July 1984 WRRI Report No. 181

Proceedings of

29th Annual New Mexico Water Conference

Water Law in the West

New Mexico Water Resources Research Institute

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WATER LAW IN THE WEST

PROCEEDINGS OF THE TWENTY-NINTH

ANNUAL NEW MEXICO WATER CONFERENCE

New Mexico Water Resources Research Institute

New Mexico State University

Las Cruces, New Mexico

April 26-27, 1984

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Proceedings Editor: Linda G. Harris
Editorial Assistant: L. Diane Prince

PREFACE

A lot can change in a quarter century. That is certainly true of water law. Even the best of laws must reflect the needs of the society it governs. Pressures on water resources from outside the state as well as demands from competing uses within the state call for a renewed look at how law affects water resources in the West. With that in mind, the 29th Annual New Mexico Water Conference returned to a topic that was covered 25 years ago at the 1959 New Mexico Water Conference--water law.

This year's conference, entitled "Water Law in the West," was held April 26-27 before an attentive audience of 267. Because of the popularity of the conference topic, registration was full more than two weeks before the conference.

Participants were not disappointed. The first set of speakers provided a clear and informative history of water law in the Southwest as well as in New Mexico. The second group of speakers dealt with the important issues facing western water law--El Paso, Indian water rights, and interstate water disputes. A third session covered other economic and environmental issues affecting water development.

Former WRRI Director Garrey Carruthers made a quick trip from his post at the Interior Department in Washington, D.C., to give the conference luncheon address. He followed his tongue-in-cheek review of his proposed book How to Survive in Washington with a serious assessment of state and federal responsibilities in water resources management.

For the first time in nearly a decade, students presented research papers at the conference. Water Conference Advisory Committee members Fred Allen, Lynn Brandvold, Jim Daniel, Charles Hohn, Brian McDonald, Tom Moody, Merle Niehaus and Doug Schneider screened the entries and judged the presentations. Ben Greene, an NMSU graduate student in chemistry, presented the winning paper. The papers of the four student finalists are included in the proceedings.

A successful water conference requires the cooperation of many individuals and organizations. Special thanks goes to the Water Conference Advisory Committee for its advice and support.

THOMAS G. BAHR
Director

Funds required for publication of the proceedings were provided by registration fees, the U.S. Department of the Interior, and by state appropriations to the New Mexico Water Resources Research Institute.

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Garrey Carruthers
Jed D. Christensen
Robert Emmet Clark
Sam Deloria
Charles T. DuMars
Bruce S. Garber
Jesse B. Gilmer
Ben Greene
Lawrence J. Jensen
Craig L. Mapel
Catherine Rankin
V. Phillip Soice
Gerald W. Thomas
Ross Douglas Turnbull
Peter Thomas White

29th Annual New Mexico Water Conference

"Water Law in the West"

April 26-27, 1984
Anderson Hall - Carbine Auditorium
New Mexico State University
Las Cruces, New Mexico

Thursday, April 26

MORNING SESSION

Moderator: Thomas G. Bahr, Director, WRRI

8:00 - 8:45	Registration: WRRI Lobby
9:00 - 9:15	Opening Remarks - Thomas G. Bahr, Director, WRRI
9:15 - 9:35	Keynote Address - Gerald W. Thomas, President, NMSU
9:35 - 9:45	Announcements
9:45 - 10:05	Evolution of Western Water Law Robert Emmet Clark, Professor Emeritus, University of Arizona Law School
10:05 - 10:15	Discussion
10:15 - 10:45	Break
10:45 - 11:05	Perspectives on New Mexico Water Law Peter Thomas White, Special Assistant Attorney General, New Mexico State Engineer Office
11:05 - 11:15	Discussion
11:15 - 11:30	Student Presentation: Removal of Uranium from Drinking Water, Catherine Rankin, Civil Engineering, NMSU
11:30 - 11:35	Discussion
11:35 - 11:50	Student Presentation: Irrigation Scheduling Models as Economical Farm Management Tools, Craig L. Mapel, Agricultural Economics, NMSU

11:50 - 11:55	Discussion
12:15 - 1:30	LUNCH - Holiday Inn, Brazito Room Luncheon Address - Garrey Carruthers, Assistant Secretary, Land and Minerals Management, Interior Department

AFTERNOON SESSION

Moderator: John Hernandez, Professor, Civil Engineering, NMSU

1:45 - 2:00	Student Presentation: Removal of Heavy Metal Ions from Contaminated Water, Ben Greene, Chemistry, NMSU
2:00 - 2:05	Discussion
2:05 - 2:20	Student Presentation: Toxicity of New Mexico Brackish Groundwaters to Fingerling Channel Catfish, Ross Douglas Turnbull, Wildlife Science, NMSU
2:20 - 2:25	Discussion
2:25 - 2:40	Break
2:40 - 3:00	The El Paso Water Suit Thomas G. Bahr, Director, WRRI
3:00 - 3:10	Discussion
3:10 - 3:30	New Mexico Water Litigations Charles T. DuMars, Professor of Law, University of New Mexico
3:30 - 3:40	Discussion
3:40 - 4:00	The Rio Grande Compact Jesse B. Gilmer, Texas Commissioner, Rio Grande Compact
4:00 - 4:10	Discussion
4:10 - 4:50	General Discussion
5:30	NO-HOST SOCIAL - Holiday Inn, Brazito Room

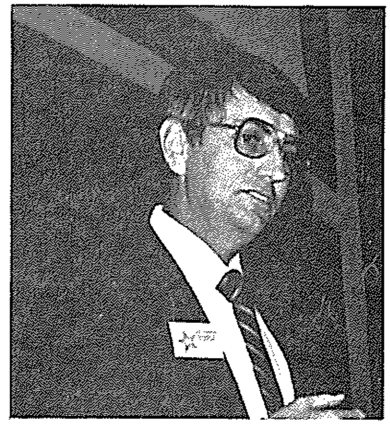
Friday, April 27

Moderator: Frank DuBois, Assistant Director,
New Mexico Department of Agriculture

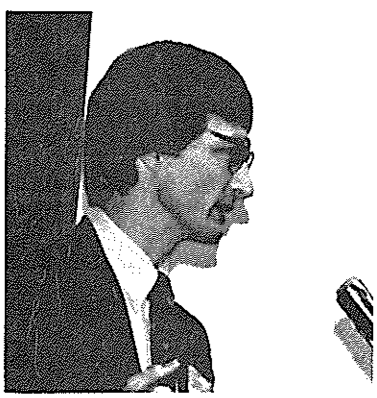
9:00 - 9:20	Winters Doctrine and Indian Water Issues Lawrence J. Jensen, Associate Solicitor, Energy and Resources, Interior Department
9:20 - 9:30	Discussion
9:30 - 9:50	A Native American View of Western Water Issues Sam Deloria, Director, American Indian Law Center, Albuquerque, New Mexico
9:50 - 10:00	Discussion
10:00 - 10:20	Water Law and Economic Development V. Phillip Soice, Water Resource Consultant and Counsel, Public Sevice Company of New Mexico
10:20 - 10:30	Discussion
10:30 - 10:45	Break
10:45 - 10:55	Student Awards Presentation Lynn Brandvold, New Mexico Institute of Mining and Technology, Water Conference Advisory Committee
10:55 - 11:15	New Directions in Western Water Development Jed D. Christensen, Deputy Assistant Secretary, Water and Science, Interior Department
11:15 - 11:25	Discussion
11:25 - 11:45	Water Quality Laws in New Mexico Bruce S. Garber, Attorney at Law, Santa Fe, New Mexico
11:45 - 11:55	Discussion
11:55 - 12:00	Closing Remarks - Thomas G. Bahr, Director, WRRI

29th ANNUAL NEW MEXICO WATER CONFERENCE SPEAKERS

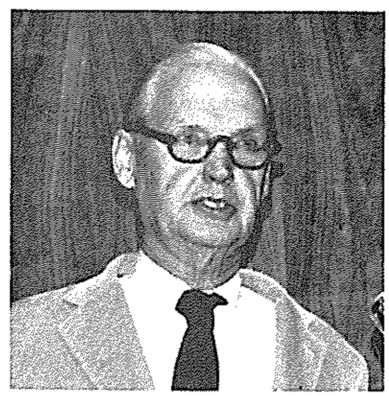
Thomas G. Bahr



Garrey Carruthers



Jed D. Christensen



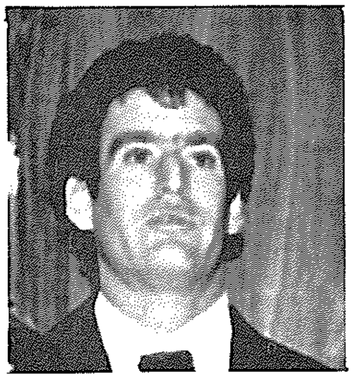
Robert Emmet Clark

Sam Deloria

Charles T. DuMars

Bruce S. Garber

Jesse B. Gilmer



Ben Greene

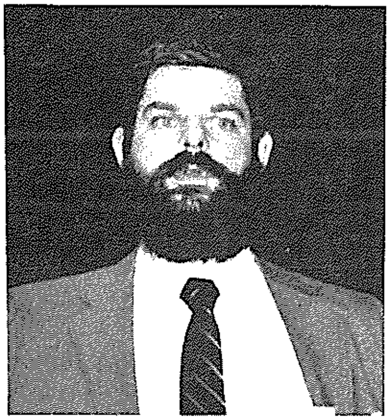
Lawrence J. Jensen

Craig Mapel

Catherine Rankin

V. Phillip Soice

Gerald W. Thomas



Ross Douglas Turnbull

Peter Thomas White

SPEAKER PREVIEW
29th ANNUAL NEW MEXICO WATER CONFERENCE

Thomas G. Bahr has been director of the New Mexico Water Resources Research Institute since 1978. In 1982-83 he was the director of the Office of Water Policy, which was established to address water issues related to Interior Department responsibilities. Before coming to New Mexico he was director of the Institute of Water Research at Michigan State University. He holds degrees from Michigan State University and the University of Idaho.

Garrey Carruthers is assistant secretary for Land and Minerals Management, Interior Department. Previously, he was acting director of the New Mexico Water Resources Research Insitute and a White House Fellow and Special Assistant to the Secretary of Agriculture. He has served on several research committees including the Western Agricultural Research Council and the Eisenhower Consortium. He holds degrees from Iowa State University and NMSU.

Jed D. Christensen is the deputy assistant secretary for Water and Science, Interior Department, where he assists with the administrative and policy oversight of the Bureau of Reclamation, Bureau of Mines, and the U.S. Geological Survey. His extensive experience in city and county management includes positions in Utah, Nevada, California and Arizona. He studied at the American University of Beirut, Lebanon, in 1964. He is a graduate of Brigham Young University and has a master's degree in public administraton from Arizona State University.

Robert Emmet Clark, namesake of the Irish patriot Robert Emmet, has nearly four decades of experience in water law. He was the chief researcher under the New Mexico Attorney General in a 1951 lawsuit with Texas over the Rio Grande, he taught law at the University of New Mexico for 16 years, and he is known as the "father of the Natural Resources Journal." In addition, he is the editor-in-chief of the seven-volume Water and Water Rights. He is a University of New Mexico graduate and received a law degree from the University of Arizona and a juris doctorate from Yale.

Sam Deloria has been director of the American Indian Law Center in Albuquerque since 1972. The center coordinates a national scholarship program for Indian law students and provides staff support for tribal relations. He is a founder of the Commission on State-Tribal Relations, an intergovernmental agency of tribes, states, counties and municipalities. In 1980, he served as deputy assistant secretary for Indian Affairs, Interior Department. He is a member of the Standing Rock Sioux tribe of North Dakota and South Dakota.

Charles T. DuMars, professor of law at the University of New Mexico, recently served as chairman of the New Mexico Water Law Study Committee. He is the author of numerous articles in the area of water law and water rights and is the co-author of Economic Impact of Alternative Resolutions of New Mexico Pueblo Indian Water Rights. DuMars, a true Westerner, was born in Arizona, received a bachelor's degree from the University of Oregon and a law degree from the University of Arizona. His grandmother taught school in Cloudcroft, New Mexico, at the turn of the century.

Bruce S. Garber, now a private attorney specializing in federal pollution control compliance, was the chief legal counsel to the New Mexico Environmental Improvement Division from 1978-1983. For six years he was legal counsel to the Water Quality Control Commission. While at the EID, he worked in various environmental fields focusing mostly on water quality. The Michigan native holds a bachelor's degree from the University of Michigan and a juris doctorate from Wayne State University.

Jesse B. Gilmer has been the Rio Grande Compact commissioner for Texas since 1969. The civil engineer began his career with the U.S. Department of Agriculture in 1934. At the USDA, he eventually became administrator of the Production and Marketing Administration and was president of the Commodity Credit Corporation. In 1948 he joined the Tri-State Equipment Co., El Paso, Texas, and is currently the board chairman. In 1974, he was named Distinguished Alumnus of NMSU's College of Engineering.

Ben Greene is an NMSU doctoral student in chemistry. The California native holds a bachelor's degree in chemistry from the University of Cincinnati and a master's degree from NMSU, also in chemistry.

Lawrence J. Jensen is the associate solicitor for Energy and Resources, Interior Department. Previously, he was the associate solicitor for Indian Affairs in the Office of the Solicitor, Interior Department. Under the Attorney General's Honors Program, he served as a trial attorney in the civil division in the Department of Justice. He also has been a member of the firm of Jones, Waldo, Holbrook and McDonough in Salt Lake City, Utah. He is a graduate of the J. Reuben Clark Law School, Brigham Young University.

Craig L. Mapel is an agricultural economics graduate student at NMSU. He holds a bachelor's and master's degree in history. He is a native of Hamilton, Ohio.

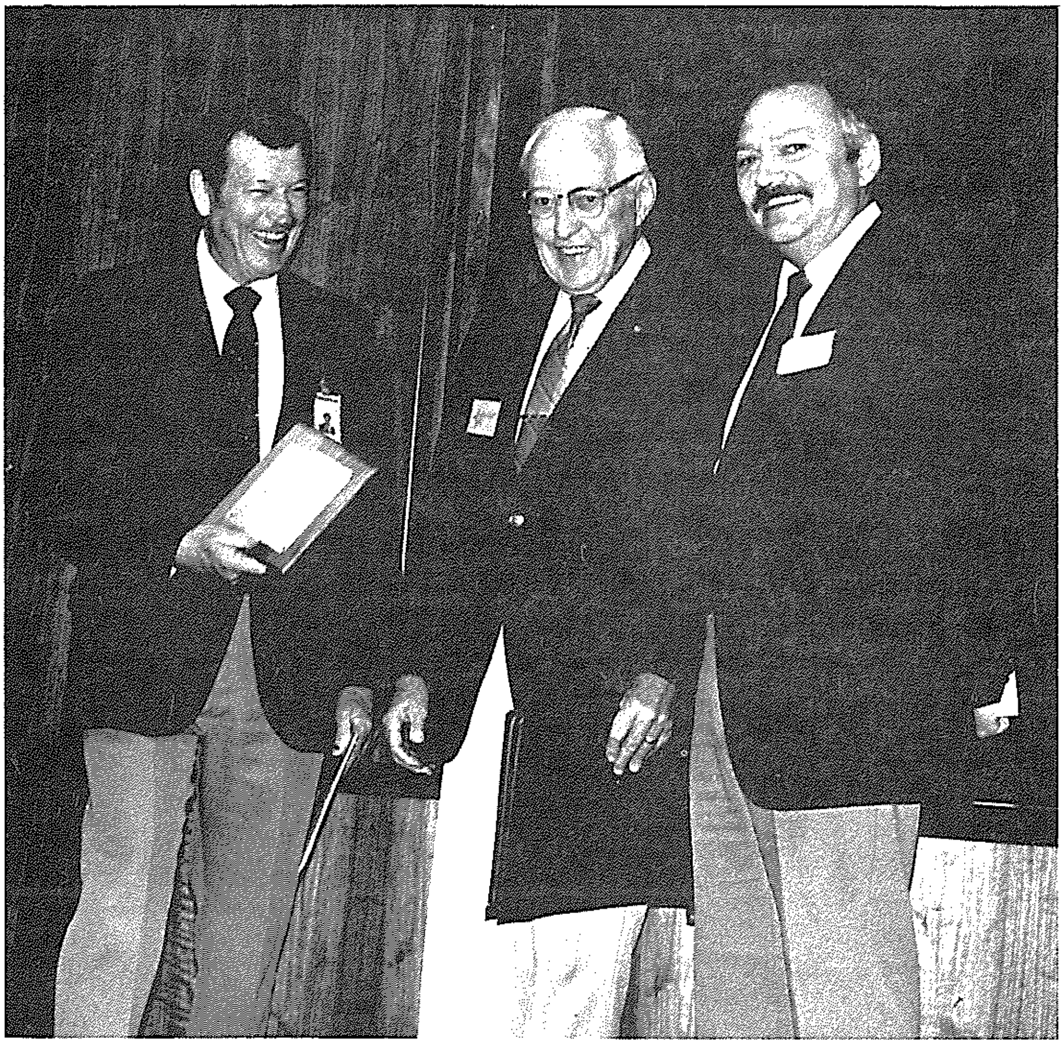
Catherine Rankin is an undergraduate senior at NMSU majoring in civil engineering. She is from Las Cruces, New Mexico.

V. Phillip Soice has been the executive assistant in Water Resources, Public Service Company of New Mexico since 1979. At PNM, he coordinates the acquisition, development, maintenance, and sale of water rights by PNM. Previously, he was senior project engineer with Blatchley Associates, Inc., Denver, Colorado, and project engineer with Black and Veatch Consulting Engineers. He grew up in Montequma, Kansas, and graduated from the University of Kansas with a B.S. in civil engineering and an M.S. in water resources engineering. He also holds a law degree from the University of Denver.

Gerald W. Thomas, president of New Mexico State University, will retire from the university in July after 14 successful years at the helm. In honor of his significant contribution in the fields of agriculture, ecology and resource management, the establishment of a $1 million endowed chair in food producton and natural resources is underway. Thomas is the author of Progress and Change in the Agricultural Industry and co-author of Food and Fiber for a Changing World. Before his tenure at NMSU, Thomas was dean of agriculture at Texas Tech University. He holds degrees from the University of Idaho and Texas A & M University.

Ross Douglas Turnbull is completing his master's degree in fishery and wildlife sciences at NMSU. The Toronto, Canada, native received his bachelor's degree from the University of Missouri.

Peter Thomas White is the general counsel for the New Mexico State Engineer and the Interstate Stream Commission. He has been with the agencies since 1969. He is the lead counsel for State of New Mexico v. Aamodt, the Indian Pueblo water rights case and Texas v. New Mexico. He holds a bachelor's degree and a juris doctorate in law from the University of New Mexico. He was born in Evanston, Illinois.



The institute's long and valuable association with New Mexico State University President Gerald W. Thomas was recognized at the conference. Dr. Thomas (left) receives a plaque of appreciation from Dr. Ralph Stucky, former WRRI director, and Dr. Thomas Bahr, WRRI director. In addition, members of New Mexico's congressional delegation presented him with letters of appreciation, which are printed on the following pages. Dr. Thomas, who will retire from NMSU in July, has been a staunch supporter of water research in New Mexico.

STATE OF NEW MEXICO
OFFICE OF THE GOVERNOR
SANTA FE
87503

TONEY ANAYA
GOVERNOR

April 12, 1984

RN 1002

Dr. Gerald W. Thomas
President
New Mexico State University
Box 3Z
Las Cruces, New Mexico 88003

Dear President Thomas:

On behalf of the citizens of this state, I want to commend you for the outstanding leadership you have provided New Mexico State University during your tenure as its president. Your contribution to New Mexico and the nation is magnified by those under your direction in the past fourteen (14) years - NMSU's graduates, faculty and scientists.

The endowed Thomas Chair in Food Production and Natural Resources is testimony to your personal contribution in the International fields of agriculture, ecology and resource management. It is fitting that your contribution in these areas is being recognized at the Annual New Mexico Water Conference. I know that those gathered at the conference will join me in honoring you for the outstanding personal and scientific standards you have set for New Mexico.

Sincerely,

TONEY ANAYA
Governor

TA/wps/mac

MANUEL LUJAN, JR.
1st District, New Mexico

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April 24, 1984

Dr. Gerald W. Thomas
President
New Mexico State University
Las Cruces, New Mexico 88003

Dear Dr. Thomas:

I want to join your many other friends in wishing you well when you complete your tenure as President of New Mexico State University in July.

The growth and development of the University, during the past 14 years, is well documented. You have compiled a record on which you personally can be proud and one which will mean much to the University and the state of New Mexico for many years to come.

Future generations will benefit because of your life-long interest in natural resources management, and for the leadership you have shown in international food programs, and in the unending attack on world hunger.

I am personally aware of your leadership in the area of water resources management and in your efforts to expand water resources research programs. The fruits of your labors in this particular area will mean much to us for many years to come.

Even though you will be stepping down from one leadership position, I am told that you will be staying in the Las Cruces area and will be serving in various advisory roles. This is good news for all of us, who undoubtedly will continue to call on you for advice and counsel.

I wish you every success in your future endeavors.

Best personal regards,

Manuel Lujan, Jr.

MLJ:dp

JOE SKEEN
2ND DISTRICT, NEW MEXICO

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April 26, 1984

Dr. Gerald Thomas, President
New Mexico State University
Box 3Z
Las Cruces, New Mexico 88003

Dear Gerald,

It will be hard to imagine New Mexico State University without Dr. Gerald Thomas. The two have long been synonymous and will continue to be in the minds of New Mexicans for years to come.

There is no doubt that our water is our most precious resource and the one that is becoming increasingly important to our continued growth. Because of your leadership and abilities, our state has continued to grow in our understanding of the need for conservation and wise use of our water.

Your contributions in this field make up a large part of your living legacy to our state. Please know that what you have done is appreciated and will continue to be appreciated for years to come.

I wish you all the best, my friend, in the years to come. You served your state well. Enjoy your retirement.

Sincerely,

Joe Skeen

Joe Skeen, M.C.

KEYNOTE ADDRESS

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

I am pleased to welcome each of you to the 1984 Water Conference and to make a few opening comments. I will focus on three major points. One, New Mexico State University's (NMSU) involvement in water resources research and development in New Mexico; two, what have we learned about water; and three, where do we go from here?

The first point I'll discuss is NMSU's involvement in water activities. In 1890, New Mexico State University, then the New Mexico College of Agriculture and Mechanic Arts, was designated as the land grant college for the state of New Mexico. Part of that charge was to establish an Agricultural Experiment Station. You can't talk about agiculture in New Mexico without talking about water. Consequently, the early research of Fabian Garcia, as director of the Agricultural Experiment Station, and other faculty members was aimed largely at higher crop production through the proper application of water. Even the early range and animal research recognized that the effective use of our limited rainfall was the key to productivity of livestock products.

However, the first major effort to recognize the importance of water as a major thrust of the institution was instigated by Dr. Ralph Stucky and the Department of Agricultural Economics. Starting with a seminar in 1956, our institution took the lead in inviting distinguished speakers and organizing conferences related to water resources. The first eight annual water conferences, 1956 through 1963, were considered by Dr. Stucky as the forerunners for the establishement of the Water Resources Research Institute.

I remember well the lengthy debates which swept the nation as legislation was being planned to establish water research institutes in each state. Here in New Mexico, there was no question. NMSU would be the institution and would take the lead. However, in other states there were active debates between land grant colleges and other universities and various approaches were established to the institute thrust. I was at Texas Tech at the time and, for once, joined with the University of

Texas at Austin to combat the tremendous political pressure placed on Congress by Texas A&M. In any case, both Texas and New Mexico came out with water resources research institutes, statewide in scope, and involving other universities where talent was available to look at the water issues.

Our own institute has been recognized through the years as one of the leaders in format, operations and research programs in the nation. This recognition is the result of the initial leadership of Dr. Ralph Stucky and the follow-up guidance by Professor John Clark, Dr. Garrey Carruthers, Dr. Tom Bahr, Dr. George O'Connor, and others. Two groups, always working behind the scenes, were critical to the institute's development. One was a group of statewide leaders who served as an advisory committee to the institute, and the other was a group of technical specialists at several universities who provided guidance and screening for the research projects.

Throughout the years we always have maintained close contact with State Engineer Steve Reynolds. (It is my understanding that Steve has attended or participated in all but two or three of the 29 Annual Water Conferences.) This state has indeed been fortunate to have had Steve Reynolds at the helm in the State Engineer Office.

During this last year, and in a number of previous years, we have seen congressional challenges for federal support for the Water Resources Research Institutes. This year a bill was passed by both the Senate and House and sent to President Reagan for signature. The president chose to veto the bill which would have terminated the federal support for the statewide institutes. Fortunately, with our encouragement, our New Mexico delegation joined with senators and representatives from other states to overturn the president's veto. The Water Resources Research Institutes are alive and well and will continue to perform a service for this state and the nation.

Even though federal legislation laid the groundwork for statewide research institutes, we should point out that the state of New Mexico has consistently provided strong state support. Without the commitment from the state, we could not approach the massive task that lies ahead.

Now let's look briefly at the second point--What have we learned about water? Please allow me to summarize.

1. Water is our most critical and most important resource. Water is more critical in the long term than either land or energy. We can and must find solutions to the energy problem. We can and will determine ways to operate with a smaller relative land base, but the amount of water in our system is fixed. There is no substitute for water. Water is a renewable resource. Man uses it as it moves through the hydrologic cycle, usually pollutes it to a certain extent, and feeds it back into the system. While we can reduce the dependence upon water by increasing the efficiency of water use, there is a very limited supply which must be husbanded with great care as the world population increases.
2. As our standard of living rises, so does our per capita use of water for domestic, industrial and agricultural purposes. An individual needs only a small amount of water for drinking, but water use for other purposes rises rapidly with the level of income. If we could project the water use requirements of the average American to the world-wide populaton of 4.7 billion, we would see immediate and severe shortages worldwide. And, keep in mind that last year we added 83 million more people to the population base, so our plans for today must be projected into the future where worldwide population eventually may level off at between 10 and 12 billion individuals.
3. Our largest per capita water requirement is for food. Depending on how you measure this need, it is easy to associate one ton of water with a loaf of bread, and as much as 100 tons of water on rangelands with a production of one pound of beef. In the agricultural sector, keep in mind that this water is used as it passes through the hydrologic cycle. Often, other businesses and municipalities have a shot at the same water at another point in the cycle. However, such statistics provide a convincing argument for better water management in the food sector. And,

as I stated in my report on sub-Saharan Africa, it is time to assemble better data on such water use and to design systems for food production which "value water with the concern of the desert nomad."

4. If you take a very limited and strictly economic approach to allow water to migrate to its highest value use, then agriculture can no longer compete against municipalities, business and industry. To designate water use in the future to move only to the highest-value activities eventually would lead to serious problems of food and fiber production.
5. Water is ubiquitous; that is, no place on earth is wholly without water--although I have personally visited some places on earth with no "measurable" precipitation.
6. Water is a heterogenous resource. Water is found in liquid, solid and gaseous states, and all of these forms are important to the rate of movement of water through the hydrologic cycle.
7. We cannot discuss water without examining both the quantity and quality aspects. Water shortages are one problem--water pollution is another harder and more serious problem.
8. From a world perspective, it is not possible to separate the water resource from climate because evaporation, transpiration and precipitation are a part of the climate complex. Decisions made in this decade about our energy options will have a profound effect on future climate and water supplies. For example, the burning of fossil fuels continues to contribute to the carbon dioxide loading in the upper atmosphere and to the potential for climatic change. Granted, there are still opportunities for genetic engineering and crop adaptation to more arid environments, but any significant shift in the climate would work to the disadvantage of the United States and to the potential advantage of the Soviet Union. And, while we may overcome water shortages by a certain amount of genetic engineering to improve the use of water for cultivated crops, the impact on the vast uncultivated land base could be much more difficult to cope with.

Now, let's look more specifically at the third point--Where do we go from here? In the first place, it should be obvious that much more research must be committed to our water problems. The rush to the Sun Belt may come to a screeching halt after a decade if we do not plan now to meet our future water needs.

We must learn to measure everything that we do in units of water and become more conscious of water in all aspects of our daily life. Unfortunately, too much of our research is not now designed with water as a constraint.

We must step up our research on photosynthesis not only to capture more energy from the sun by this process but also to determine more effective ways to increase the efficiency of water in the food and fiber sector.

Lastly, we must find ways out of the water law and litigation problems that are increasing daily as water becomes more and more critical to our livelihood. I was particularly impressed with the statement in Megatrends by John Naisbitt. He said, "Lawyers are like beavers. They get in the mainstream and dam it up." Because the theme of this conference is "Water Law in the West," I do not want to make a blanket condemnation of lawyers, but my impression of the present litigation problem in this state is that the El Paso lawyers are like beavers--they certainly got into New Mexico's mainstream and dammed it up! I am very suspicious and concerned that future decisions about our water resource ultimately will be decided on legal grounds and not on the basis of logic or proper concern for the distribution of water in time or in space. We are hung up on legal precedent. Perhaps there is no way around this, but I enter this conference with concern.

It is my hope that those participants whom we have invited to the conference this year will help us find not only a legal route to our important water future but will help us design the more important scientific, technological, social and political solutions to the problem we now face. Our future is indeed tied to the decisions we make today about water--our most important and valuable resource.

WESTERN WATER LAW: HOW IT EVOLVED AND WHERE IT IS GOING WITH IMPLICATIONS FOR NEW MEXICO

Robert Emmet Clark
Professor Emeritus, University of Arizona Law School

I take the words in the title to mean that my assignment is to offer some background for non-lawyers and lawyers.

This introduction is divided into three uneven sections on: geography, history and technology (referring here to the handmaiden of the sciences that continues to shape the law, particularly in relation to ground water and water quality).

GEOGRAPHY

Western water law is essentially state property law with very important federal dimensions. It is generally defined to include court decisions, legislation and administrative procedures in the 17 states beginning with the tier from North Dakota south through Texas. Climate and rainfall in this region encouraged irrigation or made it necessary, except in certain mountain and coastal areas. You may add Alaska and Hawaii in this grouping although each has a different water law system I will not discuss.

The water law evolving in the West until about 50 years ago applied almost exclusively to surface waters, which include visible sources, streams and other water bodies. Ground water law emerged more recently. New Mexico, a pioneer in ground water legislation, passed its first statute in 1927. Increasing withdrawals in the Roswell area produced that law, reenacted in 1931, and laws in other states in recent years, as we shall see in comments on technology.

As to surface waters, however, some form of appropriation law, that is, the pioneer first in time, first in right principle, applies in all western states even where common law riparian rights were recognized, as in the six states traversed by the 98th meridian and the three along the Pacific Coast. But in the eight mountain states, which are the tier from

Idaho and Montana south through Arizona and New Mexico, prior appropriation law applies exclusively to surface waters with statutory modifications that relate mainly to management.

The two groups of states are known as "California" or "Colorado" doctrine states. The difference is of little importance with respect to ground water legislation, which varies greatly in the West as we shall see in a moment.

The geography of the western states heavily influenced water law origins and later development. Unique water dependencies in the Colorado River Basin produced the Compact of 1922, and geography and history shaped allocations of the Rio Grande above Fort Quitman, Texas. All of us here know of the demands on the Arkansas, Platte and the Pecos rivers that have been litigated for years, and we realize that interstate mining of the Ogallala Formation by six states cannot go on indefinitely without an interstate institution of some kind.

But as a minimum, we have now identified the physical area in which western water law evolved and was a major factor influencing national legislation, such as the Reclamation Law. To a large extent water law continues to determine development in the West.

HISTORY

The history of water law in the western states is as colorful as the geography and terrain. Although the origin of Prior Appropriation Doctrine--the first in time, first in right principle applied to water use--is quite clear, some closely related U.S. history is not clear. Moreover, the vacillating attitudes of Congress, some courts and several administrations toward the public lands, the U.S. Constitution and the meaning of federalism, have complicated the whole field of resource law, including water law. These complications are part of the reality of our constitutional system and still promote confusion, as I will try to demonstrate with a question at the end of this discussion.

Obviously water rights questions begin with the aboriginal people, the Indians, who have been living for centuries along the Rio Grande, the

Colorado, and other streams, and at Acoma, Jemez, Zuni and the Hopi second mesa. There were others before them, like the Anasazi and the Hohokam of Arizona.

All of these people had water and land use practices of some kind. However, we know little about them except as similar practices continue today, or as can be inferred from the ruins of canals and abandoned communities like Chaco Canyon or Bandelier.

This early period is emphasized to explain that prior appropriation, as it was developed in the West, was not derived from Indian law or customs although similarities can be inferred as they have been from the evidence of ancient irrigation practices along the great rivers of Egypt, Mesopotamia, India and China, among the so called hydraulic civilizations. However, pioneer water law--the prior in time, prior in right idea--as adopted in the West, did not originate with the Indians. Like the ancients of the Middle East, they were less individualistic than our pioneers, but we can assume that the law of necessity also shaped many of their customs, as it has ours.

When the first Europeans arrived in our region--Coronado spent the winter of 1541-42 on the banks of the Rio Grande near Bernalillo, and Juan de Onate established his settlement in 1598 near Espanola--they brought the law and customs of Spain with them. Similar developments by the Spaniards occurred in Sonora, Arizona, and California 150 years later. These early Spaniards generally encountered two types of Indians in the Southwest: the nomadic tribes with a hunting culture who ranged over large areas and often followed the buffalo, and land based tribes like the pueblo people who cultivated maize and had an agricultural economy. (Other tribes were dependent on the fish of certain rivers and lakes and settled near them, such as the Pyramid Lake Indians in Nevada.)

We should not forget that Indians hold to an attitude different from ours toward the land, the mountains, the streams. One poet said Mother Earth is our home, our granary and our graveyard. (We could suggest that the Indian has maintained a more sophisticated view of land tenure than the white man, but that would require a 15-week seminar to explore.)

In any case, we know that the early Spaniards in the Rio Grande Valley confirmed Indian rights in tribal lands and water supplies. If you are following the Aamodt case you know that four pueblos near Santa Fe currently claim water rights antedating claims of the earliest Spanish settlers. These Indians do no rely on the prior appropriation doctrine, but on paramount rights against the claims of the descendants of the early colonists making gringos like us mere bystanders in the struggle.

If valuable records had not been destroyed in the Pueblo Rebellion of 1680, perhaps the resolution of this controversy would be easier. Nevertheless, we know that the Spaniards arrived with their own system of law and military force.

We know also that Spanish law contrasted sharply with the Indian's attitude toward man's brief tenure on this planet. As it later developed, English land law conflicted with Spanish law and with Indian custom and practice as well.

Spain's land law derived in part from Roman law and preserved an important and a more formal distinction between possession and ownership. Nowhere was this more confused and misunderstood than in the nineteenth century struggle over the private land grants that comprised more than 40 percent of the state of New Mexico and contributed to the unique land situation in Texas before and after it entered the Union.

Spanish law held that the minerals beneath the surface and flowing streams were the patrimony of the Crown, the central government; grants of land did not include the minerals and flowing waters unless expressly included in the grant. Many of the large grants were of surface rights only. Stream flows were limited to riparian uses for culinary purposes and stock watering.

In general, rights to withdrawals from wells and springs remained the same all over Europe and England for centuries, though modern technology is changing ground water law there also.

England was emerging from feudalism and ending the absolute powers of kings in the seventeenth and eighteenth centuries of our colonial period and shaping the beginnings of constitutional government. Meanwhile, English land lawyers were perfecting the notion of the fee simple absolute. A line in a poem by William Empson called Legal Fiction describes the landowner's rights as follows: "Your rights extend under and above your claim Without bound; you own land in Heaven and Hell."

The English landowner's property rights extending "under and above your claim without bound . . ." included riparian rights. In a humid climate with abundant water, the riparian right made sense. Water was plentiful in streams bordering landed estates and because irrigation was not practiced, there was enough water for all contiguous owners without diminishing the hydraulic head needed for mills on the stream. This was the essence of the riparian doctrine the English settlers contributed and is still basic law east of the Missouri where not modified by statute.

Prior appropriation never applied in England or in the eastern states during this formative period.

West of the 98th meridian, however, and along the wavering 20-inch rainfall line, the many uncertainties connected with riparian rights became as obvious to the early settlers as they had centuries earlier when Roman colonists settled in semiarid southern Spain. They, and the later Arabs (for 800 years), practiced irrigation and adopted allocation rules still followed before La Tribunal de las Aguas that meets regularly before the great doors of the Valencia Cathedral. Allocation rules, and institutions such as the community ditch, or acequia madre, the mayor domo, or zanjero, the ditch boss, were brought to the New World. Their origins go back 1,000 years; indeed la acequia is an Arabic word, as is the other Spanish word for canal, la zanja.

In this history there are similarities, or parallels, with ancient irrigation principles, but despite misleading statements by a few of our courts, it is clear that the appropriation doctrine, as we know and apply it, did not come from Spanish law.

A quotation, in a recent Supreme Court decision, from a reclamation engineer's report says, "That afternoon, July 23, 1847, was the true date of modern irrigation . . . ." when the first Mormon pioneers diverted water from a creek near the site of the present Mormon Temple and flooded five acres to plant potatoes. This is not a claim that the Mormons were the originators of prior appropriation law. While crossing the plains they had seen irrigation practices, including the community ditches of the Pueblo Indians and the Spanish colonists.

Now you are ready to ask, "Where did prior appropriation come from?" The answer is simple: It grew out of the customs and rules devised by the gold miners on the public domain after the discovery of gold in California in 1848. Thousands of 49ers were trespassers as they diverted streams in their search for gold. A handful of soldiers could not keep them off government property, and little was done to remove them until President Lincoln got an ejectment decree.

In the meantime, crucial American history had occurred in the turmoil over slavery; the admission in 1845 of Texas to the Union, the compromises of 1840 and 1850, the Mexican War in 1846 and the acquisition of the Southwest and California.

The treaty of Guadalupe-Hidalgo in 1848 and the Gadsden Purchase in 1853 specified protection for land owners or occupiers, under the laws of Spain and Mexico. In many cases the main problem was to determine the nature of their rights. Many rights were lost, relinquished for a pittance, or the grantees were defrauded. In other cases, the land claims were enlarged beyond all reasonable interpretation and there were delays in the courts of 30 years or longer. Valuable water rights on the public domain were involved in many private land grant claims as shown in the reports of the Court of Private Land Claims.

However, by the turn of the century prior appropriation was well established in the western states and territories. The early California miners had formed mining districts (some writers think the idea came with immigrant miners from northern Europe where such districts existed), and the idea spread to Oregon, Nevada and other states. Rules were useful in resolving disputes between trespassers, but these rules were not the law. However, later prospectors were prevented from going upstream to divert water from an earlier prior user's gold washing sluice boxes. As some miners became disenchanted, they turned to farming and irrigated fields and orchards under the principle of first in time, first in right. The custom, without the sanction of law, was effective; it prevented and reduced friction and it spread rapidly.

But it was not until after the Civil War in 1866 that Congress passed the first mining law, actually the first water law applicable to the public lands, in which the custom of prior appropriation was recognized by the U.S. government:

> Whenever, by priority of possession, rights to the use of water for mining, agriculture, manufacturing and other purposes have vested and accrued, and the same are recognized and acknowledged by local <u>customs</u>, laws and decisions of the courts . . . .

Thus, water rights claimed by trespassers on the public domain became valid against the United States and a legal property interest. The Mining Law revisions of 1870 and 1872 which are the laws today, and the Desert Land Act of 1877 also recognized that patents of land and homesteads granted by the United States were "subject to vested and accrued water rights." Needless to say, disputes arose and water law controversies multiplied in the courts.

At the same time a belief was encouraged, which a later decision of the U.S. Supreme Court seemed to support, that the U.S. government had parted with rights in waters on the public domain in the states and territories. This notion had previously run into conflict with the rights of Indians who had been put on reservations. Here you recognize the allusion to the <u>Winters</u> case that in 1908 confirmed the existence of reserved water rights. But even before the <u>Winters</u> decision, the supreme Court had said ". . . in the absence of specific authority from Congress, a state cannot, by its legislation, destroy the right of the United States, as the owner of lands bordering on a stream, to the continued flow of its waters, so far, at least as may be necessary for the beneficial uses of government property . . . ." This 1899 decision, which made possible the building of Elephant Butte Dam, refers to the federal responsibility for the public lands, namely the plenary power of Congress under Article IV of the U.S. Constitution. That responsibility was not removed by the recent New Mexico decision in which the U.S. Supreme Court held 5-4 that water was reserved on public lands for growing timber but not for the wildlife inhabiting public lands, or livestock permitted to be there.

These decisions remind us that although water law is primarily state law, there are large federal implications under the U.S. Constitution with respect to the Indians, in treaties, interstate compacts, Supreme Court decisions and decrees, and Congressional allocations such as Arizona v. California and later Colorado River legislation.

Now we can summarize the crucial differences between prior appropriation law and riparian rights:

1. The nature of the riparian right

   The concept assumes a humid climate and virtually unlimited supply.

   The right is inherent in land contiguous to a water body.

   The right exists without being exercised.

   The right is part and parcel of the realty and cannot be lost by nonuse.

   The right passes with title to the land absent statutory or deed changes.

   Most troublesome of all, the right is unquanitifed, or open-ended.

The courts have said there are no riparian rights in New Mexico.

2. The nature of the appropriative right

   The right is separate or may be separated from ownership of land, though it may be appurtenant.

   The right is always conditional on there being a supply of water.

   The right is conditioned by the legal priority, first, second, etc.

   The right is conditional on beneficial use.

   The right may be lost or forfeited for nonuse, or nonbeneficial use.

   The right is quantified either in a decree, or administrative determination and is always limited to the duty of water for a beneficial purpose, or agricultural practice specified by law.

Before we turn to technology, remember that the discussion thus far has been primarily of surface water rights and doctrines.

TECHNOLOGY

New technology has greatly influenced ground water law development. The old hand pump and the windmill had limits in the level of lifts and withdrawal capacity, and not many artesian aquifers continue to provide free-flowing water supplies.

In New Mexico, economics and geology in the Roswell Basin shaped ground water law in the 1920s with the help of science and technology. As more reliable data and cheap power became available, artesian flows decreased with the drilling of more wells. The 1927 statute resulted. In a few other states the courts and legislatures responded to similar events but most of the legislation was inadequate, or too late, as in Arizona in 1980. The background of different rules, as well as ignorance and political pressure, contributed to the delay.

The early legislation was concerned primarily with the acquisition and protection of ground water rights; later statutes embodied management systems and, more recently, included measures to prevent contamination. Obviously there is great need for rational ground water management and for re-examination of the several ground water doctrines applied in the western states that can be summarized:

1. The English common law rule of unlimited withdrawals, a carry-over from the absolute notions regarding real property mentioned earlier, allows pumping from one's land even to the detriment of a neighbor. This is the general rule in Texas.
2. The so-called American rule of "reasonable use" is a variation of the common law rule, which means that withdrawals can be limited if they are unreasonable, a conclusion rarely reached as Arizona has demonstrated.
3. California's "correlative rights" concept is a variety of reasonable use, which relates the amounts pumped to the proportion of overlying surface ownership.
4. New Mexico, Nevada, Utah and other states purport to follow prior appropriation law but recognize that a ground water right

is not like a high priority on a dependable stream when the ground water source is being mined as, for example, in the Lea County basin where calculated depletion is taking place under a long term plan that includes well spacing. In the Roswell Basin, the management controls involve the artesian aquifer, the shallow valley fill above it, and flows from the Pecos River.

5. Another category could be added here to include legislation passed to correct or manage overdraft problems. Colorado passed such legislation, and the 1980 Arizona statute recognizes a severe overdraft that has existed for a generation. The law replaces, in part, an unworkable "reasonable use" doctrine and anticipates planned withdrawals through the year 2025, when it is hoped that balance in recharge and withdrawals will be achieved.

Technology improved conservation practices and made many changes in surface water irrigation: for example, lined canals, closed flumes, and drip, sprinkler and center pivot irrigation. With respect to ground water, new drilling techniques and deep well pumps have not only made changes in the law necessary, they also have revolutionized agriculture on the High Plains, for example, and make interstate cooperation necessary.

An important dimension of water law can only be alluded to in passing: water quality. The subject will be more and more at the center of water law changes.

Advanced technology has increased the dangers from contamination of surface and ground water sources; that fact is recognized in federal legislation, though still insufficiently as to ground water. The same legislation mandates a reversal of the pollution process and has large implications for New Mexico and the Southwest. We can hope that the planned document on a Strategy for Groundwater Protection by the Office of Safe Drinking Water will be available soon. The last such proposal appeared in 1980 and was never followed up.

Speaking of following up, I promised to leave you with a question.

QUESTION

The question stated here rhetorically with an outline for your analysis, has practical and constitutional implications, not limited to New Mexico.

You have heard that in 1982 the U.S. Supreme Court resolved a dispute over water uses in Nebraska and Colorado by applying the Commerce Clause and holding that water is an article of interstate commerce.

Recalling the geography (and demography) and history of the Southwest, and how it was acquired by the United States under our constitutional system, this is my question:

What is the present obligation of the United States under Article IV, Sec. 3, Cl. 2 with respect to conserving, managing (and protecting the quality of) ground water resources beneath the public lands, in this case BLM lands in New Mexico that El Paso hopes to mine for domestic purposes?

This question calls your attention to a fact, often passed over in discussions of the El Paso case, an important fact that makes the New Mexico case different from the Sporhase case: NO public lands of the United States were involved in that case.

Recall for a moment the history of Texas and how it was first a sovereign state, then joined the Union in 1845 before the Mexican War. Think of the territory that was involved. As an independent state, Texas entered the Union with no public lands belonging to the United States. The lands acquired from Mexico were previously held under the law of Mexico and Spain, which meant that subsurface minerals and other interests passed in 1836 to the Sovereign State of Texas under principles of continental law and the regalian concept.

Now think of the Treaty of Guadalupe-Hidalgo in 1848, and the Gadsden Purchase of 1853 after the Mexican War, when the United States acquired, as sovereign and proprietor, vast territory including and surrounding huge private land grants in New Mexico and other lands occupied by persons who had no more than surface tenure or possession. All property interests of the Republic of Mexico in the vast territory passed to the government of the United States subject to the conditions and terms of the treaty and purchase.

The United States knew that the regalian concept applied in Mexico. In part, the principle was recognized when, in disputes over land titles, the United States authorized the selection of nonmineral lands by claimants such as the heirs of Luis Maria Baca. But with most dispositions, the United States followed the fee simple concept, and patented, in fee, land to grantees on private grants, and to citizens of the United States. That is history now, as are the abuses under the Mining Law of 1872, which invites miners to go on the public domain and discover minerals and acquire "unpatented claims," claims which, if perfected according to law and upon receipt of a patent, become a fee simple absolute. That law of 1872 is still in effect today. The United States also transferred lands to the railroads and to homesteaders in nonmineral areas under the same general policy until just before World War I. In 1916 Congress passed the Stock Raising Homestead Act, which expressly reserved minerals. Not until 1920 did Congress pass the Mineral Leasing Act. However, the United States still holds, as sovereign and proprietor, public lands administered by the Forest Service and the Department of the Interior.

It is not my intention to go into the semantics of ownership. If the United States doesn't own the public lands, who does? Not the descendants of Mangas Coloradas or Geronimo, or the individual states. At the very least, the United States is "trustee" of the public lands for all of the people of the United States; public lands do not belong to New Mexico although New Mexico has certain regulatory powers over the withdrawal of ground water. The public lands remain subject to the plenary control of Congress under Article IV which reads:

> The Congress shall have Power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States; and nothing in this Constitution shall be so construed as to Prejudice any Claims of the United States, or of any particular State.

The United States has not disposed of these lands and, at least since the report of the Public Land Law Review Commission in 1970, U.S. policy is to retain public lands except in special circumstances shown to be in the public interest.

The Supreme Court held long ago that the states are entitled to establish water law systems. The court has also held that water is not a mineral for purposes of property designation. In the Sporhase case, the U.S. Supreme Court recognized that the states have an interest in controlling and protecting ground water for certain purposes. But nowhere has Congress or the Supreme Court said that all rights in ground waters have been disposed of by the United States.

Now the Supreme Court has held that water can be an article in interstate commerce. What does this mean as applied to the public lands? Do the states have to relinquish control of ground water when it is withdrawn from federal property for transfer across state lines? Does the Commerce Clause in these circumstances become superior to Article IV and the responsibility of the United States to all of the people for their resource stored under public lands?

Isn't this a matter for congressional attention?

PERSPECTIVES ON NEW MEXICO WATER LAW

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The various elements of western water law need to be viewed from a broad perspective in order to realize a uniform system for the administration of water rights. The many differences between surface and ground water and the differences among state, federal, and interstate water law make it difficult to obtain this perspective. Although the prior appropriation doctrine could provide a foundation for a unified system of water law, it will have to be flexible enough to allow for necessary modifications in order to survive the many challenges to its application. As a lawyer, I hope to outline briefly some of the important challenges to the doctrine of prior appropriation in the context of current water law litigation in New Mexico.

The two basic principles governing New Mexico water law are set forth in Article 16 Section 2 of the New Mexico Constitution. Individuals may obtain rights to use public waters, but they do not own water in natural streams or underground water basins and the water right may be lost by nonuse. The public ownership principle originated in Spanish law. The second principle is that the water resources of the state shall be allocated among the water right owners according to the equity maxim: first in time, first in right. This principle arose out of the mining law of California. These two principles are the essential elements of the prior appropriation doctrine, which has been adopted as the law governing the appropriation of water in the western states. Federal and interstate water law incorporate important aspects of the doctrine of prior appropriation.

Probably the most significant development in the doctrine of prior appropriation has occurred in its application to underground water.

The New Mexico ground water code was enacted in 1931. It established a permit system for new appropriations and changes in water rights in basins declared by the state engineer. Since 1931, the state engineer has declared basins covering approximately 70 percent of the lands in the state. The ground water code requires the state engineer to grant an application to appropriate water if there is unappropriated water and the proposed appropriation would not impair existing water rights. In 1983, the New Mexico Legislature adopted two additional criteria. The appropriation of ground water must not be contrary to the conservation of water within the state, and it must not be detrimental to the public welfare of the citizens of the state.

New Mexico water law is based upon two basic goals: first, the maximum beneficial use of the water resources of the state and, second, the protection of existing water rights from impairment. These goals are hinged upon the concept of "unappropriated water." The appropriation of unappropriated ground water is primarily constrained by time limitations that differ between rechargeable and nonrechargeable basins.

In a rechargeable basin, there is a hydrological interconnection between a surface water stream and a ground water aquifer.

The 1962, New Mexico Supreme Court opinion in City of Albuquerque v. Reynolds was the first case to recognize the statutory authority of the state engineer to conjunctively administer interrelated surface and ground waters. Albuquerque applied to appropriate water from wells in the Rio Grande Underground Water Basin. The state engineer denied the permits on the grounds that the city must acquire and retire from use, surface water rights in amounts sufficient, at each point in time, to compensate for the increasing effects of pumping ground water on the river. The scheduled retirement of rights could ensure that surface water rights would not be impaired while allowing a time-limited new appropriation of ground water in storage.

In a nonrechargeable basin, the natural recharge to the aquifer equals the natural discharge. Any appropriation will result in the mining of ground water.

The 1966 New Mexico Supreme Court opinion in Mathers v. Texaco confirmed the authority of the state engineer to administer ground water in a nonrechargeable basin. Texaco applied for a permit to appropriate 700 acre-feet of water per year from the Lea County Underground Water

Basin for the secondary recovery of oil. When the state engineer declared the Lea County basin in 1952, he determined the amount of water that could be withdrawn from each township in the basin and still leave one-third of the water in storage at the end of 40 years. It was assumed that it would not be economically feasible to withdraw the water remaining after 40 years for agricultural and most other uses. The court ruled that the very nature of the finite stock of water in a nonrechargeable basin compels a modification of the traditional concept of appropriable supply under the prior appropriation doctrine. The court upheld the 40-year economic life, which established a time dimension for defining unappropriated water in a nonrechargeable basin.

The March 1984 opinion of the New Mexico Supreme Court in the consolidated cases of Stokes v. Morgan and Stokes v. Sanders involved applications to change locations of wells in the Portales Underground Water Basin, a nonrechargeable basin. Two kinds of water quality problems were considered by the court: sodium hazard water measured by the sodium adsorption rate, and salinity hazard water measured by electroconductivity. The court stated that the determination of acceptable salinity levels for irrigation water is not a simple task. It suggested that a change in water quality, based upon local soil types, from class 1 to class 2 or from class 2 to class 3 might create a strong inference of impairment of water rights. The court concluded, however, that the "same common sense approach" as that taken in Mathers v. Texaco should be applied in salinity cases. It held that withdrawls of water that cause a minimal increase in salinity do not constitute impairment as a matter of law.

In summary, the time limitations on the appropriation of water in rechargeable and nonrechargeable basins have significantly modified the concept of appropriable water and restricted the priority principle of first in time, first in right.

It might be useful to compare the development of New Mexico ground water law to recent developments in Colorado water law. In April 1984, the U.S. Supreme Court refused to review an opinion of the Colorado Supreme Court, which held that Colorado could control the appropriation and use of ground water that was not tributary to a natural stream. The landowners in that case had contended before the Colorado Supreme Court that the statutory provisions for the issuance of well permits to appropriate nontributary ground water were inconsistent with or constrained by the landowners' property rights in the water underlying their lands. They had argued that the nontributary ground water was not "severed" from the land at the time the federal government patented the land to private owners. The Colorado Supreme Court rejected this argument and held that, under the federal scheme for the transfer of public domain lands, the states were granted broad authority to provide for the use of non-navigable waters within their borders. The U.S. Supreme Court, in refusing to hear the appeal, affirmed the principle of public ownership of water resources.

In its 1983 opinion, the Colorado Supreme Court also stated that the pure right of prior appropriation applies only to waters in natural streams or tributary to natural streams. The court also ruled that in order to permit full economic development of nontributary ground water, a modified form of prior appropriation applied to the acquisition or rights to such water. The court stated that the "curtailing of junior appropriations in inverse order of priority does not provide a satisfactory method of protecting senior appropriations of nontributary ground water, for cessation of diversion from one well does not immediately make available an equivalent amount of water at another."

In an earlier opinion, the Colorado Supreme Court stated that "the hydrological realities of ground water make categorization a difficult factual issue . . . ." The court also stated that the distinction in some cases between tributary and nontributary ground water is "only a matter of degree." In a 1974 opinion, the court held that if it will take ground water over a century to flow a distance of eight miles to a stream, the tributary character of the water is de minimis and it is in effect "non-tributary tributary water." On the other hand, in 1979, the court indicated that if the pumping of wells, not the flow of water, would affect a stream in less than 100 years, the ground water is tributary to the stream.

Colorado's distinction between tributary and nontributary ground water is comparable to the New Mexico distinction between rechargeable and nonrechargeable basins. There is, however, an important difference in the way the two states apply these concepts. Colorado law may allow ground water mining in an aquifer even though it is hydrologically connected to a stream. New Mexico would allow a time-limited new appropriation subject to an obligation to offset effects by retiring surface water rights. In New Mexico three acre-feet domestic and stock wells are exempt by statute from the nonimpairment requirement. The small appropriations of water from these wells, taken individually, should have only a de minimis effect on stream flows. In the Rio Pojoaque adjudication suit, however, the Indian pueblos have requested the federal court to enjoin all domestic and stock wells drilled after 1924 on the grounds that the stream system was fully appropriated prior to 1924, and the 1,500 domestic wells drilled after 1924 impair their surface water rights. The federal court is expected to rule on this priority call after a final adjudication decree is entered. If the pueblos can show impairment, common sense would suggest that the prior appropriation doctrine should be modified to at least exempt some domestic use from their priority call.

I wish to turn now to interstate water law based upon compacts between states or decrees entered by the U.S. Supreme Court. There are eight interstate compacts and one Supreme Court decree apportioning interstate streams in New Mexico. The U.S. Supreme Court has recognized that: "Priority of appropriation is the guiding principle . . . ." But if "an allocation between appropriation states is to be just and equitable, strict adherence to the priority rule may not be possible." The only exception to the priority rule applies to junior water rights in a fully appropriated stream system.

In the case of Colorado v. New Mexico, a suit to equitably apportion the waters of the Vermejo stream system, which is fully appropriated in New Mexico, the Supreme Court is considering whether to create two new exceptions to the priority rule. The special master's most recent report to the court recommended an award of 4,000 acre-feet to Colorado. The master's recommendation was based upon three basic findings: (1) that water shortages do not excuse the failure of New Mexico users to fully develop decreed rights; (2) with proper conservation measures, there is an adequate water supply to satisfy the needs of all users in New Mexico; and (3) the injury, if any, that New Mexico users would likely suffer as a result of Colorado's diversion is insubstantial and does not outweigh the benefits which Colorado would gain.

In the near future, the U.S. Supreme Court will issue an opinion in this case, which may fundamentally alter or restrict the doctrine of prior appropriation as it is applied in the equitable apportionment of interstate streams.

The court will decide whether water that has been or could have been conserved in one state may be claimed for new uses in another state. For example, water users in the Vermejo Conservancy District have constructed a closed domestic and stock water delivery system, which may save 790 acre-feet in providing 36 acre-feet for consumptive beneficial use. Can Colorado claim the conserved water, which is equivalent to a diversion of 1,500 acre-feet in Colorado, even though the water was conserved in order to reduce serious shortages in New Mexico?

The court also may decide whether there should be an exception to the rule of priority based on a benefit-cost analysis. The analysis compares the benefit of future high-value uses of water in one state against the cost of terminating existing low-value uses in another state.

It is unlikely that the court would adopt a benefit-cost analysis exception to the priority rule. If it adopts a conservation standard, which applies to all interstate streams, whether previously apportioned or not, it will fundamentally change interstate water law.

Federal law is the third source of water law in New Mexico. Because the United States was the sole proprietor of most of the lands in the arid West, there was no occasion for the direct application of the common law riparian doctrine. Only upon the disposal of public lands did Congress and the courts have to consider what water rights, if any, were appurtenant to them. The federal reserved doctrine evolved out of the development of public land and water laws.

The public land acts of 1866, 1870 and 1877 severed all waters from the public domain, potentially leaving none under the control of the federal government for existing or future federal purposes. The protected "special uses" of lands reserved from the public domain did not expressly include water rights that might have been needed to facilitate the land uses.

In the 1908 Winters opinion, the Supreme Court established the doctrine of federal reserved water rights for lands withdrawn by the government from the public domain. In doing so, the court implied rejection of any riparian water right claims of the United States.

The United States had brought suit on behalf of the Fort Belknap tribes to enjoin upstream appropriations on the Milk River in Montana. The United States asserted two theories in the complaint: (1) that a modified form of the riparian doctrine was the law of Montana and applied to defendants; and (2) that the 1888 agreement with the Fort Belknap tribes, which was ratified by Congress, retained or granted the right to divert and use the Milk River waters on the Indian reservation.

In a supplemental brief filed with the Supreme Court, the United States changed from the state law riparian theory to a theory of federal reserved rights. It argued that the right of the United States to a continued flow of water applied to property set aside for a specific use, but did not apply to lands that were part of the public domain.

The court adopted the federal reserved water right theory as follows:

> The power of the Government to reserve the waters and exempt them from appropriation under the state laws is not denied, and could not be . . . . That the Government did reserve them we have decided, and for a use which would be necessarily continued through the years. This was done on May 1, 1888 . . . .

The Winters opinion determined who reserved what rights, when, and under what circumstances. The United States reserved the water rights, the Indians did not retain them. The rights so reserved were rights to the then unappropriated water of the public domain at the time of the reservation, not riparian rights within the federal reservation. The implied intent to reserve water rights both defined and limited the rights reserved.

In United States v. New Mexico, a 1978 opinion, the Supreme Court considered the reserved water rights claims of the United States for the Gila National Forest. The court ruled that: "Where water is necessary to fulfill the very purposes for which a federal reservation was created, it is reasonable to conclude . . . that the United States intended to reserve the necessary water."

In summary, when the United States withdraws public land from entry and reserves it for a specific, congressionally authorized purpose, by implication, it also reserves the necessary unappropriated water to fulfill the purpose of the reservation. The reservation of unappropriated water attaches to and becomes a servitude on those lands granted from the public domain.

Federal reserved water rights are basically appropriative not riparian rights. They differ, however, in two basic ways from rights under the prior appropriation doctrine: (1) due diligence is not required to relate the priority date back to the initiation of the right, and (2) they are not lost by nonuse. In pending adjudication suits in New Mexico, Indian pueblos and tribes are seeking to exempt themselves from the priority rule by claiming legally paramount rights or rights with an aboriginal priority date. Certain tribes also have claimed that the congressional purposes for the federal reservation of land do not limit the adjudication of rights.

In conclusion, I believe that the genius of New Mexico water law is based upon the broad definition of the prior doctrine appropriation in its constitution and the statutes that allow the specific application and evolution of the doctrine by the state engineer and the courts on a case by case basis as the need arises.

LEGAL, HYDROLOGICAL AND ENVIRONMENTAL ISSUES SURROUNDING THE EL PASO WATER SUIT

Thomas G. Bahr
Director, Water Resources Research Institute

In organizing the program for this year's water conference, we wanted to have speakers talk about some of the more important water litigations taking place at this time. The El Paso water suit certainly ranks high in this regard. A problem we had, though, was to find a knowledgeable speaker who was not involved in the litigation. Most lawyers involved in this suit generally avoid much public comment about it for fear of jeopardizing their case. This is understandable. After several unsuccessful phone calls, I finally decided to make this presentation myself.

To begin, let's back up a few years and look at some of the facts and issues involved in this case. On September 5, 1980, the El Paso Public Service Board filed suit in Federal District Court seeking to overturn a New Mexico law that prohibited anyone from drilling a well in New Mexico and transporting the water for use in another state. The thrust of El Paso's argument was that the New Mexico statute was unconstitutional because it represented an impermissible burden on interstate commerce.

Because of the potential for a surge of speculative drilling in the area, the state engineer about a week later declared the Lower Rio Grande Underground Water Basin and then the Hueco Underground Water Basin. This action effectively put any further ground water appropriations under the jurisdiction of the state engineer. The day after each of these declarations, El Paso filed first for 266 applications to appropriate 246,000 acre-feet a year from the Lower Rio Grande Underground Water Basin and next for 60 applications to appropriate 50,000 acre-feet a year from the Hueco Underground Water Basin. The city of El Paso is thus first in line with their applications seeking a total of 296,000 acre-feet a year.

On April 21, 1981, the state engineer denied these applications on the grounds that New Mexico law does not permit our ground water to be transported out-of-state. U.S. District Court Judge Howard Bratton later declared this case ripe for litigation and the first round of hearings were held here in Las Cruces on January 11-13, 1982.

During this same period, but in another part of the country, another water case was brewing. This case, involving a farmer in Nebraska, eventually would shape the outcome of the El Paso case. Let me tell that story and then come back to the El Paso case.

A farmer named Joy Sporhase owned a farm in southwestern Nebraska as well as adjacent farmland in Colorado. Sporhase wanted to irrigate 140 acres of corn and beans on the Colorado portion of the farm with ground water from a well 55 feet inside the Nebraska state line. Nebraska said no to the request , citing a provision in Nebraska law that prohibits the out-of-state export of ground water to any state that did not have a reciprocal agreement. Colorado law had no such reciprocal arrangement with Nebraska and eventually Sporhase was overruled by the Nebraska Supreme Court. That decision was appealed to the highest court in the land and they agreed to hear the case.

Lawyers for Sporhase based their arguments on a seemingly small technicality, claiming that ground water is an article of commerce and that the Nebraska reciprocity provision was unconstitutional because it burdened interstate commerce. During the legal proceedings, 17 legal briefs were filed with the court in opposition to the position taken by Sporhase. Those who filed these briefs in support of the permise that Nebraska was correct in preventing Sporhase from exporting ground water will give you an idea of the complexity of the issue and the high stakes involved. Three groups in particular should be of interest: farmers, environmentalists and railroaders--strange bedfellows if I do say so myself. Each group had its own reason for opposing the export:

1. Farmers were concerned that out-of-state energy interests would drain water from agriculture.
2. Environmentalists saw out-of-state export as a threat to water-based state fish and wildlife programs.
3. Railroaders saw it as opening the door to coal slurry pipelines--a competing mode of transportation.

It should go without saying that several western states also filed briefs: New Mexico, Colorado, Utah, Nevada, Kansas, North Dakota, South Dakota and Missouri. Arguments here were that water is different than coal, gas, oil, etc., and should not be subject to the commerce clause analysis.

There was only one "friend of the court" brief filed in support of Sporhase. That brief was filed by the city of El Paso.

The U.S. Supreme Court listened to all sides of the argument and rendered its decision on July 2, 1982. It was an 18-page opinion, accompanied by a six-page dissent prepared by two Arizona justices, Rehnquist and O'Connor. Hundreds of pages already have been written on what the court said in the 18 pages, but let me summarize the opinion this way. The court held that:

1. Ground water is an article of commerce and as such is subject to regulation by Congress.
2. Nebraska's reciprocity provision was unconstitutional because in the court's opinion, it represented an unnecessary burden on interstate commerce.

Many consider the opinion to be very narrowly construed. The court, however, did add language to clarify their reasoning. Let me summarize a few:

1. State ownership of its own ground water is a legal fiction.
2. States should not assume that congressional silence in deference to states' rights in water management means that Congress has given states blanket authority to impose impermissible burdens on interstate commerce. (In other words, before a state can legally place burdens on interstate commerce, Congress must expressly and affirmatively authorize them to do so.)
3. A demonstrably arid state conceivabley might be able to marshall evidence to justify even a total ban on exportation of water.

There were some other statements in the opinion that suggested a state can impose restrictions on water export that could discriminate in favor of its own citizens. However, these restrictions (statutes) must regulate even-handedly to achieve a legitimate local public interest.

Furthermore, the effects of such a statute on interstate commerce must be only incidental. The court said "to conserve and preserve diminishing sources of ground water" is unquestionably legitimate. It also said that a state's power to regulate the use of water in times and places of shortage for the purpose of protecting the health of its citizens--not simply the health of its economy--is at the core of its police powers.

Let's turn back to the El Paso case. As I said, the U.S. Supreme Court rendered its decision on July 2, 1982, and in view of its relevance to the El Paso case, Judge Bratton on July 14, 1982, asked if both sides in the El Paso case would like to prepare additional arguments. New arguments were heard in another hearing on September 13-14, 1982, in Albuquerque. Five months later on January 17, 1983, Bratton made his decision and ruled in favor of El Paso. His ruling held that:

1. New Mexico's statute is invalid.
2. The Rio Grande Compact is not relevant to this case.

Bratton went on to indicate that New Mexico was not able to prove that the embargo statute served a legitimate local purpose nor was it narrowly tailored to meet that purpose. He did say that the embargo did serve a legitimate local purpose for health and safety requirements, however, outside of fulfilling human survival needs, water is an economic resource. Most of you are aware of this decision, but let me point out that it did not grant El Paso a drop of water--it simply struck down our old law.

As most of you know, the 1983 New Mexico Legislature repealed the embargo statute and passed a new law that does allow for the export of ground water. New Mexico also appealed Bratton's decision to the 10th Circuit Court of Appeals. Earlier this year that court remanded the case back to Bratton's court for "fresh consideration" in view of the fact that the old law was repealed and a new one enacted. As you know, Bratton heard arguments on April 24, 1984, in Albuquerque relating to El Paso's challenge to our new law and also a two-year moratorium on ground water development here in the Mesilla Valley. I'll not get into a discussion of the moratorium other than to say, as a nonlawyer, that El Paso is now on far weaker legal grounds than before.

Before going any further, let me touch on the new law. The law says that out-of-state use of New Mexico water is permissible but will require a permit from the state engineer after he determines that:

1. The use will not impair existing water rights.
2. The use is not contrary to the conservation of water in the state.
3. The use is not otherwise detrimental to the public welfare of New Mexicans.

The law also lists six factors the state engineer must consider:

1. The supply of water available in New Mexico.
2. Water demands of New Mexico.
3. Whether there are water shortages in New Mexico.
4. Whether the water applied for could be feasibly transported to alleviate water shortages in New Mexico.
5. The supply of water available to the applicant state.
6. The demands on the applicant's supply in the state where the water will be used.

I stated before a legislative committee last fall that "protection of the public welfare is the cornerstone" of the new law and somehow that statement cropped up in an El Paso brief filed on March 19, 1984, as somehow supporting their argument against our new law. I question the relevance of El Paso quoting me, since I have absolutely nothing to do with administration of water rights in this state.

After this long discussion of how the case got to this point, the question is, what does it all mean? First, it's clear that El Paso is very serious in their efforts to obtain ground water in New Mexico.

Secondly, it's clear that our state has a legitimate interest in protecting the health, safety and well being of its citizens. One may argue over what constitutes public welfare, and indeed this may be an important legal argument. However, I don't think anyone arguing the New Mexico side of the case believes that economic protectionism is implied when defining public welfare. Framers of the U.S. Constitution, in creating the commerce clause and also the privileges and immunities clause, had great foresight in our federal system of government. They did not want, nor do we want, this country to be broken up into economic fiefdoms creating economic balkanization of the union. Our forefathers believed that fragmentation of individual states created by imposing burdensome measures on interstate trade will weaken the economy of the nation. I don't believe New Mexico's water policy conflicts in any way with these concepts. Our policy is simply to assert the state's legitimate police powers, which were also given to us by that same constitution.

Let me now turn to three important facts in this quest for New Mexico ground water by the city of El Paso. First, El Paso wants 296,000 acre-feet a year. How much is that? It's enough water, at 3,000 gallons a second, to fill a back yard pool in six seconds. And it's 100,000 acre-feet more than the current consumptive use within the Elephant Butte Irrigation District. The second fact is that El Paso claims there are some 60 million acre-feet in storage. That figure probably comes from a USGS report that mentions theoretically recoverable ground water. What is theory and what is reality are two different things. For example, theoretically we could extract all the water we would ever need from the air that blows by Las Cruces every year. All we would need would be a few thousand miles of copper refrigeration coils and condensers, some freon (a few super tankers full), and a compressor powered by a few dozen nuclear power plants. Then we could build a gigantic dehumidifier that produces pure water. The point is that water available for appropriation in a practical sense is far less than what is theoretically recoverable. The ground water in this valley comes from a stream related aquifer. Simply stated, that means the river water and the ground water are connected in such a way that drawing on the ground water in excess of recharge will ultimately reduce the flow of the river.

I like to compare the drawdown to what I call my milkshake model. If you put a straw in the middle of a thick milkshake and suck, you will create a "cone of depression" around the straw. The level of the milkshake will be higher on the sides than in the middle. The more you suck, the deeper that cone gets and the closer it moves to the side of your container. This is similiar to what happens when pumping a water well.

Now picture this situation existing in the Mesilla Valley where you have the Rio Grande passing along the edge of this cone of depression. At some point, the stream will intercept the depression and flow down to fill the depression. Ultimately, if you keep on sucking water from the aquifer, the entire stream will flow into the depression and you will reach an equilibrium whereby what you pump from the well is equal to what flows from the stream into the depresson. The total amount of water you sucked out from the time you started until the time equilibrium was reached could be considered the amount of ground water available for appropriation. Two things are important to remember from this situation:

1. There is still a lot of ground water left in the aquifer.
2. The flow of the river has ceased. The water now goes into the ground and out the well.

This means you can only extract a fraction of that in storage before you "dry up" the Rio Grande. To do this in a legal sense, you somehow would have to compensate those who had rights to the flow of the stream. In New Mexico this is handled by conditioning a well permit such that an appropriator has to acquire and then retire surface water rights according to a schedule set by the state engineer. This is to assure that the river keeps flowing the way it did before pumping began.

So, in terms of the second fact I mentioned, there is probably some ground water available for appropriation in the Mesilla Valley, but certainly <u>not</u> 60 million acre-feet. Hydrologists are currently trying to arrive at that number. I should also mention that one has to be very careful in granting a permit to appropriate ground water because if you miss the mark and overappropriate, it may be many years before you know it and then it may be too late to do anything about it. The third fact is that large scale ground water development can create undesirable water quality and environmental consequences. The first consequence concerns salt water encroachment from shallow ground water to the deeper, better quality aquifer. To illustrate, let's go back to the milkshake model. If you had a layer of salt floating on the top of your milkshake and if you suck from deep within your container through the straw, you will get a good quality milkshake--for a while. Eventually you will suck the depression to the point where salt enters your straw. If you are unfortunate enough to be sucking from another straw in the same milkshake, only from a shallower depth, you would very quickly be sucking salt.

A similar situation would happen in the Mesilla Valley because the shallow ground water is much more saline than water from deeper in the aquifer.

A second environmental consequence is a very real possibility of land subsidence, which would be created by large scale ground water development. Layers of clay material in the aquifer, when dewatered, can shrink. When they do, the overlying land will also sink. There are examples of this phenomenon all over the country. I've seen accounts of well casings sticking out of the ground many feet in the air. The casings didn't get poked up from below. They stayed in place, and the ground sank around them.

I would hazzard to guess that it might be in the interest of public health and safety not to have well casings sticking up in the air with the ground sinking around the local prison, fire department or hospital, for example.

I don't think anyone knows for sure at this time how much water can be safely extracted from the Lower Rio Grande Underground Water Basin. I suspect a few million acre-feet may be available. I further expect that what is available can be legitimately claimed by New Mexico for use by New Mexicans to protect our health and safety and provide us with the means to continue living as New Mexicans in an environment we choose to live in.

I view the law as a tool. If you want to remove a head bolt from an engine, you don't use a pair of vice grips; you use a strong socket and breaker bar. If you use vice grips, you are likely to tear up the head of the bolt and make it unusable.

I'm not suggesting that the commerce clause is a bad tool. It's a good tool for some jobs, but not for apportioning water in water scarce states. Congress needs to say that loudly and clearly enough for the lawyers to understand. Congressional inaction in this case opens the door for lawyers to use their imagination in finding all sorts of tools to remove head bolts from an engine. The lawyers certainly get paid for their efforts, but in the meantime they certainly can mess up a lot of head bolts. Let's hope they don't mess up our water supply.

CURRENT NEW MEXICO WATER LITIGATION: HARD CHOICES FOR NEW MEXICO IN THE FUTURE

Charles T. DuMars
Professor, University of New Mexico Law School

The importance of water in the world and in the Southwest cannot be overstated. Dr. Philip Handlar, former president of the National Academy of Sciences has concluded: "It is the world's fresh water supply that will really determine the number of Homo sapiens (mankind) in the next century." This statement is particularly true in arid regions of the world such as the Southwest. The majority of the states in the United States are experiencing some water shortage. Yet, we cannot seem to cope with the problem. It takes at least a generation--26 years or longer--to move water projects from inception to completion. The demand for water is a combination of the need for food and energy.

As an example of the escalating demand for food, suppose that at the time of Christ, the world population had been only one couple, and the population had grown at 2 percent a year, as it does now, the population of the earth would be 25 million times its present size. This supposition reflects, perhaps the truth of the predictions of Thomas Malthus in 1798, that our capacity to produce people so far exceeds our power to produce food that the world will someday face massive starvation.

Irrigated land is essential to food production. While only 15 percent of the world's cropland is irrigated, it produces 30 percent of the world's food supply. In the short run, however, it is unlikely that water will remain in irrigation, at least in the western United States. Water is demanded for energy and municipal and industrial development throughout our fast growing Sunbelt region. Indeed, when an air conditioner is turned on in Los Angeles, the power generator is turned on in our Four Corners region. New Mexico's water supply is used to generate steam to serve the generators in those coal-fired power plants.

By the year 2020, New Mexico will face a possible water deficit of 720,000 acre-feet. This deficit, however, is dwarfed by the anticipated deficits in its sister states Arizona, of 1.6 million acre-feet and Texas, of 9.5 million acre-feet. By the year 1990, Texas alone will have a deficit four times the annual depletions from the Rio Grande in New Mexico.

These figures lead to the inevitable conclusion that the product of this water scarcity will be intense competition; competition between agriculture and industrial uses; competition between states; and competition between the federal government and the states. Four New Mexico cases illustrate this point.

On the issue of interstate competition, we in New Mexico are aware of the *Sporhase* decision as well as the *El Paso* case. Another decision, *Colorado* v. *New Mexico* illustrates this same interstate competition.

The Vermejo River originates in Colorado and flows into New Mexico for about 55 miles before it joins the Canadian River. No one in Colorado has ever used the river. In New Mexico, however, in 1941 a New Mexico State District Court in effect ruled that the river is fully appropriated and apportioned its waters among New Mexicans. In 1978, however, Colorado filed an original action in the U.S. Supreme Court to apportion 4,000 acre-feet of the river to Colorado to be used in steel production. A special master heard the case and ruled for Colorado. On appeal to the U.S. Supreme Court, the special master was upheld in principle, but the case was reversed and remanded to the special master because the factual findings were insufficient.

The importance of the case is that the court adopted a "cost-benefit" analysis and ruled that even though New Mexico had prior rights to the entire stream, some of that water may go to Colorado if the existing agricultural uses are so wasteful and the new industrial uses are so efficient that "the benefits (to Colorado) outweigh the harm to existing uses in another state (New Mexico)." The case has been reargued and the U.S. Supreme Court will, I hope, rule that the benefit to Colorado *does not* outweigh the injury to New Mexico.

Two cases in which I am currently participating, and which are now pending, clearly reflect the agricultural/industrial competition for water. In one case, the Angel Fire Development Corporation is seeking to put down wells in a ground water aquifer hydrologically connected to a stream that fills Eagle Nest Lake where senior agricultural users have rights. Rather than buy and retire surface rights as they are affected by the well pumping, Angel Fire argues that the creation of parking lots and ski runs creates more runoff to the stream. The corporation argues that the surface owners should accept this new source of supply as a replacement for the water lost by well pumping. The agricultural users relying on Eagle Nest water argue that the new source is an insufficient and illegal substitution.

Another case involves the attempt by the New Mexico Department of Game and Fish to transfer water rights out of the Carlsbad Irrigation District up the Pecos River to Santa Rosa Lake. The irrigation district argues that the transfer would substantially impair the agricultural base of the district. The Game and Fish Department argues that the water will be used in a recreational lake, which would be a beneficial use, and the transfer is consistent with New Mexico water law.

The final case is New Mexico v. Aamodt, involving the Pueblo Indians on the Rio Grande and its tributaries above Santa Fe. This is an action to adjudicate the rights of certain northern New Mexico water users, including the Nambe, Tesuque, Pojoaque and San Ildefonso pueblos. At issue is the Nambe-Pojoaque River system tributary to the Rio Grande. The pueblos claim sufficient water to irrigate all of the "practicably irrigable acreage" on their reservations, with the first priority on the river, even though those lands have never been irrigated.

If the same argument were made and won by all of the other pueblos on the Rio Grande, such a ruling would grant to the pueblos an amount many times greater than the entire flow of the river. A major issue in the case is how Mexican and Spanish law would have resolved the controversy. The non-Indians have argued that under Spanish law there was an obligation to balance all interests of the parties in a way that maximizes the interest of all and not just the interests of one group to the absolute detriment of another. The existence of this important Indian water rights case once more illustrates my point that the name of the game in 1984 is competition.

In conclusion, I am obligated in a forum such as this to make some predictions as well as some recommendations. First, the impact of interstate competition, as reflected in the Vermejo case, will not be great because of existing interstate compacts. I believe, however, it will be difficult to stop the more economically powerful and politically influential states from taking the waters of resource-colony states such as New Mexico. It is my firm hope that Congress in its wisdom will acknowledge the principle embodied in the 10th Amendment to the U.S. Constitution. The principle holds that states constitutionally cannot be forced out of business because of lack of water, and that the concept of the public welfare of the state means the constitutional right to conserve water for each state's future generations.

If Congress does not recognize the concept of state sovereignty, New Mexico should consider establishing a system of "state reserved rights." The federal government and the Indian tribes have long recognized this concept. We western states have somehow missed the vital idea of reserving water for the future. We need to assert our state reserved rights by negotiating compacts and, where necessary, appropriating out of the water market, sufficient water to meet the needs of future generations. We already have done so with surface water in the recently dedicated Ute Reservoir in eastern New Mexico. Where necessary, we may need to do the same for ground water.

Second, concerning intrastate competition among agricultural, municipal and industrial uses, it is likely that the water will be transferred to uses that can generate more money. The state law does now, and should continue, to support a forum that allows a free and fair exchange of price between buyer and seller and allows other water right owners who might be involved, the right to protest those exchanges. In addition, an appropriate state agency should look closely at the environmental and conservation consequences of these water rights transfers to higher economic valued uses.

Finally, on the issue of federal versus state competition, the Indian water rights cases do not frighten me. I know of no reserved water rights case that has ever actually curtailed off-reservation ground water pumping to support a subsequently adjudicated Indian water right. Neither do I believe that the Pueblo Indians want, nor could use, all the surface water rights on the Rio Grande. Rather, I believe the tribes want respect for their tribal governments and a reasonable amount of water to support their tribal needs, both of which I hope and expect they will receive.

An additional concern at the federal and state level is the possibility that water in the public domain could one day be seen as a federal asset, or cash register, for financing the federal debt of the more populous eastern states. By this, I mean that tomorrow Congress, by simple amendment of the Desert Lands Act, could pass a law that says all unappropriated ground water in the public domain belongs to the federal government and is not subject to appropriation under state law. Vast quantitites of ground water thus could be taken from the western states' jurisdiction immediately. Congress is now taking a hard look at hydropower electricity generated from reservoirs in the West as a source of federal revenue. With equal ease, Congress could place a federal severance tax on water, or it could decide to lease water like coal, oil and gas. Coal was a locatable mineral until the 1920s when its obvious basis as a source of revenue brought about the leasing system. Geothermal waters on federal land are allocated by a leasing system. Of course, Congress is not going to act tomorrow, and hopefully never, on such all-encompassing legislation. Once again, though, the state has the capacity to pre-empt such action under the existing Desert Lands Act by appropriating ground water on the public domain and taking it out of Congress' hands.

I am not now advocating massive state appropriation of water. Rather, I hope I am giving you food for thought about what the water demands for the next 20 years may be. I am saying only that the competition for fresh water will be fierce and that federal and tribal governments may have something in this concept of "reserved rights" for future generations.

To show I am on the right side of every issue, I have decided to close with a quote from the Bible, Genesis 26:18-22:

> Isaac dug anew the wells which had been dug in the days of his father Abraham and which the Philistines had stopped up after Abraham's death; and he gave them the same names his father had given them. But when Isaac's servant, digging in the wadi, found there a well of spring water, the herdsmen of Gerar quarreled with Isaac's herdsmen, saying, "The water is ours." . . . And when they dug another well, they disputed over that one also . . . He moved from there and dug yet another well, and they did not quarrel over it; so he called it Rehoboth, saying "Now at last the Lord has given us ample space to increase in the land."

I am afraid that in New Mexico, the search for Rehoboth is over. Unlike Isaac, New Mexico cannot just move on and find new water. Rather, we must conserve and control what we have.

THE RIO GRANDE COMPACT

Jesse B. Gilmer
Texas Commissioner, Rio Grande Compact

The recorded history of the Upper Rio Grande watershed began with the discovery of the Rio Grande by Coronado in 1540. We have not been able to pinpoint the exact location where Coronado discovered the Rio Grande, but it would be a safe statement to say it was in the general vicinity of what is now Bernalillo, New Mexico.

The Rio Grande originates in the Colorado Rockies and the San Juan Mountains of New Mexico, and flows southward out of Colorado for more than 400 miles across New Mexico. After leaving New Mexico, it forms the boundary between Texas and Mexico for about 1,250 miles to its mouth at the Gulf of Mexico. The total length of the river is about 1,800 miles.

For many years explorers thought the Upper Rio Grande above what is now Fort Quitman, Texas, and the Lower Rio Grande below Fort Quitman, Texas, were two different rivers. I do not have the exact date when it was finally determined that the two rivers were one and the same.

It was evident to the Spanish explorers that the Upper Rio Grande in what is now New Mexico and Colorado had been farmed by the Indians, probably Pueblo Indians or their predecessors, for perhaps hundreds of years. There was evidence of irrigation systems with irrigation ditches having been prepared by the Indians.

The Spaniards brought with them to the new world the Mighty War Machine (the horse), Christianity and irrigation customs, law and knowledge. A few years ago, the great John Clark, a former director of the Water Resources Research Institute here in Las Cruces, was invited to Spain to attend a meeting of an irrigation district board, which had met regularly for about 900 years.

Irrigation by non-Indians in the San Luis Valley of Colorado began in the early 1850s.

The Rio Grande is an interstate and international stream. It rises in Colorado, flows southward for more than 400 miles across New Mexico, and down the international boundary to the Gulf of Mexico, furnishing irrigation water to the different irrigated areas of the three states.

Above Fort Quitman, Texas, almost all of the water of the Rio Grande originates in Colorado and New Mexico. Below Fort Quitman, Texas, the river is supplied mainly by tributaries from Mexico.

The main natural divisions of the Upper Basin north of Fort Quitman, Texas, are: (1) the San Luis Valley section of Colorado, (2) the middle section of New Mexico; and (3) the Elephant Butte, Fort Quitman, section in New Mexico-Texas and Mexico.

In the early 1890s, water shortages occurred along the Rio Grande in the Mesilla and El Paso valleys. It became evident that certain sections on the Upper Rio Grande were being overdeveloped and that some interstate and international attention should be applied to the consequent problems. In 1896, the secretary of the Interior Department embargoed any new development of the Upper Rio Grande.

On February 25, 1905, Congress authorized the Rio Grande Reclamation Project, which now operates Elephant Butte Dam and below and is known as the Rio Grande Project.

In 1906, Mexico and the United States completed the negotiation of a treaty having to do with the division of the waters of the Upper Rio Grande between the United States and Mexico. The treaty also allowed for delivery by the United States at El Paso, Texas, of 60,000 acre-feet a year to Mexico.

After the authorization of the Rio Grande Reclamation Project and the Treaty of 1906 between Mexico and the United States, Elephant Butte Dam was authorized. Elephant Butte Dam was completed in 1916.

In 1923, Colorado and New Mexico enacted statutes authorizing their respective governors to appoint commissioners to negotiate a Rio Grande Compact. In 1924, the first meeting of the Rio Grande Compact Commission was called to order by the Honorable Herbert Hoover, then secretary of Commerce who was designated by the United States to be the nonvoting federal chairman of the commission. Secretary Hoover, who was appointed by President Coolidge influenced negotiations of a temporary compact. The Compact of 1929 was entered into among New Mexico, Colorado and Texas. The compact was to have a life of six years, which would give the three states an opportunity to negotiate a permanent compact. The temporary compact was later extended to about 10 years.

New Mexico State Engineer Thomas M. McClure took the position as New Mexico commissioner. He stated that within the context of the Compact, Elephant Butte Reservoir would be the dividing line between New Mexico and Texas. He also stated that New Mexico was willing to negotiate the right to the use of water under the Elephant Butte Project on the basis of fixing a definite amount of water to which that project would be entitled. Texas Commissioner Frank B. Clayton also considered the lands in both states below Elephant Butte Reservoir as a unit.

In order to obtain a large volume of dependable data on which to base the negotiation of a permanent Rio Grande Compact, the states requested, through the president, that the United States have a study performed by the National Resources Committee.

In August 1937 the chairman of the Consulting Board of the Rio Grande Joint Investigation, said:

> For three-quarters of a century the Western States have been creating and perfecting, gradually but definitely, the legal principles and the social institutions needed where irrigation is the chief basis of economic life. Although much remains to be accomplished, none of the Western States lacks authority for adequate control and administration of intrastate waters, whether surface waters or underground waters. On the other hand, the authority of a State to control and administer interstate waters is limited. If the claims of two or more States to such waters are in conflict, the States may settle the controversy through negotiation of an interstate compact or may have recourse to the Supreme Court of the United States for adjudication of the differences at issue. The weight of public opinion favors the interstate compact. Moreover, the Supreme Court repeatedly has taken a friendly attitude toward the compact mode of action.

The U.S. Constitution sets forth the following in Section II:

> The Judicial Power shall extend to all cases in Law and Equity arising under this Constitution . . . to controversies to which the United States shall be a party; to controversies between two or more states . . . .

The National Resources Committee composed of many agencies of the United States, submitted a report entitled, <u>The Rio Grande Joint Investigation In the Upper Rio Grande Basin, In Colorado, New Mexico, and Texas</u>. The study was conducted in 1936 and 1937. The committee report was printed in February 1938 and consisted of 566 pages of detailed narratives, maps, charts, graphs and statistical data.

The agencies involved in the Rio Grande Joint Investigation were: the U.S. Department of the Interior; the U.S. Geological Survey (USGS), Water Resources Branch Division of Ground Water, Water Resources Branch of Quality of Water, Conservation Branch; Bureau of Reclamation, Water and Power Division; and the Office of Indian Affairs. The U.S. Department of Agriculture was involved with the Bureau of Agricultural Engineering, the Soil Conservation Service, the Bureau of Plant Industry, and the Resettlement Administration.

In 1939 due to the thoroughness of this report and the hard work of the three states and the federal chairman, the resultant Rio Grande Compact became the law of Colorado, New Mexico, Texas and the United States. The compact has not been amended since its establishment in 1939. There has been no request by any signatory state to have the compact amended.

The Rio Grande Compact is a concise, clear document. It is administered by the Rio Grande Compact Commission. The commissioners for Colorado and New Mexico are the state engineers of their respective states. The commissioner for Texas is appointed by the governor of Texas. The chairman of the Compact Commission is appointed by the president of the United States, and presides without vote. All official actions of the commission require the unanimous consent of the commissioners.

The first paragraph of the Rio Grande Compact reads:

> The State of Colorado, the State of New Mexico and the State of Texas, desiring to remove all causes of present and future controversy among these states and between citizens of these states, and citizens of another state, with respect to the use of the waters of the Rio Grande above Fort Quitman, Texas, and being moved by considerations of Interstate Committee, and for the purpose of effecting and equitable apportionment of such waters have resolved to conclude a Compact for the attainment of these purposes . . . .

The compact provides for an equitable apportionment of all waters of the Rio Grande above Fort Quitman, Texas, and provides for the operation and maintenance of about 20 gaging stations upstream from Fort Quitman.

The compact sets forth the obligations of Colorado to deliver varying amounts of waters to New Mexico and Texas at the Colorado/New Mexico state line. For example, Colorado's yearly obligation to deliver water in the Rio Grande at the Colorado/New Mexico state line would be 350,000 acre-feet of water out of 1 million acre-feet passing various key Colorado gauges. The compact sets forth New Mexico's obligation to deliver to Texas varying amounts of waters at Elephant Butte Reservoir for users below the reservoir. For example, New Mexico's yearly obligation to deliver water to Texas at Elephant Butte Reservoir would be 800,000 acre-feet, if the amount of water flowing past the Otowi index station would be 1,200,000 acre-feet. Also in the compact are articles that control the allowable water storage and release from water storage of Colorado and New Mexico in upstream reservoirs, and the circumstances surrounding the control of such storage.

The compact recognizes that conditions in the Upper Rio Grande above Elephant Butte Reservoir are such that annual and seasonal variables in the amounts of run-off and the conditions under which water can be stored must be considered. The compact provides that upstream states above Elephant Butte Reservoir may from time to time and under certain circumstances incur debits, both annually and accumulatively. It also provides for conditions and actions required in the event that Elephant Butte Reservoir spills.

Now that the San Juan-Chama Project has been constructed, the compact recognizes that waters brought from the western slopes of the Continental Divide to the eastern slope will be separate from those of the Rio Grande.

The compact recognizes and acknowledges that the schedules contained and the quantities of water allocated shall never be increased or diminished by reason of any increase or diminishment in the delivery or loss of water to Mexico. Nothing in the compact shall be construed as affecting the obligations of the United States to Mexico under existing treaties, or to the Indian tribes, or as impairing the rights of the Indian tribes. There are about 17 Indian tribes in the Rio Grande watershed upstream from Elephant Butte Reservoir. New Mexico has spent many years in the federal court system attempting to work out water rights, water entitlements, and places of use of the water with the Indian tribes.

The federal courts have held that when interstate compacts are negotiated, and have been approved by the U.S. Congress, the law set forth in the compact overides any conflicting law of a state, concerning questions arising therefrom.

The Compact Commission works with many agencies outside the commission itself. These agencies include the Bureau of Reclamation, the Corps of Engineers, the USGS, Fish and Wildlife, Parks and Recreation, universities, water resources research institutes, irrigation districts, canal companies, state agencies, legislatures, the U.S. Congress, and the U.S. International Boundary and Water Commission.

The Compact Commission, with and through its engineer advisors, determines transmission losses of the Rio Grande and its tributaries, detemines evaporation from reservoirs, accounts for all of the water flowing in the system, as well as transmountain diversions of water coming from other river systems into the Rio Grande. For example, the Bureau of Reclamation in Elephant Butte Reservoir now stores Rio Grande waters, San Juan-Chama waters in the Permanent Recreation Pool, and San Juan-Chama waters for the French wine grape growers project east of Elephant Butte Reservoir. Permanent recreation pools also are being operated, or being studied for, Jemez, Cochiti and Abiquiu reservoirs in New Mexico.

About 25 important reservoirs are in the Upper Rio Grande system, north of Elephant Butte Reservoir. Four of these reservoirs are operated by the Corps of Engineers, which also has responsibilities and authority in connection with the operation of Platoro Reservoir in Colorado under certain circumstances.

The reservoirs north of Elephant Butte Reservoir in the Upper Rio Grande system include: Cochiti, Abiquiu, Jemez, El Vado, Heron, McClure, Nichols, Galisteo, San Gregorio, Acomita, Squaw Lake, Rio Hondo, Hermit Lakes, Troutvale, Big Meadows, Nambe and Rio Grande.

The distribution of waters for agricultural use in the Upper Rio Grande Basin in Colorado is the primary responsibility of the Colorado state engineer working with the irrigation districts and other entities having to do with delivery of waters to farmers.

In New Mexico above Elephant Butte Reservoir, the waters are under the jurisdiction of the New Mexico state engineer who works with the Bureau of Reclamation, and the groups representing irrigation districts, community ditches and small acequias.

The delivery of water to farmers below Elephant Butte Reservoir in New Mexico, which for compact purposes is the state of Texas, is handled by the Bureau of Reclamation and the three irrigation districts below Elephant Butte. There is one irrigation district in New Mexico and two in Texas. The surface waters of the Rio Grande below Elephant Butte Reservoir historically have been divided by the Bureau of Reclamation under the authority of the secretary of the Interior. This division process, which also involves the irrigation districts in New Mexico and Texas, roughly divides the waters at 57 percent to New Mexico and 43 percent to Texas. The waters below Elephant Butte originally were divided between New Mexico and Texas in about 1907. The current contracts between the irrigation districts and the Bureau of Reclamation covering water deliveries were entered into in 1938. These dates contain the basic divisions of the waters between New Mexico and Texas and are acknowledged and recognized by each.

The Rio Grande Compact of 1939 has been operated for about 45 years. In that time, the Compact Commission probably has met more than 60 times. The records of the compact meetings are available in the office of the secretary at Santa Fe, New Mexico. The USGS serves as secretary to the Compact Commission.

The three states all have had some rough sledding during the 45 years. There have been strong conflicting positions and opinions taken on many occasions. In the large majority of the discussions, the three compact commissioners have been able to resolve differences in a manner satisfactory to all, or through compromise.

The Rio Grande Compact, as now written, is here to stay. The compact has survived droughts, floods, population explosions, rapid growth of industry, change in demand and prices for agricultural commodities, increase costs for production of agricultural commodities, changing techniques in agriculture, wars, depressions, and strong personalities.

The day <u>must</u> come when we citizens of the Rio Grande learn to live together in trust and respect. Then we will all reap optimum benefits from our precious river's waters. I hope the Water Resources Research Institute will have another report on the Rio Grande Compact this century.

THE WINTERS DOCTRINE AND INDIAN WATER ISSUES

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At the outset let me say that I appreciate the invitation to participate in this conference with you. This is my first trip to New Mexico and although I am a stranger here, I am not a stranger to New Mexican warmth and friendliness. I have had the pleasure of working with some New Mexicans in the Department of the Interior, principally Garrey Carruthers, Frank DuBois, and Tom Bahr, and I have very much enjoyed that association.

Yesterday Professor Clark, in his excellent discussion of the evolution of western water law, characterized western water law as "essentially state property law" with what he termed "important federal dimensions." My purpose this morning is to discuss with you just briefly what those important federal dimensions are--specifically, the nature and extent and status of what we call the federal reserved right. I will focus that discussion by addressing three simple questions: First, what do we know about the federal reserved right? Second, what don't we know about it but would like to know or are anxious to learn? Finally, what are we doing with it? How does the federal reserved right fit into the general scheme of western water law and the attempts to wisely allocate our western water resources?

WHAT WE KNOW ABOUT THE FEDERAL RESERVED RIGHT

Surprisingly, although the federal reserved right has only relatively recently been a subject of intense concern and interest in the West, most of what we know about it we have known for a long time, ever since the Supreme Court decided in the 1908 case United States v. Winters, 207 U.S. 564 (1908). That case was the first judicial recognition of what we call the federal reserved right. Its teachings on what that right is have gone virtually unchanged since that time. It is worthwhile to layout the facts of the Winters case because even today they illustrate very well the fundamental concepts that make up the federal reserved right. The facts were these: In 1888 the federal government concluded a treaty with certain Indian tribes in Montana. Under the terms of that treaty, the tribes ceded to the United States a large portion of lands the tribes had been occupying and using. In return, the United States established in Montana a reservation for those tribes, which is now known as the Fort Belknap Indian Reservaton. The northern boundary of the reservation was the Milk River. The United States then took the lands that had been ceded to them by the tribes and opened them up to settlement by homesteaders. The homesteaders moved on to the land and, as you would expect, they immediately began to dig ditches and canals, and build dams and reservoirs to divert the waters of the Milk River, which were upstream of the reservation, for use on their own farmlands. In the early 1900s, the United States built on the reservation an irrigation project for the benefit of the Indians who lived there. However, when they completed the project they found that the upstream diversions by the homesteaders were so great that there was insufficient water for the irrigation project. As a result, the United States brought suit against the homesteaders to enjoin them from diverting the waters of the Milk River upstream of the reservation. The United States claimed that those diversions were in derogation of the United States' rights to the use of the waters of the Milk River. The homesteaders responded by pointing out that: (1) they had acquired their rights legitimately under Montana state water law by prior appropriation; (2) they had been applying them to the land for several years; (3) they had spent several thousands of dollars constructing the irrigation works that carried the water from the river to their lands; and (4) the lands themselves would be valueless, at least as farm lands, unless there was water to irrigate those lands and make them productive. The court, however, held against the homesteaders. The decision turned on the treaty which had established the reservation. Although the treaty said nothing specifically about the water rights of the Indians, the court found that by implication it had set aside sufficient water to fulfill the purposes of the reservation.

In the case of the Fort Belknap Indian Reservation, the treaty said that one of the primary purposes was to assist and encourage the Indians to develop a pastoral way of life, a life built on an agricultural economy.

We learn from the Winters case, then, that the federal reserved right is a federal right that is independent of state water law. If that right arises prior in time to otherwise valid state rights, it can defeat those state rights. The priority of the federal reserved right, in most instances, is the date of the creation of the reservation. Also, the federal reserved right does not have to be exercised in order to continue in existence and it cannot be lost by nonuse. In other words, the right to use this water arose at the time of the creation of the reservation in 1888. Although the homesteaders upstream of the reservation then appropriated water under Montana law and put that water to use, when it came time for water to be used in the irrigation project the federal government had constructed, the right was still in existence; it had not been lost by nonuse. The Indians did not have to exercise it in order to maintain it, so the homesteaders who had existing rights and who had been using the water had their rights defeated in this case by the federal reserved right.

The Winters decision was in 1908. Since then, several Supreme Court cases have reaffirmed the doctrine, but they haven't really told us a great deal more about it. The court has held in Cappaert v. U.S., 426 U.S. 128 (1976), that these federal reserved rights attach not only to Indian reservations, reservations of land to be used for the settlement of the Indian tribes, but also to other federal reservations as well--federal parks, national monuments, wildlife refuges and military reservations. Basically, whenever the government reserves land for its own purposes, whether the agreement is explicit or not with respect to the water rights, there is implied a reservation of water sufficient to fulfill the purpose of the federal reservation. The other significant thing that we have learned since Winters about the federal reserved right is that it is measured, at least for most Indian reservations, by reference to the practicably irrigable acreage on the reservation. The Supreme Court heard in Arizona v. California, 373 U.S. 546 (1963), the case in reference to several Indian reservations on the Colorado River that had been set aside primarily for the purpose of encouraging the Indians to develop an agricultural economy. The court held that the only way to measure the extent of that right was to determine the practicably irrigable acreage on the reservation and then fix the amount of water the Indians had the right to use with reference to that acreage.

Yesterday, when Professor Clark was talking about water law generally in the West, he summarized his remarks by comparing the riparian water rights system with the appropriative water rights system. For purposes of our discussion this morning, let me add the federal reserved right to that comparison. First, the federal reserved right, as I have pointed out, is like the riparian right in the sense that it does not have to be put to use in order to exist. It has been reserved for the use of the Indians or the military or the Park Service whenever water is necessary to fulfill the purposes of a reservation. As a corollary, the federal reserved right, like the riparian right, cannot be lost by nonuse.

The riparian right, for the most part, is unquantified because there is enough water for everybody in those states where the riparian system is used. On the other hand, there is enormous pressure to quantify appropriative rights in the arid West. They are quantified by reference to the concept of beneficial use. You can use as much water as you can appropriate and put to beneficial use. In contrast, the reserved right is quantifiable in terms of what is needed to fulfill the purpose of the reservation, whether it has been put to use or not.

The riparian right is not a system where it makes any difference who was using the water first. You derive your right to use the water by being riparian to the stream. Water shortages are shared equally by all users. In the appropriative system, on the other hand, it is critical who got there first. First in time is first in right. When there is a water shortage, the senior user can defeat the rights of the junior user. For the federal reserved right, the priority date is normally the date on which the reservation was created. For most Indian tribes, that priority date usually will be one of the most senior, if not <u>the</u> senior right, on most waterways and streams in the West because their reservations were created in the past century.

WHAT WE DON'T KNOW ABOUT THE FEDERAL RESERVED RIGHT

If that is what the federal reserved right is and that's what we know about it, what don't we know about it? What are the issues still outstanding? What are the questions that have been raised about the extent and nature of those rights that either are now in litigation or have been posed as theoretical matters that would give us more insight into the nature of the reserved right and its impact on western water law? The biggest question is just how much water in the West is subject to the reserved right. We don't know the answer partly because we are not far enough along in the adjudication process to determine exactly how much water is subject to federal reserved rights. There are also some other reasons why we can't even guess very well what the quantities may be. In the case of an Indian reservation where farming is one of the reservation's primary purposes, the court has given us a measure of what the water right might be. It is measured in terms of the practicably irrigable acreage. We don't, however, have a great deal of experience in courts of law with the exact type of proof that will be required to show what that acreage is. We don't know how strictly or how generously the courts are going to construe this concept of practicably irrigable acreage. We also don't know a great deal about whether there are other appropriate measures besides practicably irrigable acreage. Many of the treaties and executive orders that established Indian reservations, for example, stated that one of the purposes--indeed the primary purpose--of the reservation was to set aside or create permanent homelands for the Indian tribes. At the time, the treaty makers may have had in mind that the reservation would be a permanent homeland as a farming community. Now, however, the question being raised is if this land was set aside as a permanent homeland for the Indians and it would now be sensible for the Indians to develop the reservation's mineral wealth along with its farms, does the reserved right allow the Indians enough water to develop the minerals on the reservation? That may not have been a purpose that was specifically foreseen at the time the reservation was created, but it is certainly an arguable part of this larger concept of reservations as permanent homelands for the Indian tribes.

Another thing that we don't know about the federal reserved right, which I think will be very important, particularly to the Indian tribes, is whether they can take their reserved water rights into the marketplace and sell them off the reservation. We do know that in the few instances where we have been involved in serious negotiations over the extent of the federal reserved right, one of the key elements has been the desire of the tribes to have the right to sell their water rights off the reservation if they so choose. We don't know yet whether that is an incident of the federal reserved right as a matter of law, but we certainly know that it is an important component in negotiated settlements. Another thing we don't know about the federal reserved right is the extent to which it can be exercised by non-Indians. A great deal of Indian land, land within the reservations, was at one time allotted to individual Indians in 160-acre or larger parcels. Much of that land was then conveyed to non-Indians. As a result, a great deal of land within the borders of most reservations today is owned in fee by non-Indians. The question thus arises whether a non-Indian who acquired an Indian allotment also acquired a reserved water right with its early priority date. There is at least one case, Colville Confederated Tribes v. Walton, 647 F.2d 42 (9th Cir. 1981), in the state of Washington which has held that the reserved right attaching to an allotment can pass to a non-Indian.

Another question we can't answer with certainty yet, and which is now being raised in two legal cases, is what happens with lands within a reservation which pass out of Indian ownership at some time and are conveyed to non-Indians, but then are reacquired, perhaps by the tribe, 50 years later? Does the federal reserved right that originally attached to those lands continue to attach to the reacquired lands and, if it does, what is the priority date? Is the priority date the date upon which the lands are reacquired or is it the date upon which the reservation was created, although the lands may have been out of Indian ownership for a substantial period of time since the reservation was created? And, finally, what is the extent to which an Indian tribe has regulatory power over the use of water on the reservation, particularly over the use of water by non-Indians on the reservation? Those are some of the issues you can look to for answers as the cases are decided.

WHAT WE ARE DOING WITH THE RIGHT

That is what we know about the reserved right and some of what we don't know about the right. Let me conclude by making some comments on what we are doing with the right. From my perspective, what we are doing mostly is litigating. In my office in Washington, more than 50 lawsuits are pending. Most of them are general stream adjudications, all of which involve the controversial issues of the extent and nature of the federal reserved right, more often than not in the context of an Indian reservation. These 50 lawsuits involve 13 major river systems in nine of the western states. They involve almost 50 separate Indian nations and tribes and thousands upon thousands of other western water users. Some of them have been going on for an awfully long time. The relatively new ones are 5, 10, and 15 years old. The older ones date back 60 or 70 years. They are very expensive pieces of litigation. They are also very time consuming because of the technical nature of the proof that is required. Moreover, one of the things that is most discouraging to me is that even if we pursue these lawsuits to their bitter end, and even if we come up with the resources to adjudicate all of the streams in the West and figure out who has the right to use how much water, when we are done, we may find we have a very unsatisfactory result. The reason I say that is, for the Indians, at least, the right that is decreed at the end of that process may very well be only a paper right. Yes, the court will have recognized that they have a right to use "x" amount of water, but they may find themselves lacking the means, the economic resources, to do anything with that water right. And although the right will have been quantified, the real difficult adjustments will have to be made in western water management in the future. That is when the actual exercise of the Indian right defeats state water rights on non-Indians and requires the actual displacement of non-Indian users. Also, lawsuits are not very well suited to resolving difficult and critical water management and water conservation issues. The focus in these adjudications is on "me and mine" and "thee and thine," instead of focusing on how we can cooperate together as a community in managing the water and sharing the water and improving the resource and conserving it. Thus, we may find after having gone through this very difficult exercise that we really haven't resolved much when it is all over.

Another reason why the results may be unsatisfactory for the Indian tribes is that to the extent that they have to quantify their right today, they will have to do it in terms of today's technologies, only to find 15 years later that there are new technologies and that had they waited, had they quantified their right 15 years later, they would have been entitled to more water.

In view of the disadvantages of the adjudication process, what are we doing? At the Interior Department we have been trying in the past two or three years to encourage negotiation of disputes over water in the West. We think it only makes good sense for people to sit down and talk this out, to bring a little flexibility to the negotiating table instead of being locked into the rigid formulations of a court of law, to see if we can't address in negotiations some of these management and conservation issues and put some of these disputes to rest. We have had some significant success. We succeeded in putting together a negotiated settlement of part of the claims of the Papago Tribe in and around the city of Tucson, Arizona. We are in the middle of trying to satisfy the claims of the Ak Chin Indian Community in Arizona. We are also in the process, which I hope will succeed, of negotiating a settlement of the dispute over the waters of the Truckee-Carson River basins and the Pyramid Lake. This dispute has been going on for many years and has involved 14 or 15 lawsuits at one time or another. We also have been contacted by Indian and non-Indian interests in New Mexico, California, Washington, Oregon, Utah, Montana and South Dakota who are anxious to begin talking.

Let me conclude by saying that I was struck by President Thomas' image yesterday of the attorneys as beavers who spend their time damming up the streams. That may or may not be true, but one thing that is clear to me, though, is that if the log jam is to be broken, we need to look to people other than attorneys, we need to look to water professionals like yourselves. This area of western water rights offers a tremendous opportunity for statesmanship, for people to reach out to each other, to break down some of the hostilities, some of the mistrust. It can be the chance to work together in cooperative efforts to figure out how we can live together, how we can manage our water resources and not simply be locked together in lawsuits where we are making our arguments to a judge. So I would hope that you would take that to heart, that in your various responsibilities you would take the opportunity for a little statesmanship, that you would encourage those with whom you have contact to consider negotiating. By doing so, we can resolve what is really one of the most difficult issues in western water law today.

A NATIVE AMERICAN VIEW OF WESTERN WATER DEVELOPMENT

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This paper presents an individual Native American, or American Indian, view of western water development and not necessarily the view of a particular tribe or its government. A disclaimer of this kind is necessary because there has been a historical tendency in this society to look for a single Indian spokesman and search for that spokesman among the Indians who say what society wants to hear. But the Indian community, while sharing many characteristics and problems, is culturally and politically diverse and there are no real shortcuts to dealing with it in all its diversity.

Indian water rights, as they relate to western water development, must be seen against the backdrop of the history of the hemisphere. Ever since the arrival of the Europeans on the continent, an important current in the development of the legal system has been to define Indian rights and then develop an orderly process for taking them away. From the formulation of the doctrine of discovery itself, this two-step exercise has served the humanitarian purpose of attempting to accord some fairness to the Indians while providing discipline to the competition among non-Indians for the right to use Indian resources. Recognition of full and natural rights of Indian sovereignty and ownership in the hemisphere is commonly viewed as having been a historical impossibility, just as denying them all rights was not practically and morally feasible. The problem then, was and is to balance the two historical necessities appropriately.

In the case of Indian water rights, many of the legal battles which we see today involve the definition of the scope of the rights--their priority dates, the measure of the rights and the uses to which they can be put. This initial step is vitally important to the American legal system because the broadest formulation of the scope of Indian rights can--in this context--be characterized as Indian "claims" to water. As the legal system proceeds to narrow these "claims," society can assure itself that it is merely "defining rights," not taking them away. Being property, Indian water rights cannot be taken away without just compensation.

Indian water rights can be put to productive use in the American economy by the Indians themselves if they can obtain the enormous sums necessary to support modern forms of development. These water rights can be put to use through the normal channels of law and commerce by non-Indians if they pay an appropriate sum of money to the Indians for the use of the Indians' water. But it is also possible, because of the unique nature of water, for non-Indians to use what would otherwise be Indian water outside the legal and economic channels if Indians are excluded from the normal system of planning, allocating and funding water development. If Indians lack the funds to develop their water resources, their water rights remain dry and abstract, and those who use the same water need not compensate them.

The attack on Indian water rights, then, is on two fronts: one, to narrow their definition as much as possible, and the other to delay their actual development as long as possible--to the point where the costs become out of reach. Both strategies are based on keeping Indian water rights as an exception to the system of defining, allocating and developing water resources. And both strategies are integrated into the system of law and policy in such a way as to preserve the appearance of fairness.

The system attempts to guarantee fairness to the Indians through federal trusteeship; Indian tribes and their property are subject to the trusteeship of the federal government. If there is any purpose to the federal trust relationship between Indian tribes and the United States, it is to ensure that things of economic value in the non-Indian economy to which Indians assign a different cultural value are not lost to the Indians during the period when they have a competitive disadvantage in the majority system due to their culture or their poverty. This trusteeship commonly applies to trust funds, to land and to water.

It has been said--most notably by former President Nixon in his 1970 message to Congress on Indians--that the federal Indian trusteeship is fundamentally defective because the federal government has a conflict of interest between its Indian trust responsibilities and its duty to promote the general welfare. Former President Nixon's candid acknowledgment of this conflict is very important, of course, but somewhat simplistic. It is rare that a specific interest of an Indian tribe will clearly conflict with the general public interest, i.e., the interests of all the people of the United States. It is more likely that the interests an Indian tribe seeks to have protected by its federal trustee will conflict with the specific interests of an identifiable group of non-Indians. It is, then, a highly subjective judgment of whether this specific non-Indian interest rises to the level of legitimately calling on the constitutional duty to promote the general welfare.

The notion of a federal conflict of interest can be used by the federal government as an excuse for what is in reality an exercise of discretion to prefer the interests of a specific group of non-Indians over the trust interests of the Indians. The real process by which non-Indian interests are favored over those of the Indians in the federal government is rarely reviewable by the courts, and hence, the system offers the Indians little protection in that sense. Instead, non-Indian interests tend to be favored in the exercise of executive discretion, in the development of the budget, the allocation of funds, and in technical assistance. These all relate to the overall strategy of appearing to define and protect Indian water rights while keeping them as narrow as possible. This strategy makes it virtually impossible for the Indians to take advantage of what rights are confirmed.

We, in this country, have just come through an era of 15 years of hindsight, during which we engaged in guilt over the treatment of the Indians by the non-Indians in the nineteenth century. Yet, this moral cartharsis has not led to an adjustment of the process by which the same treatment can be substantially repeated--without, one hopes, military confrontation.

The nineteenth century arguments were, with respect to land, that the Indians claimed more land than they could possibly put to productive use and that if their claims to land were confirmed as rights, they would frustrate the progress of non-Indian development embodied in the concept of Manifest Destiny. We now see basically the same argument made with respect to the settlement of Indian water rights in the West. The question is whether in the next century, our descendants will look back with embarassment at the ways in which we have allowed the system to be manipulated to deny fundamental fairness to the Indians.

It has been said that there are three systems of water law in this country--riparian, prior appropriation and federal reserved. In fact, the notion of federal reserved rights makes no sense outside the context of a larger system of allocating private and state rights. It is more accurate to see that there are basically two systems, and that they are both subject to the power of federal reservation which includes the protection of Indian water rights.

The nation has been operating--at national, state and local levels--for many years as if Indians didn't really exist. That was the perception largely because of the vain hope that Indian societies were so close to extinction and assimilation that there was no need to define the system with them as a permanent part. The problem with this view is that it is unrealistic, and because it is unrealistic, the system must be adjusted from time to time to allow for Indian rights.

The time is right for society to include Indians and their rights and claims as part of the system from the beginning, plan to take care of their needs and rights as part of the system, and include them in the overall process of planning and allocation of resources. Such an approach would be cheaper in the long run and would allow for the regularity and predictability that is essential to development in the West.

Several specific steps could be taken. Granting that the federal decision process exists in a context of legal, bureaucratic, economic and social considerations, conflicts of political, economic and social interest should be managed in a system that ensures a regularity of process and fairness to the Indians. This is simply a management problem. There always will be competing interests affecting the federal process. The goal should be to manage those interests fairly by removing them from a process where conflicts are resolved by bureaucrats in internal meetings to one where everyone concedes the existence of a conflict which is then managed through an open and fair procedure.

Next, Indians must have the technical capability to participate in the mainstream process. They must have the technical capability to support their claims to water and to make sensible and timely plans for its development. Because of the federal trusteeship, this assistance must come from the federal government. Federal assistance is necessary because the tribes largely lack the funds to provide it for themselves, because of the federal complicity in historically preventing the tribes from developing this capability for themselves, and because it is the most efficient way to move the problem toward a solution that will resolve outstanding problems.

Society must create incentives for Indians to help move the process to one of predictability. In order to do that, society must deliver on its promises and demonstrate to the Indians that there is a fairness to the process and that they will receive the benefits of a fair share of the water. Currently, Indians are provided little incentive to do anything other than make the system as costly and inefficient as possible by disputing every issue. But if litigated judgments resulted in developable water, and if negotiated settlements resulted in developed and delivered water, Indian tribes might be more likely to cooperate.

The American Indian Law Center--the organization of which I am the director--has for the past eight years provided the staff work for the Commission on State-Tribal Relations. The purpose of the commission--which is composed of tribal chairmen, state governors, attorneys general, legislators and county commissioners--is to identify areas of actual and potential cooperation among tribes, states and counties.

States and tribes only compete for water if there is an assumption that there are two economies--state and tribal. Otherwise, there is a great deal to be said for the notions that the development of tribal water rights is an important asset to the state's economy and that the nature of Indian reserved rights is an asset to the state in its regional competition for water with other states.

It may be argued that if the states embrace a broad definition of Indian water rights as a potential "wild card" in the regional competition with other areas of the country, this wild card status would disrupt an orderly system for the allocation of water resources. While that argument has some merit, if the orderly system its proponents seek to preserve excludes Indian water rights, then it is by definition unrealistic and inefficient--and unfair to the degree that its success depends on denying Indians the benefits of their rights. Additionally, the present system, for all its pretense of orderliness, is well known to be a complex system of law, economics, influence and pork barrel politics. To introduce Indian rights into such a wide open competition probably would not make it any more disorderly than it already is.

The fundamental issue is this: As long as Indian rights are seen incorrectly as an exception to the system, and as long as funding for their development is considered to be an additional cost, Indian tribes will have no choice but to fight every inch of the way, making the system as costly and inefficient as possible. But if those who are interested in water development in the West come around to the view that it is in their interest to see that Indian water rights are defined in such a way as to satisfy reasonable Indian needs, Indians and non-Indians in the West will be able to sit down and plan development that meets the common and interdependent needs of all people and interests in the West.

In the bluntest possible terms, those who are interested in western water development will be acting in their own interest if they become the Indians' most effective lobbyists.

WATER LAW AND ECONOMIC DEVELOPMENT

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There is an old saying concerning water and economics indicating that "water either flows downhill or towards money." Indeed, in the Rio Grande Valley of New Mexico, downhill or towards money may well be the same direction. However, regardless of direction, the saying would imply that under the laws of nature, water flows downgrade or downhill; and under the laws of man, water flows towards its highest economic use. This relationship between water law and economic development in New Mexico will be the subject of the remainder of this paper.

ECONOMIC DEVELOPMENT IN NEW MEXICO

The economic development of a state can be measured in several ways, but probably two of the most widely used indicators are: (1) per capita income, and (2) unemployment rate. New Mexico had an average unemployment rate of 10.1 percent during 1983 compared to a U.S. average of 9.6 percent. As to per capita income, New Mexico ranked 39th in the United States which was lower than all its neighboring states except Utah. Although both the unemployment rate and per capita income have improved of late, these statistics would indicate room for improvement in New Mexico's economy.

If it is desirable to increase New Mexico's economic well being, then four fundamental resources are required. These are natural resources encompassing land, water and energy adequate to support the development desired, and human resources, the trained and willing people who carry out that development. For instance, in order for a utility to generate electricity, it must have land to site its generating station, water to cool and operate the plant, fuel sources to heat the steam, and people to operate the system. Similarly, if the development is agriculture, it will require land for growing the crop, water to irrigate it, energy to power tractors and pump the water, and, of course, people to operate the system. Although each development requires a different mix of these four resources, each resource is necessary to the enterprise being considered. There are, of course, other considerations affecting economic development, including the quality of life, availability of capital, the quality of universities and many more. However, in the interest of brevity, only those fundamental resources--land, water, energy and people will be discussed here.

How then does New Mexico stack up as being able to provide these resources? As to land, New Mexico is the fifth largest state in the union with a population density that ranks 37th. Compared to other states, it would appear that New Mexico has an abundance of land.

As to energy, in 1981, New Mexico ranked fourth in natural gas production, seventh in crude oil production, thirteenth in coal production, and first in both reserves and production of uranium. Largely because of the coal reserves, New Mexico also has sources of electrical power, which are available and reliable. It would appear that New Mexico is indeed rich in energy resources.

As to human resource requirements, New Mexico has a younger than average work force with lower than average wage rates. Our unemployment rate is usually slightly above the national level while our capability to attract new citizens is enhanced by our sunbelt status. All of these factors would indicate that New Mexico has, or can readily obtain, the human resources required for economic development.

The fourth necessary resource is water. Water availability in arid New Mexico is of paramount importance to all who consider investment in the state. A part of this concern can be attributed to the arid nature of the state, although a part may be attributed to the general perception that there may be a "water crisis" during the 1980s that would rival the "energy crisis" of the 1970s. From a factual standpoint, an estimated 2.2 million acre-feet renewable water supply is available to the state of New Mexico. During 1980, the State Engineer Office estimated that total man-made depletions exceeded 2.5 million acre-feet, indicating a slight deficit. However, New Mexico is fortunate to have large quantities of ground water in storage. Indeed, it has been estimated that there may be 3 billion acre-feet of fresh ground water in New Mexico. This amount of water would sustain the current deficit for many thousands of years. Admittedly, neither the surface nor ground water supply is uniformly distributed in New Mexico, and local situations differ from statewide averages; but overall, the state would appear to have adequate physical water supplies for economic development.

Of course there have been and will continue to be inherent economic limitations to water related development in New Mexico. New Mexico probably never will enjoy the cheap transportation offered by navigation, and it is doubtful that rain forests will ever be much of a tourist attraction in New Mexico. But despite the obvious limitations of an arid state, New Mexico does have a considerable resource in water for economic development.

There are, however, legal constraints to the development of those water supplies, and it is this relationship that will be investigated in the following section.

WATER LAW IN NEW MEXICO

The law that governs water allocation in New Mexico is a mixture of state law, interstate compact, and federal law, each having its own application and area of influence. But regardless of the sources of the law governing water, its major effect on economic development is that of imparting certainty or uncertainty to the acquisition of one of the essential resources in economic development. That essential resource is water, and the certainty factor is one of obtaining the right to develop and maintain a reliable water supply for the duration of the particular development. If methods for acquiring needed water supplies are predictable, then economics will govern economic development. However, if methods are unpredictable, then economic development may be foregone regardless of the economic factors.

The state system of water law is that enunciated by the doctrine of prior appropriation. Prior appropriation has developed throughout the years to include the following four basic elements that have an impact on economic development:

1. First in time is first in right. The first in time to appropriate water to a beneficial use from a given source obtains a priority of right against all that come later. This appropriation can be to the total exclusion of latecomers if there is only enough water to satisfy the first user.

   The element of appropriative right offers a strong incentive to develop a water supply because the initial developer's investment is offered considerable protection against all who come later. This concept also provides the certainty desired for economic development.

2. An appropriative water right is a property right. Although a water right is not an ownership of a certain corpus of water in a stream, it is the right to use a certain quantity of water from the stream. This use right is afforded most of the rights enjoyed by real property in the United States. That is to say, it can be bought, sold, leased, or otherwise transferred, and unlike riparian rights, it can be separated from the land.

   The element of an appropriative right provides further incentive for development of a water supply, because once the water right is acquired, it maintains a value beyond its initial use; such as transferring the water rights to other locations and other uses. This element also imparts considerable flexibility to the allocation system in adjusting to changing times and the demand for water.

3. A water right can only be transferred if other water rights are not impaired. Although an appropriative right can be transferred as to type of use, point of diversion, or place of use, it can be transferred only if other existing water right holders are not injured thereby. Even a latecomer has the right to see the stream condition maintained as it existed at the time of his appropriation. Any transfer of a prior right that would impair another existing user's ability to divert will not be allowed or will be conditioned such that the potential injury is alleviated.

The element of an appropriative water right acts to limit transfers of senior water rights to those who will not impair the water rights of juniors. The property transfer concept is subordinated to the desire to provide certainty to the water rights of other appropriators.

4. An appropriative right must be put to beneficial use or it is subject to forfeiture or abandonment. Beneficial use shall be the basis, the measure and the limit of the right to the use of water. Without a use, the water right is subject to statutory forfeiture, or common law abandonment.

   The element of an appropriative right requires that the water be put to a beneficial use and maintained in that use or the appropriator will stand to lose the right. This "use it or lose it" concept serves to minimize "dormant" water rights that create uncertainties as to the amount of water actually available in a particular area.

Therefore, from a review of the state prior appropriation system, it is apparent that it has, in the past, provided an incentive to develop the state's water resources; and it currently provides the certainty desired by economic development. If any uncertainties exist in the New Mexico prior appropriation law that might hinder economic development, it would have to be the lack of court adjudication of water rights in developing basins such as the Rio Grande. Other than this uncertainty, the precepts of prior appropriation are largely conducive to furtherance of economic development.

The second level of water law in New Mexico is that of interstate compacts. Eight interstate compacts affect the use of water in New Mexico. These agreements essentially are contracts between states as to the allocation of interstate water. The contracts subsequently have been ratified by the U.S. Congress. Although these compacts do not encourage development as does prior appropriation, they do impart a considerable amount of certainty to the water supplies allocated to each state, whether they are developed immediately or not. Because compacts essentially are contractual in nature, their terms often are subject to various interpretations that impart some uncertainty in the determination of the water supplies available. This is evident in interpretations of the Pecos River Compact and the Colorado River Compact. Although the various compacts generally create a predictable outcome, the problems associated with the interpretation of those compacts could adversely affect economic development.

A final segment of water law in New Mexico is that of the federal laws affecting water. These laws are exemplified by federal reserved water rights claimed by reservation Indians and the water rights claimed for national forests and national parks. Also to be included in this category are water rights claimed by Pueblo Indians under federal law and the allocation of interstate water under the doctrine of equitable apportionment. It is this category of water rights that imparts the greatest uncertainty to the overall New Mexico water allocation system. Federal reserved and Indian water right claims are, at best, loosely quantified, their flexibility and transferability are largely unknown, and there is no requirement of use. These water rights can lie dormant for centuries only to become valid when a perceived need arises. The water rights themselves are very uncertain and where they coexist with other water rights, that uncertainty is generally transmitted throughout the basin. Likewise, the allocation of interstate waters under the doctrine of equitable apportionment is about as certain as the current consensus of what is equitable. Even with all the factors itemized an "equitable apportionment" is at best a subjective exercise.

To further illustrate the uncertainties involved in the application of federal laws affecting water allocation in New Mexico, let us evaluate the Aamodt and Vermejo cases and their possible effect on economic development.

The Aamodt adjudication suit has been ongoing for some 18 years in an effort to determine the water rights of four Indian pueblos and some 1,000 non-Indians in the Pojoaque River Basin of northern New Mexico. Currently there are about 3,500 acres under irrigation, 1,000 of which is irrigated by Indians and 2,500 by non-Indians. The basin is estimated to yield slightly in excess of 10,000 acre-feet annually and has been fully appropriated for some time. In addition to the uncertainties associated with the lengthy litigation, the Pueblos claim water rights to more than 30,000 acre-feet per year with a time immemorial priority date. Now, without regard to the merits or the equities of the case, it would seem that those involved in economic development requiring significant water would be prudent in carefully evaluating the situation before investing.

A second example of federal law uncertainty is the pending allocation of interstate waters of the Vermejo River by the U.S. Supreme Court under the doctrine of equitable apportionment. In this case, New Mexico has fully appropriated the waters of the Vermejo River while Colorado belatedly seeks to develop those waters arising in Colorado. Although the case has yet to be resolved, the initial special master's finding would have been an economic windfall for Colorado and an economic burden for New Mexico. Economic development in Colorado would greatly benefit from 4,000 acre-feet of "free" water that could be used for future industrial development, while New Mexico would have to invest heavily in conservation measures just to maintain its existing agricultural economic development. The economic realities of the situation would be in stark contrast to a similar transaction in New Mexico under the doctrine of prior appropriation. Here, an industry could only obtain an agricultural water right if the agricultural interest chose to sell, if the agreed upon price was paid, and if other water rights were not injured by the transfer. It would appear that resolution of this type of conflict under the prior appropriation doctrine would be more certain and equitable than that initially fashioned by the special master.

Therefore, it is apparent that water law can affect economic development in New Mexico depending upon the certainty of acquiring adequate water resources as perceived by the investor. A certain water supply for the life of the project will encourage business to invest according to other economic factors, while an uncertain supply may preclude such investment regardless of other economic factors. It is evident that New Mexico currently has the need for economic development and the ability to sustain it if our natural resources and human resources are used wisely. However, further definition of federal water rights, especially Indian claims, will be required before the certainty of investment attributed to the prior appropriation system and interstate compacts can again be the cornerstone of economic development in New Mexico.

As this paper began with the old saying that "water either flows downhill or towards money," so should it end with a new one stating that "water law goes downhill if it does not allow for economic development."

NEW DIRECTIONS IN WESTERN WATER DEVELOPMENT*

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Over the three years I have been involved in the daily workings of the political process in Washington, D.C., I have attended a variety of meetings on water and water law. Although I had some experience in the needs of the local water districts, which I had worked with in local government, much of what I absorbed during these meetings and in my position the first year was new to me. For the next few years, it seemed a lot of effort was put into getting something new accomplished in the field of water resources, but very little of it was getting anywhere. Since December 1983, we have seen these efforts come together. A lot of critical steps have been taken by the department and the administration which have added some new elements to the national water picture. Things are changing in the way we are dealing with the states when it comes to developing and quantifying their water resources--changes that are for the better.

The three key elements in these changes have been the realignment of responsibilities within the Department of the Interior, which resulted in the creation of a newly designated assistant secretary for Water and Science, the enunciation of a water project financing policy by the president, and the finalization of rules and regulations implementing the Reclamation Reform Act of 1982. Some of these changes have a more direct impact on New Mexico than others, but all will play an increasingly important role as we work with you in the future.

From the water perspective, the realignment accomplished three things. First, it brought all of the major actors in the department's water research and development teams together under the same leadership for the first time since early in this century. Interestingly enough, both the Bureau of Reclamation and the Bureau of Mines were originally

*Because Jed Christensen introduced a U.S. Bureau of Reclamation film on the Rio Grande entitled "Ribbon of Life," time did not allow for his speech. The text of that speech is presented here.

part of the U.S. Geological Survey (USGS). All three agencies are now under the same assistant secretary.

Second, it placed all of the major agencies with research responsibilities under the direction of one assistant secretary. The Bureau of Mines and the USGS both carry out pure and applied research in mineralogy, geology and geography, while the Bureau of Reclamation carries out research in concrete and other construction related matters.

Finally, the realignment united most of interior's agencies that have overseas development assistant programs. All three agencies have major overseas programs aimed at helping developing countries build resource based economies. Interior Secretary William Clark, with his background as National Security adviser and experience in the State Department, has shown particular interest in these programs. We are likely to be seeing increasing involvement by Interior Department bureaus overseas. The Three Gorges Project in China, which includes plans for the largest dam in the world that far overshadows the bulk of Coulee Dam and the height of Hoover Dam, is one of the many projects the Bureau of Reclamation will be involved in, at the request of the People's Republic of China.

Some of you might not be aware of the major functions of the USGS Water Resources Division. Previously, the survey was under the direction of the assistant secretary for Energy and Minerals. Most of the attention focused on the energy and strategic and critical minerals needs of our country. That is an important task. Unfortunately, the Water Resources Division of the USGS didn't receive the public attention it should have received under that organization. The realignment has helped bring the important work the USGS does in tracking our nation's water supply and quality situation into the mainstream of departmental decision making.

One of the products of the USGS Water Resources Division is the National Water Summary for 1983. Some of you may have seen it, and more than likely you've read about it in newspapers. The summary was initiated under Secretary James Watt, who thought it would be useful for leaders in all levels of government to have a current status report on our nation's water supply. The USGS produced this volume in less than a year, relying on a network of more than 800 federal and nonfederal cooperators and a water resources data base that stretches back almost a century. Judging by the response we've had so far, the National Water Summary hit the mark. Newspapers in every state covered the release of the report, and the first 8,000 copies were sold out in less than two months. We are now reprinting the 1983 edition, as work continues in preparation for next year's summary. The summary was originally viewed as purely an informational document. We believe this is the best way to approach future water summaries. While it is likely that much of the policy analysis that is done by the Interior Department and other federal agencies will be based on information from the summary, the summary will continue to be an informational, not a policy document.

As the Department of the Interior, the other federal agencies that make up the Cabinet Council, and ultimately, the president, approach the task of creating federal water policy, we've found that solid, current information is invaluable in reaching a consensus. Sometimes the information needed is purely technical, but frequently decision making involves a much wider picture. During the extensive discussions held within the administration over the past three years on cost sharing policy, we had to consider the realities of the federal budget, the historical and legislative backgrounds of the dozens of federal agencies that deal in water development, and the regional impacts of certain proposed actions on the different regions of the country.

After years of discussion within and among the agencies that regularly deal in water development (and admittedly with a good deal of confusion in Congress and among the water-using public who were keeping a close tab on what was being proposed), the president has issued a statement that outlines this administration's policies. As we have pointed out since the president made his views known in a letter to Senator Paul Laxalt early this year, Secretary William Clark, Assistant Secretary Bill Gianelli, and Director David Stockman all set administration policy in their different positions. However, only one person can declare the policy of the administration on any given issue--President Ronald Reagan. The discussions that have gone on before are all preliminary. The administration's policy has been clearly set and we intend to follow it.

Essentially, the policy that the president set has two major components. First, it requires each agency to negotiate nonfederal financing for each water development project it undertakes. I'm certain many of you are aware of the discussions within the administration and within Congress regarding fixed formulas for cost sharing. Because the existing financing mechanisms used by water development agencies such as the Corps of Engineers, the Soil Conservation Service and the Bureau of Reclamation are so different, trying to fit all of the differing programs into one fixed formula simply doesn't work. For example, Corps of Engineers' projects don't require repayment contracts with the beneficiaries to recover the capital costs, but Bureau of Reclamation projects do. Projects built by the Soil Conservation Service already require that the nonflood control aspects of each project be paid for up front by the beneficiaries. The end result of a fixed formula approach to cost sharing would be an inequitable program. Beneficiaries who aren't currently required to guarantee the return of their project funds to the U.S. Treasury certainly would have to be more responsive and provide an increased amount of funds. However, those who already provide repayment would be burdened with additional payment responsibilities. Clearly, that is not the fairest approach to the problem. The approach adopted by the administration will still require greater financial participation by all water users, but it doesn't unfairly penalize one group of water users to the benefit of another.

The president's policy also recognizes the vast differences that exist between agencies, not only in their financing arrangements, but also in their entire responsibilities. While this might seem a fine point with little bearing on the question of financing, it does have some real impact in the West.

Let's look at two specific areas of Interior Department responsibilities. Because the legislation creating the Bureau of Reclamation essentially makes it a western agency, its projects are built in what you might call public land states. Some of the benefits of our projects go to the public lands. Now, if a fixed formula were to be applied, who would pay the required nonfederal contribution for the benefits that accrue to public lands? The answer is probably nobody. The end result, under a fairly strict interpretation of the policy that has been discussed and is still currently part of legislation before Congress, would be no project. Without the fixed level of nonfederal funding, a project simply wouldn't get built.

In other instances, Bureau of Reclamation projects provide benefits to Indian communities. Congress already has enacted legislation that says that certain project features are to be built without cost to the Indians. If a fixed formula were to be applied, who would pick up the nonfederal portion covering the Indian benefits? Again, the end result would be no project.

The second major component of the president's letter was his statement regarding Safety of Dams work at federal dams. The president said Safety of Dams work at federal dams was a federal responsibility. Although this may seem like a statement of the obvious, several members of Congress and some interest groups didn't see things the same way. They forgot that the mandate to bring unsafe dams up to the proper level of safety didn't come as a request from western water users. It came by a decision of the federal government.

The safety problems at federal dams are not results of poor operation and maintenance practices. Instead, they have discovered as newly available hydrologic and geologic studies have revealed problems at dams previously thought to be safe.

As an alternative to safety modifications at these dams, some have suggested holding the reservoir water levels artificially low. I don't need to point out to you the results of such an action. Not only does it ignore the fact that valid contracts exist for the delivery of water from these projects, it isn't a very wise use of your resources. Lowering water levels would result in an artificial drought in many areas of the West.

The president did state that if new benefits resulted from the Safety of Dams work, the project beneficiaries would be expected to pay for those new benefits. That is reasonable and proper. Westerners have steadily demonstrated their willingness to meet the financial requirements necessary to develop water supplies, and we expect that they will continue to do so in the future.

But, we also expect that things will be changing a bit too. We can plan on seeing greater participation in project planning and design as the local beneficiaries work with us in the development of their projects to ensure that their funds are being spent the way they feel they should be. There also will be other changes in the way the Bureau of Reclamation handles its day-to-day responsibilities. As a result of the Reclamation Reform Act of 1982, many of those changes already are underway.

Because much of the impetus for reform of the Reclamation Act of 1902 came from farmers in California, many westerners have tended to view the Reform Act as a purely California issue. Nothing could be further from the truth. Parts of the new law will have an effect on every one of the reclamation states. Rather than give a section-by-section analysis of the major elements of the new law, I'd like to highlight the areas that will have an impact on New Mexico.

One of the biggest changes will be in the area of leasing practices that have been common to reclamation farmers throughout the West. In the past, unlimited leasing was allowed. The new law makes some changes in that practice, and also specifies the terms and forms of acceptable leases. Instead of verbal agreements, which I understand are quite common, all leases must now be in writing. Leases for perennial crops may be written for a term of up to 25 years. All other types of cropland are limited to 10-year leases.

The issue of leasing is at the root of the most controversial part of the 1982 Reclamation Reform Act. Although most of you should be familiar with the more elementary parts of the law, it might be useful to give you a quick review of the choices open to districts and individuals. Basically, the new law allows an individual to receive irrigation water for up to 960 acres of owned land. Water delivered to leased lands above the 960-acre cap will carry a full-cost component. One section of the law extends the application of Class 1 Equivalency to districts that choose to come under the new limits. We also have provided rules that allow individuals who make an irrevocable election to come under the new law with the opportunity to apply equivalency formulas to their operations, under certain circumstances.

The new law does allow individuals and districts to elect which of the limitations they will accept, the 160-acre limitation of the 1902 Act or the 960-acre limit of the 1982 Act. However, the 1982 Reclamation Reform Act maintains that full cost, which is essentially an interest component, must be charged for water delivered to leased lands above the 160-acre limit if a district decides to maintain the provisions of the old law.

As you might imagine, that part of the law has provoked considerable controversy. The Department of the Interior, after extensive study of the comments provided on that section of the law by water users and legislators alike, has concluded that it may well have the practical effect of abrogating contractual rights. As a result, we have proposed legislation to repeal that section of the law, commonly known as the "hammer clause."

The new certification and reporting requirements of the law also have raised considerable controversy. The certification provision, which applies only to districts with new or amended contracts, outlines requirements for the water districts to furnish certificates from the landowners and leaseholders within their areas stating that they are in compliance with 1982 reclamation law. Obviously, there needs to be some method of ensuring that 1982 reclamation law is being followed. Congress decided that, for districts coming under the new law, certification was the best way of doing that.

There will be districts, however, which will choose not to request the new law's expanded acreage limition. The self-implementing provisions of the law give the secretary the right to request that each district supply a reasonable amount of information to ensure that the applicable provisions of 1982 reclamation law are being followed.

Congress made it clear that it wants the limitations enforced and gave us the authority to do so. Frankly, the certification and reporting requirements of the law are the best methods we have for checking compliance without incurring huge costs to the federal government. We do not intend to complicate the daily business of the districts, or saddle them with needless, expensive paperwork in implementing the law. We have exempted small noncommercial farms from these requirements. We also have done considerable pretesting of the forms and responded to the problems that have been identified by the users. We believe we have ironed out the problems in our proposed forms, which should be fairly simple to fill out. The certification forms are due out shortly, and the reporting forms will follow in a little over a month.

The changes that have been finalized over the past few months are beginning to shape the way Washington deals with western water. It is important to stress that it is the West's water, but its just as important to realize that Washington does play a role. If western water users choose not to actively participate in the legislative process, their concerns and needs may well go unanswered. It took a lot of cooperation to make reclamation reform a reality. We will need that same cooperation from western water users as we attempt to complete the legislative process and fully incorporate the president's cost sharing policy into the existing financial framework of federal water law. The recent house action on Safety of Dams work was just one step. It was a step in the right direction, but we will need to take many more steps together as we work to keep water flowing to the lands and people who need it.

WATER QUALITY LAWS IN NEW MEXICO

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INTRODUCTION

No matter how well the water rights laws and regulations function, no matter how much water a party is allocated for beneficial use, and regardless of whether interstate export of water is ultimately required by the courts, if the water is polluted, it cannot be used. The importance of water quality in New Mexico has taken on increasing proportions as the demand for usable water has grown and as the sources of pollution have increased. Although water pollution has been recognized for hundreds of years as undesirable and wrong, until 1963 only the common law was available as a remedy for parties aggrieved by water pollution. In 1963, the state adopted a public nuisance statute that specifically outlawed water pollution. The public nuisance statute, however, provides little guidance on what pollution is or how one can determine when water pollution exists. In the 21 years since the adoption of the public nuisance statute, the state of New Mexico has promulgated hundreds of pages of additional laws, regulations, standards, plans and other documents attempting to answer those questions. The new state adoptions include the Water Quality Act and regulations addressing both surface and ground water pollution. In that same period, the federal government has generated thousands of pages of documents aimed at the same purpose.

Some might surmise that what we have is the typical lawyers' conspiracy to keep other lawyers occupied. How often have we heard it said that lawyers complicate simple matters and perpetuate their profession through the promulgation of unnecessary lengthy and confusing regulations? In part this may be true, but in defense of the legal profession, it should be noted that other factors have been instrumental in complicating the process of addressing water pollution. One complicating factor is scientific progress. Not only does science continuously revise the standards of what is safe and acceptable and what is not, but new chemical compounds are discovered every day, each of which might exist in an infinite number of combinations with existing and other new chemical compounds. Each combination may have a different degree or type of toxicity.

There are also many difficult political or policy questions to resolve. Some water already is so contaminated that it cannot be used. Is it acceptable to allow such water to be further contaminated without control? Other water is found in quantities that may not be sufficient to support a continuing use. Should this water be protected from pollution? Other questions that complicate the matter include: Should water pollution requirements in the arid and semi-arid southwest, where water is scarce, be the same as those where water is relatively plentiful? Should discharges be held responsible for pollution that occurred before pollution laws came into effect? Should some degree of water contamination be tolerated or should a zero discharge goal be set? These policy questions are addressed in the thousands of pages of state and federal documentation. Although the basic approaches for the control of surface and ground water contamination have been established, there are fundamental differences between the New Mexico and the federal policies of water pollution control that remain unresolved.

HISTORICAL WATER POLLUTION CONTROL

The primary rational for protecting water against pollution is that polluted water is not available for use. Under the common law (the principals and rules which were developed by usages, customs, and court decrees dating back to the ancient unwritten law of England [BLACK'S LAW DICTIONARY 345-6, 4th ed., 1968]), it was a nuisance to pollute water. A neighbor could sue another neighbor for compensation if he could prove to the court that his well was being fouled or his stream polluted by the actions of the other. Also, under the common law, public officials could sue those creating water pollution public nuisances, which affected the public at large. Common law remedies include monetary compensation and court ordered injunctions. These remedies are still available in New Mexico. The common law of nuisance provides an adequate means of relief for a party aggrieved by a clear and definite case of polluted water. However, scientific progress and increased water demands have created the demand for legislative action.

STATUTORY PUBLIC NUISANCE

The first attempt of the New Mexico Legislature to define water pollution was in 1963. That definition states: "Polluting water consists of knowingly and unlawfully introducing any object or substance into any body of public water causing it to be offensive or dangerous for human or animal consumption or use" (Section 30-8-2 N.M.S.A. 1978). The Legislature made polluting water punishable by up to one year imprisonment and a $1,000 fine. It also made water pollution subject to a civil action in state district court for abatement. Any private citizen or public official could take such an action. While the public nuisance statute served to clarify the criminal sanctions and civil remedies available for polluting water, the definition of water pollution did not provide sufficient guidance to a judge to assist him in complex technical matters. For example, there are no standards in the definition to determine what is offensive or dangerous for human or animal consumption or use. Scientists and doctors could argue, and have argued for decades, about appropriate or safe levels of contamination. While the properties of certain contaminants are well known and understood, those are in a small minority. Neither the time nor the resources have been devoted to epidemiological and laboratory studies on the effects of all of the potential water contaminants and the various combinations in which they might be found. Something more than the public nuisance statute was needed.

THE EXPLOSION OF WATER QUALITY LAWS

Following adoption of the Public Nuisance Statute in 1963, New Mexico adopted the New Mexico Quality Act in 1967 (Section 74-6-1 at sec., N.M.S.A. 1978). The act, for the first time in New Mexico, established a framework for a comprehensive and detailed scheme for the prevention, abatement and control of water pollution. That act mandates the adoption of water quality standards as a guide to water pollution control (Section 74-6-4 C.N.M.S.A. 1978) and the adoption of regulations to prevent or abate water pollution (Sections 74-6-3 and 4 N.M.S.A. 1978). To adopt the standards and regulations, the Legislature created the Water Quality Control Commission. That commission is constituted of heads of eight state agencies or departments and one member-at-large. The eight agencies include representation of those interests in New Mexico that are concerned with water quality and the expertise that those agencies possess. They include the heads of the Environmental Improvement Division, the State Engineer Office, the New Mexico Department of Game and Fish, the Oil Conservation Division, the State Park and Recreation Division, the New Mexico Deparment of Agriculture, the Soil and Water Conservation Division and the New Mexico Bureau of Mines.

Since the adoption of the Water Quality Act, the commission has adopted standards for every perennial stream in the state, as well as lakes and reservoirs. The commission also has adopted formal planning documents, which outline future research and pollution control strategies throughout the state. Other commission enactments include regulations prohibiting surface water and ground water pollution and regulations establishing criteria for certification of sewage treatment plant operators.

During the same period that New Mexico's water pollution requirements expanded, the federal government also adopted several water pollution acts. They are: the Water Quality Act of 1965; the Federal Water Pollution Control Act of 1972; the 1977 amendments to that act which make up the current Federal Clean Water Act (The Clean Water Act addresses pollution of surface waters.); the Safe Drinking Water Act (adopted 1974, amended through 1980); the Resource Conservation and Recovery Act (RCRA) (adopted 1976, amended through 1983); the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund Law, amended through 1983); as well as other federal laws that address ground water pollution control. Additionally, each of the major federal legislative enactments has been the springboard for a new body of federal regulations.

PROTECTION OF SURFACE WATER IN NEW MEXICO

The Water Quality Control Commission in August 1973 first adopted its standards for interstate and intrastate streams in New Mexico. The focus on those standards is protection of the use of surface waters. The commission established designated uses for stream segments, reservoirs and lakes. Those designated uses include high quality cold water fisheries, warm water fisheries, irrigation, and primary contact recreation (swimming). Each designated use was then assigned allowable contaminant limits. The quality of the water in each stream is mandated by the designated use. For example, a stream designated as a high quality, cold water fishery has more stringent stream quality requirements than one designated as a warm water fishery.

The New Mexico stream standards are enforced through a joint effort by the federal Environmental Protection Agency (EPA) and the state. Under the Federal Clean Water Act, all discharges to surface waters in the United States must have a permit from the EPA. Under the federal system, New Mexico is allowed to certify requirements for inclusion in those federal permits to ensure that the Water Quality Control Commissions' stream standards cannot be exceeded. The federal government is mandated by law to include the state certified requirements in the permits and then to enforce them. Surface water pollution was the first type of water pollution addressed by both federal and state regulatory agencies throughout the country. Once the regulatory scheme was in place, the emphasis changed to ground water quality protection.

NEW MEXICO GROUND WATER QUALITY REGULATIONS

New Mexico was a leader in the development of regulations to protect ground water quality. Following an extensive public hearing in June 1976, review of numerous public comments, and extensive deliberations, the Water Quality Control Commission adopted the nation's first comprehensive regulations designed to protect ground water quality on January 11, 1977, nearly 10 years after the state law first authorized such regulations.

Although those regulations address many technical and procedural points, in concept they are quite simple. The commission first established standards for some of the most common water contaminants. The regulations require anyone who discharges a potential ground water contaminant onto or below the surface of the ground to notify the director of the Environmental Improvement Division, or in some cases, the director of the Oil Conservation Division. The appropriate director may then request that a discharge plan be submitted. The discharge plan is a permit application. The basis for approval of a discharge plan is a demonstration by the discharger that the discharge will not cause any of the commission's ground water standards to be exceeded at any place in the present or reasonably foreseeable future use. In its ground water regulations, the Water Quality Control Commission has again focused on the useability of water. The commission considered the importance of water use to both the discharger and to the potential future user. A balance was struck. A discharger is allowed to use water and discharge some contaminants so long as the discharge does not adversely impact future use by others. The regulations provide a large degree of flexibility for dischargers to demonstrate compliance while, at the same time, they empower the director to require information and future monitoring from the discharge to ensure that future users will not be harmed by contaminant discharges. The New Mexico ground water regulations have been upheld by the State Court of Appeals and the State Supreme Court and have remained fundamentally unchanged since 1977.

Two major additions have been made to the ground water regulations since their original adoption. The first is a new definition of toxic pollutants. This definition lists approximately 77 chemical compounds and defines them as toxic when they exist in concentrations . . .

> which upon exposure, ingestion, or assimilation either directly from the environment or indirectly by ingestion through food

> chains, will unreasonably threaten to injure human health, or the health of animals or plants which are commonly hatched, bred, cultivated or protected for use by man for food or economic benefit. As used in this definition injuries to health include: death, histeopathologic change, clinical symptoms of disease, behavior abnormalities, genetic mutations, physiological malfunctions or physical deformations in such organisms or their offspring. In order to be considered a toxic pollutant a contaminant must be one of the potential toxic pollutants listed and be in a concentration shown by scientific information currently available to the public to have potential for causing one or more of the effects listed above. Any water contaminant or combination of water contaminants in the list below creating a lifetime risk of more than one cancer per one hundred thousand exposed persons is a toxic pollutant (WQCC regs. 1-101 UU).

Some critics of the toxic pollutant definition have argued that is is too complicated or confusing to implement. While there is little question that numerical standards are preferable, pollution control measures such as the toxic pollutant definition will continue to exist in our laws and regulations because of the insurmountable task of determining safe and acceptable concentration levels for each and every potential water contaminant. For this reason among others, the toxic pollutant definition was upheld by the State Appellate Courts in 1982.

The second major development since the adoption of the Water Quality Control Commissions Ground Water Regulations is the addition of Part 5 of the regulations. Part 5 is the first of a trend in the state's regulatory process. Part 5 was required to be adopted by the EPA and federal laws in order for the state to maintain certain federal grant monies and the authority to carry out a federal program, in this case the safe drinking water program. Part 5 constitutes 30 pages in the Water Quality Control Commission regulations. It focuses on a very small group of discharges and injection wells. Also, Part 5 mandates, in detail, specific requirements for the installation and use of those wells. It is approximately twice as long as the entire body of the original ground water regulations, which adresses almost all sources of potential ground water pollution. It is questionable whether or not Part 5 adds any additional protection to the ground water of New Mexico. However, the federal government's insistence on uniformity throughout the country and the carrot and stick effect of federal monies affecting state regulations were responsible for the adoption of Part 5 of the Water Quality Control Commissions regulations.

STATE-FEDERAL POLICY CONFLICTS

Specific provisions in the Water Quality Act ensure that overzealous control of water pollution cannot impact adversely on the ability to use water. Limitations in the New Mexico Water Quality Act include:

> The Water Quality Act does not grant to the Commission or any other entity the power to take away or modify property rights in water, nor is it the intention of the Water Quality Act to take away or modify such rights (Section 74-6-12 A.N.M.S.A. 1978).

and:

> In the adoption of regulations and water quality standards and in any action for enforcement of the Water Quality Act and regulations adopted thereunder reasonable degradation of water quality resulting from beneficial use shall be allowed (emphasis added) (Section 74-6-12 F.N.M.S.A. 1978).

The Water Quality Control Commission has followed these requirements by focusing its regulations on the protection of the use of water. The term "reasonable degradation" has been interpreted by the state as degradation that does not impair future beneficial use of water. In other words, in New Mexico some water quality degradation is permitted so long as it is not harmful to future users. For example, if a water quality standard for a stream is 25 mg/l for chloride and the existing concentration is 1 mg/l, under state law, a discharger will be allowed to discharge chloride to that stream so long as the concentration in the stream does not exceed 25 mg/l. This approach allows beneficial use of water by adequately protecting future users without unduly restricting the activities of dischargers. In a state such as New Mexico where water is often the limiting factor in growth, it makes sense to allow maximum beneficial use of water.

Unlike New Mexico's water pollution control policy, the federal approach does not focus on beneficial use. Rather, beginning in 1972 with the adoption of the Federal Water Pollution Control Act, the federal approach has focused on technology based pollution control requirements. Through the 1972 Federal Water Pollution Control Act and its 1977 Clean Water Act amendments, the federal government has addressed allowable discharges to surface waters on an industry by industry approach. EPA regulations and guidelines establish specific levels of control that must be achieved by each category of discharger. Also, each category is divided into existing and new dischargers, with the new dischargers held to an even higher standard of control. Simply stated, the federal approach is to require every discharger to maximize pollution control, regardless of the necessity to protect water for future use. If, for example, the EPA guidelines allowed no discharge of a contaminant, the discharger would be required to comply, even if some discharge of that contaminant could occur without resulting in harm to future uses or in any violation of stream standards.

The difference in the state "reasonable degradation" requirement and the federal "technology based" approach is one of the main reasons New Mexico did not elect to accept delegation of the federal surface water discharge permit program. Since 1972, the EPA has administered that permit program in New Mexico. The state refused to change its reasonable degradation policy and therefore could not adopt EPA's rigid technology based requirements.

The same state-federal policy conflict exists between the federal hazardous waste RCRA regulations and the New Mexico ground water regulations. While the ground water regulations allow reasonable degradation of ground water (within the limits of the standards) resulting from beneficial use, the RCRA regulations specify technology for each case. The ground water regulations would allow water containing contaminants to be discharged if discharge would recharge an aquifer without adverse impact on the health or safety of future users. The same discharge might be required to be placed in impermeable ponds and evaporated under the RCRA regulations. While evaporation of such water may be an acceptable procedure in areas where water is plentiful, it could be considered a waste of usable resources in areas like New Mexico where water is scarce. The RCRA approach to control of ground water pollution apparently has failed to take into account the special needs in water short areas. Until the federal approach is revised or the state policy changes, the conflict will remain.

CONCLUSION

The field of water pollution control law has expanded at an incredible rate over the past 20 years. While progress has been made, questions remain unanswered and some conflicts remain unresolved. The next 20 years of change in water pollution control laws will be crucial to the future of our most important resource--water.

REMOVAL OF HEAVY METAL IONS FROM CONTAMINATED WATER BY CHLORELLA VULGARIS

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SUMMARY

Several aspects of the binding of heavy metal ions with *Chlorella vulgaris* in aqueous solutions were investigated. In particular, it was found that several heavy metal ions may be removed successfully from solution by adsorption onto the cell walls of the algae, or by precipitation with macromolecules that are probably proteins derived from the algae cells. Some operating conditions which were studied included pH, salt effects, the effect of competing metal ions, and the mass of algae used. Specific attention was given to the binding of Hg^{2+} (very strong binding occurs), which is suspected of binding to sulfhydryl groups on the algae surface. The binding of other metal ions, including Pb^{2+}, Cd^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+}, Cr^{3+}, Al^{3+}, and Ca^{2+}, also were investigated, and results with these ions indicated that the binding to the algal cells was very pH dependent. With these metals the binding is reversed by lowering the pH.

It was shown that ionic strength alone is not a limiting factor when working with salt containing solutions, but that competition of certain ions such as Ca^{2+} of Mg^{2+} for binding sites or interactions with complexing ligands may limit the use of *Chlorella vulgaris* for metal removal operations in some waters.

The UO_2^{2+} ion also was bound very strongly to algal cells, and the successful removal of UO_2^{2+} from contaminated waters taken from

the Ambrosia Lake area in northern New Mexico indicated that the use of Chlorella vulgaris may be an attractive alternative to the use of ion-exchange resins in water clean-up operations. In one sample, the UO_2^{2+} concentration was reduced from about 20 ppm to 1.4 ppm using 10 mg/ml algae (dry weight). These results indicate that the use of Chlorella vulgaris is promising for large scale use in removal of heavy metal ions from mining or industrial wastewaters.

INTRODUCTION

The development of effective, low-cost water purification and recovery techniques for the removal of heavy metal ions from water supplies is important from both environmental and economic standpoints. The interactions of some microorganisms with heavy metal ions in aqueous solutions may result in an active uptake or binding of the free metal ions to the cell. Complexation or precipitation of metal ions by substances derived from the organism also may occur. Many reports on the abilities of several microorganisms including bacteria, fungi and various algae to accumulate heavy metal ions indicate promise for industrial exploitations in the microbiological recovery of Pb^{2+}, Cd^{2+}, Zn^{2+}, UO_2^{2+}, Ni^{2+}, and other metal ions from contaminated waters (Ferguson and Bubela 1974; Kollman and Lynch 1981; Brierly and Brierly 1981; Nakajima, Horikoshi, and Sakuguchi 1981; Khummongkol, Caterford, and Fryer 1982; Galuh, Keller, and Malki 1983; Wook and Wang 1984). The success of the biosorption process depends on the organism, conditions of pH, metal ion and salt concentrations, and the presence of competing metal ions or complexing ligands in the solution.

The organism Chlorella vulgaris, a weedlike green algae grown locally and inexpensively, is known to interact with several important heavy metal ions in aqueous solutions (Ferguson and Bubela 1974; Khummongkol, Caterford and Fryer 1982). To further test the application of Chlorella vulgaris to the biotechnological removal of a variety of heavy metal ions from contaminated waters, we experimentally studied several realistic operating parameters. In a specific application study, we can report the successful removal of uranium from contaminated ground waters from the Ambrosia Lake area of New Mexico.

Mechanisms for the biological removal of metal ions from aqueous solutions may be divided into three categories: (1) adsorption onto cell walls, (2) intracellular uptake, and (3) chemical transformations of metal ions by organisms, including complexation or precipitation by biologically derived materials. The first and third mechanisms are of particular interest because they may occur under conditions normally toxic to living cells. Evidence suggests that adsorption of metal ions on the surface of either living or dead microorganisms is an ion-exchange process involving amine, carboxyl, hydroxyl, sulfate, sulfhydryl, imidazole, or amide functional groups (Kollman and Lynch 1981; Driscoll, Hassett, and Shecher 1982; Walsh and Garnas 1984). Processes that compete with adsorption of metal ions on the cell surface may be complexation or precipitation by biologically derived solution species (Bird and Haas 1931; Ferguson and Bubela 1974; Laegreid et al. 1983). The latter behavior is typical of metal ion-humic or fulvic acid interactions (Saar and Weber 1980; Saar and Weber 1982). We present evidence that this occurs with Chlorella vulgaris and may also play an important role in the distribution of metal ions in algae-treated waters.

MATERIAL AND METHODS

Chlorella vulgaris was cultivated outdoors in growth media containing KH_2PO_4 (0.3 g/l), $MgSO_4 \cdot 7H_2O$ (0.3 g/l), KNO_3 (2.0 g/l), and urea (0.6 g/l) made up in tap water. The pH was maintained near 5.5 with carbon dioxide. The cells were harvested by centrifugation, dialyzed against distilled water to remove salts, and lyophilized. In metal uptake experiments, this material was resuspended in the desired solution. Adjustments of pH were made with concentrated NaOH or HNO_3.

Most metal ion uptake experiments were performed in 0.05 M sodium acetate, a complexing media chosen in part to help prevent the precipitation of metal hydroxides. Experiments were typically performed by suspending a known mass of algae and adjusting the pH. The appropriate metal ion(s) was then introduced into an aliquot and the suspension was mixed continuously or at frequent intervals. Prior to metal ion analysis, the pH was re-checked and recorded. After the required time, the reaction mixture was centrifuged to remove algal cells, decanted immediately, and the supernatent was analyzed for the appropriate metal ion. The results of several kinetic studies indicated that in general, equilibrium is reached before one hour with an initial metal ion concentration of 1.00×10^{-4}M. The reaction of p-Hydroxymercuribenzoate with algae cells was fast, within two minutes. In most metal ion removal experiments, an equilibration time of two hours is allowed. Precipitation experiments were performed using the supernatant from an algae suspension. Metal ion analyses were performed on the supernatants by Flame Atomic Absorption Spectrophotometry (FAAS) or Direct Current Plasma Emission Spectrophotometry (DCP).

An Instrumentation Laboratory 457 atomic absorption/atomic emission (air-acetylene flame) or a Spectrametrics Spectraspan V direct current plasma emission spectrophotometers was used. Several analyses with DCP were performed using a multielement cassette for the simultaneous determination of Pb^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Al^{3+}, Cr^{3+}, Mg^{2+}, and Zn^{2+}. Where possible, matrix matching was used to minimize possible ionization interferences. The method of standard additions was used to quantitate initial concentrations of uranium in ground water samples; background scans of the emission spectrum around the uranium peak at 424.2 nm showed less than 5 percent interference. The precision of either method was within 1-3 percent at the 10^{-4} to 10^{-6}M levels. Other instrumentation used was a Spex Fluorolog spectrofluorimeter, a Perkin Elmer model 320 uv-visable spectrophotometer, a Perkin Elmer model 283-B infrared spectrophotometer, and a BAS model CV1 voltage generator equipped with an X-Y recorder and a voltmeter.

RESULTS AND DISCUSSION

The Effect of pH on the Removal of Metals from Algae Suspensions

The amounts of metal ions removed by adsorption on algal cell walls, or by precipitation due to interaction with material derived from the algae cells, may be strongly dependent on pH, depending upon the particular metal ion. Figure 1 shows the pH dependence of the simultaneous removal of Pb^{2+}, Cd^{2+}, Zn^{2+}, Al^{3+}, Cr^{3+}, Cu^{2+}, Ni^{2+}, and Co^{2+}, each at an initial concentration of $1.00 \times 10^{-4}M$ from aqueous solutions containing algae at 5 mg/ml (dry weight). Diagrams of this type are useful in determining optimum pH conditions for metal removal. Reversal experiments, in which equilibrium mixtures of metal ions and algae are acidified, indicated that the binding of Pb^{2+}, Cd^{2+}, Zn^{2+}, Al^{3+}, Cr^{3+}, Cu^{2+}, Ni^{2+}, and Co^{2+} was reversible and that these ions, adsorbed at pH values ranging from 2-7, may be quantitatively desorbed by lowering the pH.

Examination of figure 1 shows that the removal of most of the metal ions by the algae suspension is very pH dependent. It is also apparent from this figure that selective removal of metal ions can be accomplished by judicious adjustment of pH. At pH 3.5, Al^{3+}, and Pb^{2+} can be rather selectively removed. In the pH 6-7 range most of the metal ions tested can be significantly removed under these conditions.

We have found that some metal ions are not only bound to the surface of the algae cell, but also to macromolecules that are solubilized when the lyophilized algal cells are suspended in solution. Several experiments showed that the clear supernatant solution resulting from a centrifuged algae suspension, which we refer to as "algae supernatant," has the capacity to react with certain metal ions to produce a precipitate. The formation of this precipitate results in a decrease of the metal ion concentration in the solution. Spectral analysis (UV, fluorescence, IR) give indications that the metal-containing precipitate contains proteinaceous material. The IR spectrum of the uranyl-precipitate very closely resembles that described by Nakajima et al. (1981), who claim it is that of uranyl ion adsorbed on the cell walls of Chlorella regularis. A more accurate mechanism for the removal of uranyl ion, which may be precipitated extensively (figure 2), is perhaps bioprecipitation or bioflocculation (in 0.05M sodium acetate), rather than bioadsorption. The pH studies in figure 2 with UO_2^{2+} showed that UO_2^{2+} was very strongly removed by either the algae suspension

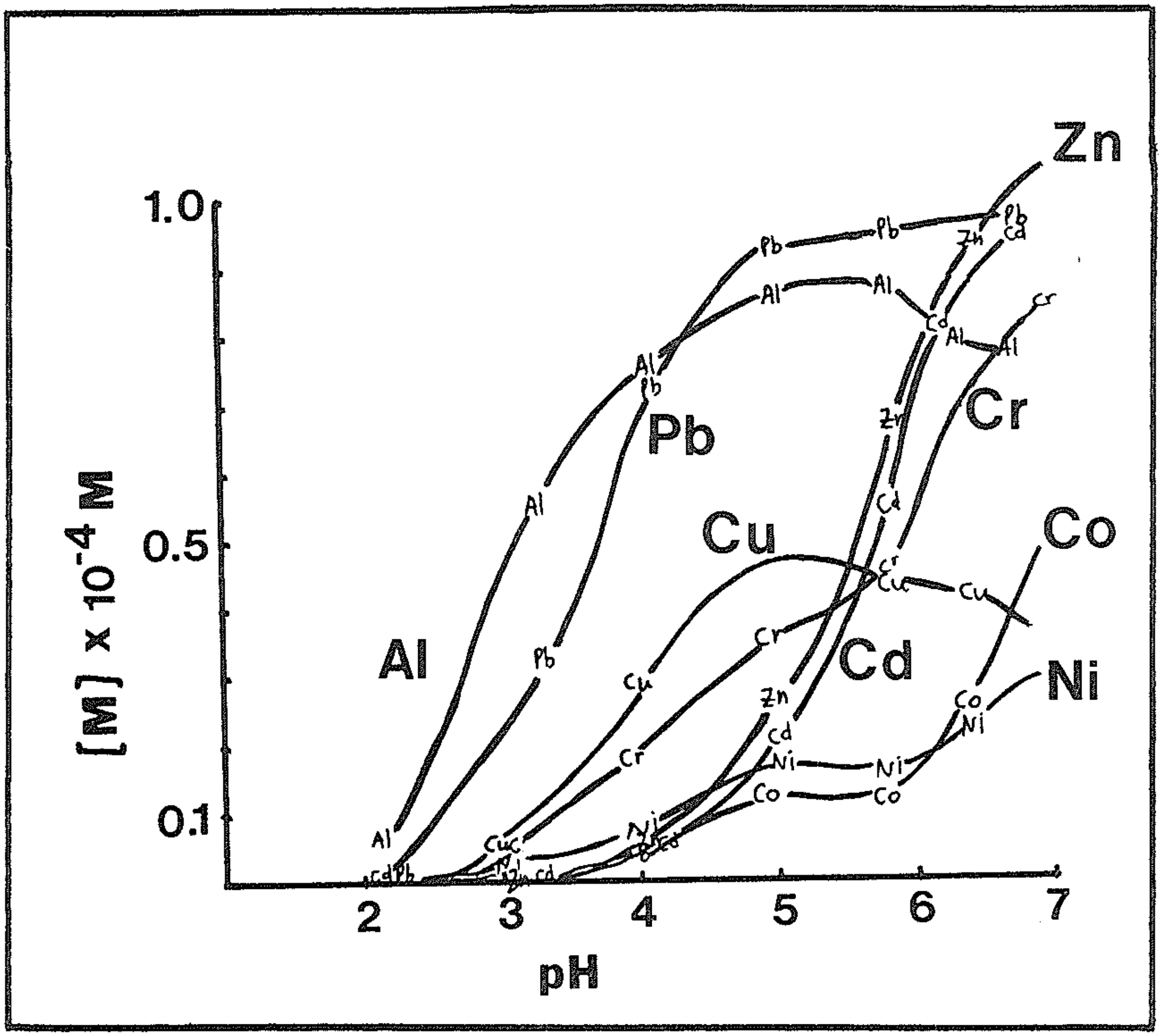

Fig. 1. The Effect of pH on the Removal of Eight Different Metal Ions from aqueous Solutions by Chlorella vulgaris. Algae (5 mg/ml, dry weight) was reacted at the appropriate pH's with solutions which were initially 1.00 x 10^{-10}M in Pb^{2+}, Cd^{2+}, Zn^{2+}, Co^{2+}, Cr^{3+}, Cu^{2+}, and Ni^{2+} (from an equimolar stock solution of the metal acetates) in .05 sodium acetate. After two hours, the mixtures were centrifuged and the supernatants were analyzed for each metal. The ordinate represents the concentrations of metal ions which are removed from the solution, i.e., the initial concentrations minus the final concentrations of each metal in the solution, and includes both the effect of adsorption by the cells and precipitation by macromolecules (see text).

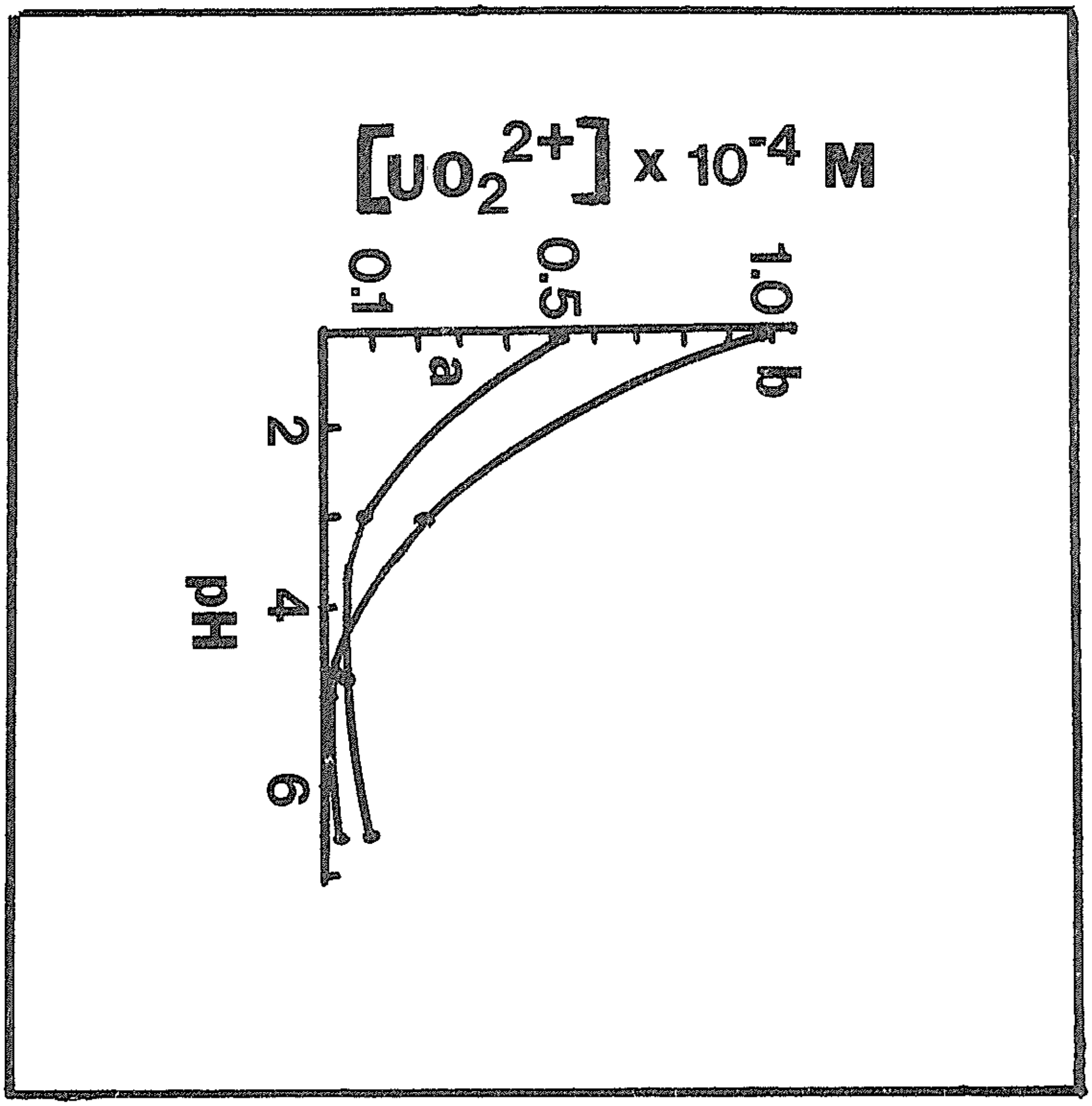

Fig. 2. The Effect of pH on the Removal of UO_2^{2+} by Adsorption and Precipitation. Algae suspensions (a), 5 mg/ml (dry weight), were reacted with 1.00×10^{-4}M $UO_2(C_2H_3O_2)_2$ in 0.05 M sodium acetate at pH's in the 1-7 range. Curve (b) is obtained from the corresponding reactions of $UO_2(C_2H_3O_2)$ with the supernatant obtained from centrifugation of 5 mg/ml (dry weight) suspensions of algae. The ordinate represents the final concentration of UO_2^{2+} measured in the solutions after centrifugation.

or the algae supernatant in the pH 4-6 range. Below this range, from pH 1-3, it becomes possible to differentiate the amounts of UO_2^{2+} bound to the cells and in precipitated form. Although it is experimentally difficult to measure the amount of precipitated metal ion in an algae suspension, experiments with algae supernatants give first approximations to the amounts of metals that are removed by the soluble macromolecules. Subtracting the quantity of metal ion precipitated in a supernatant experiment from the total quantity of metal ion removed in the corresponding algae-suspension experiment gives a calculated value for the amount bound to the cells. Some metals for which precipitation by the algae supernatant can be significant are Pb^{2+}, Cu^{2+}, UO_2^{2+}, Hg^{2+}, Fe^{3+}, and Al^{3+}.

In several experiments with Hg^{2+}, it was desired to minimize the effect of precipitation due to Hg^{2+} interactions with the algae supernatant while maintaining strong binding to the cells. It was found that a pH 2 Hg^{2+} is not precipitated by the algae supernatant while greater than about 80 percent of the metal (at an initial concentration of 1.00×10^{-4}M) is bound to the cells using an algae concentration of 1.5 mg/ml.

The Effect of Salts on the Removal of Metal Ions by *Chlorella vulgaris*

The extent of metal ion removal is affected by the presence of certain salts in solution. Experiments showed that the removal of Pb^{2+} or Zn^{2+} (5 mg/ml algae, pH 5.5) was not inhibited in solutions containing up to 1.0 M concentrations of KNO_3. This suggests that ionic strength alone has little effect on adsorption of the metal ions. Other salts, however, may play a major role. Under the same conditions as above, increasing Ca^{2+} or Mg^{2+} concentrations resulted in an interference with the removal of Pb^{2+} or Zn^{2+}. This suggests that high concentrations of Ca^{2+} and Mg^{2+} may successfully compete for binding sites otherwise available to the heavy transition metal ions.

The presence of complexing ligands also may inhibit metal ion binding. Experiments with increasing sodium acetate concentrations (same conditions as above) also resulted in decreasing amounts of Pb^{2+} and Zn^{2+} removed, as might be expected on the basis of competing metal ion complexation by acetate. Other anions such as carbonate, bicarbonate, chloride, and sulfate may also cause interferences in the removal of heavy metal ions, and further investigations into the effect of these ions are in progress.

The Effect of Algae Mass on the Removal of Heavy Metal Ions

A comparison of the binding of several heavy metal ions to algae cells suggests that distinct categories of metal ion binding sites exist. These include: (1) very strong binding metal ions such as Hg^{2+} and possibly UO_2^{2+}; and (2) metal ions which are more weakly bound and which exhibit pH dependent binding. These include Pb^{2+}, Cd^{2+}, Zn^{2+}, Al^{3+}, Co^{2+}, Ni^{2+}, Cr^{3+}, Cu^{2+}, and Fe^{3+}. In the case of reaction with a very strong binding metal ion, such as Hg^{2+}, concentrations of algae at about 1 mg/ml were sufficient to remove essentially all of the metal ion from solutions containing 1.00×10^{-4}M concentrations of metal ion. This suggests that specific binding sites are responsible for the strong interactions.

Competition effects may occur in the algae supernatant, where complexation and precipitation equilibria may be altered by the presence of other metal ions. Results show that the amount of Pb^{2+} which was precipitated by the algae supernatant was decreased by more than 50 percent when equimolar amounts of Zn^{2+} and Cd^{2+} were present. This suggests that Zn^{2+} and Cd^{2+} not bound to the algae may preferentially form soluble complexes with the components in the supernatant which would otherwise precipitate Pb^{2+}.

The Removal of Uranium from Contaminated Ground Waters with Chlorella vulgaris

Metal ions originating from uranium milling operations may enter ground water supplies. In addition to UO_2^{2+}, other important heavy metal ions which may be present are vanadium, MoO_4^{2-}, Co^{2+}, Zn^{2+}, arsenic, Cu^{2+}, Ni^{2+}, and Pb^{2+} (Dreesen et al. 1982). Two uranium ground water samples used in these experiments were derived from mining operations in the Ambrosia Lake area of New Mexico. Each sample had a pH of 7.6; the initial uranium concentrations were 7.1 and 2.5×10^{-5}M (about 20 and 7 ppm U_3O_8). Figure 3 shows the dependence of UO_2^{2+} removal from the ground waters as a function of mass algae,

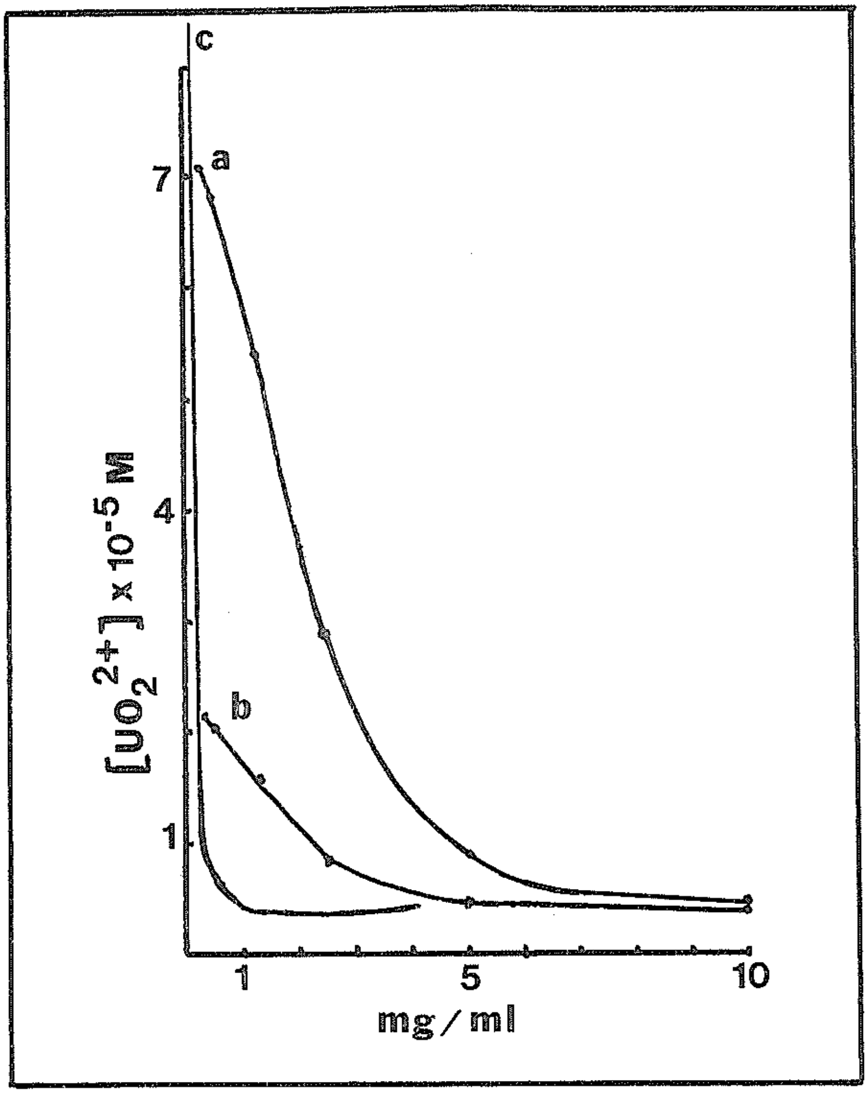

Fig. 3. The Effect of Algae Mass on the Removal of UO_2^{2+} from Natural Groundwater Samples and from Solutions of 0.05M Sodium Acetate at pH 5.0. The UO_2^{2+} containing solutions were allowed to react with different amounts of algae in the 0.05 - 10 mg/ml range, and after two hours, the suspensions were centrifuged and the free UO_2^{2+} concentrations were measured. Curve (a) and (b) represent two different groundwater samples taken from the Ambrosia Lake area of Northern New Mexico. Each was at pH 7.6; no pH adjustments were made. Curve (c) represents a solution of 0.05M sodium acetate at pH 5, containing 1.00×10^{-4}M $UO_2(C_2H_3O_2)_2$. The initial UO_2^{2+} concentrations were about 7.1×10^{-5}M and 2.6×10^{-5}M, in curves (a) and (b), respectively. The final concentrations in the groundwater samples were about 1.4 ppm.

and for comparison the removal of UO_2^{2+} from 0.05 M sodium acetate. Inspection of the slopes of these curves shows that interfering substances may affect the efficiency of UO_2^{2+} removal from the ground water samples as compared to the sodium acetate, but with larger concentrations of algae, a similar removal level of uranium from these solutions is approached, about 1.4 ppm. However, these experiments clearly show that the algae is effective in removing uranium from natural water samples.

CONCLUSIONS AND PROJECTIONS

Chlorella vulgaris is very effective in the removal of several important heavy metal ions from metal ion-containing waters. Success with UO_2^{2+} removal from ground water samples indicates that algae treatment of uranium-contaminated waters may be promising on a large scale. The high binding capacity for UO_2^{2+} combined with the low cost of algae production (less than 50¢/lb) may make Chlorella vulgaris an attractive alternative to the more expensive ion-exchange resins (up to $100/lb) that are now being used in many clean-up operations. In the event that metal ion recovery is not practical by desorption or dissolution, simple combustion may provide a relatively efficient way of recovering the bound metal ions.

Evidence has been presented that the precipitation of some heavy metals from algae supernatants may be an important path for the removal of these ions. We believe that metal ion removal by precipitation in this manner can be further exploited for the removal of heavy metal ions from contaminated waters. Currently, we are investigating the use of dialysis bags to contain the algae and the associated macromolecules that are responsible for the precipitation. The results of preliminary experiments in which a dialysis bag containing an algae suspension was submerged in a solution containing Pb^{2+} indicate that Pb^{2+} was removed very rapidly from the outside solution, with no precipitation outside the dialysis bag occurring. These results suggest that the molecules responsible for precipitation of metal ions from the algae supernatant are macromolecules and are being retained within the dialysis bag. The development of methods of this type may enable the facile removal of metal ions from contaminated waters without the necessity of centrifugation.

A very real advantage of using the system for removal of metal ions from industrial or mining wastewaters is that the system can be used under conditions that might normally be toxic to living cells. Since the process we are observing is not dependent upon a living organism, it can be used under a variety of conditions.

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IRRIGATION SCHEDULING MODELS AS AN ECONOMICAL FARM MANAGEMENT TOOL

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SUMMARY

If irrigated agriculture is to remain viable in arid regions of the West, an effort must be made to improve its profit structure. One of the more promising technologies for improving irrigated producers' profits is the use of irrigation scheduling models. Producers will accept new technology only when the economic value of these models is proved. This analysis is an attempt to do so for a case study in the Roswell-Artesian Basin in New Mexico.

Two existing irrigation scheduling models were developed and validated for the major crops grown in the Roswell-Artesian Basin of New Mexico: (1) a profit maximization dynamic programming model (DPM), and (2) a physically based yield maximization model. The DPM takes into consideration the price of water before it makes an irrigation decision and applies irrigations only when the value of the water in use exceeds the cost of using it. The physically based model does not take the cost of using water into consideration, but will apply irrigations when the soil moisture level falls below a certain level.

Yield and water applications derived by both models were higher than current practices. The DPM increased yield and net returns for alfalfa, corn and grain sorghum above the physically based model in almost every case.

Results indicate that the irrigation water demand function for alfalfa is relatively elastic while the demand function for corn is relatively inelastic, and for sorghum it is intermediate. These findings imply that grain crops should be subjected to moisture stress, while

alfalfa should not. Furthermore, water prices would have to increase substantially before water conservation would result.

It can be concluded that both producers and water policymakers could benefit from the use of either of these irrigation scheduling models, but the use of the DPM would generally result in higher yields and net returns.

INTRODUCTION

Water resources in the western United States have recently become more scarce as population growth has increased faster than the national average. Increased activity in the minerals and mining sectors also have placed stress on these limited resources. In some areas, ground water resources have begun to decline. For example, the Ogallala aquifer in the Great Plains is declining at the rate of one to three feet a year. As ground water tables have declined, farmers have been forced to pump water from greater depths. Increased pumping costs due to pumping from greater depths and dramatically higher energy costs, combined with low crop prices have placed farmers who irrigate in a severe price-cost squeeze. This bind has encouraged them to look for alternative methods to increase farm level profits. One such method that might increase farm level profits is the use of systematic irrigation scheduling models and procedures.

Two recent models developed by researchers are physical, water balance yield maximization models, and water balance models that maximize profits through the incorporation of economic principles. Both types of models are adaptable for use at the farm level, but the potential economic gains from using such models have not been evaluated. This analysis was an attempt to perform such an evaluation for the Roswell-Artesian Basin of New Mexico.

Two existing irrigation scheduling models: (1) a profit maximization dynamic programming model (IRRG), and (2) a physically based yield maximization model (IRRSCH) were validated for a 35-year-period for three major crops (alfalfa, corn and grain sorghum) grown in the Roswell-Artesian Basin of New Mexico. IRRG takes into consideration the price of water before the model makes an irrigation decision and applies irrigations only when the value of the water in use exceeds the costs of using it. The physically based model does not take the cost of using water into consideration, but will apply irrigations when the soil moisture level falls below a certain level.

IRRG and IRRSCH are extremely versatile and can be used for several locations in New Mexico. Climatological data, irrigation application uniformity, information on soil types, and crop water production functions are all that need be known in order to operate the models.

MODELS

A Dynamic Programming Model-IRRG

IRRG is a stochastic dynamic programming irrigation scheduling model. The objective function of IRRG is to maximize the profits from the production of a single specified crop. The model was constructed to make a decision to irrigate only if the dollar returns from a unit of water exceeded the costs of using that unit of water. The model was constructed to account simultaneously for the probability and amounts of rainfall, the cost of pumping water, soil moisture, crop development, and crop price.

IRRG is conceptually divided into eight "control" equations and an objective function (gain in net income). The control equations describe the state of the system as measured by the change in soil moisture from one time period (stage) to the next, based on transpiration, evaporation, deep drainage and rainfall. The model uses, as its basis for making an irrigation decision, heat units accumulated over the growing season (instead of the calendar year) to model crop growth and development. Using accumulated heat units to determine irrigation decisions is unique in the literature. Each stage in the model was defined as a 20 heat unit increment of a particular crop's growing season. Mapel (1984) has written a detailed description of the model.

Figure 1 presents the dynamic irrigation decision process of IRRG and the ongoing process over the growing season. The data needed for IRRG to

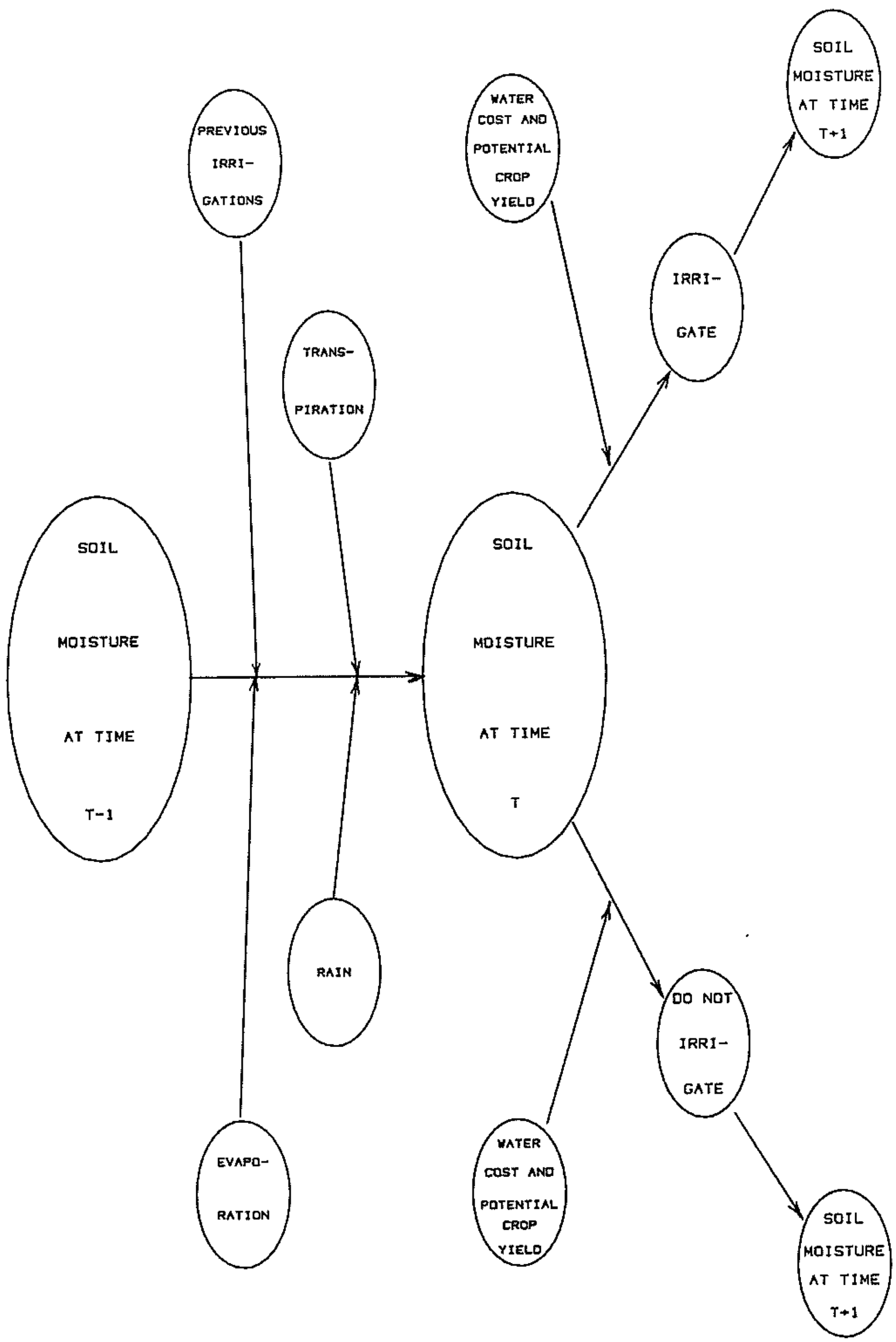

Figure 1. The Dynamic Irrigation Decision Process of IRRG.

make an irrigation decision--water costs, crop stress point, soil water holding characteristics, planting and harvesting dates based on heat units, and crop type and price--are entered into the model.

Conceptually, the model works backward in time, beginning with the last decision point, assigning a value to all "nodes" in each stage, where a node is a discrete level of the state variable. In this case, the nodes are discrete levels of soil moisture at a given number of stages into the growing season. To value the objective function associated with the current state node in time (t), the model calculates the t + 1 node positions derived from alternative irrigation decisions and adds it to the value for those nodes previously calculated. A selection is made for the optimal irrigation decision which simultaneously values the current node. The net return associated with each alternative irrigation decision is the cost of the irrigation subtracted from the expected value of the resulting nodes in stage i + 1. Because of the stochastic nature of precipitation, each decision has a range of possible outcomes.

In addition to the optimal irrigation schedule, the model also can be used to derive irrigation water demand functions. This is done by changing water price while holding all other variables constant (Varian 1978). These functions indicate the value of additional units of water in terms of net revenues.

A Linear Water Balance Model-IRRSCH

IRRSCH is an irrigation scheduling model developed by Sammis (1982) that determines the response of seasonal plant yield to irrigation timing and amount and is based upon a model introduced by Hanks (1974). The model takes into account differences in soil type, application uniformity, management practices and weather variation. Irrigation water is applied when user instructed or when the plant available water (PAV) falls below a certain predetermined level, usually 40 to 60 percent. PAV is a measure of the amount of soil moisture that is available for plant use. It is the ratio between field capacity and permanent wilting point. The model also can read any given irrigation schedule as input.

The model uses weather data from a specific site or from simulated weather data derived from a particular site. The model incorporates the effect of a non-uniform application of irrigation water over a field by modeling transpiration (T) at several locations within a given field. Model output includes estimated crop yield and estimates of seasonal T and soil evaporation [A more complete description of IRRSCH is developed by Hanks (1971) or Lansford et al. (1983).]

RESULTS

Crop prices used to calculate gross returns were taken from recently published data and are presented in Table 1. Water costs were calculated using the cost of a pumping model developed for the High Plains Ogallala Aquifer Study (Lansford et al. 1982) and are presented in Table 1 for a surface irrigation system. Natural gas was assumed to be the energy source used for pumping, and water costs were calculated for a pumping lift of 125 feet. Well output of 1,000 gallons per minute (GPM) and a pumping plant efficiency of 13.8 percent also were assumed. The other variables needed by both models to calculate soil moisture levels are presented in Table 2.

Model Comparisons

The water applications, yield and net returns that resulted from the optimal irrigation schedule of IRRG are presented on the left side of Table 3. The yield, water applications, and net returns resulting from the simulations of IRRSCH for the three different levels for PAV are presented to the right. Net returns are defined as gross returns (yield times crop price) minus the total cost of pumping water (amount of water in acre-inches times the cost of pumping per acre-inch). Since water is the only input that is assigned a cost, the net returns exclude costs of other factors of production, i.e., land, labor, management and capital exclusive of irrigation water.

The results from the physically based model (IRRSCH) specified for the 40, 50 and 60 percent PAV level indicate that net returns would be highest for alfalfa at the 50 percent level (Table 3). IRRSCH would apply 58.86 acre-inches of water per acre, which would result in a yield of 8.14 tons per acre and a net return of $420.90 per acre.

TABLE 1. CROP PRICES, WATER COSTS AND PUMPING ASSUMPTIONS USED FOR ANALYSIS

ITEM	PRICE	FURROW* IRRIGATION	PUMPING LIFT	GALLONS PER MINUTE
	(DOLLARS)	- - - ($/ACRE-INCH) - - -	(FEET)	(GPM)
CROP				
ALFALFA	67.00/TON			
CORN	.05/LB.			
SORGHUM	.05/LB.			
WATER COST				
FUEL		1.52		
REPAIRS		0.21		
LABOR		0.38		
TOTAL		2.11		
PUMPING ASSUMPTIONS			125	1,000

SOURCE: NEW MEXICO AGRICULTURAL STATISTICS, 1982
*ASSUMES A NATURAL GAS PRICE OF $4.57/MCF AND WELL EFFICIENCY OF 13.8%

TABLE 2. PARAMETERS ASSUMED FOR COMPARISON OF IRRG TO IRRSCH

ITEM	PARAMETER
SOIL TYPE	LOAM
FIELD CAPACITY	31 (PERCENT BY VOLUME)
PERMANENT WILTING POINT	15 (PERCENT BY VOLUME)
(PAV)	
ALFALFA	50 (PERCENT BY VOLUME)
CORN	60 (PERCENT BY VOLUME)
SORGHUM	50 (PERCENT BY VOLUME)

Table 3. Comparison of per acre net returns, yields and water applications-IRRG vs IRRSCH pumping lift of 125 feet & IRRSCH set at 40,50 and 60% of plant available water (PAV) surface irrigation on a loam soil-35 year average

Crop	IRRG Average Yield	IRRG Average Net Returns	IRRG Average Water Applied	IRRSCH Average Yield	IRRSCH Average Net Returns	IRRSCH Average Water Applied
	(tons/acre)	(dollars)	(acre-inches)	(tons/acre)	(dollars)	(acre-inches)
					40% PAV	
Alfalfa	8.41 ***	433.81 ***	61.49 ***	7.88	409.64	56.11
Corn	(lbs./acre) 9197 ***	360.05 ***	47.31 ***	8010	332.28	32.34
Sorghum	7878 ***	318.20 ****	35.89 ***	7670	322.97	28.69
					50% PAV	
Alfalfa	8.41 ***	433.81 ***	61.49 ***	8.14	420.90	58.86
Corn	(lbs./acre) 9197 ***	360.05 *	47.31 ***	8890	360.34	39.89
Sorghum	7878 *	318.20 *	35.89 *	7802	314.61	35.77
					60% PAV	
Alfalfa	8.41 ***	433.81 ***	61.49 *	8.16	419.83	60.23
Corn	(lbs./acre) 9197 *	360.05 *	47.31 *	9165	358.20	47.43
Sorghum	7878 *	318.20 ***	35.89 ***	7798	293.21	45.83

125 foot lift uses a water cost of $2.11 per acre-inch
* The means between IRRG and IRRSCH are statistically the same
** 95% Confidence that the means between IRRG and IRRSCH are statistically different
*** 99% Confidence that the means between IRRG and IRRSCH are statistically different
**** 90% Confidence that the means between IRRG and IRRSCH are statistically different

The water applications by IRRG would be significantly higher (more than 5 acre-inches) than those required by IRRSCH at the 40 percent PAV level, but it would generate a significantly higher yield (.53 tons per acre) and significantly higher net returns ($24.17 per acre). At the crop stress point of 50 percent, IRRG would require significantly higher per acre water applications (2.63 acre-inches), but would significantly increase net returns ($12.91 per acre). At the 60 percent PAV level, the irrigation schedule of IRRG would generate a significantly higher yield (0.25 tons per acre) and significantly higher net returns ($13.98 per acre) with no significant difference in water applications.

For corn, the physically based model would generate the highest net return when the PAV level default is set to 50 percent. The net return would be $2.14 per acre higher than under the 60 percent level (Table 3). At the 50 percent level, IRRSCH would apply 7.54 acre-inches less water than at the 60 percent level and would generate a higher net return. This indicates that some moisture stress on corn would be beneficial to producers needing to increase profit levels.

Comparisons between the two models for corn indicate that the irrigation schedule derived by IRRG would result in higher yields under all PAV levels, but the irrigation schedule of IRRSCH would result in the highest net revenue at the 50 percent level of PAV ($360.34 per acre). At the 60 percent level of PAV, yield, water applications, and net returns would not be statistically different between the two models.

The results from the simulations of IRRSCH set at the three levels of PAV indicate that for grain sorghum, net returns would be highest under IRRSCH set at the 40 percent PAV level. IRRSCH would apply 28.69 acre-inches of water at this default level and generate net returns of $322.97 per acre (Table 3). Yield would be substantially lower under the 40 percent level than at the 50 and 60 percent levels, but this would be offset by lower water costs as a result of the lower water applications.

Comparisons between models for grain sorghum indicate that IRRG would generate the highest yield at all PAV levels, but at the 40 percent level of PAV IRRSCH would increase net returns by a significant amount (Table 3). The irrigation schedule of IRRSCH would increase net returns by

$4.77 an acre and would require significantly less irrigation water per acre (7.2 acre-inches). At the crop stress point of 50 percent PAV yields, water applications, and net returns would not be statistically different. However, the irrigation schedule derived by IRRG would result in significantly higher net returns of $3.59 per acre, largely as a result of slightly higher yields. At the 60 percent PAV level, the yields from the two models would not be statistically different. However, per acre water application requirements by IRRG would be substantially less than those of IRRSCH (9.94 acre-inches) and would result in a significantly higher net return for IRRG of $24.99 per acre.

Irrigation Water Demand Functions

The demand function for an input--irrigation water, for example--shows the amount of irrigation water that will be required at each price, if profits are to be maximized. Knowledge of this relationship is useful, particularly to farmers attempting to maximize profits and to governmental agencies attempting to encourage water conservation.

The demand function for irrigation water for alfalfa is relatively elastic (price responsive) from $0.00 per acre-inch up to $5.00 per acre-inch (figure 2). Only when water prices are increased to more than $5.00 does the demand function begin to show more price responsiveness and even then it remains relatively elastic to $18.00 per acre-inch. Only at water prices more than $18.00 per acre-inch does the demand function become relatively inelastic.

The water demand function for corn is relatively elastic up to water prices of $5.00 an acre-inch (figure 3). As water prices are increased to more than $5.00 per acre-inch, the demand function begins to become increasingly inelastic. Like alfalfa, however, the function does not become relatively inelastic until water prices reach a high level ($30.00 per acre-inch).

The irrigation water demand function for grain sorghum is relatively elastic at water prices up to $5.00 per acre-inch (figure 4). The demand function becomes relatively less elastic at water prices from $5.00 to $18.00 an acre-inch, then relatively inelastic at water prices more than $18.00.

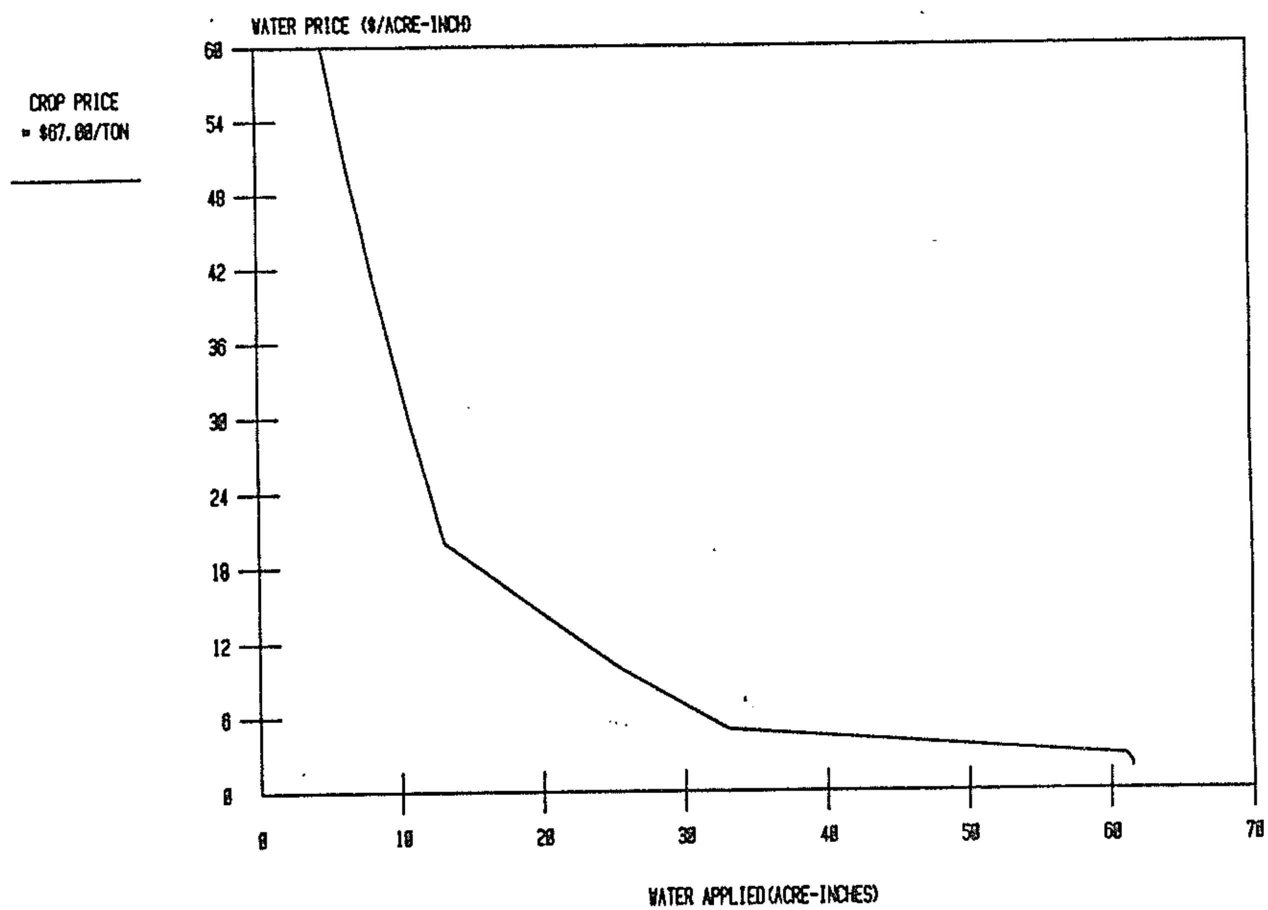

Figure 2. Stochastic irrigation water demand function for alfalfa, Roswell-Artesian Basin, NM.

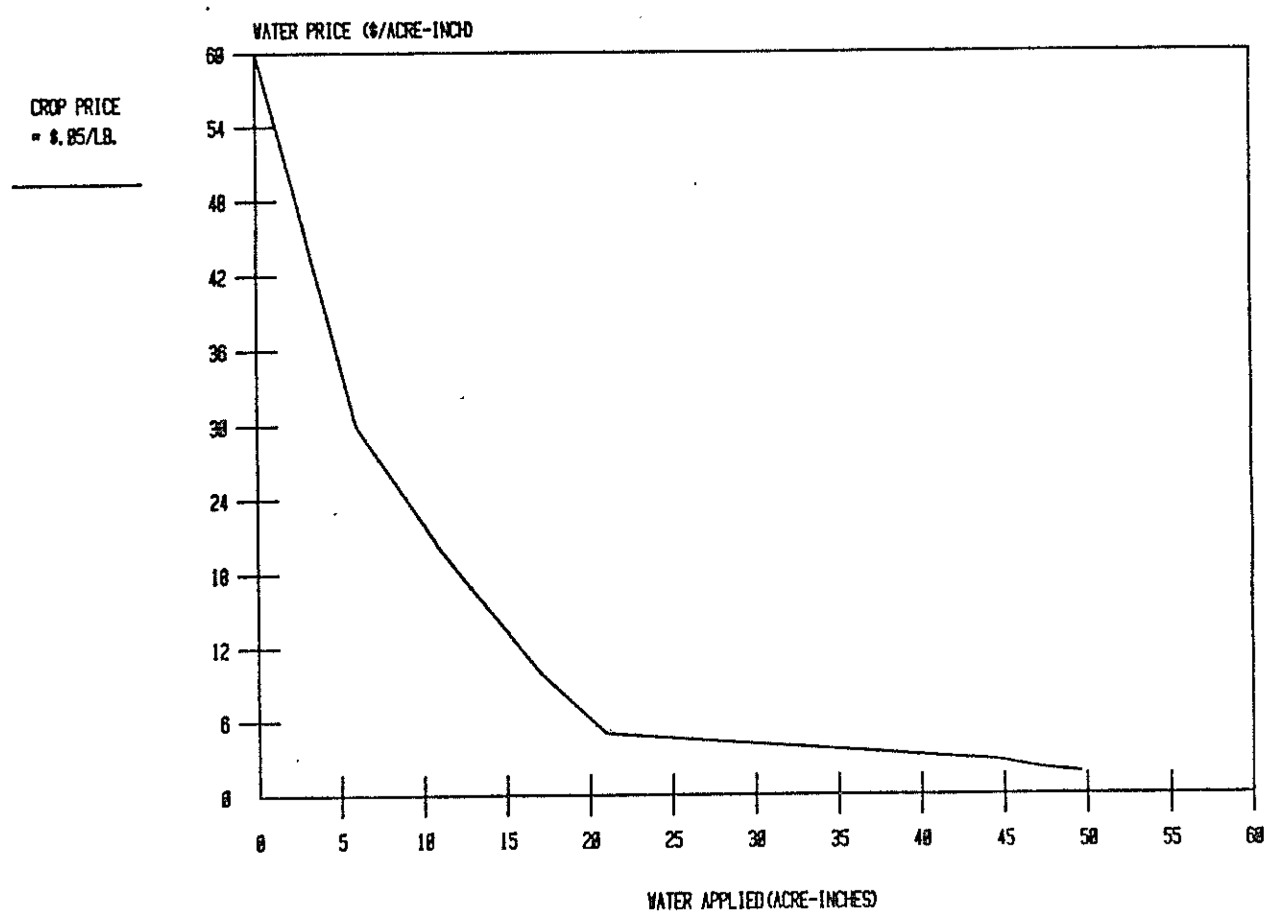

Figure 3. Stochastic irrigation water demand function for corn for grain, Roswell-Artesian Basin, NM.

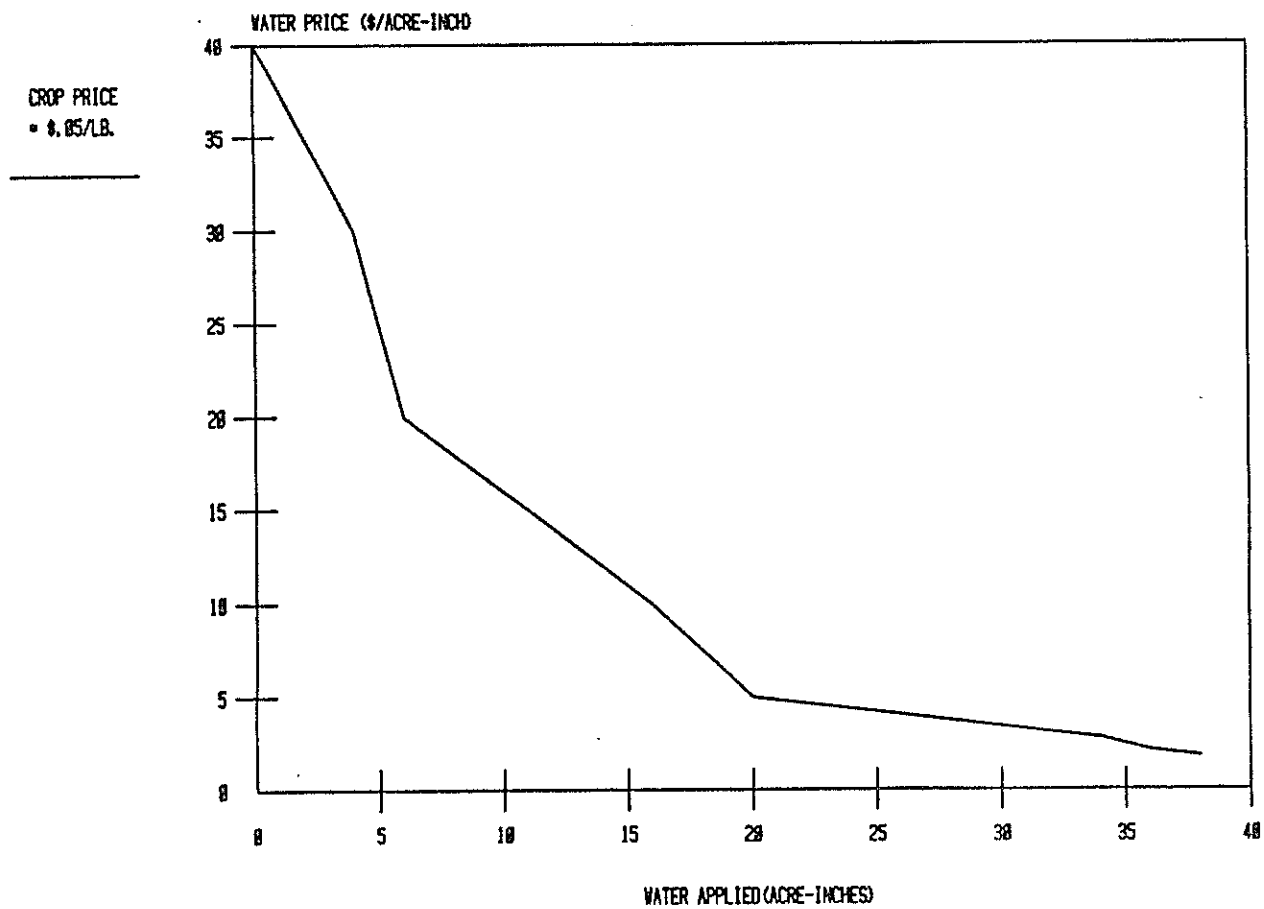

Figure 4. Stochastic irrigation water demand function for grain sorghum, Roswell-Artesian Basin, NM.

IMPLICATIONS

Upon examination of the generated data for the two models for surface irrigation, in almost every case, the irrigation schedule derived by IRRG resulted in higher yields and in higher net returns than IRRSCH. In some instances, the differences between the outputs of the two models in terms of yield and net returns were statistically nonsignificant.

Budgets compiled at New Mexico State University were representative of above average managed farms, they indicate that about 48 acre-inches of water is typically applied on surface irrigated mature alfalfa (Libbin 1984). This point is on the low price end of the alfalfa water demand function depicted in figure 2. Similar budgets prepared for grain sorghum indicate that 32 acre-inches is typically applied during the growing season (Libbin 1984). If the management practices reflected in the budgets are any indication of water applications in the area, producers are indeed operating at a point less than profit maximization given current water and grain prices.

Yield could be increased substantially by the application of more water than is now being applied. For example, from the same budget data for the Roswell-Artesian Basin, with 48 acre-inches of water, 6.25 tons of alfalfa is the budgeted yield on an above average managed farm (Libbin 1984). From the results of this analysis, by applying 60 acre-inches, producers could obtain about 8.5 tons per acre and substantially increase their profit levels.

Yield data from the area also indicate that for surface irrigated corn, yield on an above average managed farm is 6,440 pounds per acre. This level of production is achieved with a budgeted water application of 26 acre-inches (Lansford 1979). IRRSCH's and IRRG's irrigation schedule at the optimal stress point of 60 percent and a water price of $2.79 per acre inch resulted in yields of 9,165 pounds per acre and 9,197 pounds per acre, respectively, with the application of 47.43 and 47.31 acre-inches, respectively (Table 3). These findings imply that yields would be higher under both model's schedules given current water and crop prices. The results also imply that given the higher yields under IRRG resulting from the simulations of the models, the irrigation schedule of IRRG would result in higher yields and higher net returns than IRRSCH, if irrigation scheduling models were adopted by producers who irrigate.

The results indicate that producers should avoid moisture stress in the production of alfalfa and corn, and should subject grain sorghum to moisture stress to increase profits. Net returns were consistently greatest under the irrigation derived by IRRG for alfalfa production. IRRG will apply irrigations only when the value in use of the water exceeds the costs of using it. Therefore, alfalfa should not be allowed to stress, because the additional irrigation water should increase production. The situation is similar for corn, although it appears that the optimal stress point lies somewhere between 50 and 60 percent on the basis of the results from the simulations of IRRSCH.

In the production of sorghum, the results are the opposite. The net returns for sorghum production were consistently greatest under IRRSCH set at the 40 percent PAV level, given any water price. The higher level of net returns associated with subjecting grain sorghum to some moisture stress implies that lower water applications during the growing season would increase profits for producers.

The water demand functions are important to producers. The water prices producers are now faced with are low. The implications for producers are that they should increase their level of water applications in order to increase profit levels. It appears that producers are operating on the low price end of the water demand functions and that yield and net returns could be increased substantially by increasing the amount of water applied at given crop-water prices.

From water prices ranging from \$1.00 to \$5.00 an acre-inch, the water demand functions for all crops studied in this analysis are relatively elastic over this range (figures 2, 3 and 4). Along this elastic portion of the water demand function, the responsiveness of water demanded to water price increases is relatively large.

If the demand functions are as elastic as this analysis indicates, it is advantageous for producers to apply more water at current low water prices in order to maximize profits and if policymakers want to conserve water they should encourage producers to operate in the elastic portions of the water demand functions by allowing pricing mechanisms to operate.

All crops studied in this analysis have relatively elastic water demand functions at water prices up to $5.00 per acre-inch. It appears that current water prices would have to be increased substantially (in relative terms) before moderate levels of water conservation would result.

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REMOVAL OF URANIUM FROM DRINKING WATER

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SUMMARY

Uranium contaminated drinking water is a common problem, particularly in the western United States. Federal regulations limiting the amount of uranium in drinking water do not exist. Proposed regulations would limit uranium concentration to 10 picocuries per liter (pCi/l) or 15 micrograms per liter (μg/l). If these regulations are accepted and enforced, many communities will be forced to remove the uranium from their drinking water supplies.

Removal of this radioactive element produces the new problem of radioactive waste disposal. The physical form of this waste and the longevity of uranium cause difficulties in formulating a waste disposal plan.

The three disposal alternatives proposed in this report are dilution/release, reuse or resale, and burial. The disposal alternative chosen naturally will be based on economic feasibility. In this case, dilution/release is easily the least expensive alternative. However, the choice also must be based on environmental acceptability. Each participating community will have unique drinking water and waste characteristics. For this reason it is not possible to prescribe one solution to the problem. Each community must consider its situation and choose the optimum plan on that basis.

INTRODUCTION

More than 80 percent of the drinking water in the United States is supplied by ground waters (Pienciak 1983). The quality of ground water for drinking purposes is dependent on its mineral and biological content, which varies widely from source to source. It appears that all ground water contains at least some dissolved uranium. Little is known about the tolerance levels or effects of injesting low levels of uranium and thus, no national regulations for a maximum concentration level currently exist. It is assumed in the scope of this paper that uranium concentrations in excess of 15 μg/l should be removed or reduced. A removal process will result in the generation of a radioactive waste.

The purposes of this report are:

1. to present uranium contaminated drinking waters as a problem,
2. to explain the uniqueness of the problem of managing uranium waste,
3. to present alternatives for the management of this particular waste, and
4. to recommend a management procedure based on the criteria and alternatives presented.

URANIUM REMOVAL

Uranium is an alpha-bearing radionuclide. For the purpose of this EPA funded project, uranium will be removed from drinking water supplies when the concentration is in excess of 15 μg/l (Simon 1980). Thus, alpha-bearing waste will be generated. Two methods are being investigated to achieve either removal or a reduction in concentration. Various forms of waste will result.

Removal Methods

Ion exchange is the first and most efficient removal method. This method removes about 98 percent of the uranium (Lee 1982). The water is filtered through a column of anion exchange resin. Uranium is a strongly negatively charged ion at normal pH values. As it passes water through the column, chloride ions are released by the resin in exchange for uranium. The resin is regenerated with a small volume of very concentrated salt solution of sodium chloride. This time, the resin will release the uranium in exchange for the chloride due to the high chloride concentration. Now the extracted uranium is concentrated into a small volume of regenerant liquid. This concentrated liquid waste must be disposed of in some manner.

The second removal technique is chemical clarification. Chemical coagulants form a charged gelatinous floc which is very pH dependent (Kump 1983). Uranium concentration can be reduced with this water treatment process. The addition of either aluminum sulfate (alum) or ferric chloride causes coagulation. The efficiency of this process will vary from 40 to 99 percent, depending on pH and coagulant dosage. The waste from this process will be in the form of a sludge. One disadvantage associated with chemical clarification is that the pH adjustment must be made in order to achieve maximum uranium reduction.

Uranium Concentration Levels

It appears that most ground waters contain some uranium. The concentration of uranium in natural waters is typically much higher in the western United Stated than in the rest of the country.

The calculations within this report are based on "elevated" uranium levels in New Mexico drinking water supplies (Appendix I). The definition of "elevated levels of uranium" is based on the proposed federal regulations of 10 pCi/l uranium or greater (Pienciak 1983). Furthermore, the calculations are based only on the "larger water systems" in New Mexico, which are defined as systems serving 1,000 people or more (Pienciak 1983).

The majority of the New Mexico water systems that meet the criteria mentioned range in concentration from 10.5 to 28 pCi/l. This range is equivalent to 15 to 42 μg/l (Appendix I). The average state value, based on these wells, is approximately 6 μg/l of uranium (Appendix I). An extremely high concentration has been found in a New Mexico State University well (NMSU #8). The uranium concentration in this well is about 165 μg/l. This value was not included in the state average.

Concentrated liquid or liquid/slurry waste results from the ion exchange method. A powdered or cake waste also can be obtained by heat application. It is assumed that the resin is capable of cleansing 3,500 liters of raw water per liter or resin before the resin must be regenerated using 1.5 liters of regenerant fluid. Accordingly, the waste concentration based on the extreme (NMSU #8) will be approximately 380 milligrams per liter (mg/l). The waste concentration from the average New Mexico well would be approximately 50 mg/l.

Sludge waste would result from a chemical clarification procedure. Using ferric chloride as a coagulant, the waste resulting from purifying the extreme uranium concentration would be approximately 2.72 mg U/kg sludge. The state average uranium concentration in sludge resulting from this coagulant would be 0.43 mg U/kg sludge (Appendix II).

UNIQUE PROBLEM OF URANIUM WASTE MANAGEMENT

Uranium is a long lived alpha-bearing element. The uranium waste generated by this project is not part of the nuclear fuel cycle. By these criteria, the waste focused on in this report would be classified as low-level waste. Current low-level waste management and disposal methods are geared toward wastes that remain toxic for a few hundred years at most. The half-life of uranium is 4.5 billion years (Wededohl 1978). For example, if 100 grams of uranium-238 were stored in a box in the year 1492, the amount of Uranium-238 remaining in 1983 would be 99.999999 grams. It is impossible to predict risks involved with disposal over such a long period. The disposal problem becomes even more complicated because the management technique must not only provide low risk to the environment but remain economically feasible for the small waste volumes created.

URANIUM WASTE MANAGEMENT/DISPOSAL ALTERNATIVES

Conditions to be included in the consideration of disposal methods and management procedures are as follows:

1. Food and water supplies should not be contaminated by an excess or radionuclides.
2. Minimal risk to man from exposure to radiation levels will be above safe tolerance levels.
3. Access to any mineral wealth above or below ground will not be adversely affected (Simon 1980).

Numerous waste disposal alternatives are available. However, some methods do not meet the physical requirements of the waste, while others lack either technical or economical feasibility. Three alternatives that meet both the physical and feasibility requirements will be considered in this paper.

Dilution and Release

One alternative is to dilute and release the uranium concentrated salt solution back into the environment. According to the New Mexico Water Quality Control Commission Regulations (Sec. 3-103) the allowed concentration of uranium to be returned to the environment is 5 mg/l (Perkins 1980).

A concentration of 380 mg/l of uranium per liter of waste fluid would be generated from the "worst case." In order to reduce this concentration through dilution to 5 mg/l, a dilution factor of 75:1 is necessary. A usage rate of 150 gallons of water per day, per person, was assumed. This would result in a total waste volume of about 65 gallons per day, per 1,000 people generated by an ion exchange unit (Appendix III). Under these conditions, approximately 4,400 gallons of uranium-free water per day per 1,000 people would be needed for dilution purposes. The 4,400 gallons of dilution water needed for every 150,000 gallons distributed, amounts to 3 percent of the total water treated. On the state average, the waste concentration of 60 mg/l, requires a dilution factor of 12:1. One-half of one percent of the total volume of treated water will be used for dilution.

The process of dilution and release is mechanically simple. The waste can be diluted and drained into the municipal sewer system simultaneously. Any intent to release the waste into the environment must be brought to the attention of environmental authorities. The procedures must be in accordance with the Water Quality Control Commission Regulations and Hazardous Waste Management Regulations (Goad 1983). The primary concern with this alternative is that the uranium, being turned out into the environment may enter another municipality's water treatment facility downstream.

Reuse or Resale

A second alternative would be to ship liquid/slurry waste to a uranium mill where the waste could be processed along with the incoming ores (Kump 1983). Several steps would be involved in this process including collection, intermediate storage, shipment, and possible packaging of the waste.

The liquid waste is a concentrated solution of uranium salt. The uranium can be precipitated from the solution either chemically or physically (heat). Because the regenerant solution is sodium chloride, sodium hydroxide can be added to form a precipitate of sodium diurinate (Waligora 1984).

Intermediate storage will require a holding tank to store the waste until a large enough volume is collected for a shipment. This storage will require licensing and a permit from the State Hazardous Waste Management Division and approval of the Radiation Protection Bureau (Steward 1983). The alpha particle has a very low penetration factor. Since uranium is an alpha emitter, a steel or fiberglass tank probably would be the simplest solution to intermediate storage. Based on 5,000 shipments and depending on population size and use of the well, the storage period will range from a minimum of one and one-half weeks to two and one-half months. One well could serve a community with a population ranging from 1,000 to 10,000 people. Storage costs include the initial cost of tank construction and any maintenance required thereafter. The current estimated construction cost of steel tanks is about 25 cents per gallon of volume. The construction cost for a 10,000 gallon holding tank would be about $2,500.

The next stage of this alternative is shipment. Two mills are currently operating in the United States, both of which are located in northern New Mexico. The shipping distances to these sites would be fairly short and feasible for most of New Mexico, Colorado and Arizona. The risk associated with accidents during shipping and storing the waste must be considered. Licensing by the State Hazardous Waste Management Division would be required for shipment on public roads and highways (Stewart 1983). The uranium mills mentioned operate specially designed trucks which are licensed to transport this liquid/slurry.

When considering sale or reuse of the ground water waste, several possible financial arrangements might be feasible (Sloan 1983). The limiting factors, however, will be the concentration and volume of the waste. It is conceivable that the uranium mill would split the shipping costs with the municipality. It might also be possible for the municipality to receive royalties from the sale of its uranium. Even if a cost sharing or a royalty arrangement is made, the operating costs of this alternative greatly will exceed those of the dilution alternative. Therefore, it is necessary to make a decision based on the involved risk compared to the extra costs of each alternative.

Disposal through Burial

The third choice available for either liquid or a sludge waste disposal is storage or burial. Collection, intermediate storage, shipment, and a solidification and/or volume reduction process must be included before shipment to a burial site. A solidification process could be implemented for either a liquid or sludge waste. Solidification can be achieved by several methods.

In-drum solidification is one process now being used by the Department of Energy (Bucholtz 1983). The waste (either liquid or sludge) is put into drums. Cement is added and the drums are then sealed and tumbled for mixing.

Vermiculite also is used for solidification of sludge or liquid waste. Waste is added to vermiculite filled drums. The vermiculite will expand and incorporate the waste in its matrix (Bucholtz 1983).

A vacuum filtration method will solidify sludge waste as well as reduce its volume (Bucholtz 1983). The vacuum filtration system produces sludge cakes which can be packaged and shipped to a burial site.

Heat can be used to drive off the water after precipitation of an ion exchange waste. The result will be a yellow cake or powdered sodium diurinate (Waligora 1984). However, this process is very expensive and energy intensive. Because the solid waste form presents a much smaller shipping risk compared to the liquid waste, licensing would be easier to obtain. It is difficult to assess costs because the solidification processes are relatively new.

These high cost facilities are located long distances from most burial sites. Several southwestern and midwestern state legislatures (including New Mexico's) are currently considering a bill to form a compact among themselves for a radioactive waste burial site. If the bill were to pass, each state would take its turn providing waste burial facilities for a determined period of time. Such a site should greatly reduce shipping costs involved in this alternative. Because of the shipping distances and management procedures, storage or burial of the waste would likely be the most expensive disposal alternative.

CONCLUSION

Uranium waste presents unique disposal problems because of its longevity. Economic factors also complicate the choice of a disposal alternative. For a large percentage of municipalities that have uranium in their drinking water supplies, the uranium concentration is relatively low. In these cases, it may not be economical to dispose of the waste by shipment to mills or burial facilities.

In other cases, however, the uranium concentration may be quite high, or several ground water systems in one municipality or one area may contain uranium concentrations. In these cases where a large volume of waste feasibly could be produced, it may be more advantageous to consider shipping the waste to a mill or a disposal site. Large volumes of waste also would cause the alternative of dilution and release to be less environmentally desirable.

Uranium waste produced by upgrading drinking water must be disposed of in some manner. The manner will be unique to each community based on local concentration, the size and location of the community, and local economic factors.

Three alternatives have been presented in this report. One may be more acceptable than another to various communities. Other alternatives may become available as research and development continues. Whichever means of disposal is chosen, it must not only be economical, but more importantly, it must be environmentally acceptable.

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APPENDIX I

Uranium Levels of Selected New Mexico Water Systems

System	Source	Uranium Level (pCi/l)
Dona Ana	Composite	11.2 + 0.8
Espanola	Bond Well	16.2
	El Llano Well	18.9
Lordsburg	Well #1	24.5 + 2.5
	Well #2	28.0 + 2.8
NMSU	Well #8	110 + 6*
	Well #9	23 + 2
Santa Fe	Buckman Composite	12.0 + 1.0
Tucumcari	Well #1	12.6 + 1.3
	Well #4	10.5 + 0.7
	Well #6	10.8
	Well #12	22 + 1
	Well #13	16.9 + 0.8
	Well #17	19.8 + 1.0
	Well #18	15.4 + 1.5
	Well #19	15.4 + 1.5
	Well #20	20 + 1

*NOTE: Tests run in 1979-1980 by the Environmental Improvement Division values are probably a composite of four quarterly samples. (EID, Santa Fe, NM, Steve Pierce, written correspondence, 1983)

Average Uranium Level = 17.32 + 1.5 pCi/l
Worst Case (NMSU #8) = 110 + 6 pCi/l

Convert pCi/l to mg/l: 666.7 pCi/l = 1 mg

Average: 17.32 pCi/l x 1 mg/666.7 pCi = 0.02598 mg/l
= 25.98 μg/l use 26 μg/l

Worst case: 110 pCi/l x 1 mg/666.7 pCi = 0.16499 mg/l
= 164.99 μg/l use 165 μg/l

APPENDIX II

Waste Characteristics and Concentrations

Ion Exchange Removal Method - Uranium Concentrated Liquid Waste

A. Assumption case 1:
   1. 1 liter of resin
   2. 3.5 kliters of raw water are treated before regeneration
   3. Removal efficiency is 98%
   4. Volume of regenerant fluid is 1.5 liters

B. Assumption case 2:
   1. 1 liter of resin
   2. 5.0 kliters of raw water are treated before regeneration
   3. Removal efficiency is 97%
   4. Volume of regenerant fluid is 1.5 liters

*NOTE: Advantage of case 1 assumption; resin will remain effective for a longer period of time.

C. Table I. Waste Concentrations Resulting from Ion Exchange

Bed Vol.	% Removed	Reg. Vol.	U Conc(i)	U conc(f)
Average				
1. 3.5 kl	98	0.0015 kl	26.0 μg/l	60 mg/l
2. 5.0 kl	97	0.0015 kl	26.0 μg/l	84 mg/l
Worst Case				
1. 3.5 kl	98	0.0015 kl	165.0 μg/l	380 mg/l
2. 5.0 kl	97	0.0015 kl	165.0 μg/l	535 mg/l

*Only values obtained using case 1 assumptions will be used for further calculations.

Chemical Coagulation Removal Method - Uranium Concentrated Sludge Waste

A. Assumptions:
   1. Coagulant is Fe Cl, dosage is 20 to 200 mg/l
   2. Percent of Uranium removed is 99%
   3. Solids concentration (floc) before filtration is 3%
   4. Final sludge waste (after filtration) is 50% solids

B. Table II. Waste Concentrations Resulting from Coagulation

	Raw conc.	U removed	Wt of sludge	U conc.
Avg.	26.0 g/l	25.74 μg/l	0.060 kg/l	0.429 mg/l
Worst	165.0 g/l	163.35 μg/l	0.060 kg/l	2.720 mg/l

Example calculation:

Raw water concentration x % U removed = mass of Uranium
26.0 g/l x 99% = 25.74 μg/l

Vol. of water x % solids concentration = Wt of solids
(after initial coagulant dosage)
1 kg/l x 3% = 0.03 kg solids/liter water

Raw water conc. = 165 g/l
165 g/l x 0.99 = 163.35 μg/l removed
0.06 kg sludge will contain 163.35 g of U

% solids after coagulation/% solids after filtration = weight of final sludge per unit of water
0.03/0.50 = 0.60 kg sludge/liter water

U removed/wt of sludge = U concentration in sludge
25.74 g/l/0.06 kg/l = 0.429 mg U/kg sludge

APPENDIX III

Daily Waste Volumes Generated

Ion Exchange Method

A. Assumptions:
   1. usage rate = 150 gpcd x 1,000 persons - 150,000 gal/day
   2. for every 3,500 1 of water used, 1.5 1 of waste is generated (see Appendix II)
   3. conversion: 1 1/s = 0.2642 gal/s

Daily volume of waste produced per 1,000 people:

150,000 gpd x 1.51/3,500 1 = 64.3 gpd/1,000 people

Chemical Coagulation

A. Assumptions are the same as those use above.
B. densities: water = 1,000 kg/1
   1. sludge solids = 1,060 kg/1 (sludge is 50% water and 50% solids)
   2. final sludge = 1 (.5) + 1.06 (.5) = 1,030 kg/1
C. from appendix II--0.06 kg of sludge is produced per liter of water

Daily volume per 1,000 people:

volume = mass/density

0.06 kg/1,030 kg/m^3 = 5.825 x 10^{-5} cubic meters

convert to English units:

5.825 x 10^{-5} m^3/0.02832 ft^3/m^3 = 0.0020 ft^3 sludge/1

(0.0020 ft^3/1) / (0.2642 1/gal) = 0.0079 ft^3 sludge/gallon

daily volume:

150,000 gal/day x 0.0070 ft^3/gal = 1,168 ft^3 sludge/day

(1,168 ft^3/day) / (27 ft^3/yd^3) = 43.25 yd^3

Table III. Waste Volumes

U removal method	Daily volume per 1,000 people
Ion exchange	64.3 gallons
Coagulation	1,168 ft^3 = 43 yd^3

TOXICITY OF NEW MEXICO BRACKISH GROUNDWATERS TO FINGERLING CHANNEL CATFISH

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SUMMARY

A two phase experiment was conducted testing the tolerance of channel catfish to high-sulfate brackish waters. Fish were exposed to concentrations of 8,000; 10,000; 11,000; 12,000; 13,000 and 14,000 mg/l total dissolved solids (TDS) formulated from city and brackish well water available at the Roswell Test Facility. The brackish well water contains about 10.5 percent sulfate ion in solution. Sixty-two percent of the fish at 14,000 mg/l TDS died within 12 days while 17 percent died at 13,000 mg/l in the same time period. Only one other death was recorded at 8,000 mg/l during the experiment. It appears that no significant difference occurs between the toxicity of this brackish well water to channel catfish and the toxicity of waters formulated using sodium chloride or diluted sea water.

INTRODUCTION

Channel catfish (*Ictalurus punctatus*) production in the south central United States increased 43 percent from August 1982 to August 1983 (Anon. 1983). This increase follows a trend of expanding United States aquacultural production predicted to rise in value from $89 million in 1979 to $485 million in 1989 (International Resource Development, Inc., 1979). To keep domestic supply equal to demand, aquacultural production facilities must be increased. One method of doing this is to spread the catfish farming industry out from its focal point in the Mississippi Delta.

If commercial aquaculture in New Mexico is to contribute to this growth, two problems must be overcome. Because of New Mexico's arid climate and relatively short growing season, traditional warm water pond culture with fresh water (2,000 mg/l TDS) is not feasible, indicating a need for alternate production methods such as closed, recirculating systems. Also, most freshwater sources suitable for aquaculture are allocated to more conventional agricultural uses. This water could be reallocated. However, existing users may be reluctant to convert to aquaculture because of lack of experience, high initial investments for conversion, and lack of information relating to the best waters and production systems for New Mexico. An unused and possibly cheaper source of water for potential aquaculturists is the abundant brackish ground water (2,000 to 30,000 mg/l TDS) found throughout the state. However, New Mexico's ground waters contain high concentrations of sulfate ions (O'Connor 1980), which may be toxic to channel catfish (Lewis 1971) or other aquatic species.

Raising channel catfish in brackish waters could improve production efficiency. Catfish culture in brackish water 1,500 to 8,000 mg/l TDS has proved beneficial in reducing off-flavors in catfish flesh by controlling blue-green algae in warm water ponds and in controlling outbreaks of parasites, such as Ichthiopthirius multifilis, in high-density systems (Avault 1982). Adding sodium chloride to culture water alleviates stress from nitrite poisoning, the source of brown blood disease in high-density channel catfish production facilities (Tomasso et al. 1979). Fish may grow even better in more brackish environments because they expend less energy to maintain osmotic equilibrium (Canagaratnam 1959).

Results reported here are preliminary trials to determine short-term mortality of channel catfish at high concentrations of TDS and uppermost salinity tolerance without mortality. Further trials will determine long-term growth and survival at sublethal salinity levels established here.

METHODS

Fish were obtained from the Uvalde National Fish Hatchery, Uvalde, Texas. One month prior to this study, these fish were treated with 25 mg/l formalin every other day for five days to remove external parasites.

No death occurred after the formalin treatment and all fish appeared healthy. Microscopic checks of gill tissue and gross external examinations indicated no parasite or disease problems. Twenty fish were held in three tanks containing Roswell city water for three to four weeks prior to the tests. The purpose of this control group was to determine toxic effects of local tap water with no subsequent mortality.

The experiment was conducted in two phases, the first to estimate upper tolerance of channel catfish to brackish water and the second to estimate sublethal salinities.

Phase I

Twelve 60-l aquariums, each with 24-l of water at four different TDS concentrations (3 replicates at each level), were prepared for a 14-day bioassay at the Roswell Test Facility east of Roswell, New Mexico. Based on an estimated TDS of 14,000 mg/l for the brackish well water and 1,000 mg/l for the city water (Table 1), appropriate ratios of well water to city water were calculated to create approximate concentrations of 8,000; 10,000; 12,000 and 14,000 mg/l TDS (Table 2). Water was mixed into each aquarium and allowed to stand aerated for 24 hours. Water temperature was maintained at ambient room temperature and remained near 27^{o}C throughout the experiment.

Ten channel catfish (mean total length 62 mm) were placed in each aquarium after 24 hours. Fish were not fed for the 14-day duration of the experiment and tanks were checked for deaths twice daily for the first 3 days and daily thereafter. Death, assumed when fish showed no opercular movement, was ascribed strictly to experimental treatments because no signs of parasites or diseases were observed during the experiment.

Phase II

In phase II, tests were conducted for 12 days in waters mixed to produce estimated concentratios of 11,000; 12,000; 13,000 and 14,000 mg/l TDS. Actual salinities and calculated salinities for the 12 tanks are contrasted in Table 2. The water in tanks 14A through 14C in Phase II was from the same batch of water that was tested as Deep #1 and Deep #2 except that it had stood for 24 hours. The difference in TDS

Table 1. Concentrations of various ions and total dissolved solids in mg/l for Roswell city water and brackish well at the Roswell Test Facility.

Constituent	City Water[a]	Deep Well (Brackish) Water		
		12/20/83[a,c]	Deep Sample #1[b,c]	Deep Sample #2[b,c]
Sodium (Na)	67	4,449	4,420	4,570
Potassium (K)	1	23	27.3	27.1
Calcium (Ca)	184	525	541.1	532.4
Magnesium (Mg)	51	156	148.5	148.2
Chloride (Cl)	97	6,948	7,367	6,974
Sulfate (SO_4)	451	1,488	1,350	1,350
Bicarbonate (HCO_3)	238	190	190.4	191.6
Dissolved Solids (Evap)	1,055	14,240	13,648	14,036
Total Hardness ($CaCO_3$)	670	1,950	-	-
Conductivity (25°C)	1,470 μmhos	22,100 μmhos	-	-

[a]Source: S. Isaacs, Chemist, Roswell Test Facility; tested December 20, 1983.

[b]Source: A. L. Bristol, Dept. Crop and Soil Sciences, New Mexico State University, Las Cruces, N.M.; tested December 22, 1983.

[c]Waters are from the same brackish well, sampled 10 days apart.

Table 2. Actual versus calculated total dissolved solids concentrations for test waters in phase II and conductivity of test waters in phase I.

Tank	TDSc	Conductivity[a] (mhos) (phase I)	TDS (mg/l)[b] (phase II)
8 A	(8,000 mg/l)	11,200	-
8 B		11,100	-
8 C		11,200	-
10 A	(10,000 mg/l)	14,100	-
B		13,800	-
C		14,000	-
11 A	(11,000 mg/l)	-	11,036
B		-	10,492
C		-	10,940
12 A	(12,000 mg/l)	16,100	12,016
B		15,800	11,592
C		16,500	11,732
13 A	(13,000 mg/l)	-	12,456
B		-	12,700
C		-	12,512
14 A	(14,000 mg/l)	17,900	13,400
B		18,000	12,960
C		18,600	13,056

[a]Conductivity taken with YSI conductivity meter; results are unsubstantiated.

[b]Samples taken for 14 A, B and C and Deep Sample #1 and #2 are from the same batch of water. Source: A. L. Bristol, Dept. Crop and Soil Sciences, NMSU.

[c]Calculated TDS levels based on brackish well water at 14,000 mg/l and city water at 1000 mg/l TDS.

concentration may be due to precipitation of some of the constituents. This may be the reason all measured concentrations were slightly below the calculated concentrations.

RESULTS AND DISCUSSION

Phase I

No deaths occurred in any tank during the first 96 hours. On the fifth day, fish started dying in tanks at 14,000 mg/l and deaths occurred sporadically over the remainder of the experiment (figure 1 and 2). After 14 days, a total of 18 fish had died in water at 14,000 mg/l TDS. One other fish died during the experiment, on the fifth day, in a tank at 8,000 mg/l. Because this was the only fish from either experiment to die in water with less than 12,000 mg/l TDS, it is likely that it died from causes unrelated to toxicity, such as malnutrition or handling stresses.

Phase II

No deaths occurred for the first 96 hours and none occurred in tanks at 11,000 or 12,000 mg/l TDS over the course of the experiment. Fish began dying in waters with 14,000 mg/l TDS on day 5, and 20 of 30 were dead by day 12. In one tank with 13,000 mg/l TDS 5 fish died, starting on day 8 (figure 1).

A chi-square test comparing 12-day mortalities between Phases I and II at 14,000 mg/l TDS showed no significant difference at the 5 percent level. The waters were taken from the same well about two months apart and TDS levels should not have varied greatly over that time.

The deaths occurring in one of three replicates at 13,000 mg/l TDS may have been due to the slightly higher TDS concentration in that tank (Table 2). This finding indicates that water about 13,000 mg/l TDS may be the sublethal threshold.

The results of this experiment show that at 27^{o}C fingerling channel catfish cannot survive long-term exposure to high-sulfate, brackish ground waters above 14,000 mg/l TDS and that the sublethal, short-term tolerance is at or slightly higher than 13,000 mg/l TDS. Internal osmotic pressure of body fluids is maintained in fish at about 10,000 mg/l

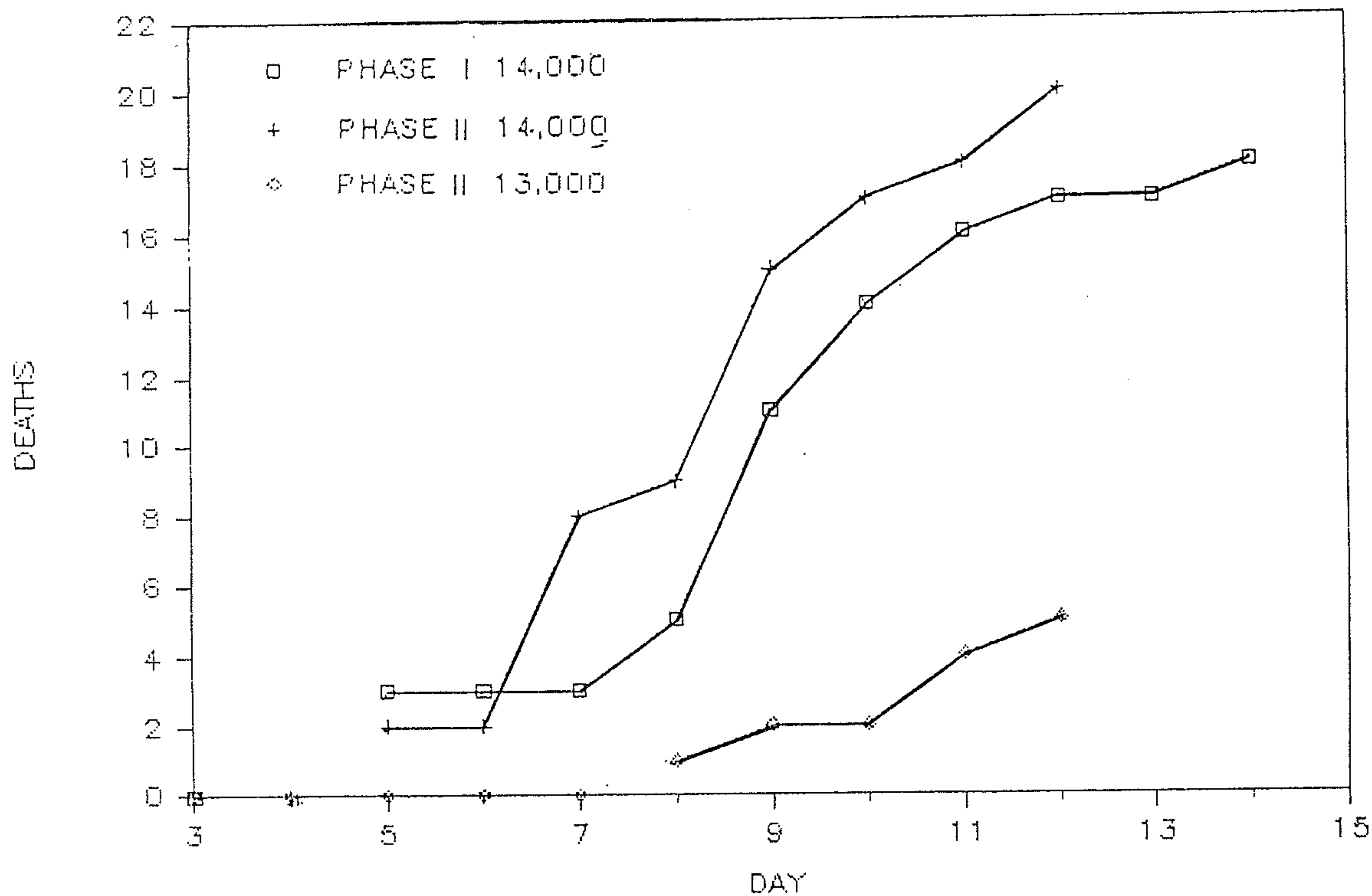

Figure 1. Cumulative deaths of channel catfish fingerlings (phases I and II) in waters at concentrations of 13,000 and 14,000 mg/l total dissolved solids.

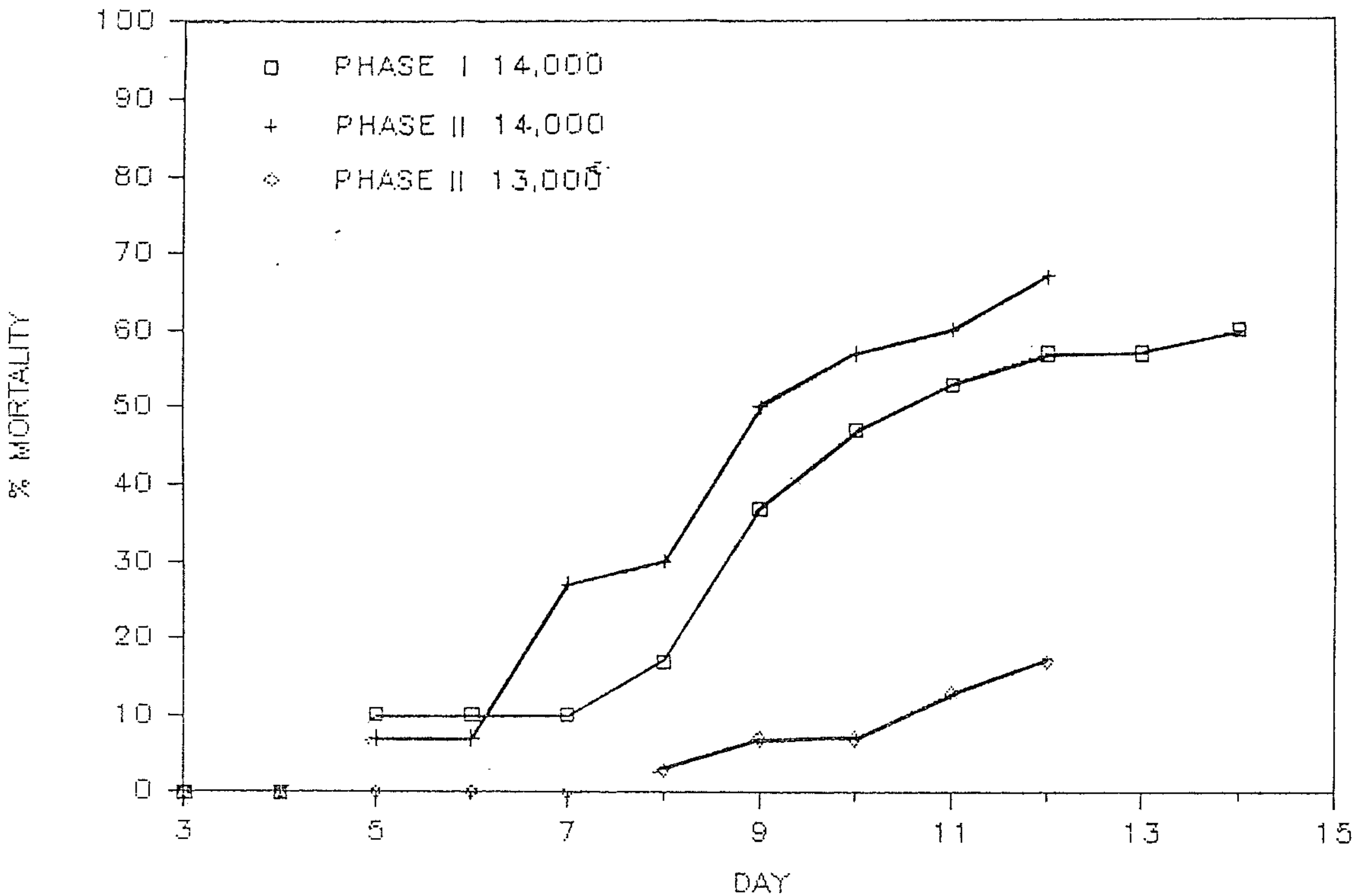

Figure 2. Cumulative percent mortality of channel catfish fingerlings (phases I and II) in waters at concentrations of 13,000 and 14,000 mg/l total dissolved solids.

salinity ($\pm$ 2,000) by regulation of plasma ions (Brett 1979). Growth, a function of energy storage, drops off rapidly after the isotonic point in stenohaline freshwater fish. This suggests that a great deal of energy is put into maintenance of internal osmotic pressure during exposure to high salinities. It would appear that stress caused by excess energy demand and osmoregulatory problems were the cause of death of fish in waters with TDS concentrations above 12,000 mg/l.

Channel catfish have survived TDS concentrations up to 15,000 mg/l for two to three days (Stickney and Simco 1971) in brackish waters formulated using diluted sea water or sodium chloride, however, long term survival limits are closer to 12,000 mg/l (Allen and Avault 1971). As channel catfish get larger, their tolerance to brackish water increases (Allen and Avault 1969) although the difference between fingerlings and one-year-old fish is only 1,000 to 2,000 mg/l TDS. Allen and Avault (1971) found that some fingerling channel catfish (30-45 grams) could survive 14,000 mg/l TDS for up to eight days but most fingerlings died between days four and six. In another experiment (Stickney and Simco 1971), some fingerlings (50-70 mm TDS, 2-6 g) survived for 96 hours in water with salinities up to 15,000 mg/l, but most tests at 14,000 to 14,500 mg/l TDS resulted in fingerlings dying within the first 40 hours.

Allen and Avault (1969) reported that channel catfish fry survived poorly at 10,000 mg/l TDS, fingerlings died within 100 days at 12,000 mg/l, and six-month-old fish could survive and grow indefinitely at 12,000 mg/l.

Lewis (1971) found higher mortality of channel catfish in waters containing 1,700 mg/l sodium sulfate than in waters containing 1,700 mg/l sodium chloride, indicating a toxic effect of the sulfate ion. Trama (1954) found sodium sulfate to be more toxic than sodium chloride to bluegills (*Lepomis machrochirus*), although a saturated solution of calcium sulfate (2,980 mg/l) showed no significant mortality.

My experiments were not designed to test the relative toxicity of sulfate ions and other ions, but mortality and lethal limits (12,000 to 14,000 mg/l TDS) for brackish ground waters in New Mexico are similar to those expressed elsewhere for channel catfish exposed to waters formulated using sodium chloride or diluted sea water. The results of this experiment have been used to select an upper limit for subsequent evaluation of long-term effects of New Mexico brackish ground waters on channel catfish.

This subsequent research has been designed to determine growth and survival of channel cafish in high-sulfate, brackish ground water from 1,000 mg/l to 11,000 mg/l TDS over a six-month period, about the time required to raise 150 mm channel catfish to market size (450-500 g). The results should show any difference between growth and survival of channel catfish cultured in New Mexico's ground water and channel catfish cultured in brackish waters formulated using sodium chloride or dilute sea water.

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