PROCEEDINGS OF THE

SEVENTH ANNUAL NEW MEXICO WATER CONFERENCE

Water in 50 Years of Statehood With a Look to the Future

October 31 and November 1, 1962

- Agricultural
- Municipal
- Industrial
- Recreational Uses

New Mexico State University
University Park, New Mexico

NEW MEXICO WATER CONFERENCE

Sponsored by

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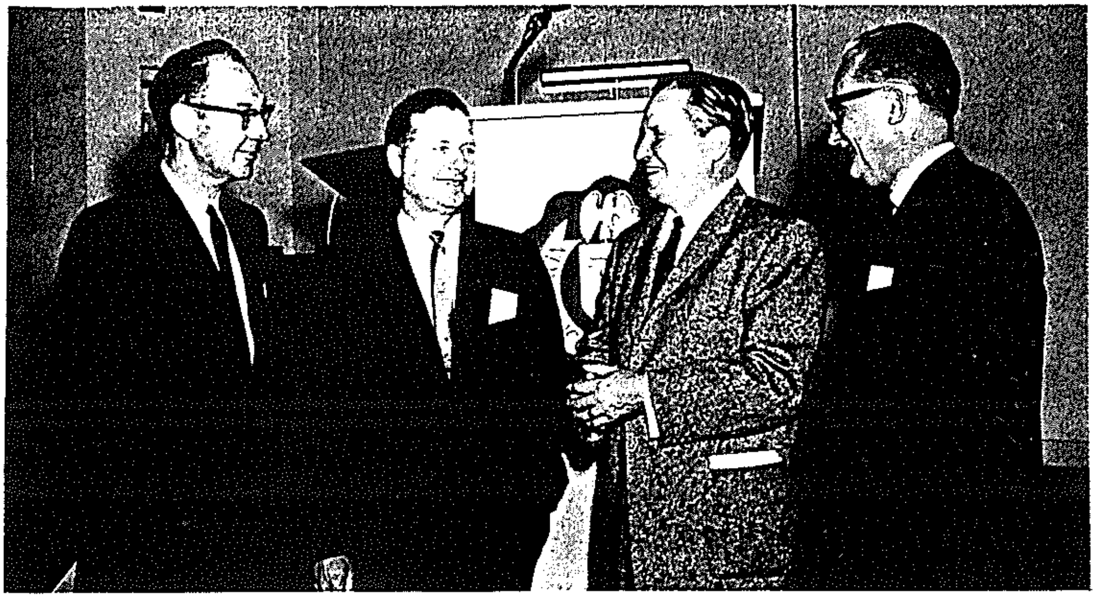


Discussing the important problems of the day are Dr. Philip J. Leyendecker, Dean and Director of Agriculture, New Mexico State University, Left; Rogers Aston, South Springs Foundation; Floyd E. Dominy, Commissioner of Reclamation, U.S.D.I.; and President Roger B. Corbett, New Mexico State University. Mr. Dominy was the keynote speaker for the Annual Water Conference.

E. O. Moore, Farmer and President of the New Mexico Association of Soil Conservation Districts, Left; Dr. H. R. Stucky, Head, Department of Agricultural Economics and Agricultural Business, New Mexico State University and Chairman of the Water Conference Committee; Dr. George A. Pavelis, Leader, Water Use Investigations, U.S.D.A.

FOREWORD

Water in 50 Years of Statehood, With a Look to the Future--for Agricultural, Municipal, Industrial, and Recreational Uses, was the subject of the Seventh Annual New Mexico Water Conference.

The papers presented in the Conference helped to clarify many of the present and emerging problems in connection with the industrial development of the state and our rapidly growing population. The paper presented by Floyd E. Dominy, Commissioner, U. S. Bureau of Reclamation is a comprehensive review of the subject of Recreation in Multiple Use Projects. Other papers on Irrigation Water Use, Water Pollution, Municipal Uses, and Physical and Economic Trends in Beneficial Use of Water rounded out the program. Discussion from the floor brought out many important points for clarification.

The conferences are open to every interested person and are designed to permit free and constructive consideration on how our New Mexico water resources can be conserved and developed. The auditorium in the new Agriculture Building on New Mexico State University campus was the site for the Conference.

Senator Clinton P. Anderson's address to the Centennial banquet in commemoration of the 100th Anniversary of the founding of the Land Grant Colleges and the U. S. Department of Agriculture entitled, The Technological Revolution in Agriculture in the United States Brought About Largely By Land Grant Colleges, is included in this report (see pages 106-116). The banquet was held prior to the Water Conference, but because the address was mostly on water, the paper is presented here.

The Water Conferences are sponsored by New Mexico State University through the Agricultural Experiment Station, Agricultural Extension Service, College of Agriculture, College of Engineering, and Cooperative Agencies of USDA-Agricultural Research Service, and Soil Conservation Service, with the cooperation of the Water Conference Advisory Committee and the New Mexico Department of Development.

The papers in this publication appear in the order they were presented in the Conference. The program which follows this statement will serve as an index to the papers.

H. R. Stucky

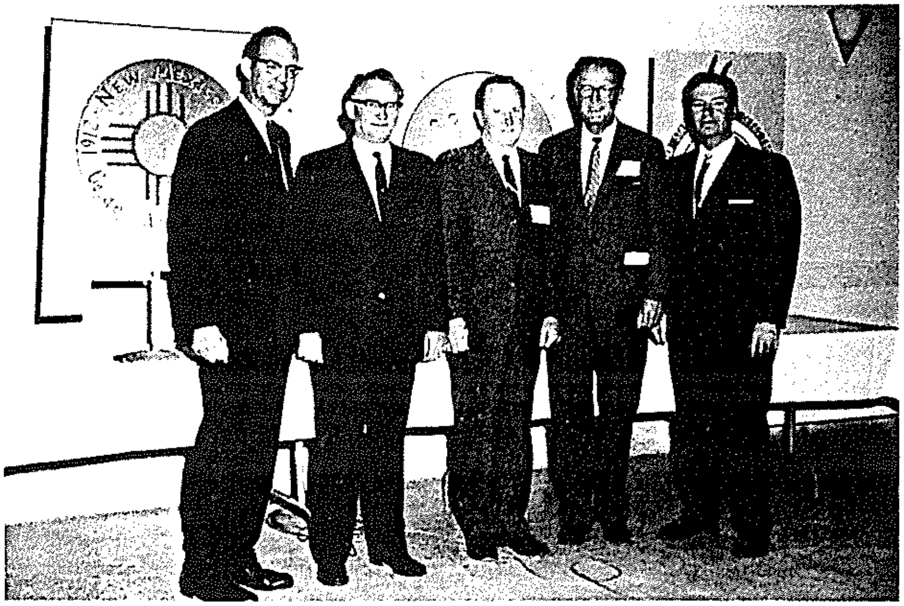
H. R. Stucky, Professor and Head
Department of Agricultural Economics
and Agricultural Business
and
General Chairman of New Mexico Water
Conference

NEW MEXICO WATER CONFERENCE

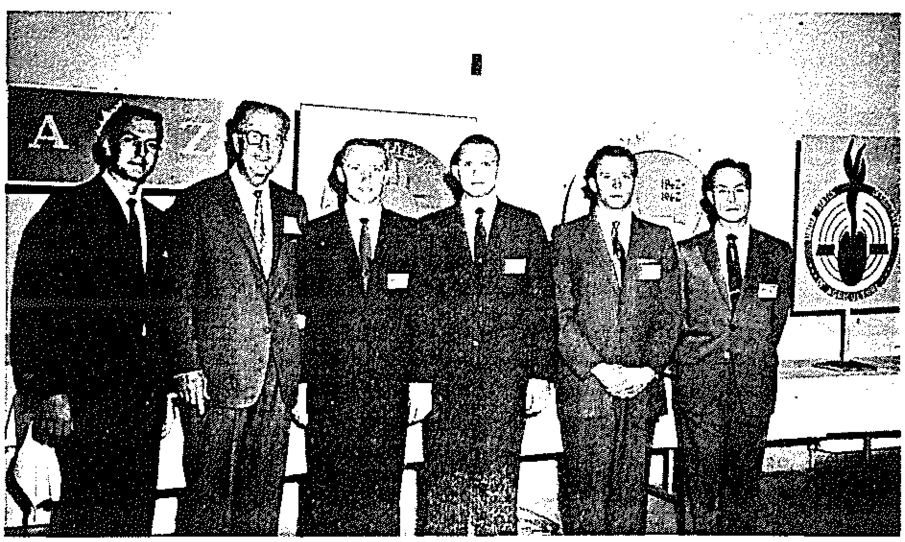
New Mexico State University
October 31 -
November 1, 1962

THEME OF CONFERENCE - "WATER IN 50 YEARS OF STATEHOOD--
WITH A LOOK TO THE FUTURE"

*This paper was presented by Senator Clinton P. Anderson at the Centennial Dinner in connection with the 100th anniversary of United States Agriculture and Land Grant Colleges on Friday, October 26, 1962, just four days prior to the Seventh Annual New Mexico Water Conference. Since the paper included so much in connection with water, it was felt that it should appropriately be included along with the report of the Water Conference so that it might be available to many of those who attended the Centennial Dinner and the Water Conference.



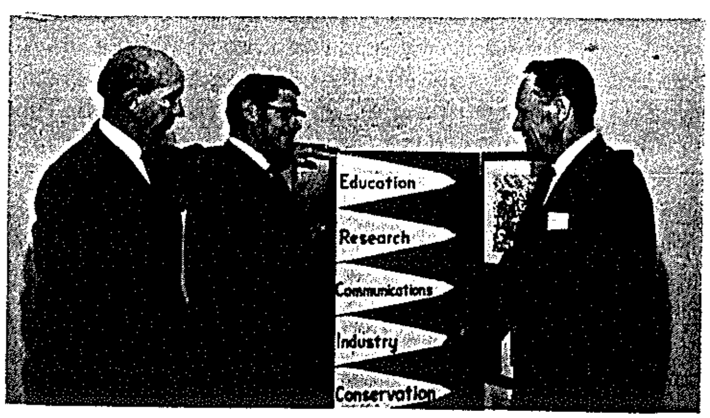
Senator Clinton P. Anderson was the speaker for the Centennial Banquet commemorating the 100th Anniversary of the 1862 Act establishing the Land Grant Colleges and the Department of Agriculture. With Senator Anderson are Dr. Philip J. Leyendecker, Dean and Director of Agriculture, New Mexico State University, Left; Dr. Roger B. Corbett, President, New Mexico State University; Fred Kennedy, Regional Forester, U. S. Forest Service; Senator Anderson; and C. A. Tidwell, State Conservationist, Soil Conservation Service, U.S.D.A. Senator Anderson's talk was largely on water problems and needs and is included in this report due to its importance and interest to New Mexico.



Senator Anderson and officers of the New Mexico Chapter of Alpha Zeta at the time of the initiation of Senator Anderson as centennial honorary member for New Mexico. In the picture are Gary Carruthers, Chancellor of the New Mexico State University Chapter of Alpha Zeta, Left; Senator Anderson; Kenneth Sanders; James Widner; Raymond Ditterline; and Andrew Cunningham. Alpha Zeta is a National Agricultural Honorary Fraternity.

Dr. Lloyd E. Meyers, Director, U. S. Water Conservation Laboratory, Tempe, Arizona, Left; W. H. Gary, Farmer and Member of the New Mexico Interstate Streams Commission; and Frank Irby, Chief, Water Rights Division, State Engineers Office. Dr. Meyers and Mr. Irby were speakers on the program and Mr. Gary served as Chairman.

Dr. Warren Viessman, Jr., Civil Engineer, New Mexico State University, Left; Ralph Bonnell, Rancher and Farmer, Upper Hondo Conservation District; and Dr. Narendra N. Gunaji, Civil Engineer, New Mexico State University discuss the importance of water to agriculture and to the industrial and municipal uses in New Mexico. Dr. Viessman and Dr. Gunaji were on the Conference program.



James F. Cole, Assistant to President Corbett, New Mexico State University, Left; Dr. Ross Leamer, Soil Scientist, U.S.D.A.; and Fred Kennedy discussing five important points in research and education required to advance the water programs in New Mexico.

RECREATION USE OF WATER PROJECTS

Floyd E. Dominy[1/]

I am honored to have been asked to take part in your 7th Annual Water Conference, the theme of which is, "Water in 50 Years of Statehood--With A Look to the Future."

In looking back I note with some pride that the Bureau has played an important role in water developments in the State. And also that its activities in this area predate New Mexico's statehood by a decade.

In looking forward we should be encouraged and challenged by the new era of economic opportunities that will unfold with the new water resource development now planned and under construction.

The first Bureau of Reclamation activity in New Mexico took place on the Carlsbad and Rio Grande Projects, shortly after Reclamation came into being. The economic welfare of sizable areas of the State is supported as a result of construction or rehabilitation under Reclamation Law. I will briefly describe the old projects.

The Carlsbad Project on the Pecos River serves 25,000 acres with water regulation supplied by Avalon, McMillan, and Alamogordo reservoirs. The Fort Sumner Project, also on the Pecos, serves 6,500 acres by direct diversion from the stream.

The Rio Grande Project is a multi-purpose development that provides irrigation water for lands in two Nations, and two states; provides flood control, power, and recreational opportunities. Total irrigable area served in the Rio Grande project in New Mexico and Texas is 178,196 acres. About 64 percent, or 102,082 acres, is in New Mexico.

The next project upstream from the Rio Grande Project is the Middle Rio Grande. While irrigation in the Middle Valley had been practiced for many years through private diversions and works constructed by the Middle Rio Grande Conservancy District, continued river channel deterioration and the need for water salvage and conservation prompted Federal assistance beginning in 1951. This project includes about 121,000 acres of water right land including land of 6 Indian Pueblos. During the 10-year period, 1951 to 1961, an estimated total of 556,700 acre feet of water was salvaged by channelization and drainage works.

1/ United States Commissioner of Reclamation, U. S. Bureau of Reclamation, Washington, D. C.

The Bureau has constructed two projects on the Canadian River in New Mexico. The largest is the Tucumcari Project, and facilities of this project provide water for 41,400 irrigable acres. Water is supplied from Conchas Reservoir which was constructed by the Corps of Engineers.

Upstream on the Canadian River in the vicinity of Maxwell, New Mexico, is the Vermejo Project. Construction on this project involved complete rehabilitation of the old Maxwell Irrigation District system. This work was substantially completed by 1955 and the facilities serve about 7,400 acres.

The Pine River Project, located in New Mexico and Colorado, lies in the San Juan River Basin, with about 1,000 acres located in New Mexico.

These projects developed under the Reclamation program, involving approximately 305,000 acres of land in New Mexico, produce crops ranging in value from $35 to $40 million annually. The total construction cost of these seven projects amounts to about $84 million. The cumulative gross crop value to date is 14 times as much as the total construction cost. The average annual gross crop production value per irrigable acre ranges from about $50 to a high of $275 per acre.

On the two oldest projects--the Carlsbad and the Rio Grande--which are nearly as old as the Reclamation program itself, the cumulative gross crop value over the years amounts to approximately 39 times their construction cost.

To further illustrate the broad impacts of Reclamation projects in the State, a recent study shows (1) about 30 percent of the land irrigated in the State is in Reclamation projects; (2) there are 2,500 full-time Reclamation farms and 6,700 part-time farms--this is about 35 percent of the State's irrigated farms; (3) the sustained on-farm investment on Reclamation farms is estimated at $120 million; (4) through the export sale of products grown on Reclamation farms, the community and State business activity is stimulated and sustained in excess of $105 million annually; (5) Reclamation projects provide nearly $50 million in personal income, which supports 48,000 people; and (6) the total investment in farms and facilities provides a tax base which contributes about $700,000 in State and local taxes, and supports directly and indirectly a total tax burden of $11.2 million per year.

The economic impact of agricultural production on a local area is illustrated by a study the Bureau made in 1960 on the Rio Grande Project. The study involved measuring the business activity generated from harvesting, ginning, processing, handling, and marketing cotton.

The study showed that each bale of cotton produced, the harvesting, ginning, compressing, storing, and hauling the baled cotton created 8.6 hours of labor valued at $10.95. Interest on capital and returns to management for these operations amounted to $6.22 and $2.53 per bale, respectively. In processing cottonseed, 3.5 hours of labor valued at $5.42 per ton of cottonseed milled were required. The return to capital was $1.92 per ton, and to management $8.41.

Multiply these dollar values by the total cotton produced on Reclamation projects in the State in 1961, and we find that the total economic impact from the items above amounts to more than $2-3/4 million. Of course, the effects just described are only a fraction of the total impact the cotton crop has on the local economy. The gross income received by the farmers from cotton sales in 1961 was nearly $23 million.

Other Reclamation investments are in the offing for New Mexico. The Navajo Dam of the Colorado River Storage Project was dedicated in September and there is now a sizable pool of water behind it. Nearing completion is the Hammond Project, a participating project of the Colorado River Storage Project, located in the northwestern part of New Mexico. The Hammond Project facilities will divert and pump water from the San Juan River for 3,900 acres.

Future water developments include the San Juan-Chama and Navajo Indian Projects, which were recently authorized by Congress. The Animas-La Plata Project, located north of the Farmington area, is a potential development on which feasibility investigations are in progress. This project would serve and provide full irrigation service to about 14,700 acres and supplemental service to 5,500 acres in both Colorado and New Mexico.

The plan for initial stage development on the San Juan-Chama Project contemplates an average annual diversion of about 110,000 acre feet from the San Juan River to the Chama River for utilization in the Rio Grande Basin in New Mexico. The imported waters would be used for an additional municipal and industrial water supply (57,500 acre feet) for the city of Albuquerque and to provide a supplemental water supply (29,900 acre feet) to 39,300 acres of land in the Cerro, Taos, Llano, and Pojoaque tributary irrigation units in the Rio Grande Basin in New Mexico, and to provide supplemental water (22,600 acre feet) for lands in the Middle Rio Grande Conservancy District.

The plan of development for the San Juan-Chama Project involves three major elements comprising the diversion facilities (diversion dams and conduits), regulation facilities (Heron #4 Dam and Reservoir and enlargement of outlet works for the existing El Vado Dam), and water-use facilities (principally for the tributary irrigation units). The Navajo Indian Irrigation Project will also be constructed by the Bureau of Reclamation. This project, as proposed, involves diverting San Juan River water from the Navajo Dam and Reservoir to some 110,000 acres of irrigable land.

Estimated cost of work under construction and authorized, including the Navajo Dam and Reservoir, the Navajo Indian Project, the Hammond Project, and the initial stage of the San Juan-Chama Project, aggregates about $265 million.

These new Reclamation projects will provide water for about 1,300 new commercial farms containing 128,000 acres of new farm land and a supplemental water supply for an additional 127,000 acres now irrigated. They are expected to produce $6.8 million per year in net farm income, $1.3 million in farm wages, and $17.8 million in income for workers in agriculture-supported trades and industries.

The new municipal and industrial water supplies for the Albuquerque area from the San Juan-Chama development are expected to support industries that will add an estimated $181 million in personal income to the State each year.

I have given you this inventory of Reclamation projects and plans in New Mexico to give you some idea of the magnitude of our operations and the importance of local, State, and Federal cooperation and coordination if we are all to get the maximum benefits from this investment.

In Reclamation's infancy, projects were single-purpose in concept; and irrigation was the only recognized paying water entity. A gradual shift to the multiple-purpose concept has come about over the years. Legislation was passed in 1906 permitting construction of power generating facilities and the sale of power to finance associated irrigation construction.

With the passage of the Reclamation Project Act of 1939 and subsequent legislation, the multiple-purpose concept has been more fully recognized, and more and more functions are being added to water resource developments.

Today, multi-purpose projects may include a combination of the following functions: irrigation, power, municipal and domestic water, industrial water, recreation, fish and wildlife, pollution control, flood control, sediment control, and navigation.

On many of the older projects, multi-purpose benefits have been occurring regularly since the projects were built, but recognition was not made of these benefits in the project authorization and no costs have been allocated to them. Among these, of course, is recreation. Regardless of whether recreation is a planned benefit, every new reservoir automatically creates a new swimming hole and people just naturally take advantage of it. Recreation has become a big business in the United States.

The National Park Service, for example, contemplates an increase nationally from 1960's 79 million park visitors to about 400 million by the year 2000. Looking ahead to 1980 and considering the increase projected by the National Park Service, it seems reasonable to expect that outdoor recreation, in terms of visitors to public recreation areas, may increase three or four times.

The 1960 National Survey of Fishing and Hunting by the United States Fish and Wildlife Service measured the hunting and fishing potential and the amount of money which sportsmen spend for these activities. The report shows that 30 million Americans over the age of 12 either fished or hunted in 1960. It also shows that an estimated $4 billion was spent by fishermen and hunters in pursuit of their sports.

Secretary Udall has only recently established a new Bureau of Outdoor Recreation to coordinate and aid in the planning and use of outdoor recreation facilities. We welcome their advice and assistance in developing such recreation uses as we may be authorized by law to incorporate in Reclamation projects.

Many people in New Mexico, other than the farmer-water users, know Reclamation projects best because of the opportunities that the project reservoirs have created for a variety of outdoor recreational activities. The demand for all types of recreation has soared in recent years. The demand for fishing, boating, swimming, waterskiing, and camping activities has greatly increased within the last decade.

Reservoirs on Reclamation projects generally offer facilities for several, or all, of these activities and are, therefore, subjected to recreational usage that was not anticipated a few years back. Sales of sporting and camping supplies, boats, trailers, etc., have soared even in a place like Albuquerque, which is many miles from water impoundments.

Hundreds of people in New Mexico and many thousands in the Nation make their livelihood from manufacturing and selling sporting and camping goods and supplies, which are needed because of Reclamation projects and other water recreational areas.

Reservoirs of the Reclamation projects in New Mexico during 1960 recorded over 1.4 million visitor-days. This is more than half the visitors that visited the renowned Lake Mead area for the same year. The upsurge in recreation activities has resulted in a large volume of business done by retailers in the State. Selling sporting goods and boats has been of material benefit to the entire economy of the State.

The National Park Service, in computing recreational benefits to be used in comparing the cost for determination of economic justification of proposed recreational developments, has used a figure of $1.60 per visitor-day. On this basis, using the 1960 recorded visitors, the Reclamation projects in New Mexico from recreational standpoints could justify an annual cost of $2-1/4 million, and over a 100-year period an expenditure of about $82 million.

We should mention, also, Conchas Reservoir on the Canadian River near Tucumcari and Clayton Reservoir located in northeastern New Mexico near Clayton, both of which contribute a great deal to the recreational opportunities in the State. Conchas Reservoir was constructed by the Corps of Engineers and Clayton Reservoir by the New Mexico Department of Game and Fish.

To illustrate further, the impact that the recreation use of existing projects has upon New Mexico's economy may be determined by use of data developed in other studies dealing with recreational aspects of water resources. Studies made by Dr. Nathaniel Wollman and Associates of the University of New Mexico have developed information from on-the-spot surveys relating to recreation expenditures by fishermen, boaters, and picnickers which indicate that each person visiting New Mexico reservoirs is probably spending at least an average of $5 per visitor-day.

Based on $5 a day, the total expenditure made by 1.4 million persons spending a day at New Mexico reservoirs in 1960 would be $7 million annually. This money is spent for both capital and current expenditures items on boats, camps, trailers, groceries, gasoline, car depreciation, fishing licenses, boat licenses, etc.

Dr. Wollman and associates also developed data showing that about 29 percent of the expenditures made by the fishermen, picnickers, and campers represent value added to the State gross products.

It is estimated that $996,000 is the annual increase in personal income in the State caused by the recreationists who used Reclamation project reservoirs.

The use of New Mexico project reservoirs is expected to continue and increase for some time. Benefits accruing to the State will increase in proportion.

With the addition of the Navajo and Heron No. 4 reservoirs and the State-constructed Ute Reservoir at Logan, recreational opportunities and total use will increase greatly and will significantly stimulate business. The National Park Service estimates that the reservoirs of potential Reclamation projects in New Mexico will have recreational use amounting to about 400,000 visitor-days per year.

It is anticipated that the bulk of these visits will occur at Navajo Reservoir, which will offer the largest water surface area in the State. There is no doubt that the recreation opportunities that will be offered on potential projects will be well utilized. It is anticipated that recreational usage of the potential projects proposed and being constructed in New Mexico will cause $2 million in added visitor expenditures annually. It is estimated that 200,000 persons will visit Navajo Reservoir in 1963 when the reservoir is still filling and recreational facilities are just being developed.

Congress for several years has recognized recreation as a function of multi-purpose projects and in the last few years has authorized construction of minimum basic health and safety facilities on a nonreimbursable basis. However, as yet they have not authorized allocation of joint works costs on a nonreimbursable basis.

Further recognition of recreation benefits to the State and Nation was extended by Congress when money when appropriated to provide public-use facilities on some of the older projects. The first such appropriation in New Mexico was for Alamogordo Reservoir in the amount of $25,000. While the facilities provided in this instance were minimal, they have been appreciated by those using the area. A very substantial appropriation was made for providing minimum basic recreation facilities at El Vado, and the work was completed this year.

Public Law 87-545 approved by the President July 25, 1962, providing for establishment of additional recreational facilities at Elephant Butte and Caballo Reservoirs, authorized a nonreimbursable expenditure of $607,000 for construction of public-use facilities. Most of you are acquainted with the limited facilities which are available for the public to use on Elephant Butte and Caballo Reservoirs. You may not be aware that these limited facilities were constructed by the Civilian Conservation Corps back in the 1930's. That group of young men did fine work and I support Secretary Udall's recommendations for a new youth corps.

They have been supplemented by the concession developments in an effort to meet the needs of the public. Construction of these badly needed facilities will no doubt attract many more visitors. Current usage is estimated at 1,270,000 visitor-days on Elephant Butte and 70,000 visitor-days on Caballo Reservoir. During 1961, there were 1,900 boat permits issued.

In earlier years, fishing was the primary attraction for visitors; however, recently boating, waterskiing, and vacationing have become important uses. This phenomenal growth in recreation use seems to be typical of many areas. In this case, the facilities authorized will assist in meeting a demand which is steadily increasing.

Early developments in the State were agrarian in nature, and because of the aridness of the country it was necessary to develop irrigation water supplies from scratch for agricultural production. As a result, all of the firm waters of the State were appropriated by the irrigators in the early days of irrigation development.

Later water projects and rights to use water are based on storage and regulation of flood and return flows and in some instances underground water supplies. State and Federal statutes protect the valid claimants to water.

Water is considered appurtenant to the land, and water rights are transferred along with the land when it is sold or transferred. These rights are guarded zealously by their owners in a water-short area such as this. The statutes provide for the beneficial use of water according to priority of appropriation, but do not preclude its use and reuse for other purposes, such as recreation.

The later users of water must recognize and honor the established rights of the early appropriators. Unfortunately, this is not always done and we hear about situations arising where the sportsmen have enjoined the irrigators in an effort to stop legitimate stream diversions or reservoir releases. Such unorthodox action has made the primary water-right holders distrustful of secondary users. This, in turn, has made it difficult to expand recreation uses of water.

There is not only competition between various users of water of a reservoir area, but there are conflicts between individual sportsmen themselves. Some reservoirs may have to be zoned as some natural lakes now are in populous centers of the east and midwest. For example, a part of a reservoir might be designated for waterskiing; another portion designated for bathing and swimming, still other portions designated for fishing although how we will get the fish to understand that is beyond me. Time-zoning has proved effective in some heavily utilized water areas.

Zoning of reservoirs to achieve maximum use of facilities is often brought about through legislative action. Using Foss and Fort Cobb Reservoirs in Oklahoma as an example, the upper portions of these reservoirs are being used primarily for wildlife management, and fishing. The lower portions of the reservoirs are being used for camping, boating, picnicking and skiing.

Nonreimbursable allocation of joint reservoir costs for fish and wildlife benefits to offset these benefits was included in the authorizing legislation.

Limitations on authority for the older Reclamation projects have prevented orderly consideration of recreation use pressures that have developed in recent years. Most of these older projects, when authorized, required little or no consideration of recreation. Consequently, today we must deal with these various individual authorizing documents as best we can.

Until further authority is provided by the Congress, a uniform administrative program for recreation on Bureau of Reclamation projects is not possible.

At the present time, we are not managers of recreation facilities on Bureau projects although we do have certain administrative responsibilities resulting from management agreements under which management functions are transferred to other qualified agencies. We look to the National Park Service and the Bureau of Sport Fisheries and Wildlife to administer areas of national significance for recreation and wildlife. The Forest Service usually undertakes this job on reservoirs within or adjacent to national forest lands.

We look to the State agencies for administration of areas that are of local and State significance. In the case of El Vado Reservoir, the New Mexico State Park Commission has contracted for its administration. The Bureau of Reclamation administers Elephant Butte Reservoir and in cooperation with the Carlsbad Irrigation District handles the recreational aspects of Alamogordo.

Your sister State of Oklahoma has a strong recreational program and through its State Park Division has one of the most efficient and enthusiastic programs in this part of the country. Through the sale of bonds, arrangements for adequate finances to construct lodges at reservoirs throughout the State were made. Other facilities such as launching ramps, picnic facilities, picnic shelters and domestic water supplies have been provided through the appropriations made by the State Legislature.

A study of the Oklahoma State Park program would be well worthwhile. I noticed in a newspaper story just a couple of months ago that the State of Texas, through its Parks Division, has sold bonds and plans to construct lodging facilities on the Texas side of Lake Texoma. California and Washington states also have very active and well financed State parks divisions.

I would be happy to see the New Mexico State Park Commission take the leadership in more fully developing and administering recreation of existing reservoirs and participating to the fullest extent on the new reservoirs. To accomplish this task in an effective way, and to derive the maximum benefits, you will need the support of all the people to obtain adequate financial backing. About the only way to obtain the wholehearted endorsement of the States' citizenry is to inform and impress them of the benefits of these programs and of the needs and demand for recreation.

It has been a pleasure to speak to you. I thank you for your indulgence in my remarks about our common problems and successes. I offer my congratulations on the progress New Mexico has made in 50 years of water resource development. May our efforts and achievements be continued and multiplied in the future.

IRRIGATION USES, PRACTICES, PROBLEMS

James F. Cole[1]

When one atom of oxygen is mixed with two atoms of hydrogen, and this gaseous mixture is ignited, the resulting product is water. Probably the most impressive mass demonstration of this basic chemical fact in history occurred at Lakehurst, New Jersey, May 6, 1937, when the German airship, Hindenburg, caught fire and burned.

For a product frequently used to extinguish fires, water in the West, has stimulated many heated and fiery controversies, sometimes with a minimum of light. In the past, it often caused lifelong friends to strap on their hardware and even today, few subjects can more quickly arouse ill-considered comments.

As the major consumptive user of water in the West, irrigation is sometimes the target of bitter invective. Since water rights provide water users with a measure of security, laws governing water rights are also attacked.

Consider this sample from a national magazine under the heading "Prior Appropriation Strangles the West."

"Sportsmen of seventeen states of the West are held helpless to fight for wildlife in the iron grip of a legal principle as outmoded as the one-horse-shay. Under this principle, judges must rule in favor of one, at the expense of many...simply because a law made to apply to the unique circumstances of one century does not work when applied to the entirely different circumstances of the next century. The law that is today being used in the West by a small but vicious vested-interest group is called the law of 'prior appropriation'."[2]

From the Hearings before the Senate Select Committee on Water Resources comes this:

"My second point is the fact that our group is anxious that cooperation may be obtained in the multiple use concept in the use of water and all other natural resources and public property. We are firmly convinced that any people or group

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1/ Assistant to the President and Agricultural Economist, Department of Agricultural Economics and Agricultural Business, New Mexico State University.

2/ Carhart, Arthur H., "Prior Appropriation Strangles the West," Sports Afield, Vol. 140, No. 1, New York: July, 1958 of people that want something for their own use only and to heck with the other fellow, are simply narrow-minded and have no concern of their children or their fellowman, or for the well-being of the Nation."3/

Water laws are not the only laws attacked by segments of the population. Laws regulate human activities and are, therefore, destined to come in conflict with human desires and beliefs. The United States Constitution, containing the basic law for our unique form of government, is constantly under attack.

Here is a statement from a widely publicized and highly influential sociological study:

"This conservation in fundamental principles has, to a great extent, been perverted into a nearly fetishistic cult of the Consitution. This is unfortunate, since the 150 year old Constitution is in many respects impractical and unsuited for modern conditions.... Modern historical studies of how the Constitution came to be as it is, reveal that the Constitutional Convention was nearly a plot against the common people."4/

The criticisms strike directly at the institution of private property. The incentive to develop, maintain and improve the efficient use of resources has its roots in the American concept of property rights. It is fundamental to the continued operation of our economic system as we know it today. The institutional factor of law is not the basic framework. It merely serves to modify economic influences. Many who would be furious and would strenuously oppose suggestions to have land declared public property of the state, see no parallel when such action is proposed for water. If we intend for property to seek its highest and best use, tenure must be assured and restrictions on use held to the minimum. Lack of tenure certainty will cause buyers to refuse to pay as much for property if a protected right cannot be conveyed, and holders of a right will hesitate to make significant development when there is a risk of seizure.

When an individual invests in land, buildings, equipment, or an irrigation system, he expects to recover these sunk costs. A farmer or any other investor, in a developing irrigated area with no well-defined water law, may be uncertain about the reliability and cost of his future water supply. As a result, he will probably hesitate to make permanent improvements and could probably find scant credit assistance for such improvements. He may even disinvest over time, in that he allows

3/ Water Resources, Hearings before the Select Committee on National Water Resources, United States Senate, Albuquerque, N.M., U. S. Gov't. Printing Office, Washington: 1960.

4/ Myrdal, Gunnar, et. al., An American Dilemma. New York: Harper and Brothers, 1944.

improvements already made to suffer from lack of maintenance and repair.[5]

Uncertainty regarding property rights often leads to wasteful depletion. When property rights in resources are indefinite they become "fugitive" resources, to be captured by using them. To defer use gives rise to uncertainty. Competitors may capture the resource in the meantime. This was one of the fundamental issues in the declaration of the Rio Grande Underground Water Basin. Industry, as well as agriculture, requires valid and protected rights to water to protect investment. States without adequate water laws are increasingly confronted with this problem of tenure certainty.

A resource is something that people can use--land, water, ores, grass, machinery, labor. The object must have use to be a resource. Ground-water districts meant little to the Apaches. This water was not a resource until the settler developed it. A dictionary printed about thirty years ago defines uranium as follows: "A worthless metal, not found in the United States." In the light of present day exigencies, uranium has achieved resource status.

Conservation of resources does not mean non-use. Conservation refers to the rate of depletion. Conservation of such things as minerals is meaningless outside of this concept. Conservation has both economic and technical aspects. Technology concerns such matters as geology, hydrology, biology, or engineering. Economic considerations often prevent the adoption of conservation practices even though their technical feasibility has already been demonstrated.

The economics of conservation deserve more careful study. Natural resource users may use these resources wastefully, not because they know no better, but because they are compelled by economic forces to do so.

The theoretical efficiency framework for water resources decisions has developed slowly because we have only recently begun to think of water as a scarce resource. Most resources can be used for any one of a number of purposes. Allocation to one purpose, often means foregoing, or deferring, or reducing their use for other purposes. Economics has much to contribute to the solution of water problems but meaningful economic analysis requires large quantities of technical data.

5/ Hirshleifer, Jack, James C. DeHaven, and Jerome W. Milliman, Water Supply Economics, Technology, and Policy. Chicago: The University of Chicago Press, 1960.

The principal economic device used in balancing resource allocation in a competitive economy, is the pricing system. Individual wants and desires differ. In economic terms, people derive varying degrees of satisfaction or utility from the use of resources. In an exchange economy like ours, price allocates resources. If, for example, industrial use of a resource gives a higher net return than agricultural use of the resource, then, in a free economy, industry will purchase the resources from farmers.

In the allocation of resources, under a market system, the economist must emphasize--not the existence of unsatisfied wants or needs, but the effective demand--the measure of willingness and ability to buy. I may want or need a new suit, and do, but until I take cash in hand or an acceptable promise to pay to the local clothier, he will refuse to relinquish the suit. I want, and have rationalized that I need, more time off. Here again, the market system confronts me with alternatives. A less demanding job would probably not be hard to obtain if I were willing to forego some income and other satisfaction. No matter how badly I may need or want these things, it is highly unlikely they will come my way without some tangible commitment of my own resources and the more scarce the objects of my desires become, the greater the required commitment to obtain them.

Conservation has regretably become involved in moral, political, and enigmatic issues that add little to the solution of conservation problems. Resource conservation decisions involve carefully considered choices between uses within the framework of a market economy.

New Mexico water law meets two fundamental economic criteria. It provides the requisite security, so that investors may make improvements free from the threat of arbitrary action. Lending agencies feel free to commit their depositors' money. At the same time, New Mexico water law has incorporated within it the necessary flexibility to permit voluntary transfers of water rights within the market system. Changes in ownership, place of use, method of use and point of diversion have occurred and are occurring constantly within the administrative framework of the law so long as such changes do not impair existing rights.

New Mexico laws governing water rights closely adhere to the principles of Prof. Frank J. Trelease's Model State Water Code, a widely acclaimed pattern for water allocation legislation. Prof. Trelease says, "Prior appropriation, in the balance, seems to be the best extant system of law for river basin development in the United States....and the best of this law could be used as a model by any state to meet its local needs. The west has had a century of experience with water shortages; the east is just beginning to fear them. The doctrine of prior appropriation has shown that it contains elements of remarkable flexibility and an ability to grow. It has made the transition from a pioneer system of acquiring water rights to a modern system of state control of water resources. Practically every suggestion yet made for the improvement of eastern water law has been based upon ideas, techniques or practices now current in the west."6/

Students of water law have marvelled at some of the farsighted water legislation adopted in our state. In addition, New Mexico has been blessed, as has been noted in previous conferences, with a practically unbroken series of able, and dedicated public servants in the office of the State Engineer. I'm sure that the group attending this conference will agree with me that the current occupant of that office exemplifies the highest standard of public service.

The beginnings of irrigation in New Mexico are lost in antiquity. The state has the oldest recorded history of irrigation development in the United States. Archeology has turned up well-developed stone reinforced irrigation systems dating back well before the Crusades, and when Coronado arrived in 1540 he and his men found flourishing irrigation systems along the major river systems.

Irrigation development continued to advance, utilizing the community acequia system that prevails even today in many parts of the state.

In 1846 Brig. Gen. Stephen W. Kearny entered New Mexico and promulgated the Kearny Code, which recognized previous water rights.

The Treaty of Guadalupe Hidalgo and the First Territorial Legislature laid a more solid basis for the doctrine of appropriation.

In 1850, improved land in farms in New Mexico totalled 166,201 acres and the value of farm property was $3.2 million. It was estimated that about two-thirds of the improved land was irrigated.7/

6/ Trelease, Frank J., A Model State Water Code for River Basin Development. Reprinted from the symposium on River Basin Development. Published as the Spring 1957 issue of Law and Contemporary Problems, Duke University School of Law and Contemporary Problems, Durham, N. C.

7/ United States Census data.

Post-Civil War Development

This year, 1962, marks the 100th anniversary of the signing of the Morrill Act by President Lincoln. This act set up the nation-wide system of higher education of which New Mexico State University is a part. I had hoped, in my research for this paper, to find some significant tie-in with developments following the Civil War. Several authors alluded to the rapid influx of settlers. During the period 1870 to 1880 New Mexico's population went from 91,874 to 119,565, an increase of about 30 percent in the ten-year period. The value of farm property went up five-fold and the acreage of improved land in farms increased nearly 66 percent. The big crops were corn, wheat, and other cereals.8/

The population was concentrated in the northern counties and settlers cultivated a considerable acreage under rainfall conditions. The community acequia system still flourished but enterprising individuals began to develop private diversion and distribution systems.

From 1880 to 1890 there was only a small increase in the improved lands in farms. The acreage of alfalfa more than doubled during the period, largely at the expense of small grains. In 1890 New Mexico had 91,745 irrigated acres divided among 3,085 farms. The big irrigated areas were in Mora, Dona Ana, San Juan and San Miguel counties.9/

During the next ten years, the number of irrigated farms trebled and total irrigated acres more than doubled. The acreage of alfalfa continued to increase faster than any other crop.

New Mexico State University was founded in 1888. The following year it became a part of the Land-Grant system of education, research, and service; and the Agricultural Experiment Station was established. Research work was immediately instituted on agricultural problems.

In the Fourth Annual Report of the Experiment Station (1892-93) R. F. Hare, Asst. Chemist, reported on his analysis of Rio Grande River waters. Irrigation research on various crops, including small grasses, alfalfa, sugar beets, fruits and vegetables, was furnishing valuable data for the rapid influx of farmers, most of whom knew little or nothing about irrigation techniques.

The first farmers' institute ever held in the territory met on this campus in January, 1896, only a few hundred yards

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8/ Ibid.

9/ Ibid.

from the site of this meeting. One of the major subjects for discussion was windmill irrigation.[10]

In 1900, nearly 90 percent of all crops produced in the state were irrigated. The average value of all irrigated land was $29.00 per acre but it ranged up to $369.00 per acre on the Carlsbad Reclamation Project. In 1900, the big irrigation counties were Mora, Dona Ana, San Miguel, Rio Arriba, Chavez, Colfax, and San Juan, in that order.[11]

1907 Water Code

The office of Territorial Engineer was established under the 1905 laws and in 1907 the basic water code in force today was passed by the Territorial Legislature.

In his First Biennial Report (1907-08), Territorial Engineer Vernon L. Sullivan acknowledged the assistance of the United States Reclamation Service and the Geological Survey. He observed that the citizenry was becoming aware of the rules promulgated to conserve water and perfect water rights. In an optimistic vein, Sullivan predicted that by 1915, two million or more acres would be under irrigation. Based on an assumption that forty acres would support an average family of four people, he predicted a farm population of close to 200,000 plus a substantial increase in the population of towns and business centers supported by agriculture.[12]

"The first prerequisite of a model state system of water law," says Trelease, "is that it should encourage, or at least not deter, maximum development."[13] The Basic Water Code passed in 1907 appears to have met this criterion.

The first ten years of the twentieth century saw the most rapid development of irrigation in New Mexico's history. Between 1900 and 1910, total irrigated acreage jumped from 203,893 to 644,970--a whopping 216 percent increase. The value of farm property trebled during the ten-year period.

10/ Annual reports of the New Mexico Agricultural Experiment Station.

11/ Census, op. cit.

12/ Biennial reports of the Territorial and State Engineers of New Mexico.

13/ Trelease, op. cit.

Eastern capital was attracted to the territory. Population increased 68 percent during the decennium. The number of acres in hay quadrupled, occupying about half of the irrigated area. Other major crops were wheat and corn.14/

The $4 million invested in the Carlsbad Project represented almost half the value of all irrigation construction in the territory. Except for that project, development was financed largely by private and cooperative effort. All over the territory irrigation development was booming. It was a promoter's paradise. In San Juan County, one project alone proposed the development of over a million acres.15/

The Pecos Valley Improvement Association had, a few years earlier, made an extensive development, including two irrigation systems, on the lower Pecos. One of these was washed out in the 80,000 second ft. flood in 1904 and the system was subsequently sold to the United States for a reclamation project. The upper project was "one of the best managed and most prosperous projects in the west." Called the Northern Canal, it took water from the Hondo River and later became the property of J. J. Hagerman. Near Maxwell, 6,800 acres were in cultivation on the Maxwell Irrigated Land Company Project in 1907, with expansion to 20,000 acres expected by 1908.16/

At Elmendorf, on the Bosque del Apache Grant, the Socorro Company proposed to irrigate 22,000 acres of sugar beets, grain and alfalfa; and Engineer Sullivan urged that a sugar factory be established. Sugar beets were also to be the major crop of the Farmers Development Company of Springer. Also located near Springer was the French Land and Irrigation Company, contemplating the development of 43,000 acres; and the Lake Charette Reservoir and Ditch Company, which sought to appropriate the waters of Ocate Creek.17/

Charles Springer of Cimarron owned the following projects: Cimarron, Ponillo, and Vermejo and the well-known Eagles' Nest, where a dam was to be constructed.18/

14/ Census, op. cit.

15/ Biennial reports, op. cit.

16/ Ibid.

17/ Ibid.

18/ Ibid.

West of the Rio Grande two companies were at work on the Rio Puerco. Development of some 21,000 acres in the Blue Water and San Mateo Valleys was in progress. Projects were underway in Union, Taos, Otero and San Miguel counties and the big project, already in the planning stage, was Elephant Butte--planned to irrigate over 100,000 acres from storage in the "largest artifical lake in the world."19/

The 1909 irrigation district legislation permitted the setting up of public corporations in order to bond land as security for construction loans. Noting the tendency to exaggerate the water supply, a bond schedule proportionate to the water to be appropriated was set up in 1910, to reduce speculative filing.20/ Three years later Director Fabian Garcia of the Agricultural Experiment Station observed that the get-rich-quick attitude was beginning to disappear.21/

Ground-Water Development

During this whirlwind of activity involving surface waters, a few artesian wells were drilled (some as far back as 1860), and by 1910 there were over 400 flowing wells in the territory. In 1891, the first large, flowing well in the territory was drilled in the Roswell Artesian Basin. About 1902, farmers began to use artesian water for irrigation. At the time, the supply was considered inexhaustible; however, from 1905 to 1914 a noticeable lowering of the artesian head occurred and more and more farmers had to shift to the use of pumping equipment for the artesian acquifer.22/

The first irrigation by pumping was largely from windmills. Adaptation of the centrifical pump to irrigation around 1900, greatly stimulated interest in ground-water development. In 1900, a little over 1,000 acres of New Mexico crop land was watered from wells. Two years later, New Mexico College of A & MA sunk a 48 ft. well near what is now the seed house (about ½ mile west of the New Agriculture Building), and began testing various types of pumping equipment. An Experiment Station Bulletin published in 1903 described pumping problems and in 1905, the first experimental data on cost of pumping in the territory, was published by the station. The pumping plants were steam powered, using gasoline, oil, or tornillo wood as

19/ Ibid.

20/ Ibid.

21/ Annual reports, Agricultural Experiment Station, op. cit.

22/ Biennial reports, op. cit.

fuel. The lift was about 35 ft. and the discharge 1,325 g.p.m. Total cost of water per acre foot, ranged from $2.21 to $13.20, depending on the type of fuel used. The average total cost per acre foot was about $6.00; closely comparable to present day costs. The college had some experience with well development prior to 1900. Records of the Experiment Station show that $591.00 was spent for the development of an artesian well at the Pecos Valley Substation in 1897.23/

Pumping tests continued and in 1908 R. F. Hare and F. L. Bixby, staff members of the Agricultural Experiment Station, conducted pumping tests in the newly developed Estancia, Deming, and Pecos Valley areas.24/

Cooperative irrigation work with the United States Department of Agriculture was initiated in 1898, and I am proud to say that this cooperation is continuing in 1962.

Pump irrigation was initiated in the Portales Valley about 1910, by the Portales Irrigation Company; although prior to that time, a few farmers irrigated small tracts with windmill flow. The company installed an electric generating system and had 69 pumping plants in service. During World War I the generating system was dismantled and sold. About 1925, irrigation interest revived and by 1931 more than 166 pumping plants were in operation.

The Mimbres Valley around Deming had a similar experience. Development began about 1908 and expanded rapidly to a peak of about 200 wells in 1915. Farmers were inexperienced, costs were high, and by 1919, only 25 plants remained in use. In 1927 land owners and business men conceived the idea of forming an irrigation or conservancy district and asked for a ground-water survey. A period of renewed activity followed and ground-water development increased steadily to a peak of almost 35,000 acres in 1953.25/

In 1920, there were 461 irrigation pumping plants in the state, irrigating some 24,000 acres. An additional 37,000 acres were irrigated from flowing wells, making the total acreage irrigated from wells--61,000. Ten years later, in 1930, this total had increased by only 4,000 acres. In the meantime, the acreage irrigated by flowing wells had gone

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23/ Annual reports, Agricultural Experiment Station, op. cit.

24/ Ibid.

25/ Biennial reports, op. cit.

steadily down and by pumped wells--steadily upward. About 12 percent of the irrigated land in the state received water from wells.26/

By 1940, the total acreage irrigated from wells had nearly doubled to 120,566 and 21 percent of the irrigated land in the state received water from wells.27/

After World War II, under the impetus of high prices for farm commodities and a mobile population, irrigation in ground-water areas expanded rapidly; and in 1960, nearly two-thirds of the irrigated land in the state received water from wells. During this period, irrigation development was initiated in Hidalgo and Curry counties and greatly expanded in Lea, Eddy, Dona Ana, Torrance, Luna and Roosevelt counties.28/

In the fiteen years between 1940 and 1955 the number of irrigation pumping plants increased nearly five-fold. The big factor in this increased acreage was cotton.

Cotton was found by Coronado's men as far north as the Upper Pecos River and the 1860 census records that 19 acres of cotton was produced in the territory.29/

In 1920, the value of cotton produced in New Mexico was $1.4 million. In 1959, it was $73 million. The acreage increased from 10,666 acres in 1920 to a peak of 315,000 acres in 1953. During the 1940's, the acreage of corn steadily decreased; the acreage of barley increased; bean acreage, decreased; oats, decreased and alfalfa remained fairly constant although acreages of all of these crops fluctuated from year to year.30/

The New Mexico ground-water code enacted in 1931 was originally designed to firm up ground-water rights in order to attract credit to ground-water districts within the state. It has prevented the type of uncontrolled exploitation of ground-water resources which has cocurred in neighboring states--accompanied by rapidly falling water tables and continuing scrambling for the precious water supply by lowering wells and other emergency investments.

One of the painful results of that type of development is rapidly increasing costs of pumping. The deliberate mining of ground-water supplies in declared underground water

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26/ Census, op. cit.

27/ Ibid.

28/ Biennial reports, op. cit.

29/ Census, op. cit.

30/ Ibid.

basins in New Mexico has been found by economic analysis to offer a much more favorable amortization period for private investment, as well as public investment in social institutions.

Surface Irrigation Since Statehood

Over the past 50 years the number of acres irrigated from ground-water supplies has increased ten-fold but the acreage irrigated from surface supplies has remained fairly constant. New appropriations in some areas have been offset by acreage abandoned in others. The big surface water development has been the Tucumcari Project. El Vado Dam was added to improve the control of water on the Rio Grande and several fine flood and sediment control structures have been built on the Rio Grande, Pecos and Canadian river systems.

The proposed Navajo Project is the big hope of the future irrigation development in the state. This type of development raises fundmental policy questions which have been discussed at great length. The major issue raised involved the advisability of public investment in agricultural development in view of chronic crop surpluses. You are all familiar with the argument. It goes something like this: the demand for agricultural commodities in the aggregate is inelastic--that is, an increase of one percent in supply results in more than one percent reduction in price (perhaps on the order of four percent.). It is further alleged that additional production is not now needed and may never be.

Some have even contended that it is sound public policy to invest in new water development programs on the grounds that food and fiber prices will be reduced and the public will thereby benefit.

The opposite view is that such projects produce crops not now in surplus and further, that the present agricultural base will not be able to provide the food and fiber needed by our rapidly expanding population.

The advantages to New Mexico and the Navajos are obvious.

The major problems of surface water irrigation users since statehood have been drouth, drainage, floods, losses to nonbeneficial vegetation, sedimentation and seepage.

Recurring drouth has led to some changes in irrigation patterns. In the lower Rio Grande and lower Pecos Valleys, farmers have drilled hundreds of wells to supplement surface-water supplies. Investment in pumping equipment increases capital costs by approximately $80 per acre. These wells are a kind of drouth insurance.

Drought has aggravated the problems of silting, seepage, and phreatophytes. Conveyance losses are like fixed costs in a business. A reduced volume of flow does not reduce seepage losses proportionately. The water salvage work already completed and in progress on the Rio Grande and Pecos rivers has paid and will continue to pay big dividends. We need to make a much larger investment in research on phreatophytes and problems caused by sedimentation but we cannot afford to to wait for final research results. The State Engineer, the Bureau of Reclamation and other agencies involved in this vital work are doing a splendid job.

Drainage problems along the Rio Grande became evident nearly seventy years ago. They cropped up later in the Pecos Valley. By 1907, 58,000 acres in the Middle Rio Grande were badly seeped. Conditions developing below Elephant Butte were just as bad. Nearly two-thirds of the land in the Mesilla Valley had water within four feet or less of the surface. According to Bloodgood, the total irrigated area in the state in 1919 was 538,377 acres of which an estimated 300,000 acres badly needed drainage. Subsequent work by the Bureau of Reclamation has greatly alleviated this problem.31/

Two of the most violent floods in the history of the Rio Grande occurred in 1929 when the river overflowed its banks near Albuquerque and the towns of San Acacia and San Marcial were wiped out. Damage ran in the millions of dollars. Serious floods have also occurred on the Pecos and Canadian rivers as well as on tributaries of these three systems. Flood control dams and levee reinforcement have largely eliminated the danger of major floods and the dams have also helped to reduce aggradation of stream beds due to sedimentation.

Seepage losses on farms, in distribution systems, and rivers continue to be a major problem. Seepage losses in canals and reservoirs appear to be large.

As mentioned earlier in this paper, farmers may occasionally use resources wastefully, not because they do not know better but because they are compelled by economic forces to do so. The water user can ill afford conservation of one resource which may lead to waste of other resources. It may be cheaper to leave water untended for certain periods and risk some over-irrigation than it is to hire a man to watch it all the time.

31/ Annual reports, Agricultural Experiment Station, op. cit.

Before investing in productive facilities, the investor wants to know whether the investment will give a reasonable return. There is a tendency to discount for risk, uncertainty, and time preference. The appropriation doctrine reduces risk and dependable water supplies reduce uncertainty but a dollar today is still worth more than a dollar, five years from today. Low incomes discourage conservation.

Favorable commodity prices following World War II stimulated an impressive private investment in water conservation in agriculture. Fields were leveled; irrigation systems, reorganized; irrigation structures, improved; ditches and farm reservoirs, lined; and erosion control structures, built.

Since 1935, and largely since World War II, over four million lineal feet of irrigation pipe has been installed and over four million lineal feet of ditches lined with concrete. Over 300,000 acres of land have been leveled for greater irrigation efficiency. These private improvements plus others mentioned above have involved the investment of some $50 million in conservation.[32/] Emphasis on this type of conservation should be continued.

The duty of water for various crops has not changed much over the years but the efficiency of water use has greatly improved. We are getting much more product and a higher quality product from the same amount of water input.

There is widespread concern that our water supplies are failing and only unprecedented measures will save us. The continued well-being of our economy depends on an abundance of low-priced water. The demand for water is increasing year by year and water is becoming increasingly scarce relative to demand. In casting about for a water supply some quite naturally covet the 95 percent of New Mexico's water allocated, by prior right, to irrigation.

Irrigation development was highly desirable in the early years becuase it brought in settlers, improved the tax base, and greatly increased employment opportunities. Modern agriculture is highly efficient. Commodity prices are low. Less labor is used. Agriculture is diminishing in relative economic importance in the state. I emphasize relative economic importance, since sales of farm products continue to expand but at a less rapid rate than sales in other sectors of the economy. But agriculture holds the water rights which might be used by others.

32/ Estimated from SCS data.

Agricultural development often occurs in areas where unrelated activities could not or would not locate. Foregoing agricultural water uses in these situations would mean no development at all. The irrigator is obviously a direct beneficiary of irrigation development, but the businessman and his family living in a trade center, or handling farm products, or furhishing supplies, is an indirect beneficiary. Social institutions, including hospitals, schools, churches and recreational activities must also have an adequate resource base.

Depletion of a limited ground-water resource may make it possible for a community to thrive sufficiently to enable it to grow and prosper and even bring water in as Los Angeles has done.

Under New Mexico water law the early appropriation of water by agriculture represents a kind of holding action. When it becomes economically feasible to purchase irrigation water for other uses, transfers take place just as transfers of land occur, at a market price. The law permits and even encourages changes in water use, not by encroachment but through the market system.

Any redistribution of resource use has many consequences. Some parts of the economy expand--others, contract. Shifts in water use may impoverish one area to enrich another. Experience in other states emphasize the many problems associated with mass transfers.

I am not prepared to predict the trend in irrigation use over the next 50 years. There are too many variables--economic growth, long term supply, price levels, water salvage propositions, etc. It is possible, however, to say that some ground-water areas will be in serious trouble unless recharge is greatly increased. This is an area of research which merits greatly increased emphasis.

Americans have a huge and growing appetite for water. We use many times as much water by weight than all other resources combined.

Fifty years from now our nation's population will have doubled. What will our water requirements be then? What will our food requirements be? One gets the feeling that somehow or other the Malthusian doctrine has some validity after all.

WATER POLLUTION - SOURCES AND REMEDIAL MEASURES

Warren Viessman, Jr.[1/]

Introduction

Pollution can be defined as the introduction into a body of water of substances whose characteristics and quantity alter or impair its usefulness or render it offensive to the senses of sight, taste, or smell. It may involve either a surface or underground supply. By definition, the process involves an intermediary whose function is to introduce the pollutant into the body of water. This intermediary is normally man. Pollution may therefore be considered a direct function of population. Historically, population growth and increased pollution have occurred simultaneously.

Since the colonization period, quantities of waste have grown until at present it is not at all uncommon to find that a once sparkling stream has turned into a turbid sewer. Such impairment of water quality has resulted in extensive loss of aquatic life and in the loss of the lives of other creatures using the stream as a habitat or for drinking purposes. In addition, and of utmost importance, pollution has effected a real loss of part of our country's water resources. If the water is so foul that its treatment for public consumption or industrial use is not economically feasible, then other sources of supply must be sought and the polluted body of water can be considered as much of a loss as if it were physically removed from the area.

Today considerable emphasis is placed on the quality of our water resources. This comes in the face of increasing population, accelerated industrial activity, and large scale pollution. Waste abatement operations range from simple technical adjustments to the consideration of exceedingly complex social-political-ecological-psychological problems. A complicating factor is that each pollution abatement problem is different. In addition, the motivations for abatement programs are shifting from the pure health hazard base to an inclusion of aesthetic valuations. As ably stated by Renn (1961), we undoubtedly have more common interests in pleasant living and are less moved by moralistic views. If we don't like dirty water for any reason, we simply don't like it, and we don't argue that it must necessarily be toxic or bad for health. There is profit in offering a more pleasant future and we know it. We take it for granted that we have a right

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to some minutes of leisure, irresponsibility, and beauty without reproach. In fact, a very large fraction of our economy rests on this presumption.

Water Quality

The usefulness of the maximum water supply available to man is determined in large part by its quality. As precipitation, this water is usually quite pure. By the time it has penetrated the soil with its various minerals and rocks and flowed in streams contaminated by municipalities and industries, its quality may be seriously degraded by bacteria, organic matter, dissolved salts, acids, and possibly even radioisotopes.

The drinking water standards set forth by the United States Public Health Service recommend that the total dissolved solids content for human consumption should not exceed 1,000 ppm. The United States Geological Survey states that waters containing more than about 2,000 ppm dissolved solids are generally unfit for long term irrigation under average conditions. This value will depend however, on the elements present, soil type, and tolerance of the crop and may thus vary considerably from the average allowable concentration. Sodium and boron for example, are particularly undesirable in agricultural waters.

a. Ground Water

The quality of ground water is a direct function of the quality of its source. Changes in source waters or degraded quality of normal supplies may seriously impair the quality of the ground water supply. Sewage and industrial wastes entering an aquifer are major sources of pollution. Because it is difficult to introduce large quantities of wastes underground, gross organic pollution of ground waters rarely occurs. Inorganic solutions, however, pass readily through the soil and once introduced, are removed only with great difficulty. In addition, the effects of such pollution may continue for indefinite periods since natural dilution is slow, artificial flushing is expensive, and treatment is generally impractical. Thus, great care should be taken to insure that ground water storage capacity is not irreparably harmed by the disposal of waste materials.

The percolation of water through 6 or 7 feet of fine grained soil is generally considered sufficient to reduce the presence of most harmful enteric organisms below a tolerable level (Hirshleifer 1960). However, as the water passes through the soil, a significant increase in the amounts of dissolved salts may occur. These salts are added by soluble products of soil weathering and of erosion by rainfall and flowing water. Locations downstream from heavily irrigated areas may thus find that the water they are receiving is too saline for satisfactory crop production. These saline contaminants which are introduced by nature (primarily a problem in western parts of the country) are difficult to control because removal methods are exceedingly expensive. A possible solution is to dilute with waters of lower salt concentration (possibly sewage treatment plant effluent) so that the average water produced by mixing will be suitable for use.

b. Surface Water

The primary causes of deterioration of surface water quality are municipal and domestic sewage, industrial wastes (organic, mineral, cooling water), and solid and semi-solid refuse. A municipality obtaining its water supply from a surface body may find upstream users discharging untreated sewage and toxic chemicals in such quantities as to render the stream unsuitable or too costly to treat for use as a water supply. It is significant however, that the waste products discharged by cities and industry can be controlled at the point of initiation. This has been borne out by recent successes in cleaning up such watersheds as the Delaware and Susquehanna in the eastern United States. Effluent treatment is assuming increased importance and today thousands of industrial plants treat their wastes. Chemical and Engineering News in 1956, suggested that the chemical industry alone is spending 50 million dollars a year in new water pollution control facilities.

Some Modern and Future Pollution Problems

While industry and municipalities are accelerating programs to cope with waste abatement problems, the nature and dimension of these problems is also rapidly expanding. MacKichan in 1957, indicated that industrial water use increased 43 percent from 77 billion gallons to 110 billion gallons a day from 1950 to 1955. Total waste volumes discharged by the chemical industry very likely rose even more strikingly during this period. New products such as synthetic detergents, insecticides (DDT), herbicides (2,4D), and numerous others, are contaminating surface and ground waters with the wastes associated with their manufacture. Some of these contaminants are exceedingly difficult to remove from waste waters and many technical problems concerning them are yet to be solved. Thus, although pollution control practices have improved and their application has spread, industrial vitality has produced a whole new spectrum of waste disposal needs. The remainder of this paper will be concerned with a brief discussion of four of these modern and future waste pollution problems.

a. Saline Brine Wastes

Pollution of ground and surface waters by inland desalination plant wastes is destined to become an exceedingly serious consideration as economic desalination becomes a reality. Consider the following excerpt from "Desalination Research and the Water Problem," published by the National Academy of Sciences - National Research Council, 1962.

> "In the long run when man's desalination of sea water approaches the magnitude of natural events, brine disposal will become a worldwide problem. Probably the oceans are now more saline than is optimum for sea life, and most marine organisms are more vigorous in sea water diluted as much as 50 percent. Thus man may wish some day to dispose of his brines in such a fashion as to isolate them from the sea."

Regarding inland conversion processes, the publication further states:

> "The problem of brine disposal from the processing of inland saline waters is much more difficult. If useful by-products are present, the brines can be employed for this. Otherwise, it is probably undesirable merely to return them to the channel or to the original stratum from which the parent water was derived without a careful hydrologic investigation."

In July of 1962, construction of the world's largest brackish water distillation plant was begun at Roswell, New Mexico. The completed plant will deliver one million gallons of pure water to the city of Roswell each day. It will also burden the city with the disposal of about one-third million gallons per day of waste effluent having a dissolved solids concentration of about 100,000 ppm. This amounts to 139 tons of solids per day. Present plans (1962) are for the disposal of the brine waste by solar evaporation in five, forty acre ponds.

Even on such a relatively small scale of water production, the disposal problem is of immense proportions. Of equal significance is the potential pollution hazard by pond seepage which will menace the quality of already saline or borderline ground waters in the area. It is significant that the ponded waste will have no self-purification properties since its constituents are the simplest of inorganic compounds. This, combined with the prospect that the operation may be continuous for many years, indicates the seriousness of the problem. The pollutional aspect of ponded brine wastes relates directly to the possible impairment in quality of agricultural waters and thus to the amount and kind of salts in the water. A measure of potential sodium hazard may be had by computing the sodium-adsorption-ratio (SAR) defined below,

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where ion concentrations are expressed in milliequivalents per liter. The higher the SAR, the greater the potential Sodium hazard from using the water. An indication of how the SAR can be used as a pollution index is presented below using Roswell as an example.

The United States Geological Survey (USGS) indicates four classes of waters with respect to sodium hazard. These are low, medium, high, and very high depending upon the specific conductance and SAR. Using this classification and values of specific conductance reported by Dregne (1954) for several Roswell waters, a value of about 7 is determined as the SAR separation point between medium and high harzard waters. Designating this as a desirable upper limit (the pollution index), a determination can be had of the effect of brine seepage on waters in the disposal area.

From data reported by Hantush (1957), it is estimated that the rate of water movement in the area of the proposed site is 303 gallons per day per foot of aquifer. Seepage from the ponds will be assumed at a rate of 0.03 cubic feet per square foot per day (a minimum value reported by Koenig (1958) for seepage from sealed canals). Using the data and average values of calcium, magnesium, and sodium concentrations reported by Dregne (1954) for Roswell, New Mexico, well waters, and Office of Saline Water figures for the plant feed water, SAR values before and after the advent of seepage can be estimated. These estimated values are as follows:

a. SAR (before seepage) = 6.8

b. SAR (original ground water mixed with seepage) = 7.2

This prototype problem illustrates how an increase of 6 percent in SAR would result from seepage. It also shows how the SAR is increased to a value above the designated pollution index. Thus, it can be seen that even for seepage rates which are currently considered low for canal losses, brine pollution might easily result.

Since the pollution problem stems from the potential increases in salinity of a ground water or surface water source through seepage from brine ponds, it is imperative that seepage rates be significantly less than the best figures currently indicated for satisfactory seepage losses from irrigation canals. A careful study of seepage losses from brine ponds is thus necessary and may indicate that chemical sealants, liner materials or means of collecting the irreducible minimum of seeped liquor will be required if pollution is to be prevented.

b. Heat

Many of our country's surface water courses are experiencing rising temperatures due to the increasing use of water for cooling purposes. This is a direct result of the necessity for disposal of waste heat by industrial operations such as steel mills, steam electric power plants, petroleum refineries, and paper mills. Unfortunately, the effect of heat discharge on stream temperature is generally most severe during summer periods when river flows are often low and demands for cooling waters high.

Increased temperatures can make water sources less desirable for municipal, industrial, and recreational uses and can have fatal effects on various forms of aquatic life. The Aquatic Life Advisory Commission of the Ohio River Sanitary Commission (1956) states that fish kills may result from sudden temperature increases, from short periods of lethal temperature, or from prolonged periods of sublethal temperature. This stems from the fact that the amount of dissolved oxygen in a stream decreases significantly as temperature rises while at the same time oxygen requirements increase. In addition, it has been shown by Klein (1957) and others that biochemical reactions using oxygen proceed at an accelerated rate at higher temperatures. Harmful effects of compounds toxic to fish also increase with rise in temperatures.

Although Sanders and others (1962) have shown there are records of extreme thermal loads in a few streams, heat discharges are only now beginning to emerge as significant problems. The Federal Government has no guides for regulating heat discharges and only a few States have tried to legislate the problem by setting maximum allowable temperatures. In addition, there is as yet little uniformity or agreement on what the temperature limits for receiving bodies of water ought to be.

Increased heat loadings which are expected to develop through future industrial expansion can cause a serious deterioration in the usefulness of many water supplies.

Estimates prepared for the Senate Select Committee on Natural Water Resources indicate a sixfold increase in cooling demands by the year 2000. Although the effect of heat discharges on the temperature of receiving waters may be somewhat mitigated by low flow augmentation projects during critical summer months and through increased use of cooling towers and spray ponds, substantial increases in temperature of surface bodies of water may be expected in the future. Extensive State and Federal regulatory activity is also certain to follow. Regulations limiting the temperature rise of a stream may become a controlling factor for industries selecting plant sites, deciding on expansion of existing facilities, setting production schedules, and estimating the need for evaporation facilities.

c. Synthetic Detergents

The increasing use of synthetic detergents in household and industry is creating problems in maintaining potable water supplies. Because detergents are not successfully removed by most sewage treatment operations, their concentration is steadily increasing in many of our water courses. Babbitt (1962) and numerous others have shown that synthetic detergents cause foaming; affect the taste and odor of water; make coagulation, settling and filtration more difficult; increase the difficulty of iron and manganese removal; increase the difficulty of regeneration of base exchange materials; may produce physiological reactions such as nausea; are toxic to tropical fish; cause increased corrosivity; and deteriorate the quality of water in distribution systems. They also possess the ability to destroy bacteria and other living organisms some of which are important to biological treatment operations.

Indications are that detergents persist in stream waters for considerable periods and may thus adversely affect coagulation processes in water treatment plants far downstream. There are also indications that detergents may affect results of tests such as the test for biochemical oxygen demand. Solutions to many of the problems created by synthetic detergents are not yet available and a great need exists for the development of procedures for the removal of these substances from our waters.

d. Radioactive Materials

Although radioactive wastes from nuclear power plants, hospitals, research laboratories, and chemical plants processing reactor fuels are not at present a major problem in the United States, nuclear operations may some day become common enough to make radioactive waste pollution a primary source of concern. Numerous major cities are currently monitoring their water supplies to make certain that radioactive contamination does not exceed safe or tolerable levels. This is important since only minute quantities of radioactive wastes can be discharged into surface or ground waters without danger of creating a health hazard.

There are several important differences between radioactive wastes and other common municipal and industrial wastes. Ackerman (1959) states that these differences appear in the degree of toxicity of the contaminants, the rate at which they can be naturally purified in streams, the methods for removal of wastes from plant effluents, and the final disposition of the removed waste materials. In all of these respects, radioactive pollutants are a substantially more serious and difficult problem than wastes previously or presently discharged into receiving waters.

Partial removal of radioactive materials may be had by the common operations of coagulation, sedimentation, and filtration. Straub (1951) also lists the following methods: evaporation, ion exchange (including natural clays), electrodialysis, metallic displacement, solvent extraction, electrolytic separation, biological processes, and crystallization. Removals up to 80 to 90 percent can be expected but these may have little significance from the health point of view because residual radioactivity may still exceed tolerable levels. In addition, the removed radioactive materials are still retained in the treatment plant or discharged in increased concentration in the plant waste effluent.

Without doubt, considerable future effort must be directed towards public control of radioactivity in streams and ground waters. An increasing need for knowledge related to measurement, physiological effects, and methods for reduction of radioactivity in waters is thus of utmost importance.

Conclusions

Waste abatement problems are increasing daily in number and complexity. Pollutants such as synthetic detergents, brines, heat, insecticides, herbicides, and radioactive substances are assuming increased importance. Solutions to many of the modern pollution problems are yet to be obtained and can be developed only through concentrated research efforts. An additional problem results from the fact that even when abatement methods are available, it is not always easy to institute them. As stated by McKee (1960) "There's no great technical or engineering block to building more waste treatment plants. The trouble is getting people to vote bonds. Water issues pass, but sewerage bonds are tough; particularly when it takes a two-thirds vote." Nevertheless, progress is being made and today, without question, man is becoming more aware than ever before of the importance of achieving and maintaining a satisfactory quality in his water resources.

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MUNICIPAL USES, PRACTICES, PROBLEMS

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Introduction

It has been said that the people of the semi-arid western United States appreciate the value of water more than any other group. Certainly to any observer in this area, the line which divides rich land from waste land is a water line and every citizen of this region is aware that water is the key to their present and future economy. Thus, in broad terms, the importance of water to our survival is self evident. The value and use of water, however, is obscured by a vast array of human attitudes and activities and therefore, the basis for its proper and economic evaluation is extremely elusive. Foremost among the usages of water are municipal uses to satisfy elementary human needs. Generally speaking, municipal use constitutes the consumption of water for domestic, industrial, and public purposes.

Factors Affecting Water Use

The relative abundance of water in most parts of the United States has been a basic factor in shaping our patterns of water use. Water has been traditionally free for the taking just as have many of our other natural resources. Only in the semi-arid regions have special practices evolved from a concept of scarcity. In addition to the abundance of freedom of capture, water is usually cheap to transport and handle. The consequence of these and other factors have led to patterns of water uses which are very generous and perhaps wasteful in most parts of the country. As water grows relatively scarce, changes will be required in our water use practices. Public welfare in many areas may require a more restrictive use of water for all purposes.

Effects Of Use On Quality

The quality of water is often affected by the use to which it has been put. This is particularly important from the consideration of its reuse. This phase of water supply is complicated and only a few generalities will be discussed. Domestic use of water generally results in increased amounts of dissolved chemicals and suspended organic materials. Organic pollution can be removed to a large degree by known methods of sewage treatment. The dissolved chemicals cannot readily be removed. The quality of waste water is thus downgraded from domestic use.

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The use of water for industrial enterprises causes a variety of qualitative effects. Cooling water is usually increased in temperature in proportions to the heat it absorbs but with no further harmful effects. Process water on the other hand, is affected by the solution and suspension of waste products of the particular industry involved. Removal of these contaminants can be accomplished in many cases by special industrial waste treatment processes.

Reuse Potential

A subject which is closely related to quality criteria is the general practice of using our streams as waste disposal systems. The widespread use of home garbage disposal units has tremendously increased the amount of waste reaching our streams. Although it is true that large streams can safely absorb some waste, the general practice is detrimental to the quality of our water resources. Probably more water is rendered useless by this practice than through other orthodox uses of water. It would seem that we shall be forced in the future to concern ourselves with this problem to a much greater extent than today. We shall, however, always use our streams to dispose of treated waste water since to do otherwise would mean to deny ourselves the opportunity for reuse of water. It is possible, therefore, to recapture and reuse our used water provided quality standards can be met. The reuse potential of our water resources is important in any analysis of the demand-supply situation. Depending upon the degree of degradation, the standards of quality of subsequent use, and the consumptive losses, we can anticipate varying degrees of reuse. Waters of initial high quality may be used for domestic purposes as much as four or more times. Similar use of industrial use is possible if no serious degradation of quality takes place during each use cycle. Reuse is normally the greatest in regions of relative water scarcity. This also points out that reuse may take place within a plant or may occur at some place far removed from the original use.

Domestic Use

Use of domestic water has grown steadily to record high rates today and will keep on growing with new innovations and technological advances. Although there are variations in use in different regions, these variations are not large because of the relatively uniform standards of living. Local variations can generally be explained by such particular needs as use for irrigation of lawns and shrubs. Price has little effect on use since costs are normally modest and have minor restraints on use. Per capita municipal use for cities in the United States varies from 50 to 500 gallons per day but of this some is for industrial and commerical use. The 1960 figures indicated that the average use was of the magnitude of 130 gallons per capita per day.

Industrial Use

Use of water for industrial ventures varies in the extreme as between products and even between different plants producing identical products. The nature of the use is variable and the effects of the use on the waste water may vary likewise. A few industries such as soft-drink plants and breweries actually use water in their products, as well as in processing. The two major industrial uses are, however, for condenser water and in manufacturing processes. In the latter use, there is a wide range. For example, a canning plant may need only wash water, while paper mills require large amounts of water to suspend pulp fibers and steel mills may require large amounts of water to quench and descale the steel in rolling mill. Industrial use of water is therefore, a complex matter and cannot be easily defined. In the United States, it is customary to use water circulated per manufactured unit as a measure of industrial water use. It is important to recognize that these values are largely controlled by choice rather than necessity. Table I shows some typical industrial water uses.

TABLE I. Typical Industrial Use

Industry	Unit	Typical Use (Gallons)
Steel	Ton	65,000
Paper	Ton	38,000 to 184,000
Refined Petroleum	Barrel	770
Explosive	Ton	200,000
Alumina	Ton	2,200
Aluminum	Ton	32,000
Thermo-Electricity	1,000 kw. hr.	80,000
Synthetic Rubber	Ton	660,000
Hydrogen	Ton	660,000
Carbon Black	Ton	280 Contact Process
		140,000 Furnace Process
Coal Hydrogenation	100 Barrels	730,000
Glycerin	Ton	1,100
Oxygen	1,000 cu. ft.	2,000

Gross Use of Water In The United States And Time Phasing Of Water Requirement

Demands for different type of use such as domestic, industrial, and agricultural vary throughout the year. Agricultural uses especially for irrigation are concentrated during the growing season and when precipitation is deficient. This concentration of demand has very serious effect on water use management. Domestic use increases by about 200 percent of the average in summer time and also shows pronounced changes during the day time. Many industrial uses are relatively uniform although some show seasonal variations such as food processing uses. Water demands may or may not have a fortitous phasing with dependable supplies. This phase of the problem requires detailed studies for each region before intelligent water resources development can be undertaken.

Gross use of water by areas in the United States is shown in Table II. The consumptive requirements have been estimated. These uses have been estimated on the basis of average efficiencies of irrigation in the various regions. Consumptive use of domestic and industrial water has been estimated to vary between 5 percent for humid areas to 10 percent for arid regions. Consumptive use estimates sometime are subject to considerable error.

TABLE II. Fresh Water Use In The United States
(All figures are in MGD)

Region	Gross Use: Domestic	Gross Use: Industrial	Gross Use: Agricultural	Total	Estimated Consumptive Use
New England	710	2,750	50	3,510	180
Delaware-Hudson	1,900	7,660	180	9,740	520
Chesapeake	500	2,610	130	3,240	180
Eastern Great Lakes-St. Lawrence	580	9,940	140	10,660	540
Western Great Lakes	770	13,750	210	14,730	750
Upper Mississippi	490	8,350	320	9,160	920
Southeast	1,020	9,990	840	11,850	890
Tennessee-Cumberland	190	4,690	100	4,980	260
Ohio River	1,140	22,350	280	23,770	1,190
Missouri-Hudson Bay	560	4,410	18,380	23,350	11,070
Lower Mississippi	410	3,550	1,090	5,050	710
Arkansas-White-Red	500	1,990	4,990	7,480	3,140
Western Gulf-Rio Grande	670	3,640	13,560	17,870	9,160
Colorado	170	300	16,430	16,900	10,730
Great Basin	200	270	8,540	9,010	5,800
Pacific Northwest	500	1,450	25,890	27,840	13,000
South Pacific	970	1,350	19,430	21,750	12,800
United States	11,280	99,050	110,560	220,890	71,840

Factors Affecting The Estimates For Future Use

Consideration for future uses of water involves many factors other than merely extrapolation of present demands. Among these factors are a relatively fixed water resource, changing use patterns particularly for industry and agriculture, competition for available cheap supplies of water, regional characteristics of water supply, threatened increased costs for supplimentary dependable supplies and legal problems.

Future Domestic Use

Future uses of water for domestic needs are in part directly related to future population. It is expected that per capita requirements will materially be increased. There is no reason to expect any revolutionary change in the consumption for domestic purposes but such things as more bathrooms per home and greater use of water in connection with air conditioning along with more generous use for established uses, causes a progressively higher per capita demand. By 1980, it is expected that domestic use per capita will be 160 percent of 1960 figures assuming that there is no unforeseen restraint on water supply.

Water being a regional resource, we must consider the probable trend in regional population and estimate where the greatest impact of these needs will develop. Data on increases show a marked increase in the growth of the Pacific Coast states and a continued trend to growth of the medium and large sized cities. Factors favoring trends toward urban and suburban living seem destined to continue. An accurate forecast region by region is beyond the scope of this discussion.

Future Industrial Water Use

In the realm of future industrial water use, we find uncertainty of changing economic factors to be a major effect on the future use patterns. The use of water in the future appears certain to increase at a greater rate than the level of industrial production. The manufacturing methods used and the net effects of such use on the supply situation is important and affects the use patterns. The pressures for the control of industrial pollution are growing and are expected to cause rather remarkable changes in industrial uses and on disposal of waste. Economic and administrative pressures are being generated which will force more conservative industrial water use practices. The net effect of these pressures is very hard to estimate aside from some relief of pollution.

Since one of the major uses of industrial water is for cooling in thermo-electric generation stations, it is important to anticipate trends in this segment of industry. Industrial activity generally correlates with overall power generation and therefore, the latter should indicate to us some index of water demands of industry. The experience of the electric-power industry shows an approximate doubling of power production in each decade. Assuming the same ratio of electric power generation by 1980 as is in present use, we arrive at an index of about 600 percent. By 1980, thermonuclear power stations will probably be commonplace and they will require large amounts of cooling water. Other industrial uses may not require as great an increase in water as that expected for cooling purposes. Taking into consideration the above factors, it is estimated that the industrial fresh water demand by 1980 will be about 400 percent of the present demand.

Gross Future Use--1980

Table III shows the gross estimated water use and corresponding estimates of consumptive use by 1980. These data are crude and have been extrapolated without major concern as to how demands might be met except for those areas which are presently approaching full scale development. In such a case, the limitation of gross supplies is a primary factor for future prediction.

Factors Affecting The Future Use Patterns By 1980

Potential and conflicting forces will affect future water use patterns. Some of these forces are relatively obvious as, for example, costs and availability of supply. On the other hand, legal action and administrative measures are far less apparent. Some of these factors are shown below.

For Greater Use	For Restrictive Use
Population growth	Decreasing quality
Greater per capita domestic use	Increasing cost
Agricultural need	Decreasing relative availability
Economic incentives	Legal restraints
Industrial activity	Administrative measures
Convenience	Trend towards highest use of priority
	Competition by class of use

TABLE III. Estimated Fresh Water Use In United States By 1980
(All figures are in MGD)

Region	Gross Use: Domestic	Gross Use: Industrial	Gross Use: Agricultural	Total	Estimated Consumptive Use
New England	1,570	11,000	500	13,070	880
Delaware-Hudson	5,080	19,100	700	24,880	1,560
Chesapeake	1,410	9,900	1,300	12,610	1,210
Eastern Great Lakes-St. Lawrence	1,820	34,800	600	37,220	2,130
Western Great Lakes	2,410	55,000	2,300	59,710	6,850
Upper Mississippi	1,380	33,400	10,000	44,780	8,450
Southeast	3,740	60,000	8,000	71,740	7,590
Tennessee-Cumberland	600	18,700	1,500	20,800	1,720
Ohio River	3,110	83,800	8,000	94,910	8,350
Missouri-Hudson Bay	1,450	13,200	28,000	42,650	18,200
Lower Mississippi	1,060	17,700	9,500	28,260	5,680
Arkansas-White-Red	1,080	8,000	10,000	19,080	6,890
Western Gulf-Rio Grande	2,420	14,600	12,000	29,020	9,440
Colorado River	780	1,200	14,000	15,980	9,310
Great Basin	630	1,100	7,000	8,730	4,710
Pacific Northwest	2,370	8,700	36,300	47,370	18,800
South Pacific	6,310	4,000	16,000	26,310	11,300
United States	37,220	394,200	165,700	597,120	123,070

We shall seldom find all of these factors dominating the situation at the same time. These forces are evolutionary and we shall experience progressive but constant readjustment in practices. Before restrictions on use become effective, the future demand must exceed the supply.

Industrial Growth And Its Relation To Water Use and Supply

Water is an essential constituent in many products and is a necessary adjunct to most manufacturing processes. Different products require it in different quantities. It is only one of the elements, however, in a long and complex chain to which we call our modern industrial process. It is also one of the items of cost for a particular plant. There must be real overall efficiency in each industrial plant if it is to compete successfully in its respective industry. Therefore, cost and availability of water is an important factor. There can be little question that availability and cost of water will be important to industrial growth and it will have substantial effect in determining the location and manner of operation of new industrial plants.

Physical Problems As Related To Water Use

The extreme variations under which water occurs is a physical fact of great significance. Only through an adequate understanding of these conditions can we effectively meet the problems of use and developments of our water resources. Another physical problem is the effect of large concentration of demand. Where this happens there normally develops a problem of supply because of disproportionate demand over supply. Ideally, demand should be established where supply exists in order to minimize the transport of water from distant sources.

Political Problems As Related To Water Use

To every citizen of the Nation water is important, yet fixing the responsibility of safeguarding water is very difficult. It can be said that water is everybody's problem, and like most problems of this nature, it tends to become nobody's business. Of principle importance in this matter is the fixing of responsibility of several levels of government and private enterprises. In recent years, steps in this direction have been taken as shown by several case-studies. There is, however, a corollary to this problem and that is the education of the population to the true character of the water problems of the Nation. Without this latter enlightment, wise public policy towards conservation of water resources seems impossible. A consequent action stemming from governmental responsibilities is the development and functioning of administrative facilities to carry out public policy and law. There exists a serious lack in this field. No administrative unit of the federal government is now equipped or responsible for the co-ordination and direction of the total federal executive function in water resources, and except for a few western states, there is little counterpart organization at the state level. Lacking federal, state, and local level definition of responsibility, there is bound to be jurisdictional disputes over the conservation and development of our water resources. This is in part due to the lack of common agreement on relative importance of competing uses of water. It is, therefore, important that there be developed policies leading to the most beneficial use of water and that a demand - supply equilibrium be established.

Legal Problems As Related To Water Use

Part of the difficulty we face now and in the future is the confused state of water law and judicial interpretation. Except in a few western states, there does not exist a workable water law at the state level. Serious conflict exists between federal and state laws. Courts have, unfortunately, interpreted law and civil suits on a traditional basis without regard to natural laws affecting the situation. Here again, enlightment of the legal profession is desirable and necessary.

Economic Problems As Related To Water Use

Water is now considered essentially a free commodity to be captured by the most enterprising. It is not priced in relation to value but in relation to cost. It is one of the cheapest commodities in the market today, and we generally disregard its cost in our use habits. In the future, it appears that price will become more of a factor. Future development of water will be more expensive than water already developed because we habitually develop our cheapest resources first. Therefore, we may as well utilize a pricing structure to encourage restricted use of water rather than the contrary which is our practice today. In addition to extra cost for new supplies, we shall face also added costs for disposal and treatment. The net effect of increasing cost is beyond the scope of this discussion, but it is obvious that it will be a factor tending to restrict the use of water. Economic competition for water is partially defeated by legal and administrative measures. This competition is functional and geographic and in the future, we may experience more of it.

Conclusions

Water is used for many purposes, the foremost among which is the use for human needs. Industrial use varies between types of plants and even between plants of the same type. The major industrial use of water is for cooling. All users of water compete for the same basic source of supply. Therefore, when water is in short supply, there is a severe competition for each user to share. Many uses of water are not permanently harmful, and there is widespread opportunity for reuse. This reuse is totally dependent on the subsequent quality and diminution which occurs during each use. Under favorable circumstances several reuse cycles of domestic and industrial waste water can be accomplished. Water uses for industrial and domestic purposes have developed in an environment of relative abundance of water and uses have been very generous.

In the future, such uses will seem wasteful and we can anticipate more restrictive uses. So far, the water use patterns are not affected by price but in the future this might change. Water use is expected to rise in the future and in 1980 it is anticipated that 600 billion gallons per day will be used by our Nation. The major increase in use is expected to be industrial. There is a confused state of affairs in the matter of policy and governmental responsibility in water resources development. The confusion results from a lack of sound body of law and experience. The problems of water resources development have been emerging only in recent years and the citizens are not well informed in all phases of the problem. There is a lack of knowledge of the natural, economic, and political aspects of water resources and little is being accomplished to dispell this ignorance.

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NEW MEXICO SHOULD CONCENTRATE ON ITS NATURAL ADVANTAGES IN ECONOMIC DEVELOPMENT

Jack Lacy[1/]

When a man travels by air across New Mexico he can see the crests of the Rockies until the mountains drop from sight in Colorado and Wyoming.

As you look East, you can see the plains stretching alongside the mountains from horizon to horizon.

But if you look for other men, you will see them clustered, as at an oasis, in communities that lie along the slopes of the Rockies from Montana to Mexico.

In this area of the Rocky Mountains and the Great Plains, man has confronted the forces of nature with practically no comprehension of their meaning for his life, and his adjustment to the realities of his environment has been seriously incomplete.

For the central fact is that the area is in a partially developed, semi-arid hinterland, while for the most part the local human settlements have borrowed their ways of life from quite different environments...from the humid East Coast, the interior manufacturing areas, the corn belt, and the agricultural South.

This borrowing has made the internal workings of these communities very similar to cities in the rest of the country. Traffic entaglements, frustrated planning efforts, housing congestion and zoning inconsistencies are common problems in most cities.

But the impact of the semi-arid environment has posed special difficulties and suggests distinctly different solutions from those relevant to other parts of the nation.

In the mountain-plains area men faced periodic shortages of water, but doggedly planted heavy green lawns and water consuming trees, preferring to consider wet years as normal years. They largely ignored the splendid building materials of the area (rock and earth) and erected wooden houses which are blasted by sand and wind.

We do not assume that man, like a chamelon must assume the coloration of his surroundings. But we assert that the natural forces of the mountain-plains area are extremely powerful, and a failure to accept their restrictions as well as their opportunities will cause continuing distress. The efficient use

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of water, for example, is indispensable to sustained population growth in the area.

What sort of adaptations and inventions, then, might permit the most efficient use of the physical and human resources of the area?

The Civic Design Study recently completed research, done under a Rockefeller Foundation Grant at Colorado College, set about to answer some of these questions.

The answers are predicated on the assumption that certain conditions in the mountain-plains area are likely to continue for some time. These conditions include a continued rapid growth of population and continued water shortages.

Their suggested solutions fall into two major categories:

1) For optimum future development, the mountain-plains area should concentrate on its natural advantages and natural resources as a specialized service and recreational area for the rest of the nation.

2) The area should serve as a model for the advancement of other semi-arid regions of the world and as a laboratory for experiments in living designs for these other regions. What we do to develop the mountain-plains area will be watched with great interest by such places as Africa and the Middle East.

The arid or semi-arid feature of New Mexico is not unique to our particular State. It is a feature shared, incidentally, by over three-fourths of the world's land area located in the same latitude belt. Strangely, many writings about the history, law, economics or literature of the region have tended to ignore the fact of aridity or to discount its importance.

Most of the water available to the area falls in the rugged mountains, where it cannot be used effectively. Even if the mountain water can be used, there is the problem of transporting it effectively to the places where it may be used. The largest water users are the cities and the farming regions east of the Rocky Mountain water basins.

To move the water from the mountains to the plains, it must be transported through a complex of trans-mountain tunnels and aqueducts, stored in reservoirs and then distributed through pipes and ditches to the cities and farms.

The expense of this gigantic supply system is almost prohibitive.

Only through the massive infusion of federal government funds have some of the most important projects been possible.

Moreover, Congress has frequently balked at further support of water diversion projects because more water in the farm fields means more farm crops. More farm crops mean bigger surpluses, and the political delemma is compounded rather than resolved.

Litigation continues as dehydrated cities raid the mountain slopes in search of additional water.

Added to the problems of competition is a foreseeable upper limit on the available water. The United States Select Committee on National Water Resources estimates that by 1980 the four major river basins involved in the mountain-plains area will be developed to their maximum extent.

As with the use of land when the frontier was closed, any new water using activities will then be possible only at the cost of other water consumers. Who then, will give in? When the question arises, most eyes turn nervously but ominously to the greatest water consumer of all, the farm and the water then becomes its most valuable resource.

One partial solution may lie in the more efficient use of existing water. Cities can do substantially more to reuse water to cut runoff to a minimum. The farms may benefit from further exploration into ground water prospects or from scientific breakthrough in the desalinization of water. But the weight of the evidence indicates that better administration and technology will only mitigate and not resolve the basic issue of water supplies.

It is only natural that residents of the mountain-plains area want to have the same kind of economics that have brought prosperity to other sections of the country.

This is why we so many times find our efforts leading to the dubious conclusion that what will work in Syracuse, New York, will work in Santa Fe, New Mexico.

Barring radical shifts in population trends in the mountain-plains country will expand population two to threefold by the year 2000. Too often the assumption has been that the kind of economy that has supported growth elsewhere will support this anticipated growth on the mountain-plains.

But evidence is that there are environmental impediments to certain kinds of economic activity in the area.

The potential instability of so many parts of the economy has thus led some observers to the conclusion that industrial development is the most satisfying answer to the call for economic prosperity.

New industries bring in new people with big payrolls. The people need places to live; new houses, new stores, and new service to follow naturally.

Lured by this enchanting prospect, delegations from mountain-plains cities have roamed the nation in search of restless business.

In the short run the reticence of industry to throw its lot with the mountain-plains cities is partially explained by the excessive distance of the area from the major markets of the country.

And, despite the wealth of natural resources which have been extracted from the area, the heavy manufacturing industries have always sought to build up their business in close relationship to heavy eastern consuming centers. The present expansion of industry to the West Coast and the Gulf Coast follows the pattern of this relationship to population and marketplace.

In addition, land-locked hinterlands with unnavigable rivers suffer from the lack of cheap water transportation. Further, freight rate discrimination and an inadequate skilled labor force tend to hamper industrial development.

Hovering over these short-run factors is the long-run spectre of inadequate water supply. Industries requiring huge quantities of water are reluctant to settle where their most essential commodity may be depleted over a period of years.

Certain industries--the so-called "clean" industries such as electronics and aerospace firms--have found the mountain-plains much more compatible with their interests.

Water supplies and freight differentials are not so crucial in light industry, and the employees of such firms enjoy living in impressive mountain surroundings.

In spite of the obvious difficulties in the regional economy, the growth of the area is unmistakable.

New Mexico with its thirty-nine percent population increase in the last decade ranks seventh place in the nation's growth and enjoyed comparable jumps in prosperity.

But the central question is this: Will the residents of the region expend their energies in search of industries which pose difficult problems in this kind of environment...or will they listen to the dictates of their land and pattern their economic livelihood in a way which recognizes the realities of water, weather, and geography?

The environment sets fairly narrow limits on large-scale industrial development; however, certain industries are highly suitable to the area. These are the high-cost, low volume industries such as production of electronic equipment and advanced scientific research centers.

A beginning has been made in establishing businesses of this sort, but the surface has barely been scratched.

These enterprises tend to hire personnel with more education, at a higher rate of pay than heavy industry, and such people demand expensive cultural facilities.

At the same time we must continue exploration and development of minerals and recreational resources.

Despite the 600,000 acre feet of water being developed in the San Juan-Chama area, and another 200,000 acre feet expected to be available through the Canadian River development which was started by the construction of the dam at Logan we should never expect New Mexico to be the location of heavy industry demanding tremendous quantities of water. These new sources of water supply will serve as insurance to serve the human needs of an ever-growing population which will continue to boom and grow on the basis of selective industrial development and recreation expansion.

Never forget that our State has been growing at the rate of 27,000 per year, based on gains from 1950 to 1960 and we have no reason to believe this has changed.

This means we will pass the million population figure by the end of this year 1962, and by 1970 we will count nearly a million and a half persons living in the Land of Enchantment.

The demand for municipal water and recreational will be ever-increasing and these demands are being met by the far-sighted planners, engineers, and law makers who have carefully put together a continuing program to keep pace with growth.

USES PERMITTED AND CONTROL ON USES
Under the General Topic of
Physical and Economic Trends in Beneficial Uses of Water

Frank E. Irby[1/]

"Physical and Economic Trends in Beneficial Uses of Water" is the general topic of the first item of the program this morning. "Uses Permitted and Control on Uses" is the subject of my remarks, under the general topic.

In order to avoid confusion it is necessary to define the word permitted. In the sense used here the word means all uses within the legal concept of the law. The Constitution, the Statutes, and the Courts of New Mexico state that beneficial use is the basis, the measure and the limit of the rights to the use of water. The Constitution and the Statutes are based on the doctrine of prior appropriation which means that first in time is first in right. Appropriations which will detrimentally affect existing rights are prohibited.

In conformity with the theme of this conference "Water in 50 Years of Statehood--With a Look to the Future," I will begin with the situation in 1912, or as nearly thereto as historical information available to me will permit.

In 1912 public waters were being used for agriculture, industry and municipal and domestic purposes. The United States Census has reported that 461,718 acres of land were under irrigation in the year 1910. I have been unable to find a figure for the year 1912, so I will use the 1910 figure, 461,718. It is assumed that the water used per acre, statewide, was 2.0 acre feet per year which computes to be 923,436 acre feet for the year.

Industrial uses in 1910 included manufacturing, power, mining, milling, and smelting, lumbering, and water for transportation facilities such as railroads. I have been unable to obtain any statistics, if they exist, concerning the amount of water which may have been used by these industries at that date. Municipal and domestic uses of water at the time New Mexico was admitted to statehood, exclusive of any water used for minor industries, have been computed. In making this computation, I have used the United States Bureau of Census figure for the population of New Mexico which in 1910 was 327,301 persons, and have assumed that the per capita use was 50 gallons per day. Using these figures and this method of computation, I have found that 18,331 acre feet

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per annum were used in municipal and rural domestic consumption. This added to the 923,436 acre feet of agricultural use gives a total accountable use of 941,767 acre feet.

Data for uses in 1962 are not available. However, reasonable assertions can be made by the use of the data contained in New Mexico's statement to the U. S. Senate Select Committee on National Water Resources (September 1959).

It is estimated that there are approximately 960,000 acres irrigated now. The estimated depletion is 2 acre feet per acre which gives a total consumptive use of 1,920,000 acre feet by irrigation.

Municipal, industrial, and rural non-agricultural consumptive use in 1962 is estimated at 110,000 acre feet.

Based on these figures we have a total consumptive use of 2,030,000 acre feet for 1962.

Therefore, consumptive use for irrigation has increased by about 110% during the period of statehood, the consumptive use for municipal, industrial, and rural non-agricultural use has increased by 500%, and the increase in all consumptive uses amounts to 115%.

Please bear in mind that these figures are based on what are considered to be reasonable estimates and that reliable statistics to make such computations could not be found.

Control on Uses

As stated in my earlier remarks, New Mexico water law is based on the doctrine of prior appropriation for beneficial use. The basic surface water code under which the State Engineer administers the water of this State became effective on March 19, 1907 and has been amended, to at least some small extent, by almost every regular legislative session since that date. The basic groundwater code became law in June 1931, after the ground-water laws passed in 1927 were declared unconstitutional by the courts. This 1931 code also has been amended from time to time by our legislature. All of the waters of the State of New Mexico are declared to be public waters and the foundation law, as we might say, is very similar, for both ground and surface water. Agricultural rights are appurtenant to specifically described lands and may not be servered therefrom without the consent of the owner.

I will discuss control on uses of surface water first.

Creation and change of water districts and sub-districts and appointment of a watermaster to administer the surface waters thereof in accordance with the decrees of the courts and the permit issued by the State Engineer are authorized by statute. Five (5) such districts have been created and are presently being administered by the State Engineer.

All surface water rights initiated prior to 1907 were recognized as vested and existing rights by expression of the legislature. Declarations of these vested and existing rights are accepted and filed by the State Engineer; and are considered prima facie evidence of the truth of their contents. Appropriation of water, construction of storage or diversion dams, or canals, change of place or purpose of use of water and change of point of diversion after 1907 can be accomplished only by application to and permit from the State Engineer.

Plans and specifications must be filed and approval of the State Engineer obtained therefor if the dam exceeds 10 feet in height above the lowest natural ground surface elevation, or impounds more than 10 acre feet of water, except for stock dams whose maximum storage capacity does not exceed 10 acre feet, and works designed solely for silt retention which do not impound or divert water.

The application must be advertised once each week for three consecutive weeks and a period of ten days must elapse before action is taken by the State Engineer. If such applications are protested before the end of the ten-day waiting period, the State Engineer must hold a hearing and render his decision on the basis of the information available after the hearing. If no protest is filed, the State Engineer may act on the application at the end of the 10-day period following advertisement. In order to approve the application, it must be determined that unappropriated water is available for the beneficial use applied for and that no existing right will be detrimentally affected thereby. Any decision of the State Engineer may be appealed to the District Court in 30 days after it is rendered, if the aggrieved party so desires. If no appeal is taken before the expiration of the 30 days, the State Engineer's decision becomes final.

Headgates and measuring devices may be required by the State Engineer if he deems it necessary for the measurement and apportionment of the water.

Forfeiture of a water right occurs after four consecutive years of non-use unless circumstances beyond the control of the owner have caused non-use, such that the water could not be placed to beneficial use by diligent efforts of the owner and unless the lands are officially in the Soil Bank.

Unauthorized use of water to which another person is entitled, or the willful waste of water to the detriment of another or the public is an illegal act.

Within the external boundaries of irrigation districts and conservancy districts the delivery and apportionment of water is a function of the officers of the district. The authority and duty of the State Engineer in such districts pertains generally to the total diversion of water, the points of diversion, the storage of water and the safety of the structures.

Section 75-14-60, New Mexico Statutes, deals with ditches or acequias and exempts the officers of public community acequias established and in operation prior to March 19, 1907 from making any application to, or obtaining any permit from, the State Engineer in order to change place of diversion; Provided that by such change no increase in the amount of water appropriated shall be made beyond the amount to which the acequia was formerly entitled.

Now I will discuss the control on uses of underground water.

The laws governing the appropriation and use of Underground Waters and the drilling of wells were passed by the 1931 session of the Legislature, as mentioned in my general remarks.

The general basic laws, which apply to surface water and have been related previously, are also applicable to the groundwater law. This refers to the waters being the property of the public, to the appropriation doctrine, to the requirement that the use be beneficial and to the statutes which prohibit the impairment of existing rights. Although the basic law covers the entire state no jurisdiction in the administration of the law is assumed by the State Engineer except in basins which have been declared by him. Nineteen basins have been declared and are now administered by the State Engineer. The statutes provide that applications for domestic and stock use, properly submitted to the State Engineer, shall be approved. It is necessary that a person, firm or corporation desiring to appropriate water, other than for domestic and stock use, make application to the State Engineer and advertise the application and if objection is entered go through a hearing before the application can be acted upon as in case of surface water. Rights initiated prior to the enactment of the 1931 groundwater laws were recognized as vested existing rights by the expression of the legislature. Changes of place or purpose of use of water and change of location of well are provided for in the statutes upon the showing that such a change or changes will not impair existing rights. As in the case of an original appropriation it is necessary that application to, and permit from, the State Engineer be made. Advertisement, hearing and decision are necessary in these cases if the application is protested, the same as in surface water law. Also the State Engineer's decision must be made on the basis of the information before him after the hearing. As in the case of surface water, the State Engineer's decision becomes final within 30 days after it is rendered unless appealed to the District Court by an aggrieved party.

Permits are also granted to drill and pump wells in lieu of taking surface water provided the granting of the permit will not impair existing rights of others. A surface water user may desire to transfer only a portion of his surface water right into such a well and this is also permissible if the conditions are such that impairment will not occur to existing rights.

Permits granted for a change of purpose in the use of water must be computed on the basis of the water consumed by the different uses. For example, in irrigation an appreciable amount of water is returned to the ground water system and thereby to the entire drainage system. This may vary in different localities because of the difference in texture of soil and other reasons. Returns from most municipal uses are measurable because they necessarily go through sewage plants and the effluent therefrom can be measured. Returns from most industries, such as power production, manufacturing, etc., are measurable both in quantity and quality. Returns from construction, such as highways and airports, are so insignificant that they are not measurable.

Declarations of rights to beneficial use of water which were initiated prior to the declaration of a ground-water basin or extension thereof are accepted and filed by the State Engineer and are considered prima facie evidence of the truth of their contents.

Forfeiture of a water right after four consecutive years of non-use also applies to the ground water; however, the exceptions to forfeiture are slightly different than those stated in the surface-water statue. Upon applications to the State Engineer and a proper showing of reasonable cause for delay, the State Engineer shall have the power to grant extensions of time, not to exceed a term of one year for each such extension, in which to apply to beneficial use the water for which a permit to appropriate has been issued or a water right has vested, was appropriated or shall have been adjudicated; Provided, further, however, that periods of non-use when irrigated farm lands are placed under the acreage reserve program or conservation program provided by the Soil Bank Act (Public Law 540, 84th Congress) shall not be computed as part of the four-year forfeiture period; Provided, further, however, that period of non-use when water rights are acquired and placed in a water conservation program adopted by an Artesian Conservancy District shall not be computed as part of the four-year forfeiture statute.

Removal of underground waters from the State of New Mexico to any other state is prohibited, except that water produced in New Mexico may be transported to another state by tank truck where the water is used for exploration and drilling of oil and gas. The owner of the well from which the water is withdrawn shall have the duty to acertain that the water exported is used only for the above purposes and such owner shall keep and maintain accurate records of the amount of water withdrawn and make such records available to the State Engineer upon request. The amount of water withdrawn from any one well for such exploration shall not exceed 3 acre feet.

Drilling of wells in any basin declared by the State Engineer of New Mexico is prohibited unless the driller has been licensed by the State Engineer. Drillers licenses are subject to revocation for failure to comply with the laws governing the drilling of wells.

Under certain conditions the owner of a water right may drill and use a replacement well drilled within 100 feet of the original well, prior to application to the State Engineer, and the publication and hearing. He must file application or notify the State Engineer Office of the facts and the location of the proposed replacement well by registered letter prior to drilling, and he must file application for a permit within 30 days after drilling commences.

The owner of a water right may drill and use a replacement well drilled more than 100 feet from his original well after making application but without waiting for the completion of publication and hearing; Provided the State Engineer finds that the change does not impair existing water rights and grants him a permit authorizing the drilling and use of the replacement well prior to the publication and hearing.

Under certain circumstances, the owner of a water right may drill and use a supplemental well after making application but prior to publication and hearing if the State Engineer finds that the supplemental well does not impair existing rights and grants him a permit authorizing the drilling and use of the supplemental well.

When the State Engineer has declared an underground water basin, which shall include an area in which any person has drilled a well or wells either for production purposes or as test wells and has proved the existence of underground waters in such a basin with the intent at the time to establish or augment a water supply for beneficial use, or when the State Engineer shall hereafter include such an area within the boundaries of an existing underground water basin, such a person shall have 90 days from the date of first declaration of such a basin, or its enlargement, by the State Engineer, in which to file with the State Engineer plans for the development of such water for beneficial use in accordance with such intent. Such plans shall set forth all information required by the State Engineer to judge the matter.

The State Engineer upon application of such a person prior to the expiration of the time limitation, may grant an extension or extensions of time for application of water to beneficial use and for the development of water according to the plans so filed.

After the filing of the plans mentioned above with the State Engineer, such a person shall have the right to proceed with the development of such water for beneficial use in accordance with the statutes and subject to the limitation imposed by the act. Before placing any such well on production or drilling any additional wells in such a basin or extension, the person shall make application to the State Engineer for permit to do so and for the appropriation of waters to be produced therefrom. The application shall be executed on forms furnished by the State Engineer and set forth all pertinent information required on the form. Advertisement of the proposal shall be made in the same manner as on all other applications required to be published. A 10-day period in which protests may be filed must elapse before the State Engineer can take action on the application. If a protest is filed a hearing must be held by the State Engineer as in the case of other protested applications. If, after such a hearing, it shall appear that there are no unappropriated waters in said underground basin or that the proposed appropriation would impair existing rights the application shall be denied. Successive applications within the limit of the intent of such a person at the time of drilling the intial well or wells, as such intent shall be determined by the State Engineer, may be made and filed with the State Engineer and each such application shall be treated separately by the State Engineer and notice thereon shall be given and hearing thereon shall be had and determination with respect to the allowance thereof shall be made as provided above. No right to the use of water under this act shall rest in any person until after the granting of the permit and application of the water to beneficial use.

THE CONSERVATION AND BENEFICIAL USE OF WATER
Under the General Topic of
Physical and Economic Trends in Beneficial Uses of Water

Lloyd E. Myers[1/]

Introduction

Conservation and beneficial use are synonymous terms although this may not be immediately apparent. Beneficial use is defined in the dictionary as a use which is advantageous, profitable, or directed toward a good end. Conservation is defined as preserving, protecting, or keeping in safe or entire state. Common usage in the natural resources field has extended the definition of conservation to mean protection against waste. Since waste can hardly be defined as a beneficial use, the basic principles defining the beneficial use of water should coincide with the basic principles of water conservation. There may be some disagreement concerning the definition of waste.

Some of us have been guilty of using a double standard, based on personal interests, in defining water waste. Irrigated agriculture has been a favorite whipping boy in the water resource field and has been accused of wholesale waste of vast quantities of water. These accusations are based on calculations which assume that any water diverted or pumped for irrigation which is not specifically required by the crop plants is waste. We might examine domestic water use in the same light. Studies have been made which indicate that the minimum essential amount of water required for domestic purposes is 20 gallons per capita per day. Reports of the Senate Select Committee state that average domestic use in the United States is approximately 60 gallons per capita per day. If we apply the same criteria to domestic water use that have been applied to irrigation water use, we can say that two-thirds of the water used for domestic purposes is not essential and can be classified as waste. This latter statement will be disputed on the grounds that the water used, although not absolutely essential, is being used beneficially and is not being wasted. The same argument can be made regarding irrigation. Most disagreement will relate to defining the amount of water which can be used above that which is absolutely essential before the increased use can be defined as waste. Regardless of all other considerations, it should be clear that the same basic beneficial use criteria should be applied to all water use, whether it be industrial, domestic, agricultural, or recreational.

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Water Supply Problems

Means of obtaining higher degrees of beneficial use have, for many years, been of concern to numerous individuals working in the water supply field. The general public has more recently begun to be concerned with water supply problems by virtue of being bombarded with stories, statements, and advertisements which imply that the United States is in imminent danger of catastrophic shortage. The situation is confused by occasional statements which imply that there is no national water supply problem at all. The reason for these conflicting statements is quite simply the fact that although we do have many local water supply problems, the United States as a whole is not in any real danger of running out of water. There are certain areas which are short of water. Thirty-four percent of the land area of the United States is classified as arid or semi-arid. The water supply problem in these regions is compounded by the fact that low precipitation is accompanied by low runoff percentages. Less than 10 percent of the already low precipitation in the Colorado River Basin appears as runoff in the Colorado River System. There are, however, water supply problems facing other regions where rainfall is high. There are water supply problems on the lower reaches of the Mississippi River in the state of Louisiana where annual rainfall is approximately 55 inches and the entire flow of the Mississippi River would seem to be available. Water supply problems are not necessarily related to available rainfall but are related instead to the management and use of the supplies that are available.

A universally proposed solution to water supply problems is the development of new water supplies. These are proposed in several different ways. One approach is the design and construction of conventional water diversion, storage, and distribution projects which are based on thoroughly tested principles and methods. Development of new water supplies has also been proposed through an approach which might be classified as the hopefully pending scientific breakthrough. These proposals usually relate to the modification of weather to increase rainfall or to the low-cost removal of salt from sea water. These latter approaches have had great popular appeal and the public, not recognizing the nature of the scientific and engineering problems involved, has perhaps expected too much too soon. At the present time, no scientific breakthroughs have occurred and our hopes for the development of completely new water supplies must at the moment depend upon the conventional approaches.

Essentially new water supplies can also be obtained by water conservation. There are many opportunities for reducing the present loss of water on forest and range lands, in agricultural use, and in municipal and industrial use. Although these opportunities have always existed, water conservation has been an unpopular subject and has received little national attention. This is because of the understandable reluctance of any and all water users to admit that they may be wasting some water. Increased attention to water supply problems is rapidly reversing this attitude, and it is now becoming evident that water conservation will soon play a major role in the solution of our water supply problems.

Opportunities for Water Conservation

Forest and range lands occupy over one-half of the land area of the United States. Non-beneficial evaporation and transpiration from these lands represent tremendous quantities of potentially available water, particularly in arid and semi-arid regions. On an average basis for the United States, approximately two-thirds of the precipitation never reaches the stream channels but returns directly to the atmosphere through evaporation from soil and plant surfaces. There are many opportunities for recovering a considerable portion of this water. A summary of studies conducted throughout the world indicates that, on the average, runoff does not occur from brush or forest covered lands until precipitation exceeds 16 inches annually. Average runoff from grassed areas is about nine-tenths of the precipitation in excess of 11 inches. This indicates that runoff from areas with precipitation in excess of 11 inches can be increased by replacing brush with grass. Vegetation management is an extremely complicated subject, and the successful implementation of this practice will require the development of a vast amount of new information concerning watershed hydrology and plant-soil-water relationships.

Conservation of precipitation can also be obtained by the treatment of selected areas to increase rainfall runoff. The potential value of this practice, which is called water harvesting, can be illustrated by pointing out that 1 inch of rain produces 5.6 gallons of water per square yard. Ten inches of rain on 1 square yard will fill a 50-gallon barrel with 6 gallons left over. Rainfall in New Mexico averages 84 gallons per square yard. Average rainfall for the continental United States is 170 gallons per square yard. It becomes obvious that a relatively small area of waterproofed soil can produce large volumes of water. Recent research indicates that water harvesting areas can be constructed for an annual cost of 2 cents per square yard. This means that in a 10-inch annual rainfall area water can be produced for 36 cents per thousand gallons. Continued research should lower costs to the point where water can be produced in the state of New Mexico for an average cost of 45 dollars per acre-foot or less. Water harvesting areas can be constructed above existing reservoirs or ground-water recharge areas to take advantage of existing distribution systems. They can also be constructed in any size, shape, or color to avoid scenic damage and can utilize lands which have little or no value for domestic animals, recreation, or wildlife.

Present knowledge indicates that any useful reduction in agricultural water use must relate primarily to irrigation. Evaporation losses from large reservoirs, chargeable in part to irrigated agriculture as well as to hydroelectric and urban water uses, are estimated to total about 12 million acre-feet per year. Attempts to reduce these losses by use of monomolecular films have not been encouraging. There appears to be a good possibility, however, that monomolecular films may be utilized to reduce the estimated 3,400,000 acre feet of evaporation which occurs from stock ponds and small lakes in the 17 Western States. Conveyance losses from canals in the 17 Western States total approximately 20 million acre feet annually. This loss will be reduced through the development of economical canal linings and seepage reducing treatments. Water losses incurred in the application of irrigation water to fields totals approximately 30 million acre feet annually. This loss occurs largely because the irrigator has not been provided with the information or equipment required for efficient water application. This loss can be greatly reduced through the development of improved methods for the design of farm irrigation systems, practical and reliable methods for measuring soil moisture and scheduling irrigations, and practical devices for automatically controlling, measuring, and applying irrigation water.

The possibility of reducing domestic water use has been mentioned. This use will not be decreased if water is distributed solely on ability to pay, as is sometimes proposed. It would seem that factors other than ability to pay must be considered where portions of the national economy are artifically controlled. Regardless of arguments on this point, domestic water use can be reduced if necessary. There is also room for conserving some of the water presently used by municipal public agencies for washing streets and watering parks at an average national rate of 25 gallons per capita per day. There is little question but that industrial water use can and will be lowered as the situation demands. Industry is considerably more susceptible to economic and regulatory pressures than are municipalities and agriculture; and for this reason, industry has already made great strides in modifying various processes to use less water or to use water of lower quality. Little information is available concerning opportunities for water conservation in the field of recreation. Recreation should not be exempt from the general responsibility for maximum beneficial use of water supplies. Means for producing the maximum amount of fish, game, water sports, and other recreational products with minimum loss of water for other users must be of concern.

Water supply problems associated with urban water use, which includes domestic, industrial, and public use, now relate primarily to pollution. It has been stated that only about 2 percent of the water diverted for urban use is consumptively used. About 98 percent of the water withdrawn for urban use is reported as returned to the streams or lakes. It should be recognized that pollution is sometimes so severe that the cost of purifying the water is greater than the cost of developing completely new supplies. Such polluted water must then be considered to have been completely consumed, since it is unfit for other uses. Moreover, upstream water withdrawals are limited by the necessity for leaving enough water in the rivers to dilute upstream pollutants so that there may be some downstream use. Considerable attention is being paid to reclaiming sewage effluents, and rapid progress in this field can be safely predicted. Many of the sewage pollutants are potentially useful substances which can be used for a number of purposes including the production of energy or food for animals.

Problems in Water Conservation

Although mankind has used, handled, and studied water for many thousands of years, progress in the field of water conservation is seriously hindered by the many things we do not know about water. We do know the arrangement of hydrogen and oxygen atoms in water molecules, and we do know the molecular structure of bulk water and ice. We do not know how water molecules are arranged when they are in close proximity to soil particles. Because of this, we do not know exactly how water moves through soil. This problem may not bother us too much in designing filter beds for water treatment, but it bothers us considerably when we try to measure and predict such things as the infiltration of water into soil or the evaporation of water from soil. We do not have sufficient knowledge about the physical state and dynamic behavior of water in plants, and this causes some trouble in determining the actual requirements and use of water by plants. We do not know very much about the physical properties and dynamic behavior of water flowing in thin sheets over rough, porous surfaces. This knowledge is needed for progress in irrigation, soil erosion, and water supply hydrology. There are other things we do not know about water and its physical behavior.

Accurate measurement is necessary for the efficient planning, development, and management of water supplies. Our present accuracy in water measurement leaves much to be desired. Precipitation data are inadequate in many regions of the United States because of physical and financial problems involved in the use of present measurement techniques. Measuring, tracing, and predicting the movement of water into and through soil is now largely qualitative rather than quantitative. Evaporation from water, soil, and plant surfaces cannot be directly measured in the field. These measurements are required for many purposes including the determination of potential versus present yield of water from a watershed. Existing methods for measuring the flow of water in pipes and channels are inadequate. Flow measurement in natural streams is often only an intelligent approximation rather than an accurate measurement. Flow in large pipes and artificial channels is measured with limited accuracy because of the difficulty of calibrating large measuring structures in place. The problem may be emphasized by pointing out that most water measuring devices used today are copies or minor modifications of devices designed more than 50 years ago. Accuracy which was good enough when water was plentiful is not good enough today.

Water conservation is materially influenced by legal decisions on water rights. This complicated and argumentative subject will only be acknowledged and will not be discussed except to point out that sound legal decisions must be based on sound information. Here again the basic problem relates to the development of better information so that legal decisions can be based on proven facts rather than beliefs or opinions.

The attitudes and knowledge of the ultimate user, the so-called average citizen, will often determine whether or not we are to achieve the optimum beneficial use of our water supplies. It is unfortunate that the average citizen does not usually appreciate his personal concern with water supply management until water stops coming out of the faucets at home. This is not because he is not interested but because he has not been properly presented with the facts. Perhaps this is a job for the Madison Avenue advertising firms, but I doubt it. I believe that is a job which must be recognized and accepted as a collateral responsibility of all agencies, groups and individuals working with water resources. Among other things, we need a water conservation counterpart of that famous forest conservationist, Smoky Bear. The average citizen will support the water supply programs, projects, and research if he understands the need for them. We must pay more attention to informing this average citizen, for the problems will not be solved without his support.

Outlook

An impartial evaluation of the evidence at hand indicates that the United States, as a nation, will not suffer any catastrophic shortages of water. Estimates which have predicted such shortages have erred in several ways.

1. These estimates have assumed that our presently luxurious use of water will continue and that in some instances water will be used with less efficiency than it is today. This assumption will certainly be wrong if serious water shortages develop. Although little effort has been directed toward increasing water use efficiency by municipalities, agriculture, and industry, much greater efficiency can be achieved through the application of existing knowledge.

2. These estimates have made no allowance for research progress in the fields of water supply development and management. Research and development now underway is gradually revolutionizing these fields. Although our research on water is not well publicized and does not appear as glamorous as space technology, our scientists and engineers are quite competent and are doing some amazing work. The principles and techniques of sonics, nuclear physics, physical chemistry, electronics, surface chemistry, plant physiology, micrometeorology, hydrodynamics, analogs and high speed computors are being skillfully applied to solve problems as complex as anything encountered in space technology. Radically new materials and machines are being developed by industry to help solve our construction and maintenance problems. We can be certain that this work will not only increase the efficiency in use of existing water supplies but will permit us to develop new sources of supply.

3. A major source of water supply which has received too little attention is the precipitation which is now lost to non-beneficial evaporation and transpiration. Calculations of maximum available water supplies have been based on the national average streamflow of about 1,200 billion gallons per day. These calculations assume that we can do nothing about the 3,000 billion gallons per day lost to evaporation. We can and will capture part of this water by means of vegetation management and water harvesting. How much we capture will depend upon seriousness of our need for additional water.

Summary

Conservation and beneficial use of water are both based on the same principle - the reduction of waste in the use of our water resources. Although there may be differences of opinion concerning the definition of waste, there is no doubt that present water use efficiency can be increased by all users. There does not seem to be any reason to expect a disastrous national water supply problem. Application of the principles of conservation and beneficial use and the application of new knowledge to develop new water supplies can solve any foreseeable water supply problems. Catastrophic water supply problems can develop only if the people responsible for water supply development sit on their hands and do nothing. This will never happen.

ECONOMICS OF BENEFICIAL USES OF WATER
Under the General Topic of
Physical and Economic Trends in Beneficial Uses of Water

H. R. Stucky[1/]

The assigned topic, Economics of Beneficial Uses, is one of three subjects in this section of the program being discussed under the general heading, Physical and Economic Trends in the Beneficial Uses of Water. The legal and the economic basis for the value of water in New Mexico will be considered under the concept of "Beneficial Use" as established by the laws of New Mexico and legal discussions and practices which have been followed in the allocation of water rights.

Before considering economic use we should understand the importance of the term "Beneficial Use" in the laws of New Mexico as applied in the Doctrine of Appropriation.

The Territorial Supreme Court in 1898 - stated that "The law of prior appropriation existed under the Mexican Republic at the time of the acquisition of New Mexico, and one of the first acts of this government was to declare that the laws heretofore in force concerning water courses shall continue in force, as stated in the Kearny Code of September 22, 1846."

The New Mexico state constitution signed January 6, 1912 among other items, states four points quite clearly as follows:

(1) All existing rights to the use of any waters in the State for any useful or beneficial purpose are hereby recognized and confirmed.

(2) The unappropriated water of every natural stream, perennial or torrential, within the State of New Mexico, is hereby declared to belong to the public and to be subject to appropriation for beneficial use, in accordance with the laws of the State.

(3) Priority of appropriation shall give the better right.

(4) Beneficial use shall be the basis, the measure and the limit of the right to use of water.

1/ Professor and Head, Department of Agricultural Economics and Agricultural Business, New Mexico State University and Chairman of the New Mexico Water Conference Committee.

The 1931 act, Ground Water Legislation, replacing one passed in 1927, declares that "The water of underground streams, channels, artesian basins, reservoirs, or lakes, having reasonably ascertainable boundaries, are hereby declared to be public waters and to belong to the public and to be subject to appropriation for beneficial use."

Beneficial use is declared in the 1931 Ground Water Act to be "the basis, the measure, and the limit to the right to the use of the waters" described in the act.

Waste of Water

The State Court said in 1914 - "No one is entitled to waste water. When his requirements have been satisfied, he no longer has a right to use the water, but must permit others to use it." This allows the junior appropriator to use the excess above the prior appropriator requirements.

An ammendment of the appropriation code in 1955 provided that - "In issuing permits to appropriate water for irrigation.....the State Engineer shall permit the amount consistent with good agricultural practices and which will result in the most effective use of the available water to prevent waste."2/

We see from the constitution and from the State law that:

(1) All existing rights of prior appropriation were recognized.

(2) Unappropriated water in streams and ground water were declared to belong to the public.

(3) That these waters are subject to prior appropriation for beneficial use. And

(4) that beneficial use shall be the basis, the measure, and the limit of the right to the use of water.

There are many "beneficial uses" recognized by either court decisions or legislative action in New Mexico. Among these uses are:

Irrigation, Mining and Other Beneficial Uses. A Federal Court stated that the appropriative rules were applied by the earliest settlers to the uses of water for "irrigation, mining, and other beneficial purposes."

2/ The above quotes are from Wells A. Hutchins, LLB (Production Economics Research Branch, USDA). The New Mexico Law of Water Rights, published by State Engineers Office in cooperation with Production Economics Branch, USDA, as Technical Report No. 4, Santa Fe, New Mexico - 1955.

Stock Water. The Supreme Court has held that the use of water in stock raising is a beneficial use for which water may be appropriated.

Domestic Use and Use of Water by Travelers. These have always been considered as a beneficial use of water.

Municipal and Industrial Uses. Most of the water used for industrial and municipal purposes in New Mexico is from wells, as is most of the domestic water for the cities and towns of the state. These are recognized as beneficial uses and water rights have been issued for these.

Recreation. The Supreme Court in 1945 held that an organization which has impounded water for future use has no exclusive privilege in their use while they remain public water and no right of recreation or fishing distinct from the right of the public therein.

The water allocations in the Navajo and San Juan-Chama projects, which are now in the process of development, include uses for irrigation, municipal, industry, recreation and power.

Not An Exclusive List

These statements indicate the wide meaning of the term "actual use for some beneficial and legal purpose." The list above is not intended to indicate all of the beneficial uses recognized in New Mexico for which water rights are now in existence.

A Water Right is a Property Right. Court decisions have had this to say regarding the validity of water rights: "The appropriative right, ... is property," and "it is property right of high order." In one decision the court stated: "Such a right is real esatate," and in another decision "an action to determine rights to the use of water is in the nature of a suit to quiet title to realty."

Much more complete papers on the subject of Water Laws and their application under the Doctrine of Appropriation and the Concept of Beneficial Use are included in the report of the Fourth Annual New Mexico Water Conference. Important papers, among others, which were reread in preparation of this paper were those by Wells A. Hutchins, Robert Emmet Clark, Ross Malone, and Justice Irwin Moise, all eminent attorneys and authorities in this field.

All of these men recognized that there are problems in connection with prior appropriation and beneficial use. Justice Moise stated in his paper, and I quote, "Let us inquire, whether our reliance on the prior appropriation doctrine slightly modified, by what was said in Young & Norton v. Hinderlider, supra, if still applicable, and in the Cartwright case, supra, and without giving preference to one beneficial use over another was poorly conceived or has not worked.

"I am constrained to feel it has worked reasonably well for two principal reasons. First, demands for other uses are only now arising. If use for irrigation had not been made, water which flowed unused downstream during the many years since this country was settled would have been lost entirely, either by passing unused to the sea, or to what would have been a worse fate, so far as we are concerned, by being put to beneficial use in states lying between us and the sea, so that prior claims would have arisen in these users to have the flow continue undisturbed.

"What has happened to Arizona on the Colorado River, and to New Mexico to a lesser extent, and what has given rise to the case of Arizona v. California, et. al., is an example of what can happen, and should be sufficient proof of one of the errors present in failing to make the earliest and greatest use of all water available for use in any state.

"Secondly, the appropriation doctrine has been the foundation and basis of a large part of the growth of our State to its present position. It would have been neither desirable nor economical in my mind to have permitted the water to flow by, unused and unclaimed, producing nothing, and being lost forever, with great likelihood that the future flow by the same failure to use was likewise being lost for all time." End of quote.

Professor Clark in his study on "Water Law Institutions and the Community" said,

"our doctrine of appropriation has become hardened into verbal formulations called constitutions and statutes and case decisions, and that whereas our problem heretofore has been one of rights of appropriation and acquisition, we are entering into a new era where the problems are more related to transfer of rights to different locations or other uses or involve more complex forms of ownership and administration."

Justice Moise in answer to his own question,

> "Can we, or should we by changing our laws attempt to give preference to these so-called higher uses?"

stated,

> "As to the water already appropriated and put to beneficial use for irrigation, the short answer is that we probably can't even though we would. Property rights have been acquired in this water, and these rights are protected against confiscation or unreasonable or unjustified infringement by both our state and federal constitutions."

The Select Committee Print No. 32 on "Water Supply and Demand," 1960,3/ reports the following population projections for the major river basins affecting New Mexico in comparison to 20 other river basins and the United States.

Population projection areas	Census 1950	Projection - medium rate 1960	1980	2000
Upper Rio Grande-Pecos	1,000,000	1,200,000	1,800,000	2,000,000
Colorado	1,200,000	1,700,000	2,900,000	3,200,000
Total	2,200,000	2,900,000	4,700,000	5,200,000
Total Growth in the Two Basins Over 1950			+2,500,000	+3,000,000

Regional Population Growth Ratio to Average of United States Growth

Areas	1960-1980	1980-2000
Upper Rio Grande-Pecos	1.65 : 1	1.35 : 1
Colorado	1.40 : 1	1.90 : 1

Note: The Colorado River is projected to have the highest area ratio to United States growth in the United States in the 1980-2000 period.

The Rio Grande-Pecos is projected to have the fourth highest area ratio to United States growth in the 1960-1980 period. This

3/ "Water Supply and Demand," Select Committee Print No. 32, August 1960.

basis will be exceeded only by three southwest and south Pacific areas.

The Select Committee rated all of the rivers on the basis of water supplies and water needs by 1980. The number one basin, having the least water was the Rio Grande-Pecos, and the number two water shortage area was the Colorado River basin.

Problems Compounded

The water problem of these two basins important to New Mexico are compounded by the fact that the population growth will be high, while the amount of water to be developed to care for this growth is small, relative to increasing needs of the area, and relative to other United States river basins.

In the Life Magazine, dated December 21, 1961, there is a 14-page article reviewing the water supplies and problems of the United States. It lists the Colorado as "the Nation's river where water is most sought-after and fought-over." The Rio Grande-Pecos is not far behind. Also, the magazine quotes an eminent scientist as saying "you never completely solve water problems, you merely create new choices."

Present Volumes of Water Use in New Mexico

The present use for beneficial purposes as indicated by the next table is about 2.25 to 2.50 million acre feet of water. Of this, about 60 percent is from ground and 40 percent from surface water sources (page 7).

In percentage use, about 94 percent of the total is used for irrigation and 6 percent for municipal, industrial, and other uses.

New Mexico's Allocations Are Now Being Developed

The Navajo and San Juan-Chama developments will put to use 600,000 acre feet of water allocated to New Mexico under the Upper Colorado Compact. Also, the Canadian River is now being dammed, at Logan, to make available to New Mexico the 200,000 acre feet allocated to the State under the Canadian River Compact. These developments will increase our usable water by about 800,000 acre feet over present uses. The saline water plant now under construction at Roswell may make available a significant amount of water primarily for industrial and municipal uses.

NEW MEXICO WATER USE IN ACRE FEET*

GROUND WATER (Diversions - 1955)	Acres	Acre Feet
For Irrigation		
From ground water only	443,020	967,140
Ground water - supplement to surface	144,670	294,520
Total for Irrigation		1,261,660
Municipal and Industrial Uses		104,890
Rural Non-agricultural Uses		13,010
Total All Uses From Ground Water		1,379,560
SURFACE WATER (Depletion - 1950)		
For Irrigation	507,700	922,200
Municipal and Industrial Uses		20,000
Total All Uses From Surface Water		942,200
GROUND AND SURFACE WATER		
Ground Water and Surface Water Total Use		2,321,760
Losses - evaporation from reservoirs	331,000	
non-beneficial uses	833,000	
Total losses		1,164,000
Total disappearance		3,485,760

* Source: Ground water - U. S. Geological Survey and State Engineer - 1955.
Surface water - U. S. Bureau of Reclamation - 1950. State Engineers report to Select Committee, September 1960.

Even with these developments the people of New Mexico must give full recognition to the increased demand for water which will be associated with the projected population increases. This will also give rise to many questions as to how the present property rights to water may be transferred to other and possibly new uses which may be more economically productive than in its present uses. More attention must also be given to conserving both the quantity and quality of the water for all uses in New Mexico.

The Market System Based on Supply and Demand

We know the supply of water in New Mexico is relatively limited and that the demand of water in its present and in new uses is increasing. Because the population increases will be mostly in cities and the employment opportunities will be in industries, we would expect a considerable expansion in industrial and municipal uses. However, a larger percentage increase in municipal and industrial uses does not require as large a percentage increase of the State's water supply. For example, a 50 percent increase in water used for industrial and municipal purposes would require only 3 percent of the water that is now being used in New Mexico.

The State Engineers report to the Select Committee[4/] carries an estimate of increase of water in Bernalillo County which was made by the Bureau of Business Research, University of New Mexico as follows:

Projections of Population and Water Requirements of
Albuquerque Metropolitan Area
(Bernalillo County) 1956-80

Year	Population	Total Diversion: Million gallons per day	Per capita	1,000 acre feet per year
1956	220,000	47	210	53
1960	264,000	58	220	65
1965	354,000	81	230	91
1970	463,000	109	240	122
1980	672,000	168	250	188
Increase 1980 over 1960	408,000			123

4/ New Mexico Statement submitted to the U. S. Senate Select Committee on National Water Resources, September 1959. Revised September 1960.

The anticipated increase in demand for water for industrial and municipal use, reflects both the increase in population and increase in gallons of water used per person per day.

It is estimated that the population of New Mexico will be 2,256,000 by 1980, or an increase over 1960 of 1,267,000. The diversion for use in the Albuquerque metropolitan area in 1956 was at the rate of 210 gallons per person per day. The estimated required diversion for 1980 is at the rate of 250 gallons per person per day. It should be pointed out that these rates are much higher than present state and national average diversion rates. However, based on these estimated increases in population and in per capita use, it would require a 1980 diversion of 355,000 acre feet more than in 1960.

This 355,000 acre feet is a sizable increase, but we are developing about 800,000 acre feet of new uses from the waters allocated to New Mexico from the San Juan and Canadian rivers. This indicates that New Mexico has adequate water to meet the new demands if the water is conveyed to the correct places. About 110,000 acre feet of water from the San Juan is presently planned for diversion to the Rio Grande Basin and another 125,000 acre feet of diversion is possible under present Bureau of Reclamation plans.

Value in Various Uses

A Resources for the Future Study,[5/] led by Dr. Wollman at the University of New Mexico and participated in by other staff members at the University of New Mexico, staff members of the State Bureau of Mines and Mineral Resources, and staff members from New Mexico State University came out with a rough estimate of the value of water for various uses as shown on next page.

The Values Maintain Only for Limited Quantities

It should be noted that the value of $293.00 per acre foot of water was for 18,000 acre feet of water, and the value dropped to $198.00 when 37,000 acre feet were allocated

5/ Wollman, Nathaniel, et. al., The Value of Water in Alternative Uses - With Special Application to Water Uses in the San Juan and Rio Grande Basins of New Mexico, University of New Mexico Press, 1962, 426 pp.

Gross Product Per Acre-Foot of Water in Alternative Uses
San Juan and Rio Grande Basins of New Mexico

Uses	Depletion acre feet	Value[1/] per acre foot
Recreation	18,600	$ 293.00
	37,000	198.00
Municipal and Industrial	72,600	$3300.00
	147,600	1273.00
Agriculture	379,000	$ 18.00
	379,000	17.00

1/ After adjustment for total water cost.

to recreation. In municipal and industrial uses, it was estimated that the use of 72,000 acre feet could contribute as incomes: $3,300 per acre foot, while 147,000 acre feet in the same uses could contribute only $1,237 per acre foot. In agriculture with average crops on average quality land water has a value of $17.00 or $18.00 per acre for all the water available to it. Also, the per capita income per user of water in agricultural uses is equal or above per capita income per user in the other above mentioned uses.

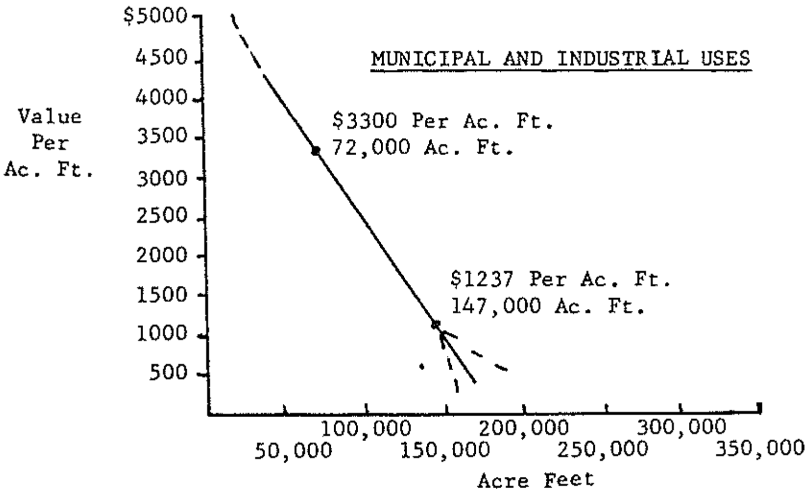
Chart I indicates only the relative values in each and the changes in value as the amounts allocated increase. For minimum amounts of water in municipal uses the values would be much higher than indicated. The same is true in other uses.

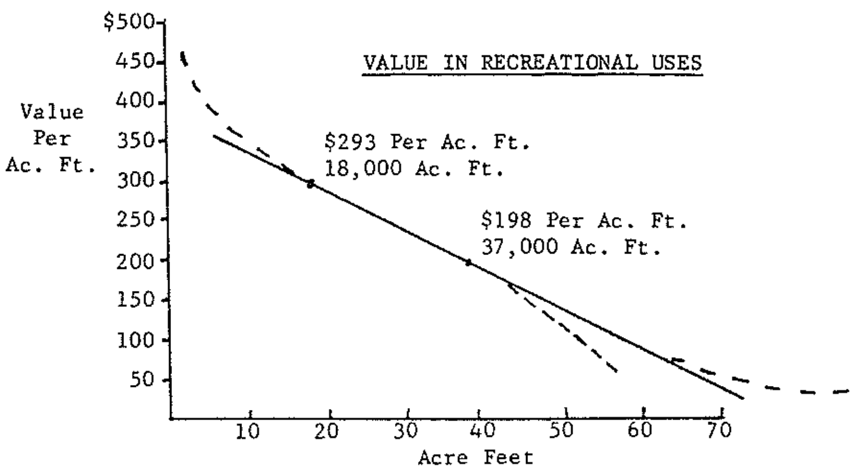
This indicates that the marginal value of each added acre foot of water for recreational and municipal uses drops rapidly, but that these uses can pay high prices for the water they can put to efficient use. The marginal value in agricultural uses is stable, regardless of the amount allocated, because we have large acreages of land which are suitable for irrigation if water were available.

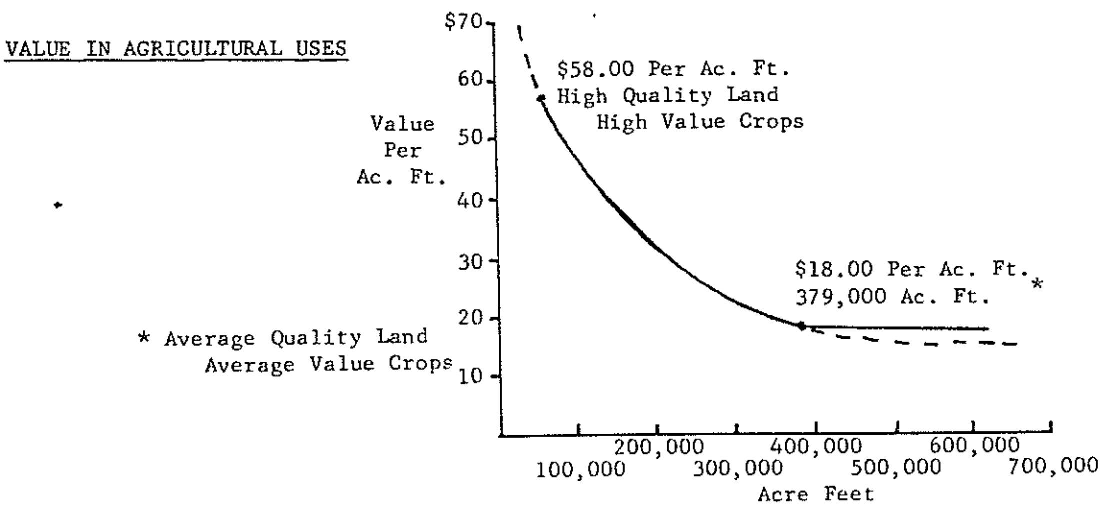
Actual Dollar Demand Should Acquire the Necessary Supplies

This indicates that when the demand increases and the demand is expressed in a "bid price" for water for use in recreational and municipal and industrial uses, that the necessary water will easily transfer from agriculture to the higher value uses, under the ordinary market price system.

GROSS PRODUCT PER ACRE-FOOT AFTER ADJUSTMENT FOR TOTAL WATER COST







These water transfers are being made in certain areas of New Mexico now and more will be made as the purchase offers are made. Many acres of land have been transferred from farming uses to municipal and industrial uses. There is no apparent reason why this might not happen rather freely in the transfer of water as the demand increases.

To summarize I should like to emphasize the following points:

The majority of the water in New Mexico has been appropriated under the doctrine of appropriation for beneficial use by those holding the water rights.

These appropriated rights are property rights and as the courts have stated, "property rights of a high order."

New Mexico is an area of scarce water supply. However, we are adding about 800,000 acre feet of water for new uses under the San Juan and Canadian river developments. This amounts to about a 30 percent increase above our present controlled uses.

New Mexico during the last 10 years had an increase in population of 36 percent or about double the national average. It is expected that a similar rate of increase will be experienced during the next 2 or 3 decades.

We will be forced to conserve water and to protect both the quantity and quality of the water available for beneficial uses.

There will be need for shifting some of the water from its present use to other uses.

The market system, based on supply and demand, with demand expressed in firm money offers, and not just on expression of wishes or desires, has functioned in the past and is functioning at present to shift water from one use to another.

Economics indicates that the market system can be depended upon and should be depended upon to allocate these waters to their future uses, whether they stay in their present or move to some other use.

Water transfers are presently being made where purchase offers are made, These real estate rights to water should be expected to move in the future from one use to another just as the realty rights in land and building are commonly transferred.

Winston Churchhill has been quoted as follows: "The further you look back, The further you can see ahead."

A study of our past history with the Doctrine of Appropriation and Beneficial Uses in New Mexico, and of the emerging problems of states, that do not have good basic water laws, indicates that in spite of its faults, New Mexico is fortunate to have a time tested method for the allocation of both surface and ground waters. In 1954 the Iowa Legislature passed a water rights law establishing a permit system administered by a water commissioner (Iowa Code, Chapter 455A, 1958). This Iowa law regulates both existing and unused rights to water. Our State water laws permit development of our water resources based on a long history of property rights in water and a steadily developing economy in New Mexico has resulted under these laws.

ECONOMICS OF WATER ALLOCATION

George A. Pavelis[1/]

Thus far in the conference, we have heard excellent reports on recreation, irrigation, municipal water use, and pollution as specific water uses or problems that require serious evaluation as New Mexico charts its future years of Statehood. The main avenues of improvement in achieving an efficient yet equitable future allocation of the State's water resources have been outlined in these discussions. Additional contributions have been made by Mr. Irby on legal aspects of water use, Mr. Meyers on water conservation opportunities and Dr. Stucky on the economics of beneficial uses. Consequently, I approach the subject of water allocation with considerable trepidation, realizing that most of what I say has already been said by other economists at other times and places, may have questionable relevance to the most pressing water resource problems of this State and, even if this is not the case, is already implicit in the contributions of my program predecessors.

Considering these factors and the Conference theme of looking to the future as well as at the past and present, I concluded that the most fruitful way to discuss the economics of water allocation was to review the development of allocation principles and techniques against the background of historic, current, and future water allocation problems of the country and this region; and further, to perhaps show what economists mean when they say that limited water should be allocated among uses so as to maximize the overall economic values of water use. But there is another difficulty here, involving recognition that some very important alternative water uses such as recreation seem to defy complete monetary evaluation. Recourse to allocation principles not dependent on complete monetary evaluation seems logical in these situations, and I hope to illustrate one variant of this approach as having some potential for resolving future water allocation questions.

The discussions of economic techniques for water allocation will be introduced by: Suggestions on how economists might view allocation problems from a physical as well as an economic angle; a review of current and estimated future water use and water allocation in the United States and New Mexico (29)[2/] and an all-too-brief commentary on the recently

1/ Leader, Water Use Investigations, Land and Water Economics Branch, Farm Economics Division, ERS, U.S. Department of Agriculture.

2/ Underscored numbers in parentheses refer to Literature Cited.

published San Juan-Rio Grande research study of the University of New Mexico and Resources for the Future. The latter study will introduce the two examples of techniques for optimum water allocation, one to fit situations where benefits are measurable and the other to fit situations where they may or may not be completely measurable.

Physical-Economic Considerations

In general, any water allocation problem has four dimensions: the total quantity of water to be allocated; the use to which the supply might be allocated; substitution possibilities between uses; and the criteria that are to govern the allocation decision. Total allocable quantities can be specified with respect to any phase of the hydrologic cycle and any natural or artificial sources of supply subject to management, as pointed out by hydrologists (2). Relevant uses are any that can feasibly draw on the physically defined supply. Substitution possibilities are given by quantities of water required for varying quantities of products associated with each use relative to other uses. Finally, allocation criteria may give preference to uses with lower water requirements per unit of product simply on the basis of physical efficiency, may consider substitution possibilities in relation to comparative economic values of products, or may simply grant preference on the basis of established legal doctrines grounded in such concepts as time priority, beneficial use, and adverse possession.

Despite the overriding importance of legal criteria for allocation in the arid West, various applications of criteria based on economic value are applicable where substantial supplies are unappropriated, are under the direct control of public agencies, or where legal criteria are flexible enough to allow market-type reallocations. Thus we see that the problem of allocating water between uses cannot be stated in general terms even within a State with a uniform set of water statutes and comparable economic conditions. Variations in available ground and surface supplies, if nothing else, dictate unique water allocation situations and possibilities that can be analyzed most meaningfully on a watershed basis.

Considering specific situations, problems of water allocation between uses can be roughly divided for discussion purposes into those concerned with rainfall, runoff, and ground water as the basic resource quantities available for allocation or re-allocation. Of course there may be no ground water to exploit. Also, local runoff may be a trivial factor in the water supply situation and, because of excessive rates of evapotranspiration, would remain so even if rainfall were to be substantially increased by artificial means. This "on-site evaportranspiration," as it is often called, must be recognized as a primary use of water with considerable economic significance.[3/]

The frequent neglect or assumed constancy of evapotranspiration in economic studies of water development is rather surprising. Opportunities for economic allocation of rainfall exist where its division into evapotranspiration and 'water yield' can be controlled to an appreciable degree by modifying vegetation, harvesting timber on a hydrologic pattern, complete stripping of vegetation, and regulation of snowmelt. The Department of Agriculture estimates, for example, that opportunities for increasing water yield through watershed or vegetation management appear favorable on about 15 percent of the area of the Western States (23). Potential increases over present yields range from one-fourth inch or less in areas dominated by pinyon-juniper as in much of New Mexico, to nearly one inch in the ponderosa pine and douglas-fir stands of northern New Mexico, and up to 6 inches in the true-fir areas of California.

The economic nature of water allocation problems involving rainfall as the basic supply and on-site evapotranspiration and off-site water yield as alternative water uses can be illustrated by commonplace examples. At one extreme, foresters or grazing interests might prefer that evaportranspiration be maximized, realizing that soil moisture conditions improve as a smaller portion of rainfall is permitted to reach streams, and would approve watershed management practices appropriate to this end. The other extreme of minimizing evapotranspiration use is illustrated by municipalities or irrigation farmers preferring that rainfall in upland areas appear as water yield, especially where they do not have recourse to ground water for supplying their needs. Economic data could likely be developed that would support arguments for both of these groups, but the basic question of allocation is broader than this. It requires identification of some intermediate or compromise solution that would be in the best interests of the groups combined. This involves determining what would be the optimum or ideal amount of evaportranspiration to permit (and thus an ideal water yield to obtain) for a particular basin for a given period of time, either by altering the extent and type of vegetation or otherwise modifying the water regimen of the area. The detailed

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3/ The importance of evapotranspiration for U. S. agriculture is indicated by the fact that only about 20 percent of the value of all crop production, 6 percent of the value of pasture production, and 19 percent of crop and pasture values combined is due to irrigation (24). In the Rio Grande Basin of New Mexico and Texas, comparable figures range near 95 percent for crop production but down to 5 percent for pasture production.

research necessary to adequately resolve this allocation question amounts to a comprehensive analysis of water use and development for entire basins, since all upstream as well as downstream water uses would require thorough evaluation in a benefit-cost framework. This in turn implies that any plan for water resources development that does not examine watershed management possibilities in relation to downstream water yield has not fully considered the question of allocating water among alternative uses.

This leads to consideration of streamflow and ground water as supplies available for distribution among uses. For streamflow, economists must first note the variations in allocable supply made possible through watershed management as just described, and then storage possibilities. Reservoirs are creators of water supply in an economic as well as an engineering sense by serving to reallocate natural streamflow both geographically and over time. In effect they convert water from an intermittent 'flow' resource into a 'stock' resource usable for irrigation, municipal-industrial, and other withdrawal purposes, or perhaps for recreation as a nonwithdrawal use. In hydropower generation and flood control, emphasis is on conversion from intermittent to regular flows, either to harness or dissipate energy at a controlled rate. In most of the West the problem of allocating surface water among alternative uses reduces to the question of allocating storage capacity among uses, uses that may be competitive (flood control versus irrigation), or largely complementary (recreation with power generation). These interrelations dictate multipurpose planning of reservoirs and water resource projects. To be applicable to current planning, economic principles and techniques for water allocation must therefore draw heavily from the economic theory of joint production. An example will be given later.

Analytically, ground water poses allocation problems similar to those for surface supplies, in that given quantities must be distributed in some optimum fashion among alternative uses. The most important difference is that ground water is truly a stock resource (or stored) in its natural state. Also, the stock supply usually can be allocated or used over an extended period, although storage carry-over permits intertemporal allocation of reservoir water also, at least on a short-term basis. For ground water, the allocation problem must be stated in terms not only of how the given stock should be allocated among uses, but also of how pumping for each use should be regulated, either to not exceed recharge or to exploit aquifers at an optimum rate, considering both the immediate and future values of the withdrawn water, pumpin technology, costs, and physical characteristics of different aquifers. Both the physical and economic aspects of ground water allocation have received increased attention in recent years.[4/] Notable empirical economic studies are those of Hughes, Magee, and Cole in the High Plains (5) (7), Kelso (8) in Arizona, and Snyder (17) in the Antelope Valley of California.

This sketchy physical-economic view of ground water underlines the earlier statement that water allocation in its most relevant sense must often deal simultaneously with a multiplicity of alternative uses, users, and sources of supply--on an intrabasin, interbasin, or interstate basis as dictated by physical economic and institutional factors peculiar to given areas.

Macroeconomic Approaches to Water Allocation

In view of the need for evaluating water resource planning in a physical-economic-institutional setting, how can water allocation as such be discussed in purely economic terms? More particularly, can the economics of water allocation be discussed in an historical yet problem-oriented context? Both approaches are possible but the second is taken here as being more consistent with the Conference theme of reviewing the past for the purpose of focusing on future problems.

Historical aspects of water allocation

Considering the fact that "regulation" is implicit in the term "allocation," historical data on water use are appropriate to allocation economics to the extent they reflect past regulation or indicate needs for greater future regulation of limited supplies. Consider figure 1, which illustrates U. S. trends since 1940 in agricultural as well as nonagricultural water withdrawals and consumption. It is mainly based on Geological Survey data (11). In an essentially free enterprise economy such as ours, one might infer that the greater increases over time in nonagricultural than in agricultural water use have been due to greater increases in demands for industrial products and municipal water services than in demands for agricultural products, particularly the products of irrigated agriculture. Irrigation alone accounted for 115 million acre feet (38 percent) of the 303 million acre feet of water withdrawn, and 54 million acre feet (80 percent) of the 68 million acre feet of water consumed in the United States for all productive purposes in 1960. The inference is correct for the country as

4/ See especially the proceedings of the 1961 New Mexico Water Conference (13) and the 1960 Western Resources Conference (6), both of which were devoted to ground water.

a whole, the East as a whole, and with respect to general non-agricultural versus agricultural demands, but it is much less true considering western irrigation. Most of the increases in nonagricultural uses since 1940 have occurred in the water-surplus East; most agricultural increases are due to irrigation development in the West, where water is in short supply and subject to relatively strict institutional allocation. The importance of institutional limitations on increased water use in the West assumes even greater significance when we consider that crops in surplus were grown on about 43 percent of the 33.2 million acres of U. S. irrigated land in 1959.[5/] If water-supply and institutional factors were less limiting, irrigated acreages of nonsurplus crops, hay and pasture would likely be adjusted more rapidly to market forces, with corresponding changes in water use. Hay and pasture alone accounted in 1959 for nearly 38 percent of the U. S. irrigated acreage.

Moving from historical regulation as deducted from historical use to the question of further allocation of limited supplies, the 303 million acre feet of water withdrawals shown for 1960 in figure 1 (also table 1) amount to 22 percent of the Nation's annual renewable runoff supply of 1.3 billion acre feet, and even only 85 percent of the present dependable renewable supply of somewhat over 350 million acre feet.[6/] The situation in the West is much less favorable and underlies increasing controversies over the role of water rights legislation in reallocating supplies as well as supply-increasing projects. This is true for ground water stocks as well as renewable surface supplies. The limiting nature of ground water resources is indicated by increasing reliance of further irrigation on ground water despite declining water tables in many areas. About 45 percent of the irrigated acreage in the West is now dependent on ground water, with the proportion running as high as 89 percent in Kansas, 82 percent in Texas, 61 percent in New Mexico and down to 2 percent in Montana and Wyoming as the only two Western States with more than 85 percent of their irrigated acreage still supplied from surface sources (31). The rapid increase since 1939 in ground water use for irrigation in the United States is illustrated in figure 2.

A sharper historical perspective of agricultural and non-agricultural water use, considering sources of supply and contrasting geographic factors, can be obtained by comparing

5/ Estimates from Census of Agriculture. Except for rice and perhaps potatoes this does not mean that surplus production is due to irrigation.

6/ After Woodward (30), dependable supply is defined as aggregated maximum monthly streamflow at major points of use under present conditions of development.

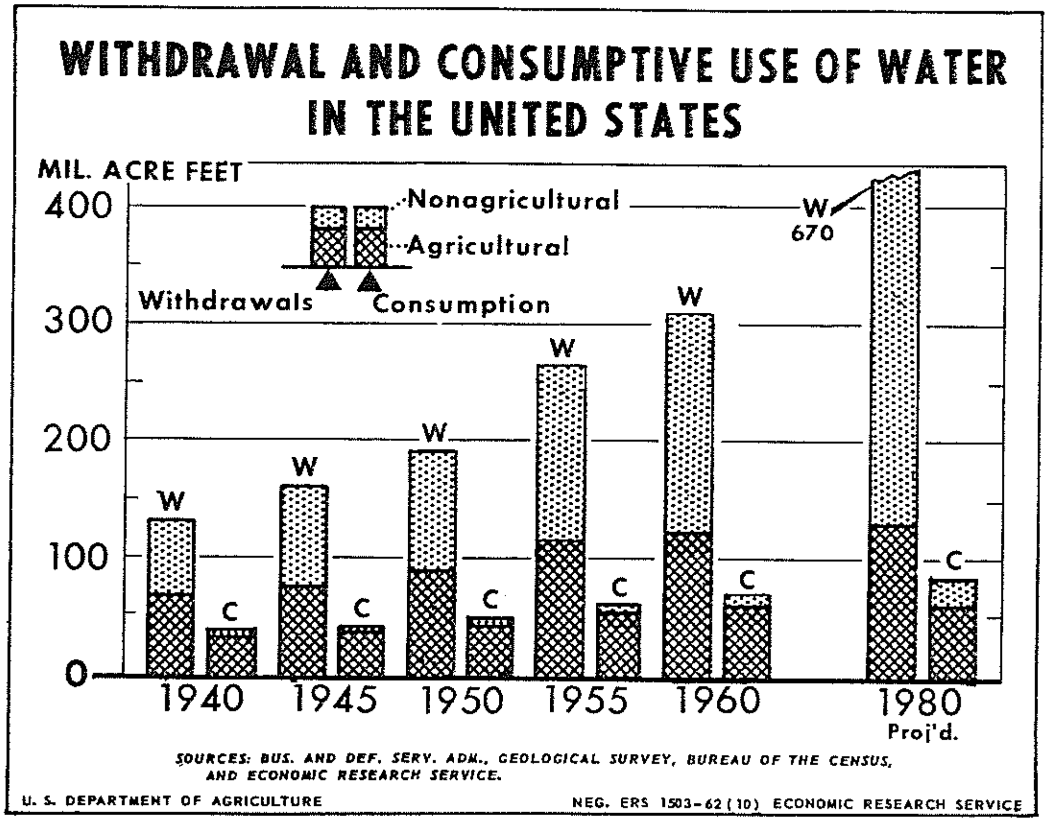


Figure 1

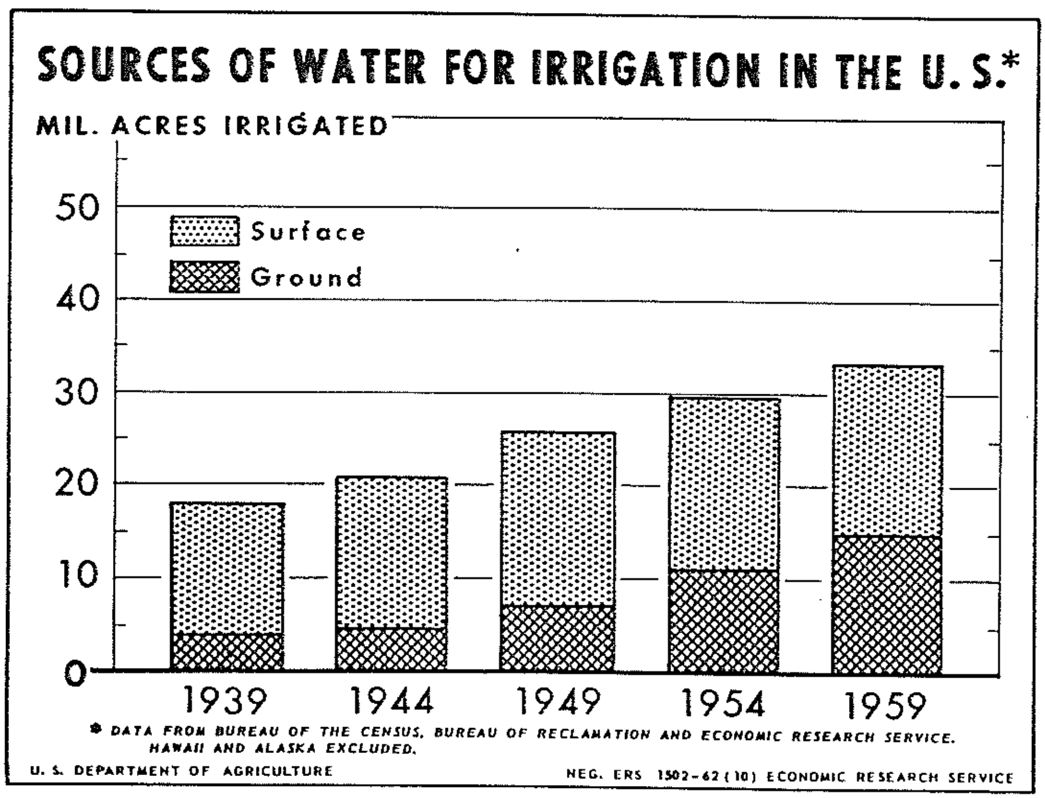


Figure 2

recent (1950-60) trends in the United States and New Mexico. Background data are provided in tables 1 and 2 and graphed in figures 3 and 4. Comparing the charts with respect to agricultural uses in 1960 shows that agriculture (irrigation) in New Mexico is only slightly more dependent on ground water (39 percent of irrigation withdrawals) than U. S. agriculture as a whole (31 percent of withdrawals). However, agricultural ground water withdrawals in the State have almost doubled in the last decade, compared with a 76-percent national increase. Industrial and municipal ground water withdrawals in New Mexico have increased by 82 percent since 1950, compared with a 225-percent increase in surface water use for these purposes. In this respect New Mexico accents a national trend toward greater reliance on surface water development than on ground water pumpage in meeting nonagricultural water requirements. The opposite trend is evident with respect to agriculture, both nationally and in New Mexico. Since 1950, surface withdrawals for agriculture have increased by 19 percent nationally and by 10 percent in New Mexico, compared with respective increases in ground-water withdrawals of 76 and 97 percent.

The data of tables 1 and 2 and the corresponding charts facilitate other interesting comparisons of recent trends in uses and sources of water. But the essential conclusion with respect to ground water allocation in New Mexico is that immediate pressures on ground water supplies as between agricultural and nonagricultural interests will likely be roughly proportional to current ratios of use; that is, 10 percent of the added future demand for ground water in New Mexico will be exerted by the municipal-industrial sector of the State's economy. But this assumes the absence of a ground water allocation policy geared to a program for accelerating industrial development.

For surface water development and allocation we could assume that future municipal-industrial demands in New Mexico will be much more pressing than suggested by current use, and that these demands compete much more effectively with agriculture than in the case of ground water in the absence of revised allocation policies. Additional surface water development holds, as we all know, considerable potential for meeting future supply requirements of all uses including agriculture, industry, municipalities, and recreation. In this respect New Mexico typifies the Southwest at large, which has been characterized by Ackerman (1) and the Senate Select Committee on National Water Resources as a region where comprehensive water development is essential for economic growth.

A further important aspect of surface water use that is importantly related to water development concerns the prodigious quantities of existing supplies depleted by reservoir and pond

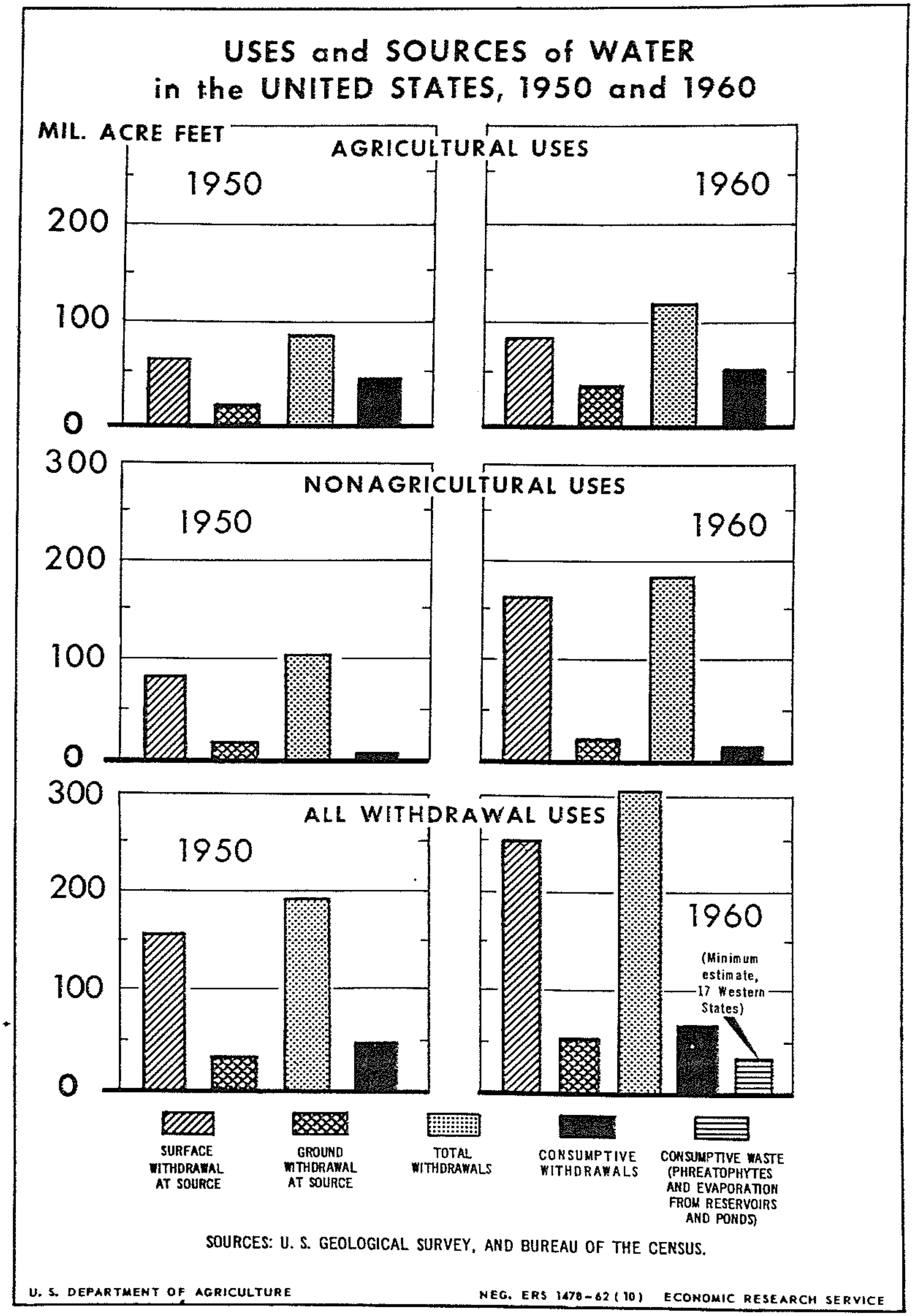

USES and SOURCES of WATER
in the UNITED STATES, 1950 and 1960
MIL. ACRE FEET
AGRICULTURAL USES
1950
1960
200
100
0
300
NONAGRICULTURAL USES
1950
1960
200
100
0
300
ALL WITHDRAWAL USES
1950
1960
200
100
0
(Minimum estimate, 17 Western States)
SURFACE WITHDRAWAL AT SOURCE
GROUND WITHDRAWAL AT SOURCE
TOTAL WITHDRAWALS
CONSUMPTIVE WITHDRAWALS
CONSUMPTIVE WASTE (PHREATOPHYTES AND EVAPORATION FROM RESERVOIRS AND PONDS)
SOURCES: U. S. GEOLOGICAL SURVEY, AND BUREAU OF THE CENSUS.
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 1478-62 (10)
ECONOMIC RESEARCH SERVICE

Figure 3

Table 1. Agricultural and nonagricultural water use in the United States in 1960 and changes from 1950 to 1960, by source of supply[1/]

Uses and items	Surface sources	Ground sources	Total withdrawals	Consumptive withdrawals
All withdrawals: 1960, mil. ac/ft.	249	54	303	[2/] 68
Percent of total 1960 withdrawals	82	18	100	22
Percent change, 1950 to 1960	58	50	58	39
Agricultural withdrawals: 1960, mil. ac/ft.	[3/] 82	[4/] 37	119	[5/] 57
Percent of agricultural withdrawals, 1960	69	31	100	[6/] 49
Percent change, 1950 to 1960	19	76	32	30
Percent of all withdrawals, 1960	33	69	39	84
Percent of all changes, 1950 to 1960	14	89	26	68
Nonagricultural withdrawals: 1960, mil. ac/ft.	167	17	184	11
Percent of nonagricultural withdrawals, 1960	91	9	100	6
Percent change, 1950 to 1960	92	13	80	120
Percent of all withdrawals, 1960	67	31	61	16
Percent of all changes, 1950 to 1960	86	11	74	32

1/ Data mainly from U. S. Department of the Interior, Geol. Surv. Circs. 115 and 456, Estimated Use of Water in the United States, 1950 and 1960, by K. A. MacKichan (Circ. 115) and K. A. MacKichan and J. C. Kammerer (Circ. 456). Some estimates from various reports of the Bureau of the Census.

2/ Excludes at least 16 million acre feet of reservoir-pond evaporation and 20 million acre feet of consumptive waste in the 17 Western States.

3/ Includes about 1 million acre feet for livestock and rural domestic use, with the remaining 81 million acre feet for irrigation, 24 million acre feet of which is lost in conveyance.

4/ Includes about 3 million acre feet for livestock and rural domestic use, with the remaining 34 million acre feet for irrigation, of which 2 million acre feet is lost in conveyance.

5/ Includes about 3 million acre feet for livestock and rural domestic use, with the remaining 54 million acre feet for irrigation.

6/ About 60 percent if based on actual farm delivery.

evaporation, phreatophytes, and canal seepage, even discounting the latter in view of recovery possibilities. Meyers' recent report on evaporation in the Western States (12) indicates that major reservoirs and regulated lakes annually evaporate on the order of 13 million acre feet of water; and that small ponds evaporate another 3 million acre feet. He reports evaporation losses in New Mexico of 200 thousand acre feet from the large impoundments and regulated lakes, and 150 thousand acre feet from small ponds and reservoirs. If we add to these evaporation losses the consumptive use of valuable water by phreatophytes and other useless plants, conservatively estimated from Robinson's data (16) at 20 million acre feet in the 17 Western States and from Senate Select Committee data (23) at 200 thousand acre feet for New Mexico alone, we find that "consumptive waste," as it is aptly called, comes to a minimum of 36 million acre feet for the United States, or about half as much water as that consumed beneficially (see figure 3). The total in New Mexico is about 550 thousand acre feet or two-fifths as much water as that consumed beneficially (figure 4).

These gross estimates of consumptive waste suggest dramatic possibilities for effectively increasing water supplies for all beneficial purposes. Their significance in an allocation context can be indicated by examining them on an incremental substitution basis and with respect to alternative beneficial uses of the water conserved. In New Mexico, for example, consumptive use in agriculture averages 49 percent of withdrawals, excluding consumption associated with conveyance, while consumptive use averages 32 percent of withdrawals for nonagricultural uses (table 2).7/ This is to say that, on the average, water goes at least 1.5 times as far in meeting municipal-industrial needs as in meeting irrigation requirements. By inference one could also say that, to justify an added acre-foot diversion for irrigation where nonagricultural water requirements were not being fully supplied, the economic value of an acre-foot of water consumed in irrigation would need to be 1.5 times its productivity in nonagricultural uses.8/

7/ Nonagricultural withdrawals are only about 6 percent consumptive nationally, due to the preponderance of low-consuming self-supplied industrial uses relative to municipal and other public uses. Over 70 percent of nonagricultural withdrawals in New Mexico in 1960 were from public systems.

8/ For the moment we are ignoring various empirical studies that suggest irrigation values much lower than this. For example, the New Mexico-Resources for the Future study of the San Juan and Rio Grande Basins (29) indicates that industrial water values may range from $3,000 to $4,000 per acre foot, compared with $50 per acre foot for irrigation.

Table 2. Agricultural and nonagricultural water use in New Mexico in 1960 and changes from 1950 to 1960, by source of supply[1/]

Uses and items	Surface sources	Ground sources	Total withdrawals	Consumptive withdrawals
All withdrawals: 1960, thous. ac/ft.	1,709	1,203	2,912	2/ 1,400
Percent of total 1960 withdrawals	59	41	100	48
Percent change, 1950 to 1960	13	95	37	37
Agricultural withdrawals: 1960, thous. ac/ft.	3/ 1,657	4/ 1,079	2,736	5/ 1,343
Percent of agricultural withdrawals, 1960	61	39	100	6/ 49
Percent change, 1950 to 1960	10	97	34	35
Percent of all withdrawals, 1960	97	90	94	96
Percent of all changes, 1950 to 1960	82	90	88	92
Nonagricultural withdrawals: 1960, thous. ac/ft.	52	124	176	57
Percent of nonagricultural withdrawals, 1960	30	70	100	32
Percent change, 1950 to 1960	225	82	110	103
Percent of all withdrawals, 1960	3	10	6	4
Percent of all changes, 1950 to 1960	18	10	12	8

1/ Data mainly from U. S. Department of the Interior, Geol. Surv. Circs. 115 and 456, Estimated Use of Water in the United States, 1950 and 1960, by K. A. MacKichan (Circ. 115) and K. A. MacKichan and J. C. Kammerer (Circ. 456). Some estimates from various reports of the Bureau of the Census.

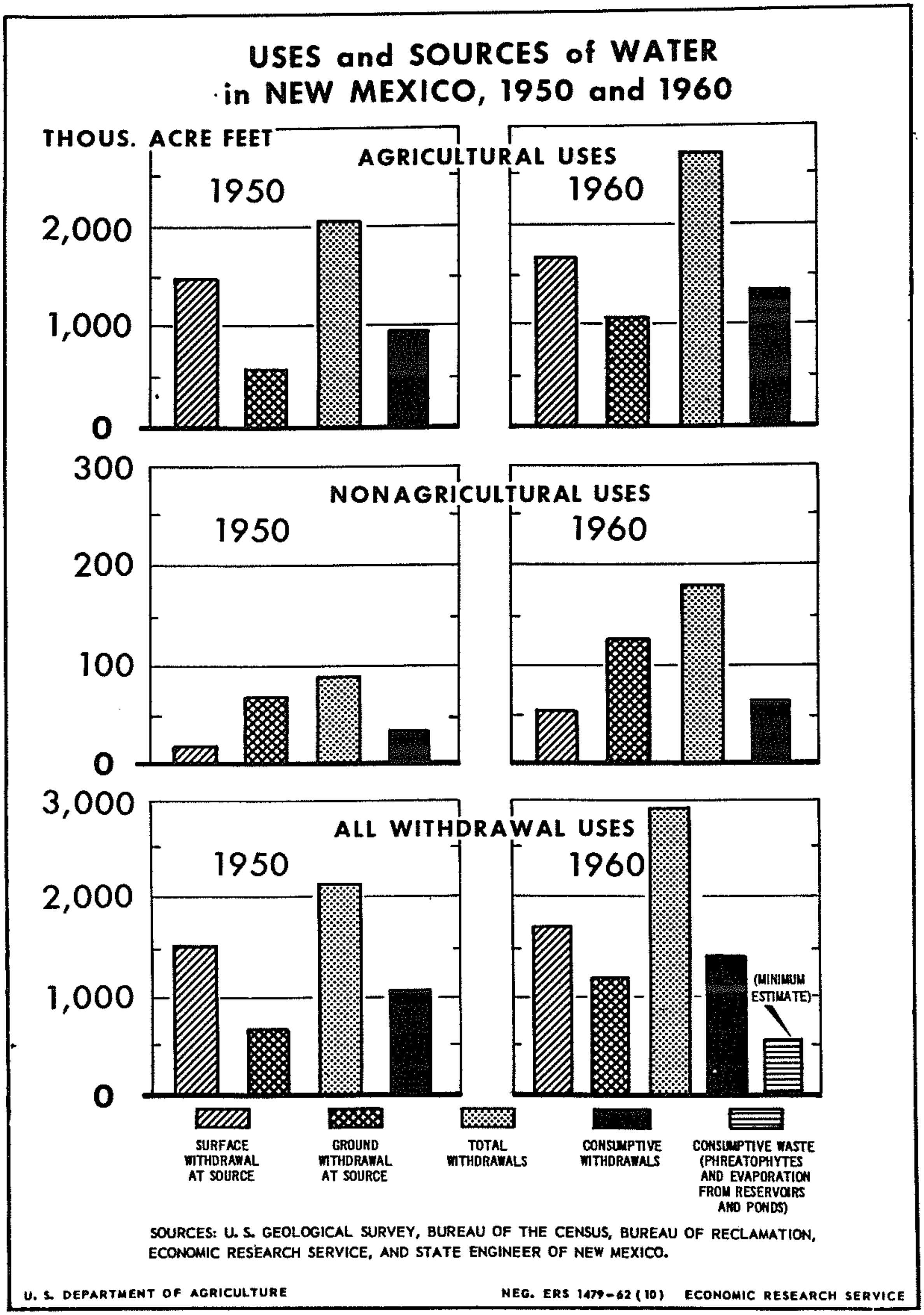
2/ Excludes at least 350 thousand acre feet of reservoir-pond evaporation and 200 thousand acre feet of consumptive waste.

3/ Includes about 5 thousand acre feet for livestock and rural domestic use, with the remaining 1,652 thousand acre feet for irrigation, 622 thousand acre feet of which is lost in conveyance.

4/ Includes about 25 thousand acre feet for livestock and rural domestic use, with the remaining 1,054 thousand acre feet for irrigation, of which 19 thousand acre feet is lost in conveyance.

5/ Includes about 16 thousand acre feet for livestock and rural domestic use, with the remaining 1,327 thousand acre feet for irrigation.

6/ About 64 percent if based on actual farm delivery.



USES and SOURCES of WATER in NEW MEXICO, 1950 and 1960
THOUS. ACRE FEET
AGRICULTURAL USES
1950
1960
2,000
1,000
0
NONAGRICULTURAL USES
300
200
100
ALL WITHDRAWAL USES
3,000
(MINIMUM ESTIMATE)
SURFACE WITHDRAWAL AT SOURCE
GROUND WITHDRAWAL AT SOURCE
TOTAL WITHDRAWALS
CONSUMPTIVE WITHDRAWALS
CONSUMPTIVE WASTE (PHREATOPHYTES AND EVAPORATION FROM RESERVOIRS AND PONDS)
SOURCES: U. S. GEOLOGICAL SURVEY, BUREAU OF THE CENSUS, BUREAU OF RECLAMATION, ECONOMIC RESEARCH SERVICE, AND STATE ENGINEER OF NEW MEXICO.
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 1479-62 (10)
ECONOMIC RESEARCH SERVICE

Figure 4

The crude calculations just given explain current pressures in the State and elsewhere for allocating scarce water to industry in preference to agriculture, even to the extent of modifying historic prior appropriation and other legal doctrines. We are not concerned here with the legal or equity aspects of reallocating water rights, except to note that a more promising alternative for increasing nonagricultural allocations may well lie in basinwide programs for evaporation suppression, phreatophyte elimination, and seepage reduction. For while nonagricultural diversions (in the above example) may effectively total 1.5 acre feet for every acre foot denied agriculture, they effectively total 3.1 acre feet for every acre-foot reduction in consumptive waste. The simultaneous possiblity in New Mexico for increased agricultural diversion of around 2 acre feet per acre-foot reduction in consumptive waste would seem to set the stage for cooperative water conservation programs, the costs of which might be shared in proportion to the benefits observed to accrue to appropriators not fully supplied under preprogram conditions. Data on economic values of water in different uses could thus be useful in formulating programs for economic reallocation through water conservation as well as argument for discouraging low-value but beneficial uses. Such programs would be similar in concept to situations where appropriated water can be reallocated on a seasonal basis under the various lease, rental, and other arrangements as those studied by Anderson (3) in Colorado.

Macroeconomic planning aspects

From an economic standpoint, future aspects of water allocation can be discussed in terms of three fairly distinct approaches to estimating water use patterns that might or should prevail at a given date. The first alternative is the prediction of future water uses and the future extent of water development activities from historical data, either directly or indirectly through preliminary prediction of such related variables as population growth, land use trends, industrial and agricultural output, and so on. The predictions may or may not be limited to extrapolation of historical trends and relationships. The essential point is that no judgments are made as to the economic desirability of the water use pattern emerging from the analysis. Emphasis is on description rather than planning keyed to predetermined policy objectives. However, the predictive approach has an important economic implication for policy-based analyses. It can aid evaluation of the possible benefits of policy changes, in that a benchmark is provided for evaluating the potential economic benefits of not allowing matters to take their own course.

A second approach is to determine a water-use pattern or patterns consistent with predetermined levels of population, industrial output, agricultural output, general land use patterns, or other factors, some of which may have been assumed (as population and crop yields) and others calculated as necessary for achieving given levels of domestic or foreign consumption. Resulting water use or other resource use patterns are commonly called "projections," to emphasize their lesser reliance on statistical prediction than the foregoing historical approach. Their main application to resource allocation is for suggesting policies and programs that might be instrumental in achieving the given levels of consumption, by encouraging or otherwise facilitating the indicated changes in present resource use.

The best example of an essentially projective analysis of land and water allocation is the familiar work of the Senate Select Committee on National Water Resources in all major water resource regions of the United States (22). Comprehensive planning to meet projected consumption needs for 1980, under the Committee's medium U. S. population assumption of 244 million, was considered essential in the Upper Missouri, Rio Grande-Pecos, Colorado, South Pacific and Great Basin water resource regions, thus verifying that the Nation's water allocation problems come into sharpest focus in the southwestern States.

For the country as a whole, the Committee projected total annual water withdrawals of 626 million acre feet by 1980. This is 86 percent over the 337 million acre feet of withdrawals the Committee calculated for its base year of 1954, and a virtual doubling of the 303 million acre feet estimated by the Geological Survey to have been withdrawn in 1960 (table 1). The apparent decline in water withdrawals between 1954 and 1960 is largely explained by the per-acre irrigation withdrawal rates of the Senate Select Committee analysis being based on considerations of adequacy rather than on actual use, although future gains in the efficiency of water conveyance and application expected by the Committee would tend to equalize its future withdrawal rates with the current rates of the Geological Survey. This comparison is not made to question either the Committee's projective findings or the Geological Survey's current estimates, but to point up the sensitivity of any national water allocation study to assumptions and predictions involving irrigation, which will remain the primary consumptive user of water in the United States well beyond 1980.

An example of a resource allocation study that combines historical prediction with the projective approach taken by the Senate Select Committee is given by a recent report (20) of the Department of Agriculture's Land and Water Policy Committee. This Committee assumed a U. S. population of 261 million for 1980, which coincides with the average of the Senate Select Committee's medium (244 million) and high (278 million) population assumptions for the same year. Shifts in land use (including a 51 million acre net reduction in total cropland) needed to meet specified crop, pasture, livestock and timber demands corresponding to export and domestic consumption requirements were estimated by first dividing per-acre yields into the requirements to obtain needed acreages devoted to crop, livestock, and timber production, and then comparing the computed acreages with the present use of land for these purposes.[9]

Estimates of future water use were derived more directly from historical data. For example, trends since 1940 in per-acre rates of water withdrawal and consumption for irrigation were analyzed separately for withdrawals from streams and ground water. Between 1940 and 1960, withdrawals averaged 3.87 acre feet per acre irrigated from surface sources and 2.00 acre feet for ground water irrigation, with no consistent upward or downward trend in the rates in either case. As shown in figure 2, however, ground water irrigation is know to have increased steadily, and now amounts to about 45 percent of the total acreage irrigated in the United States, compared with 17 percent around 1940. Statistical extrapolation of this trend, qualified by limitations on the remaining extent and capacity of aquifers, indicated that about 50 percent of the total acreage irrigated in 1980 would be served from ground water, with a corresponding average surface-ground withdrawal rate in 1980 of 2.93 acre feet per acre (3.05 acre feet per acre in 1960). Total irrigation withdrawals in 1980 were thus estimated conservatively at 124 million acre feet for 42.4 million acres of land expected to be irrigated as determined from extrapolated Census trends. This estimate and time-series-derived minor agricultural and nonagricultural estimates for 1980 are shown in figure 1. Total estimated withdrawals of 670 million acre feet determined from statistical projection are about 7 percent over the Senate Select Committee's medium estimate for 1980 of 626 million acre feet.

A third economic approach to formulating future water allocation policies or programs requires that planning be keyed to a quantitatively defined economic objective, such as

9/ For more detail on the conceptual basis of the Land and Water Policy Committee's land use projections, see Harry A. Steele and Norman E. Landgren. Demands for land for agriculture: Past, Present and Future. Address before Homestead Centennial Symposium, Lincoln, Nebraska, June 12, 1962. (To be published in Symposium Proceedings).

the minimization of costs or the maximization of net benefits, subject to specified limitations on the resources available for planning, the productivity of these resources in creating benefits by alternative measures, the comparative costs of each measure, and given institutional conditions. Solutions to planning problems of this nature can be obtained through "equilibrium" types of analysis for which mathematical programming techniques have been found to be quite efficient. Possibilities for planning water development and allocation with programming techniques as well as the more classic methods of economic analysis are best illustrated by the research conducted in the Harvard Water Program (10). The major difficulty in applying such methods is the lack of empirical data necessary to establish continuous functional relationships relevant to actual planning situations.

A variant of this approach, similar in concept to programming for maximum benefits, but where basic data collection can be flexible with respect to data availability and available planning resources, involves comparative analysis of two or more specified allocation patterns with respect to maximum income or minimum costs. The selected pattern or program is considered optimum in the sense of yielding more benefits or involving less costs than any of the others. In varying degree this approach characterizes most current water resource planning activities. As refinements are introduced in the way of the number and empirical detail of alternative patterns evaluated, the approach becomes more synonymous with programming or other formal types of analyses based on precise mathematical relationships. In essence, it can identify points on a "benefit surface" that would at least be feasible and highly economic if not the precise optimum solutions that might result from programming. Moreover, such feasible solutions might be considered analogous to "program activities" and programmed themselves to identify an intermediate optimum solution.

The New Mexico-Resources for the Future evaluation of water allocation in the San Juan and Rio Grande Basins (29) is an excellent example of a macroeconomic study of alternative water use patterns based on the income-generation effects of different allocations of water to various sectors of a State's economy. This research examines the impact on State income of two levels of interbasin water diversion (110 and 235 thousand acre feet from the San Juan to the Rio Grande Basin), six allocations of the diverted and remaining unappropriated water to irrigation, six allocations to industry, and three allocations to recreation through fish and wildlife-habitat development.

Conceptually, each of the eight postulated patterns of use accommodating these different allocations represented an alternative program for water development in the two basins, with 1954 as the base year and 1975 as the target year. It is unnecessary to examine here the specific values assigned to various water uses or the aggregate effects of the various allocation patterns on State income. Though none of the study's conclusions are questioned they aid in focusing on current water allocation problems needing additional research, particularly problems for which microeconomic methods of analysis and welfare economics principles may be applicable.

Planning With Microeconomic Techniques

A conclusion of the San Juan-Rio Grande study with far-reaching implications for agriculture in New Mexico and other arid States relates to the minimal computed values of water if used for irrigation rather than for industrial and recreational purposes, even with recreation evaluated only for its secondary effects on the regional economy. An estimated contribution in one of the better agricultural patterns of only $50 per acre-foot to the State's gross product from additional water use in irrigation compared with estimated contributions of $250 from recreational use, and up to $3,500 for industrial use. The answer to the question of which economic activities should be accelerated to maximize State income is fairly obvious, assuming no substantial variations in such average values as different allocations were made. The study in question properly considered possible ranges in per-unit values of water in each use by its analysis of the eight alternative allocation patterns.

A related conclusion concerned the dependence of industrial values of water on the actual existence of the industries in the target year. If the implied expansion of industry or other potentially high-value sectors cannot be assumed unequivocally, the selection of optimum patterns can be appropriately qualified in view of the most probable rates of expansion. This question was created by not emphasizing the effects of the optimum pattern to the exclusion of other patterns possibly more consistent with current rates of industrial expansion and recreation development.

It may be useful at this point to review how an optimum water allocation can be determined microeconomically; that is, from a schedule of total supply costs and schedules of demand (or average benefits) per unit of water that might be allocated to, say, industrial use versus irrigation use. Such demand schedules could be derived from a series of allocation models as those set up in the San Juan-Rio Grande study or perhaps from detailed field surveys. They would likely reflect diminishing returns to water used in both irrigation and industrial production and, if included in a planning framework, could be discounted for uncertainty to account for different probabilities of given allocations actually being demanded at different dates.

The economic theory underlying water allocation in a multiple-use framework is fairly straightforward and derives from multiple-product or multimarket monopolistic firm theory. Notable contributions are those of Castle (27), Ciriacy-Wantrup (26), Regan (26) (28), and Timmons (18) (26). Where resources are nonlimiting, the necessary theoretical condition for maximization of aggregate net benefits is that the incremental (marginal) total costs of development be equated with the incremental aggregate benefits for all uses combined, and that the incremental benefits from allocation to all uses also be equated. Where resources such as capital benefits are maximized by allocating the newly-supplied water to the alternative use or combination of uses in which incremental benefits are greatest; that is, in a manner that minimizes the rate of decline in aggregate incremental benefits as greater total quantities of water are supplied.

While the economic literature is replete with discussion and elaboration of these principles, little attention is given the mechanics of their application in concrete situations, with resulting overestimation of their complexity by project planners. Appendix I gives an example of how optimum total capacity for a reservoir or an optimum interbasin diversion of water might be determined where the water can be used economically in either industry or irrigation.[10] Only the relations between (1) total supply and costs; (2) average industry values per acre-foot; and (3) average irrigation values per acre-foot are essential for this determination. In view of present New Mexico conditions, note the higher average and incremental values for initial increments allocated to industry, but a more rapid decline in these values than in the irrigation values as allocations are increased (equations 3, 5, 8, and 9). Also, the procedure simultaneously considers the allocation of water and water-supply costs between the alternative uses, recognizing the inter-relatedness of water allocation and cost allocation in project planning.

10/ The mathematics of solving joint production problems of this nature are outlined in Tintner (19, ch. 18). The graphics of optimum allocation between competing uses involve the classic theory of price discrimination in separate markets as given in standard texts; see Weintraub (25, ch. 14). However, the difficulty of generalizing to more than several alternative water uses limits application of graphical methods, which in any case rely on mathematical functions.

An additional note on the San Juan-Rio Grande study involves the method of estimating recreational values of water. The primary value of water for recreation was considered indeterminate, while the primary values of water for irrigation and industrial use were estimated as the net returns to farmers from irrigation water use or the net returns of water use in industry. The assumption followed from observations that recreation in the study area is not ordinarily a salable commodity in itself. This somewhat implies that recreational water use could be evaluated as completely industrial and irrigation uses in cases where the provision of water-based recreational services was or could be made a function of private enterprise. But by focusing on the secondary as well as primary values of competing water uses, a major contribution of the San Juan-Rio Grande study may well be its indication that the primary values of water for recreation are academic in cases where its secondary values alone (per unit) substantially exceed the more completely determined values for competing uses (over the range of feasible different allocations). In other words, the difficult evaluation of primary recreation or other intangible values might best be deferred until the more easily measured values had been determined, and then attempted only if the allocation decision might otherwise hinge on partially-estimated recreation values that appeared unduly low or were marginal.

The increasing general emphasis on recreation in land and water resource development in all parts of the country, with accompanying difficult problems of benefit evaluation, raises a significant question on the applicability of conventional methods of water allocation to planning projects that provide recreational benefits.[11]

Welfare Principles and Allocation Techniques

The difficulty of measuring recreation and other intangible benefits in the same way as other project benefits suggests that the results of benefit-cost analyses may be so qualified by the intangibles as to be of questionable value in the decision-making process. This implies that future water allocation decisions may need a stronger economic footing than the monetary benefits that could be estimated for any project purpose, and that it may be useful to fall back on the criteria that guided water resources development before benefit-cost procedures become highly refined. For example,

11/ See the general report (14) and a separate report on water recreation (21) of the Outdoor Recreation Resources Review Commission. See Clawson (4) for a review of evaluation problems and techniques.

one must admit that while prior appropriation and beneficial use concepts may not result in the same water use patterns as those resulting from the interplay of competitive market forces, they have been considered necessary for economic development in many areas--suggesting that institutional and comparative-value concepts of water allocation stem from a common philosophy, somewhat akin to the idea of the "the greatest good for the greatest number."

Translating this rather nebulous objective into clear form for guiding water allocation policy is difficult, but one approach would pose the question of how satisfied the opposing potential users might be made and what price they would be willing to pay for recreational or other water in order that project costs could be recovered. This states the problem a little differently than conventional studies, which frequently accept costs or prices actually paid as indicators of recreational benefits, with the result that benefits can be easily underestimated but not likely overestimated.

These points all indicate the need for allocation techniques that incorporate the two objectives of maximum satisfaction and equitable price from all uses and for all users of water--in other words, a goal of making all users feel as well off as possible without making any potential user feel worse off. The analytical framework for objectively pursuing this goal is given by the theory of "welfare economics," in which monetary benefits and costs would play an important but not all-important role in determining the particular allocation of water among different uses that would maximize the satisfaction of the potential users.[12]

The core of a welfare approach to water allocation would be a series of utility (indifference) functions, each showing the dependence of a potential user's satisfaction on various combinations of all commodities or services he might consume, including such services as recreational use of leisure time. Given the costs of producing various quantities of goods and services and consumer incomes, it would then be possible to determine the quantities of each commodity or service purchased by each consumer in order to maximize his level of satisfaction, as well as the market prices paid for each commodity or service.

12/ Basic references on modern welfare theory include Reder (15) and Little (9). In addition see Weintraub (25) for a welfare-based analysis of alternative cost allocation policies appropriate to water allocation as well as other production problems. Welfare principles for water allocation have been discussed previously and discarded, but largely on practical rather than theoretical grounds; for example, Castle (27).

The logic and mechanics of a welfare approach to water allocation can be made more apparent with a simple example. Suppose an irrigation farmer's general satisfaction with his lot in life could be expressed as an index dependent on two factors: (1) A feeling of income security provided by irrigating; and (2) an additional element of satisfaction derived from his using water for recreational as well as irrigation purposes. In other words, he would be willing to sacrifice some of the incomes and satisfactions from irrigation if they were outweighed by increased satisfactions from recreational water use. This irrigation farmer would have different ideas on the best use of a reservoir site than one with no apparent interest in water-based recreation, and would be interested in irrigation as a source of revenue for building on recreational storage capacity as well as a source of total disposable income to spend on both purposes.

The information essential for planning a reservoir on this basis would include: (1) The functional relationship (or utility function) between irrigation and recreation capacity, showing the incremental rate at which the farmer would substitute one for the other in maintaining the same level of utility or total satisfaction; (2) the usual functional relation between reservoir capacity and costs, regardless of how the capacity were allocated between competing uses; and (3) the usual functional relation between net farm revenues from irrigation and irriation water use. The latter revenues are the income from which the farmer must recover reservoir costs, assuming personal consumption by the farmer of all capacity allocations to recreational use.

Appendix II illustrates how optimum total storage capacity can respective allocations to irrigation and recreational water use would be determined in view of maximizing a given utility index instead of net revenues. Note that it is not necessary to estimate the monetary benefits of recreation to arrive at a design that is optimum in a maximum welfare sense as well as economically and financially feasible in the conventional sense.

The method outlined could be workably generalized, although computing requirements would multiply rapidly with the number of competing water uses and users considered. Nevertheless, increasing competition for water for productive and recreational uses, combined with continued improvements in computer technology, indicates that practical considerations will not limit the application of such methods to the extent they have in the past. A corresponding implication for future water resources planning in New Mexico and elsewhere is that utilizing all appropriate and theoretically-consistent water allocation techniques in arriving at water development decisions will be of great benefit.

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APPENDIX I

Benefit-Cost Analysis of Optimum Storage Capacity

Givens are: (1) Irrigation, i, and industry, m, as alternative uses (and users) of total storage capacity; (2) a maximum of net benefits from the two uses combined as the planning objective; and (3) the assumption that costs will be allocated to each of the two uses in proportion to their share of gross benefits. The planning problem is to determine how to maximize aggregate net benefits--by determining the optimum total capacity to develop and the optimum allocation of this capacity between the two uses, and then to distribute costs between the two uses and indicate the resulting distribution of maximum net benefits. Only equations (3), (5), and (10a) need to be determined in pre-planning investigations. Storage capacities, benefits, and costs may be defined in any convenient units.

<u>Total storage capacity</u> (S_t) as sum of capacity for irrigation (S_i) and industry (S_m):

$$S_t = S_i + S_m \qquad (1)$$

<u>Total benefits</u> (B_t) as sum of benefits for irrigation (B_i) and industry (B_m):

$$B_i = S_i D_i = 11 S_i - 0.50 S_i^2, \text{ where} \qquad (2)$$

$$D_i = 11 - 0.50 S_i \text{ (average benefit per unit irrigation allocation)} \qquad (3)$$

$$B_m = S_m D_m = 22 S_m - S_m^2, \text{ where} \qquad (4)$$

$$D_m = 22 - S_m \text{ (average benefit per unit industry allocation)} \qquad (5)$$

$$B_t = B_i + B_m = 11 S_i + 22 S_m - 1.50 S_i^2 - S_m^2 \qquad (6)$$

$$D_t = (B_i + B_m) / S_t \text{ (average benefit per unit total capacity)} \qquad (7)$$

<u>Incremental total benefits</u> from irrigation (B_i ') and industry (B_m ') allocations, where B_i ' and B_m ' are first derivatives of (6) with respect to S_i and then S_m:

$$B_i' = 11 - S_i \; ; \; B_m' = 22 - 2 S_m \qquad (8)(9)$$

<u>Total costs</u> (C_t) in terms of total developed storage (S_t) as allocated to irrigation (S_i) and industry (S_m):

$$C_t = 2 S_t + 0.02 S_t^2, \text{ which from (1) is expanded to .} \qquad (10a)$$

$$C_t = 2 S_i + 2 S_m + 0.02 S_i^2 + 0.04 S_i S_m + 0.02 S_m^2 \qquad (10b)$$

<u>Distributed costs</u> to irrigation (C_i) and industry (C_m), proportionately in relation to benefits:

$$C_i = (B_i / B_t) C_t; \; 100 (B_i / B_t) = \text{pct. costs to irrigation} \qquad (11)$$

$$C_m = (B_m / B_t) C_t; \; 100 (B_m / B_t) = \text{pct. costs to industry} \qquad (12)$$

Average costs ($\overline{C}$) on basis of cost distribution and allocated capacities:

$$\overline{C}_t = C_t \;/\; (S_i + S_m) \qquad (13)$$

$$\overline{C}_i = C_i \;/\; S_i \;;\; \overline{C} = C_m \;/\; S_m \qquad (14)\ (15)$$

Aggregate net benefits, from total benefits in (6) less total costs in (10b):

$$N_t = 9\ S_i + 20\ S_m - 0.52\ S_i^2 - 1.02\ S_m^2 - 0.04\ S_i\ S_m \qquad (16)$$

Net benefit distribution from (2) and (11), and (4) and (12):

$$N_i = B_i - C_i \;;\; N_m = B_m - C_m \qquad (17)\ (18)$$

Maximization of aggregate net benefits in (16) by first computing incremental net benefits to irrigation and industry where N_i' and N_m' as incremental net benefits are partial derivatives of (16) with respect to irrigation and then industry:

$$N_i' = 9 - 1.04\ S_i - 0.04\ S_m \qquad (19)$$

$$N_m' = 20 - 2.04\ S_m - 0.04\ S_i \qquad (20)$$

Determination of optimum allocations to irrigation and industry by increasing respective allocations until incremental net benefits are zero. Setting (19) and (20) equal to zero gives a pair of simultaneous equations:

$$1.04\ S_i + 0.04\ S_m = 9 \qquad (21)$$

$$0.04\ S_i + 2.04\ S_m = 20 \qquad (22)$$

Solutions of (21) and (22) are $S_i = 8.29$ units of optimum storage for irrigation; $S_m = 9.64$ units of optimum storage for industry, and $S_t = 17.93$ units of total developed storage. By substitution total benefits (B_t) are 175.96 from (6), total costs (C_t) are 42.27 from (10) and aggregate net benefits (N_t) are a maximum of 133.69 from (16). Remaining data are summarized in Table 3.

Table 3. Benefits and costs of optimum allocation of storage capacity to irrigation and industry

Items	Equation references or notes	Competing uses: Irrigation	Competing uses: Industry	Total or averages
1. Developed and allocated storage capacity	21, 22, 1	8.29	9.64	17.93
2. Total benefits from storage	2, 4, 6	56.81	119.15	175.96
3. Percent total benefits (and costs)	11, 12	32.29	67.71	100.00
4. Total benefits per unit capacity	3, 5, 7	6.86	12.36	9.81
5. Incremental total benefits	8, 9	2.72	2.72	2.72
6. Incremental total costs	1/ 10	2.72	2.72	2.72
7. Total costs per unit capacity	2/	1.65	2.70	2.35
8. Total costs of storage	10, 11, 12	13.65	28.62	42.27
9. Total benefits per unit costs	3/	4.16	4.16	4.16
10. Net benefits of storage	4/ 16, 17, 18	43.16	90.53	133.69
11. Net benefits per unit capacity	5/	5.21	9.66	7.46
12. Incremental net benefits	19, 20	0	0	0

1/ Differentiate 10 with respect to S_t, S_i, and S_m
2/ Divide item 8 by item 1.
3/ Divide item 2 by item 8.
4/ Alternatively, item 2 less item 8.
5/ Divide item 10 by item 1.

APPENDIX II

Welfare Analysis of Optimum Storage Capacity

Givens are: (1) Irrigation, i, and recreation, r, as competitive uses of total storage capacity for a given potential user of both, whose utility or indifference function is known; (2) an objective of maximizing the utility index through an optimum allocation of capacity to the two uses; (3) the assumption that all costs must be recovered through the income-creating effects of irrigation alone; and (4) that the user will charge off irrigation and recreation capacity costs at the same average rate (price). The planning problem is to determine how to maximize the utility index--by determining the optimum total capacity to develop and the optimum allocation of this capacity between irrigation and recreation, and then to distribute costs between the two uses. Only equations (1), (5), and (8) need to be determined in pre-planning investigations (eqs. 5 and 8 are from Appendix I). Storage capacity, revenues, and costs may be defined in any convenient units.

Utility function in terms of storage capacity for irrigation (S_i) and recreation (S_r):

$$U = S_i \, S_r \qquad (1)$$

Marginal rate of substitution in consumption of recreation capacity for irrigation capacity:

$$U'_r \,/\, U'_i = S_i \,/\, S_r, \text{ where } U'_r \text{ and } U'_i \text{ are marginal utilities of recreation and irrigation} \qquad (2)$$

Cost-consumption relation between recreation and irrigation under the assumption of equal average costs ($\overline{C}_r$ and $\overline{C}_i$) per unit capacity (see assumption 4 in par. 1):

$$(S_i \,/\, S_r) : (\overline{C}_r \,/\, \overline{C}_i) = 1 \ ; \text{ so} \qquad (3)$$

$$S_r = S_i \text{ (all capacities will be equally divided to } S_i \text{ and } S_r) \qquad (4)$$

Total costs (expenditures on irrigation and recreation) in terms of total developed storage (S_t) and allocations to irrigation (S_i) and recreation (S_r):

$$C_t = 2\,S_t + 0.02\,S_t^2 = 2(S_i + S_r) + 0.02\,(S_i + S_r)^2 \qquad (5)$$

$$C_t = 4\,S_i + 0.08\,S_i^2 \text{ , since from (4), } S_r = S_i \text{ and } S_t = 2\,S_i \qquad (6)$$

Total revenues from irrigation available for recovering storage costs, whether storage is for irrigation or recreation:

$$B_t = B_i = S_i\,\overline{B}_i = 11\,S_i - 0.50\,S_i^2, \text{ where} \qquad (7)$$

$$\overline{B}_i = 11 - 0.50\,S_i \text{ (average revenue per unit irrigation capacity)} \qquad (8)$$

Maximization of utility index by maximizing expenditures on irrigation and recreation, provided revenues from irrigation production are sufficient to recover these expenditures. Since total costs and total revenues are now in terms of irrigation capacity (S_i), optimum S_i is solved for by equating (6) and (7):

$$4 S_i + 0.08 S_i^2 = 11 S_i - 0.50 S_i^2 \qquad (9)$$

$$-0.58 S_i^2 + 7 S_i = 0; \; S_i = 12.06, \text{ and } S_r = 12.06 \text{ from } (4) \qquad (10)$$

Maximum utility index is 145.44 from (1) and optimum equal allocations of 12.06 units to irrigation and recreation as determined from (4) and (10). Optimum total capacity is 24.12 units. Total revenues from irrigation and total costs of irrigation and recreation combined are 59.94, from (6), (7), and (10). Average costs per unit capacity are 2.49; they are assumed from par. 1 to be equal for irrigation and recreation. Allocated costs to irrigation and recreation are equal at 29.97. Net revenues from irrigation are also 29.97 but are all spent to obtain recreational capacity. This equilibrium is point A on figure 5. Point B is a suboptimal welfare position resulting from simple maximization of irrigation net revenues, also subject to the condition that total capacity be allocated equally to irrigation and recreation.

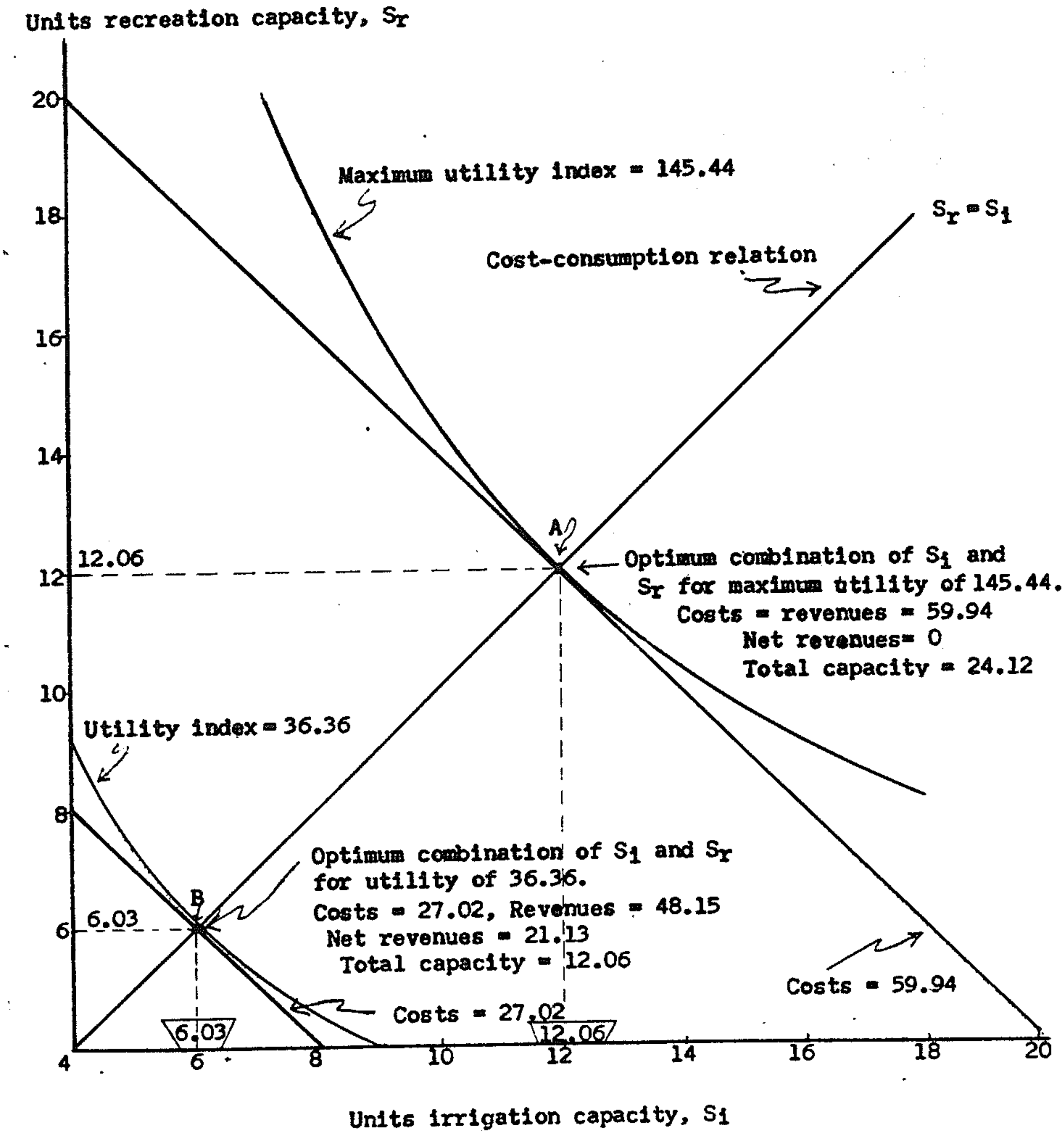

Figure 5. Determining optimum combination of irrigation and recreation storage capacity to maximize a utility index

This paper was presented by Senator Clinton P. Anderson at the Centennial Dinner in connection with the 100th anniversary of United States Agriculture and Land Grant Colleges on Friday, October 26, 1962, just four days prior to the Seventh Annual New Mexico Water Conference. Since the paper included so much in connection with water, it was felt that it should appropriately be included along with the report of the Water Conference so that it might be available to many of those who attended the Centennial Dinner and the Water Conference.

THE TECHNOLOGICAL REVOLUTION IN AGRICULTURE IN THE UNITED STATES BROUGHT ABOUT LARGELY BY LAND GRANT COLLEGES

Clinton P. Anderson[1/]

It is a source of pleasure to be invited to participate in the observance of the centennial of the land grant college system and the 75th anniversary of the Hatch Act which established our agricultural experiment stations.

These institutions have a large measure of responsibility for the revolution that engulfs the world today--the revolution against want, against the malnutrition, unnecessary disease and suffering which accompany such want. The technological revolution in agriculture in the United States, which the land grant colleges have largely brought about, has demonstrated to the people of the world that want can be banished and they are determined that it shall be. The same colleges may very well hold the key to the outcome of the collateral struggle which accompanies the revoluation against want--the cold war between communism and the free world.

President Abraham Lincoln signed into law three acts of great historic importance. Infrequently associated with his administration because he was a war president.

One was the act creating the Department of Agriculture. The second was the Homestead Act. The third was the Morrill Act offering federal land grants to each state for the establishment and maintenance of institutions of higher education.

In the early histories of Lincoln's administration, these three Acts have been all but overlooked by the

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1/ United States Senator from New Mexico, Washington, D. C.

historians. In another century, the Morrill Act of 1862 may prove no less important than the document for which he is most famed--the Emancipation Proclamation.

The Morrill Act was a momentous step in the development of the educational policy of the United States. It represented a determination by the national government to make higher education available to all of its citizens and to disseminate as widely as possible, through such peoples' colleges, available knowledge in such practical fields as agriculture and the mechanic arts.

The subsequent Hatch Act of 1887, to provide for the establishment of agricultural experiment stations, was an equally momentous step in the development of national research policy--a decision to provide public endowment for research in a practical field on a geographically widespread basis, expanding the exploration for new knowledge beyond the struggling research laboratories of a relatively few private colleges and universities, business institutions and individuals.

There were some very fundamental policies involved in the research policy decisions embodied in the Hatch Act, including the determination that, even in this then new nation's private enterprise economy, the federal government could properly augment research in fields where the public interest is great and the general welfare is heavily involved.

Interestingly, the Act was sponsored by two gentlemen who had previously participated in a rebellion against federal authority: Congressman William H. Hatch of Missouri and Senator James George of Mississippi, both former Confederate Army officers.

Two of the principal opponents of the Act were Senators Joseph R. Hawley of Connecticut and John J. Ingalls of Kansas, both former Union Army officers.

The measure can be described as a bi-parties product, for it was approved by a predominantly Republican Senate as well as a Democratic House of Representatives. It was signed by President Grover Cleveland, a Democrat.

There was a third important step in the development of our national education and research policies--the establishment of a system for communicating new knowledge widely, an extension education system to take out from the colleges and universities to all citizens who would take advantage of it, the expanding body of practical knowledge available through the land grant institutions.

Democracy is more than a system of social communication to those of us who were born and reared and have spent our full lives in a democratic country. It means equality of opportunity and the right to participate in the development of policies all the way from local government to the national level.

The democratic educational system and our mechanisms for social communication, exemplified by our land grant institutions, are the logical outgrowth of the basic democratic concept of the equality of man and the right of every citizen to share in opportunities--including knowledge. They make possible the achievement of such widespread application of scientific techniques that we have demonstrated that all mankind can have abundance and freedom from ignorance, want, fear, and oppression. Thus, the Morrill Act which Abraham Lincoln signed, may ultimately be credited with creating more of freedom for mankind than did the presently far more renowned proclamation abolishing slavery.

The land grant college system is entitled to all of the acclaim it is receiving in this centennial year for its key role in developing and demonstrating, particularly in the field of agriculture, the effectiveness of these democratic research and educational policies. The constantly increasing productivity of our farms has <u>not</u> resulted just in the production of an abundance of food for all our citizens, plus a so-called surplus. It has freed a large part of our population to provide abundant industrial production. It has provided a good deal of research and many new processes and techniques beyond the field of agriculture. It has made possible the conservation and maintenance of our land resource, lack of which has caused the downfall of nations in the past. It has made not only possible but desirable the utilization of land for nonagricultural uses. We can afford to take enough land out of agricultural production for highways and airports and for millions of our citizens to live in individual homes with a little breathing space about them, and to provide recreational facilities--even wilderness--without endangering food and fiber supplies.

The record of this first century of the land grant college system is one of which to be very proud. It has had a far greater effect on the course of world history than most citizens, involved in day-to-day activities and decisions, have stopped to realize.

It is because I appraise so highly the key role of the educational institutions brought into being by the Morrill Act, both in their past performance and future potentialities, that I am happy to have a part in an occasion like this.

One century is only a beginning--the moment of birth--in historic perspective.

The state university and land grant college system is certainly only in the infancy of its potential service to the nation, and to all mankind.

There is agreement on both sides of the Cold War that a great scientific revolution is under way. There is a demonstrated world-wide belief that the side which moves ahead the most swiftly in scientific fields will win the ideological struggle between free and dictatorial forms of government.

The free portion of the world clearly has the lead in the area in which the land grant colleges and univiersities have specialized: the technology of agricultural production.

But far more remains to be done if free institutions are to win the race for world-wide adherents.

The Agricultural Committee of the National Planning Association recently proposed that you be given an international dimension in the agricultural field, with a responsibility not only for supplying and training agricultural technicians for other free world countries, but also for assisting them in establishing their own institutions for research and instruction in the field.

This should be done.

The Planning Association Committee was quite severe in its comments on past performance in the international agricultural development field as being the result of "drift rather than design." The national government must take a very large part of the responsibility. Year-to-year authorizations and appropriations for foreign aid programs have not been conducive to the development of well designed, long-term proposals.

Regardless of where fault lies for "drift rather than design," I believe that if the land grant institutions will develop and propose a program for international assistance of the sort proposed by the National Planning Association. Congress will authorize it. When need is as clearly recognized as it is in this instance, Congress ultimately does what should be done.

The report of the National Planning Association's Agricultural Committee itself has a serious shortcoming, reflecting an all too common impression that the Morrill Act institutions are single purpose, <u>agricultural</u> education and research centers.

The charter of the land grant institutions is a broad charter.

The original Morrill Act of 1862, and subsequent revisions of that Act, all provide that the land grant funds provided shall be devoted "...to the endowment, support, and maintenance of at least one college (within each State) where the leading object shall be, without excluding other scientific and classical sudies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

This is not restrictive language. The author took precautions not to exluce "other scientific and classical studies" from the field of these colleges. He gave as much emphasis to the mechanic arts as to agricultural, and he referred to "the several pursuits and professions," not to a single one.

There is abundant room for the land grant college system to expand, and there are many areas, including the international field already discussed, where your services and the genius you have demonstrated in the agricultural field are urgently needed.

There are two areas in which I would like to see the colleges heavily involved. They relate to agriculture but are not exclusively agricultural problems and they should not be dealt with as such--the fields of recreation and water resources.

The Outdoor Recreation Resources Review Commission made a very extensive study of the recreational desires, or demands, of American citizens. A scientifically selected cross section of 19,000 Americans was questioned in detail about their present recreational activities, and what they would like to do if they had a little more time and a little more income.

We found that the bulk of recreational demand is not for elaborate, far-off recreational opportunities, but for simple, relatively nearby activities: a short drive for relaxation, a walk in the woods or beside a stream or lake, a short picnic or fishing trip, a place to play outdoor games, to swim, or to ride a bicycle. Even annual vacation trips, in more than half of all instances, are within a 500-mile distance.

There was a time, a couple of generations ago when "grandpa's farm" was a great recreational center. Sons and daughters who had moved into the towns and cities returned to their birthplace to enjoy the out-of-doors, a big country dinner of chicken and dumplings--and to let their children become acquainted with farm animals and roam and romp in the meadows and the woods. Sometimes the family enjoyed a week or two on the farm. But our population has been so swiftly urbanized that only a fraction of us anymore have grandparents on the farm from whom we can sponge recreational opportunities.

There is unquestionably a chance in every area of the nation for some farm operators to add to their incomes, or even convert entirely to the recreation business. But whether or not this potential new farm "crop" is first over-developed, to the economic injury of those who fail at it, or comes along on a sound basis can depend to a large extent on guidance provided through land grant institutions.

But there is no restriction on the colleges and universities which limits them in the recreation field to farm-related aspects of the problem. The provision of urban as well as rural recreation is a pursuit and a profession well within the mandate of the Morrill Act where trained personnel and a great deal of research is and will be urgently needed for as far ahead as we can foresee.

The Outdoor Recreation Resources Review Commission estimated that recreation "activity occasions" will increase from the 4.4 billion level of 1961 to 6.9 billion in 1976 and to 12.4 billion in the year 2000. More people with more leisure, more income and greater mobility are going to maintain a pressure on recreation facilities which will require both public and private efforts to meet.

The second area to which I want to see the colleges apply their great abilities and potentialities is the field of water resources.

Two days after I introduced a bill in the Senate to provide financial assistance for the establishment of water resources research institutes at the State univiersities and colleges, the National Science Foundation approved a recommendation, yet to be generally released, that these land grant institutions be involved in research on all natural resource matters.

I am not in any disagreement with the Foundation recommendation.

Because of the urgency of water resource problems, it is my feeling that they should be given great emphasis, if not a priority, in the years just ahead.

The Senate Select Committee on Water Resources found, in its 1960 report, that four areas in the Southwest--the South Pacific, the Colorado, the Upper Rio Grande-Pecos and the Great Basin of Nevada--plus the Upper Missouri Basin in the Midwest, will have reached the limit of their water resources by 1980.

By the year 2000, the Upper Arkansas-Red, the Western Great Lakes and the Western Gulf regions will require full development of their water resources if anticipated demands are to be met.

Here in New Mexico, with the completion of the San Juan-Chama project, we will be virtually at the end of our presently usable water supply. We confront increasingly urgent problems of allocation to the most economic uses, increased efficiency in the uses made, reclamation of brackish and saline waters, and experimentation with weather modification to find a way to increase rainfall and the total of water available to us.

The new brackish water plant at Roswell represents a costly federal effort to extend water supplies, but an effort which will repay its cost many times, on a world-wide basis, if the research and experimentation proves up an economic method of purification. It is a project serving not just New Mexico, but areas around the world short of water of usable quality.

Because of our supply situation, phreatophyte control, and the reduction of evaporation and seepage in our management of the water we do have, are pressing problems for us, not only in terms of agricultural supplies, but to meet industrial, municipal and recreational requirements as well.

In reality, water problems are equally pressing in some of the humid States, where supplies are abundant but are being so seriously misused--polluted--that they are valueless to meet needs. Washington, D. C. is located on the Potomac River at tideland with a vast expanse of water on its western boundary--water so putrid that when a boat upsets the hapless occupants are rushed to the showers to prevent infections.

I am told that one of the greatest recreational opportunities in the nation is on the Delaware and Monongahela rivers in Pennsylvania. They are today so polluted with municipal and industrial wastes they contain virtually no aquatic life. Restored to reasonable purity, they could provide swimming, camping and fishing opportunities for several million urban residents in one of the nation's most congested areas.

The Select Committee on Water Resources made five general recommendations for meeting water problems. The first was the preparation of optimum use plans for the water of every major river basin. The second was to appropriate funds to assist the States in Water Resource planning at State level.

The third recommendation was that the nation undertake a coordinated scientific research program on water.

The fourth and fifth recommendations proposed that an assessment of the water-supply demand outlook in each region and the nation be prepared biennially, and that steps be taken to encourage efficiency in water use.

The Interior and Insular Affairs Committee of the Senate, on which I serve as chairman, originated the Select Committee and its studies. It has a continuing responsibility of seeing that the recommendations of the Select Committee are acted upon.

Pursuant to that responsibility, the Committee is working on planning bills and this year undertook a study of the statue of water resources research in the federal government, and in the various water regions of the nation.

The Committee has obtained reports from federal agencies working in the water field on their research activities, and reports from more than a hundred colleges, universities, private institutions, firms and individuals--including land grant institutions in all 50 States.

These reports, shortly to be available as a printed Committee document, underscore several points of particular importance in relation to water research.

One of the major points made, in my mind, was the necessity of tying research and education together. Typical of the response in this area was the comment of Dr. Carl E. Kindsvater of the University of Georgia, who wrote:

> I would emphasize that research and education cannot be considered separately, for just as education is essential to the performance of research, so is research essential to the education process. I believe, therefore, that a considerable part of the Federal Government's investment in water-related research should be earmarked for the support and

intensification of university research and graduate study programs.

A second reason for stimulating college and university work in the water resources field is the present shortage of experts on hydrologic fields.

One agency in Washington, in the bureaucratic tussle for dominance in the developing water program, has even contended that it has all the well-qualified hydrologists in the nation on its staff. That is not so far-fetched as it may sound. There is only one school in the nation today where a scholar can take a full graduate course in hydrology--the University of Arizona--and that has been true there for only one year.

John C. Geyer, chairman of the department of sanitary engineering and water resources at Johns Hopkins University, responding to the Committee for his school, wrote:

> Scientifically trained people of exceptional ability rarely go into the water field. If an attempt were made to establish broadly based fresh water science research institutes, difficulty would be encountered in staffing them with competent people. Universities need support in developing water science training programs to provide staff for such institutes. Students should be attracted from all the sciences and professions and afforded an opportunity to pursue any of a variety of educational and research projects related to water.

A third point repeatedly emphasized in response to the Interior Committee inquiry was the necessity for involving many disciplines, or specialized fields of knowledge, in water research work.

In view of the shortage of scholars in the many related fields who have specialized in water problems, it is apparent that for a time, at least, water research projects should be located where scholars of many disciplines may be induced to work in the water resources field, to become specialists on water and to train others in the field. The colleges and universities are the one place where this may be possible.

There was one further point, or factor, which caused me to propose the establishment of water research institutes throughout the land grant system. This was their ability to work on regional problems and their experience in the field of communication; of disseminating and making useful to the agencies and the citizens throughout each State the knowledge which results from scientific research.

The reports of our Committee showed that many college and university faculty members were working and consulting with State planning boards, state water agencies, municipalities, irrigation districts, drainage districts, farmers and other individuals on water problems ranging from deep well supplies in the arid areas of the West to oyster propagation on the East coast; and from the planning of water management on small, individually owned tracts to the planning of water resources on a statewide basis.

The demand for research and scientific advice on water resource problems is broader even than the demand on the present agricultural experiment stations and the extension service. Water problems extend into the towns and cities and can be pressing problems for everyone--farmer, householder, industrialist, flood victim, sportsman, <u>all of us</u>. They vary from region to region, and there is need for a widespread system of laboratories which can investigate the specialized problems of their own area, as well as the broader national problems.

In the water field, as in the agricultural field, there is an extensive demand for practical results--for answers to immediately pressing concerns. Basic research--pure, scientific research aimed solely at understanding the laws of Nature, without regard for immediate practical results--is easily shunted aside, as it has been for too long in public and private profit research programs.

It will be a great mistake for the federal government, and for the colleges and universities, if, in the establishment of a coordinated water research program, we do not make a liberal allocation of funds for basic research work which will be unimpeded and unharrassed by the practical exigencies of the world at any particular moment.

So far as I can determine, federal appropriations have always gone almost exclusively to applied research. This was true in the case of atomic energy. The basic research had been done before a scientist sold Franklin D. Roosevelt on the possibility of perfecting an atomic bomb that would end World War II.

Our times call for more liberal support of basic research than it is now being given anywhere in the free world. We have a common responsibility to see that it is forthcoming.

There are people in politics who like to claim that they are New Dealers, or New Frontiersmen, or Progressives blazing new trails toward national and world abundance, security, and peace. This is the season which comes in each even numbered year, where these claims become the loudest.

In reality, those of you in the colleges and universities are the frontiersmen of our times, blazing trails into new physical and social science fields which may lead mankind around a cataclyamic war to the abundance and security upon which a lasting peace can be built.

The challenge of the second century to the land grant collges and state universities is to become leaders on these frontiers, to occupy new and critical fields of research, instruction and communication of scientific knowledge, just as rapidly as your persuasive power with public policy making and appropriating bodies will permit.

I have been tremendously gratified with the response of the land grant institutions--and other colleges and universities--to our inquiries in the water research field. A few of them are ahead of us, leading the way, as they should be. They already have established water research institutes or broader natural resource research institutes. All of the rest indicate a desire to move ahead.

The products of your research into scientific fields, and particularly into water and natural resource fields, are of far wider significance than their economic value within this nation alone.

They are items we can export--useful everywhere in the world where there are resource problems. They can tie free world countries more closely together, and perhaps even tie together political enemies like Pakistan and India, or Israel and Egypt in cooperative projects to solve mutual water and natural resource problems.

Ultimately, they might tie all mankind into a society which turns to science rather than conquest to solve its problems of security and abundance. I hope you will continue your contributions toward that end.