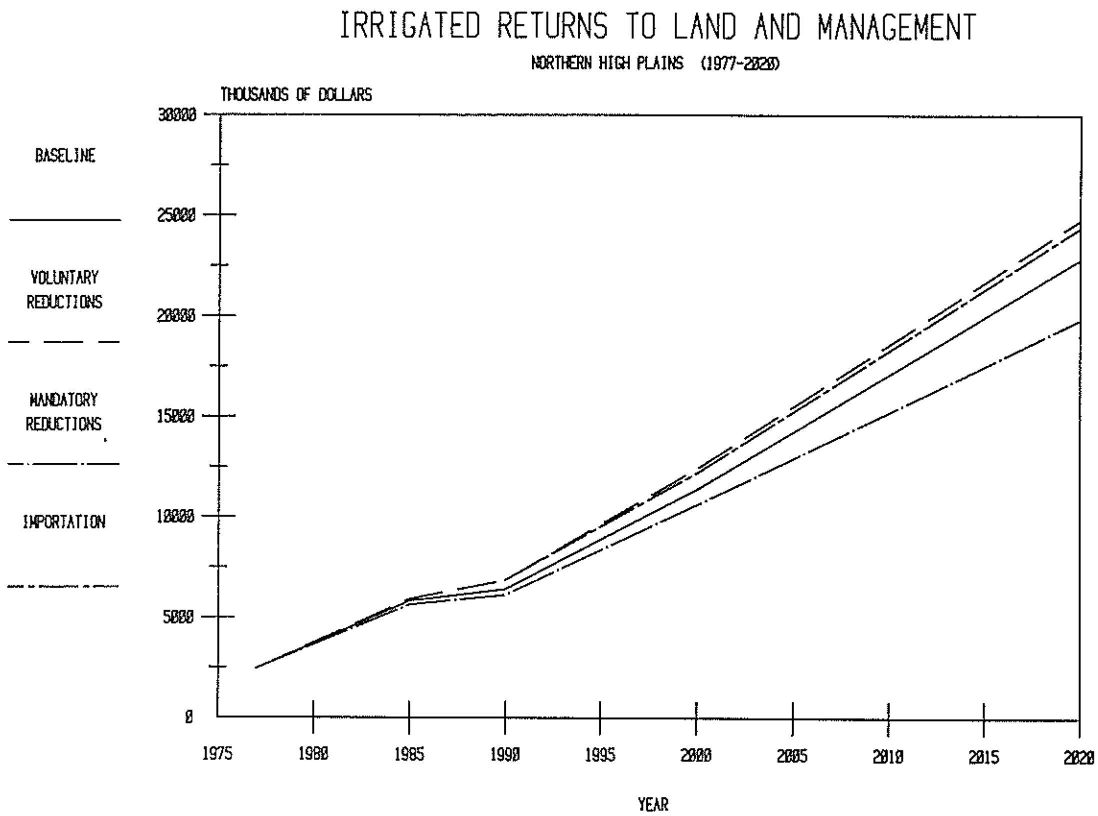


Figure 7

The irrigated value of production and returns to land and management under the mandatory strategy are expected to be less than the baseline or the voluntary strategy. This general reduction in both the value of production and returns is due to the changes in the cropping patterns, farm management techniques, and irrigation technology necessary to meet the mandatory water reductions.

Both the value of production and returns to land and management for dryland crop production were slightly greater under the mandatory strategy due to some areas converting to dryland from irrigation.

Southern High Plains. The irrigated and total value of production and returns to land and management for the Southern High Plains were calculated for each of the management strategies. The irrigated value of production for baseline is expected to peak in 1985, then begin a declining trend that continues through 2020, where it is expected to be only slightly less than the 1977 value. The dryland value of production is expected to increase by 268 percent by 2020. The range livestock value of production is expected to increase by a modest 28 percent over the study period. The total agricultural value of production is expected to increase to 2000, then decline slightly to 2020 due to irrigated cropland going out of production. Total agricultural returns to land and management are expected to increase over time. The irrigated returns to land and management are expected to increase from 1977 through 2000, but decrease in 2020 (Figure 8). The increase in returns from 1977 to 2020

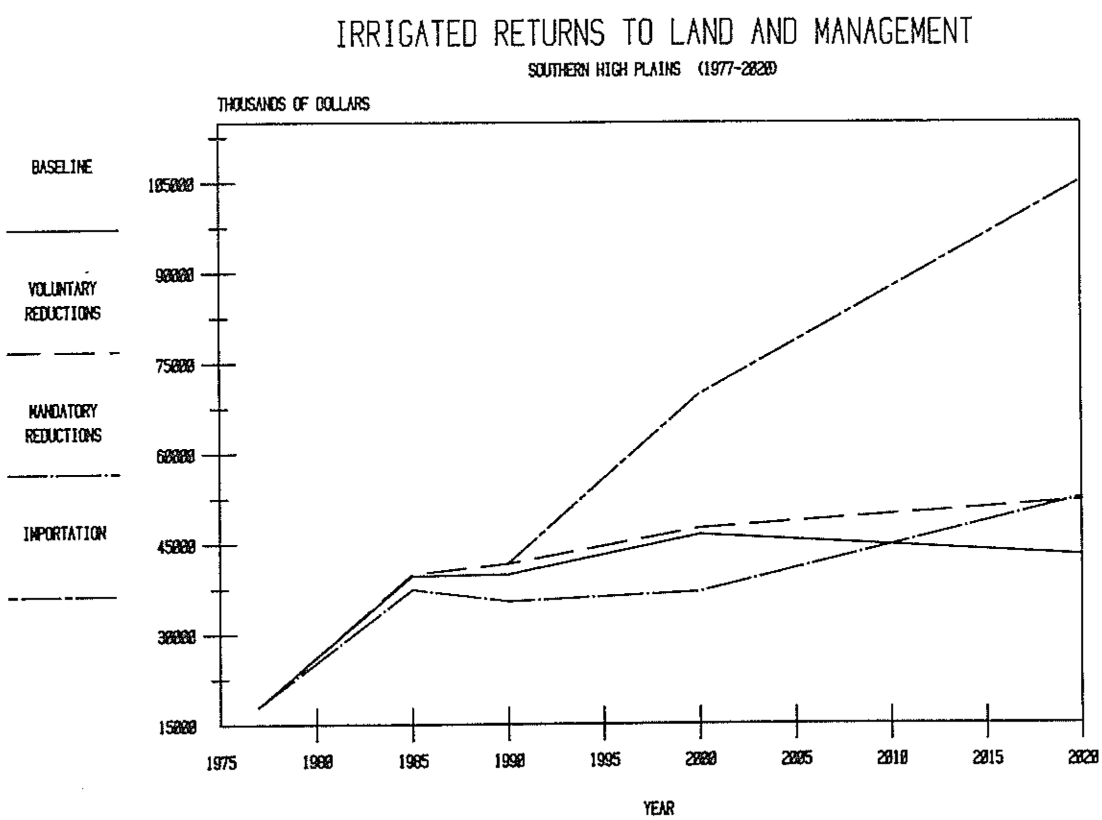


Figure 8

is expected to be about 140 percent, despite the decline from 2000 to 2020. Dryland returns are expected to show significant and increasing gains in net returns over the study period. The dryland returns to land and management in 2020 are expected to be more than 8 times the returns in 1977. The rangeland returns are expected to show a modest 44 percent gain over 1977.

The voluntary strategy follows an almost identical pattern as the baseline except in 2020 when both the value of production and returns to land and management for irrigation are expected to be higher, and dryland lower, due to more land being left in irrigated production.

The irrigated value of production under the mandatory strategy is expected to be less than baseline through 2000, but higher in 2020, since more irrigated land remains in production longer (about $24 million more than baseline and about $8 million more than the voluntary strategy). Even though the irrigated value of production is expected to be $8 million greater in 2020, the irrigated returns to land and management are expected to be about $275 million less than the voluntary strategy over the 40-year study period. This general reduction in both the value of production and returns in 1985, 1990 and 2000 under the mandatory strategy from baseline and the voluntary strategy is expected to be due to the changes in the cropping patterns, farm management techniques, and irrigation technology necessary to meet the mandatory water reduction. This indicates that it is expected to be more expensive to grow crops under the mandatory water reductions. Both the value of production and returns to land and management for dryland crop production were greater under the mandatory strategy. This was due to some areas converting to dryland from irrigation.

If the natural water supply in the Southern High Plains is augmented with imported water under the conditions of voluntary water demand reductions during the last half of the study period, it is expected there would be the least impacts on irrigated acreage, water diversions and on-farm employment. In addition, it is anticipated that this policy would result in by far the greatest increase in both total and irrigated returns in the latter part of the study period.

Under the importation strategy irrigated value of production and returns to land, management and water are expected to increase significantly in 2000 and 2020. This is expected to be due primarily to the importation of water that enabled previously irrigated areas that had been dewatered to restore irrigation. In addition to the acreage restored to irrigation, there is expected to be no water cost associated with the imported water which will further increase net returns. The irrigated value of production and returns to land, management and water are expected to be highest of any management strategy in 2000 and 2020 under the importation strategy. The importation strategy, therefore, provides for the greatest economic recovery.

Costs for Route D, as proposed by the U.S. Army Corps of Engineers, are expected to range from $320 to $370 per acre-foot. In addition to these costs, $200 to $400 per acre-foot would be needed to construct local distribution systems to deliver water from terminal storage to farm headgates. Farmers can only afford to pay about $150 per acre-foot.

	Ability to pay in 2020		
	(Acres)	($/Acre)	($/Ac-Ft)
Portales East	25,500	251.43	164.33
Curry County	157,900	231.78	151.49
Quay County (House Area)	5,000	43.68	21.31
TOTAL	188,400		
Weighted Average		$229.45	$149.77

The dryland value of production and net returns to land and management for the importation strategy for 2000 and 2020 were less than the other management strategies. This was due to the restoration of previously irrigated, presently dryland, acreage back into irrigation with imported water. The value of production and returns to range for the importation strategy were the same as the voluntary strategy.

REGIONAL ECONOMIC IMPACTS

Gross Output

The gross output for baseline by major sector and year is presented in Figure 9. The total gross output was about $2,384 million in 1977; and is expected to be $3,852 million in 1985 (an increase of about 62 percent); $3,674 million in 1990 (5 percent decrease); $2,817 million in 2000 (23 percent decrease); and $2,704 million in 2020 (4 percent decrease).

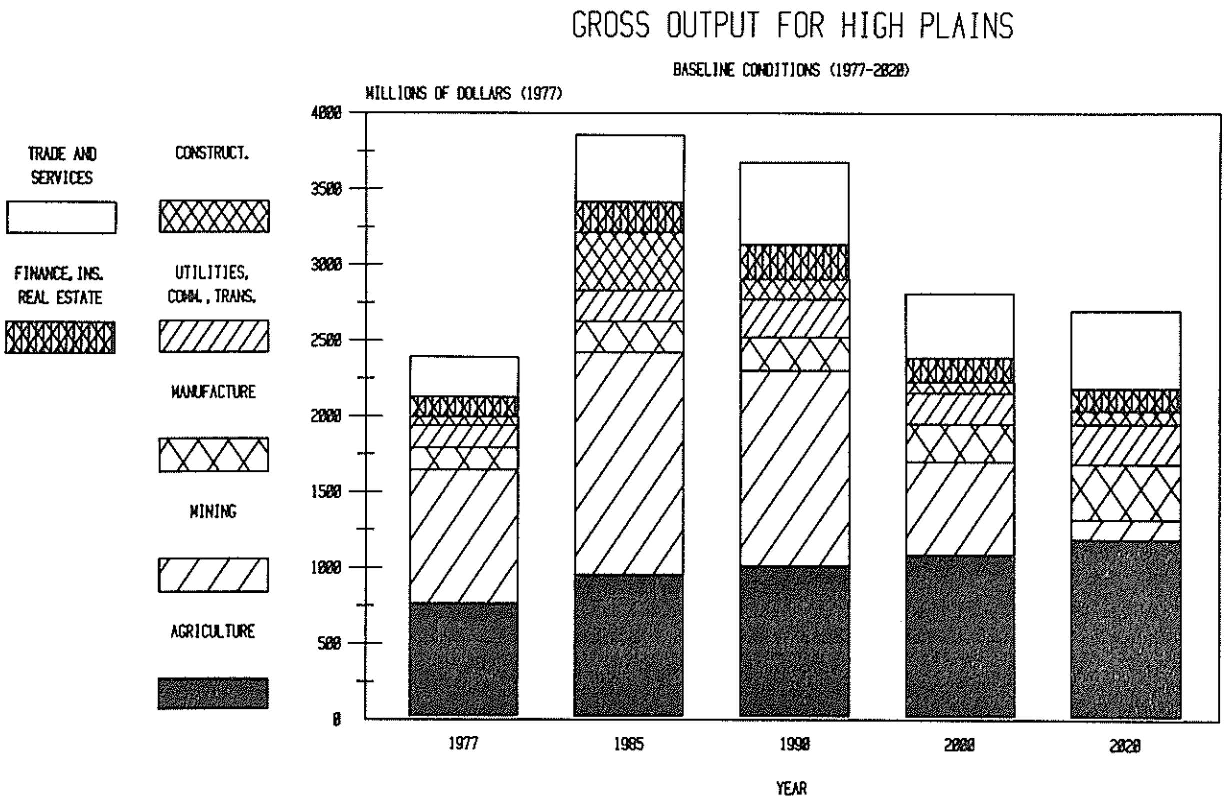


Figure 9

The mining sectors were expected to have substantial growth between 1977 and 1985, but then begin a decline that would result in very little mining activity remaining in the area in 2020. In 1977 the mining sectors accounted for about $883 million or 37 percent of the total. At their peak in 1985 they accounted for $1,467 million or about 38 percent of the total. By 2020 they were projected only to account for $132 million or about 5 percent of the total.

The agricultural sectors are expected to increase between 1977 and 2020 from about $759 million in 1977 to $1,195 million in 2020. This growth was projected to be relatively stable over the period. In 1977 the agricultural sectors accounted for about 32 percent of the total and by 2020 were projected to account for more than 44 percent. Most of the individual agricultural sectors were projected to increase in a similar pattern with the exception of irrigated grain sorghum which was projected to decline in importance in the area.

The manufacturing sectors were projected to increase between 1977 and 2020 from $148 million in 1977 to about $364 million in 2020, or a growth of about 146 percent. The contribution of the manufacturing sectors to the total was about 5 percent in 1985, 6 percent in 1990, 9 percent in 2000 and 13 percent in 2020.

The utilities, communication and transportation sectors taken together generally were expected to increase over the period with a decrease occurring in 2000. These sectors were projected to be about $146 million in 1977, $196 million in 1985, $243 million in 1990, $202 million in 2000, and $266 million in 2020. The contribution of these sectors to the total was about 6 percent in 1977, and is expected to be 5 percent in 1985, 7 percent in 1990, and 10 percent in 2020.

The construction sectors were projected to increase significantly between 1977 and 1985 then begin a decline following fairly closely the output pattern of the mining sectors. These sectors accounted for about $53 million in 1977; and are expected to account for $383 million in 1985 (a six-fold increase); $126 million in 1990 (a 67 percent decrease); $76 million in 2000 (a 40 percent decrease); and $88 million in 2020 (a 16 percent increase).

The finance, insurance and real estate (FIRE) sectors were projected to increase between 1977 and 1990, then decrease to 2020 as the total economy began slowing down in the area. In 1977 they were expected to produce about $138 million, increase to $202 million in 1985, $236 million in 1990, then decrease to $159 million in 2000, and $148 million in 2020.

The trade and services sectors are expected to expand rapidly between 1977 and 1990, then decline in 2000, followed by a recovery in 2020. In 1977 they accounted for about 11 percent of the total and by 2020 were projected to reach almost 19 percent.

There were only minor differences in the alternative management strategies over the period. These differences were stimulated by the agricultural sectors, and their impact was evaluated in the on-farm impacts results.

Jobs

The total employment in the form of jobs for each of the alternative management strategies for the major sectors is presented in Figure 10.

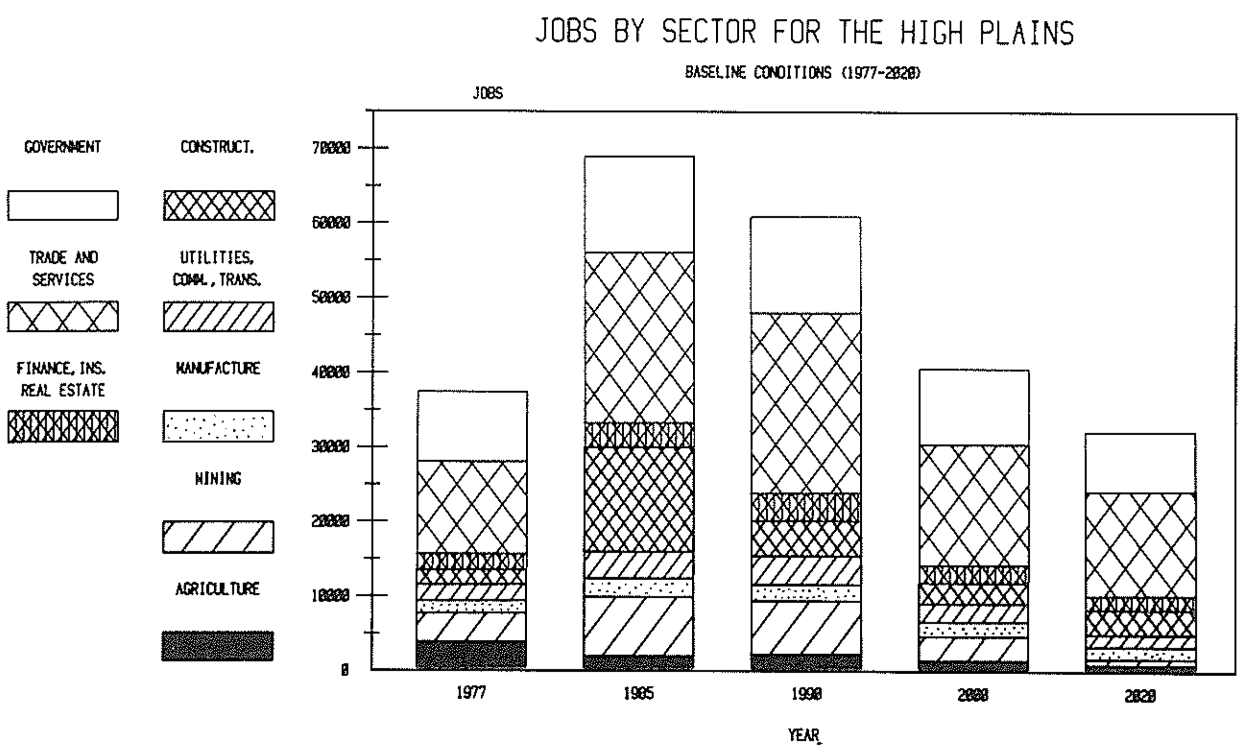


Figure 10

The total number of jobs was projected to be about 37,248 in 1977, increasing to 69,646 in 1985, then decreasing to 32,211 by 2020. The trade and service sectors were the largest employers accounting for about 33 percent in 1977. The percentage is expected to remain the same in 1985, then increase to 39 percent in 1990, 40 percent in 2000, and 43 percent in 2020. Government employed about 24 percent in 1977, and is expected to employ 19 percent in 1985, 21 percent in 1990, and 25 percent in 2000 and 2020. Agricultural employment was about 11 percent in 1977, but was expected to decline to about 2 percent in 2020. Mining employment accounted for 10 percent in 1977, but was expected to increase to 11 percent in 1985, 12 percent in 1990, then decline to about 9 percent in 2000, and 3 percent in 2020. Construction was estimated to provide only about 5 percent of the jobs in 1977, but in 1985 would contribute more than 20 percent, then decrease to 8 percent in 1990, 7 percent in 2000, and increase to 10 percent in 2020.

Population

The region's population was projected to increase significantly between 1977 and 1985 with an increase of about 63,900, or about 47 percent. This is an annual growth rate of 5.9 percent. Between 1985 and 1990 the population was projected to decrease by about 14,000, or about 7 percent. By 2000 the population was projected to decrease even further to 108,481. This is about 80 percent of the 1977 level.

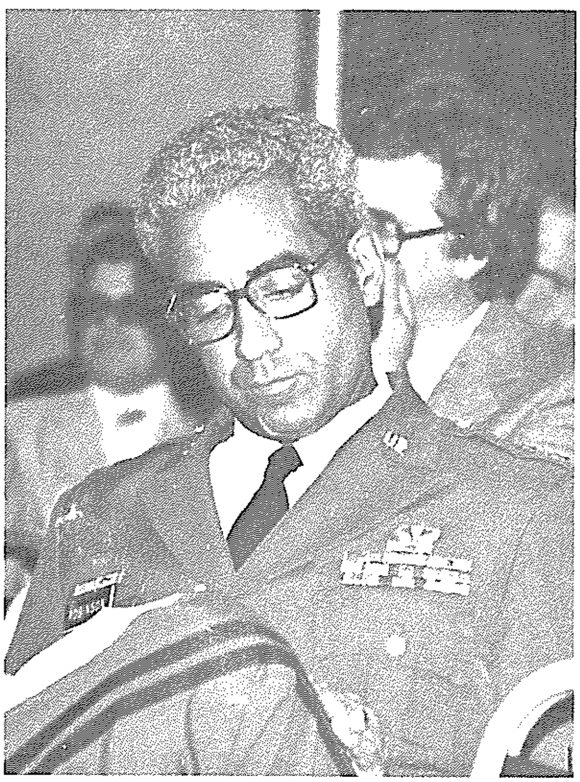
Population

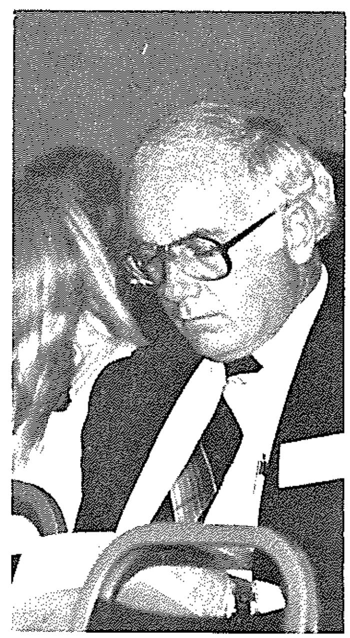
	1977	1985	1990	2000	2020
Baseline	136,284	200,142	185,838	137,947	108,481
Voluntary	136,284	201,641	186,725	139,066	109,007
Mandatory	136,284	201,684	186,803	139,252	109,529
Importation	136,284	201,641	186,725	139,846	110,841

CONCLUDING REMARKS

Research results and recommendations from the $6 million, six-state study will be presented to Congress in the fall of 1982. In New Mexico, county-level reports are being prepared for Lea, Roosevelt, Curry, Quay, Union, and Harding counties. They will be published by the New Mexico Water Resources Research Institute at New Mexico State University and should be available in late summer. These reports will provide additional detail for each county.

SESSION II





MEET THE SPEAKERS

SESSION II

Wayne Cunningham is an agriculture policy analyst with the New Mexico Department of Agriculture. He is an alternate on the Water Quality Control Commission and the 1902 Reclamation Act Committee. He is a member of the National Water Resources Board of Directors and a past member of the Interstate Stream Commission. Previously, he was manager of the Elephant Butte Irrigation District. He attended the University of Pennsylvania at Scranton and NMSU.

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James R. Gilley is professor of agricultural engineering at the University of Nebraska. His primary research interests include energy reduction in irrigation agriculture, water management and reduced pressure center-pivots. He holds degrees from the University of Minnesota and Colorado State University.

George H. Abernathy is head of the agricultural engineering department at NMSU. Several of his publications deal with research on various energy sources used to power irrigation pumping. He is a member of the American Society of Agricultural Engineers, the New Mexico Society of Professional Engineers, the New Mexico Solar Energy Association, Sigma Xi and Phi Beta Tau. He holds degrees from Oklahoma State University and the University of California at Davis.

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B. J. Creel is a research specialist for the agricultural economics and agricultural business department at NMSU. He was a member of the research team that conducted state-level research for the New Mexico portion of the High Plains Ogallala Aquifer Study. He is a member of the American Agricultural Economics Association and the Western Agricultural Economics Association. He will receive a doctorate from the University of New Mexico in the summer of 1982. He also holds degrees from NMSU.

WATER SAVING TECHNIQUES

William M. Lyle
Professor, Texas Agricultural Experiment Station
Lubbock, Texas

INTRODUCTION

In areas like eastern New Mexico, the total water resource includes irrigation water plus rainfall. Therefore, water saving techniques should be directed toward maximizing the efficient utilization of both sources of water. The objective of the irrigation-soil-crop system should be that of storing the maximum amount of both rainfall received and irrigation water pumped in the soil root zone for timely crop utilization.

In order to efficiently utilize a resource requires a certain degree of control over that resource. Normally, the greater the degree of control, the higher the resulting efficiency. Conventional furrow and sprinkler systems cannot maintain the control necessary for consistently high irrigation efficiencies. In furrow or flood irrigation, variables such as soil intake rate, soil non-homogenity, length of run, slope, pumping capacity and varying water management skills make precise control of applied water difficult. Climatic conditions also have a significant effect on the irrigation efficiencies of a sprinkler system. In high wind conditions, both the distribution uniformity and the application efficiency of a sprinkler system can be lowered drastically.

In order to alleviate these problems an irrigation system was designed with the objective of maintaining a high degree of control over the total water resource. This system is characterized by and has been labeled a low energy-precision application (LEPA) system, which rather than spraying water into the air at moderate to high pressures, distributes it directly to the furrow at very low pressure through drop tubes and orifice controlled emitters. This occurs as the system continuously moves through the field in a linear or pivotal fashion. The system is used in conjunction with microbasin land preparation which also optimizes the utilization of rainfall by minimizing runoff. The combined system was designed to minimize the effect of soil and climatic variables which adversely influence furrow and sprinkler irrigation efficiencies.

Since 1979, the LEPA system has undergone evaluation in terms of irrigation efficiency, water use efficiency (yield per gross unit of water delivered to the field), and energy saving potential. An equal gross application of water was applied by impact sprinklers installed on the same system and by furrow methods for comparative purposes. These results will be reviewed briefly along with a slide presentation of producer adoption of the concept. Irrigation efficiency was evaluated in terms of distribution uniformity and application efficiency.

DISTRIBUTION UNIFORMITY

Timed volumetric catchments were taken from each drop tube in a series of 14 field tests to determine Christiansen's coefficient of uniformity (C_u) for the LEPA system. Nozzle discharge rates ranged from one to 2.5 gpm. The range of C_u measured was from 94.2 to 97.2 with a mean of 96.1.

Sprinkler C_u values were obtained from water catch cans placed 6.6 feet apart and parallel to the system (perpendicular to the direction of movement). The volumes of water caught in catch cans were adjusted according to volumetric figures obtained in separatory funnel gauges which were filled with diesel oil and located at four catch can sites. Sprinkler C_u values ranged from 66.4 to 96.6 with an average of 90.2.

Furrow irrigation uniformity was estimated by the change in soil moisture storage down the irrigation run as determined by neutron moisture measurements made prior to irrigation and again two days following irrigation. Furrow C_u estimates ranges from 24.5 to 75.2 with an average of 53.9.

APPLICATION EFFICIENCY

Application efficiency (E_a) was defined for these tests as the ratio of water stored in the root zone to the water delivered to the field and was thus influenced by: (a) evaporation losses from water flowing on the soil surface or in the air from sprinkler nozzle spray; (b) deep percolation below the root zone; (c) runoff; and (d) soil surface evaporation during irrigation.

The only measurable water loss occuring during LEPA testing was evaporation from the ponded water in the micro-basins following irrigations. A free water surface remained between 30 and 90 minutes following irrigation on loam and clay loam soils. Pan evaporation measurements indicated these losses to be less than 1 percent of the water applied in all tests. Deep percolation losses were absent as confirmed by neutron soil moisture measurements extending below the root zone. The furrow dikes successfully eliminated runoff except after three or four consecutive irrigations without rediking. Between 2 to 3 percent runoff was normally experienced on the fourth or fifth consecutive irrigation due to dike erosion. However, the resulting average application efficiencies still remained above 98 percent as defined herein (not considering soil surface evaporation following irrigation).

The drop tube application of water without the furrow basins had an average E_a of only 87.6 percent due primarily to runoff. This points out the necessity of using micro-basin tillage with this water application method.

Sprinkler application efficiency was influenced primarily by spray evaporation losses. Measured application efficiencies ranged from a low of 5.9 percent to a high of 98.9 percent. A two-year average of 85 percent resulted where furrow basins were employed and 82.8 percent where conventional tillage was used. Some runoff, although slight, did occur in the absence of basin tillage. An average daily windspeed of 22.1 mph was responsible for the 5.9 percent E_a figure. However, peak gusts of 40 mph were measured during the day.

The light irrigations (from 1 to 2.5 inches) that were applied by all methods resulted in high furrow application efficiencies. Furrow E_a

values ranged from 57.8 percent to 99.3 percent with the two-year average being about 86.4 percent for both tillage treatments. The micro-basins were removed to allow furrow irrigation. The major loss was runoff with very little deep percolation being detected.

IRRIGATION WATER USE EFFICIENCY

Irrigation water use efficiency was obtained by dividing the average yield obtained from each irrigation treatment by the gross water applied to the treatment. The numbers are quite different for the two years due to below average rainfall in 1980 and above average rainfall in 1981. A total of 19.4 inches of irrigation water was applied in 1980 compared to 9.3 inches applied in 1981. Total water delivered to the crop (rainfall plus gross irrigation) averaged 26.2 inches in 1980 and 24.4 inches in 1981.

These data can best be described by tables along with values previously given concerning irrigation efficiency. Table I contains 1980 data, Table II that data obtained in 1981, and the two-year combined data in Table III. Each irrigation treatment was applied to land which was either basin tilled or conventionally tilled with the results reported for each land treatment.

ENERGY SAVING POTENTIAL

Energy required for the application of water for irrigation is proportional to the gross water delivered and to the pumping head or pressure required for the application as follows:

$$E_r \approx Qh \qquad \text{Eq. [1]}$$

where E_r is the required energy, Q is the gross application, and h is the head or pressure required. The head (h) referred to in this case is that required by the application system and is a function entirely of the operating constraints of that system. The gross water application (Q) is

TABLE I

1980 IRRIGATION EVALUATION DATA

(April-Sept. Rainfall - 7.2 inches)

	BASIN TILLAGE			CONVENTIONAL TILLAGE		
	LEPA	SPRINKLER*	FURROW	LEPA	SPRINKLER*	FURROW
Gross Water Delivered, A-in/A	19.36	19.37	19.63	19.16	19.37	19.63
Application Efficiency (%)	98.70	78.80	91.00	90.80	80.00	89.00
Distribution Efficiency (%)	96.10	91.00	53.80	96.10	91.00	51.90
Average Yield, bu/A	33.70	29.60	21.90	23.00	23.90	24.50
Water Use Efficiency, bu/A-inch	1.70	1.53	1.12	1.20	1.23	1.25
Pumping Energy/A (kw-hrs)	668	892	630	661	892	630
Energy Ratio, kw-hrs/bu	19.80	30.10	28.80	28.80	37.30	25.70
Energy Cost/bu	$ 0.99	$ 1.51	$ 1.44	$ 1.44	$ 1.87	$ 1.29

*Sprinkler irrigation with Royal Coach 10122 sprinkler head with 7/32" x 1/8" 20° nozzle operating at 55 psi.

TABLE II

1981 IRRIGATION EVALUATION DATA

(April-Sept. Rainfall - 15.3 inches)

	BASIN TILLAGE			CONVENTIONAL TILLAGE		
	LEPA	SPRINKLER*	FURROW	LEPA	SPRINKLER*	FURROW
Gross Water Delivered, A-in/A	9.09	9.37	9.08	9.35	9.38	9.08
Application Efficiency (%)	99.00	90.00	82.00	84.40	85.60	83.40
Distribution Efficiency (%)	--	89.40	--	--	89.40	--
Average Yield, bu/A	44.70	36.20	49.10	45.20	35.70	48.60
Water Use Efficiency, bu/A-inch	4.82	3.90	5.29	4.90	3.85	5.24
Pumping Energy/A (kw-hrs)	315	358	291	325	358	291
Energy Ratio, kw-hrs/bu	7.05	9.89	5.93	7.19	10.03	5.99
Energy Cost/bu	$ 0.35	$ 0.30	$ 0.30	$ 0.36	$ 0.50	$ 0.30

*Sprinkler irrigation with Nelson F33AA sprinkler head with diffuser nozzle operating at 20 psi.

TABLE III

COMBINED IRRIGATION EVALUATION DATA (1980 - 1981)

	BASIN TILLAGE			CONVENTIONAL TILLAGE		
	LEPA	SPRINKLER	FURROW	LEPA	SPRINKLER	FURROW
Total Gross Water Delivered, A-in/A	28.45	28.74	28.71	28.51	28.75	28.71
Average Application Efficiency (%)	98.90	84.40	86.50	87.60	82.50	86.20
Average Distribution Efficiency (%)	96.10	90.20	53.80	96.10	90.20	51.90
Total Two-Year Yield, bu/A	78.40	65.80	71.00	68.20	59.60	73.10
Water Use Efficiency, bu/A-inch	2.76	2.28	2.47	2.39	2.07	2.54
Total Pumping Energy/A (kw-hrs)	983	1250	924	986	1250	921
Energy Ratio, kw-hrs/bu	12.54	19.00	12.97	14.46	20.97	12.60
Energy Cost/bu	$ 0.63	$ 0.95	$ 0.65	$ 0.72	$ 1.05	$ 0.63

a function of the net application desired and the overall irrigation efficiency.

Numerous researchers have proposed the use of the product of application efficiency and distribution efficiency to determine the total amount of water which should be applied to satisfy the net requirements throughout the designated root zone for the entire irrigated area (Bagley and Criddle, 1956; Hansen, 1960). Thus equation [1] would be expressed as:

$$E_r \approx \frac{q}{E_a \, E_d} h \qquad \text{Eq. [2]}$$

where q is the net application desired, E_a is the application efficiency, and E_d is distribution efficiency.

The LEPA system offers excellent potential to decrease irrigation energy consumption in each area represented by equation [2]. These are: (1) lower net irrigation requirement (q) through greater rainfall retention in supplemental irrigated areas; (2) high application efficiency (E_a); (3) high distribution efficiency (E_d); and (4) low operating head requirements (h).

The actual energy required for pumping water by the various methods in 1980 and 1981 are given in Tables I and II, and combined in Table III. It is then presented as an energy ratio representing the energy consumed for pumping for each bushel of soybeans produced. Next, the pumping cost per bushel is given assuming an energy cost of $0.05 per kw-hr.

SUMMARY

Perhaps the best summary of data taken to date would be in terms of net return realized by each treatment over the irrigation energy expense. This data is shown in Table IV. The average price received for soybeans in 1980 was about $8.00/bu and about $5.00/bu in 1981. Energy expense was assumed to be $0.05 per kw-hr for both years.

LEPA irrigation demonstrated a distinct advantage over all other treatments in the dry year of 1980 where irrigation had a greater

TABLE IV

NET RETURN OVER IRRIGATION ENERGY EXPENSE* ($/ACRE)

	BASIN TILLAGE			CONVENTIONAL TILLAGE		
YEAR	LEPA	SPRINKLER	FURROW	LEPA	SPRINKLER	FURROW
1980	236.20	192.20	143.70	150.95	146.60	164.50
1981	206.20	163.10	231.00	209.75	160.60	228.50
Two-Year Total	442.40	355.30	374.70	360.70	307.20	393.00

* 1980 Soybean Price ∿ $8.00/bu
1981 Soybean Price ∿ $5.00/bu
Energy Cost ∿ $0.05/kw-hr

influence on yield response. Excess rainfall in 1981 caused some indication of negative yield response to retained water and therefore favored furrow irrigation. Furrow diking or basin tillage is considered an integral part of the LEPA irrigation concept and the data supports the importance of its inclusion in the system.

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IRRIGATION SCHEDULING

James R. Gilley
Professor, Agricultural Engineering Department
University of Nebraska, Lincoln, Nebraska

INTRODUCTION

The results of the High Plains, Ogallala Aquifer study indicate that many areas in the High Plains of New Mexico will be facing a serious water supply situation within the next 20 years. Various forecasts of the future indicating technologies that might alleviate these projected conditions were developed by the High Plains Council. These scenarios are being described in detail by several presentations at this meeting. Potential technologies range from very costly water importation, both intrastate and interstate, to the less exotic modifications such as improved water conveyance and application systems and improved irrigation farming practices including irrigation scheduling.

The purpose of my presentation is to describe the current irrigation water management (irrigation scheduling) procedures which can be used to reduce the amount of water pumped and how they might be used in New Mexico. Irrigation is a major consumer of three scarce commodities: energy, water and fertilizer. The need for conservation through good irrigation management practices is urgent -- especially in view of the cost price squeeze facing many U.S. farmers and the rapidly declining water supplies.

To help meet these needs, the agricultural engineering department at the University of Nebraska has developed an irrigation scheduling program which has been used by a variety of clientele including professional consultants and individual grower-operators. While the concepts developed in the program can be applied using relatively simple methods, its primary usage has been through a computer network.

BACKGROUND

Before describing the irrigation scheduling model in detail, I want to discuss some general concepts describing an overall irrigation water management program. Such a program considers an individual irrigator's agricultural production system including the crop, irrigation system, soil, labor supply, energy supply and economic situation. Irrigation water management is important to the grower for a number of reasons including water conservation, energy conservation, reduced production costs and, of course, yield improvements.

One of the primary components of an irrigation water management program is the incorporation of an irrigation scheduling procedure. I prefer to define irrigation scheduling as a scientific determination of when to irrigate and how much to apply to meet specified management objectives. While this definition includes the timing of the irrigation and how much to apply, it also includes a very important additional component, that being specified management objectives. These management objectives may include such goals as: maximum yield, maximum economic benefit, maintenance of a favorable salt balance, minimum leaching and perhaps others. Thus, to develop an irrigation scheduling procedure one must first specify the management objective desired.

For our discussions in this paper I want to define the following management objective which we are striving for. Presently, most of the irrigation scheduling procedures which have been developed are primarily for those conditions when water is not limiting. Thus, our management objective is to minimize water application but not to reduce yields. In some cases in the High Plains the water supply is already diminished to a point where there is not sufficient water to meet the plant water requirements. Thus, the procedures I will be discussing may not be directly applicable. However, these concepts combined with other techniques may be applicable to conserve the available water supply.

The inefficient use of irrigation water results from both the physical conditions of the off-farm conveyance systems and the on-farm irrigation system, as well as the improper management of these systems.

In addition, the efficient use and management of irrigation water may be influenced by existing institutional and social factors. In the High Plains of New Mexico, most of the water is derived from individual wells pumping from ground water sources. Thus, the efficient use of water is primarily a function of the management of the on-farm irrigation systems by the individual grower-operators. Irrigation scheduling could be a key management component for many of these growers.

IRRIGATION SCHEDULING MODEL

The agricultural engineering department at the University of Nebraska has developed an irrigation scheduling model called IRRIGATE for the AGNET (AGricultural computer NETwork) system. This network serves the University of Nebraska and the state of Nebraska as well as several other states. As with all AGNET programs, the irrigation scheduling model is designed for teaching, research and extension programs. Access to AGNET can be made through small portable computer terminals. These are priced from $2,000 and are about the size and shape of a portable typewriter. They can be used wherever there is a telephone and an electrical outlet -- the IRRIGATE program even could be run on a farmer's kitchen table!

The basic component of the irrigation scheduling model is the on-farm water balance. Irrigation water is applied in areas where natural precipitation and stored soil water is insufficient to meet the crop water requirements during the growing season. This water is applied to the soil surface through a number of different types of systems ranging from the most elementary to the more sophisticated. The disposition of water during and after an irrigation event is called the on-farm water balance. The irrigation scheduling model maintains a field's daily soil moisture status since planting, and answers the important questions of when and how much water should be applied in future irrigations.

Kincaid and Heermann (1974) provide an excellent treatment of the basic scheduling theory followed in IRRIGATE, and especially in the use of the modified Penman equation to predict a crop's evapotranspiration

(ET) from the climatic variables: daily maximum and minimum air temperatures, average dew point temperature, daily solar radiation, and the daily wind run. Heermann et al. (1976) presents a detailed description of the output format of the irrigation scheduling program.

IRRIGATE is designed to be user oriented; very little knowledge of computer operation is required. The computer interacts with the user by asking questions. Special detailed help messages are available throughout the program if particular questions are not understood. If certain input parameters are not known by the user, the program will assume standard values for the given type of irrigation system, soil and crop.

IRRIGATE can be used with a wide variety of irrigation systems (center pivots, solid set, gated pipe, siphon tube, etc.); with nine commonly grown crops (small grains, beans, soybeans, potatoes, sugar beets, corn, alfalfa, pasture and sorghum); with eight common soil types (silty clay loam to fine sand); and with a mimimum of climatic data (maximum and minimum temperature only) if necessary.

While the entire scheduling procedure could be done using today's programmable calculators, the computer offers the convenience of easy access to an entire season's data and a neat, readily obtained record of a field's soil water condition. This is even more convenient if a few field parameters are changed and a new season's run is made. This is frequently required in answer to "what if" questions -- important in management planning.

Irrigation scheduling is much like managing a checkbook. The season begins with an initial soil moisture content (beginning account balance). Daily evapotranspiration by the crop depletes the soil water (daily withdrawals). Irrigations and rains represent deposits to the soil moisture account. Future irrigations (deposits) are then scheduled based on an estimated average rate of evapotranspiration (estimated future withdrawals) and the irrigation system's capacity to apply water. Soil moisture depletions should not exceed a particular value to prevent crop stress and a resulting yield decline. For most soils and crops this is estimated at 50 percent of the available water holding capacity of the soil although different values can be used in the model. Irrigations are scheduled to avoid undue stress on any part of a field before the next irrigation.

The model automatically builds and maintains a field data file to store the data pertinent to any one field. The first time the program is used for each field, the program will ask for details describing the crop including the planting date and expected maturity date; soil texture; location and types of soil moisture blocks (if used); type of water meter (if used); desired scheduling method; field area; and irrigation system parameters (such as system capacity, cycle time and application in inches).

The field file also stores the rainfall, irrigation and soil moisture data for the field. On subsequent scheduling sessions the user only enters new data for rainfall, irrigation and soil moisture data. Other field data are automatically recalled from the field data file.

Irrigations are scheduled based on the soil moisture depletions at the two extreme positions of a field, the normal "start" and "stop" position of an irrigation cycle. The program assumes that field positions in between these two extremes follow the same rhythmic cycle as the "start" and "stop" positions. The earliest starting date is based upon the soil moisture depletion at the "start" position. The recommended starting date is the day when the expected soil water depletion at the starting point is greater than or equal to the irrigation depth applied. This is the earliest starting date that will avoid deep percolation losses. The "no later than" date is the time when the system must be started to irrigate the "stop" position before the soil water depletion exceeds some predetermined value (typically 50 percent). To avoid plant stress at the "stop" position, particularly during early growth stages, the "start" position should be irrigated before the soil water depletion in the area reaches the mimimum application depth, even though there will be some deep percolation losses.

Because the three key parameters of rain, irrigation and infiltration variability are often not well defined, field feedback is necessary for accurate scheduling. Thus, periodic soil moisture readings are recommended to provide the needed feedback to ensure that the scheduling is based on the best possible estimation of soil moisture depletion. These readings help to ensure that the ET estimates are correct. They also act as a check on factors such as irrigation efficiency, uniformity of irrigation, rainfall variability and non-uniformity of the soil. Soil moisture updates usually are advised at least every 10 days.

The monitoring of soil moisture may be accomplished by a variety of methods including the soil probe, gypsum resistance blocks, tensiometers, neutron probe and others. Each method has advantages and disadvantages depending upon soil type, cost, etc. The proper soil moisture monitoring technique for the given situation must be carefully determined. Soil moisture blocks are a convenient method to measure soil water status in the finer textured soils (they don't respond well in sandy soils). Block readings can be entered directly into IRRIGATE for the particular soil. Soil moisture block stations are located near the normal starting and stopping location of the irrigation system cycle.

Besides the field data file, which is maintained for each individual field, a weather data file also is kept. The weather data file contains daily maximum and mimimum air temperatures, solar radiation, wind run and dewpoint temperatures for a climatic region. However, that data need not be an input to the model if the Penman option of estimating ET is not used. Because such weather data can be used throughout a climatic region, that data file could be maintained by an irrigation district.

The output of the scheduling program is shown in Figure 1 (p. 91). The output is divided into three basic components: 1) the update; 2) the forecast; and 3) the schedule. The top portion of Figure 1 is the update of the water budget computed with climatic data collected since the previous output. Tabulations include daily water use, irrigation and rainfall amounts, irrigation dates and calculated soil water depletion at the "start" and "stop" positions.

The center part of Figure 1 (the forecast) indicates the maximum useful rain and irrigation amounts that could be applied at any given date. This part of the output represents estimated water use calculated from average climatic conditions for a given area. It can be used by management to evaluate the effectiveness of rainfall which comes during the week and the actual timing of the irrigations.

The bottom portion of Figure 1 (the schedule) shows the recommended starting dates based upon the system capacity and amount of rainfall. In addition, alternate dates are given for the second irrigation assuming that the system was started on the previously recommended "start" date. The operator must judge when to start a system. He has the latitude of starting the system any time between the "start" and "no later than" date. On sandy soils, the center-pivots generally are started on the first recommended "start" to maintain a full soil water profile and avoid excessive depletion should the system malfunction. The time interval between the "start" and "no later than" dates is generally smaller for coarse textured soils than for finer textured soils. Operators with finer textured soils tend to delay an irrigation until after the first recommended starting time which allows them to more effectively use any rainfall that may occur.

Growers whose management objectives are obtaining maximum yields tend to start an irrigation at the first recommended starting time. Others who operate their systems more extensively to minimize irrigation and fertilizer costs tend to start their systems closer to the "no later than" date.

RESULTS

Because the irrigation scheduling program is intended to be used under the guidance of qualified irrigation schedulers, the University of Nebraska periodically offers short courses to train irrigation schedulers.

The irrigation scheduling model is available for use on the AGNET system by university personnel, private individuals, private irrigation scheduling companies, irrigation districts and others. While the exact area being scheduled using the IRRIGATE program has not been determined, Fischback (1981) estimated that more than 1.5 million acres of irrigated land were scheduled in Nebraska in 1979. This area included those scheduled by county agents as demonstration projects, consultants and irrigators themselves.

REGION EXAMPLE (ALL WATER AMOUNTS ARE INCHES)

FARM EXAMPLE CORN DATE Aug 10

UPDATE

DAY	WATER USED	IRRIGATION AND RAINS	IRRIGATION DATES	DEPLETION WHERE SYSTEM STARTS	STOPS
Aug 4	.15	0.00		.15	.15
Aug 5	.22	0.00		.37	.37
Aug 6	.26	.80	STARTED	0.00	.63
Aug 7	.27	0.00		.27	.10
Aug 8	.19	0.00		.46	.28
Aug 9	.25	.80	STARTED	0.00	.53
Aug 10	.28	0.00		.28	.01

FORECAST

MAXIMUM USEFUL RAIN AND IRRIGATION AMOUNTS

LARGER AMOUNTS WILL BE LOST

DATE	AMOUNT
Aug 11	.58
Aug 12	.88
Aug 13	1.17
Aug 14	1.45
Aug 15	1.68
Aug 16	1.90
Aug 17	2.11

SCHEDULE

IF THE SYSTEM APPLIES .8 INCHES AND MAKES A REVOLUTION
In 51. HOURS, THE RECOMMENDED STARTING TIMES ARE:

AMOUNT OF RAIN	START	NO LATER THAN
No rain	Aug 13	Aug 19
0.25	Aug 14	Aug 20
0.50	Aug 15	Aug 22
1.00	Aug 17	Aug 24

ASSUME THE SYSTEM WAS STARTED AUG 13
THE NEXT STARTING TIMES ARE:

AMOUNT OF RAIN	START	NO LATER THAN
No rain	Aug 16	Aug 22
0.25	Aug 17	Aug 23
0.50	Aug 18	Aug 24
1.00	Aug 20	Aug 27

Figure 1. Sample Irrigation Scheduling Output (Heermann et al., 1976).

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PUMP TESTING

George H. Abernathy
Head, Agricultural Engineering Department
New Mexico State University

Irrigation pump testing has been carried on by the agricultural engineering department at New Mexico State University since 1976. The original project was a joint program between the Department of Energy and Minerals through their old Energy Research and Development Program and the Agricultural Experiment Station. About 400 pumps were tested during the 1976, 1977 and 1978 growing seasons. Results of this pilot program indicated there was much to be gained by informing farmers of the efficiencies of their pumps so that new equipment and improved efficiencies could result in fuel savings and cost reductions. In recognition of these results, the Energy Extension Service, through the New Mexico Cooperative Extension Service carried on pump testing for the 1979 and 1980 seasons. They tested almost 400 pumps, some of which were repeats of earlier tests. Energy extension funds ceased to be available for the 1981 crop season and only a few tests were conducted by the extension agricultural engineer. Prior to the 1982 season, the Interstate Stream Commission and the Four Corners Regional Commission made funds available to purchase equipment and set up a test van that would be available during the 1982 crop year. Funds also are available to employ a qualified engineer and an assistant to carry out the pump testing. This program is aimed mainly at the High Plains area where high lifts and high energy costs are causing severe problems for farmers in the highest crop production areas of the state.

The most critical areas are the High Plains from Tucumcari southward through Lea County, the Estancia Valley area and the Deming-Lordsburg pumping area. Most pumps on the Pecos and Rio Grande Rivers are involved in much shallower lifts and are not as critical for energy consumption as the above listed areas.

Pump tests during 1982 will consist of a quick overall evaluation between the energy source and the pumped water. This overall efficiency will be used to determine whether further testing is necessary. In the case of electric drive motors only a quick test is possible and the motor is assumed to be operating at the efficiency specified in catalog ratings. For natural gas units, if the efficiency is above about 16 percent, then both pump and motor must be operating about as efficiently as can be expected and no further tests will be conducted. If the efficiency appears to be low, a torque meter will be installed between the engine and the pump and a complete engine evaluation will be carried out. This will help the farmer determine whether he needs to do engine work or pump work. Past experience would indicate that low efficiencies are generally the result of pumps rather than engines.

The program in 1982 will be conducted similarly to the previous projects with the farmer contacting the county agent who refers lists of the pumps to be tested in his county to the test crew. It is anticipated that nearly all requests in the High Plains area can be honored, but the crew does reserve the right to organize the testing in a logical community pattern. Therefore, the first request may not be the first served. In so far as possible all wells that are requested will be tested.

It should be noted that no alternate fuels are presently available to relieve the farmer's dependence on conventional energy sources. For the forseeable future it appears that coal, agricultural wastes and solar power are not economical when compared to the conventional energy resources of natural gas and electricity. The farmer's only choice in these hard economical times is to know that he is using the energy resource as economically as possible and reducing to the extent practical his consumption of high priced energy.

HIGH PLAINS STUDY RECOMMENDATIONS -- OPTIONS FOR ACTION

Noel R. Gollehon and B. J. Creel
Research Specialists, Agricultural Economics Department
New Mexico State University

INTRODUCTION

The High Plains Study was designed to evaluate alternative futures (Management Strategies). The possible futures examined were baseline, voluntary water demand reduction-conservation, mandatory water supply reduction, and increasing the water supply. The researchers at NMSU developed a list of possible options for action that would help to make each of these futures possible.

The people attending the second session of the water conference were asked to respond as to their preference from the list of possible actions. In addition they were asked to indicate the degree with which they agreed or disagreed with each of the possible actions.

Described below are the possible actions considered by each of the possible futures.

POSSIBLE OPTIONS FOR ACTION

A. Baseline

1. "Business as Usual" - no action.

This alternative for action is the first alternative considered for any situation. It means that present conditions and policies will continue.

2. Establishment of an export promotion board.

A critical assumption of all the alternative strategies was that of crop prices. Since crop prices are closely tied to export demand, the establishment of a group to promote exports could help stabilize or increase crop prices.

3. Increased funding of agricultural research, demonstration, and extension.

A second critical assumption of all the alternative strategies was that of increasing crop yields. Much of the improvement in crop yields in the past has been the result of agricultural research. Federal and state spending for agricultural research is not keeping pace with inflation. Federal funding buys 30 percent less research now that it did 10 years ago, while state funding buys about 10 percent less research. Agricultural producers contribute to research when they buy inputs from companies with large research budgets or when they sell commodities with checkoffs earmarked for market promotion or agricultural research. Greater public and private financial support for agricultural research is a cost-effective way to increase agricultural yield. This alternative proposes that funding be increased to agricultural research, demonstration, and extension in order to help increase future crop yields.

4. Increase SCS technical and financial assistance in the Ogallala area.

The state conservationists from the U.S. Soil Conservation Service (SCS) in the six-state Ogallala region have requested that this region be targeted for increased technical and financial assistance to improve water and soil conservation practices. This assistance will be particularly important as thousands of acres in this region go from irrigation back to dryland production and rangeland. Additional personnel are also needed to help conduct on-farm irrigation efficiency tests and promote effective seasonal water management practices. At the federal level, the USDA Soil Conservation Service and Agricultural Stabilization Conservation Service should continue the current education and assistance programs. These programs can provide an excellent means of increasing the adoption rate of new technology via technical assistance from SCS and financial assistance via ASCS, These programs are informally directed by the priorities of the farmers in the area.

5. Continued funding for monitoring groundwater depletion and its effect.

Without updated knowledge of the rate of aquifer depletion and its effects, there is no information to plan for local exhaustion and domestic, municipal and industrial water sources.

B. Voluntary Water Demand Reduction -- Conservation

1. Accelerate research and demonstration of crops that produce more per unit of water.

This alternative for action would require the acceleration of crop breeding programs utilizing the latest (and most expensive) techniques such as genetic engineering and tissue culture reproduction. The goals of this program would be: (a) develop new varieties of existing crops that produce equal yield on less water or more yield on equal water, and (b) adapt "alternative crops" which are low water users to the climatic and physical conditions of the region. "Alternative crops" are low water use crops which have not traditionally been grown in the Ogallala region. Some possible alternate crops include: sunflowers, which require about half as much water as corn; gran amaranth, whose seeds yield a high quality protein and oil; and the Jerusalem artichoke, a starchy tuber suitable for human consumption or fuel alcohol use. A systematic inventory and analysis of alternate crops with both economic and adaptability potential is urgently needed -- not only for the High Plains but other areas of the state as well. In addition to determining whether such crops can be adapted and raised in the state, such studies must investigate problems and opportunities in processing and marketing alternate crops.

2. Establish ET (Evapotransporation) reporting stations.

With the help of local newspapers and radio stations, daily ET reporting stations could be established. Daily ET requirements are necessary for the establishment of low cost irrigation scheduling. Because rainfall and climatic conditions vary from place to place, this service chiefly benefits those within 30-50 miles of the reporting station. Establishing ET reporting stations would require a one-time cost of $3,000 to $5,000 for equipment for each station, plus modest labor and telephone costs for five months each year to read and transmit the ET information to cooperating newspapers and radio stations. Expenses could be cut if local organizations helped to operate these ET stations.

3. Accelerate research to determine the effect on crop yield of water application timing and amounts.

The determination of the timing and amounts of water necessary for "critical" stages of crop production is necessary before an irrigator can consider profitable supplemental irrigation. Before an irrigator can successfully eliminate an irrigation, and reduce water application by some amount, the knowledge of which irrigation has the least impact on crop yield, quality, and harvest considerations is necessary.

4. Expanded research and education programs to encourage irrigation scheduling.

Irrigation scheduling is among the best management techniques for significantly reducing water applications (up to 20 percent) while maintaining yield, at a relatively low per acre cost. Expanded research is needed to "localize" scheduling and include all crops. Increased educational programs are needed by both the public and private sectors to encourage its adoption and wide-spread use.

5. Accelerate research and education of water conserving irrigation system design.

Expand the programs in irrigation system design (moving trickle, low pressure center pivots, leveling, etc.) these efforts could save up to 20 percent of the water applications. At the private action level, some form of communication is needed between manufacturers and distributors of irrigation equipment and the Experiment Stations, Agricultural Research Service, Conservation Districts, and innovative farmers. For example, the Low Energy Precision Application (LEPA) system, developed and tested at the Agricultural Experiment Station in Lubbock, and other high efficiency systems developed and implemented by individual farmers, could be much more widely adopted if a mechanism existed for convincing manufacturers to produce and distribute these systems soon after they are tested and proven effective. Research institutions could test and compare existing and new equipment and distribute results to manufacturers, and to farmers in order to stimulate production of the most efficient equipment.

6. Establishment of low interest loan program for improved irrigation systems.

Establish low interest federal or state loans to encourage adaptation of water conserving technology. Local, state and federal governments should develop a source of loanable funds, available at interest rates below contemporary bank customer rates, to be used for purchase and utilization of water-conserving equipment. Tax incentives should also be urged to provide tax relief on water-conserving agricultural equipment. Exemption from property tax or taxing these items of property at a reduced rate at the local level is one possibility. The same effect could be achieved at the federal level via tax credits in a manner similar to energy-conserving tax credits currently available.

7. Increase Cooperative Extension Services support in irrigation system and water application education (additional area irrigation specialist).

The extension service now has a full-time agricultural engineer/irrigation specialist for the entire state handling both irrigation and farm machinery. Due to extension service budget cuts, there is an open position for an agricultural engineer. As pumping costs increase, water supplies decrease and new irrigation systems emerge, it will become more and more important to provide up-to-date, practical information at the farm level on methods to improve water use efficiency.

8. Increase testing, monitoring and education programs for pumping plant efficiencies.

The efficiency of the pumping plant has a significant impact on the amount of water pumped for the fuel utilized. As irrigation fuel prices increase in the future, a pumping plant operating at a "good" efficiency will operate on much less fuel and money. The expansion of an ongoing pump testing program has the potential for a tremendous fuel and money saving impact.

9. Initiate large scale research, demonstration, and education program on alternative irrigated farming techniques (minimum till, low pressure, trickle), partial irrigation farming, and improved dryland farming techniques.

The establishment of a farm-sized research unit to demonstrate new and improved cultural and irrigation techniques in farm conditions. This unit would place emphasis on the demonstration of water conserving irrigation technologies, and cultural practices for both full and partial irrigation levels, as well as improved dryland farming techniques. The unit would be designed and operated for demonstration and education purposes.

10. Initiate programs that will increase farmer cooperation on testing new technologies in a commercial farm condition.

The lack of commercial-scale research and demonstration projects is one of the chief obstacles to adopting more efficient methods of conserving water on High Plains farms. Any change in cropping patterns, cultivation practices, or irrigation methods is usually a major business decision. Because the financial stakes are so high, farmers tend to discount the relevance of research information developed from small plots of land.

11. Establish producer and agri-business funded research foundations.

The establishment of producer and agri-business funded research foundations has several advantages. First, it indicates the importance of the problem to state, regional, and national policy makers. Second, it enables high priority funding of research or specific local problems.

12. Establish a producer information network (price, education, new ideas, etc.)

With the advent of the affordable personal computer in conjunction with a WATS telephone line, it is now possible for the almost instantaneous transfer of information. This in conjunction with the public broadcasting networks (television and radio) could provide a huge amount of information to agricultural producers. This information could include producer price information, descriptions, and advantages of new technologies, research information, and notices of importance to agricultural producers.

13. Establish programs to assist farmers wishing to switch from irrigation to rangeland.

As the aquifer lowers, there will be cases where farmers wish to convert all or part of their irrigated acreage to grassland. A program should be established to encourage and aid in this process. This program could provide information on grass varieties and financial assistance in order to assure a smooth transition to rangeland.

C. Mandatory Water Supply Restrictions

1. Mandatory well spacing.

If this action alternative was implemented, it would require changes in or additional laws. This action alternative would mandate that there be no more than "X" active wells per section. This would have the effect of lengthening the aquifer life by controlling the number of wells.

2. Reduce allowable water withdrawals to less than 3 acre-feet per acre per year.

If this alternative was implemented, it would require changes in th present laws. In addition, this alternative would require monitoring of the water pumpage from each well and limiting pumpage to less than 3 acre-feet per acre per year.

3. Restrict crop water applications to a percent of their full requirement.

If this alternative was implemented, it would require changes or additions to present laws. In addition, this alternative would require monitoring of the water pumpage from each well and limiting pumpage to a percentage less than the full per acre water requirement (full ET) for each crop.

4. Require irrigation scheduling.

If this alternative was implemented it would require that farmers implement, for each crop, a scientific irrigation timing and quantity management technique. The farmer could do it himself or hire it done. This alternative would also require substantial changes to present laws.

D. Increase Water Supply (Importation and Management)

1. Continue interstate feasibility studies with emphasis on quantity, sources, timing and cost.

Interstate water importation feasibility studies would be continued with emphasis given to the determination of the amount and availability of surplus water in the basins and states of origin. The states of origin should be included in the institutional mechanism set up to conduct the study. Other studies for importing water to the High Plains region should be included in addition to the Corps of Engineers' analysis through the High Plains Study to import from the Missouri/Mississippi River system.

2. Study of feasibility of using alternative energy sources (wind, solar, etc.) to transport interstate and intrastate water.

(1) Study the feasibility and develop demonstration projects for using wind energy for: (a) transporting intrastate and interstate imported water; (b) irrigation water pumping; (2) study the feasibility of biomass fuels for transporting imported water; (3) monitor the development, perform feasibility studies and develop demonstration project for photovoltaic electricity production for irrigation water pumping; and (4) develop on-farm energy conservation demonstration and education program.

3. Study the feasibility of using playa lakes as a recharge water source or an irrigation water source.

Water which normally runs to playa lakes could be diverted to nearby cultivated areas, or the lake could be modified (pits) to provide increased deep percolation while reducing surface evaporation.

4. Expand the demonstration and education program to increase farm soil moisture availability from natural rainfall and snow.

Expand "on-farm" research and implementation programs to increase soil moisture availability from precipitation by such methods as water runoff management and new land treatment methods. Water that enters the soil and is surplus to plant needs will ultimately add to recharge of the underground aquifer. Increase and implement programs that expand land treatment for non-cultivated areas (i.e., pitting, terracing, removal of phreatophytes and replace with grasses) and determine suitable aquifer recharge sites and carry out demonstration projects.

5. Expand the research effort into the utilization of saline water.

If crops can be made more salt tolerant, the possibility exists to either use straight saline water or mix saline and fresh water to increase local supplies.

RESULTS

The responses to the above list of possible options for action are summarized in the following section.

Of the registered attendance at the New Mexico Water Conference, about 55 percent responded to the survey. The composition of those responding to the survey is summarized in Figure 1. Residents of the Ogallala region of New Mexico accounted for 31 percent. Of those responding, 9 percent were agricultural producers in the Ogallala area and 22 percent were non-agricultural residents in the Ogallala area. Agricultural producers from outside the Ogallala area accounted for 12 percent of the total. Most of the respondents (57 percent) were not agricultural producers and were from outside the area.

The responses are summarized in Exhibit 1 with the numbers representing the percentage responding to the preference level. The responses are also summarized in Figures 2 through 5. Figure 2 summarized the responses for the baseline measures. Figure 3 for the conservation measures, Figure 4 for the mandatory measures, and Figure 5 for the importation measures.

There were some definite opinions expressed by the responding group regarding the options for action listed under the baseline strategy (Figure 2). The majority of the group (87 percent) disagreed with A-1 (no action). About 94 percent of the respondents agreed with A-5 to continued monitoring groundwater depletion, 85 percent agreed with A-3 to

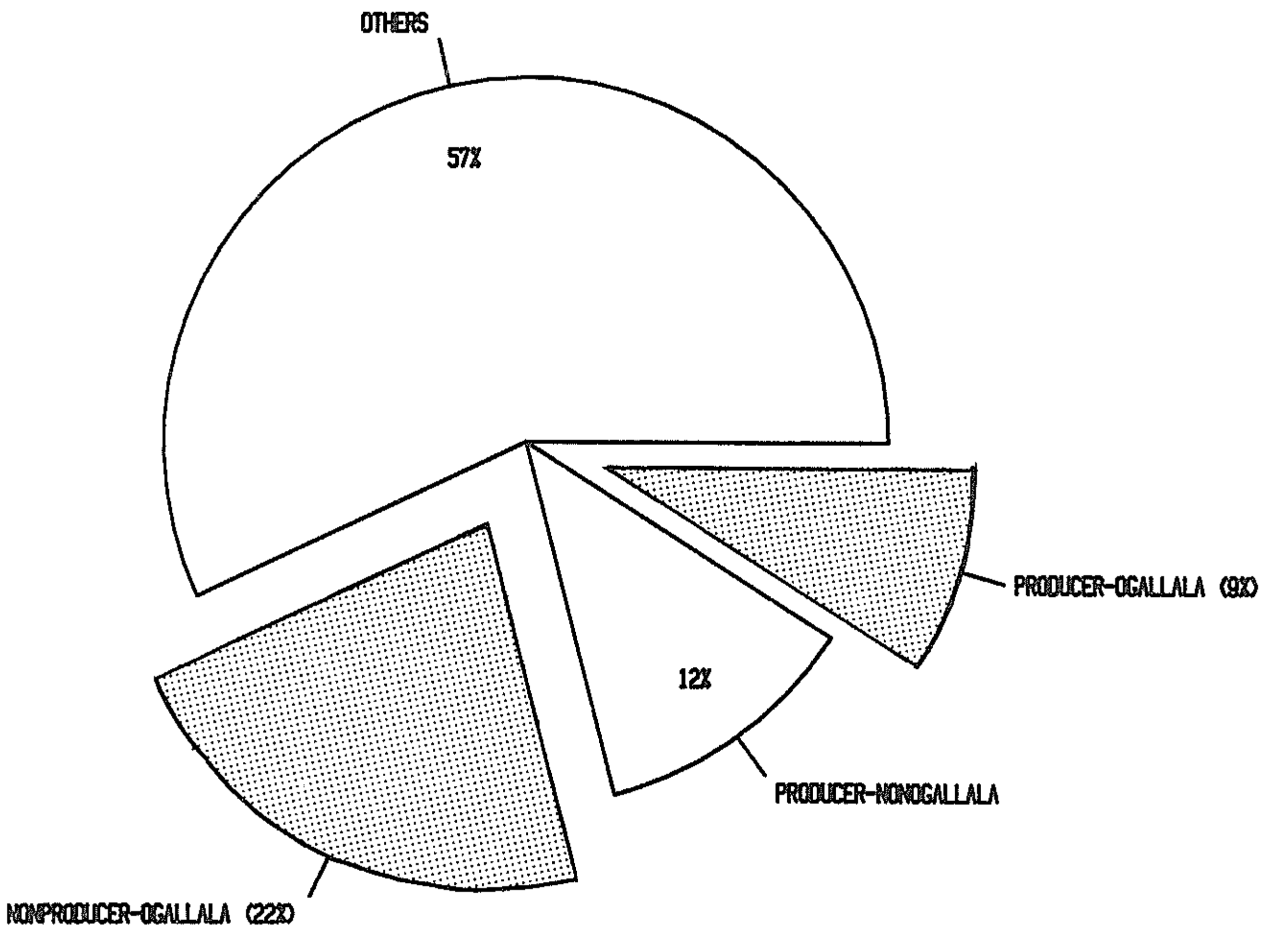


Figure 1. Composition of respondents to survey for options for action, New Mexico Water Conference, 1982.

HIGH PLAINS RECOMMENDATIONS
Responses from N.M. Water Conference, Clovis, N.M., 1982

YES	NO	
		I live in ____________ County
___	___	I live in the Ogallala Region of New Mexico
___	___	I am a rancher or farmer
___	___	I irrigate using Ogallala Aquifer water

Please indicate the extent to which you agree or disagree with each of the following recommendations.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
A. BASELINE					
1. "Business as Usual" -No action.	1	4	7	37	50
2. Establishment of an export promotion board.	10	34	37	18	1
3. Increased funding of agricultural research, demonstration, and extension.	28	57	14	1	0
4. Increase SCS technical and financial assistance in the Ogallala area.	10	57	28	8	0
5. Continued funding for monitoring groundwater depletion and its effect.	44	50	6	0	0
B. VOLUNTARY WATER DEMAND REDUCTION--CONSERVATION					
1. Accelerate research and demonstration of crops that produce more per unit of water.	44	51	5	0	0
2. Establish ET (Evapotrasporation) reporting stations.	17	64	18	1	0
3. Accelerate research to determine the effect on crop yield of water application timing and amounts.	35	55	9	1	0
4. Expanded research and education programs to encourage irrigation scheduling.	34	53	13	0	0
5. Accelerate research and education of water conserving irrigation system design.	37	57	6	0	0
6. Establishment of low interest loan program for improved irrigation systems.	20	45	20	12	3
7. Increase Cooperative Extension Services support in irrigation system and water application education (additional area irrigation specialist).	20	49	21	10	0
8. Increase testing, monitoring and education programs for pumping plant efficiencies.	17	56	21	5	1
9. Initiate large-scale research, demonstration, and education programs on alternative irrigated farming techniques (minimum till, low pressure, trickle), partial irrigation farming, and improved dryland farming techniques.	31	49	10	9	1
10. Initiate programs that will increase farmer cooperation on testing new technologies in commercial farm conditions.	22	53	24	1	0
11. Establish producer and agri-business funded research foundations.	20	44	29	7	0
12. Establish producer information networks (price, education, new ideas, etc.).	21	49	27	3	0
13. Establish programs to assist farmers wishing to switch from irrigation to rangeland.	22	29	40	9	0
C. MANDATORY WATER SUPPLY RESTRICTIONS					
1. Mandatory well spacing.	15	27	25	25	8
2. Reduce allowable water withdrawals to less than 3 acre-feet per acre per year.	9	35	32	14	11
3. Restrict crop water applications to a percentage of their full requirement.	4	22	33	30	11
4. Require irrigation scheduling.	14	34	24	17	11
D. INCREASE WATER SUPPLY (IMPORTATION AND MANAGEMENT)					
1. Continue interstate feasibility studies with emphasis on quantity, sources, timing and cost.	14	45	18	13	10
2. Study of feasibility of using alternative energy sources (wind, solar, etc.) to transport interstate and intrastate water.	15	42	21	13	9
3. Study the feasibility of using playa lakes as a recharge water source or an irrigation water source.	9	58	23	9	1
4. Expand the demonstration and education program to increase farm soil moisture availability from natural rainfall and snow.	23	66	8	3	0
5. Expand the research effort into the utilization of saline water.	27	62	8	3	0

Please indicate which three recommendations should have the highest priority (Example: A-1, B-7, C-4) B-1 A-5 B-9 D-5 /A-3

Of the four general strategies (A,B,C,or D) please indicate the one area where the major efforts should be directed. B

Please list other comments on back side.

Exhibit 1. Total responses from New Mexico Water Conference in percent, 1982.

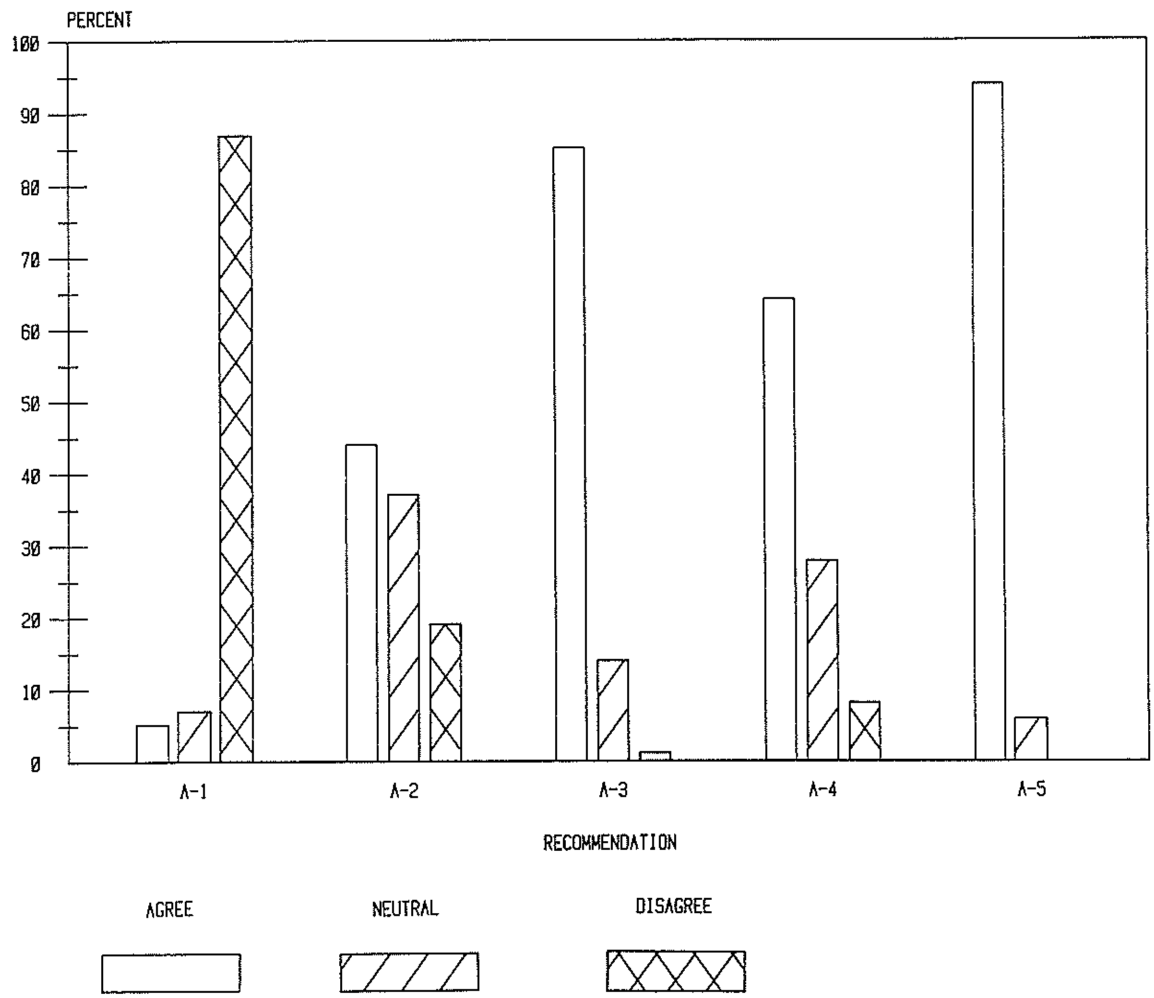


Figure 2. Recommendations for options for action for baseline measures, New Mexico Water Conference, 1982.

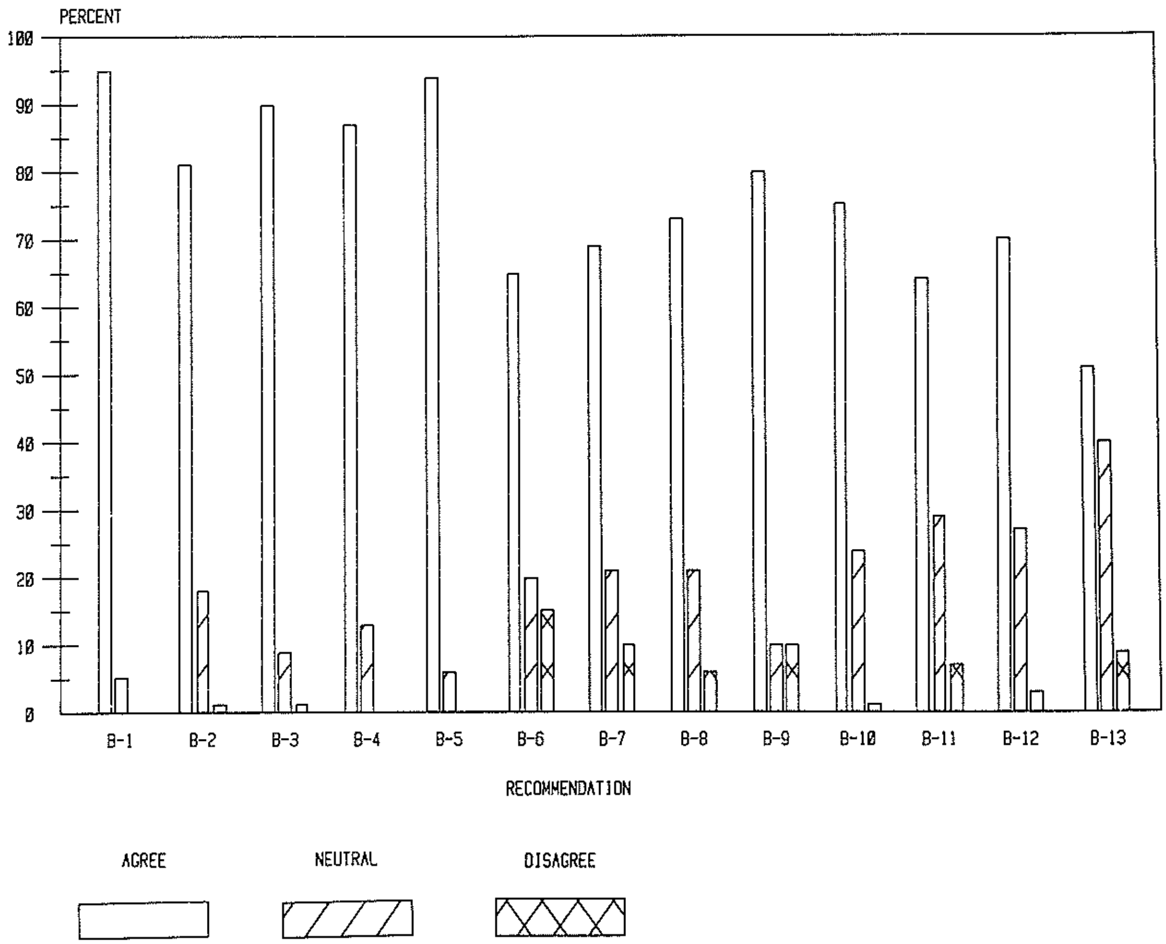


Figure 3. Recommendations for options for action for voluntary conservation measures, New Mexico Water Conference, 1982.

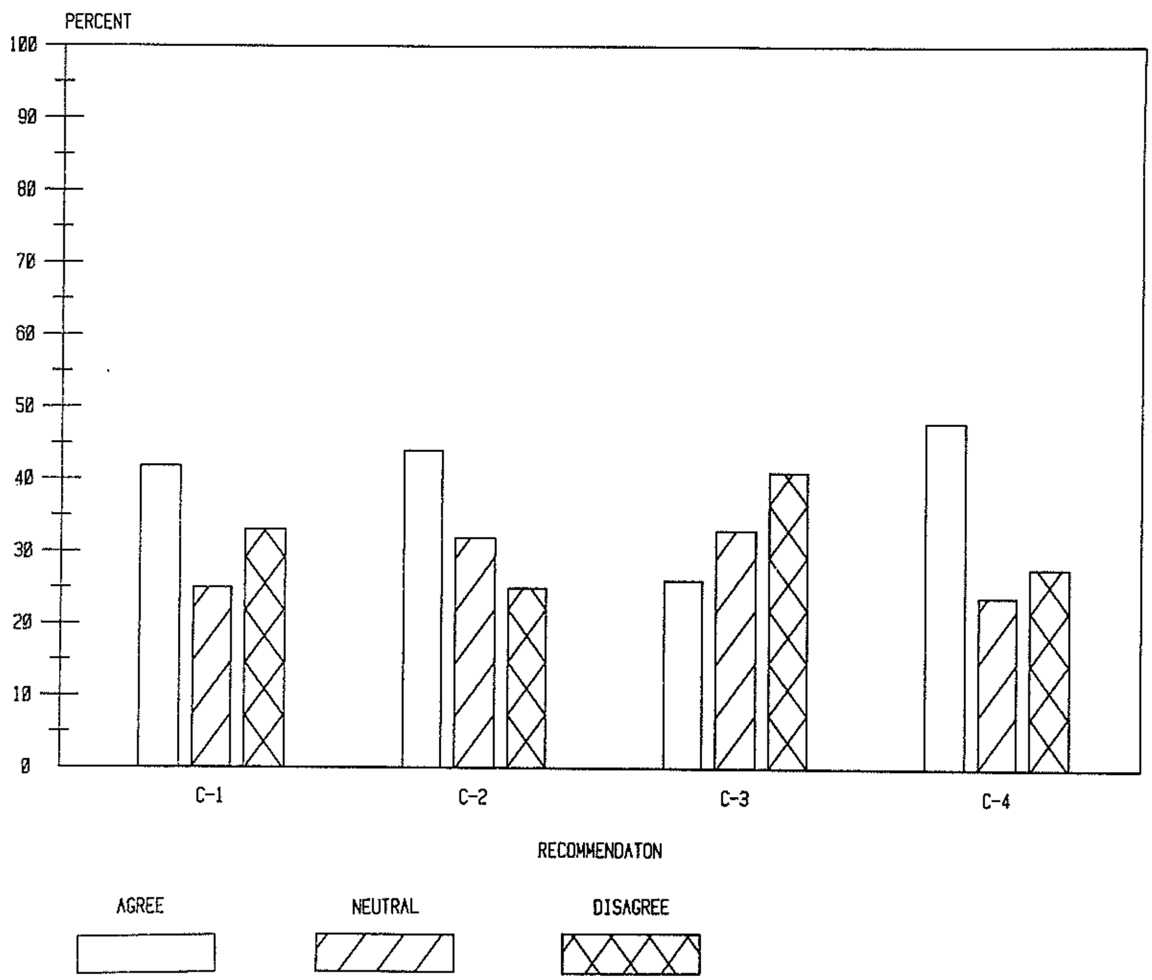


Figure 4. Recommendations for options for action for mandatory conservation measures, New Mexico Water Conference, 1982.

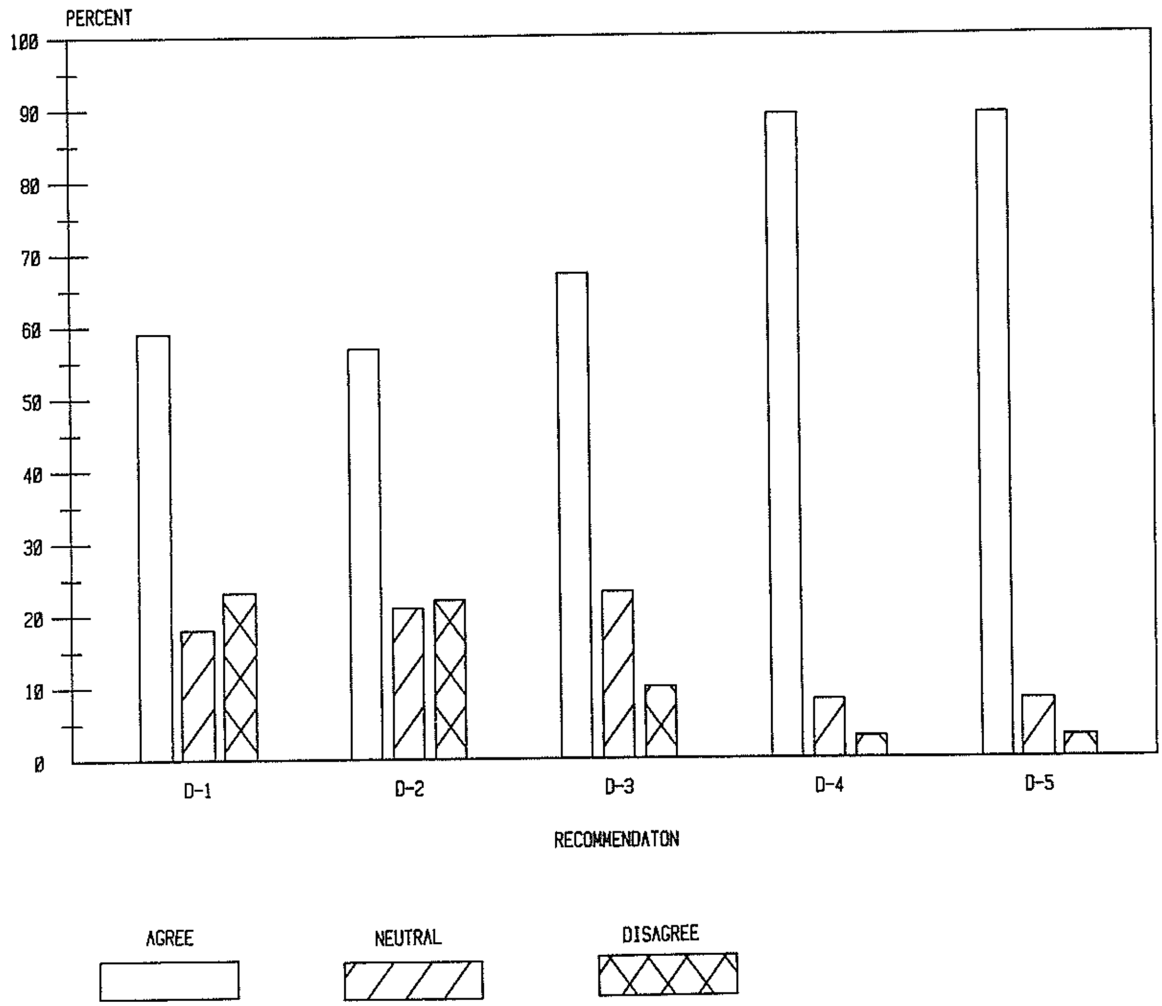


Figure 5. Recommendations for options for action for importation measures, New Mexico Water Conference, 1982.

increased funding of research, demonstration and extension, and 64 percent agreed with A-4 to increased SCS assistance.

The responses of the agricultural producers for baseline measures followed the total responses very closely for the most part. There were, however, a few notable exceptions. While only 44 percent of the total group agreed with A-2 for the establishment of an export promotion board, 79 percent of the agricultural producers agreed with this option.

All of the options for action examined under the voluntary strategy had a majority of the respondents in agreement (Figure 3). Option B-1 for crops that produce more per unit of water had 95 percent of the respondents in agreement, and B-5 for water conserving irrigation design had 94 percent. Other options for action receiving strong agreement were B-3 (water timing effects on yield), B-4 (irrigation scheduling), B-2 (ET reporting station), and B-9 (large-scale research and education farms) with 90, 97, 81 and 80 percent, respectively. With all the possible options for action under the Voluntary Strategy the agricultural producers were within 10 percentage points of the group total, except for B-10. On option B-10, which was to initiate programs that will increase farmer cooperation on testing new technologies in commercial farm conditions, 86 percent of the agricultural producers agreed with this while only 75 percent of the total respondents agreed.

None of the proposed options for action under the mandatory strategy received a majority either in agreement or disagreement. Slightly over 40 percent of the respondents agreed with C-1 (mandatory well spacing) and C-2 (reduce withdrawals to a percent of full). On all the possible options for action there were at least 25 percent with an opposing view and at least 24 percent that were neutral. A greater percentage of the agricultural producers were neutral on all the options except for C-1. Agricultural producers disagreed more strongly with option C-1, mandatory well spacing.

More than 50 percent of the respondents were in favor of all the options for action under the importation strategy. There were 89 percent in favor of both D-4 (soil moisture from natural methods) and D-5 (research saline water). Under the increase water supply strategy, 20 percent of the agricultural producers agreed with D-1, to continue studying the feasibility of interstate transfers, and 15 percent agreed with D-2, to study moving interstate and intrastate water with alternative energy sources.

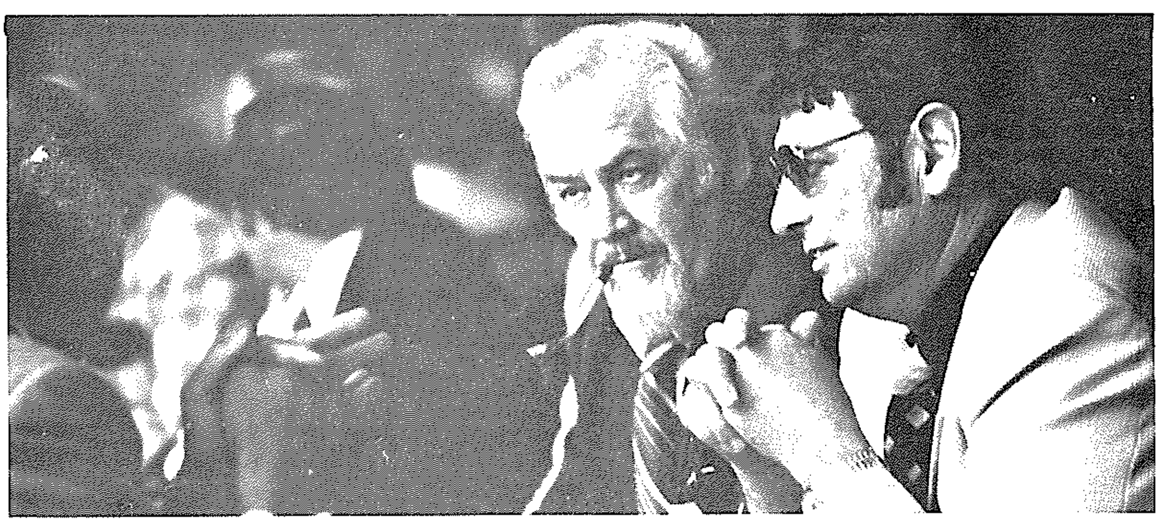
The four options for action the respondents listed as having priority were B-1, A-5, B-9, and D-5 tied with A-3 (Exhibit 2). These options for action were selected by asking each respondent to indicate his top three priority options. The B-1 option, to accelerate research and demonstration of crops that produce more per unit of water, was selected most. Option A-5, to continue funding for monitoring groundwater depletion and its effect, was second. B-9, to initiate large-scale research, demonstration, and education programs on alternative irrigated farming techniques (minimum till, low pressure, trickle), partial irrigation farming, and improved dryland farming techniques, was third. Options for action D-5, to expand the research effort into the utilization of saline water, and A-3, to increase the funding of agricultural research, demonstrations, and extension, tied for fourth place.

Of the four general strategies considered: A-baseline, B-voluntary water demand reduction -- conservation, C-mandatory water supply restrictions, and D-increase the water supply (importation and management), the strategy recommended where major efforts should be directed was B or voluntary water demand reduction -- conservation. About 85 percent of those responding selected this measure as the guiding policy (Exhibit 2).

	Priority options for action (percent)	Priority general strategy (percent)
A. BASELINE		4
1. "Business as Usual" -No action.	2	
2. Establishment of an export promotion board.	2	
3. Increased funding of agricultural research, demonstration, and extension. . . .	7	
4. Increase SCS technical and financial assistance in the Ogallala area.	2	
5. Continued funding for monitoring groundwater depletion and its effect.	9	
B. VOLUNTARY WATER DEMAND REDUCTION--CONSERVATION.		85
1. Accelerate research and demonstration of crops that produce more per unit of water.	10	
2. Establish ET (Evapotrasporation) reporting stations.	1	
3. Accelerate research to determine the effect on crop yield of water application timing and amounts.	5	
4. Expanded research and education programs to encourage irrigation scheduling. . .	2	
5. Accelerate research and education of water conserving irrigation system design. .	5	
6. Establishment of low interest loan program for improved irrigation systems. . .	4	
7. Increase Cooperative Extension Services support in irrigation system and water application education (additional area irrigation specialist).	2	
8. Increase testing, monitoring and education programs for pumping plant efficiencies.	2	
9. Initiate large-scale research, demonstration, and education programs on alternative irrigated farming techniques (minimum till, low pressure, trickle), partial irrigation farming, and improved dryland farming techniques.	8	
10. Initiate programs that will increase farmer cooperation on testing new technologies in commercial farm conditions.	4	
11. Establish producer and agri-business funded research foundations.	4	
12. Establish producer information networks (price, education, new ideas, etc.). . .	2	
13. Establish programs to assist farmers wishing to switch from irrigation to rangeland.	4	
C. MANDATORY WATER SUPPLY RESTRICTIONS		4
1. Mandatory well spacing.	1	
2. Reduce allowable water withdrawals to less than 3 acre-feet per acre per year. .	3	
3. Restrict crop water applications to a percentage of their full requirement. . .	1	
4. Require irrigation scheduling.	3	
D. INCREASE WATER SUPPLY (IMPORTATION AND MANAGEMENT)		7
1. Continue interstate feasibility studies with emphasis on quantity, sources, timing and cost.	3	
2. Study of feasibility of using alternative energy sources (wind, solar, etc.) to transport interstate and intrastate water.	1	
3. Study the feasibility of using playa lakes as a recharge water source or an irrigation water source.	1	
4. Expand the demonstration and education program to increase farm soil moisture availability from natural rainfall and snow.	5	
5. Expand the research effort into the utilization of saline water.	7	

Exhibit 2. Options for action and strategy priorities, responses from New Mexico Water Conference, 1982.

SESSION III



MEET THE SPEAKERS

SESSION III

Hoyt Pattison is a 20-year member of the New Mexico state legislature representing the sixty-third district. He is the House minority floor leader. He lives and farms north of Clovis on the farm his father homesteaded. He is a member of several agricultural related organizations including the advisory committee for the Plains Branch Agricultural Experiment Station and the board for Water Incorporated. He is an NMSU graduate.

Darrell W. Webber is the new regional director of the Bureau of Reclamation, Southwest Region at Amarillo. He is responsible for administering the development and conservation of water resources in all or part of five southwestern states including New Mexico. In his 25 years with the bureau he has held several scientific and administrative posts. He is a graduate of the University of Kansas.

Merle H. Niehaus is head of the agronomy department at NMSU. His research background includes grass management and soybean breeding at Ohio State University where he also was associate chairman of the agronomy department. He is a member of the Council for Agricultural Science and Technology, the American Society of Agronomy, the Crop Science Society of America and the American Association for the Advancement of Science. He holds degrees from Purdue University and Oklahoma State University.

William R. Pearson is assistant chief of the planning division of the Corps of Engineers, Southwestern Division Office in Dallas. In more than 20 years with the corps, he has served on several Washington-level water policy task forces dealing with planning studies and water conservation measures. He is a graduate of South Dakota State University and is a member of the American Society of Civil Engineers, the Society of American Military Engineers and the American Water Resources Association.

BUREAU OF RECLAMATION WATER PROJECTS

Darrell W. Webber
Southwest Regional Director
U.S. Bureau of Reclamation

It is a real treat for me to take part in your conference and to have the opportunity to get acquainted with all of you. You have certainly made me feel welcome here in the "Land of Enchantment." Coming from the plains of Kansas, I already felt at home here on the High Plains of the Southwest or the Llano Estacado. There are many similarities with my home in Kansas.

It seems that in both areas, many times we are plagued by a sudden overabundance of water or we are handicapped by a prolonged lack of water. In fact most residents of both areas would probably agree with my hydrologists who say the last time we had an accurate weather forecast was when God told Noah there was a 100 percent chance for rain.

It has long been a fact of life in this region that water must be stored during those moisture fat years to be used during the lean years. With increasing demands on available water supplies as a result of a growing population, a need for more irrigation water, and heavier industrial requirements, it is not surprising that the predictions on the life of the Ogallala aquifer are of deep concern.

Since 1902, the Bureau of Reclamation has been involved in water development in the west, and today I want to describe some of our current activities here in New Mexico.

Obviously the theme of your conference, "Hope for the High Plains," reflects your concern for the future of this area. A future which depends on a dependable supply of water. I am sure citizens in the other five states involved in the Economic Development Administration's High Plains Study share your feelings.

Shortly after Congress initiated the High Plains Study (1976), we launched the Llano Estacado Playa Lake Water Resources Study in New Mexico, Texas, Oklahoma, Colorado, and Kansas (1977). Since our findings assess a specific water resource in the area and methods employed to utilize it, we feel the information is pertinent to the High Plains Study.

The purpose of our study was to investigate the availability of playa lake water supplies in the southern High Plains regions of eastern New Mexico and the Texas Panhandle in addition to the High Plains areas of Colorado, Kansas, and Oklahoma lying south of the Arkansas River.

Playa lakes are natural depressions, sometimes reputed to be buffalo wallows, which collect rainfall and snowmelt seasonally. Most of the water collected is lost to evaporation. Some farmers use the water as a supplemental supply. There are some efforts to lengthen the storage period by structural modification. The thrust of the investigation was to determine:

1. the dependability of the supply;
2. where, when and how much of this water is available; and
3. how and to what extent these playa lake water supplies are being utilized.

We found that since evaporation rates are seldom exceeded by precipitation amounts, the uncertainty of the supply and the costly modifications required to produce carryover storage, the playa lakes are unlikely candidates for any large scale projects.

The results paint a positive picture of local conservation practices in the vast area covered by the study. In fact the myriad of conservation methods being employed is quite impressive.

Innovative farmers and ranchers are changing water application practices, timing, and spacing. Many of the crops are drought-resistant strains developed through extensive research and which also consume less water. These progressive minded conservationists are also employing soil moisture sensing and better, more efficient water-saving cultivation practices. Our studies pointed out that tailwater systems are being used extensively to re-use surface runoff.

Some irrigation districts maintain quite active conservation pursuits under the bureau's Rehabilitation and Betterment Program. In May 1968, the Carlsbad Irrigation District signed a Rehabilitation and Betterment contract with the United States.

This contract is being accomplished with district forces and machinery purchased with program funds. The project is 87 percent complete with 89 miles of canals and laterals now lined. All work under the contract is scheduled for completion in 1984 for an approximate cost of $6 million. Anytime you are in this area we would encourage you to see for yourself how these repayable dollars were used to modernize an irrigation system.

A rehabilitation and betterment study is underway for the Arch Hurley Conservancy District on the Tucumcari Project. A rough draft of the R&B report has been completed and is being reviewed in our regional office.

Some rehabilitation work is underway on the Middle Rio Grande Project's low-flow conveyance channel. The channel begins at the San Acacia Diversion Dam and continues downstream for approximately 70 miles. The overall intent of the low-flow conveyance channel was to effectively salvage and transport water through the lower portion of the middle valley and into the normal pool of Elephant Butte Reservoir. Water salvage continues to be of increased importance due to the state of New Mexico's obligation under terms of the Rio Grande Compact.

As a result of several years of sediment accumulation and deterioration of channel slopes over the period of 1975 to 1981, the channel is presently inoperable.

Partial funding was made available by the Commissioner of Reclamation late in calendar year 1981 and a contract was awarded January 27, 1982, for rehabilitation of the first seven miles of the channel. Depending on the availability of funds, a contract will be awarded this summer for rehabilitating an additional 13 miles. Floodway rectification and channelization to Elephant Butte will be accomplished in 1983 and 1984, once again depending on available funding.

While the bureau has been active in New Mexico for many years, we will continue to seek ways of providing water and power where it is needed in New Mexico so the acute need does not become a chronic anemia.

We are to conduct special studies to determine the feasibility of developing hydropower energy by constructing hydroelectric power plants at the existing Caballo and El Vado dams. Both studies will be completed during FY 83.

Subject to concurrence of the Office of Management and Budget and Congress, the bureau is gearing up to start a $68 million, eight-year program to prove whether or not winter cloud seeding can increase the water available in the Colorado River Basin. A substantial amount of runoff could occur in the Rio Grande Basin. Financing for the program is being sought through funds provided by the sale of hydroelectric energy from the bureau's Colorado River facilities. This weather modification effort could well enhance the prospects for a project we are studying now.

Feasibility investigations for the Gallup Project were initiated in November, 1973. Initially, this investigation was aimed at developing a water supply for the city of Gallup, New Mexico. In early 1975, the Navajo Indian Tribe indicated an interest in joining with Gallup in the planning of a water delivery system from the San Juan River. We renamed the study, Gallup Navajo Indian Water Supply Project, and began to paint with a broader brush, extending the study to include the eastern part of the Navajo Reservation. The investigation evaluates three plans for development of additional water supplies from the San Juan River to meet immediate and long-term demands. We are scheduled to complete the draft feasibility report and the Draft Environmental Statement May 31, 1982.

The preferred plan calls for water to be released from Navajo Reservoir into the San Juan River and diverted from the river just upstream from the Animas River junction, then delivered to 32 communities in New Mexico, Arizona, and Utah. The plan also includes a regional water treatment plant so that treated water would be delivered to project users.

A private dam and reservoir are under study by the bureau in north central New Mexico. The Santa Cruz Dam and reservoir provide irrigation service to approximately 4,200 acres in the Santa Cruz Irrigation District. The dam was privately constructed in 1929 with an initial reservoir capacity of 4,500 acre-feet, of which about 25 percent has been lost to sediment deposits. In addition, there has been structural deterioration of the dam face, and the spillway capacity is inadequate by present standards.

The study will determine the present dam deficiencies and cost for repair and modifying the spillway as well as the need for additional water and the economic feasibility of providing additional reservoir capacity. The investigation is scheduled to be completed in 1983.

In southeastern New Mexico there soon will be more tangible evidence of reclamation at work in the state. The Brantley Project is located on the Pecos River in Eddy County about midway between the cities of Carlsbad and Artesia. A safety evaluation of McMillan and Avalon dams showed that potential flood would exceed the existing spillway capacity at McMillan and cause the structure to be overtopped, which could result in failure of the dam. The study also showed that the existing spillway capacity of Avalon Dam downstream, would protect that structure only from a flood originating below McMillan Dam. A failure of one or both of these structures would result in serious downstream flooding, particularly to the city of Carlsbad.

As planned, Brantley Dam will replace McMillan Dam which is deemed unsafe and will provide flood control storage not presently available in the two existing structures. Final designs for Brantley Dam are currently under preparation. Present plans call for a contract award in the summer of 1984, and it is expected that a four-year construction period will be required.

We welcome opportunities to work closely with the states in our region. We are presently completing designs for spillway modifications to the Ute Dam for the state. Ute Dam, located on the Canadian River near the New Mexico-Texas border, was constructed by the New Mexico Interstate Stream Commission in 1963 to accomodate the storage allocated to New Mexico under the Canadian River Compact. As originally constructed, the spillway was not equipped with gates. However, provision was made in the design for future installation of gates to raise the conservation pool elevation by 27 feet, which would provide all the storage permitted under the compact.

In 1979, a contract was executed between the state and the bureau that provided for bureau design and supervision of construction for the spillway modification, subject to reimbursement of all expenses by the state.

Designers at our Engineering and Research Center in Denver determined that $30 million would be required for gate installation which was more than the state could spend. At the request of state officials we conducted studies of alternative means of providing the storage. As a result, a labyrinth weir to replace the existing uncontrolled ogee spillway was selected. The crest of the labyrinth will be 27 feet higher than the ogee and will require raising the earth dam and dike 10 feet to provide the necessary surcharge storage.

Final designs were started after the state legislature appropriated the necessary funds in the spring of 1981. The designs and specifications should be completed late this spring. The state will issue the specifications, take bids, and award the contract this fall. Construction is anticipated to take about 18 months.

We in reclamation want to re-emphasize our eagerness to work with state and local governments, other non-federal entities, and private interests. The allocation of water resources must be in accordance with state law, and management of water resources should reflect maximum state and local government involvement.

Since my recent selection as Southwest Regional Director for Reclamation, I have been impressed with the efforts expended to assure that we are developing, managing, and using our water resources in the most beneficial way. There is a growing sensitivity to the complexities of coping with present and future demands for water.

From the very beginning, reclamation was designed to pay its way through repayment of project costs by water and power users. In all, 85 percent of total costs will be repaid, half of that amount with interest. Some recreation, flood control, and other features of benefit to the nation or a region generally are not repaid by water users.

This pay back aspect of reclamation's operations sets the bureau apart as a unique federal agency, a fact many times overlooked when cries of "porkbarrel projects" are bandied about. These accusations usually originate in the east because here in the west, people are more familiar with the role reclamation has played in the progress of this country.

The truth of the matter is that reclamation projects have already returned more money to the federal treasury than they have taken out, so the bureau's projects are not a drain on the treasury. From 1902 to the start of 1980, some $8.8 billion has been appropriated for western reclamation projects. In only 38 years of that time span -- 1940 through 1978 -- those projects generated $25.6 billion in federal tax revenues.

These most interesting figures offer an opportunity to understand that priorities are different, and in fact change as you travel from one area of our country to another.

Most of us would probably agree that we live in a world of change. There have been changes in the west and its needs and uses of water; in our nation and its needs and priorities; in the attitudes concerning the relationship between the federal, state, and local governments and natural resources management. Even so we can and will be realistic.

We must shift with the winds of progress and shape the reclamation program to be responsive to the future and meet the needs of our country. We will work with you in every way possible to meet and solve the water and power demands of the present and the future. Thank you.

CONSERVATION THROUGH CROPS RESEARCH

Merle H. Niehaus
Head, Agronomy Department
New Mexico State University

In the future, water for irrigation in New Mexico and much of the southwestern United States will be more scarce and more expensive than it is at present. Economic pressure will force farmers to conserve water. Whether they conserve wisely depends, at least partially, on research now underway or being planned. Such research includes work in soils, crops, climatology, engineering, and economics. However, for this discussion, only crops research will be addressed.

In crops research one might divide the efforts into breeding and management; or into basic and applied; or into grains and forages. However, for the purposes of this presentation I am dividing crops research into research on conventional existing crops and research on new crops. I certainly won't cover all research in this area but will discuss several representative examples.

New Mexico State University has fairly large research programs on cotton and alfalfa with significant efforts on wheat and sorghum. The cotton breeding program was responsible for the release of one of the world's first hybrid cottons in 1979. While this research was not aimed primarily at saving water it certainly has that potential.

The first hybrid, NX-1, has outyielded the better conventional cultivars by about 15 percent over the last 5 years. The range has been from a 3 percent to a 36 percent yield advantage for the hybrid. It is important to note that the higher percentage comes from a year when yields were relatively low. It appears that the hybrid shows the most advantage over conventional cotton in years when there is stress. More testing is needed but apparently the hybrid is more stable across certain environments and can produce more fiber per unit of water used than can the conventional cottons, especially if water is limiting.
Unfortunately, NX-1 is not adapted to eastern New Mexico or west Texas. However, other hybrids are being developed which we hope will be. This

research is still progressing and, almost certainly, better hybrids will be released by New Mexico State University and by the 15 commercial companies which now are working on hybrid cotton.

Other types of research on cotton are being pursued by all the agricultural universities and research agencies in the cotton growing areas. Researchers with Texas A&M have a line with much better ability to produce on limited water than other cottons. Texas Tech researchers have been able to pinpoint some of the reasons for this increased efficiency using the electron microscope. The increased water efficiency appears to be caused by what amounts to a better plumbing system in the efficient line.

At New Mexico State University and in Texas, irrigation scheduling research has shown that cotton can be predisposed to a need for either more or less water by the amount and timing of irrigation during the early season. Cultivars respond differently to such treatments indicating breeding progress might be made for this characteristic.

Alfalfa is New Mexico's most important cash crop. However, it is also a large user of water with many farmers applying as much as 70 acre-inches of water per year. Observations and research indicate that despite this high use of water, alfalfa is a drought tolerant crop.

In the arid southwest, alfalfa was developed and is grown as a crop which does its best when water is not limiting. This does not mean that new cultivars cannot be developed which do well with something less than the optimum amount of water. Certainly using less water on alfalfa will result in lower yields. However, if 50 percent of the normal amount of water can produce 80 percent of the normal yield, a farmer may make more profit than would be made with normal amounts of water.

A New Mexico State University project now underway has shown that there is genetic variation in alfalfa for its ability to grow and produce when supplied with limited amounts of water. This variation exists between cultivars and also between plants within cultivars.

Furthermore, tests conducted in 1980-81 have shown that this characteristic can be passed on to the next generation. It therefore appears that an alfalfa which will be a more efficient user of water than the alfalfa now being grown in New Mexico can be developed.

Other research now underway or being planned is designed to determine the effect of limited water on the root system, the quality of the forage, and the longevity of the stand of alfalfa. An attempt has begun to develop a cultivar having the ability to produce profitable yields with limited amounts of water.

Funds have been requested which, if granted, will allow research to be done on scheduling of irrigation water where the total amount is limited. We know much about how to apply 70 inches of water for maximum yields of alfalfa. We don't know how to schedule 36 inches of water for maximum yields especially considering the fact that alfalfa is a perennial and irrigation scheduling one year almost certainly affects yields the following years.

Sorghum has long been known as a drought tolerant crop and is grown on both irrigated and dryland in the arid southwest. It does respond to irrigation but has the ability to produce a crop even when water is severely limited.

Sorghum research is being conducted at most agricultural universities and research agencies in the southwest. Hybrids have been available for 25 years and hybrids usually have their greatest advantage over cultivars when there is stress on the plants. Therefore, much of the present work is aimed at developing better hybrids, particularly for moisture stress conditions.

Sorghum work at New Mexico State's Plains Branch at Clovis is aimed at higher yield and particularly at higher yield of protein. The researchers at Clovis also have found that the use of antitranspirants can increase sorghum and other crop yields particularly when water is limiting. Most of the water a crop uses is evaporated from the leaves. Antitranspirants reduce the amount of water evaporated and therefore increase water use efficiency.

Other research aimed at conserving underground water use on sorghum includes furrow diking and water harvesting. Furrow diking consists of constructing a small dike across the furrow every few feet so that rainfall is held near where it falls rather than allowing it to move to the low spots in the field. Making such a dike requires almost no energy and can produce significant yield increases.

Water harvesting in one form consists of creating an impermeable soil surface on half the area such that all rainfall must move to the untreated area thus doubling the effective rainfall on that area. The treatment being used at Clovis is common table salt. It reacts with the clay making the surface impermeable but does no permanent damage to the soil.

Perhaps the most intensely researched crop in the world has been wheat. New findings continue to create new avenues for improvement, however, and yields continue to increase. Emphasis has been more on increasing yields under either full irrigation or dryland conditions and this research has been successful. Better lodging resistance, disease and insect resistance, and better response to fertilizer have all increased water use efficiency in wheat.

Research now underway in New Mexico and probably at other locations is aimed at evaluating available cultivars for their yield potential when they are grown under limited irrigation. Further work is needed on how to best use irrigation water when only a fraction of what is needed is available.

Other conventional crops are being studied and certainly there will be progress in developing cultivars and management systems which require less water.

Relatively new and exciting areas of research are being conducted at several locations in the southwest. Those areas of research are the introduction of new crop species to the southwest from other parts of the world, and the domestication of wild species. Several research projects are now underway. With better funding, research in these areas would be increased because they show promise of being very productive. Funding is difficult to obtain because there is no clientele group to lobby at the state or national level.

At New Mexico State one project is aimed at domesticating guayule. Guayule is a perennial shrub native to Texas and Mexico which has natural rubber in its cells. This type of rubber is in demand for radial and large heavy duty tires. The United States gets natural rubber now from Hevea rubber trees which grow in Malaysia and Indonesia, areas of the world which could quickly be cut off from the United States.

Guayule research results from Texas, New Mexico, Arizona, and California have all been promising although several years of work are needed before commercialization can proceed. A viable guayule rubber industry would be of strategic importance and would allow farmers to grow an alternate crop requiring less water. However, funding for new crops research has been very limited and, in the case of guayule, some research and seed increase plots now in the field may have to be abandoned.

Another crop being studied at New Mexico State is crambe. Crambe is closely related to the mustards and was introduced from the Mediterranean region. It produces a seed high in oil which contains high levels of erucic acid. Erucic acid oil is in demand by industry because it remains stable at very high temperatures. It can be used as a lubricant in rolled steel mills, in jet engines, and has many other industrial uses. It can also be made into a nylon which, for many uses, is superior to nylon made from petroleum. Crambe is a short season crop which therefore uses less water than many crops. It would fit well into a double-crop system.

In Texas and Arizona a crop called guar is being grown and research on how to increase yields has been initiated. Guar seed contains a gum needed by the food and petroleum industry. It is used to keep drilling mud particles in suspension and for wells drilled deeper than 15,000 feet it is almost irreplaceable. Guar does well on relatively poor soil, requires less water than many crops, and since it is a legume it requires no nitrogen fertilizer. It shows great promise as a crop which can be greatly improved by breeding and by management research. The acreage is almost certain to increase over the next few years.

Other crops being studied are buffalogourd, a protein and energy source; jojoba, an oil source which would help replace sperm whale oil; mustards and rape, edible oil and fuel sources; millet, a feed grain; and kochia, a forage crop.

New Mexico State has a kochia project at Clovis which is attempting to convert kochia from a weed to a desirable forage crop. Kochia is a very efficient user of water and produces high yields. It has some undesirable traits, however, which need to be eliminated or reduced.

Russian thistle is a similar plant which has been studied in the past. It, too, is water efficient but needs even more improvement than does kochia. There are other candidate crops that might fill a need and at the same time use less water than currently grown crops. The sunflower and Jerusalem artichoke are possibilities.

Another promising genus is *Cuphea*. It contains more than 300 species, all of which grow wild. Two are native to the southwestern United States. The others grow in Central or South America. All contain lauric acid oil having 8 or 10 carbon atoms per molecule. All of our supply of this type oil comes from palm trees and must be imported. *Cuphea* oil would be used in making soap, detergents, cosmetics, jet engine lubricants, etc. It is in demand and it does appear that *Cuphea* would require less water than most presently grown crops. There is no research on *Cuphea* in the southwest at present although funds for research are being requested.

Another genus which produces a needed oil is *Lesquerella* or bladderpod. It is found throughout the southwest. It produces an 18-20 carbon chain molecule which is needed by industry. Among other things, it is used as a grease thickener. *Lesquerella* needs much breeding improvement but limited research indicates it is a good candidate for domestication. It requires relatively small amounts of water. Again, there is no research at present in the southwest because of lack of funding.

Many other species of crops and native plants exist which might be a good source of a product in demand and which are low water users. Much research is needed to find and develop these species into crops adapted to the arid southwest.

HIGH PLAINS - OGALLALA AQUIFER STUDY
WATER TRANSFER ELEMENT

William R. Pearson
Assistant Chief, Planning Division
Southwestern Division, U.S. Army Corps of Engineers

1. Introduction

This paper presents findings on the four water transfer alternatives authorized by the High Plains Study Council (HPSC) for further study by HPSC Resolution 8. Figure 1 indicates the four alignments studied. The routes have been sized to provide costs on a range of flows to restore and maintain the maximum amount of irrigated lands projected to go out of production between 1977 and 2020 under Management Strategy One, voluntary conservation.

The total first costs shown in Table 1 (p. 149), including interest during construction, are based on 1977 prices, a nine-year authorization and design period, a fifteen-year construction period with equal investments each year and compounded using the FY 81 federal interest rate of 7 3/8 percent. The unit costs of water were computed using the quantity of water estimated to be deliverable to the farmlands. These costs include the cost of the energy necessary to pump the water from the source. The cost of energy in 1977 dollars interpolated from projections of future energy prices and other project data are shown in Table 2 (p. 150).

The Fish and Wildlife Service prepared reconnaissance-level evaluations of the potential adverse and beneficial impacts along the route corridors that might be associated with construction of the potential water transfer plans. These impacts will be discussed later in the paper.

2. Study Authority and Organization

The Corps of Engineers is charged by Section 193 of Public Law 94-587 with studying the engineering feasibility of transferring surplus water into the High Plains region from adjacent areas. In addition to determining the costs, the corps is to consider the environmental impacts

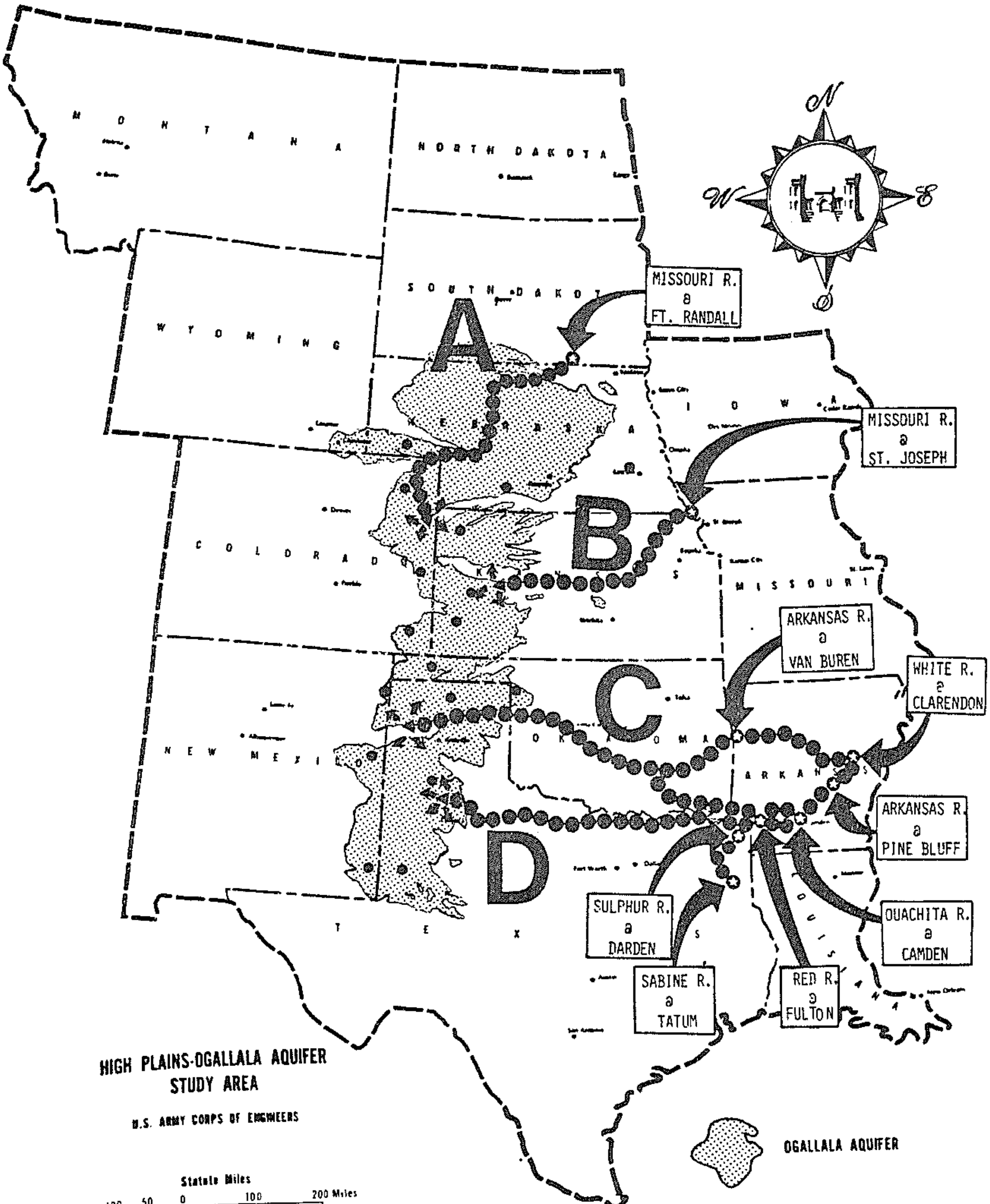

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Figure 1

of those alternative plans along corridor routes. This work has been closely coordinated with other elements of the High Plains-Ogallala Aquifer Study being undertaken by the states and the general study contractor for the Department of Commerce.

Results of the corps studies have been furnished to the general contractor who has determined the benefits of water transfer and has made estimates as to the economic impacts of water transfer to the High Plains region.

The firm of Camp Dresser & McKee Inc., heads a consulting consortium selected by the Department of Commerce to serve as general contractor for the overall study. The consortium includes the firms of Black & Veatch, Consulting Engineers and Arthur D. Little, Inc., and maintains a study office in Austin, Texas. Their work, as well as the corps', is overseen by the High Plains Study Council which is made up of the six states involved and the Department of Commerce.

To support the grassroots management philosophy of the overall study, the commander of the Army Corps of Engineers assigned management responsibility for corps involvement to the Southwestern Division located in Dallas, Texas. The Southwestern Division is being assisted by the Missouri River Division, located in Omaha, Neb., on those transfer options falling within the Missouri River Division boundaries. The Southwestern Division represents the corps on all coordinating and technical committees such as the High Plains Study Council and its Liaison Committee and the Department of Commerce's (EDA) Technical Advisory Group.

3. The Study

The initial phases of the corps' effort involved review of previous reports and identification and screening of alternatives. Those phases were begun during the Plan of Study stage and culminated in recommendations to the HPSC in April 1980. The recommendations were that the number of alternative transfer routes to be carried forward in the study be reduced to four. Those recommended routes were:

a. Alternative 2 (now called route A); source, Missouri River at Fort Randall, S.D.; route, southwest through Nebraska to terminal storage at Bonny Reservoir, Colo.

b. Alternative 3 (now called route D); sources, White River at Clarendon, Ark.; Arkansas River at Pine Bluff, Ark.; Ouachita River at Camden, Ark.; Red River at Fulton, Ark.; Sulphur River at Darden, Texas; and Sabine River at Tatum, Texas; route, west through Texas to terminal storage at Bull Lake, near Littlefield, Texas (subsequently replaced by Blanco Canyon near Crosbyton, Texas).

c. Alternative 4 (now called route B); source, Missouri River near St. Joseph, Mo.; route, southwest through Kansas to terminal storage on the Arkansas River near Dodge City, Kan.

d. Alternative 5 (now called route C); sources, White River at Clarendon, Ark.; Arkansas River at Van Buren, Ark.; Ouachita River at Camden, Ark.; Red River at Fulton, Ark.; Sulphur River at Darden, Texas; and Sabine River at Tatum, Texas; route, west and northwest across Oklahoma into the panhandle of Texas to terminal storage on the Canadian River near Canadian, Texas.

As a result of that recommendation, the High Plains Study Council passed Resolution 8 on April 17, 1980, authorizing continued study of the recommended four routes.

In February 1981 the corps provided an initial set of estimated costs to the High Plains Study Council for the four alternative transfer routes. The costs per acre-foot of water delivered ranged from $278 to $880 per acre-foot. Those costs were based on quantities of water from 2.0 to 7.2 million acre-feet per year. As a result of that exercise, it was determined that there were several opportunities to improve the consistency and breadth of approach used in the cost estimates. The current estimates, adopting those improvements, are based on a 15-year construction period with information also shown on 10- and 20-year periods; the current federal interest rate of 7 3/8 percent; 1977 construction costs; 1981 "off peak" energy costs in 1977 dollar values (interpolated from 1980 and 1985 values provided by Black & Veatch); 10 percent loss between source and terminal storage; 10 percent loss between terminal storage and farm site; 85 percent utilization of the system's annual capacity; and appropriate evaporation losses in the terminal reservoirs.

4. Water Requirements

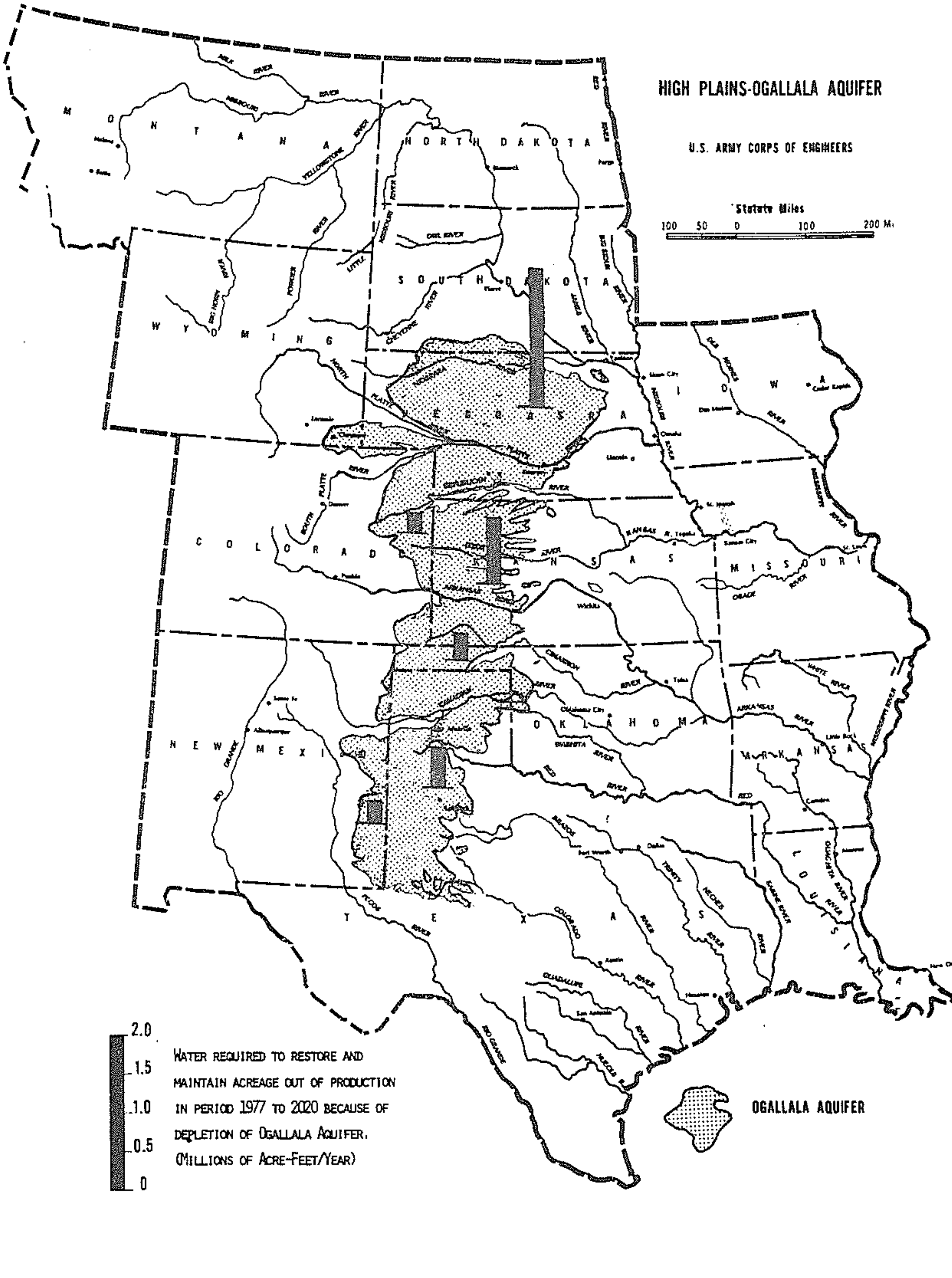
As described earlier, the corps has determined costs to transfer a range of quantities of water for each route. One end of the range has been defined by information generated by the states and provided to the corps by the general contractor. That information defined the quantities of water required to restore and maintain irrigated lands in the High Plains Study area that might otherwise go out of production between 1977 and 2020. One basic assumption behind those estimates is that Management Strategy One, voluntary conservation, is in effect. The quantities of water needed are tabulated below and shown graphically in Figure 2.

State	Water Requirements (acre-foot)
Colorado	250,000
Kansas	862,000
Nebraska	1,783,000
New Mexico	302,000
Oklahoma	334,000
Texas	525,000

The other end of the range of flows for which costs were prepared was to be defined by the requirements of Resolution 6. Preliminary guidance on base flows that would meet the intent of HPSC Resolution 6 was provided by the general contractor in October 1980. Subsequent discussions between the corps and the general contractor resulted in a letter of May 11, 1981, which provided a general outline of references to be used in complying with Resolution 6. In the absence of specific base flows, the Fort Worth and Tulsa study managers evaluated the guidance in the May 11 letter and decided on a set of base flows which appeared to meet present and future in-basin needs. Those base flows are tabulated below. The assumed base flows were provided to the general contractor for review prior to their use in this phase of the study.

Source	Average Annual Flow (cfs)	Assumed Base Flow (cfs)
Sulphur River at Darden, Texas	2,500	1,000
Sabine River at Tatum, Texas	2,300	1,000
Arkansas River at Pine Bluff, Ark.	41,500	10,000
Arkansas River at Van Buren, Ark.	30,150	10,000
Oucahita River at Camden, Ark.	7,600	3,000
Red River at Fulton, Ark.	17,400	5,000
White River at Clarendon, Ark.	29,200	5,000

Base flows for the Missouri River at Fort Randall, S.D., and St. Joseph, Mo., are to reflect current needs as defined by present operating procedures of the Missouri River Navigation System and future needs projected by the Bureau of Reclamation for the Missouri River Basin. The Missouri River Division Office of the Corps of Engineers has evaluated the base flows necessary to meet present and future requirements and the impact of various potential diversions on those base flows. Transfer alternatives A and B, through Nebraska and Kansas, have been designed to deliver an assumed minimum quantity of water per year to define the lower end of the range. In the case of route A, the studies have shown that diversion of any significant amounts of water from the Missouri River at Fort Randall Dam, S.D., would reduce the dependability of full service navigation as currently defined. Therefore, for purposes of cost estimation, a system was designed to meet the year 2020 needs of Nebraska plus one-half the needs of Colorado, or about 1.9 million acre-feet per year. The assumed source for route B, the Missouri River near St. Joseph, was projected to have about 2.1 million acre-feet of water surplus to the projected needs. Costs were analyzed for a system to divert 2.1 million acre-feet which after losses equates to 1.6 million acre-feet deliverable to agricultural land in the High Plains. The maximum quantity for which those routes were designed provides sufficient water to restore and maintain lands in Nebraska, Colorado, Kansas, Oklahoma and a portion of Texas, or about 3.4 million acre-feet per year.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WATER REQUIRED TO RESTORE AND MAINTAIN ACREAGE OUT OF PRODUCTION IN PERIOD 1977 TO 2020 BECAUSE OF DEPLETION OF OGALLALA AQUIFER. (MILLIONS OF ACRE-FEET/YEAR)
OGALLALA AQUIFER

Figure 2

Routes C and D through Oklahoma and Texas were designed to deliver a range of flows, defined at a mimimum by the quantities necessary to restore and maintain lands in Texas, Oklahoma and New Mexico, and at a maximum by the quantities available for diversion above the base flow requirements of the sources.

The range of needs assumed for the various routes does not in any way imply that those quantities are available for transfer. Judgements of that type can only be made by the affected parties after detailed studies. The range was established for the purpose of defining costs.

5. Sources

Availability of water from the designated sources is a question of the allocation of the residual resource after existing and potential in-basin uses have been satisfied. The policy for inter-basin transfer has been set by the High Plains Study Council in their Resolution 6. That policy prescribes that states in the basins of origin, both upstream and downstream of diversion points, must have prior rights in perpetuity for beneficial use of the source streams. Only water surplus to in-basin needs over time would be considered for export. Any decision on implementation of a water transfer plan would be made by the exporting and importing states in cooperation with the U.S. Congress. This paper does not attempt to report on the institutional availability of water from source states, but only to evaluate the apparent physical availability of water for transfer and the engineering feasibility of the four alternative transfer routes.

In order to represent the present and future in-basin needs which must be met before export could take place, a hypothetical base flow has been assumed for each diversion point. The base flow is planned to be sufficiently large to meet both existing and future needs. Withdrawals from the source stream would not be taken when the stream flow was less than the base amount. Amounts exceeding the base flow would be skimmed and stored in nearby source storage to be transferred to the High Plains at a steady rate. On the Missouri River it was assumed that Fort Randall Dam would act as the source storage for the diversion across Nebraska and that an off-stream reservoir would be constructed near St. Joseph, Mo., for the route through Kansas. In all cases the base flow concept has been used.

The Water Management Branch for the Corps of Engineers in Dallas analyzed the individual source points using historical flow data and determined relationships between base flow, quantity of source storage, diversion pumping rate and dependable yield. The individual study groups then utilized those relationships to select the components of their source arrangement. The final report will include plots of the data for each source location.

The use of the largest available source storage allows the maximum yield from the source river. It is also important from a cost standpoint to have the source storage located as close to the source river as possible. This is necessary because the pumps and pipelines which remove and carry the water when available from the source stream to the source reservoir are much larger than the capacity of the canal system which is designed to remove the water from the source reservoir at a constant rate. The source reservoirs as presently conceived would be single purpose and could experience wide fluctuations in water levels. Because of the size, location and operating requirements, the source storage reservoirs would cause major environmental impacts. Those impacts will be addressed in the final report.

6. Transfer Facilities

The primary means of transferring the water would be by an open, trapezoidal, concrete-lined canal. Routes were selected based on the concept of a series of ridgeline canals connected by pumping plants. The pumping plants are needed to lift the water several thousand feet to the terminal points. The individual routes, their respective elevation differences and the number of pumping plants required are shown in the following table.

Route	Total Elevation Difference (ft)	Maximum Number of Pumping Plants
A (Nebraska)	2,400	18
B (Kansas) South/North	1,745/1,965	16/29
C (Oklahoma)	3,600	49
D (Texas)	2,725	30

Gravity flow would transfer the water between pumping plants with siphons used to cross major streams, some highways and railroads. Other roads and railroads would be relocated to cross the canal by bridge. Tunnels would be used to cross some ridges or series of ridges. The pumping plants would utilize up to 10 turbine-type centrifugal pumps driven by electrical motors. The pumps would discharge into prestressed, precast concrete pipe for delivery to higher elevations where it would again flow by gravity to the next pump station. The canals would be designed for flow velocities of less than five feet per second with three to six feet of freeboard and check gates at approximately four-mile intervals. The maximum length of the canals for each route is shown in the following table.

Route	Length of Canal (miles)
A	620
B (south)	375
C	1,135
D	850

Route C utilizes the Arkansas River Navigation System Channel to transfer the water 209 miles from near Little Rock, Ark., to W.D. Mayo Lock and Dam on the Oklahoma/Arkansas border. Pumping plants would be constructed at each of the existing six locks and dams. Movement of the quantities of water contemplated in this study could probably be accomplished without increasing the dimensions of the navigation channel.

Canal dimensions are defined in the Cost and Design Manual prepared by the Corps of Engineers for this study. Figure 3 shows a cross-section of a 10,000 cubic feet per second canal which is close to the largest that might be required for the quantities under consideration.

The canal system is designed to operate at a constant discharge. For design purposes it was assumed that breakdowns, weather, etc., would limit the system to 85 percent of capacity. The canals, therefore, are oversized to provide a flow capacity of 1.18 times the design flow. Losses of water in transit because of evaporation, seepage, etc., were assumed to be 10 percent of the flow.

The tentative alignment of the canals is shown in Figure 1. Although the alignments have been selected to follow ridge lines, avoid rough terrain and environmentally sensitive areas, and minimize pumping plants and siphons, they remain tentative and should not be assumed to be the "best" routes without much more detailed studies.

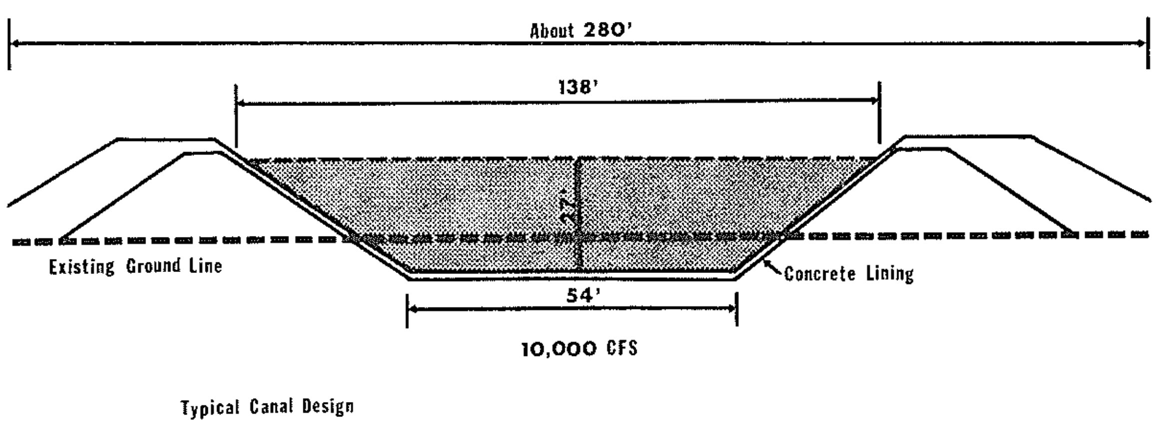

Figure 3

7. Terminal Storage

Since agricultural water needs in the High Plains area are not divided equally throughout the months of the year, it is necessary to provide storage at the terminal end to be able to distribute the water when needed. The general contractor has provided a tabulation of seasonal irrigation water needs typical of the northern and southern portions of the High Plains. That information is shown below.

Month	Percent of total year water demand	
	North	South
January	0.5	1.0
February	1.0	3.0
March	5.0	6.0
April	10.0	19.0
May	18.0	8.0
June	12.0	11.0
July	19.0	24.0
August	25.0	19.0
September	7.0	7.0
October	1.0	1.0
November	1.0	0.5
December	0.5	0.5

Terminal storage facilities were developed for each route and were designed to be of sufficient size to meet the above monthly needs while receiving a constant inflow. Evaporation consistent with the location of the particular terminal reservoir was accounted for along with an assumed loss of 10 percent between the terminal reservoir and the farm site. Route C assumed the use of existing reservoirs for terminal storage, while routes A, B and D used sites which are presently undeveloped. A tabulation of the routes and their terminal storage sites is shown below.

Route	Terminal Storage Site	Storage Required (acre-feet)
A (Nebraska)	Seven sites in Nebraska and one in Colorado	1,330,000
B (Kansas) (South)	Utica Site, Kan.	1,820,000
C (Oklahoma)	Existing Meredith & Optima lakes, Canadian Site	2,630,000
D (Texas)	Blanco Canyon Site, Texas	3,800,000

8. Multipurpose Opportunities

This reconnaissance-level study only considers costs to transfer water from specific sources to specific terminal points. However, opportunities exist throughout the system to develop related benefits which could help justify the system's costs. For example, flood control could be included in conjunction with the source and terminal reservoirs, and recreation and fish and wildlife benefits could be considered at the reservoirs and along the canals themselves. In addition, municipal and industrial water supply, as well as supplemental wildlife water supplies, are very probable multipurpose opportunities along the transfer routes. Although it was evident that additional project-related opportunities existed with each of the transfer plans evaluated, an in-depth study of them was considered to be beyond the scope of this reconnaissance-level planning effort.

9. Environmental Studies

To supplement its engineering feasibility studies, the Corps of Engineers conducted, in cooperation with the U.S. Fish and Wildlife Service, broad-based assessments of the potential environmental impacts that could be expected along each of the corridor routes studied. These studies included identification and mapping of sensitive environmental and cultural areas to assist in corridor layout that would avoid adverse impacts on state, federal and private wildlife refuges; Indian reservations; military reservations; ethnic settlements; management areas; natural areas; parks; recreation areas; archeological and historic sites; wetlands; and national or state forests. The general importance of wildlife habitat, aquatic systems, land use, physiographic features, aesthetics and environmental quality adversely affected along the study routes was assessed using known base resource data for the regions involved. General conclusions reached separately by the four Corps of Engineers' districts are summarized as follows. The actual assessments conducted are quite extensive and are currently under review in the Southwestern Division Office.

Route A (Nebraska). Looking at the entire project, it appears that most of the fish and wildlife impacts would occur in the northern half of the study area. This is due to aquatic habitat losses in Lake Francis Case and the Missouri River below Fort Randall Dam; woodland habitat losses due to construction of Eagle Creek Reservoir; and wetland, woodland, and native prairie losses due to canal construction in the Niobrara Valley and the sandhills in Nebraska.

Most of the fish and wildlife benefits would occur in the southern half of the project area (assuming that woodland habitat losses are adequately compensated for). This is due to the reservoirs providing increased public fishing and hunting opportunities, flow increases in the North Platte and Platte rivers, and the possibility of flow increases in other streams in Nebraska and eastern Colorado. Also, the construction of additional open water north and south of the Rainwater Basin area could help distribute crowded waterfowl populations over a larger area, thus reducing disease problems during spring migration.

Endangered and threatened species losses will probably be insignificant over most of the project area, except for those aquatic species associated with the Missouri River. The bald eagle, whooping crane and interior least tern could benefit from various aspects of the project.

To achieve the full compensation goal of no net loss of in-kind habitat, an estimated 10,000-25,000 acres of land would be required to compensate for anticipated woodland and wetland losses.

Route B (Kansas). Although no federal or state designated fish and wildlife area, refuge, or public hunting area would be directly affected, the construction and operation of an intake structure in the Missouri River at St. Joseph, Mo., may result in some entrainment and impingement of fish as a result of high intake velocities. Also, significant environmental effects would result from construction of the intake storage facility that would require approximately 19,000 acres of land in northeast Doniphan County near White Cloud, Kan. Construction of this reservoir would inundate an area containing scenic high loess bluffs and heavily dissected drainage valleys mantled with an oak-hickory forest containing significant terrestrial wildlife habitat.

Although 13,000 acres of terrestrial habitat would be eliminated, these acres would be supplanted by an equivalent number of aquatic acres. This ecosystem change would result in a large reduction of faunal and floral diversity.

In a region of western Kansas where terrestrial wildlife habitat is at a premium, and primarily relegated to the narrow stream borders, removal of between 15,800 and 33,000 acres of habitat for terminal storage reservoirs would have a major negative impact on terrestrial wildlife species, such as mule and white-tailed deer. However, the negative impacts of the western storage reservoirs could be ameliorated by development and management of wildlife areas adjacent to the lake shore. Management of the upper reaches of most Kansas impoundments has provided excellent wildlife cover, increasing the carrying capacity of many wildlife species in the drainage when compared to preproject conditions.

Considering the impacts along the canal corridors themselves, an adverse environmental impact on mammal movements in the area would occur. The fenced canal effectively would be an impregnable barrier along its entire length, the exceptions being small areas adjacent to the canal's siphons and lift pumps. Random population movements of such mammals as furbearers (raccoon, coyote); small game (rabbits, squirrels); and big game (mule and white-tailed deer) would be restricted once the canal was constructed.

Any water transfer route through Kansas, with the inclusion of the storage lakes, would impact on agriculture throughout its entire length. A southern route, 376 miles long, would remove between 26,300 and 37,600 acres of private land from production, depending upon the channel size selected. The northern route studies, 337 miles long, would remove between 23,600 and 33,700 acres from agricultural production.

Route C (Oklahoma). The route C water transfer system would involve the construction of more than 1,000 miles of concrete canals and associated pumping facilities, and periodic or permanent inundation of more than 300,000 acres of land for storage reservoirs. The major loss of land and associated wildlife habitat would most likely have extensive and significantly long-term environmental impacts. Each of the seven storage reservoirs would involve environmental, social and cultural resource impacts equivalent to a large multiple-purpose water resource project. The severity of environmental impacts associated with the loss of valuable wetland and flood plain habitat inundated for storage reservoirs would greatly exceed the losses from construction of the canals and pumping facilities. Also, the beneficial aspects of a lake fishery and recreation resources normally associated with most water resource projects would be limited by the single-purpose nature of the storage reservoirs due to widely fluctuating water levels.

In addition to the probable loss of aquatic organisms and flood plain habitat downstream from the diversion intakes affected by reduced flow -- including the indirect impacts on coastal regions and the possible impacts on several federal-listed threatened and endangered species -- the loss of critical habitat along the canal route itself needs to be considered and evaluated in more detailed studies.

Although not evaluated in great detail in this study, the impact of transporting water from sources of better quality than the water presently stored in Lake Meredith should be considered. Transporting softer, more acidic water to hard and basic water regions needs to be considered if further, more detailed studies are pursued. Also, future studies should determine if the transportation of water and microscopic organisms to different drainage basins would impact endemic species in the High Plains region.

Route D (Texas). Construction of more than 900 miles of concrete canals and associated pumping facilities, and periodic or permanent inundation of as much as 437,000 acres of land for storage reservoirs, would have a significant long-term environmental impact. Each of the seven storage reservoirs included in the alternative route D plan would involve environmental, social and cultural resource impacts equivalent to a large multiple-purpose water resource project. Also, the beneficial aspects of lake fishery, recreation and aesthetic value normally associated with a water resource project would be constrained in these single-purpose water transport storage reservoirs, as presently planned, due to fluctuating water levels.

It is believed that environmental quality problems relating to air and water pollution could be reduced to tolerable levels during construction. Environmental design, landscaping and reclamation of disposal sites and exposed areas also could limit impact on aesthetic values. Social impacts related to land acquisition and relocation of homes and people would also be minimized in accordance with existing laws, policies and regulations relating to economic compensation to affected landowners and tenants. Cultural resources largely could be avoided, incorporated into interpretive facilities, or mitigated through relocation or data salvage. Costs for cultural resources mitigation have been included in the water transfer facility cost estimates.

Extensive adverse impacts on wildlife habitat would be expected with construction of water transfer facilities and storage reservoirs. Potentially significant impacts on stream fisheries and indirect impacts on coastal fish and wildlife resources also are possible as a result of withdrawals of source water and construction of holding reservoirs. There are a number of ways to reduce and minimize adverse impacts on these resources through design of facilities and detailed mitigation planning. There is also a number of opportunities relating to development of fish and wildlife resources on lands acquired for right-of-way for canals and storage reservoirs and on lands which could be acquired and managed specifically to replace wildlife productivity lost to construction. Costs for wildlife mitigation also have been included in the overall cost estimates.

Severely fluctuating water levels at storage reservoirs would generally constrain development of a traditional lake fishery. However, management of water levels in a system operation, and dedication of quantities of water for fish and wildlife purposes, could result in some innovative approaches to both lake fishery development and management and downstream flow enhancement to affected streams. The canal, being a uniform concrete bottom structure, would also be a significant constraint to development of an aquatic ecosystem of beneficial use to man. The lack of bottom substrate, bank vegetation and cover, temperature fluctuation, and general lack of a supporting primary/secondary productivity ecosystem would severely limit diversity and general health of a fishery in the canal. Velocity, fluctuations in discharge, and entrainment of larvae or juveniles in pumping facilities would also constrain development of a fishery. However, the potential is there for designing an appropriate bottom structure, shelter areas, and protection devices on pumping facilities in order to create an ecosystem functional for at least a few native fish species or potential exotic introductions.

Natural heritage areas along or near the affected corridor and storage reservoirs could be considered for acquisition and incorporation into mitigation planning of the water transfer system. Opportunities to preserve some of these unique areas, and make them available to the public, would be present in detailed planning.

Due to expected water fluctuations in storage reservoirs and limited aesthetic value of concrete lined channels, recreation potential of these facilities would be limited, particularly in northeast Texas and Arkansas where natural or manmade water resources are abundant. However, in portions of north-central and west Texas, the canal and terminal storage at Blanco Canyon may provide a focal point for satisfaction of identified water resources-related recreation demand. Off channel recreation lakes utilizing a portion of the water transferred, or localized hiking, biking, or other recreational outlets along the canal itself, may be included in more detailed planning.

10. Cost Estimates and Route Comparisons

The total investment cost of each route is composed of the total first cost combined with the cost of interest during construction. The total first cost includes the estimated construction cost, plus the engineering and design, plus supervision and administration of the actual construction. Interest during construction represents the return foregone on the funds invested in the construction before the project begins to generate benefits. Because of the length and size of the routes and the resulting lengthy construction period, the interest-during-construction cost is a sizable portion of the total investment cost. The total investment cost is very sensitive to the assumed length of the construction period.

To display the costs in a more understandable way, the total investments costs were converted into an average annual cost. The average annual cost is the amount that would have to be recovered each year to repay the original investment over a specific period of time at a specific rate of interest. For this study, the interest rate used was the FY 81 Federal Water Resources Council rate of 7 3/8 percent and the period of analysis was 100 years. The average annual cost is then combined with an estimated annual operation, maintenance and replacement cost and an estimated cost of energy to arrive at a total average annual cost of the project.

In order to bring the cost data to an even more practical level, the total average annual cost was divided by the quantity of water assumed to be delivered to the farm site. This procedure results in an average cost of water in dollars per acre-foot per year. This value could be described as the cost of an acre-foot of water in storage at the terminal reservoir. It does not reflect the cost of distribution of the water from the terminal reservoir to the farm site. Table 1 shows the average cost of water per acre-foot per year. The table also shows the energy component of that total cost of water.

Electrical power costs used in the study were furnished by Black & Veatch, Consulting Engineers. They were based on 1977 price levels and projected through the year 2020. Projected completion of the water transfer project is in year 2005, so full use of electrical power would not begin until that year. Power costs beyond year 2020 were projected by linearly extrapolating Black & Veatch's projected 2000 and 2020 values. These costs are specific to each route and are generally higher for routes C and D as shown in Table 1.

11. Conclusions

Although the report is still under review and final conclusions have not been reached, the study results indicate:

a. Construction of canal systems capable of transporting up to 9 million acre-feet of water from adjacent areas is feasible from an engineering standpoint.

b. The first cost of such systems ranges from $3.6 billion for a system to deliver 1.6 million acre-feet per year to western Kansas to $22.6 billion to deliver 6 million acre-feet per year to the northern panhandle of Texas and the panhandle of Oklahoma. The costs are in 1977 dollars, and the construction period is assumed to be 15 years.

c. The annual cost for such systems ranges from $413 million per year for the Kansas route to $3.8 billion per year to transfer 8.7 million acre-feet to near Lubbock, Texas, along route D. Those annual costs include energy at current prices in 1977 dollars.

d. The costs in this report do not include a distribution system beyond the terminal reservoirs. The quantities of water have been reduced by a factor of 10 percent to account for losses in distribution.

e. The unit cost of water delivered to terminal storage in the High Plains-Ogallala area ranges from $226 per acre-foot to $569 per acre-foot in 1977 dollars.

f. The construction of any of these systems would require from 10 to 20 years, with 15 years considered a reasonable period. Reducing or increasing the construction period by 5 years can alter the investment cost by as much as 25 percent.

g. Large amounts of energy would be required to operate any of the systems. From 4 to nearly 50 billion kilowatt hours per year of electrical energy would be required to operate any one system. The annual cost of that energy in 1977 dollars would range from $140 million to $1.1 billion.

h. If increases in energy costs occur as projected, the unit cost of water will range from $320 to $880 per acre-foot in year 2105.

i. Water sources exist in areas adjacent to the High Plains with sufficient flow to provide up to 8.7 million acre-feet per year of water for transfer to the High Plains. <u>None</u> of that water has been identified as surplus to the needs of the basin of origin.

j. Construction of any of the routes would result in major environmental impacts. These impacts would include altered flow regime on the source streams, inundation of large areas for source and terminal storage, conversion of large amounts of agricultural land to other purposes, disruption of wildlife patterns, and transfer of organisms to new areas. Any future studies considering implementation should include comprehensive environmental studies.

TABLE 1

Unit Cost of Transferred Water[1]

Route	Quantity Transferred (mafa)[3]	Energy Cost[2] ($/acre-foot)	Unit Cost of Water[4] ($/acre-foot)
A	1,980	80	292
	4,135	99	292
B (North)	1,615	108	335
	3,878	104	302
B (South)	1,615	87	255
	3,878	82	226
C	1,260	154	569
	6,040	154	434
D	1,550	112	490
	8,700	130	441

[1]15-year construction period, first cost amortized at 7 3/8 percent interest for 100 years, energy and construction in 1977 dollars.

[2]Energy cost based on 1981 energy price in 1977 dollars.

[3]Million acre-feet annually.

[4]Includes energy cost.

TABLE 2

Project Data

Route	Total Static Lift (ft)	No. of Pumping Plants	Length of Project (Miles)	Quantity Transferred (maf)	Investment Cost[1] ($billion)	Energy to Operate (kwh/yr)
A (Neb.)	2,400	18	620	4.1	10.6	18,000
B (Kan.)	1,745	16	375	3.88	7.4	14,200
C (Okla.)	3,600	49	1,135	6.04	22.6	42,700
D (Texas)	2,725	30	850	8.7	20.6	50,000

[1] 1977 prices.

TABLE 3

Summary of Energy Costs

Transfer Route	Range of Quantities (million acre-feet delivered per year)	Energy Requirement (billion kilowatt-hours per year)	Energy Cost (1977 price level)	
			$/acre-foot	mil $/year
A	2.0	7.0	80	158
	4.10	18.0	99	409
B	1.62	6.2	88	142
	3.88	14.1	82	320
C	1.26	8.4	154	194
	6.04	42.7	154	930
D	1.55	7.5	112	174
	8.71	50.	130	1,134

MEET THE SPEAKERS

PANEL DISCUSSION

Don Frederick is the Santa Fe bureau chief for the El Paso Times. He has covered news events such as the El Paso water suit and the Santa Fe prison riot. He also covers the New Mexico state legislature and the governor's office. He has been a reporter for the Santa Fe New Mexican and the Grand Junction Daily Sentinal. He is originally from Washington D.C. and is a graduate of Northwestern University in Evanston, Ill.

Harrison "Jack" Schmitt is a U.S. senator from New Mexico. In 1972 he was the lunar module pilot for Apollo 17 and the only geologist in the space program. He later was the organizer and director of NASA's varied energy programs. As senator, he serves on several senate committees and subcommittees including appropriations, interior, and energy and water development. He is the recipient of numerous professional and academic awards including the NASA Distinguished Service Medal, the Arthur S. Fleming Award and three honorary doctorate degrees. He is a graduate of California Institute of Technology and Harvard University. He also studied under a Fulbright Scholarship at the University of Oslo, Norway.

Hugh G. Robinson is a Major General and the division engineer for the Southwestern Division of the U.S. Army Corps of Engineers. He is responsible for the corps' water resources development activities in all or part of eight states including New Mexico. Previously, he was the deputy director of the Civil Works Directorate in the Office of the Chief of Engineers in Washington D.C. There, he was the principal assistant to the Director of Civil Works in managing the corps' water resources development program. He is a West Point graduate and has a master's degree from the Massachusetts Institute of Technology.

Garrey Carruthers is assistant secretary for Land and Water Resources, Department of the Interior. He previously was acting director of the New Mexico Water Resources Research Insitute and a White House

Fellow and Special Assistant to the Secretary of Agriculture. His research service includes membership on several committees including the Western Agricultural Research Council, the Eisenhower Consortium and the Western Agricultural Economics Association Committee on State Agricultural Experiment Stations. He holds degrees from Iowa State University and NMSU.

John Hernandez is deputy administrator of the Environmental Protection Agency. His wide ranging administrative experience includes positions as dean of engineering at NMSU, acting co-director of the New Mexico Environmental Institute and director of the Environmental Health Engineering Program at NMSU. He also has served on several advisory committees dealing with the environment. He holds degrees from Harvard University, Purdue University and the University of New Mexico.

Harold Brayman is assistant staff director of the Senate Committee on Environmental and Public Works. For the past 13 years, he has worked closely in a number of legislative areas including air, water and solid waste pollution control and most significantly, the federal water resources development program. A graduate of Princeton University, the London School of Economics, and the Columbia University School of Journalism, Brayman wrote for The National Observer newspaper before coming to the Senate in 1969.

Steve Reynolds is the New Mexico State Engineer. He holds several state offices including secretary of the New Mexico Interstate Stream Commission, New Mexico commissioner of the Rio Grande Compact Commission and New Mexico administrator of the Water-Resources-Planning Program. He is a member of some 17 advisory committees mostly dealing with water issues. He has received numerous service awards including the Distinguished Public Service Award, the Conservation Service Award and the J.F. Zimmerman Award for Outstanding Achievement and Unselfish Service to the State of New Mexico and the Nation. He is a University of New Mexico graduate.

THE FUTURE OF HIGH PLAINS AGRICULTURE*

Harrison Schmitt
U.S. Senator, New Mexico

The productivity of the farmers and related businesses in the High Plains area of the United States is unparalleled in the history of agriculture. From what was once wasteland with isolated dry land farming activity, there has been created a literal breadbasket for Americans and for the world.

But dark clouds are visible on the horizon. The lack of a coordinated multi-state approach to the mining of the water resource that has made High Plains agriculture what it is, has set the stage for disaster for the farms and the communities of this region. Unless there is a coordinated application of efficient water use, unless there is equitable water allocation, and unless there is a stronger High Plains agricultural research effort, then vast economic restructuring in an eight-state region will be necessary.

However, there are still many attractive options left to us to stabilize the agricultural economy of the High Plains. New Federalism, a spirit that is hopefully sweeping our land, is the principal hope for the High Plains agricultural community. Current federal conservation programs must be reshaped to emphasize local priorities and give local and state governmental entities more authority to deal with problems unique to their areas. The farmer and the rancher should be in charge of their destinies.

The answer to the problems we face is additional control by farmers and new federal policies that assist and do not hinder conservation and agricultural research.

The lesson of 50 years of organized attention to conservation is that local people know best what should be done. When you here in the High

*Senator Schmitt was unable to attend the conference, but sent his prepared talk for inclusion in the proceedings.

Plains decide on what is most cost-effective and what serves your needs the best, then the federal government should support you in your efforts: efforts directed locally at conservation; efforts supported nationally by agricultural research.

No amount of federal, state or local assistance will suffice in solving the problems of the High Plains if you, the farmer-consumer, do not take responsibility for your own future.

The combination of private and public research and technology efforts which allowed the expansion of ground-water exploitation that made the High Plains what it is today, must now be focused to produce a modern and wise use of this water resource. The principal components of the technological solution will be a more efficient use of existing fresh water, improved crop varieties that use less water and can withstand more low quality water and desalinization technologies that can provide new sources of water to augment or replace that lost in the High Plains.

The U.S. Department of Agriculture to some extent has begun to place a greater emphasis on watershed problems and soil loss. Federal government funding for research on the use and improvement of soil and water, including watershed regulations, has increased from $51 million in 1981 to $55 million in 1982, to a proposed $64 million in 1983.

In spite of this increase there still appears to be no comprehensive understanding by this administration or any previous administration of just how important science and technology are to the future of agriculture and to the United States as a whole. The United States must move rapidly to regain its dominance in world agricultural markets, not only for the betterment of the United States' economy, but also to have a peaceful weapon to counter the Soviet threat of military domination of the planet. My recent exposure to briefings on the military threat now presented by the Soviet Union has convinced me that we must use effective world-wide trade embargos to force the Soviets to dismantle their ever-expanding military industrial complex.

More specifically, with respect to the federal role of coordinating and cooperating with private, state and local agricultural activities, we must see an increase in emphasis both in research and in implementation in the following areas:

1. drip and sub-irrigation systems;
2. low pressure centerpoint irrigation;
3. low-till and no-till farming practices;
4. laser-leveling;
5. infra-red thermometry;
6. less water intensive crops;
7. water harvesting, wherever such harvesting may be possible to increase run-off;
8. general water-saving techniques, particularly where flood-irrigation is still required;
9. more efficient irrigation scheduling, including far better long-term rainfall forecasting; and
10. more efficient pumping and improved crop varieties, specifically adaptable to the High Plains area.

Energy supply and price, of course, will be a major factor in the viability of High Plains agriculture. It is still my belief that the only way we are going to assure reasonable energy prices and a guaranteed supply of energy resources, is through full deregulation of our energy economy, retaining the government as a referee of that economy but not as its manager. The proof of the pudding has recently been shown again in the effect of the decontrol of crude oil prices. Steadily dropping gasoline prices at the pump should make it clear to everyone just how positive the effect of decontrol of energy prices can be.

A greater use of tax incentives for increased water conservation should be explored. In that context, I am a co-sponsor of S-569, the Soil and Water Conservation Incentives Act of 1981. This bill would allow farmers and ranchers to take a 10 percent investment tax credit for the cost of conservation efforts related to their land. An investment for credit such as this would encourage more farmers to install and maintain conservation practices on crop land with serious erosion problems. Under a 10 percent investment tax credit program each dollar on federal tax not paid would reflect a ten-dollar private investment in conservation practices, this, yielding a five-fold increase in the purchasing power of the federal conservation investment.

According to estimates by the Congressional Joint Committee on Taxation, conservation tax credit utilization is projected to reach $120 million in five years. This would represent more than $1 billion in private sector investments and conservation activities. Incentives offered by such a tax program over the five-year period would go a long way toward solving erosion and conservation problems.

In summary, the essence of the future High Plains agriculture is in cooperation and assistance; cooperation between all interested parties: private, local, state and federal government, and assistance by the federal government wherever such assistance can be most effective in encouraging responsible agricultural activity.

We must all pull together if we are going to assure the long-range viability of High Plains agriculture. If we do not work together, then we will soon see a concerted effort for the federal government to begin to take control of the allocation of the water resources of the aquifer. Whenever the government tries to allocate scarce resources, history clearly shows that what starts out as a minor inconvenience ends up as an exacerbation of shortages. The gas lines to which we were exposed during the Arab oil embargo were made far worse by the heavy-handed attempts of government to allocate a scarce resource. The gas lines that were induced by government allocations will seem a minor inconvenience to the people of the High Plains when you have to line up with water buckets.

Finally, as we look to the future of ground water resources that are truly interstate in nature, it may be necessary to develop a whole new scheme of national water law which recognizes the interstate nature of water allocation problems. One idea I am studying is the development of water compact law applicable to interstate ground water resources such as the Ogallala Aquifer. Such a water compact law could be modeled after that which is used to allocate interstate surface water resources. Any thoughts that attendees at this conference and other interested persons may have on the concept of interstate ground water compact law would be much appreciated.

Congress needs your help and ideas; let's get started now while we still have real options left.

PANEL DISCUSSION

Maj. Gen. Robinson: I want to make just three points before we get into the rest of the panel and the question and answer period. First, I would like to second what Darrell Webber said about the Bureau of Reclamation with respect to projects. I think the great amount of misinformation that the general public acts on with respect to water resource projects is unfortunate. The acronym that they use all the time that refers to water resources projects I can't even repeat, but certainly we talk about pork barrel that gets everybody's back up a little bit when we are talking about water resource projects. Our projects, much like the bureau, pay for themselves many times over. If you're talking water supply and hydropower, 100 percent of that cost is recovered over the life of a project. In navigation, the federal government pays for most of the projects, but experience has shown that the tax returns and the increase in the nation's economic base are sufficient many times over to justify the cost of the navigational projects that are being built. And every one of those projects has far exceeded its expected growth and life. Some are still growing because they are still in the growing stage. With respect to flood control, local interests carry about 30 percent on the average across the nation for flood control projects. Flood control projects have prevented three times the cost of those projects already and that's a major savings to the national interest because the federal government is involved. Federal insurance, as you know, is involved in cost recovery and provides assistance to those who suffer from floods. And the more we can prevent, of course, the fewer dollars have to go out from the federal government. And finally, of course, half the recreation cost is paid for by the nonfederal sponsors. So I think we are very proud of the fact that we do have projects that produce meaningful results for the nation and for the region that we serve.

Let me talk a little bit about the High Plains study. I know the response to the questionnaires shows something on the order of 59 percent who wanted to pursue water importation, and of the farmers who replied, more than three-fourths of them said we should pursue water importation. There are a couple things that need to be understood about the water importation problem. One is we have not really identified the exact amounts that are available at the source. And if you go and talk to the source states, they'll tell you no water is available. So there is a question there with respect to coordination with those states. Certainly, one of the first things that must be done with respect to that water importation study is to go and talk to the states and try to figure out if there are in fact some flood waters, some damaging flood waters, that can be skimmed off the top or at the source and then transferred out to the west as needed. So the availability of water from the source states is a real question mark. I guess, along with that you must ask the question: Are all the purposes for which that water is now used superior to providing water to the High Plains for agriculture? That's a matter of what's in the national interest. If you ask the region a question, each region will, of course, report whatever is going on in that region. But I think the nutshell question is: Should we, as a nation, support, for agricultural purposes, the continued type of agriculture that exists for the High Plains region? And that's a policy question that somebody is going to have to answer before we can do anything about importation of water east to west. Certainly, as you can see, the cost of the program is so great that some federal assistance will be required if water importation to the High Plains ever is to become a reality.

Now, what kind of cost sharing are you going to have for that type of a project? Tnat's really a good question and I think it is another national policy issue that must be addressed. Some would say some of the purposes for water now being used at the source points are not really economical purposes and perhaps some of those purposes could be canceled. And we could look at that water as available for importation. That's a very dynamic question which nobody has addressed at this point. The key, I think, is that we are only in a reconnaissance phase of study. It is just a very preliminary study. All of those factors that Bill Pearson pointed out to you must be looked at in considerable detail before we can consider water importation to the High Plains region. Since the title of this panel discussion is "the view from here," let me go on to the one policy issue I think is important to all water resources planners, development agencies, and everyone on this panel, and that is: What is the long term national interest in water resource development projects? Clearly the Reagan administration is emphasizing cooperation with the states and local entities, and I think that's an important aspect of this water resources development program. We always have carried on a dialogue with local interests and with the states where we have presented those programs and have gotten support as an integral part of any program we've pursued in the Corps of Engineers. But we have never involved the states to the extent that the Reagan administration is suggesting. I believe that is a positive measure that needs to be pursued at great lengths. I already have held two state coordination meetings at my headquarters in Dallas for all of the states within the southwest region division. We hoped that would introduce a clear sense of priorities and, at least for short term purposes, a clear sense of a state or a local sponsor's willingness to pay and to help in the initiation of those projects.

That really brings me to the point that bothers me the most. When we talk to you, as states and as local interests, we would like to be able to talk to you in a very positive way and say: Here is what the federal involvement is going to be. We're unable to do that today. And we're unable to do that for a lot of reasons. One is our short term budget problem which must be solved.

So we don't know exactly how much money the federal government is going to be able to put up for new water resource development programs. In the Corps of Engineers we now have a program for fiscal year 1983 for potential new construction starts in which we've gone out and talked to the local interests and said, in essence: How much money would you put up to help us start construction projects? And we have a suggestion. We are suggesting that for water supply and hydropower they put up 100 percent up front. That's pretty heavy. We suggest for navigation they put up 75 percent; for flood control, 35 percent; and for recreation, 50 percent. Now we tried those figures out on 13 project sponsors who were looking for new starts for fiscal year 1983 and the success rate was not overwhelming. It was not overwhelming because, like the federal government, states also have their budget problems and they budget well ahead for the types of projects they think are appropriate for their state. We kind of switched horses on them in midstream and asked them to come up with some money they did not expect they would have to come up with. Obviously in order to participate, they have to go back and reshuffle their programs. That's very tough in the short term. So we did not get overwhelming response, and we are not yet sure how that program is going to come out. But we do know this, that in the long term we need to be able to go to the project sponsors and to the states and say here's the extent of the federal involvement as we see it today. What is the federal interest in the various project purposes? I still believe that question is relevant to talk about a little bit. It's a very important question. It's important to you and it's important to us as a water resource development agency. We need to be able to speak with some authority when we talk to you about your developmental projects. We hope the administration very quickly will put forth its view on water resources development and the federal interest in it. We also hope Congress then will act so that we're not caught between Congress and the administration. And we, in fact, speak with one voice when we come to talk to you about project purposes and how we should proceed. That, as I see it, is the principle issue that exists today in the water policy arena.

I'll just simply close by telling you a little story about Darrell. When Darrell took over as the regional director of the Bureau of Reclamation, his predecessor had left him three envelopes in the center desk drawer. The instructions on the three envelopes read: If you get in trouble open these three envelopes for help. Darrell hadn't been there a week when he got into trouble, so he opened the first envelope and it said, "Cut the budget." So Darrell cut the budget and sure enough that worked. Things went OK for about three or four weeks and then he got into trouble again. He opened the next envelope and it said, "Reorganize." So he reorganized and that worked. But I understand that Darrell is digging a hole for himself out there. So he's going to have to turn to that third envelope pretty quickly. I'll tell you what it says, "Prepare three envelopes."

Don Frederick: I'm sure Representative Pattison might have something to say about the state budget, but first we'll hear from Garrey Carruthers of the Interior Department.

Garrey Carruthers: Thank you very much, Don. It's good to be back in New Mexico. I've gone through the three envelopes and that's why I'm back.

My mission today is to confirm the rumor that Tom Bahr is promoting, personally promoting, that he will be the new director of the Office of Water Policy in the Department of the Interior. When you deal with water policy, you must have the best and the best water folks are from New Mexico. I nominated Dr. Tom Bahr of New Mexico to Secretary Watt of the interior to head up our new Office of Water Policy. Tom said that if I didn't get anything else into my three minutes, I had to get that in. We're looking forward to having Tom come back if he can pass the full field FBI investigation. The Office of Water Policy will function in liaison with all the states, searching out ideas from them with regard to desired Department of the Interior water policy. We have in the Department of the Interior, five bureaus that have something to say about water policy. Many think the Bureau of Reclamation is the only one that deals with water. But we have to coordinate a water policy for the Fish and Wildlife Service, the Park

Service, the Bureau of Land Management, the Bureau of Reclamation, and the Bureau of Indian Affairs. Imagine what it's like to put all those people in the same arena and try to formulate a single Department of the Interior water policy. Tom will have an exciting one year working in the department. I work for Jim Watt, the somewhat inhibited secretary of the interior. We run a quiet, laid back little operation on the banks of the Potomac. Perhaps you haven't heard of our activities. Let me just advise you at least of some water policy concerns. The president, President Reagan, and Secretary Watt are very pro water development. The president is from California and some of the best water projects in the country have been built there. Secretary Watt is from Wyoming and Colorado, and he too appreciates the value of agriculture and water resources. So we are committed. The president is on record, the secretary is on record, I'm on record as wanting to do something positive in water development. We're committed to new starts. The president has indicated, and OMB has set aside in the back of their minds, $48 million in the 1983 budget for the Corps of Engineers, the Soil Conservation Service and the Bureau of Reclamation to begin some new water projects. The president and Secretary Watt have recommended that the Bureau of Reclamation budget be increased by more than 20 percent. The corps budget also is in good shape regarding the kinds of water projects you're talking about in New Mexico. Most of the budgeting damage to the corps was in navigation, and that was because the corps anticipates recovering more fees from the states and from users. The Bureau of Reclamation has done that for years and, therefore, it is not reflected in their budget. There are several policy issues in the Department of the Interior I think are of significance to the High Plains area. The first one, which you should be aware of and you should work on right away, is the new Principles and Guidelines for planning water projects. You may remember there were rules and regulations called Principles and Standards. We felt, in this administration, that the Principles and Standards were designed to keep us from ever developing another water project in this country. They were just too rigid. The secretary asked us, in his capacity as chairman of the Cabinet Council of Water Resources and Environment, to give him more flexible guidelines for corps, Soil Conservation Service, and Bureau of Reclamation projects. These new Principles and Guidelines are out for your comments. You need to read them and determine whether we've done the job -- please comment! Don't wait for everyone else to comment. Negative people always comment. Positive people often read it and say, "Ah, that's okay. Carruthers is doing good work up there. Let's just let it coast." If that occurs, you may discover our design may not fly.

In conjunction with the Corps of Engineers, we're changing the planning process. It used to take about 17 years to plan a project; we're trying to cut it to 7. And we think that is necessary. But the centerpiece of the Reagan water policy, over the next seven years of the Reagan administration, will be cost sharing of water projects. That's really the central issue. The president, Secretary Watt and Secretary Gianelli all want to build projects, but we cannot build them under the old rules. We need new partners. We need these new partners and we're not fussy about who they are. We call them nonfederal, but we'd like for the private sector to become involved. There's no reason that the Corps of Engineers has to put all the money into a project. The hydropower unit on a corps project could belong to the private sector. Water is going to be such a scarce resource that in our cost sharing consideration, we are going to look more closely to the market to allocate services and to recover costs. As a result of our cost sharing deliberations, you can anticipate the cost of water services generated by the Corps of Engineers, the Soil Conservation Service and the Bureau of Reclamation will go up. The primary beneficiaries must pay more. One question that bothers people regarding the High Plains study is, "How much up front cash is required?" I am one of the proponents of not requiring up front financing by the nonfederal sector. I'm not sure I can win that policy issue, but I'll tell you why I feel that way. If the government requires up-front financing it discriminates against certain areas and certain states. Not every one is as rich as Baja, Oklahoma (Texas). Wyoming also is very wealthy. But other states are not in good financial condition, so repayment may be their only option. Many people in Washington now believe that water really may be the energy crisis of the 1990s. So it's an exciting time for this New Mexican and I hope for my colleague, Tom Bahr, to be involved in this country's emerging water policy. Thank you for having me come here.

Don Frederick: I misspoke when I first introduced John Hernandez as from the New Mexico Environmental Improvement Division. In Washington it's the Environmental Protection Agency. From what I read there may be disputes about either type of agency.

John Hernandez: I have two really important issues to talk to you about today. The first one has to do with EPA's involvement in ground water management and the second with our responsibility for the management and operation of all the dams in the United States. I was in Philadelphia about a month and a half ago talking to the National Water Quality Planning meeting. At the meeting the president of the American Water Works Association, the people who essentially run the drinking water supply systems of America, chaired a question and answer session. One of the questions from the audience was, "What do you think should be done about those ground water basins in the United States where there is a progressive drawdown, or progressive depletion? I'm asking specifically about the Ogallala formation where there is a multi-state declining water resource that's resulting in a water quality change, and where the aquifer represents the sole source for drinking water out in that country." Having this

Easterner asking about the Ogallala surprised me somewhat. Someone there suggested that the best solution would be a federal law mandating legislative control over the Ogallala ground water system. When it became my turn to speak I said, "The last thing we feel we should have is federal legislation to control the ground waters of the United States."

The EPA has broad-sweeping legislative and regulatory authority over ground water. It comes out of three specific statutes. One of them is the Clean Water Act. The second one is the Resource Conservation and Recovery Act, the EPA solid waste management act. The third is the Safe Drinking Water Act that includes the underground injection control program and the sole-source aquifer program.

The combined effect of all of these laws is to control and limit pollution of our ground water resource. EPA does have a national ground water strategy. It is a dynamic, ongoing strategy. It has not yet been articulated in a concise fashion, nor has it been broadened to include all other federal agencies. We hope to do that in the not too distant future. Early in 1981, the EPA held meetings around the United States on the question of a national ground water strategy. I think the consensus out of those meetings -- although there were people on both sides on what ought to be done -- the consensus, in essence, forms the basis of what I think our program should be in the future. I think the basic assumptions that we're going to work on are that it is impossible to protect ground water to the extent that no degredation will occur. Some degredation is part of the natural use of water, both surface and ground waters in the United States. Some degredation of quality will occur. EPA's job is to try to limit that degredation to what is reasonable. In addition, the cornerstones of our policy will be the following. First, EPA should consolidate all of its regulations that now deal with ground water protection into a single comprehensive set. Second, EPA should delegate the administration and enforcement of those regulations to state agencies in every case. EPA should help the states operate these programs by providing partial funding for them and by providing technical assistance through research. Third, EPA should help coordinate the data collection and monitoring that is done by state agencies, regional groups and various federal agencies. Fourth, EPA should act as a catalyst in the joint planning of the water resources use, but not be a direct intervenor in the process. Any ground water classification system developed should be absolutely a state perogative; EPA should not dictate to the states on this issue. EPA should not require classification of ground waters by use or provide any kind of overall federal restriction outside those dealing with pollution control. Finally, we believe there is no need for additional federal legislation on this issue at this time.

Let me turn to the dams issue. It's probably the least known, least perceived problem, yet it is one that has the potential of being the single most important water resources issue that has come up in the last 10 years. On January 29, 1982, Judge Joyce Green rendered a decision in the National Wildlife Federation vs. Gorsuch. The issue was whether certain water quality problems arising below dams should be controlled by subjecting the discharge from dams to the NPDES permit system under Section 402 of the Clean Water Act. Under this section, EPA could require that permits be issued for the quality of the discharge from dams (water that comes over the spillway or through some kind of a release mechanism). Water from a channel or power structure would have to have an EPA water-quality permit to be released. In a sweeping opinion, Judge Green rejected EPA's long standing position that dams do not discharge pollutants into navigable waters. The court ordered the EPA: 1) to designate dams as point-source categories under the Clean Water Act; 2) to establish effluent limitations or regulators for performance standards for dams as a category rather than on a case by case basis; and 3) to monitor dams for the NPDES permit requirements. In addition, the court ordered that the EPA issue these regulations within 90 days, or by April 29th of this year. The implementations the courts ordered would require a major new permiting and rule making initiative by EPA. In particular, the agency would have to develop effluent guideline limitations for dams. In the light of the fact that there are approximately two million dams, this would be a substantial undertaking. EPA would be required to take on this new responsibility which would be enormous in terms of point-source control.

Two other practical problems should be considered. Many states that have already assumed responsibility for the NPDES programs, permit programs, may not want jurisdiction over dams. State programs may be vulnerable to charges of being inadequate, both legislatively and financially. In addition, EPA may be required to take on the responsibility of preparing environmental impact statements on all new dams. The issue in this case is whether certain dam-related pollutant problems can be characterized by the discharge of pollutants. Section 502 of the Clean Water Act defines the discharge of pollutants to include any addition of any pollutant to a navigable water from any point source. Some of the particular problems identified by the National Wildlife Federation include the release of waters that are low in dissolved oxygen, high in dissolved metals, low in temperature or high in sediment load. There is also the creation of nitrogen supersaturation conditions in waters below a dam. The EPA argued in the case that several of the alleged pollutants identified by the Wildlife Federation were not really pollutants as defined under the Clean Water Act. In addition, the EPA argued that the situations described by the National Wildlife Federation did not actually add pollutants to navigable waters, but rather allowed a pollutant problem arising in a reservoir to pass downstream. In rejecting these arguments, the court gave a very expansive interpretation to the NPDES permit program. First, the court concluded that Congress intended the NPDES permit program to have the broadest coverage possible. Second, the court concluded that the list of pollutants in the Clean Water Act was not an exclusive list of the kinds of pollutants that could be subject to permiting requirements. Third, the court concluded that a dam is not simply a physical structure that impounds water. Instead, the court accepted the Wildlife Federation's position that the discharge is from the dam-reservoir facility which includes that stretch of river above the dam that can be viewed as the dam's reservoir. Under this theory, the operator is responsible for pollution arising in a reservoir in the same way that a plant operator is responsible for pollution that occurs after passing through his wastewater treatment plant. I believe this decision could have the most fundamental and far reaching effects on the use of our natural resources. If allowed to stand, I believe the EPA will be in the position of not only setting permit requirements for all of the dams in the United States, but that these permit requirements will dictate how those dams are operated. An added impact will be how the water resources can be used in the future. I think this is a great problem and one that we hope to solve. EPA is going to appeal the case. However, I believe a change in the Clean Water Act will be needed. I'll be very pleased to answer questions on this and other issues. Thank you very much.

Don Frederick: When I mentioned that Mr. Brayman was a journalist before he went to work for the Senate Committee on Environment and Public Works, I didn't mean to imply that he made a mistake. He's a graduate of Princeton University and the London School of Economics so he's obviously overeducated to be a reporter.

Hal Brayman: One other thing Don failed to mention was the fact that he and Hugh Robinson were born in the District of Columbia, as was I. I doubt a meeting has ever been held in Clovis where three of seven panelists were born in Washington, D.C.

You heard that Senator Schmitt could not be here because of weather conditions. Senator Domenici, with whom I work, also hoped to be here, but his eldest daughter is being married tommorow.

One of the first things I learned at the knee of Steve Reynolds was "if it ain't broke, don't fix it." I think that applies to the whole issue of water policy. The program is generally, and always has been, ad hoc (without a general plan). The Reagan administration is seeking to kill off the water research program. It's trying to get out of the business of looking into desalination as a solution to some of our water problems. Then you have, whether you like it or not, the perception in much of the country that the water program is pork barrel. Whether it is or not, is not the point. The point is that the perception exists, and unless we do something to change that, this program won't be revived. We have a perception among many members of Congress that few political benefits come from pushing water projects. There is a strong and vocal group of supporters of water projects, of which the two senators from this state are members. But in general we don't have that interest. We don't have that support the way we once did.

Let's assume a High Plains importation scheme exists -- we've done all the engineering, we've worked out an agreement with Arkansas, we've worked out an agreement with the states of South Dakota and Missouri to import some of their water. As much as it may be needed, I think that stage is still 10 to 15 years off. But even if the agreements existed now, I guarantee you would not see water brought to the state of New Mexico in this century. Now that's an outrageous situation. There must be some way to revive the water development program to bring the kind of benefits that are needed to Clovis, the state of New Mexico, and the west. I am absolutely convinced, and I think if you talk to a lot of people back in Washington you will find that they are convinced, that there must be some rather fundamental changes in this whole program before you will see the spending curve going back uphill. Budget constraints are not going to go away. President Reagan may indeed be successful in reviving the economy soon, but I think it's unlikely that you're going to see any significant change in the amount of money going into water projects, or for that matter, public works in general. And I don't think you're going to find there are any partial solutions to the problem of water quality. You're not going to be able to deal with the question of reforming cost sharing without a commitment to new projects. Once you start reforms on an ad hoc basis, you're going to be cut alive. And I guess the thing that depresses me is the fact that I don't think anyone in Washington really has made up his mind that fundamental changes are necessary. Fundamental changes will turn this program around and make the program start working again. It's as if you have two Japanese sumo wrestlers: one is the Congress and one is the administration. These great huffing, snorting giants are just looking at each other and trying to figure out how in the world they are going to get the edge on each other in this wrestling match. While Garrey and others maybe disagree, that is my perception. The administration has not reached the conclusion that it must work with Congress on a broad reform package. And you have a lot of people in the Congress thinking that if we just wait this out maybe it will all go away and things will regenerate on their own.

I don't think either one of those things is going to happen. I believe, ultimately, Congress and the administration must get together to work on legislation in a package approach and to make some fundamental reforms in the way we select projects, the way we prioritize them and the way we pay for them. When that happens you will see some significant benefits coming to the High Plains of New Mexico. Thank you.

Don Frederick: Steve Reynolds. Give him a warm welcome. He has to deal with reporters way too much and he deserves a warm welcome just for that.

Steve Reynolds: Thank you, Don. I could certainly spend the time from now till noon responding to these suggestions about cost sharing and discharge permits for dams, but I won't. I'm just pleased to recognize that General Robinson acknowledges that you're going to have to go to Congress to settle this cost sharing problem and John recognized that to take care of this dam permit problem, you're going to have to go to Congress. And I think we're pretty well represented there. I do want to come back to the High Plains study at least briefly before we close. I believe that study, which has been completed but not yet submitted to the Congress, is very useful. It should help us to understand, project, and hopefully enhance the future of the economy of eastern New Mexico. The data and information in that High Plains report lead to some remarkable conclusions. The report defines the baseline condition as the continuation of present trends in crop yields and irrigation efficiency improvements, without any specific incentives and actions to improve those trends. It's the "no action" alternative you saw on the questionnaire. Under this alternative the total acreage irrigated from the Ogallala in the High Plains states will increase from 14 million acres in 1977 to 18 million acres in 2020. This net increase of about 4 million acres, incidentally, is due largely to a projected increase of about 6.8 million acres in Nebraska. But the value of agricultural production for the six-state High Plains region will increase from $4.6 billion in 1977 to $11.5 billion in 2020. Now the study makes clear that the ground water mining problem is not regionally uniform. In 1977 we were irrigating 440,000 acres in the High Plains of New Mexico and, under baseline conditions, that acreage by 2020 is projected to decline to 245,000 acres, just a little more than half of the 1977 acreage. Now the study also shows that dryland farming in New Mexico will increase from about 500,000 acres in 1977 to 730,000 acres in 2020. The value of agricultural production in the High Plains of New Mexico will increase from $125 million annually in 1977 to $220 million annually in 2020, an increase of 76 percent. The return to land and management will increase from $25 million annually in 1977 to $115 million in 2020, for an increase of $90 million or 360 percent. Now that increase in value of agricultural production and return to land and management in New Mexico could be properly included but if you gave up the other half of the irrigated acreage we'd be in great shape. I don't think that's a correct conclusion. What brings this expanding production, expanding irrigated acreage, to the whole region? And increased production in New Mexico in that study period from 1977 to 2020, could sure lead those represented in federal government and some of the states which might be considered to have potential water available for export, to ask, "What's you're problem?" Now, it's important to remember that those projections are based on what is known as the NIRAP model, the Department of Agriculture model which projects increasing crop yields and crop prices increasing faster than inflation in the future years. And I think a prudent person might reasonably question some of those assumptions. I daresay a lot of you folks that have been farming over here the last 10 years will. The strategy for importation would import a total of 4.1 million acre feet annually from adjacent areas to the High Plains states. Of that amount, 302,000 acre feet will be used for irrigation of 145,000 acres in New Mexico which will bring our total of 2020 irrigated acreage to 480,000 acres. Importation would bring the value of agriculture production in the High Plains of New Mexico to 247 percent of the 1977 value of $125 million and would bring returns to land and management to 660 percent of the 1977 returns of $25 million. I think its very appropriate that we be realistic in evaluating the prospects and the results of importation. Here are some rough numbers. It appears that the cost of bringing imported water to New Mexico, including energy costs, would be about $600 per acre foot, if you figure interest free as reclamation projects used to be figured, you get about $260 per acre foot. Quick calculations indicate that the High Plains farmer might be able to pay about $76 per acre foot on a break even proposition. That's about 13 percent of the total cost of bringing water to the land. It's important to go back to the criteria for major water projects. First the project has to be engineeringly feasible. I think from what Bill Pearson showed you this morning we can conclude their importation projects would be engineeringly feasible. The project has to be economically justified, that is the benefits of the projects must exceed the costs. There is some problem with that. It's got to be financially feasible. That is water users have got to be able to repay the costs, or somebody has to be able to repay the costs. Next, it has to be environmentally acceptable. And I think you can see from what Bill had to say this morning there's considerable question about that. Last, it would have to be politically feasible. And that, I think, of all those criteria, would be the most difficult to reach. We must not be unsympathetic with those states which we see as having surplus water. They will remind you of New Mexico's reaction to El Paso's raid on what little water we have down on the Rio Grande. I might offer just one comment on the questionnaire relating to a mandatory reduction in usage, that is, cutting the allowed useage to something less than the crop requires. Now the study shows that it does not make good economic sense to reduce the allowed diversion to less than the irrigation requirement. We can go into that in more detail if you like. But more important, I think in New Mexico, is a very serious constitutional question. That is, a man has a water right under the doctrine of prior appropriation. You simply can't come along and say that all rights are going to get cut in half. And it's my reaction, Hoyt, that if the legislature ever tells a farmer how he will irrigate and take care of his land, it's making a very serious mistake. And I don't know who they're going to get to administer it.

Don Frederick: And here to tell us how the state government is going to solve these problems is Hoyt Pattison.

Hoyt Pattison: Thank you, Don. It is indeed a pleasure to be able to visit with you folks at this water conference. You know, in the state legislature, we're involved in a number of things. Among those is taxation. You folks know the difference between a taxidermist and a tax collector. The difference is that a taxidermist leaves the hide. Before I was in the legislature, and all the time I have been there, I was a farmer. And I am a farmer, or maybe I should say was. We don't have any tax problems. The IRS is not going to get any hides from us because they're already gone.

Your questionnaire is very interesting in how the answers from agricultural producers differed from the others. I would advise you to pay attention to what the farmer is saying. Your water importation problems can be of little significance if there's no one there to use the water to grow the food. Part of that problem is the cost you're talking about here today in water importation. Farm commodities won't pay for water importation, not at today's prices. There's not a farmer in this room or in this state or in this nation that has made any money in the past two to four years when you consider all the factors. You don't even have to consider all of them for a lot of us. It's a tough problem.

The role of the legislature in water problems as far as New Mexico is concerned has been illustrated by our willingness to do what is necessary to help solve our water problems. A good example of this is the body of water law we have in our state beginning with our constitution and administered by a very able man, Mr. Reynolds. We passed the laws it takes to be sure we have good water policy in New Mexico -- one of the best systems of water law in the United States. We have to modernize it and bring it up to date every now and then, but all in all it's a good system. Our legislature is willing to appropriate the money when necessary to help solve our water problems as has been illustrated in this recent suit with El Paso. We told Steve Reynolds that whatever it took, we'd appropriate it. We knew we weren't issuing a blank check because Steve Reynolds is conservative, but he knew that when it came time to hire lawyers and so forth the money would be there. We believe in taking care of our water.

The High Plains study has considered the importation of water from other areas. Having been involved in the Water Incorporated efforts that originated in west Texas, eastern New Mexico, and parts of Oklahoma for a great number of years, it's really gratifying to see this effort having gotten this far. We need to, as a part of this effort, emphasize the use of home grown water resources. You wouldn't think of New Mexico as having very much. However, in some parts of our state we have millions of acre feet of stored fresh ground water that could be utilized. You don't have to pump it from a well 3,000 or 4,000 feet deep, you can pump it from 400 to 450 like I do. You know exactly what that means when you're talking about bringing water in from Louisiana, Mississippi, or Arkansas. You get it right here from the Tularosa Basin from maybe 1,000 feet deep. I think our legislature needs to study that and see what's available there. We need to see what could be utilized from the vast store of underground water under the Rio Grande Basin right here in our own state also. I'm sure there are similar sources of water in other states that the High Plains Study could bring out. Maybe they're closer to home and more economical to come by.

Until the food users of our nation are willing to pay for the cost to produce food, we don't need to produce any more wheat, corn, grain sorghum, or even meat because we have too much the way it is.

Now, what about energy? We could use water to produce energy on our farms. We could convert the biomass we do grow to energy. People are willing to pay for that. That might be a better idea. Or we could utilize some of the wind that's blowing today to produce energy. Farmers could sell it and quit thinking about producing food. If you double the price we get for wheat, it would only make a nickel's worth of difference in a loaf of bread. So let's solve our water problems, but let's solve the problems of the farmer along with it. The New Mexico legislature is ready, willing and able to help solve water problems that exist in our state and to help solve these other problems insofar as we can. But when you talk about water projects that affect the whole central United States, in other words the Ogallala formation, you cannot expect one state to solve those problems by itself. Therefore, these problems must be solved through a national effort. Their importance cannot be diminished as far as the federal government and our Congress is concerned. Thank you.

Don Frederick: One of the points I brought out was that New Mexico was engaged in a lawsuit with El Paso. And, of course, one of the potentials of that suit, New Mexico lawyers have maintained, is to throw all that water up for grabs and raise the question that if a state can't ban export of its ground water then should the feds step in and start answering its jurisdictional questions. It may be something someone wants to address, but maybe we'll go to the audience first and see what questions you have.

John Goar: I'm John Goar from Goar Farm Inc., north of town. I was born in central New Mexico at Estancia and grew up out here. My degree in agricultural engineering is from New Mexico State. I married a local girl. Some of you might have known her father, Bob Stone of Stone Grain & Elevator. He started El Rancho Feed Company. He was chairman of the board of the Clovis National Bank until his death. So my wife and I have a strong interest in New Mexico, eastern New Mexico and Curry County. Now as a farmer and looking at managing this water there are some things I need to know. I need to know how much water the plants are using, how efficient the systems are, how much water I have available, and how much that water costs me. I have other interests too. I sell irrigation meters and one of the biggest deterrents to sales is the farmer's fear that the State Engineer Office will monitor his wells. If the farmer pumps, say, two acre-feet per acre this year, will monitoring force him to cut back next year? This penalizes a farmer for managing his irrigation system, and these irrigation meters are a good management tool. I don't know whether to direct the question at Hoyt or Steve. I think as far as Steve is concerned, he answered the question by saying he probably wouldn't put the restrictions on us. But Steve is not going to be our State Engineer forever. Some people think he's been here almost as long as Methuselah, but not quite. I don't know what the next State Engineer is going to do. I guess the question I need to direct to you, Hoyt, is what can you see towards the protection of the farmer in order to be able to use the water as he sees fit, rather than have it dictated by somebody out of the state office?

Hoyt Pattison: The answer to that question is in our body of water law in New Mexico. You're entitled to your water. You have a property right in the water that you have appropriated for your use and the only way you can be separated from that is by compensation. I think that in New Mexico our rights are adequately protected. That is illustrated in the other areas where their contacts with the water law are greater than ours here. We're not in a water district in this part of New Mexico. We're relatively free to use it as we please, except that use is dictated by the cost of natural gas and electricity. That has certainly decreased the use of it and increased conservation. But our basic water law is our protection.

Steve Reynolds: I wanted a chance to say in discussing these mandatory provisions that they seem to me completely unnecessary in view of the cost of energy for pumping today. Going back to the original question, Mr. Goar. It's important to remember that under the constitution, beneficial use is the basis for the measure and the limit of the right to use water. And you're limited in this area at this time by that provision in Lea County and the Portales Basin. There's also a limit set forth in the permit. And, as I say, I don't think the State Engineer -- I know the

State Engineer could not -- but I don't think the legislature could come and say, no, you're no longer entitled to that three acre-feet. We're going to cut you to a foot and a half an acre. You could not be cut without compensation as Mr. Pattison indicated. Thank you.

Don Frederick: I'd really like to get some questions to some of these federal officials as long as we have them here. Over there?

Tom Morton, Jr. Basically I have four points that I made note of. One is to the gentleman who would run the water resources of the U.S. Can we expect the accuracy of your figures in the project that you are anticipating to be as accurate as they were for the Colorado River project which had a factor of 10 error due to the data that was taken on an extremely wet year. Point two. Silt handling facilities on flood waters is extremely high. And in regards to the gentleman in the back of the room, I agree with the monitoring on all wells because the record of your water consumption over a long period of time will prove in a court of law your requirements. Thank you.

Garrey Carruthers: Yes, we'll be as accurate as we were in the Colorado River. At least as accurate. Keep in mind that we have learned from these projects in the Upper Colorado, the Lower Colorado, the central valley in California and in Central Utah. The corps and the Bureau of Reclamation now cooperate in the planning process and we share this information. You will see these estimates improve. We were unable to project things, however, such as the cost of money. We were unable to project the cost of agricultural products over a long period and as a consequence we made great errors on that as well. But we do the best we can. We try to justify the project. We try to look as carefully as we can at the economics to see if it's justified and then proceed, knowing full well that there will be errors.

This administration believes that price is the best allocator and the best conserver of water. And as energy prices go up, so does the price of water. As we look at our cost sharing arrangements, we also see repayment charges going up. We will charge all users more than we have in the past for water and power services. And that's going to cause people to conserve. But we learned the lesson very well in energy; we all drive smaller cars now than we used to.

Maj. Gen. Robinson: I'd like to make just one comment with respect to corps projects. We do hope that everything that we produce will be accurate to the extent that it meets the needs of the user. That's the proper test. Does it meet the need that has been expressed by the user to the Congress? With respect to the comment that Garrey made earlier, I certainly believe that up front financing cannot be mandatory. I think he's actually right in what he says. You cannot mandate up front financing. And I want to say that Mr. Gianelli came up with those proposed percentages and made it very clear that those were proposals that would be presented to the project sponsors and if they accepted those proposals we would try to go forward. If they came up with something less, he would have to pass that on because then the Office of Management and Budget and the Congress have to act. And that was really the key with respect to that.

Don Frederick: Anybody else? Well I've got a question. For Garrey and Mr. Brayman and Mr. Hernandez in particular. I wondered if from a Washington viewpoint you could tell us, what is the perception of the problem facing the Ogallala Aquifer and how will these figures that Steve gave which show the paradox of increasing production in the face of shrinking water, how will this be perceived?

John Hernandez: I think there's a widespread perception in the eastern part of the United States that federal regulation of aquifers like the Ogallala is necessary. There is abuse of aquifers taking place which can only be controlled through federal intervention. I think there will be a strong push for some kind of ground water legislation at the federal level.

Hal Brayman: I'm not sure I agree with you, John. Unless you get a push from the members of the affected states, I assume nothing will happen on the Ogallala at the federal level. A wise man once said that Congress does two things -- it doesn't act or it over-reacts. Given the opportunity for over-reacting here in the tens of billions of dollars, I have a feeling that the alternative of no action may be more logical. And I assume the federal government never will get into the allocation of ground water. At least I hope not.

Garrey Carruthers: Don, the resolution of the problem, if you're talking about water importation, must begin in the states. The federal government will not play any kind of a lead role in putting together the solution. Once it is determined by the states involved as to how to import water, (if water is for sale to import), then you face the serious question of how to pay for this project. It is incredibly expensive. I don't believe that agriculture can pay for this project, but the states are going to have to contribute to it. Municipalities are going to have to buy in. Industry must pay a market price for water delivered. And then after all of that, you're not going to have enough money to pay for the project and will have to be astute enough politically to justify the remainder on the basis of national security. Some argue that agriculture is so important to the national security of this country that there exists a federal financial responsibility. Then, and only then, will you build the project you are talking about.

Rip Curtis: I'm Rip Curtis. I haven't been here as long as Mr. Goar. I've been here 56 years. Now if I understood General Robinson's and Steve Reynolds' comments correctly, I see no problem with this project. I think our efforts are a little bit misguided. I don't think we want to import water. I think we want to help those poor souls down in the wetlands get rid of some of that water. Now, you talked about how it was going to cost $600 an acre-foot to bring it out here. If you charged $525 against flood control, that just leaves us the $75 cost.

Steve Reynolds: Talk to the general.

Rip Curtis: You know there are logical solutions to all of these problems. I can see where we can do those folks a lot of good by getting that water out of the wetlands. If we have to blackmail them a little bit we'll threaten to send them all this real estate that's passing here today.

Maj. Gen. Robinson: Just a brief comment. I do agree that there are all kinds of ways you could figure this, but I want to point out to you that the people on the other end don't quite see it that way. The major states that are involved have already responded, and quite vociferously, to the availability of water. Missouri has responded, Arkansas has responded, and then down the river, Mississippi has. And what they're saying essentially is we need those floodwaters. Those floodwaters serve us a lot of useful purposes. Now they don't want it to go over the banks, of course, and if we could stop it from going over the banks I think maybe they might be willing to give up that water, perhaps for a reasonable price. I think they'll turn it around and go up and charge you.

Rip Curtis: Well, I think all we're interested in here at this convention is helping them out a little.

Don Frederick: Anyone else?

Maj. Gen. Robinson: Let me make one comment about what Hal said. I do believe the water policy system is kinda broke in this country, but we do need to get the policy together to the extent that the Congress and the administration get together on a policy that we can present which is comprehensive and consistent to the people that we serve. And I think that's awfully, awfully important. One of the reasons that we're 26 years -- and I won't dispute these figures, I'll just say that if it takes 26 years to start construction, a good bit of that is in the administration and the Congress because we do the study in five years and the design in two. So in between you've got a lot of sitting and waiting and that's part of the problem. We have studies right now that are sitting there in the Office of Management and Budget that have been there for six years and have not moved one bit.

Garrey Carruthers: I've got a comment on that as the only policy official here under attack by my friends from the Congress and the professionals. And I appreciate the pressure, folks. You know Hal and the Congress worry a lot about how we organize water policy in the administration. And the administration worries a lot about the Congress, too. But we have a Water Resources Council, and the Water Resources Council has been around for a while. The council worked hard; nobody bought the Water Resources Council as it evolved. It went off on its own agenda. There isn't a person in New Mexico that turned to the Water Resources Council to solve water problems. The Congress believes, since Secretary Watt has asked that the Water Resources Council be zero budgeted, that a replacement for the council might be in order. Somehow, as a result, we're going to get a national water policy. That's not going to happen. The only way we're going to get a national water policy that makes sense is to begin at the state level and bring it up because there are 50 different state water laws in the country. States allocate and manage water resources; the federal government does not and it should not. If we are going to have water policy -- a national water policy -- we've got to quit trying to do it in Washington and bring it up from the states.

Don Frederick: Mr. Brayman?

Hal Brayman: I would like to add a few things. First, I was not discussing the Water Resources Council when I was talking about the need for Congress and the administration to get together. Part of the problem is that if you have a water resources program that works, you also assume you're going to spend money on it. You may not spend as much, in percentages, as you're spending now. But ultimately it means more projects, more money, and more investment in the public sector. I think that's right.

But I think the administration is in a situation where it doesn't want to consider more spending when confronting a $100 billion deficit. Then someone comes along and says: Hey, we're going to spend some more money, significantly more money, on water resources. It is not an issue that gets a great deal of priority in Washington. The point I was trying to make is that Congress must work out some way so that the program becomes less ad hoc. We have to work out some way where there's more money going into water projects. We have to work out something on cost sharing. Those are tough issues. Those are issues, frankly, that a lot of people don't want to deal with, and those people are both in the administration and in Congress.

Don Frederick: Yes sir?

Pete Wierenga: I just can't sit here and not say anything. Two of my friends from New Mexico State are sitting up there and giving us policy issues and policy answers. I think from my point of view what we are missing in all of this is that its clear to me that we cannot build any more big canals or big dams. The money is just not there; its not cost effective. It looks to me from what the farmers are telling us that what is cost effective is water management and better use of the water that we have right now, improvement of crops and better varieties. There are a whole lot of things we can do right now and I am a little bit disappointed that our officials from Washington have not pointed out that with continued support for research in the area of agriculture, in the area of water resources, perhaps we can improve the situation or at least come to the point that we can live with the little water we have.

Garrey Carruthers: Peter -- I'd like to point out to those of you who don't know Dr. Wierenga, that he's one of the noted scientists at New Mexico State University and he speaks from the heart, not because he has a vested interest in research and receives federal money for research. It's not that at all. He speaks out of sincere interest for these measures. Pete, I would only respond -- in the traditional Reagan administration pattern -- by saying that if water is in fact a state's right, and we believe it is, then that kind of leadership comes from the state and that's what we ought to be hearing from the state. The thing we're trying to avoid is having the Bureau of Reclamation come to this state or the Corps of Engineers and say, can we sell you a water project that you'll really be pleased with. The corps, the Bureau of Reclamation, and the Soil Conservation Service have promoted their own program and sold it. We're trying to say, it's up to New Mexico to come to us and say this is what we want in the way of water and water projects. And we'll take nonstructural projects. We're not fixed on just building dams and canals, although it's a lot of fun.

Maj. Gen. Robinson: I couldn't disagree more. First of all, we are not in the business of promoting water projects.

Our projects come up from the bottom and always have and I think it's clear to recognize that. Now, we've come up with a cost/benefit ratio and we design the projects. In the past, I think we've designed that project without as much consultation with the states and the locals as perhaps we should have had, though there has been a lot. And I think the idea of having more consultation and more input from the states and locals is certainly realistic and certainly something we should do, but we do not promote water projects or come out and try to sell projects. We respond to need and I think that's important to recognize. It's an important difference. I think the bureau does the same thing. Now, let me just say one more thing about this whole issue. And again, I disagree with Garrey on this because I think what we have to have is a determination first of what is the federal interest in water resource development for all those project purposes. And once we determine that, then we need to go to the states and get their input on how to do this and how to come up with cost sharing and all of the rest of that. But until we find out first what kind of interest the federal government is going to have in this program, let's just give it all back to the states.

Garrey Carruthers: Let me say again I feel chastised. Peter, and now the general, anybody else want to get in line? But it's really the fault of the policy makers that you don't have a cost sharing formula before you. We thought, last July or August, that it seemed like a simple task, to spell out what the federal role ought to be in a water project. It seemed very simple. One proposal was that the beneficiaries ought to pay for everything, 100 percent capital plus interest. And then the question was, why do we have the Corps of Engineers, the Bureau of Reclamation and the Soil Conservation Service? Obviously there must be a reason for them to be around. There are reasons for the federal government to be involved: protection of the agricultural infrastructure is a security question. I can justify the Bureau of Reclamation's program, in part because it's important to have the Central Valley Project, and because of their great productivity. It's in the federal interest. How much federal interest? I've talked to the Secretary of the Interior, who is chairman of the Cabinet Council, on two occasions. He rejected my original proposal on cost sharing and I'll tell you why. He said, "Very simply, Garrey, this is a pro-water development administration and we cannot build water projects under the rules that you just suggested to me." He said, go back and revisit some questions. One of the questions we had to revisit was irrigated agriculture. Another was flood control. And he said we're too tough on that. There is a federal interest here and it is higher than what you're admitting it is. Now these fellows making the decisions are cabinet members reporting to the president. And so this month I will surface that again in a new cost proposal to the Cabinet Council with new resources for irrigation water and flood control.

Steve Reynolds: If I might, Mr. Chairman, I'd like to add that no federal agency that I know of has ever tried to sell or force upon the state of New Mexico a water resource project. The corps, the bureau, the Soil Conservation Service, particularly have continuously cooperated with each other and have been most sensitive to the state's objectives in the development of water resources in this state. So don't worry about them pushing any projects down our throat, Garrey.

Garrey Carruthers: Does anyone have anything nice to say about a Republican who went to Washington?

H. B. Barnard: John, you told me at the beginning of this meeting that you were hoping some of the politicians wouldn't talk too long. At the beginning of this meeting it became rather obvious that with the possible exception of Mr. Reynolds and the general that this is really turning out to be a Republican water conference. I want to point out to you that I think this is a people project and I was very interested in the remark made by my friend Rip Curtis. I think he's exactly right. We ought to assign the costs of this project to the flood control situation. I think that's obvious to anybody. My good friend, the former mayor of Clovis, sitting over here to my right, indicates to me that maybe we ought to get provincial and cut off that water before it gets out of the state. I can tell you, Steve, but you already know, and the gentlemen here from Washington know, there is a great deal of talk in that direction. I think all of you should be aware that we, as a state, are now exporting 90 percent of our natural resources. Mr. Reynolds and you gentlemen from Washington need to be advised that some of us serving in your legislature are becoming concerned about keeping those natural resources in the state of New Mexico. We want those resources to be used here. And then let's go to the second step. In other words, instead of exporting uranium to Oklahoma where it's going to be processed into yellow cake, let's put that yellow cake plant here in the state of New Mexico. I think the same needs to be said for our coal. The same needs to be said for our water. Let's use it for that second step, to provide a little industrial development of the type that New Mexico could stand.

I have not yet heard from you gentlemen from Washington any statements about water other than something about pork barrel. You're saying that water is thought of as a pork barrel project. Recently my friend Hoyt and I also have been accused of being involved in pork barrel projects, so we have some association with that term. Now, my question, gentlemen, is this: What do you feel we could do to bring our water problems to the attention of you policy makers and your friends back in Washington? What is it that we need to do, specifically, to tell the folks that the High Plains is perhaps one of the few remaining areas of the United States that can produce the food and fiber we need? What is it that we need to do, specifically, to impress upon these folks that we've got problems out here and that if they want to be fed in the year 2020 or 2050 or whatever, they need to pay attention to our problems now and try to help us out? But how do we proceed? Do you have any comments on that? Thank you, Don.

Don Frederick: OK, Garrey.

Garrey Carruthers: Well the first thing that I would respond to is that the administration is very responsive to that attitude you just expressed. The president, from California, and the secretary, from the west, understand the importance of water projects and so you don't have that problem. You have a receptive group. Again, we look to the state for leadership. Let me use the example of South Dakota. The most successful state in dealing with the Department of the Interior and the Bureau of Reclamation, in my mind, is South Dakota. The governor, the congressional delegations, and the legislature all have agreed on how they want their water problems solved in cooperation with the federal government. They have organized themselves to come forward to the Bureau of Reclamation with a seven point list of things they think ought to be done. They debated those issues in South Dakota and resolved them there. So we ask the states who want assistance from the Bureau of Reclamation and the Department of the Interior to come to us unified because we look to the state to be the leader. The state legislature, the governor and the congressional delegation can speak for their state with regard to water, so I throw it back to you.

H. B. Barnard: Do you have a copy of the South Dakota agreement?

Garrey Carruthers: I have the letters which they sent to me with the resolution from the legislature. Yes. I have that kind of documentation in my office.

Don Frederick: Mr. Brayman?

Hal Brayman: I'd just like to add a couple things. I certainly agree with what Garrey is saying. It's the High Plains states we are talking about, and the Ogallala. The High Plains states must get together and decide their agenda for ways the United States can help the High Plains states. I would just point out a couple of things about the importation issue. There was a point last summer when Congress almost enacted a prohibition on any exportation of water out of the Arkansas River, that is until Senator Domenici derailed that proposal. This kind of trashy little legislation will keep coming back and, in some form, we are going to have a shootout over these kinds of things. Be prepared for it. The second thing is that the state of South Dakota has just agreed with a coal pipeline company to sell 50,000 acre-feet of water out of the Missouri River. That is causing all sorts of problems with the downstream states, which see South Dakota's action as taking away their birthright to that water.

Don Frederick: Mr. Reynolds?

Steve Reynolds: If I may. With respect to the specific High Plains problems and Garrey's requests and the position of the states. It may be important to point out that the High Plains Study Council, on which all six of the states are represented, intends to take the report recently finished by the general contractor and sit down and formulate as an addendum to that report, the recommendations of the states. Now that will include addressing many of the issues set forth in the questionnaire that's been placed before you. We have planned two meetings. In April -- I can't give you the dates yet -- there will be one meeting in Clovis and one in Hobbs where we will present the details of the report and get public reaction in order to help us formulate those recommendations.

Don Frederick: We've got a couple of people who are going to try and fly out in this weather, so we'd better call an end to this. I've had a good time and I hope that you on the panel did too.

CONFERENCE PARTICIPANTS

George Abernathy
Agricultural Engineering
Box 3268, NMSU
Las Cruces, NM 88003

Katharine L. Adam
League of Women Voters
416 Apodaca Hill
Santa Fe, NM 87501

Tom Anderson
Soil Conservation Service
P.O. Box 1168
Tucumcari, NM 88401

Jackie D. Atkins
State Engineer Office
3012 N. Montana
Roswell, NM 88201

R. Darrell Baker
NMSU Cooperative Ext. Serv.
Star Route
Clovis, NM 88101

Wayne Baker
Rt. 2, Box 53
Portales, NM 88130

Harvey Banks, Project Director
High Plains Associates
Camp Dresser and McKee
3445 Executive Center Drive
Austin, TX 78731

Clyde Barnes
SPS Co.
500 Pile
Clovis, NM 88101

Carl Bass
Village Trustee
Box 236
San Jon, NM 88434

Russell Bean
Water, Inc.
P.O. Box 367
Lubbock, TX 79408

Shaul Ben-David
Department of Economics
University of New Mexico
Albuquerque, NM 87131

Percy Blair
NM Environmental Impr. Div.
200 E. 5th
Roswell, NM 88201

Tom Blaine
NM State Engineer Office
2425 Margaret Dr.
Bosque Farms, NM 87068

Frank Bradley
State Engineer Office
P.O. Box 1717
Roswell, NM 88201

Harold Brayman
Senate Committee on Environ.
and Public Works
Room 4210-New Senate Office Bldg.
Washington, D.C. 20510

John E. Burkstaller
NM Environmental Impr. Div.
200 E. 5th
Roswell, NM 88201

Ronnie E. Burks
Santa Fe Railway
900 S. Polk
Amarillo, TX 79106

Garrey Carruthers
Assistant Secretary for Land
and Water Resources
Department of Interior
Washington, D.C. 20240

Ken Carver
High Plains Water District
2930 Avenue Q
Lubbock, TX 79405

Lee Case
U.S. Geological Survey, WRD
505 Marquette, N.W., Room 720
Albuquerque, NM 87102

Sanford Caudill
2116 S. 4th
Tucumcari, NM 88401

Diana Clifton
Eastern Plains COG
Curry County Courthouse
Clovis, NM 88101

M. Bradley Compton
State Engineer Office
State Capitol
Santa Fe, NM 87503

Jasper Coombes
U.S. Army Corps of Engineers
P.O. Box 1580
Albuquerque, NM 87103

Quincy Cornelius
San Juan County
305 S. Oliver
Aztec, NM 87410

Jon Cranford
P.O. Box 3520
Amarillo, TX 79106

Bobby Creel
Ag. Econ. & Ag. Business
Box 3169, NMSU
Las Cruces, NM 88003

Ronald I. Cross
2026 Lipscomb
Amarillo, TX 79109

John J. Cunico
Corps of Engineers
P.O. Box 1580
Albuquerque, NM 87103

Wayne Cunningham
Agricultural Policy Analyst
NM Dept. of Agriculture
Box 5702, NMSU
Las Cruces, NM 88003

Rip Curtis
Star Route, Box 8A
Clovis, NM 88101

Pat D'Andrea
1106 Don Gaspar
Santa Fe, NM 87501

Dean Darnell
Arch Hurley Cons. Dist.
102 W. High
Tucumcari, NM 88401

L. E. Davis
Rt. 2, Box 138
Clovis, NM 88101

Tim De Young
Political Science Department
Ortega 307
University of New Mexico
Albuquerque, NM 87131

Henry Edgar
U.S. Fish & Wildlife
P.O. Box 1306
Albuquerque, NM 87103

Duncan Ellison
Water, Inc.
P.O. Box 367
Lubbock, TX 79408

E. R. Felfe
Lea County Electric Coop
P.O. Drawer 1447
Lovington, NM 88260

Ralph Finkner
Plains Branch Station
Star Route
Clovis, NM 88101

Earl Flint
Village of San Jon
P.O. Box 37
San Jon, NM 88434

Don Frederick
El Paso Times
Santa Fe Bureau
1215 Don Diego
Santa Fe, NM 87501

Dale Fuehring
Plains Branch Station
New Mexico State University
Star Route
Clovis, NM 88101

Jerry Funck
High Plains Water District
2930 Avenue Q
Lubbock, TX 79405

Sherman E. Galloway
New Mexico State Engineer Office
Box 1717
Roswell, NM 88201

Bernardo Garcia
Morton Mfg. Co.
Rt. 2, Box 40A
Morton, TX 79346

Malcolm Garrett
Curry County Grain
P.O. Box 520
Clovis, NM 88101

Sheri L. Gaubatz
Hinkle, Cox, Eaton, Coffield, &
Hensley
P.O. Box 10
Roswell, NM 88201

Robert Giebitz
Midland Agency
P.O. Box 838
Portales, NM 88130

James Gilley
Agricultural Engineering Dept.
University of Nebraska
East Campus
Lincoln, NE 68583

Jesse Gilmer
Rio Grande Compact Commission
P.O. Box 771
El Paso, TX 79945

Charles Glover
NMSU - CES
Box 3AE
Las Cruces, NM 88003

John Goar
Geoponics-Goar Farm Inc.
4907 Harvard
Amarillo, TX 79109

Noel Gollehon
Agricultural Economics and
Agricultural Business
Box 3169, NMSU
Las Cruces, NM 88003

Bob Gonzales
Village of San Jon
P.O. Box 37
San Jon, NM 88434

Manuel A. Gonzales
Bueyeros, NM 88412

Helen Gram
Los Alamos Tech. Assoc., Inc.
P.O. Box 410
Los Alamos, NM 87544

Donald Gray
State Engineer Office
Bataan Memorial Building
Santa Fe, NM 87503

Russell Grider
Eastern Plains COG
Curry County Courthouse
Clovis, NM 88101

Lt. Col. David G. Grosse
Staff Chaplain
Cannon Air Force Base
Clovis, NM 88101

John E. Guinn
Environmental Improv. Div.
300 Hondo Dr.
Roswell, NM 88201

Ed Gutentag
High Plains Regional Aquifer
System Analysis, Central Region
M.S. 412 - Denver Federal Center
Lakewood, CO 80225

Boyd Hamilton
NM Environ. Improvement Division
P.O. Box 1832
Clovis, NM 88101

Randy Harris
Clovis National Bank
P.O. Box 1509
Clovis, NM 88101

Don Hart
U.S. Geological Survey, WRD
505 Marquette, N.W., Room 720
Albuquerque, NM 87102

Ralph Hauke
U.S. Bureau of Reclamation
P.O. Box 252
Albuquerque, NM 87103

John Hernandez, Deputy Dir.
U.S. Environ. Protection Agency
401 M. Street, N.W.
Washington, D.C. 20460

T. C. Horton
Entranosa Water Coop
N.S.R. Box 150
Edgewood, NM 87015

Michael Inglis
Technology Application Center
University of New Mexico
Albuquerque, NM 87131

Allen Kelley
2701 Axtell
Clovis, NM 88101

Rex Kirksey
Northeastern Branch Station
New Mexico State University
P.O. Box 689
Tucumcari, NM 88401

Kenton Kirkpatrick
U.S. E.P.A. -- Region 6
1201 Elm Street
Dallas, TX 75270

Russell Koger
Devel and Assoc., Inc.
9412 Indian School Road
Albuquerque, NM 87112

Gary Kramer
Kramer, Callahan & Assoc.
125 Eubank, N.E.
Albuquerque, NM 87123

Mel Kramer
Kramer, Callahan & Assoc.
125 Eubank, N.E.
Albuquerque, NM 87123

Georgianna E. Kues
U.S. Geological Survey, WRD
505 Marquette, N.W., Room 720
Albuquerque, NM 87102

Sherry Kunka
Southwestern Public Service
P.O. Box 1261
Amarillo, TX 79170

Hugh Lackey
Soil Conservation Service
P.O. Box 187
Portales, NM 88130

Robert Lansford
Agricultural Economics and
Agricultural Business
Box 3169, NMSU
Las Cruces, NM 88003

Noel Larson
U.S. Forest Service
507 Gold St., S.W.
Albuquerque, NM 87102

Koert Lessman
Box 3BF, NMSU
Las Cruces, NM 88003

Cleon Ligon
Southwestern Public Service
Box 1261
Amarillo, TX 79109

William M. Lyle, Assoc. Prof.
Texas Agricultural Exp. Station
Olton Route
Plainview, TX 79072

Craig L. Mapel
P.O. Box 396
Mesilla, NM 88046

Jim Martin
Southwestern Public Service Co.
Box 1568
Clovis, NM 88101

E. W. Martin
SS Rt. Box 86
Portales, NM 88130

Tim Martin
Chamber of Commerce
215 Main Street
Clovis, NM 88101

Art Mason
State Engineer Office
P.O. Box 1717
Roswell, NM 88201

Darold McCrossen
Soil Conservation Service
P.O. Box 2007
Albuquerque, NM 87103

Paul E. McGinnis
State of NM - EID
P.O. Box 968
Santa Fe, NM 87503

Thomas Moody
NM Game and Fish
State Capitol
Santa Fe, NM 87503

George Morin
Plains Branch Station
Star Route, Box 77
Clovis, NM 88101

Richard Morse
NM State Highway Dept.
P.O. Box 149
Santa Fe, NM 87501

Merle Niehaus
Agronomy Department
Box 3Q, NMSU
Las Cruces, NM 88003

Thomas Nisbett
1604 Axtell
Clovis, NM 88101

J. B. Nixon
State Engineer Office
Bataan Memorial Building
Santa Fe, NM 87503

Laurence Nowak
State Engineer Office
300 Vista Parkway
Roswell, NM 88201

Keith O'Brien
NM Bureau of Mines
Campus Station
Socorro, NM 87801

Ben H. Ormand
Pacific Western Land Co.
P.O. Box 188
Gila, NM 88038

Matt Ormand
Pacific Western Land Co
P.O. Box 188
Gila, NM 88038

Representative Hoyt Pattison
Star Route
Clovis, NM 88101

William R. Pearson
U.S. Army Corps of Engineers
Southwest Division
1114 Commerce Street
Dallas, TX 75242

Lewis Putnam
NM State Engineer Office
P.O. Box 844
Deming, NM 88030

LTC Julian Pylant
U.S. Army Corps of Engineers
P.O. Box 1580
Albuquerque, NM 87103

Hubert Qualls, Jr.
Rt. 1, Box 190
Clovis, NM 88101

Dan Reabuck
1809 Colonial Park Way
Clovis, NM 88101

Steve E. Reynolds
State Engineer
Bataan Memorial Building
Santa Fe, NM 87503

John W. Riley
Rio Grande Compact Commission
P.O. Box 771
El Paso, TX 79945

Wes Robbins
SCS
Box 161
Tucumcari, NM 88401

Major General Hugh Robinson
Commander, Southwest Division
U.S. Army Corps of Engineers
1114 Commerce St.
Dallas, TX 75242

Ross Romero
Corps of Engineers
P.O. Box 1580
Albuquerque, NM 87103

Fidel A. Saiz
Bureau of Reclamation
P.O. Box 252
Albuquerque, NM 87103

Theodore Sammis
Ag. Engineering Department
P.O. Box 3268, NMSU
Las Cruces, NM 88003

The Honorable Senator Schmitt
1251 Dirksen-Senate Office B
Washington, D.C. 20510

Douglas Schneider
NM Environmental Impr. Div.
P.O. Box 968
Santa Fe, NM 87503

Bill Schott
1603 Babcock
San Antonio, TX 78229

Geraldine Schwab
W.K. Summers & Assoc.
P.O. Box 684
Socorro, NM 87801

Mike Scroggin
Duval Corporation
P.O. Box 511
Carlsbad, NM 88220

John Shendo, Jr.
P.O. Box 304
Mescalero, NM 88340

Oscar Simpson
5317 Granite, N.E.
Albuquerque, NM 87110

Daniel Smeal
Plains Branch Station
Star Route
Clovis, NM 88101

Don Smith
High Plains Water District
2930 Avenue Q
Lubbock, TX 79405

V. Phillip Soice
Public Service Co. of NM
Alvarado Square
Albuquerque, NM 87158

Earl Sorenson
State Engineer Office
State Capitol
Santa Fe, NM 87503

Forrest Sprester
11363 Quintana
El Paso, TX 79936

Bill Stallings
Plains Branch Station
Star Route Box 47
Clovis, NM 88101

Ernst A. Steinhoff
N.M.R.I.
P.O. Box 454
Alamogordo, NM 88310

Gail Stockton
263 Camino de la Sierra
Santa Fe, NM 87503

Bruce Stockton
263 Camino de la Sierra
Santa Fe, NM 87503

L. C. Strawn
Rt. 4, Box 281
Tucumcari, NM 88401

H. Ralph Stucky
2975 Terrace Dr., Apt. 213
Las Cruces, NM 88001

Ted L. Talmon
Technology Application Center
University of New Mexico
Albuquerque, NM 87131

David Tanner
NM Environmental Impr. Div.
P.O. Box 1832
Clovis, NM 88101

Sam Thomas
Southwestern Public Service
Box 1261
Amarillo, TX 79170

Donis Thompson
1000 Hondo
Clovis, NM 88101

Dr. Gerald Thomas, President
P.O. Box 3Z, NMSU
Las Cruces, NM 88003

Leland Tillman
Eastern Plains COG
Curry County Courthouse
Clovis, NM 88101

Eddie A. Trujillo
Interstate Stream Commission
Bataan Memorial Building
Santa Fe, NM 87503

John Tysseling
Bureau of Business and
Economic Research
University of New Mexico
Albuquerque, NM 87131

Mary Louise Vigil
Box 1
San Jon, NM 88434

Billy Wallace
Federal Land Bank Association
2420 Ashford Street
Clovis, NM 88101

Darrell Webber, Acting Dir.
Bureau of Reclamation
714 S. Tyler, Suite 201
Amarillo, TX 79101

Walter Webster
Gordon Herkenhoff & Assoc.
302 Eighth St., N.W.
Albuquerque, NM 87102

Pete Wierenga
Department of Agronomy
P.O. Box 3Q, NMSU
Las Cruces, NM 88003

Tom Williams
Southwestern Public Service Co.
P.O. Box 1937
Roswell, NM 88201

Lawson Williams
Box 118
Texico, NM 88135

David Wilt
Vinton EPPSCO Clovis
P.O. Box 1784
Clovis, NM 88101

Riva Wimsatt
Natural Resources Department
Room 118, Villagra Building
Santa Fe, NM 87503

Jim Wright
NM State Engineer
Box 1717
Roswell, NM 88201

WRRI STAFF PARTICIPANTS

Thomas G. Bahr
R. Peter Herman
Linda G. Harris
Darlene Reeves
Yolanda Arteaga
Cheryl I. Crawford
Kelly J. Kalk-Smith