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PROCEEDINGS OF THE EIGHTEENTH ANNUAL NEW MEXICO WATER CONFERENCE

Theme: State Water Plan

April 5-6, 1973

New Mexico Water Resources Research Institute

New Mexico State University ● Telephone (505) 646-4337 ● Box 3167, Las Cruces, New Mexico 88003

STATE WATER PLAN

PROCEEDINGS OF THE

EIGHTEENTH ANNUAL NEW MEXICO WATER CONFERENCE

NEW MEXICO STATE UNIVERSITY

LAS CRUCES, NEW MEXICO

April 5-6, 1973

The Advisory Committee

Fred A. Thompson
N.M. Dept. of Game and Fish
Santa Fe, New Mexico

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

James Kirby
Extension Economist - NMSU

Boyce C. Williams
Agronomy-Soils - NMSU

Rogers Aston
South Spring Foundation
Roswell, New Mexico

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New Mexico Farm & Ranch Magazine
Las Cruces, New Mexico

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State Department of Agriculture

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New Mexico Institute of Mining and Technology, Socorro, New Mexico

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Bureau of Land Management
Santa Fe, New Mexico

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University of New Mexico
Albuquerque, New Mexico

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Extension Engineer - NMSU

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Rincon, New Mexico

Hoyt Pattison, Representative
Curry County, Clovis, New Mexico

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League of Women Voters
Los Alamos, New Mexico

Marion Strong, State Conservationist
Soil Conservation Service
Albuquerque, New Mexico

Wayne P. Cunningham
Elephant Butte Irrigation District
Las Cruces, New Mexico

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Management Specialist
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Civil Engineering - NMSU

Ray Cauwet
Information Services - NMSU

L. P. Reinig, Head, Eng. Department
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

James R. Gray
Agricultural Economics - NMSU

Eldon G. Hanson, Head
Agricultural Engineering - NMSU

Col. James L. Sutton
Corps of Engineers, U.S. Army
Albuquerque, New Mexico

Gary L. Cunningham
Biology Department - NMSU

Rowland Fife, Area Engineer
U.S. Bureau of Reclamation
Albuquerque, New Mexico

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

Carrol Hunton
Farmers Home Administration
Albuquerque, New Mexico

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

T. G. Gebhard, Jr.
Civil Engineering Department - NMSU

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

Peter Hanagan, Executive Director
New Mexico Oil and Gas Association
Santa Fe, New Mexico

Dr. Carl F. Tarlowski
Regional Health Director
Las Cruces, New Mexico

George R. Dawson, Head
Agricultural Economics Department - NMSU

John W. Clark, Director
Water Resources Research Institute

Ralph Charles
Middle Rio Grande Flood Control Assoc.
Albuquerque, New Mexico

PREFACE

The Eighteenth Annual New Mexico Water Conference was held at the New Mexico State University on April 5-6 for the purpose of exchanging information pertaining to water resources.

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

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

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

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

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

John W. Clark
Director

New Mexico
Water Resources Research Institute
Box 3167
New Mexico State University
Las Cruces, New Mexico 88003

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Office of Water Resources Research
Washington, D.C.

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It is a rare privilege for us to dedicate this conference to Senator Clinton P. Anderson. He held authority in the administration of relief programs during the Depression, handled world food relief in the wake of World War II, pioneered in conservation, was in the forefront of peacetime uses for atomic energy, and led the drive for Medicare. More important, however, is the stature of the man himself. His immense reputation in Congress, the Administration, and especially among groups concerned with water development magnified his influence far beyond that of senator. Senator Anderson expanded the operations of the Office of Saline Water, promoted the Water Resources Planning Act, and wrote the legislation that provided for a Water Resources Research Institute in each state. We thank him.

This is a Public Conference. Everyone Interested is Welcome and Encouraged to Attend.

INTRODUCTORY COMMENTS

Gerald W. Thomas*

I am particularly pleased to welcome the participants in the 18th Annual New Mexico Water Conference this year. I am pleased for several reasons: (1) Because the Conference represents a cooperative effort among many agencies and organizations as indicated by their broad base of membership on the Advisory Committee listed in the program; (2) I am pleased that the Conference this year is dedicated to a distinguished New Mexico Statesman, the Honorable Senator Clinton P. Anderson, who is being recognized by a resolution of this body; and (3) I am pleased to be here because we are discussing New Mexico's most important resource--Water--and the theme is the Comprehensive State Water Plan.

No conference could have a more significant and timely objective than to have the State Water Plan as a major theme. As this decision takes place, we will all recognize new challenges to conserve the water resource.

The water problem cannot be separated from the energy crisis, from land-use problems, or even from social ills. All of these are interrelated. I had the opportunity recently to attend the National Education Association meeting in Chicago and to hear a discussion of the Club of Rome study which resulted in the book, The Limits of Growth. This is a depressing but potent statistical approach to man and the environment, but perhaps the treatment is too pessimistic.

I believe that there are alternative solutions to our pressing problems relating to man and resources, but only if we can substantially increase our research efforts, if we can step-up our educational programs, and if we properly analyze and understand the various alternatives. The Conference today represents one step toward meeting the challenge as we project our water needs to the year 2020.

* President, New Mexico State University, Las Cruces, New Mexico

A LOOK INTO THE FUTURE

Warren D. Fairchild*
Paper presented by Daniel V. McCarthy**

It is with great pleasure that I accepted the invitation from Prof. Clark to deliver the keynote address at the 18th Annual New Mexico Water Conference. The Bureau of Reclamation has had a long and rewarding program of activity in New Mexico dating back to 1905 with the Carlsbad Project. Although varying in intensity, that program has continued through today, and I am sure will continue far into the future. Of particular satisfaction in recent years has been the opportunity to make an input to your State water plan.

It is most timely that this conference is devoted to the New Mexico State Water Plan. Over the past 5 years or so there have been more penetrating, far-reaching upheavals in water-planning norms than in any like period of history. And most, if not all, of these changes call for greater State involvement in planning for the conservation, development, and management of water and related resources. This is as it should be.

Perhaps the most far-reaching development of recent years affecting planners is the changing attitude toward population growth. In the past, with demographers confidently predicting population expansion following well-tested growth rates, planners structured accordingly as they looked 20, 40, and 60 years into the future. With the growing awareness that there is a practical limit in population that a Nation's resources can support at desired standards of living, future projections may be much different from the past. State attitudes can materially affect the pattern of population growth within a State. In-migration can be encouraged or, as is now happening in some states, it can be discouraged. Your State water plan must assess this factor from the New Mexico viewpoint.

* Assistant Commissioner, U. S. Bureau of Reclamation, Washington, D. C.
** U. S. Bureau of Reclamation, Washington, D. C.

The explosive thrusts of environmental concerns in recent years have presented new challenges and added new complexities to planning processes. But here again, you in New Mexico are the ones primarily concerned with the type of future environment that should prevail, and the State water plan should reflect your desires in this respect.

A separate part of the overall environmental picture, but encompassed in a separate set of laws, is the water quality control program. The establishment of water quality standards throughout the Nation has created one more major problem that water planners must face and resolve. Hardly any project that stores, diverts, or otherwise changes the natural flow of a river or stream is unaffected by requirements of water quality considerations, be it for fish, aesthetics, or the maintenance of set standards. The State has the responsibility to set State water quality standards, and again the State water plan should reflect State attitudes here.

Two other important factors of recent years which have a significant impact on water resources development are the rising discount rates in effect for justifying Federal water resource programs and the increasing competition from urban-oriented Federal programs for the Federal dollar. By restricting Federal water resource developments, these have the effect of placing greater responsibility on State and local interests for such activity.

The very recent, and in many ways contorversial, proposed report of the National Water Commission places overwhelming emphasis on State and local responsibility for water resources development and management. The central theme of that report is to retire the Federal Government from the water resources development field and turn responsibility over to the States and local interests. While a trend in this direction is obvious, I cannot agree in total with the Commission's findings which I shall discuss briefly later.

All of these developments of the past 5 years point strongly to the need for comprehensive, well-structured State water plans. The water leaders of New Mexico are to be commended for their foresight in anticipating this need and the steps that have already been taken to develop just such a State water plan for New Mexico. I reiterate, this conference could not be more timely.

Inasmuch as it is probably the liveliest topic of conversation in the water resources field today, I would like to return to the National Water Commission.

The Commission has released and held public hearings on a review draft of a proposed report on national water policy. This draft contains 290 significant and far-reaching conclusions and recommendations. Many of the recommendations are sound, and others are proving to be quite controversial. Regardless of your personal opinion on the merits of this report, one item is very self-evident. The Commission has pointedly determined that substantial changes are needed in national water policy, and it has attempted to outline what such changes should be.

This 4-year study can have a major impact upon the organization, financing, evaluation, and management of water programs. Emphasis has been placed upon environmental considerations and greater responsibility for State and local participation in water planning and administration.

The Commission's proposal for recovery of all costs, including interest, from direct beneficiaries of water resource developments is a controversial issue, the outcome of which is uncertain. Its emphasis upon efficiency criteria for evaluation should be broadened to give greater recognition to social and environmental factors and regional and local goals. Environmental analysis needs greater precision. The Commission has made good proposals for improved management of existing water supplies. Further consideration needs to be given to the nature of Federal action programs which cannot be undertaken at the State or local level. Its recommendation for a strengthened independent Water Resources Council is not consistent with President Nixon's Executive Reorganization Proposal that envisions a Department of Natural Resources.

Many of the Commission's recommendations would require congressional legislation, and the remainder are dependent upon executive approval and State and local cooperation. The nature of these responses to the Commission's report is uncertain at the present time.

Executive reorganization and impending changes in water policy leave us with an uneasy feeling that the future may well differ from what our best guesses now lead us to expect. Water resources planning for the future is now reflected in a very cloudy crystal ball.

Extension of lines on graph paper to show what would happen if past trends should continue into the future is not enough, for the lines are changing unpredictably. There have been some indications, for example, that electric power consumption is increasing at a slower rate. It becomes necessary to envision not only one, but several sets of possible future conditions. A declining birth rate leaves us perplexed on how to evaluate the Census Bureau's high population projection of 300 million people in the United States for the year 2000, or its low projection of 250 million. The difference of 50 million people can profoundly affect future requirements for the use of water resources. Can we plan with enough flexibility to meet either condition?

The National Water Commission's report is not sufficiently flexible in this respect. It assumes, for instance, that agricultural water shortage will not be a problem to the year 2000, that consumptive water use in agriculture will decrease, and that transfer of water from agriculture to other uses will not restrict food supplies or export possibilities. The Commission therefore concludes that there is no longer any need for federally subsidized agricultural water development.

In contrast with these findings, the Commission's report, as a whole, implies that water policies of the past have not proved to be sufficiently flexible to meet changing needs. We must insure that future policies do not prove to be equally inflexible in the face of further changes in needs and conditions not now forseeable.

The trend toward decentralization of Federal Government, greater emphasis on local and State governments, revenue sharing, and increased non-Federal cost sharing is unmistakable. However, this does not signal the end of Federal involvement in the natural resource field. In my opinion, there will continue to be a need for a strong Federal role. However, recent pronouncements forecast a realignment in the level of participation among the various levels of Government--Federal, State, and local. The appropriate levels of this participation is the type of national policy that I feel this Nation should be articulating. It isn't what level of Government should predominate in the natural resource field--but rather what should be this relationship--with the knowledge that it will vary from area to area and function to function. However, let's be candid and recognize that up to the present time this partnership has weighed heavily on the Federal side.

There are two aspects of the National Water Commission report with which I particularly agree and which can have significant effect upon future water development. The Commission urges that institutions such as State water laws and interstate water compacts be reexamined and amended in light of current conditions and priorities. Granted that amendment of basic State water law is a long, agonizing experience, it is becoming more necessary each year. I doubt that there is a single State that could not profit immeasurably by updating its State water codes. Similarly, interstate water compacts negotiated decades ago and considered by many as sacrosanct often do not reflect current needs and priorities. For example, past compacts have, in most cases, allocated all of the water in a given basin among the participating States. In so doing, the problems of water quality were not recognized, and the user receiving the last drop of water at the end of the line is faced with receiving water of unusable or questionable quality. I doubt that today an interstate water compact would be approved if it did not provide sufficient outflow to assure the user at the bottom of the totem pole a quality of water he could effectively use.

The other aspect of the Commission report is that bearing on greater financial input by local and State sources to water resources development. Although I do not advocate going as far as the Commission does, the trend in this direction is unmistakable. It is time that water leaders at the local, State, and Federal level pool their thoughts and come up with new imaginative and innovative ways of financing desirable programs so that such programs can effectively move forward.

In the remaining time I have left, I would like to outline some of the evolving changes the Bureau of Reclamation is undergoing. Such changes are not new to our agency; however, the rate of change has increased in recent months because of the rapidly changing values and priorities of our Nation. I am confident that many of the new things we are doing will find application in planning future water resource programs in New Mexico.

I would like to note first though, that when those of us in an agency such as the Bureau of Reclamation advocate change in programs, we are not discrediting the past. The accomplishments of such agencies speak for themselves. However, we must recognize that such accomplishments were undertaken in recognition of priorities and values of that day--that is the principal reason they were so successful. Now we must similarly address our program to today's priorities and values and anticipate the future.

It is obvious that the automation of today signifies a different world from the clockwork mechanisms of our grandfathers. More subtle and basic aspects of our life are also changing--public goals, values, and styles of life focus on "how good" rather than "how much"--on quality as well as on quantity. As a result, we must now consider many subjects once thought to be outside of the Bureau's scope. A broader needs-oriented approach, covering social and environmental factors, has been added to the traditional resource-oriented viewpoint. The planning process considers alternative goals as well as alternative means. Multiple uses and multiple objectives require input from many professional specialities and from the public at large.

Multiobjective planning as outlined in recently adopted Bureau planning guidelines is fully responsive to these new thrusts, including the requirements of the 1969 National Environmental Policy Act. This Act specifies alternative planning and the utilization of interdisciplinary planning teams. This planning concept requires highly trained, interdisciplinary teams, which has necessitated the centralization of much of our planning capability in the regional offices. Regional Director Jim Bradley has recently announced such a planning reorganization of the Southwest Region. We will be centralizing most of our planning capability in Amarillo, Texas. However, we will be maintaining State liaison offices in such locations as Albuquerque.

I would stress that I see this program as strengthening our ability to assist your State in land and water programs. We will be maintaining a State visibility and, at the same time, have highly trained teams available to assist you as appropriate.

The planning program of our agency is being redirected to give priority to meeting the near-term needs of people. Of the six new planning starts included in the F.Y. 1974 recommended budget, five emphasize municipal and industrial water supply. Over 85 percent of the envisioned costs of constructing these projects is for the M & I function. One of these new M & I starts is a water supply study for Gallup, New Mexico.

A new category of planning investigation is that of total water management. The principal objective of these studies is to improve the management and utilization of existing supplies. We have two such studies in our program at this time; one is the Elephant Butte-Ft. Quitman investigation. This study encompasses the Rio Grande Valley between the upper end of the Elephant Butte Reservoir in New Mexico and Ft. Quitman in Texas and the surrounding region in southern New Mexico and far west Texas. As you know, all of the surface water of the area has been committed, and the ground water for municipal use is being withdrawn faster than it is being replenished.

Because of the phreatophyte growth and drought conditions, the water yield to the Elephant Butte Reservoir in recent years has been 65 percent of the long-term average inflow. This has caused economic problems in the project area. Input into the broader aspects of this study is coming from business and agricultural leaders, State water agencies in Texas and New Mexico, State universities, irrigation districts, and other local agencies. We are most pleased with the cooperation and input into this study to date. We are confident this program will evolve a plan for orderly, rational, long-term development of available material and human resources to achieve a regional economic potential within a setting of the highest quality environment.

In the short time I have with you today, I cannot cover all of the interesting and exciting activities we have underway in the Bureau. Two in particular have potential for extensive long-range beneficial contributions to New Mexico's future. One is Project Skywater, our weather modification program with which many of you are familiar. The technical problems of inducing precipitation in mountainous areas are well along to solution, and our experts are confident that increases in annual precipitation of 15-20 percent at cost of water yield in the range of $1-1/2 to $2 per acre-foot are virtually assured. The more difficult problems in weather modification may well be in the realms of environmental, ecological, and legal considerations. These problems are under study but we are not prepared at this time to forecast when they will be resolved.

The other potential is in our program to explore the feasibility of desalting geothermal brines in the Imperial Valley of California as a source of augmentation for the Colorado River. Our program is moving along with a production well now in operation and assembly of a pilot-plant desalter in process. It will still be several years before we have concrete results.

Other new programs include the Colorado River Water Quality Improvement Program; water quality studies on the Salton Sea in California and Lake Meredith in Texas; and water supply studies associated with increasing energy demands.

Our program is not without problems or conflicts, as evidenced by recent district court action on Lake Powell. There is increasing demand for releases from Reclamation reservoirs for such in-stream uses as fish and wildlife, recreation, and aesthetics.

Presently our Bureau has a $6.2 billion backlog of authorized, but unconstructed, projects. Based on present level of construction appropriations and a very modest level of increasing costs from inflation, elimination of this backlog will extend beyond the end of this century. Such a time frame would not be compatible with needs or the authorization of new priority projects. A review of this backlog is being undertaken by the Bureau and the Department to attempt to bring the backlog into more manageable form.

From this brief review of recent activity, it is clear that many new forces have entered the picture to alter the programs of Reclamation. In response to changing needs, we find changing objectives and shifts in priorities among project purposes. Our way of doing business will also change as new management concepts and modernized techniques are applied.

Not only will we stress water priorities differently among project uses, but we may well urge that, in some cases, water be reallocated from one use to another. Possibilities for fuller use and reuse of existing water supplies will receive close scrutiny. Increased emphasis will be given to nonstructural components of resource management.

In economic analysis, higher interest rates will alter optimum plans through different combinations of investment and operating cost. Desalting opportunities must be compared with large diversion proposals. Economies of development by stages will be compared with full initial development. The economic aspects of new technologies will need to be explored.

We have been undertaking special studies on improved irrigation water management. We have found that by merely assisting farmers with information as to when and to what degree to irrigate, we can increase irrigation efficiencies from about 40 percent to about 55 percent. On 8 million acres of lands served by our agency, this 15 percent amounts to a saving in water diversions of about 9 million acre-feet of water annually.

However, to achieve these savings we need cooperation of the water users and State governments. Many water users have grown accustomed to inexpensive water in copious amounts. It is the cheapest tool in their production kit. Poor water management may be less costly than the labor, equipment, or improvements to achieve the water savings. Existing State water laws can be a constraint in achieving needed improvements.

New relationships of Federal, State, and local organizations must be explored. States must develop plans and establish priorities for the conservation, development, and utilization of their water resources. Federal agencies must look to the States for such guidance on natural resource programs that are limited to State significance. Rising cost indexes for construction not only require greater benefits for justification, but also greater repayment obligations. As the States become more active in water planning, it becomes appropriate to inquire whether they can assume an appropriate part of the repayable cost. With broader objectives, we need a broader base for project financing. We also need new and innovative approaches to build new institutional arrangements and revisions in water law.

Water planning and development are long-term undertakings. Presently, we have planning reports in varying stages of completion that were initiated in days of other values. We could compare ourselves to a new car dealer when the new models come out. Many of our reports are "in" with the new styles; whereas, some are not and will have to be restyled or reformulated, and we have a few Edsels or Kaisers around that will be dropped from the "line."

Water planning today is at a crossroads, barely holding its own in the competition for national attention and funds. Repeated attempts over the years to develop a sound national water policy are still unfinished. Progress has been made in broadening our objectives, but means of implementing them are still embryonic. Not even a start has been made in authorizing correspondingly broader methods of financing. Appropriate levels of investment need to be determined. Rational means of establishing program priorities need to be selected.

The running battle between well-considered rational planning and emotional reactions to crises continues at an intensified pace. So much the more do we need well-conceived, clearly defined standards and procedures. So much greater is the need for alternative plans supported by objective data. So much more pressing is the need for institutional reorganization, such as the proposed Department of Natural Resources and new relationships with State and local organizations. So much more important is the need for public water planning agencies to represent a well-considered concept of the public interest in the broadest sense.

I am confident that the New Mexico State Water Plan, which will be explained and discussed in detail during the next two days, already reflects many of these new priorities and thrusts. I am even more confident that eventually it will accomodate them all.

STATE WATER PLAN

S. E. Reynolds*

Water has been for at least 12,000 years a rationally and emotionally important subject to the inhabitants of what is New Mexico. Consequently, it has been the subject of considerable careful thought and planning, no little plotting, and some violence.

An orderly treatment of the subject of water resources development and planning in New Mexico seems to me to require at the outset some discussion of the fundamental law governing the appropriation of water in our State. While this law may not be immutable, it must be the point of departure for planning, and rights heretofore established under it must be protected.

Our constitution provides that the unappropriated waters of the natural streams of the State, perennial or torrential, belong to the public; that these waters are subject to appropriation in accordance with law; that beneficial use is the basis, the measure, and the limit of the right to the use of the public waters; and that priority of appropriation gives the better right.

Our surface water code which was enacted in substantially its present form in 1907 and our groundwater code which was enacted in 1931 have these provisions as cornerstones. The philosophy underlying these laws is commonly called "the appropriation doctrine of water rights."

The appropriation doctrine was followed first by custom and then by law in New Mexico long before the constitution was adopted in 1912. Under this doctrine, one has no right to the use of water simply because it flows by or through or under his land. It seems clear to me that this is a very practical system for the management of water in an arid region. Certainly development of any nature would be discouraged if it were possible for the latecomer to interefere with water supply upon which earlier investments are based.

Under the statutes governing the appropriation and use of surface water, any person intending to construct works and make a new appropriation of water or to change the point of diversion or place and

* State Engineer, State Capitol, Santa Fe, New Mexico

purpose of use of an existing water right must apply for and receive a permit from the State Engineer before doing so. Before the State Engineer can issue the permit applied for, he must find that the exercise of the right to be granted will not be detrimental to any other right. These statutes provide for the publication of a notice of the application to give those who might be adversely affected opportunity for a protest and hearing on the application. The decision of the State Engineer is, of course, subject to appeal to the courts.

The statutes establishing the administrative procedures to be followed in the appropriation and use of groundwater are similar to those for surface water. When the State Engineer finds that the waters of an underground supply have reasonably ascertainable boundaries and he so proclaims, he assumes jurisdiction over the appropriation of those waters. He proclaims, or declares, an underground water basin by the issuance of an appropriate order and publication of a description of the boundaries. Thus far, the State Engineer has declared 24 underground water basins to prevent the impairment of existing rights to the use of water, to insure beneficial use of the water, and to provide for the orderly development of the groundwater resources of the State. These declared basins cover about 40,000 square miles, or about one-third of the total area of the State.

Groundwater outside the boundaries of underground water basins belongs to the public and is subject to appropriation, but anyone may develop this water and put it to beneficial use without a permit from the State Engineer.

The legislature created the New Mexico Interstate Stream Commission in 1935. The Commission consists of nine members. Eight of the members are unsalaried; each of these eight is appointed by the Governor to represent a different major irrigation district or section of the State. The State Engineer is by law the ninth member and Secretary of the Commission; in this capacity he acts as the Commission's executive officer.

The Commission is authorized to negotiate compacts with other states to settle interstate controversies or to make equitable distribution and division of waters in interstate stream systems. New Mexico is party to eight interstate stream compacts. All of our significant surface streams are now involved in such agreements. One of our streams, La Plata River, is subject to four such compacts. The Commission is responsible for the negotiation of any amendment to these compacts and for interpretations necessary to the administration of the compacts.

In addition to our constitution and statutes and the eight interstate compacts, the Supreme Court decree in Arizona v. California, et al. and three federal district court decrees, govern the appropriation and use of water in New Mexico.

The State Engineer is bound by the terms of the compacts and the federal court decrees in his administration of the water resources of the State and these agreements and rulings have an important effect on the amount of water available for use in New Mexico. When New Mexico has fully developed her surface water resources within the allowances of the interstate compacts and federal court decrees the annual river inflow to the state of about 2-1/2 million acre-feet will approximately equal the outflow and New Mexico will use, beneficially or otherwise, about the amount of stream flow that she produces--roughly 3-1/2 million acre-feet.

One of the major functions of the Interstate Stream Commission is to review and comment on plans for federal water projects in New Mexico and on interstate streams in other states to make sure that New Mexico's interests are protected. This work includes cooperation in and coordination of the work of federal agencies in planning projects in New Mexico. The Commission has participated in the formulation of project plans, operating criteria, and authorizing legislation for many federal projects, including for example, the Navajo Dam and Reservoir Project and related Navajo Indian Irrigation Project on the San Juan River, the San Juan-Chama Diversion Project, the Animas-La Plata Project on the Animas River in Colorado and New Mexico and the Hooker Unit of the Central Arizona Project, all Bureau of Reclamation Projects and the Corps of Engineers Cochiti and Galisteo Reservoir Projects.

In the past seventeen years, about $660 million worth of federal water projects have been authorized or completed in New Mexico and an additional $130 million worth of projects are presently under feasibility grade investigation.

At the present time we are diverting about 3.5 million acre-feet of water annually in New Mexico. Of this amount, about 90 percent is used for the irrigation of roughly a million acres of land; most of the balance is used for municipal and industrial purposes. All but about 150,000 acre-feet of the surface water that we are entitled to under the interstate compacts and court decrees is already committed to existing uses or to projects that are soon to be completed, such as the Bureau of Reclamation's San Juan-Chama, Navajo, and Animas-La Plata Projects.

Considering the quantity of water New Mexico has available and is entitled to, it seems fair to say that we are well along toward creating a plan for the development and control of our available water resources and implementing that plan. Nevertheless, looking ahead we see much that remains to be done in water resources planning. In 1950 the State had a population of about 680,000 people. In 1960 our population was 951,000 and the 1970 census shows a population of just over one million. Some experts tell us that we may have to accommodate a population of over four million by the year 2020. Of course, all these people are going to want water for their economic enterprise and for their pursuit of pleasure.

In 1967, the Interstate Stream Commission asked the Bureau of Reclamation to take primary responsibility for the preparation of a State plan for our water resources. The product of this planning effort will include input from a large number of State and federal agencies. The Bureau of Reclamation is coordinating the efforts of the Interior Department agencies, and the Interstate Stream Commission is coordinating the efforts of the federal agencies, other than Interior agencies, and the large number of State agencies that are participating. The Commission is also consulting with and advising the

Bureau in the plan's preparation. The scheduled completion date is now the end of fiscal year 1974.

As you will recognize, a statement of the problem is essential to its solution. The target date of the water plan is 2020, and the only way to state the problem is to make projections of the distribution of our population and economic activity at that time. Unfortunately, our vision for the target is a little less than 20-20.

To cover a wide range of alternative futures, we are using three sets of projections. To coordinate with the resource planning being done by the State Planning Office, we are using projections prepared for that office by the Bureau of Business Research at the University of New Mexico. To coordinate with the Westwide Water Plan being prepared by the Bureau of Reclamation in response to a charge of the 1968 act authorizing the Central Arizona Project, we are using projections prepared by the Office of Business Economics and the Economic Research Service (OBERS) in 1968. To represent a more conservative alternative future, we are also using the 1972 series C projections prepared by the Bureau of Economic Analysis.

The projections of population vary from 4.6 million in 2020 for the projection of the Bureau of Business Research, to 2.7 million for the OBERS 1968 projections, and 1.6 million in 2020 for the Bureau of Economic Analysis projection.

Following the circulation of the "Situation Assessment Report on the State Water Plan" last Spring, we were criticized because "tacit within the large projections is an automatic statement of policy--a policy of growth for growth's sake regardless of any side effects, a policy which has become increasingly discredited." In answer to this criticism, I assure you that the Bureau of Reclamation and the Interstate Stream Commission have neither the authority nor the ambition to set the State's policy with respect to the growth of population and economy. We see the establishment of such policy as a function of the legislature and perhaps other State agencies such as the State Planning Office. The projections of population that we are using do not reflect the policy or even the judgments of those preparing the State plan. We are constrained to the use of at least two of the projections to coordinate with other planning work. Without advocating any one of the three projections that we are using, it does seem that these will give us the opportunity to have a look at a wide range of possibilities.

I find it interesting and somewhat paradoxical that the projected water depletion requirements for 2020 are relatively independent of the population projections. Assuming a plan that would provide for irrigation depletions at about the present level plus the irrigation depletions that would be implemented by authorized federal projects, the requirement for a population of 4.6 million is 4.3 million acre-feet of water annually, and the requirement for 1.6 million people is 3.6 million acre-feet annually. This anomaly arises out of the projection techniques which estimate requirements for irrigation, power generation, and mining and milling independent of population. Other projection techniques might yield significantly different results, but these seem to be reasonable for the New Mexico plan.

The projection for irrigation, which is the largest single component, amounting to about 2.2 million acre-feet annually, assumes that about one-half of the approximately 450,000 acres currently irrigated with mined groundwater will go out of production by the year 2020, but that a similar amount will be placed under irrigation using mined groundwater from other aquifers. In addition, about 150,000 acres would be put under irrigation with surface supplies from authorized federal projects.

I should also point out that these projected requirements do not include projected requirements for recreation, which for the high projection amounts to 3.4 million acre-feet annually for lake evaporation. It does not appear that we can reasonably hope to furnish the lake surface that 4.6 million people will want for boating and water skiing.

Work completed on the water plan to date serves to at least state the problem. We can estimate that about three million acre-feet annually, including about 600,000 acre-feet from groundwater mining, will be available for depletion within the State in 2020. This estimate assumes that as the aquifers are mined out on the east side, additional mining from other aquifers, including those in the northeastern part of the State, would be undertaken; that the current groundwater mining in the southwestern part of the State will still be economic; and that we will not undertake mining of aquifers intimately related to streams such as those in the Rio Grande Basin.

The availability of three million acre-feet annually must be compared to projected requirements of four to five million acre-feet annually.

There is some hope that the difference between availability and demand can be made up by importation from sources which we are not currently entitled to have. For example, water might be imported from the Columbia River system to the Colorado River system and our entitlement to Colorado River system waters increased for use in at least the San Juan and Rio Grande systems in New Mexico. However, the law authorizing the Central Arizona Project prohibits even a study of that possibility until 1978.

There is underway a study of the practicability of bringing surplus water from the Mississippi River system to West Texas and Eastern New Mexico to sustain the irrigation economy based on groundwater mining. The construction costs of such a project, as yet unreported, are obviously enormous; a pump lift of 4200 feet, which is roughly the difference in elevation between New Orleans and Clovis, suggests very large annual operation and maintenance costs. The economic feasibility of the proposal remains questionable. With respect to the social factors, there is some question whether the project could be completed in time to save the economic structure which exists now in the area. The political viability of a project to export water from the Mississippi River Basin to West Texas and Eastern New Mexico might be the toughest question to answer. When a semiarid state begins to look past her borders for supplies beyond her current entitlements, her neighbors obviously have legitimate cause for concern. A state such as Louisiana with an apparent surplus of water must jealously guard its future and carefully weigh all conceivable future requirements for water for municipalities, industries, pollution control, including salt water intrusion, and for recreation and the maintenance of the ecology and aesthetics of bays and estuaries.

The one thing that is eminently clear is that we cannot rely, in a plan to be completed in fiscal year 1974, on importation from areas of apparent surplus supplies.

Optimism about major water resources projects is further dampened by the recent proposed report of the National Water Commission which would recommend termination of the federal policy requiring no interest and using power subsidy for repayment of irrigation project costs; interest rates for project evaluation and project cost repayment far above those that would encourage the construction of water resources projects needed for the attainment of long-range social objectives; virtual dismantlement of the federal water project construction agencies; and curtailment of irrigation in the West to make water available for growing municipal and industrial requirements.

For more than a quarter of a century now there has been reason to hope that man might manipulate the weather to increase the water supply of the western states, but work on that possibility is still, in my opinion, very much in the research phase. Uncertainty about the possibility of increasing precipitation in meteorological situations such as we experience in the summer months is as great, or perhaps even greater, than it was a quarter of a century ago. Reportedly, work done by or through the Bureau of Reclamation's Division of Atmospheric Water Resources Management gives indications that significant increases in snow melt runoff could be achieved at relatively very low cost. But even the most sanguine of those involved in the work tell us that another year or two of field trials will be needed to confirm or deny this possibility.

Even though all of the scientific questions with respect to our ability to modify precipitation were laid to rest, there would remain almost imponderable questions, and possibly insuperable problems related to the law and environmental factors. I am sure that most of you are not surprised to find that it is not universally agreed that we should increase our snow melt runoff, even if we could. Hopefully, we can better appraise the prospects for increasing our water supply by weather modification before the water plan is completed and, of course, the plan could always be adjusted after it is completed to accommodate scientific and political progress on this possibility. But at this point it does not appear that we should plan heavily on meeting our 2020 requirements with man-made precipitation.

There is some prospect that New Mexico's usuable water resources can be augmented by desalting. New Mexico has been interested in desalting as a source of fresh water for at least twenty years. In the early 1950's the question of whether the federal government should undertake a research program in weather modification or a research program in desalting to supplement water supply was an issue before the Congress. Clinton P. Anderson who represented New Mexico so effectively in the Senate is a master of political science with only slightly less acumen in physical science. He is thoroughly familiar with the importance of water to the Southwest. The Senator was a protagonist in the Congressional actions which established research programs in both fields, and he acted to sustain and expand both programs.

When Congress, in 1958, by legislation introduced by Senator Anderson, authorized the Office of Saline Water to construct a plant in the Southwest to demonstrate a desalting process, New Mexico seized the opportunity to contribute to a program which promised to enhance the Nation's water supply, and the $1.8 million forced circulation-vapor compression plant was constructed at Roswell. The location of the authorized demonstration plant in New Mexico was supported in one of the few resolutions ever adopted by this conference.

There are in New Mexico at least 8 communities of more than 1,000 population which are now using waters with a dissolved solids concentration of more than 1,000 ppm for public supply. Desalting of these supplies could make an important contribution to the welfare and comfort of the citizens of these communities and their visitors. It appears to me that in the short term this is the most likely application of desalting in New Mexico.

Working in cooperation with the Office of Saline Water, the State, through a contract with the Southwest Research Institute, has recently completed an investigation of the physical and economic feasibility of improving and increasing the water supply of five representative New Mexico communities currently using water having concentrations of dissolved solids and hardness above those recommended by the Public Health Service. This five-city study will be used in the New Mexico water plan report and should be very helpful in evaluating this potential benefit.

It appears to me that perhaps the most important contribution of the Office of Saline Water program has been the establishment of desalting techniques sufficiently well to set a floor on water supply or, if you prefer, a ceiling on water cost. By desalting, a supply of fresh water adequate for all conceivable needs could be made available if and when the value of the use for which it is needed is high enough. The prospects for using desalted water for irrigation in New Mexico do not seem imminent, but even this application is possible sometime in the future.

My hopes that desalting techniques will contribute to meeting our 2020 water problem were considerably diminished by the recent decision of the Office of Management and Budget to discontinue the demonstration and research work at Roswell and the President's budget proposals which would drastically reduce appropriations for the Office of Saline Water and terminate its research in the desalting of brackish waters.

We are considering other possibilities for narrowing the difference between availability and demand. Among those being considered are improvements in evaporation suppression, vegetation management, irrigation management including exotic techniques such as trickle and drip irrigation, exploitation of geothermal resources, air cooling for heat disposal, and urban residential water conservation measures. Some of these show promise, but the amount of water that might be developed or saved, as well as the time when such techniques might be practicable, is uncertain. At this time, it seems useful to consider but not to rely on these possibilities for closing the gap between availability and demand.

If weather modification, desalting, and improvements in water conservation do not prove productive beyond what we can now reasonably hope; if we cannot find rivers that have surplusses that can be exported for use in New Mexico--and we must continue to have some doubt that we can; and if we have to accommodate more people in the Land of Enchantment--and this seems fairly certain--there will need to be a change in the pattern of water use in New Mexico.

A key element of the problem is the fact that agricultural pursuits provide relatively little opportunity for increased employment. For example, it is estimated that the 110,000 acre Navajo Indian Irrigation Project now being constructed by the Bureau of Reclamation on the San Juan River will provide for the livelihood of 33,000 people on the Navajo Reservation. The project will divert 508,000 acre-feet of water annually and will deplete the supply by 254,000 acre-feet--a depletion of about 7.7 acre-feet per person supported. In an urban-industrial culture such as that existing in the Albuquerque area, the depletion requirement is only a little more than a tenth of an acre-foot per person. So if the problem is to support an increasing population on a fixed supply of fully appropriated water, the answer is to use a progressively larger proportion of the State's water supply for municipal and industrial uses.

A fundamental attribute of a water right held under the doctrine of prior appropriation, as our statutes recognize, is the right to change the point of diversion and place and purpose of use of the water, provided that the change does not impair any other water right. Thus, a city can purchase irrigation water rights by negotiation or condemnation at a fair value and, under conditions set to avoid impairment of any other water right, change the point of diversion and purpose of use to meet its requirements. By this mechanism, the depletion of water by municipal and industrial use in the State could be increased 100% with a reduction of less than 10% in irrigation usage.

The plan will consider potential for augmenting the usable water supply that we are entitled to, but the first phase of the water plan formulation will involve the conception of works to distribute the supplies available to the State under existing interstate agreements and court decrees to supply the projected distribution of population and economic activity. The formulation and consummation of such a plan obviously implies some interesting political problems but these do not seem unmanageable. Some changes in federal and State law covering situations where water rights are held by the federal government or political subdivisions of the state such as conservancy districts may be needed to give the desired degree of flexibility for water transfers.

Fundamental in this approach to the problem is the assumption that the value of water used for irrigation will be less than the value of the same amount of water applied to municipal and industrial purposes. This is the case today, but it seems not inconceivable that conditions in 2020 will prove the assumption invalid.

The environmental consequences of transferring water use from irrigation to other purposes and of forgoing of failing in the rescue of irrigation economies based on groundwater mining also deserve consideration. In his recent book, A God Within, Rene Dubos, a noted scientist, has pointed out:

> A great majority of persons in any case have no opportunity to experience and enjoy nature except in its humanized aspects--cultivated fields, parks, gardens and other manifestations of human settlements. In consequence it is not enough to save

the Redwoods, the Everglades, the Grand Canyon, and as much wilderness as possible; it is equally important to protect the aesthetic quality of urban settings and farm lands. Figuratively speaking, we must improve Coney Island.

The drying up of vast acreages of irrigated land to furnish water for municipal, industrial, and other purposes and by the unrelieved exhaustion of available groundwater resources would have a very serious, adverse impact on the environment of a large number of people.

For this reason, if no other, it is important that we continue to direct our thought and efforts to the augmentation of our usable water supply by importation, weather modification, desalting, and conservation.

Conclusion

I believe we have made reasonable progress in that first essential step, the statement of the problem, but the Bureau is just beginning to think about going to the drafting board to map solutions. We are not in a position yet to talk very much about specific alternatives for various localities.

Following the presentation of our situation assessment report last year, some expressed concern that "environmental factors appear not to be seriously considered." It is my current view that the water plan will give considerable attention to water quality, but that it will not be able to treat in detail such problems as air pollution, solid waste disposal, and the adverse environmental and psychological effects of high population density. There will, of course, be ample opportunity for others with expertise in these fields to make formal comments on the implications of the water plan with respect to such factors.

During plan preparation we expect to have consultation with local officials, perhaps on a county-by-county basis, and to conduct such local or regional hearings as these officials find appropriate. I also expect the Interstate Stream Commission to conduct at least one more public hearing on a draft of the final report for statewide participation and to invite all interested persons to comment in writing or orally. I look forward to further consultation with you on the New Mexico State Water Plan.

POPULATION PROJECTIONS FOR THE NEW MEXICO STATE WATER PLAN

Lee B. Zink*

Introduction

Why are we concerned about future population size in water-use planning? The answer is obvious to most and quite important for all. The first building block upon which realistic forecasts of the future are made is estimates of population size. Various levels of projected population are often used to allow planners to plan for different contingencies. Without such estimates for cities, counties, states, regions, and nations, little meaningful planning for the future could occur.

We might consider briefly some recently added dimensions regarding world population. Recent work sponsored by the Club of Rome[1] indicates that it may not be possible for the world to sustain unlimited population growth in the future, that the resources to support more and more people are limited. There are a number of alternative ways of examining this situation but the conclusion is not new to the history of mankind. It now appears that at least some countries are exhibiting rates of population growth which will assist in solving the problem. When might the world, or the United States, achieve zero population growth? Not for a long time. Current projections for water-use planning in the U.S. go to 2020 and most optimistic projections for zero growth rates are beyond that date.

We are probably more concerned with what is likely to occur here in our own area of the world. What about New Mexico and the Southwest? Many consider this part of the United States relatively underpopulated. If so, is that situation likely to obtain in the future? The obvious answer to me is "No." Unless there are absolute resource limitations, there are going to be more residents in our future, and one of the major resource considerations is that of water. So, the interactions of water-use planning and projected population of our region is a paramount concern for the future.

Clearly, population projections are extremely important. They do have severe limitations and need to be well understood in order to be used correctly. Therefore, a short examination of what they actually are is in order.

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* Director, Bureau of Business Research, University of New Mexico

1 Donella H. Meadows and others, The Limits to Growth (New York: Universe Books, 1972), 205 p.

The Nature of Population Projections

It is quite important to understand that what we are talking about here today is not accurate numbers relating to future population size of any particular area. Population projections do not predict what the actual population of an area will be at a given date in the future. Even though we sometimes forget the obvious, it should be apparent that such prognostication is beyond the capabilities of human intelligence. Projections of any activity related to human endeavor are very directly related to the assumptions upon which those projections are based. If the assumptions are in error, it follows that the projected data will also be in error. If the assumptions are fundamentally correct but contain a quantity factor which is over- or under-stated, the resulting projections will contain an error in the same direction. Too often persons looking at the printed page assume that the figures on that page are correct. That assumption is indeed hazardous with respect to population projections. Therefore, it should be emphasized once more that intelligent use of projections may be equally as important as the preparation of them.

What are projections? They are expressions of assumptions about phenomena which relate to population size. Among the items which may be considered in any set of projections are fertility rates, mortality rates, migration, economic conditions, health conditions, war or peace, natural resources, and so on _ad infinitum_. With so many potential considerations, it is clear that chances for errors or misinterpretations are great. Projections are tools for planners and as such are often expressed in ranges, e.g., the population of X will be between 10,000 and 15,000 in year Y. This is often disconcerting to users of such projections, for they want to know the _exact_ future population. Such precise prognostication appears to be beyond our grasp even with the most sophisticated techniques possible. What are population projections? They are guides along the road--baseline date--which simply tell us that if the assumptions behind them turn out to be correct, the figures depicting them may also be correct. They are that and nothing more.

Projections for Water-Use Planning 1970-2020

The projections of population, employment, and income formulated as guides for water-use planning in New Mexico are the work of two separate organizations and numerous researchers. The Bureau of Business Research at The University of New Mexico constructed two separate series at different times under quite different conditions. The series named BBR I in some publications was completed under the direction of Professor Ralph L. Edgel in 1967-68. That work was under contract to the New Mexico State Planning Office and was a part of the comprehensive planning activities of the State. It is a large work which goes into such detail as projections of employment by broad industry category. BBR II, the lower range of projections, was a much less complex undertaking. The Bureau of Economic Analysis of the U.S. Department of Commerce provided new projections for state populations in 1971. These projections accounted for changes which were registered in the 1970 Census of Population.

The projected figures were lower than previous projections. BBR II utilized these lower state totals and allocated these totals to the counties of the State on the basis of several other county distributions. This work was accomplished by staff members of the Bureau of Business Research working with representatives of the New Mexico State Engineer Office and the Interstate Stream Commission.

The OBERS projections are the third set published by the Bureau of Business Research and used in water-use planning. These data come from a continuing project of the U.S. Water Resources Council. The projections were prepared by the Regional Economics Division, Bureau of Economic Analysis, Social and Economic Statistics Administration, U.S. Department of Commerce and the Natural Resources Economics Division, Economic Research Service, U.S. Department of Agriculture. (The OBERS nomenclature was derived from the former name of the first organization combined with that of the latter.) The OBERS projections are considered preliminary and are subject to revision. They were formulated during the period 1967-71. The system used provided estimates for many areas of the United States.

Methodologies and Assumptions of Population Projections for Water Planning in New Mexico

As explained previously, assumptions, in a real sense, determine the outcome of the projections. Because they are so important and because the projections vary significantly, the general nature of these assumptions is explained below.

BBR I (Edgel)

First, the basic philosophy underlying these projections is that the size of New Mexico's population in the forseeable future will be determined by the size of the State's employment, by the nature of its resources, and by the character of the utilization of those resources. Employment is the major determinant of population size in the Edgel work. Other specific assumptions were:

1. The institutional framework within which the U.S. economy operates will remain relatively constant.

2. There will be changing patterns of resource development.

3. There will be changes in labor force participation.

4. The level of economic activity in the Nation will be the basic determinant of the level of economic activity in New Mexico.

In summary, projections to the year 2000 were made in the following steps:[2]

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2 Edgel, Ralph L., Projections of the Population of New Mexico and Its Counties to the Year 2070, Bureau of Business Research, The University of New Mexico, Unpublished, 1968, pp. 7-8.

1. As projected by Resources for the Future, the national requirements for various commodities produced in New Mexico or by New Mexico industry were examined in detail, to determine their implications for the State.

2. New Mexico industry was assigned a specific role in meeting these requirements--a role based upon the State's known and estimated resources, their quality and general accessibility, the likelihood of their being exploited at various future times, etc. A somewhat more precise account of the assumptions regarding each industry appears in a subsequent section.

3. A total for basic employment--that which is determined by demands exterior to New Mexico--was secured by adding together the figures obtained in Step 2.

4. A preliminary figure for total employment was secured by using an employment multiplier (the ratio between basic and total employment), which was increased slightly for each decade in conformity with but less rapidly than historical trends.

5. A preliminary estimate of the size of the labor force was secured by assuming an average employment rate of 95 per cent.

6. The age distribution (by broad age groups) of the preliminary labor-force estimate was obtained on the basis of the past age distribution of the labor force and the historical trends therein and the age distribution projected for the Nation by the Bureau of Labor Statistics in studies referred to above. This step produced an estimate of the size of the population 14 years old and older.

7. A preliminary estimate of the size of the total population was obtained by using the historical relationship between the under-14-years and the 14-and-over groups, modified for historical trends and projections of national population by age groups made by the Bureau of the Census.

8. A revised estimate of the volume of secondary employment was made by calculating for each industry the employment that would be required to provide local goods and services to the projected population. For this purpose we assumed a relationship between population and employment in each secondary industry which reflected the relationships of recent years, modified by historical trends and anticipated changes therein. The addition of the revised estimate of secondary employment to basic employment resulted in a new estimate of total employment.

9. The first preliminary estimates of labor force and population were then modified to reflect the new estimate of total employment, with the same relationships being used as had been assumed for the first estimates, modified to produce internal consistency in the figures.

10. The projected employment for the State for each industry for each 10-year period was allocated to the several counties on the basis of the present distribution among the counties but modified in light of past trends, known resources, and geographical relationships. In this manner a projected total employment for each county was obtained.

11. An estimate of each county's labor force and population was obtained by using past relationships among employment, labor force, and population in each of the counties, modified for apparent trends and the changing structure of each county's economy which was implied by the assumed changing employment structure.

12. After a thorough examination of the implications of the distribution among the counties of the employment and population figures obtained as above, we obtained a new set of projections of population for the State by addition of the county figures. This new set of projections was taken as the final Medium Projection of population and employment for the counties and the State.

13. Probable High and Low Projections were set up by our using the Medium Projection as obtained above and making arbitrary assumptions with respect to three variables: employment, age distribution, and labor force participation. From the numerous projections resulting from these calculations a set of High and Low Projections was selected as representing the most logical range of possibilities which should (sic) be considered in using the Medium Projection of employment and population.

OBERS

The OBERS projections are based on long-run or secular trends and ignore the cyclical fluctuations which characterize the short-run path of the economy. The general assumptions that underlie the projections are as follows:

1. Growth of population will be conditioned by a decline of fertility rates from those of the 1962-1965 period.

2. Nationally, reasonably full employment, represented by a 4 percent unemployment rate, will prevail as the points for which projections are made; as in the past, unemployment will disproportionately distributed regionally, but the extent of disproportionality will diminish.

3. No foreign conflicts are assumed to occur at the projection dates.

4. Continued technological progress and capital accumulation will support a growth in private output per manhour of 3 percent annually.

5. The new products that will appear will be accomodated within the existing industrial classification system, and, therefore, no new industrial classifications are necessary.

6. Growth in output can be achieved without ecological disaster or serious deterioration, although diversion of resources for pollution control will cause changes in the industrial mix of output.

The regional projections are based on the following additional assumptions:

1. Most factors that have influenced historical shifts in regional "export" industry location will continue into the future with varying degrees of intensity.

2. Trends toward economic area self-sufficiency in local-service industries will continue.

3. Workers will migrate to areas of economic opportunities and away from slow-growth or declining areas.

4. Regional earnings per worker and income per capita will continue to converge toward the national average.

5. Regional employment/population ratios will tend to move toward the national ratio.

BBR II

The basic methodology of these projections was to utilize relationships established under both the Edgel and the OBERS methodology and assumptions as the basis for allocating State totals provided by the Bureau of Economic Analysis to the counties of New Mexico. The only additional assumption was that all counties in New Mexico would have greater populations in 1980 than had been the case in 1970. That is, all New Mexico counties are assumed to have already reached their lowest population level.

Conclusions

Few conclusions can be drawn. We have three sets of population projections using different assumptions and methodologies to come to varying figures. These figures provide us with a high, medium, and low range of projections. Water-use planners can then utilize these figures with their own assumptions about water and devise projected water-use patterns and alternatives.

A pertinent question at this point might well be, "Is all of this worth the effort?" Population is clearly dependent upon so many variables that cannot be measured. Is it worth it? The question is complex, but the clear answer is that it must be worth the effort if New Mexico is going to grow. If we do not plan to accomodate that growth in important resource allocations, we will surely have ensuing chaos. Planning is important, and without the proper tools may be of little positive effect. So, we must have population projections if we are to plan at all. We just need to remember when using them that they are projections and are not prognostications of future census figures.

Reference:

1972 OBERS Projections, Regional Economic Activity in the U.S., "Concepts Methodology, and Summary Data" Volume I. U.S. Water Resources Council, Washington, D. C.

NEW MEXICO POPULATION, ACTUAL AND PROJECTED
By County, 1960, 1970, 1980, 2000, and 2020

County	1960*	1970*	1980	2000	2020
STATE TOTAL					
1.BBR I			1,630,000	2,778,000	4,621,400
2.OBERS	951,023	1,016,000	1,301,400	1,854,400	2,743,900
3.BBR II			1,119,000	1,336,000	1,589,000
BERNALILLO					
BBR I			531,500	948,000	1,546,600
OBERS	262,199	315,774	424,300	632,300	919,200
BBR II			353,500	425,800	514,800
CATRON					
BBR I			4,200	9,300	11,900
OBERS	2,773	2,198	3,900	5,600	8,200
BBR II			2,400	2,900	3,400
CHAVES					
BBR I			92,400	151,400	253,100
OBERS	57,649	43,335	74,200	100,100	150,900
BBR II			47,800	57,000	67,800
COLFAX					
BBR I			18,000	26,400	39,200
OBERS	13,806	12,170	14,300	18,600	22,000
BBR II			13,400	16,000	19,000
CURRY					
BBR I			68,100	123,700	215,600
OBERS	32,691	39,517	54,600	81,600	129,000
BBR II			43,600	52,000	61,800
DE BACA					
BBR I			4,600	10,100	12,900
OBERS	2,991	2,547	3,900	7,400	8,200
BBR II			2,800	3,300	4,000
DONA ANA					
BBR I			136,300	224,000	425,000
OBERS	59,948	69,773	109,300	148,400	252,400
BBR II			76,900	91,800	109,100
EDDY					
BBR I			66,500	104,200	171,900
OBERS	50,783	41,119	53,400	68,700	101,500
BBR II			44,000	52,000	61,000

NEW MEXICO POPULATION, Cont'd.

County	1960*	1970*	1980	2000	2020
GRANT					
BBR I			28,600	44,800	73,100
OBERS	18,700	22,030	23,400	29,700	43,900
BBR II			24,300	29,000	34,500
GUADALUPE					
BBR I			8,000	16,000	21,800
OBERS	5,610	4,969	6,500	11,100	13,700
BBR II			5,500	6,500	7,800
HARDING					
BBR I			3,800	8,100	10,400
OBERS	1,874	1,348	2,600	5,600	5,500
BBR II			1,500	1,800	2,100
HIDALGO					
BBR I			7,900	11,800	19,800
OBERS	4,961	4,734	6,500	7,400	11,000
BBR II			5,200	6,200	7,400
LEA					
BBR I			84,600	140,300	245,400
OBERS	53,429	49,554	67,700	92,700	145,400
BBR II			53,600	63,200	74,000
LINCOLN					
BBR I			13,900	23,900	30,500
OBERS	7,744	7,560	11,700	16,700	19,200
BBR II			8,300	9,900	11,800
LOS ALAMOS					
BBR I			34,700	56,300	92,300
OBERS	13,037	15,198	27,300	37,100	54,900
BBR II			16,800	20,000	23,800
LUNA					
BBR I			17,400	30,600	51,100
OBERS	9,839	11,706	14,300	20,400	30,200
BBR II			12,900	15,400	18,300
McKINLEY					
BBR I			58,700	88,200	145,000
OBERS	37,209	43,208	46,900	59,300	85,100
BBR II			46,600	54,800	64,600

NEW MEXICO POPULATION, Cont'd.

County	1960*	1970*	1980	2000	2020
MORA					
BBR I			5,300	10,200	13,100
OBERS	6,028	4,673	3,900	7,400	8,200
BBR II			5,200	6,100	7,300
OTERO					
BBR I			60,800	102,600	194,000
OBERS	36,976	41,097	48,200	68,600	115,200
BBR II			44,300	52,000	61,300
QUAY					
BBR I			16,200	26,500	35,500
OBERS	12,279	10,903	13,000	18,500	22,000
BBR II			12,000	14,300	16,000
RIO ARRIBA					
BBR I			26,600	43,600	70,500
OBERS	24,193	25,170	20,800	29,700	41,200
BBR II			27,000	31,500	36,200
ROOSEVELT					
BBR I			26,200	38,700	77,400
OBERS	16,198	16,479	20,800	26,000	46,600
BBR II			17,200	19,700	22,800
SANDOVAL					
BBR I			18,600	26,500	51,000
OBERS	14,201	17,492	14,300	18,500	30,200
BBR II			20,200	26,000	29,400
SAN JUAN					
BBR I			66,200	100,500	175,000
OBERS	53,306	52,517	53,400	66,700	104,300
BBR II			57,900	69,100	82,100
SAN MIGUEL					
BBR I			30,100	49,000	69,200
OBERS	23,468	21,951	23,400	33,400	41,200
BBR II			23,000	26,900	31,300
SANTA FE					
BBR I			82,200	178,500	287,200
OBERS	44,970	53,756	65,100	118,700	170,100
BBR II			59,200	70,700	84,100

NEW MEXICO POPULATION, Cont'd.

County	1960*	1970*	1980	2000	2020
SIERRA					
BBR I			9,900	18,000	24,700
OBERS	6,409	7,189	7,800	11,100	13,700
BBR II			7,900	9,500	11,200
SOCORRO					
BBR I			12,700	21,200	29,400
OBERS	10,168	9,763	10,400	14,800	16,500
BBR II			10,800	12,800	15,300
TAOS					
BBR I			24,800	37,900	52,900
OBERS	15,934	17,516	19,500	26,000	30,200
BBR II			19,300	23,000	27,400
TORRANCE					
BBR I			6,500	10,400	13,200
OBERS	6,497	5,290	5,200	7,400	8,200
BBR II			5,800	7,000	8,300
UNION					
BBR I			7,200	10,800	15,300
OBERS	6,068	4,925	5,200	7,400	8,200
BBR II			5,400	6,500	7,700
VALENCIA					
BBR I			57,500	86,500	147,400
OBERS	39,085	40,539	45,600	57,500	87,800
BBR II			44,700	53,300	63,400

* Census data

1. UNM Bureau of Business Research, first projection
2. Office of Business Economics, USDC, and Economic Research Service USDA
3. UNM Bureau of Business Research, second projection, based upon State totals provided by Bureau of Economic Analysis, USDC

A STUDY OF WATER USED ON URBAN LANDSCAPES

Fabian Chavez III and Donald J. Cotter*

Abstract

A study conducted to determine the water used by urban home owners in Las Cruces, New Mexico, to maintain their landscapes showed that from 40 to 65 percent of private metered water was used for maintaining plants in the landscape. The water quantity used was in proportion to living mesic plants. Homeowners with 90 to 100 percent of the space devoted to living plants applied 99 percent more water per home than landscapes characterized as intermediate, where living plants were maintained on only 50 to 70 percent of the space. A highly significant correlation coefficient of 0.738 was obtained between landscape water use and landscape size. However, approximately 38 percent of the average amount of water utilized for landscape irrigation is in excess of estimated optimum amounts. Renewed emphasis on education programs directed toward an attempt to encourage wise water usage is urgently needed.

Introduction

The universal importance of water for all plant and animal life forms creates many problems and complicates its optimal utilization in modern society. Formerly, Man tended to settle only where water was naturally available to sustain his basic household and agricultural needs. Now, Man has diffused into areas lacking in water. Demands of an exploding population are so numerous and so great that water problems are becoming more acute each year. Studies on how urban man uses water are urgently needed.

Water is used to maintain scenic, recreational, and aesthetic resources. Paramount amount those resources requiring water is urban-residential landscaping. Current and near future shortages of quality water available for application to urban landscapes is becoming a critical problem. It is essen-

* Student and Professor, respectively, Department of Horticulture, New Mexico State University, Las Cruces, New Mexico

tial that a better understanding of the actual water requirements of landscape plants be obtained.

Review of Literature

Value of the urban landscape as a source of avocational creativity and emotional satisfaction is real. Secretary of Agriculture Earl L. Butz[1] quotes a survey in which 59 percent of those surveyed checked "green grass and trees around me" as an item (of 26 offered) which they considered most important to their happiness. He goes on to say "....greenery and flowers satisfy some psychological need in people..."

Lanphear[2] outlines the value of plants in the urban landscape in the following five categories: 1) noise abatement, 2) natural filters for gaseous and particulate aerial pollutants, 3) biological monitors where plants serve as indicators of critical levels of aerial pollutants, 4) temperature modification where plants serve as natural air conditioners, 5) other effects such as glare reduction and visual screening of unattractive areas.

Cooke and Van Haverbeke[3] have quantified noise abatement potential of trees and shrubs. Foliage commonly results in reductions of 5 to 8 decibels, and reductions up to 10 and 15 decibels were noted in their study. While shrub placement in relation to noise source was important, species differences in noise abatement were not high.

Water use in landscape maintenance is important, not only in the amount utilized, but also in its rate of utilization. Clark and his co-workers[4] reviewed data from a study conducted in Baltimore, Maryland, which showed the mean annual sprinkling load was 30 percent of the total water used in a residence. However, during peak hourly consumption periods (normally 5:00 - 9:00 p.m.) the sprinkler load accounted for as much as 95 percent of total usage.

Little is known about landscape plants' water requirements. While they are predominantly mesic, and water requirements can be considered physiologically similar to irrigated, monocultured, crop plants, the circumstances under which they are grown and criteria for excellence differ. Interaction between plant specimens and inanimate landscaping materials such as decorative rocks, gravel mulches, or concrete has not been investigated.

The best information available is from research conducted on turf in monoculture. Tovey[5] found 20 acre-inches was required annually to maintain Burmuda turf in Nevada. Erie, et. al.[6] report that over a period of five seasons an average of 43.5 acre-inches was required for Bermuda turf in Mesa, Arizona. Turf grass water requirements were estimated to be 41.8 acre-inches for El Paso, Texas[7]. There is virtually no information on the water requirements of trees and shrubs commonly used in the landscape in either specimen or massive planting settings.

Thus, a paradox exists between the value of plants in Man's environment and the water resources expended to maintain them. This study was conducted to shed some light in this unexplored area as follows:

1) To compare total use and peak monthly periods of water used on landscapes of urban dwellers in Las Cruces, New Mexico.

2) To survey these homeowners about their knowledge concerning the amount of water they applied in relation to knowledge of plant water needs.

Procedures

A preliminary study using 10 residences was conducted to serve as a guide for establishing procedures on the subsequent test. Homes in various locations were selected. Data on the total metered water used by each residence was obtained from City of Las Cruces utility records, and surface area of each site devoted to plant material under formal landscaping was measured. Each home owner was interviewed about landscape age, watering practices, and other features which might account for large water consumption rates other than those necessary to maintain basic household requirements.

Forty-three residences were evaluated during spring, 1972. These were similar in lot size, located on the east mesa of Las Cruces, New Mexico, and possessed a similar sandy soil. Each depended entirely upon metered municipal water. Homes exhibiting drastic fluctuations in monthly water use were omitted. Landscapes with swimming pools, ponds, or other unusual water use were also excluded. Home owner permission to survey the landscape was obtained in both the preliminary and main study.

According to degree of plant materials, the landscapes were placed in one of three categories: GREEN, INTERMEDIATE, and DESERT. Only the area devoted to plants was measured. Sidewalks, driveways, gravel, and bare areas not supporting plants were omitted.

GREEN landscapes were characterized as having lawns or other mesophytic plants covering 90 to 100 percent of the possible landscape area.

INTERMEDIATE landscapes were characterized as having lawns or other mesophytic plants covering 50 to 70 percent of the possible landscape area.

DESERT landscapes were characterized as having native or other xerophytic plant materials covering not more than 20 percent of the possible landscape area.

Estimates of 1971 water use for each residence were made from City of Las Cruces metered water records. A base monthly household use rate was computed and subtracted from each monthly use. Base monthly use rates were computed by averaging the two lowest monthly water uses, usually December and January.

Results

Total water quantity applied varied in accordance to the landscape category. Annual water use for GREEN landscapes (20 residences) was 203,000 gallons, to 102,000 gallons for those in the INTERMEDIATE category (20 residences), and 36,000 gallons for the three residences in the DESERT category. These quantities were 65.5 percent, 49.6 percent, and 40.0 percent of the total metered water, respectively.

Peak monthly use period varied substantially from residence to residence through the irrigation year. Of the 43 homes surveyed, 1 reached its monthly peak in April, 2 in May, 18 in June, 18 in July, and 4 in August. Water use peaks and patterns are illustrated in Figure 1 for three residences having similar water usage in the GREEN category. Landscape A rises sharply to a peak in April and crops rather uniformly through the remaining months. Water use in Landscape B rises more slowly, peaking in June, and dropping to October. Usage in Landscape C rises slowly to an abrupt peak in August followed by a rapid decline.

A relationship of water use by residences A, B, and C compared with open pan evaporation rate is depicted in Figure 2. Maximum, nearly equal open pan evaporation amounts occurred in May, June, and July, totalling between 13-14 inches per month. If water is available, evapotranspiration of a crop plant-soil system is in reasonable proportion to the open pan evaporation rate[8]. Assuming landscape plant evapotranspiration is similar, one would predict peak usage to occur during May, June, and July. Such was not the case.

In a further attempt to explain the variation in monthly peak use patterns, Landscapes A, B, and C were plotted with the monthly rainfall (Figure 3). Since little rainfall was recorded, it could not have had a marked effect on the distribution of irrigation water. Even in July, when 1.77 inches of rainfall occurred, 18 residences recorded peak water consumption.

In a correlation analysis comparing water used in the landscape area, a correlation coefficient of 0.738 was obtained. While the relationship is highly significant, almost 50 percent of the associative variation was not accounted for by the analysis. The regression of water used on landscape size is depicted in Figure 4.

The mean water applied all to landscapes in this study was 58 inches per acre per year. Estimates of water required for turf in Las Cruces are sketchy. However, if one assumes that the usage of 43.5 inches reported for Mesa, Arizona[4] is a reasonably accurate estimate, and that approximately 1.5 inches of effective rainfall fell during the test period, then approximately 14 inches of water were applied unnecessarily to the landscapes under evaluation. The excess applied is more than 38 percent above optimal. Thus, for each three acres of residential landscape, another acre could be supported by simply reducing water application rates to the estimated yearly optimal amount.

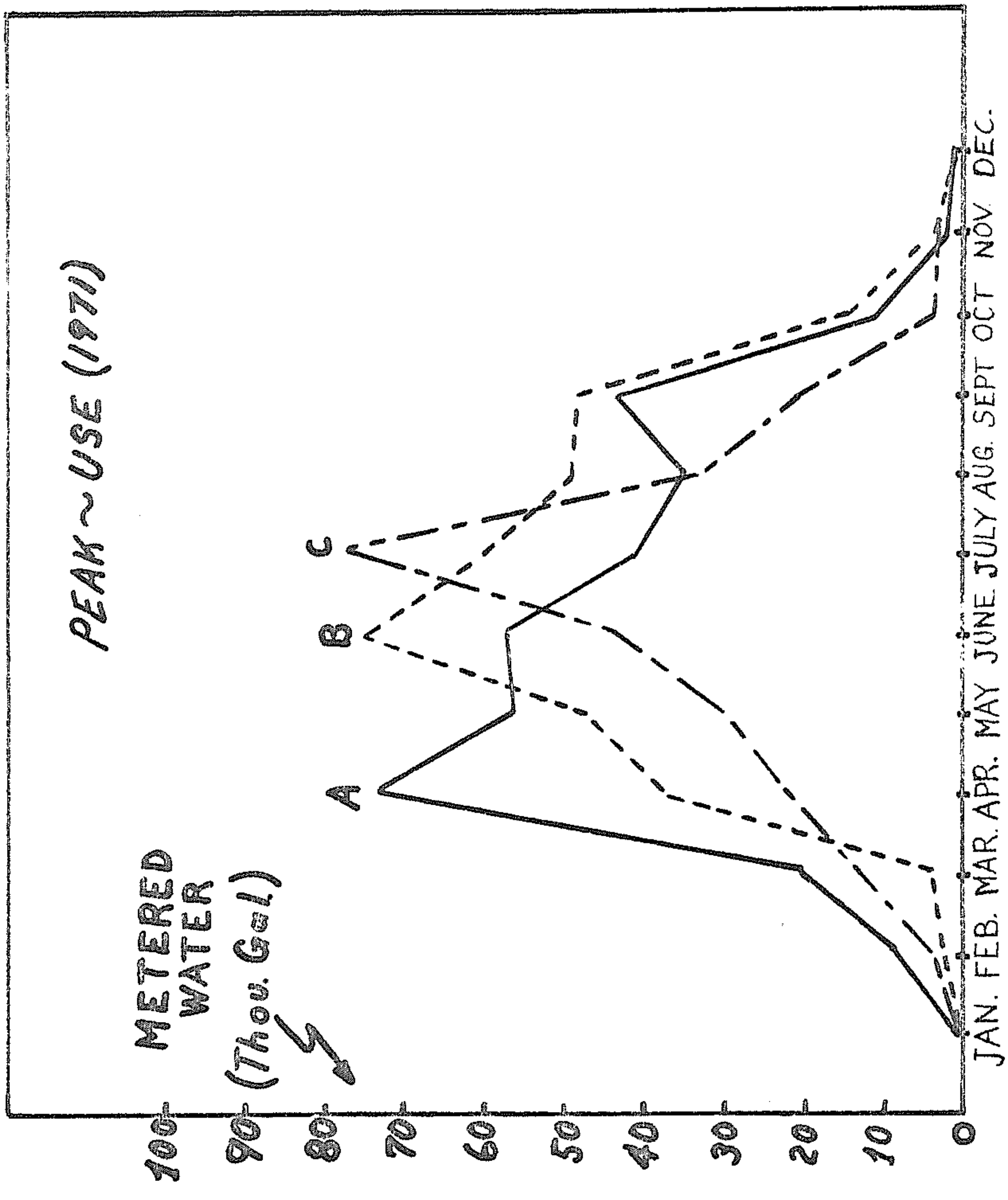

Figure 1. The 1971 monthly water consumption pattern for three urban residences used to maintain landscapes having 90 to 100 percent of available area devoted to mesic plants (green category).

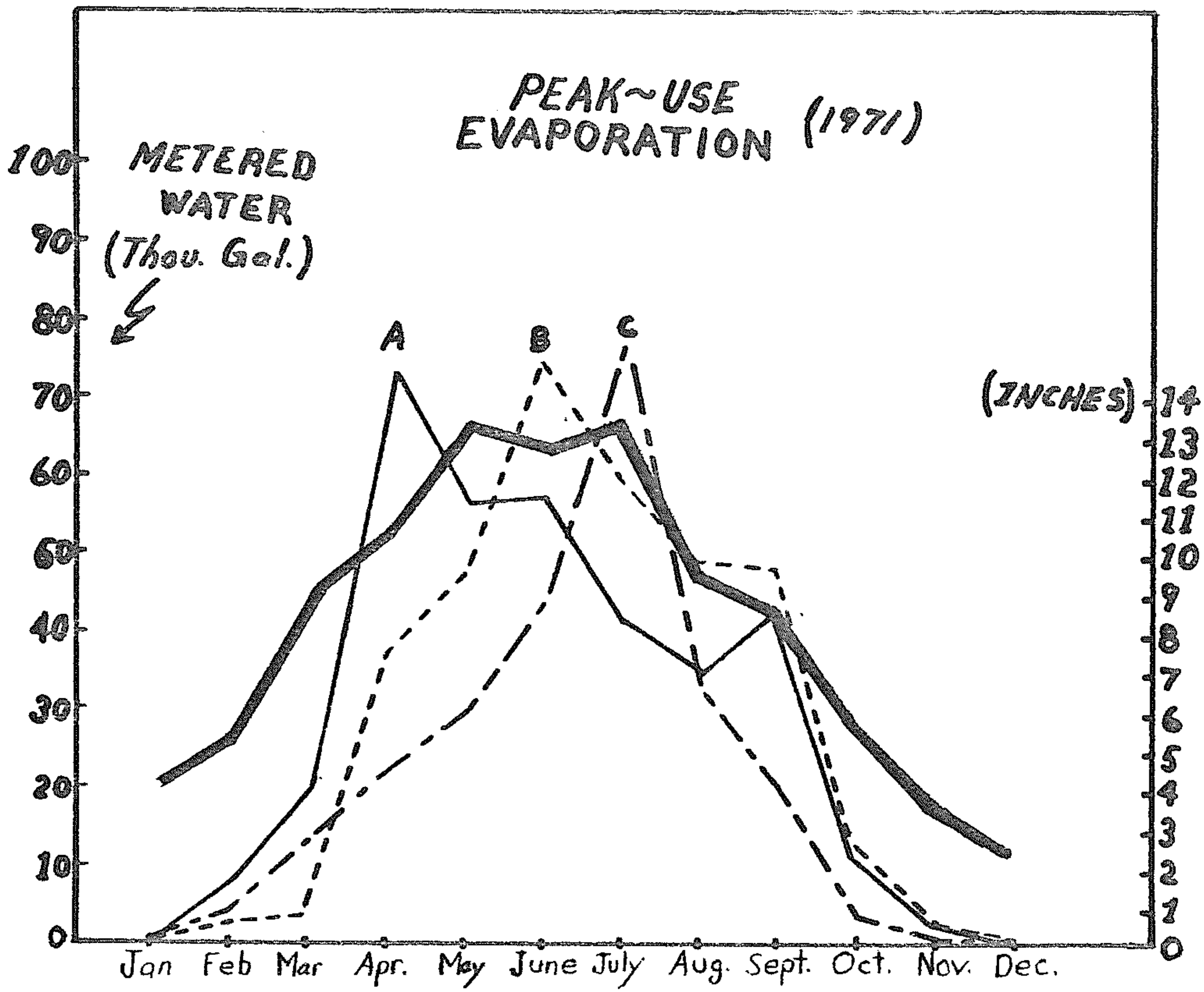

Figure 2. Monthly water consumption pattern used to maintain three green landscapes and open pan evaporation for 1971.

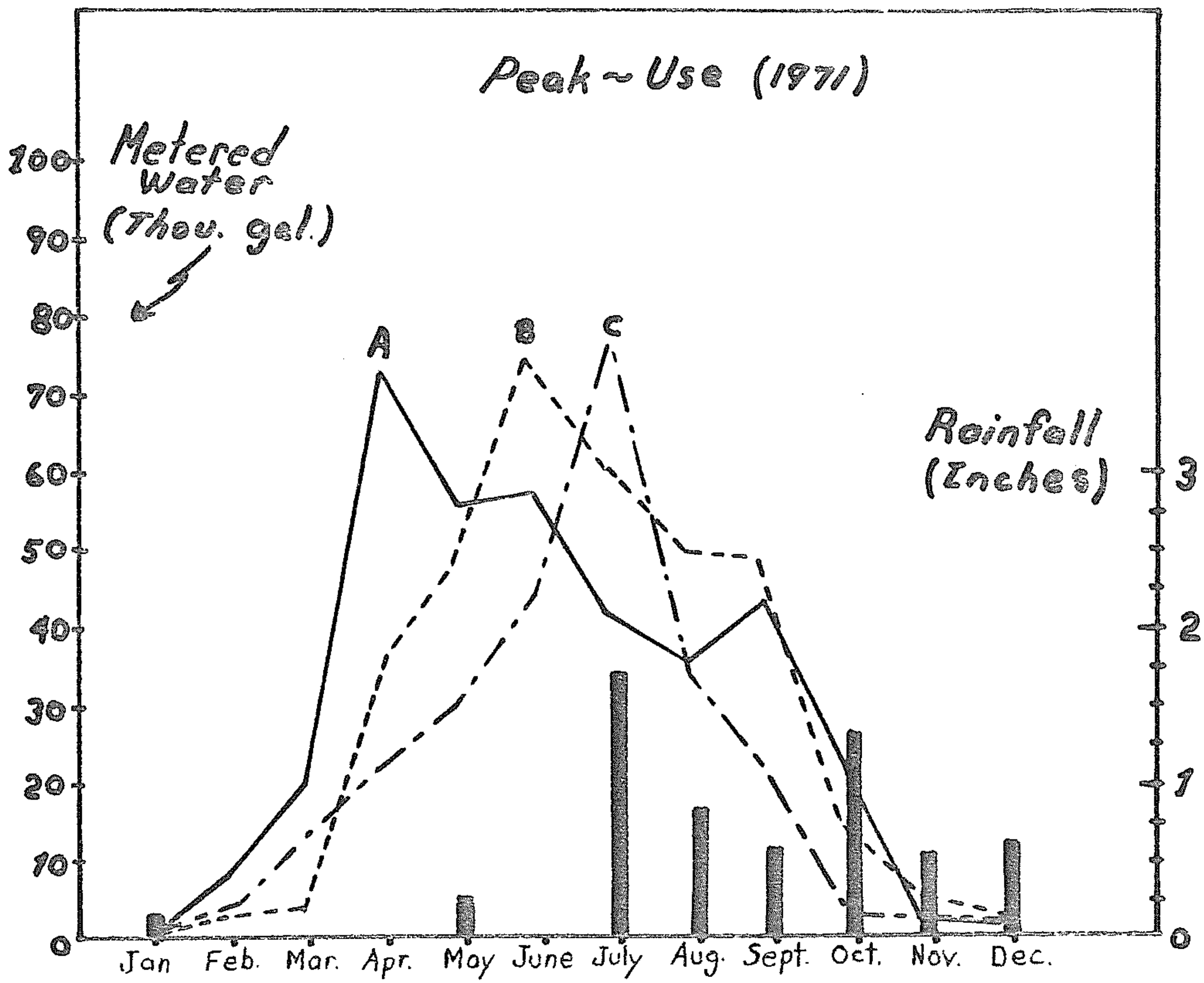

Figure 3. Monthly water consumption pattern used to maintain three green landscapes and rainfall for 1971.

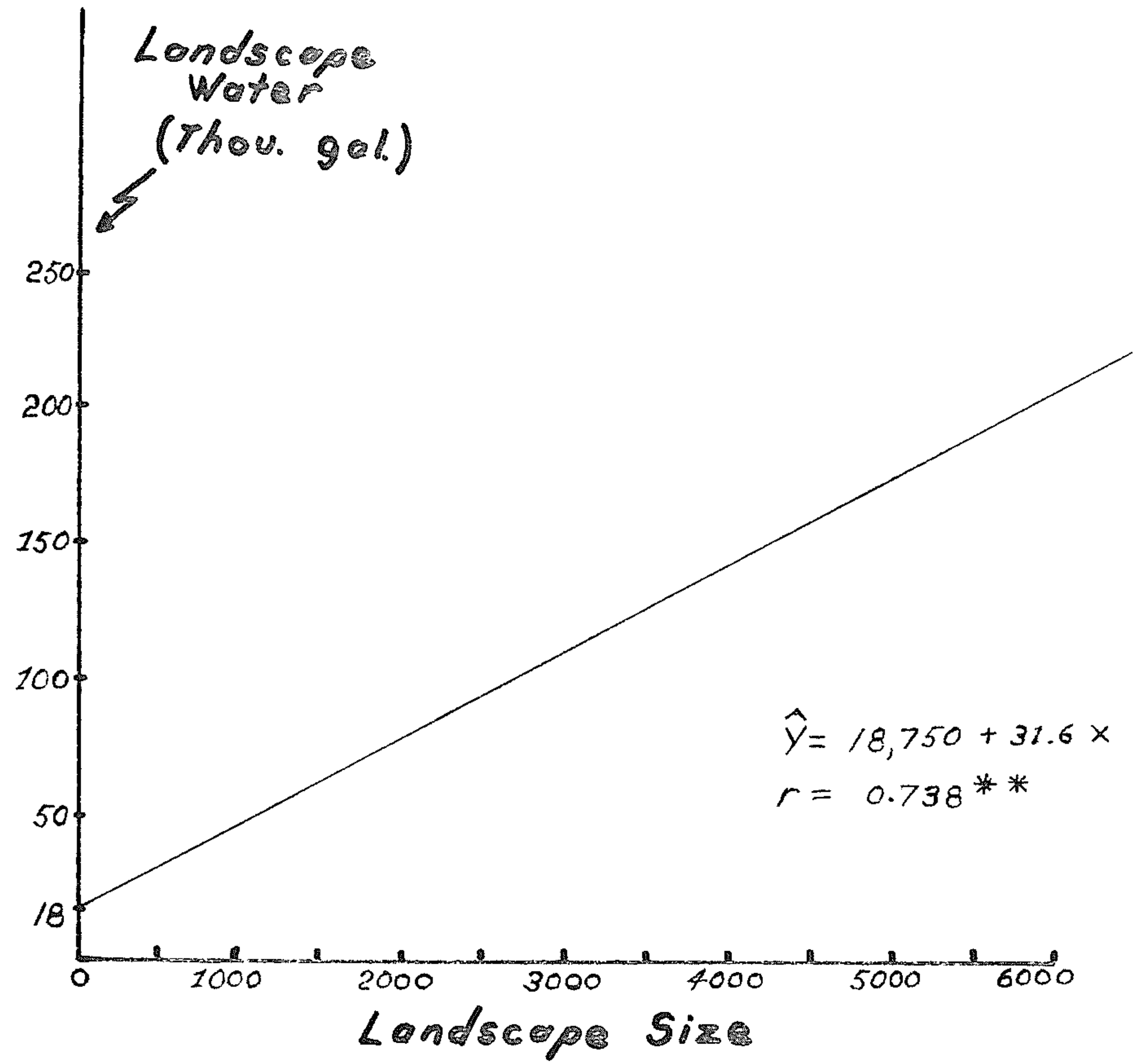

Figure 4. The regression of water use on landscape size for 43 urban residence located in Las Cruces, New Mexico for 1971.

The data above indicate that homeowners are not consistent in timing and quantity of water applied. Results from the home owner survey verify that urban residents need additional information about their landscape needs. Forty-one of forty-three home owners were neither aware of their irrigation water use patterns, nor did they have a good idea of optimum quantities landscape plants require to maintain good growth.

Conclusions

From an interpretation of the 1971 data presented, the following conclusions appear warranted:

1) Less water is applied to residential landscapes as gravel, rock, and desert plants are incorporated into the landscape plan.

2) The patterns of water used to maintain landscapes do not occur in conjunction with open pan evaporation.

3) The mean total water used was approximately 38 percent in excess of the estimated optimum amount needed.

4) Emphasis on residential homeowner educational programs directed toward encouraging efficient water use appears warranted.

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UPTAKE OF MERCURY BY FISH IN
NATURAL AND ARTIFICIAL SYSTEMS

Don H. Baker, III*,
Carl J. Popp**, and Donald K. Brandvold**

Introduction and Historical

The accumulation of mercury in food chains was dramatically brought to the world's attention in 1953 when the people of Minamata Bay, Japan, began showing symptoms of acute mercury poisoning[1]. It was found that the fish and shellfish of the Bay contained high levels of methyl mercury. The only source of mercury entering the Bay was from an industrial plant that released 20 ppb of inorganic mercury in its wastewater. It was found that the inorganic mercury was rapidly converted into organic mercury, usually as methyl mercury which is a highly toxic compound[2]:

$$Hg^{2+} + \xrightarrow{Org.} {}^{+}HgCH_3$$

The various forms of mercury present are shown in Table 1. The mercury was then taken up by the fish and shellfish which in turn were eaten by the people of the Bay causing death and disability.

Table 1

Common Organic and Inorganic
Forms of Mercury

Inorganic		Organic	
Hg^{2+}	ionic	CH_3Hg^{+}	monomethyl mercury
Hg^{o}	metallic	CH_3HgCH_3	dimethyl mercury
Hg_2^{+}	ionic	 - Hg^{+}	phenyl mercury

The second major incident of mercury accumulation in the food chain occurred in Sweden when a large portion of the bird population died of mercury poisoning[3]. It was found that the seed-eating birds were ingesting

* Graduate Student, Biochemistry Department, New Mexico Institute of Mining and Technology, Socorro
**Chemistry Department, New Mexico Institute of Mining and Technology, Socorro

seed treated with methyl- and phenyl mercury. The fish-eating birds were eating fish contaminated by mercury leached from treated seeds used on agricultural lands.

These incidences showed that a small concentration of mercury in the water can be concentrated in the food chain to the point where the higher carnivores could contain a lethal concentration of mercury.

Since New Mexico has a limited water supply, a mercury contamination problem could possibly exist on a local or state level. A small amount of mercury contamination could remove a large percentage of water from use. New Mexico at this time has a relatively mercury-free environment. The few man-made sources of mercury such as smelters and coal-burning power plants may be too scattered and too small to cause any major mercury problems. Other industrial sources do not exist, and agricultural practices have not caused any documented contaminations in New Mexico's waters.

Studies of mercury in natural waters throughout the State are now in progress at the State Bureau of Mines. The preliminary results show that the levels of mercury are relatively low (Table II)[4]. Concentration of mercury by fish from natural waters was studied at the Bosque del Apache National Wildlife Refuge south of Socorro, New Mexico. These results can be compared with data obtained from laboratory experiments of uptake by goldfish from low-level mercury concentration.

Table II

Mercury Concentrations in Natural Waters in New Mexico

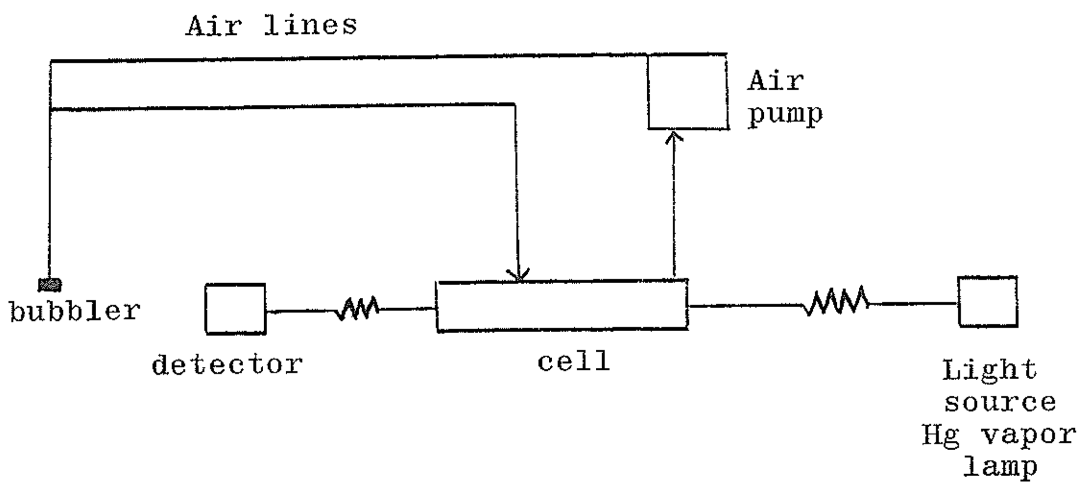
Location	ppb mercury µg/l
Copper Canyon - Magdalena Mts.	5.0
Water Canyon - Magdalena Mts.	N.D.
Rio Salado above Riley	N.D.
Morgan Lake	3.0
Navajo Bridge	0.2
San Juan River - at Hogback	0.14
San Juan River - Bloomfield	1.1
Murphy Lake	2.0
Rio Pueblo	2.0
Carrizozo Creek	N.D.
Cimmaron River	2.5
Red River	0.5
Clayton Lake	2.4
Ute Lake	3.0
Road Canyon Well ground water	0.3

Experimental

Only in the last few years have mercury concentrations in the parts per billion (ppb) range been quantitatively detectable. This is due to the development of the flameless atomic absorption method of analysis[5]. Figure I is a schematic of the analysis. When mercury is tied up in a compound or in tissue, a problem exists in breaking down the binding agent without losing the mercury. The improvements in techniques have allowed analyses of mercury where previous studies had shown none.

Figure I

Mercury Analyzer



The laboratory experiments were conducted in 38 liter tanks equipped with aerators and heaters. Goldfish (Carassius auratus) were used as the experimental fish. A mercury concentration in the tanks of 5 ppb was used to contaminate the water. This concentration was chosen since it: 1) closely represented natural waters; 2) did not kill the fish during the experiment; and 3) was in a reasonable analysis range. No previous mercury uptake studies have been reported at these low-level mercury concentrations. The fish were sampled periodically and analyzed for total mercury and the distribution of mercury in selected organs.

Results and Discussion

Mercury in Bosque del Apache Refuge Waters

Mercury analyses of the water at the Bosque Refuge showed low-level mercury concentrations (Table III). It is assumed that this mercury originated from natural sources or possibly from agricultural practice since much of the Refuge water originates from ground water. The water was sampled at eight points representing water entering the Refuge, leaving the Refuge, in ponds, and water flowing past the Refuge.

Table III

Mercury in Ground Waters

Bosque Del Apache Refuge

Sample Station Number*	Inorganic Mercury-ppb	Organic Mercury-ppb
1	2.9	0.2
2	1.8	0.1
3	1.8	0.5
4	1.6	1.7
5	2.4	1.7
6	2.2	1.4
7	3.8	0.5
9	1.7	1.1

*Station #'s 1, 3, 7, 9 - Agricultural Drains
Station # 2 - Bureau of Reclamation Channel
Station # 5 - Permanent Marsh
Station # 6 - Fishing Pond
Station # 4 - Waterfowl Pond

Fish were taken from the surface water station #6 and analyzed for mercury (Table IV). Both bottom-feeding and carnivorous fish were sampled.

Table IV

Total Mercury in Fish in a Natural System

Type	weight-g	µg of mercury	ppm
Catfish Channel	47.6112	5.21	0.11
Bullhead	69.7093	13.10	0.19
Carp	201.6721	86.72	0.43
Bass	233.271	103.42	0.47
Trout	45.30	0.47	0.01

Individual major organs of two of the fish were analyzed for mercury to determine the distribution of mercury in the fish (Table V).

Table V

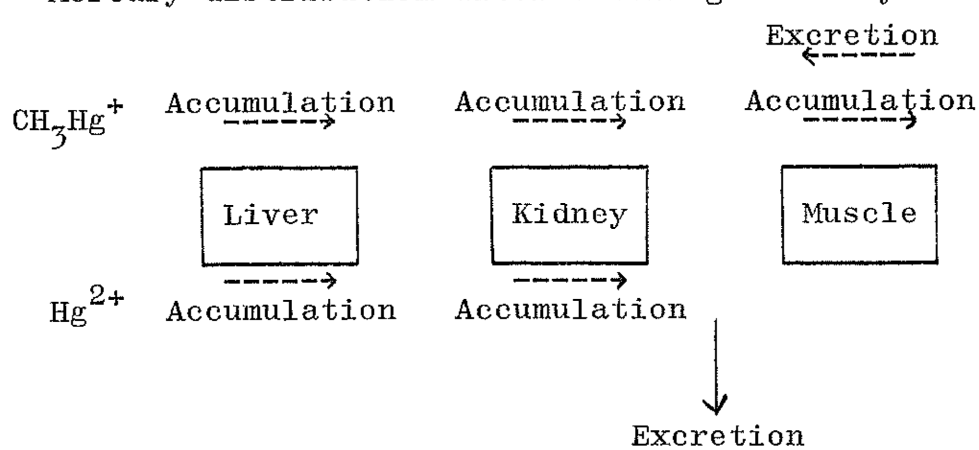
Mercury Content of Selected Tissue of Channel and Bullhead Catfish

	weight-g	µg of mercury	ppm
Channel Catfish			
Liver	1.0938	0.34	0.31
Kidney	0.1808	0.39	2.16
Muscle	2.8607	0.20	0.07
Bullhead Catfish			
Liver	2.307	0.25	0.11
Kidney	0.687	0.68	0.99
Muscle	2.741	0.38	0.14

The analysis of the organs showed that the highest concentrations of mercury were in the kidney and liver, and the lowest concentration was in the muscle. The fish were in an environment where inorganic and organic mercury were both present. A proposed pathway for the distribution of mercury in the organs[6] seems to be supported by the data (Figure II). This pathway shows that mercury--both inorganic and organic--is passed through the liver to the kidney where inorganic mercury is concentrated and excreted. Organic mercury is also excreted but a small percentage is passed on to the muscle tissue. This results in the highest concentrations in the kidney and the lowest in the muscle.

Figure II

Mercury distribution after entering the body



Total uptake of mercury is higher in the carnivores than in the bottom-feeding fish. This implies that mercury is concentrated with each step of the food chain. The rainbow trout analysis shown in Table IV was a planted fish from a hatchery and may represent a baseline concentration of mercury before the fish could accumulate mercury from natural waters. However, this conclusion cannot be supported since water analysis data from the trout's origin are not available. The low level may be due to the use of artificial food in the trout-rearing process.

Mercury Uptake by Fish Under Controlled Conditions

In order to study the uptake of mercury by fish on a controlled basis, laboratory experiments were performed on goldfish (Carassius auratus) placed in aquariums spiked with mercury.

The organs studied showed the same uptake as organs of fish in natural waters (Table VI). The kidney showed the highest uptake, the liver showed the next highest concentration, and the muscle showed the lowest concentration. The change in mercury content of the organs with time is shown in Figure III.

Table VI

Mercury content of selected tissue of Experimental Fish

Hours	Mercury content by tissue (ppm)		
	Liver	Kidney	Muscle
0	0.68	4.15	0.31
72	2.07	6.50	0.81
144	5.85	12.24	1.09
216	0.65	4.81	0.60
264	1.49	9.00	0.95
288	2.51	4.20	1.00
360	3.72	9.39	0.77
442	3.70	8.80	0.66
514	9.09	12.67	1.36
562	10.21	12.41	1.35

The total uptake showed an initial rapid uptake followed by a leveling off which remained approximately the same for the duration of the experiment (Table VII). The goldfish showed the greatest increase when the concentration of organic mercury was highest, indicating that organic mercury is more available for uptake by fish (Figure IV).

FIGURE III

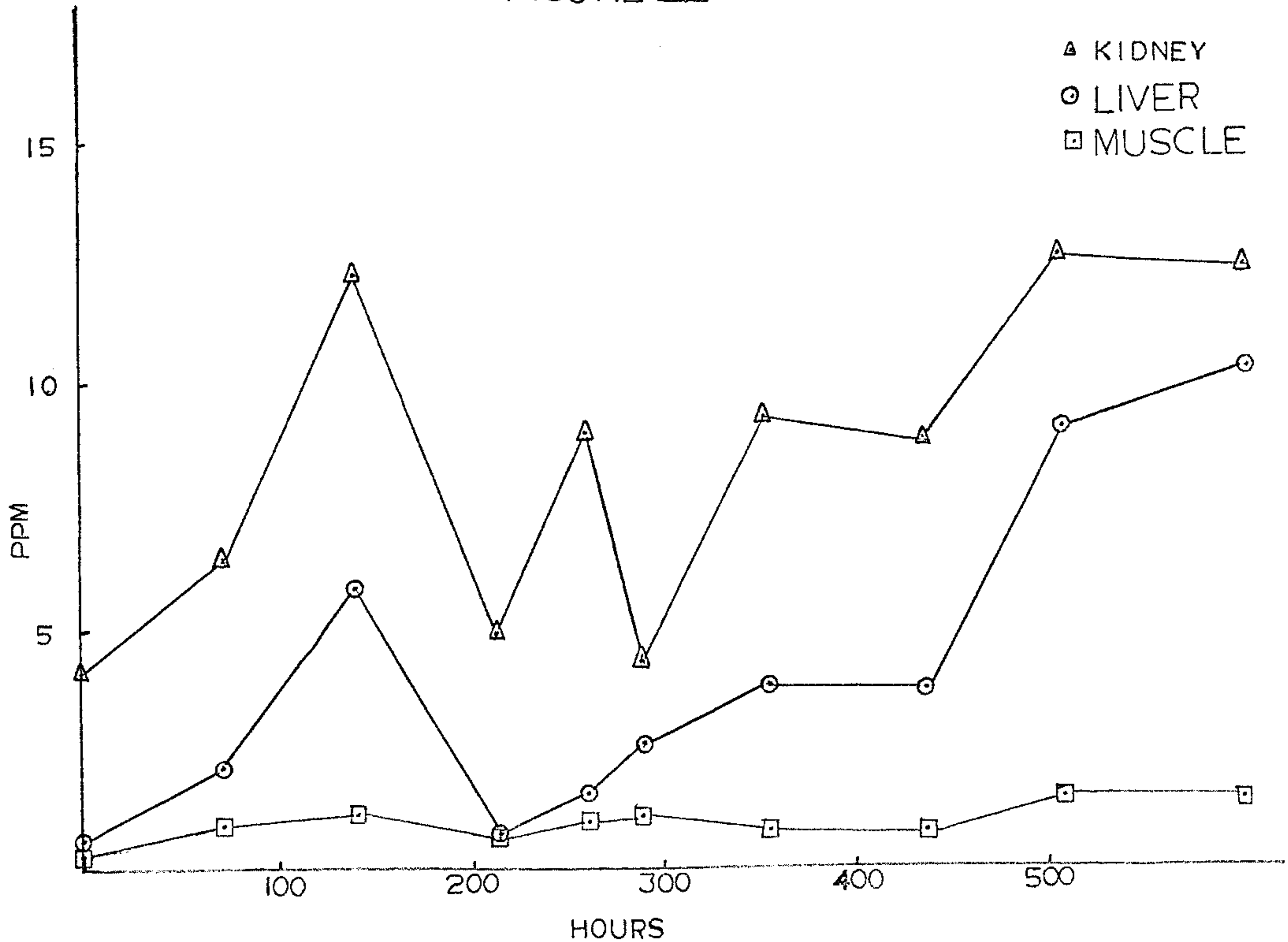


Table VII

Total Mercury Content in Experimental Fish

Hours	Hg content (ppm)
0	0.12
72	0.30
144	0.97
216	0.71
264	1.20
288	0.44
360	0.63
442	0.58
514	1.20
562	1.19

Conclusions

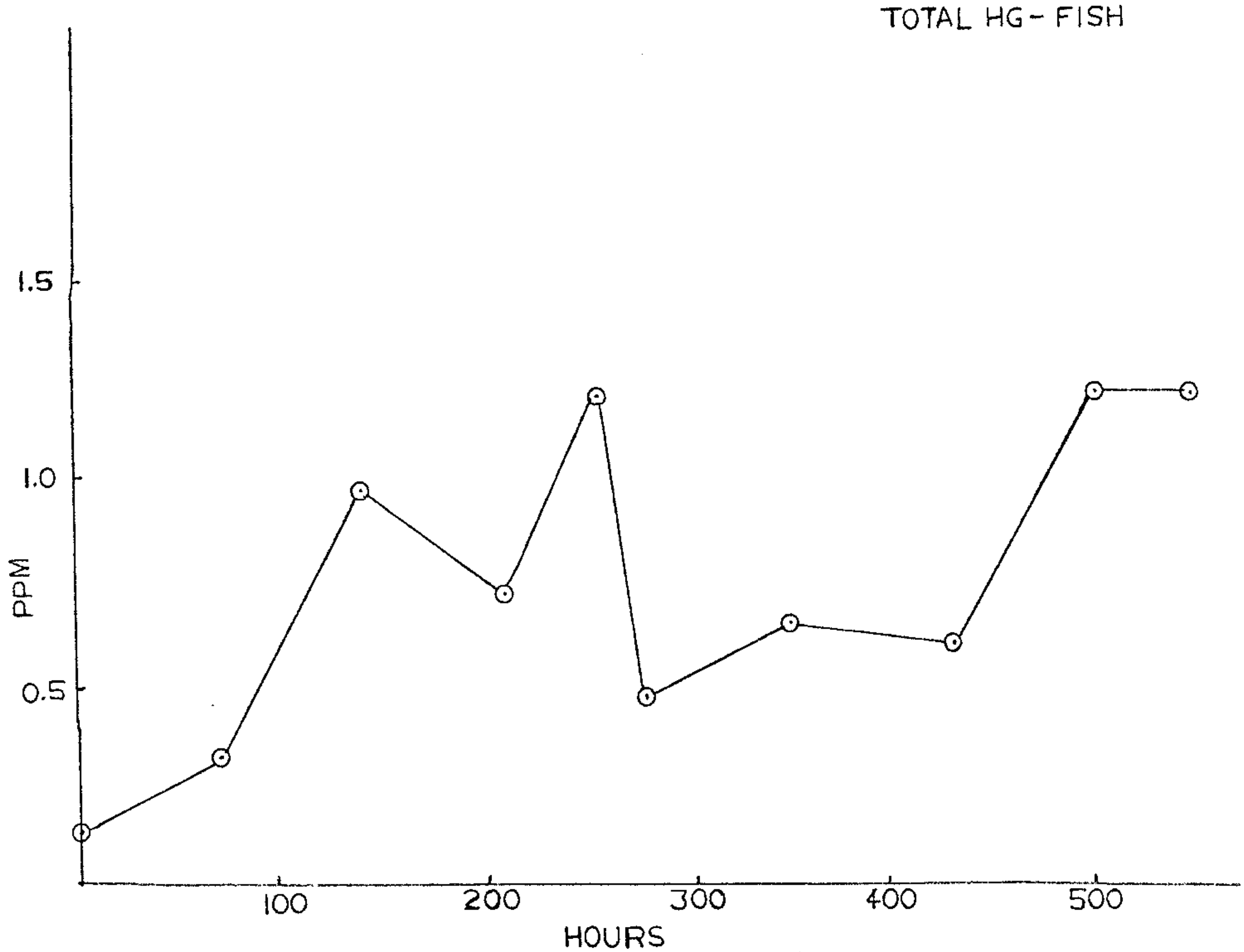
Fish have the ability to uptake and concentrate mercury from water with low-level contamination. This concentrating effect can be as high as one thousand times the water concentration. At low-levels of mercury in the water, the fish concentrations reach an equilibrium level which seems to be maintained. However, even at the low mercury concentration levels of the water in the laboratory experiment, the goldfish rapidly reached mercury accumulations which are considered dangerous by the Food and Drug Administration[7].

In the natural environment, both organic and inorganic forms of mercury are available. The mercury cycles between forms which continuously make organic mercury available for fish uptake. Not all the mercury in the water may be available for uptake since fish in the natural waters studied do not attain the mercury levels of fish in the controlled water. Some of the mercury may be tied up in sediments and suspended matter not utilized by the fish. These competing mercury "sinks" may make the mercury less available.

At this time New Mexico has no major mercury problems, but as the State grows and industry moves in, problems could arise. Due to the limited water supply, it would not require much mercury to create a problem.

More studies are needed to find ways of keeping mercury from reaching dangerous levels in aquatic environments. The only practical way known at this time is stopping the mercury and its source. As shown by this study, even a very small amount of mercury could potentially be harmful.

FIGURE IV



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ANOTHER RIO GRANDE FOR NEW MEXICO?

L. P. Reinig
R. I. Brasier
B. J. Donham
W. S. Gregory*

Like other southwestern states, New Mexico needs more water. According to the Water Resources Research Institute, the Upper Rio Grande and Pecos basins have smaller water supplies, in relation to projected demand, than any other basin in the United States.[1]

Besides needing water, New Mexico shares in the Nation's need for increased supplies of electric power, preferably electric power that can be generated without payment of a high price in terms of environmental damage. Governor King's recent executive order establishing the Governor's Energy Task Force makes an important point: "For the first time the energy crisis is not only recognized but deemed real at the state, regional, and national levels."[2]

The purpose of this report is to suggest a way in which New Mexico's needs for water and power might be satisfied, at least in large part, through imaginative use of resources already located within the State. One of these resources is a vast underground reservoir of saline water. Another is an impressive array of scientific, engineering, political, environmental, and economic talent in universities, industry, and government installations. In view of these resources, it is time to consider the possibility of producing the equivalent of another Rio Grande for the State, together with large quantities of clean electric power.

Obviously, the present report cannot attempt to prove the feasibility of the immense project it describes. All it can hope to demonstrate is that a full-scale feasibility study should be conducted as soon as possible.

The project concept to be described here is based on desalting, ultimately by means of geothermal or nuclear energy, the several hundred million acre-feet of saline ground water in the Tularosa Valley.[3] The resulting recreational-industrial-agricultural complex would ultimately encompass on the order of one million acres. It would provide one million acre-feet of fresh water per year, 2000 megawatts of electric power, valuable magnesium

* Engineers, Los Alamos Scientific Laboratory, Los Alamos, New Mexico

and other minerals separated from the saline water at a rate of several million tons per year, and many associated recreational and social benefits. The name by which we have referred to this enterprise during our preliminary conceptual studies is the Tularosa-Rio Grande (TRG) Project.

The cost of the TRG Project would be one to two billion dollars. This is admittedly a huge price tag, but it should be looked at in perspective, and with some realization of the value of one million acre-feet of fresh water annually. In The Value of Water in Alternative Uses, published by the University of New Mexico in 1962, figures are given indicating that "the contribution of the Rio Grande basin to gross national product would be about $50 for each acre-foot of water used in agriculture. It would be between $200 and $300 for each acre-foot used as fish and wildlife habitat. It would be between $3,000 and $4,000 for each acre-foot used in industry."[4] Value for such uses will only increase in future years.

Given the fact that a very large new supply of water and power would bring great benefits to the State (the scale and variety of expected benefits are described in a later part of this report), what procedure should be followed to get the Project underway? First, there would have to be a period of further study. Once confirmation of a feasible plan had been established, there would be a period of step-by-step construction. Considerable thought has been given by the authors, both to the areas in which study is needed and to the steps of construction.

The feasibility study, which is expected to occupy two or three years, will be devoted to several areas:

1. Political and legal

   The TRG Project presents a unique combination of political and legal questions. A large fraction of the land involved in the plan forms part of the White Sands Missile Range. Other lands to which access might be desirable before completion of the project are under control of such agencies as the Bureau of Land Management and the Bureau of Indian Affairs. Many formidable problems of land acquisition, multiple use of government land, and mineral and water rights, need further investigation.

   Inherent in the TRG plan, however, are certain great advantages in areas of politics and law. One such advantage arises from the fact that the entire complex will be located within New Mexico. Interstate boundaries and interstate or international water compacts are of no limiting concern. Inter-basin water transfers form no part of the plan, except for the entirely optional possibility that some desalted water from the Tularosa basin might be piped across the mountains to the Rio Grande (hence the name, Tularosa-Rio Grande Project). Certainly no inter-basin transfers will be necessary to the feasibility of the project.

2. Sociological

A project such as this would offer newly created living space and a useful way of life to many people. In doing so, however, it might create less favorable consequences for other New Mexico citizens. The meaning of the TRG Project for the average New Mexican is not easy to predict. Social consequences of the Project must be a matter of serious concern and intensive study, because the overall quality of life is, of course, more important than any combination of economic benefits. Certainly the creation of new wealth by the TRG Project would result in new opportunities for many New Mexicans. What must be guarded against, obviously, is the possibility that new opportunities for some will bring some unsuspected disadvantages to others. Those of us who have looked at this possibility have seen nothing to fear. We wish to stress, however, that potential social results of the Project must be a primary concern of the feasibility study.

3. Economic

An intensive study must be made, first to arrive at reliable estimates of the cost of project development, and second to determine the most favorable methods of financing and organizing the Project. The cost of the feasibility investigation itself will be several hundred thousand dollars. If its results are favorable, they are expected to attract private investment. The feasibility study would almost certainly have to be financed in substantial part by government agencies.

The total economic impact of the Project on the region would have to be studied, along with the potential value of mineral and other by-products, agricultural products, associated industry, appreciation of land values, and power and water sales. Economic resource management techniques would have to be developed to identify the various management alternatives.

4. Environmental

The TRG Project, like all large development plans, could have harmful effects on the environment. Unlike some other plans, however, it could have extremely beneficial effects on the environment. Both possibilities will require attention from those who perform the feasibility study.

Ways of minimizing possible deleterious effects have already been studied, in a preliminary sense. For instance, some thought has been given to the possibility of using underground transmission lines for the large quantity of electrical power to be generated. If one were limited to present technology, this would not be feasible, but it is hoped that the underground superconducting transmission lines now being developed at the Los Alamos Scientific Laboratory will be ready in time for use by the TRG Project. The matter of effluents and other environmental effects from energy sources used in pumping and desalting appears controllable but must, of course, receive more intensive study.

Possible beneficial effects of the TRG Project on the environment are exceedingly interesting. A certain fraction of the fresh water produced could well be devoted to improvement of wildlife habitat in the area. Irrigated parkland, freshwater lakes, and lakes of slightly saline water might all be created, making the Tularosa Valley a truly important nesting and resting area for waterfowl and also providing extensive water-based recreation areas.

5. Technical

Because of the step-by-step approach now envisioned, with a relatively small pilot plant to be followed by gradual scaling up, certain technological options can be left open for several years, even after construction begins. Certain aspects of desalting and of mineral recovery technology, seen more clearly as a result of experience obtained in the step-one pilot plant, will serve during later steps in ways that cannot now be predicted in detail. The feasibility study will, however, evaluate all currently available technology applicable to the TRG concept, including desalting, coupling of power and water plants, and geologic and hydrologic conditions of the Tularosa Basin.

After feasibility has been confirmed, including financing and organizational arrangements, a four-step plan (summarized in Fig. 1) would go into effect. Step one would consist of building and operating a pilot plant. The pilot plant would produce about one million gallons per day of desalted water. Its fuel would be natural gas. Its main purpose would be to define the desalting process best suited to the Tularosa application, given the particular minerals present in the water and their relative levels of concentration. The pilot plant would also serve as a laboratory for materials development and for mineral extraction studies and as an experimental facility for solving problems of scale formation and corrosion. Capital and expense costs of construction and operation of the pilot plant have not yet been calculated, but the three years scheduled for its construction are probably ample.

Step two, which would begin a year after the beginning of step one, would consist of building and operating a plant that would produce a significantly useful amount of new water, about ten million gallons per day. This is equal to 10,000 acre-feet per year, about twice the water requirement of the town of Los Alamos, New Mexico. The energy source for the ten million gpd plant would probably be natural gas, but an important part of step two would be to investigate the alternative of geothermal energy as exploited by the dry hole, water injection technique described later in this report. Other important purposes of step two would be (1) further exploration of the mineral by-product potential of the TRG Project, (2) experimental research on use of water in large-scale greenhouses, and (3) definition of the most practical component unit, or module, for much larger dual-purpose plants. Step two would be continued for at least four years.

SCHEDULE OF FOUR-STEP PLAN

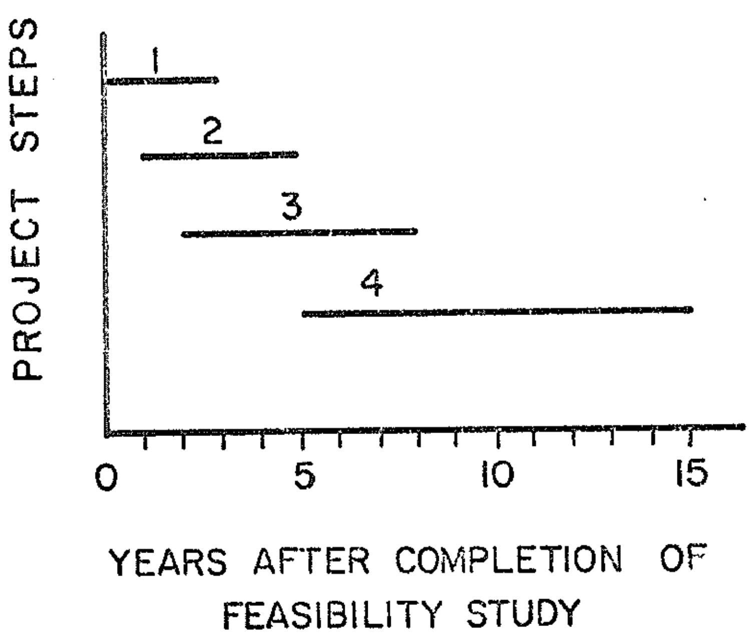


Figure 1

Meanwhile, a year after the beginning of step two, step three would begin. It would consist of the planning, design, construction, and operation of a plant producing about 100 million gallons of desalted water per day, about equal in quantity to the water introduced into the Rio Grande Valley by the San Juan-Chama Diversion. The step three plant would probably also produce marketable quantities of electric power and minerals. Its objective would be the definition of desalting systems for a plant about ten times as big. Its energy source might be fossil fuel, though its fuel requirement would be large enough to make nuclear energy almost obligatory. Because of new concepts under development at Los Alamos, geothermal energy is another possibility (as discussed on a later page.) The 100 million gpd plant would be completed about eight years after the beginning of step one.

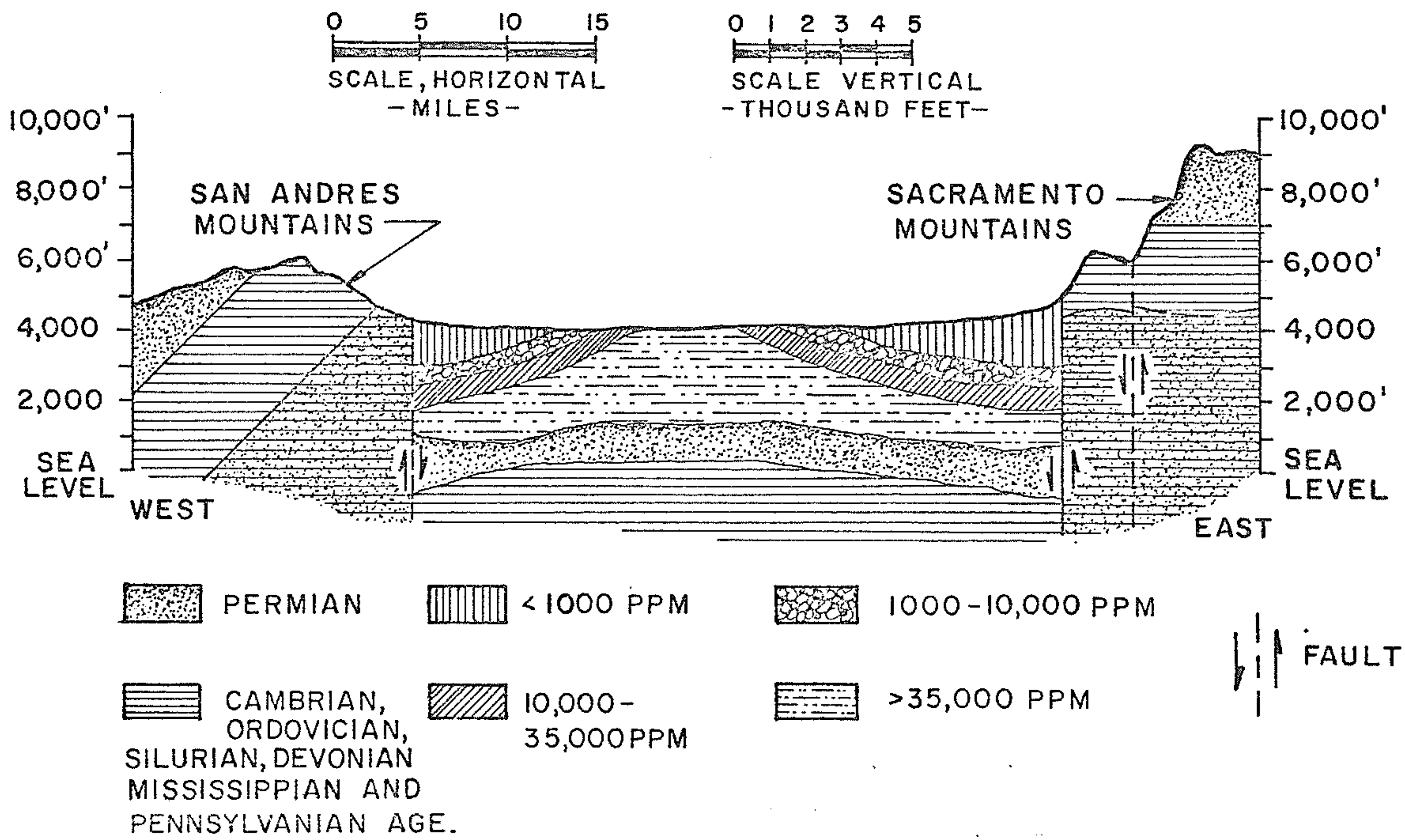
Step four, to occupy the final ten years of the fifteen-year plan, would begin three years after the beginning of step three. It would consist of the construction and operation of a plant using nuclear or geothermal energy to pump and desalt one billion gallons of water per day, and to generate 2000 megawatts of electric power.

Is the TRG Project feasible? Preliminary studies have found evidence that it may prove not only feasible but highly successful.

The Tularosa Basin is a structural trough covering an area of 6500 square miles. It is bounded on the west by the Organ and San Andres Mountains, on the east by the Hueco and Sacramento Mountains, on the north by a broad, high topographic divide, and on the south by a divide separating it from the Hueco Bolson in Texas. The basin floor is relatively flat.

According to a recent study,[5] the trough is filled with alluvial material, a large part of which is saturated with saline water to depths as great as 6000 feet. Hydrologically, the area forms a closed basin with no significant outflow of water. This has resulted in a vast underground reservoir, virtually untapped, estimated conservatively at several hundred million acre-feet. Less than 0.2 percent of the saturated deposits contain fresh water. The groundwater ranges from fresh water on the edges of the basin to concentrations greater than 100,000 parts per million at the center. An east-west cross section of the basin, taken in the vicinity of White Sands National Monument, illustrates this range in salinity (Fig. 2).

Chemical analyses of four wells have been used in the TRG preliminary study on potential mineral recovery. These analyses and the comparable data for seawater are given in Table 1.



EAST-WEST CROSS-SECTION, SHOWING SALINE WATER DISTRIBUTION IN ALLUVIAL FILL

Figure 2

LASL AEC OFFICIAL

TABLE I (ref. 6)

Chemical Analyses of Sea Water and of Wells in the Tularosa Basin

	Sea Water Mg/1	Well 1 Mg/1	Well 2 Mg/1	Well 3 Mg/1	Well 4 Mg/1
Calcium	400	965	1,660	1,260	250
Magnesium	1,272	3,360	792	62	282
Sodium	10,561	7,938	26,910	10,560	247
Potassium	380	4,617	15,490	7,040	577
Sulfate	2,560	9,280	1,060	1,450	1,210
Chloride		24,000	66,800	28,500	3,390
Bicarbonate		208	112	71	36
Total Dissolved Solids		50,300	112,000	48,900	7,000

Many alternative principles of demineralization exist, several of which have been thoroughly proven in practice during past years. At the moment, the likeliest candidate for use in the Tularosa Basin would seem to be one of the distillation processes, at least for the largest TRG plants, but several alternatives will be considered. What appears to be certain is that the important energy savings inherent in the dual-purpose idea, as illustrated in Table 2, will be taken advantage of to the fullest extent possible.

TABLE II (ref. 7)

Energy Requirement--Combination Plant

	Energy Required--Btu	Total Energy Requirement--Btu
Separate Plants		
Electricity-- 1 kwh	10,377	24,237
Water--147 lb	13,860	
Combination Plant		
Electricity--kwh	17,273	17,273
Water--147 lb		
Difference		6,964

Nuclear energy is generally thought of as the heat source necessary for production of power and desalted water in a large multi-purpose plant. By the time the TRG Project achieves full size, however, there may be an alternative energy source for medium to large-scale power generation and desalting--the geothermal energy stored in the rocks of the earth's crust. One serious limitation on geothermal energy in the past has been the fact that the heat stored in underground rocks was impossible to extract at a high enough rate for practical purposes unless the underground structure included plentiful water. This meant that geothermal energy was nearly useless except in geyser or hot spring areas.

Los Alamos scientists have now proposed a way of extracting energy from solid rock, in the absence of naturally occurring water. Their method makes use of hydrofracturing, a technique first developed for use in oil fields, as a means to establish the initial heat transfer surface in the rock. The first step in developing a geothermal power plant using energy from dry rock would be the drilling of a well into the hot volume. The second step would be hydrofracture--a process in which the pressure of water, pumped down the well from the surface, is used to crack the rock and create a vertical heat-exchange surface, several square kilometers in area. The next step is the drilling of a second hole, this time into the upper part of the heat-exchange volume. After that, water injected into the well is heated by the rocks and circulated to the surface,where its energy can be extracted by conventional means before the water is circulated downward again. Thereafter cracks progress further into the rock mass due to thermally induced strains produced in the hot rock by presence of relatively cool water injected from the surface. As the cracks progress, more hot surface area can exchange heat to the water destined to return to the surface, and so on.

Therefore, if progress continues as expected at Los Alamos, geothermal energy may prove extremely important to the TRG Project. It is known that the Tularosa Basin has at least one area in which underground temperatures are unusually high.[8]

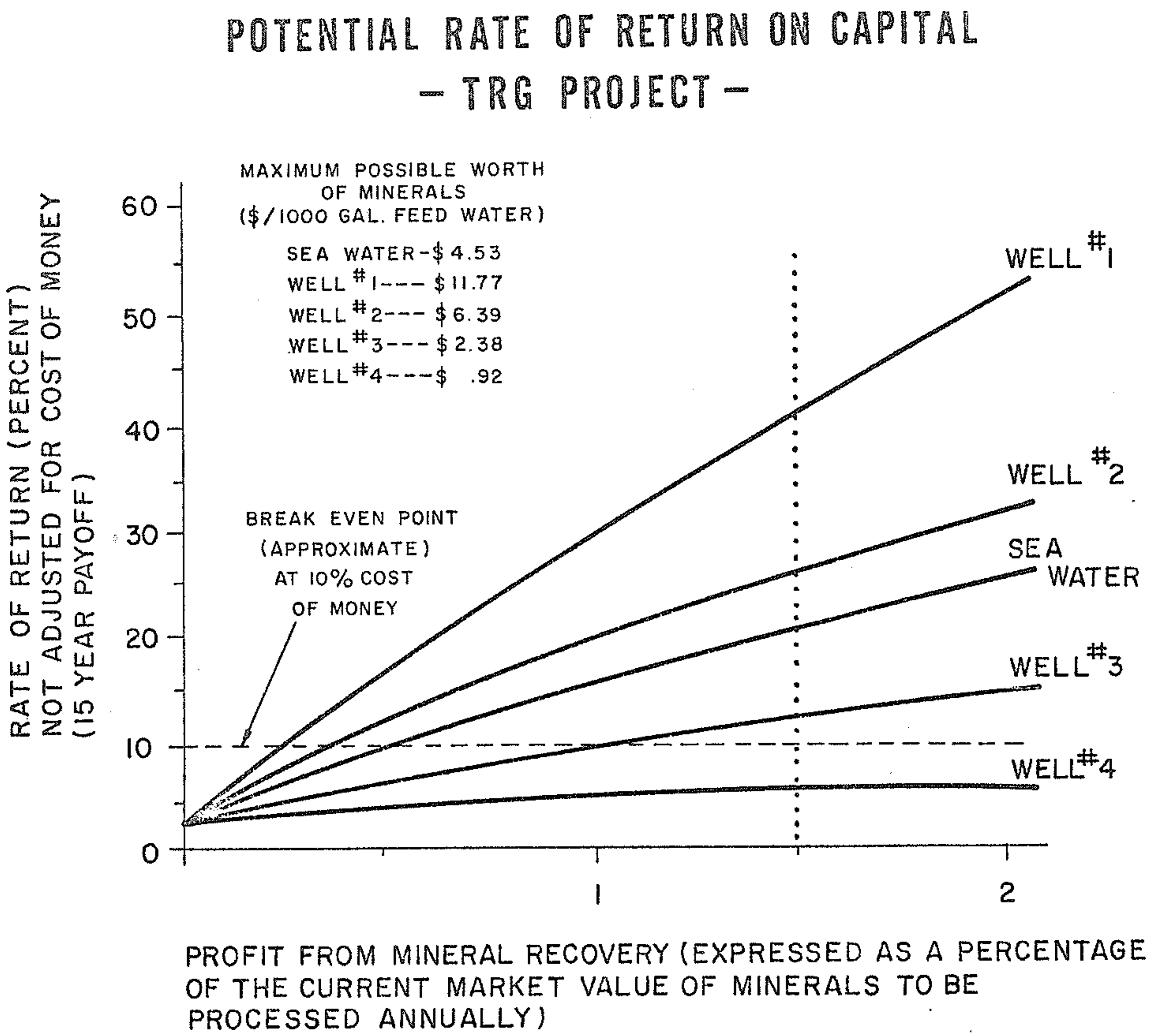
The financial feasibility of the TRG Project was the subject of a preliminary study using rough estimates of cost based on 1968 prices. A cost estimate on the order of one billion dollars was arrived at by adding the costs of the water collection and distribution systems and the land to an extrapolation of AEC-sponsored cost estimates for large nuclear agro-industrial complexes.[9]

Central to the preliminary financial study was the possibility of selling large quantities of minerals in addition to power and water. Reference 9 lists, as a first order of approximation, the mineral value of brine as 10% of the market price of the contained minerals. In this study, the concentrations shown in Table I were used.

Consideration was given to the elasticity of demand for the minerals. Since large quantities are involved, depression of the market price is a definite possibility. In the case of magnesium, for example, the price of aluminum--already produced in much larger quantities--was taken as a floor under the price of magnesium. The methods of reference 9 were then used to calculate mineral worth of the brine, with the result that the brine was found to be worth 6% of the current market price of the contained minerals.

Results shown in Figure 3 indicate that the TRG Project would be economically viable if the profit from mineral recovery were to equal or exceed only 1.5% of the value, at 1970 prices, of the minerals processed. Since reference 9 indicates a profit percentage four times this minimum requirement, the preliminary results seem to justify hopes of economic success.

In summary, this report describes a project that would provide one million acre-feet of new water annually and 2000 megawatts of new power. Evidence of feasibility already exists in the results of preliminary investigations by the authors, but they urge that a complete feasibility study be undertaken as soon as possible.



Curves based on the measured mineral concentration in four Tularosa Basin wells are shown with a comparison curve based on the average mineral concentration in sea water. The graph shows, for example, that even if only 1.5% of the 1968 market price of recovered minerals could be realized as profit, the annual net rate of return on investment over a 15-year amortization period, with money cost at 10%, would range from break-even for well #3 to about 30% for well #1. Of course a higher mineral recovery profit yield would produce a correspondingly higher return on investment. The graph is based on 5 mills/kwh and $15/acre-foot as the prices of power and water to be sold by the project, and on 50% recovery of minerals.

Figure 3

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"CLEAN ENERGY VIA COAL GASIFICATION"

A. J. Paquette and M. R. Beychock*

Part I - COAL GASIFICATION

Introduction

The commercial gasification of coal has been practiced for at least 50 years. Literature and patents on the Winkler coal gasification process date back to 1920 or earlier. Most of these early gasification processes were concerned with producing either an ammonia synthesis gas or a medium-heating-value fuel gas called "town gas."

In the past four to five years, it has become apparent that natural gas supplies are becoming short in the United States. Normally, large energy users would have switched to other forms of fossil fuel, such as coal, for which the proven reserves are very large. However, the current strong public concern with air pollution has worked against the increased use of coal. In fact, many industries now using coal are under extremely heavy pressure to develop and improve technology and apply it for the removal of sulfur from their coal or their stack gases.

This combination of events, a natural gas shortage plus the emphasis on removal of sulfur from fuels, has accelerated the search for new sources of Substitute Natural Gas (SNG) and new supplies of Liquefied Natural Gas (LNG). In the long term, it is apparent that the vast coal energy reserves in the United States must be utilized. Coal gasification can convert these large coal energy reserves into a high-Btu, clean-burning, sulfur-free fuel gas.

* Fluor Engineers and Constructors, Inc., Los Angeles, California

Realizing this fact, a greal deal of technological development is currently underway in the United States on coal gasification processes. The following Table lists the current status of the major United States coal gasification development projects:

Table 1

Process	Pressure	Developer	End-Products	Current Status
Hygas	High	Institute of Gas Technology	Gas + Char	Pilot Plant*
Synthane	High	Bureau of Mines	Gas + Char	Pilot Plant**
CO_2 Acceptor	Medium	Consolidated Coal Company	Gas + Ash	Pilot Plant*
Bi-Gas	High	Bituminous Coal Research	Gas + Slag	Pilot Plant**

*Currently starting up.
**Pilot plants currently in design phase only.

The emphasis in these pilot plant programs is to develop processes suitable for the large-scale production (250-500 MM SCFD) of the type of gas (925-970 Btu/SCF) used in the United States, rather than adaptation and modification of the older European technology for producing medium-Btu town gas. Even if they are run successfully, they will only be stepping stones to larger demonstration plants before sufficient engineering data are available for full commercial plant design. These processes will probably not be ready for commercial application for at least five years and perhaps ten years.

On the other hand, the Lurgi pressure coal gasification process, which was first developed in 1930, has proven, large-scale commercial experience. Since 1936, the Lurgi process has been used commerically in many parts of the world, including Germany, Scotland, South Africa, and Korea.

The Lurgi gasification process will be used in both the recently announced New Mexico coal gasification projects . . . the WESCO and El Paso projects.

Chemistry

In the broad sense, coal gasification has been practiced since man first reacted coal with air. This simple act of combustion gasified the coal into its final products of combustion--carbon dioxide, water vapor and its sulfur to sulfur dioxide.

In a more narrow sense, coal gasification for SNG Production is the limited reaction of coal with essentially pure oxygen in the presence of a large excess of steam.

Although the competing chemical reactions which coal undergoes during this process are complex and not fully understood at the present time, they are usually represented by the following chemical equations, shown in Figure 1:

1. The overall reaction, as shown, represents the net result of coal gasification to produce methane (SNG) and is really a composite of numerous other chemical reactions and processing steps. Since coal contains only about 5 weight percent hydrogen, exclusive of its contained moisture, additional hydrogen must be supplied during the gasification process to meet pipeline quality SNG, which is 25 weight percent hydrogen--essentially methane (CH_4). This additional hydrogen is derived from the decomposition of steam (water) which is added to the gasifiers.

2. Devolatilization indicates that, at the temperature of coal gasification, some of the heavy hydrocarbons contained in the coal undergo a degree of thermal cracking to methane.

3. The hydrogasification reaction shows that methane can be formed directly from coal in the presence of large excess hydrogen concentrations.

4. The overall gasification heat balance is maintained by the heat supplied from the combustion reaction.

5. The last reaction shows that some of the steam added to the gasification process is decomposed to hydrogen in the presence of coal.

Although the coal has been represented as carbon in these reactions, we should remember that the additional components contained in the coal are also reacting--such as nitrogen to HCN and ammonia, and sulfur reacting to hydrogen sulfide, COS and CS_2.

TYPICAL COAL GASIFICATION REACTIONS

$$2C + 2H_2O \rightleftharpoons CH_4 + CO_2 \quad \text{(OVERALL)}$$

$$\text{VOLATILE MATTER} \longrightarrow CH_4 + C$$

$$C + 2H_2 \rightleftharpoons CH_4$$

$$C + O_2 \rightleftharpoons CO_2$$

$$C + H_2O \rightleftharpoons CO + H_2$$

FIGURE 1

The net result of these gasification reactions gives a crude gas composition which is a variable mixture of mainly carbon dioxide, carbon monoxide, hydrogen, and methane.

Lurgi Gasifier

The Lurgi gas producer, commonly referred to as a pressure gasifier, consists of a number of vessels or chambers stacked vertically. These are, from top to bottom: coal bunker or hopper, coal lock chamber, water jacketed gas producer chamber, ash lock chamber, and ash quench chamber. This chamber arrangement is shown diagrammatically in Figure 2.

Located near the top of the gas producer chamber is the rotating coal distributor which maintains a uniform flow of coal from the coal lock chamber and provides a level surface on the top of the coal bed. A rotating ash grate continuously moves ash from the gas producer into the ash lock chamber.

The coal flowing down through the gas producer represents a slowly moving bed of continuously changing composition: it enters the gas producer as coal and leaves as ash. Steam and oxygen are introduced near the bottom of the gas producer and are preheated by the high temperature ash leaving the reaction zone as they flow towards the high temperature reaction zone.

High temperature crude gas and unreacted steam leaving the reaction zone are cooled as they pass through the upper portion of the coal bed which contains fresh coal passing towards the reaction zone. This cooling of the reaction zone gases provides both preheating and devolatilization of the fresh coal before it enters the high temperature reaction zone.

Figure 3 shows a simplified flow sheet of the Lurgi gasification process which will be used for the proposed WESCO project.

Crude Gas Coolers

The crude gas is cooled and scrubbed with water, which removes heavy oils and phenolics. Solids carried out of the gasifiers are removed by a unit upstream from the crude gas coolers.

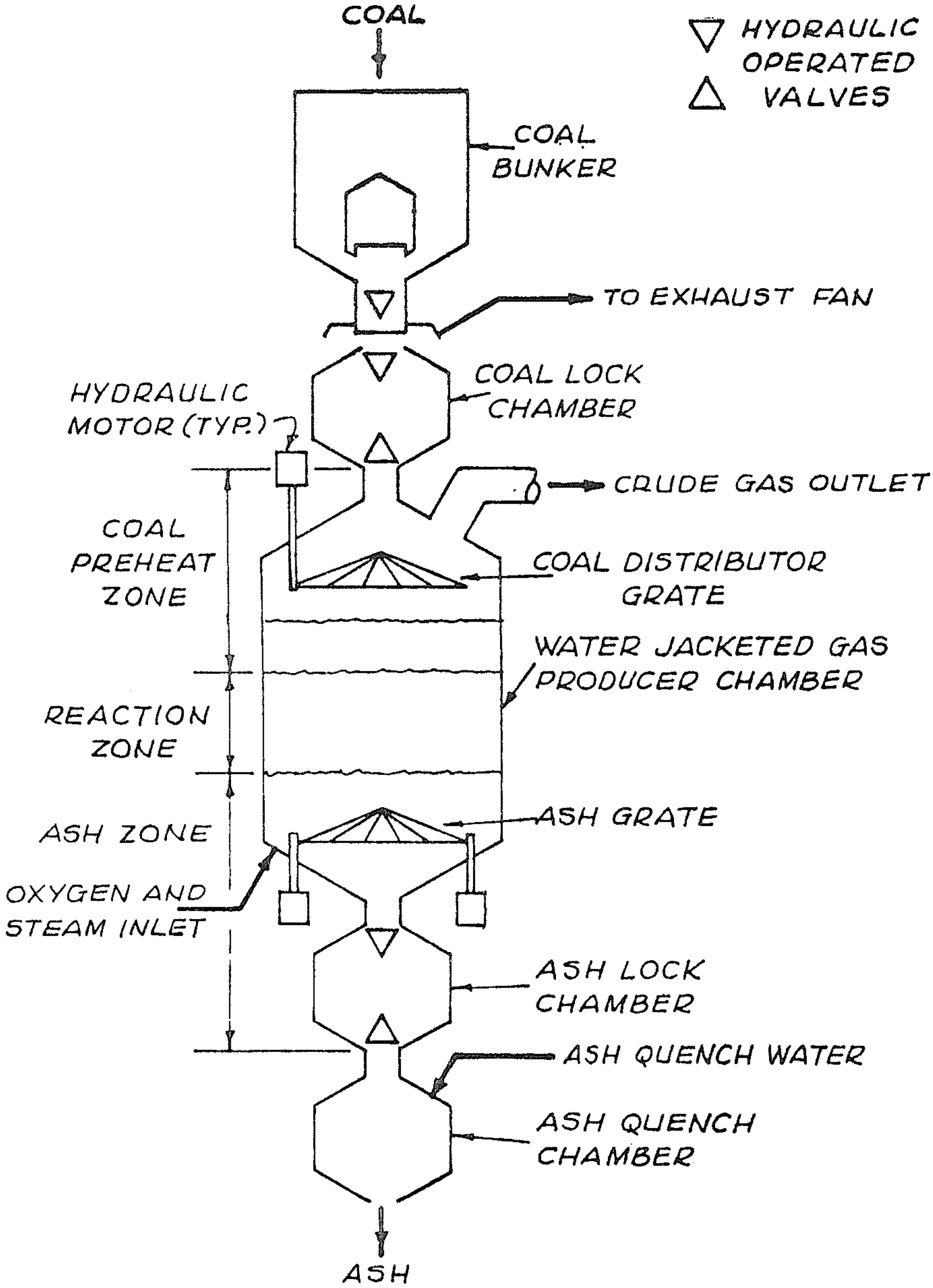
COAL
HYDRAULIC OPERATED VALVES
COAL BUNKER
TO EXHAUST FAN
COAL LOCK CHAMBER
HYDRAULIC MOTOR (TYP.)
CRUDE GAS OUTLET
COAL PREHEAT ZONE
COAL DISTRIBUTOR GRATE
WATER JACKETED GAS PRODUCER CHAMBER
REACTION ZONE
ASH GRATE
ASH ZONE
OXYGEN AND STEAM INLET
ASH LOCK CHAMBER
ASH QUENCH WATER
ASH QUENCH CHAMBER
ASH

FIGURE 2

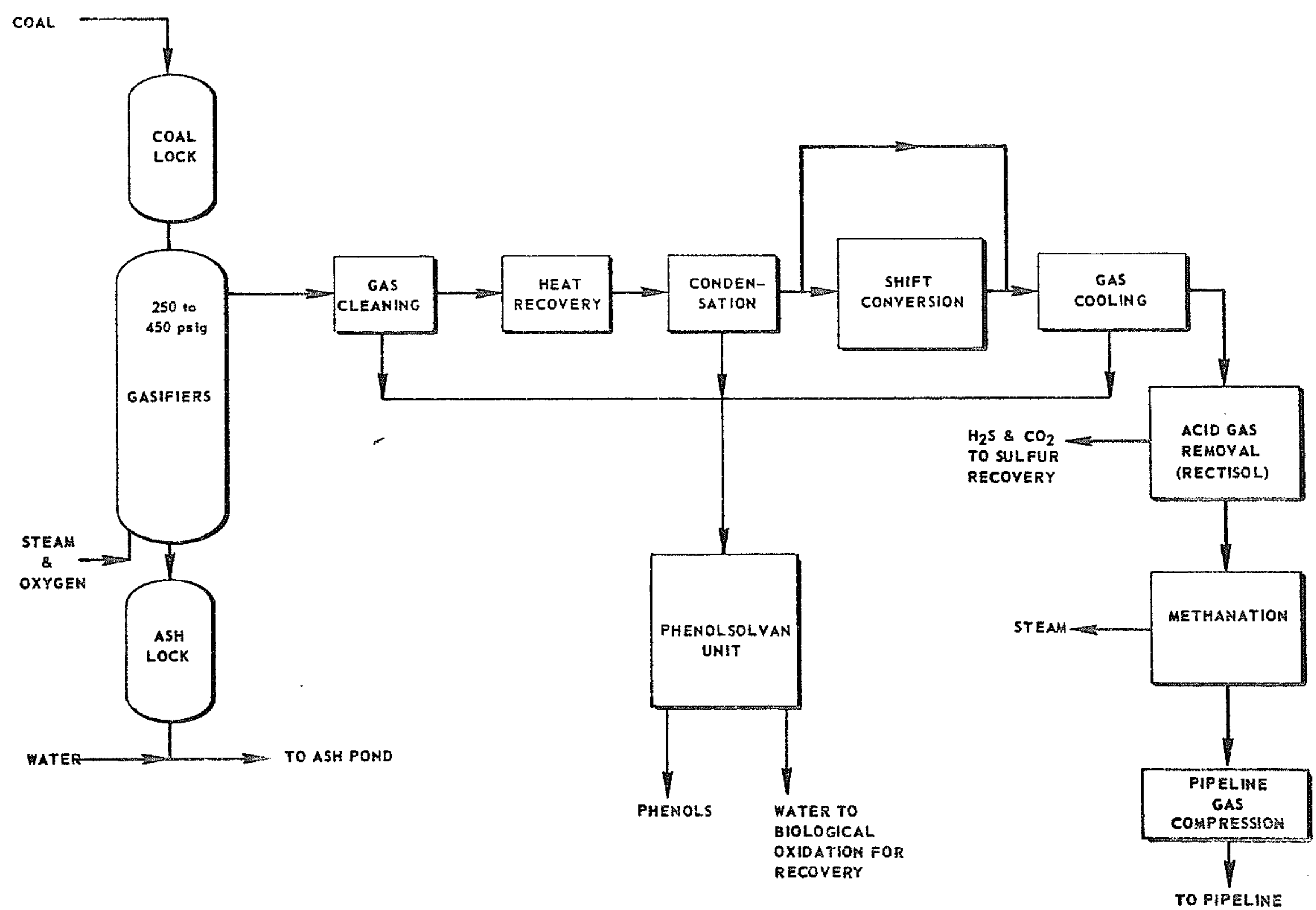

FIGURE 3

SIMPLIFIED FLOWSHEET
LURGI PRESSURE COAL GASIFICATION

Shift Conversion

The H_2 to CO ratio in the total crude gas is raised to at least 3 to 1 by "shifting" about half of the crude gas. The shift conversion is a catalytic process whereby carbon monoxide and steam are converted or "shifted" to carbon dioxide and hydrogen by the overall chemical reaction:

$$CO + H_2O \xrightarrow[\text{Catalyst}]{\text{High Temperature}} CO_2 + H_2$$

The selected operating conditions and catalyst used in this unit allow the carbon monoxide shift reaction to proceed in the presence of heavy hydrocarbons, tar-oils, and naphtha. Simultaneously, a mild desulfurization of these heavy hydrocarbons and hydrogenation of organic sulfur-bearing materials is provided.

Gas Cooling

The crude gas and the portion that has been shifted are combined and further cooled to remove light hydrocarbon oil byproducts and residual water containing phenols.

Rectisol

This is a physical absorption process utilizing low-temperature methanol for the selective removal of H_2S, CO_2, and other sulfur compounds such as carbonyl sulfide (COS). Two separate absorption steps are used:

1. In the first step, H_2S/COS are absorbed. This provides a sulfur-free (less than 0.2 ppm) methanation unit feed gas.

2. In the second step, methanated gas is upgraded to SNG quality by the simultaneous absorption of CO_2 and water.

Methanation

The methanation unit includes all the equipment to catalytically combine carbon monoxide and hydrogen to form methane plus water:

$$CO + 3H_2 \xrightarrow{\text{Catalyst}} CH_4 + H_2O$$

The water, which is chemically formed in the methanation reaction, is condensed and recovered for use as boiler feedwater. The large heat release in this reaction is recovered by generation of steam.

Phenosolvan

All the phenolic water streams generated within the gasification facility are collected. After filtering, the phenolic water is extracted with isopropyl ether which transfers phenolic materials from the water phase to the isopropyl ether phase.

The extracted phenolic water is further processed to remove CO_2, H_2S, and NH_3. The water from this processing step is then routed to biological treatment and subsequently reused within the plant. The phenol-rich isopropyl ether leaving the extraction section is further processed to produce a "phenol lean" isopropyl ether which is recycled back to the extraction section, and saleable crude phenol as a byproduct.

Auxiliary Units

These include a cryogenic air fractionation plant which extracts oxygen from atmospheric air, a conventional catalytic Claus sulfur plant which will convert the rich H_2S off-gas from the Rectisol Unit to byproduct solid sulfur, a steam plant, extensive air-cooling systems, cooling water systems, byproduct storage and loading facilities, safety systems, effluent water treatment and reuse systems, ash return system, and numerous service facilities and buildings.

The overall gasification plant material balance for the WESCO project (shown in Table 2) provides a good indication of the magnitudes involved in this project. Based on producing 250 MM SCFD of product gas, the Lurgi process feedstocks of coal, oxygen, and steam total 52,700 tons per day. These feedstocks are converted to 5,440 tons per day of product gas and 105 tons per day of byproduct phenols, plus 47,155 tons per day of byproduct fuels, ash, sulfur, ammonia, and wastewater, all of which require special consideration and integration into an overall environmental design.

LURGI GASIFICATION MATERIAL BALANCE

BASIS: 250 MMSCF/D OF SNG PRODUCT GAS

	SHORT TONS PER DAY	WEIGHT %
INPUTS:		
SIZED COAL	21,860	41.48
STEAM & WATER	25,160	47.74
OXYGEN	5,680	10.78
TOTAL	52,700	100.00
OUTPUTS:		
PRODUCT GAS	5,440	10.32
PHENOLS	105	0.20
ASH	5,876	11.15
REUSE WATER	17,851	33.87
BY-PRODUCT WATER	3,730	7.08
TARS, OILS & NAPHTHA	1,475	2.80
OFF GAS	792	1.50
CO_2 GAS	16,631	31.56
NH_3 + WATER	800	1.52
TOTAL	52,700	100.00

TABLE 2

Part II - WATER REQUIREMENTS FOR COAL GASIFICATION

The gasification of coal to produce Substitute Natural Gas (SNG) requires water for process cooling, for the generation of steam energy, for supplying the hydrogen needed to produce SNG from coal, and for various other needs. Based on our present design for a coal gasification plant in the Four Corners area, a plant producing 250 MM SCFD of SNG from 21,800 tons per day of coal will require 5,100 gpm (8,200 acre-ft. per year) of raw water intake. This amounts to 1.4 pounds of raw water intake per pound of coal, and this includes water required by the coal mining operation as well as the gasification plant and its auxiliary utility services.

Since the supply of water to our project is contractually limited, every effort has been made in our design to conserve water usage and to maximize the recycle and reuse of water. Some of the major design features used to achieve those objectives are:

1. About 250,000 hp of large compressor-driving steam turbines will be provided with air-cooled exhaust steam condensers-- this horsepower is equivalent to about 8-10 commercial jet aircraft engines. The condensed steam will be recovered and reused as boiler feedwater.

   The air-cooled condensers will provide about 2 billion Btu/hour of heat removal. If cooling water were used for this heat removal (instead of air), the evaporative water loss from our cooling tower would be increased by about 4,000 gpm (6,400 acre-ft. per year), which would almost double our raw water intake requirement. The larger cooling tower would also incur larger windage losses.

2. Raw water will be treated for removal of solids and minerals and then converted to high-pressure steam. A major portion of this steam is fed into the Lurgi gasifiers. This steam will be largely recovered as a phenolic "gas liquor" from which byproduct phenols will be extracted. The dephenolized gas liquor (wastewater) will be stripped of dissolved ammonia and hydrogen sulfide, treated for removal of oil and suspended solids, and biochemically oxidized in two stages of bio-treating. The treated and clarified effluent will then be reused as water makeup to the plant cooling water system. In fact, it will supply 100 percent of the cooling water makeup needs.

3. Byproduct water produced in the methanation reaction, and from NH_3 combustion, will be recovered and reused as boiler feedwater.

4. Mechanical refrigeration will provide the low temperatures needed in the Rectisol Unit. Mechanical refrigeration was chosen in preference to an absorption refrigeration system to avoid the very large cooling water evaporation losses associated with absorption refrigeration, since mechanical refrigeration lent itself to air-cooling for heat removal.

5. Water will be extracted from water treatment sludges and recycled for reuse.

6. Blowdown from the cooling water system will be reused for quenching of the Lurgi ash.

The total raw water available to WESCO from the San Juan River is contractually limited to 44,000 acre-ft. per year by the U.S. Department of the Interior. Since four gasification plants are eventually contemplated by WESCO, it was imperative that the water usage per plant be 11,000 acre-ft. per year or less. It is therefore apparent that the design features discussed herein were mandatory from the viewpoint of water usage conservation as well as minimizing the environmental problems that would result from higher water usages.

Based on our present design, each plant will require only 8,200 acre-ft. per year, or about 75 percent of the contract water availability. This provides us with a margin of safety for any unforeseen contingencies.

Attached hereto is Table 3, Water Requirements and Disposition. As can be seen, the ultimate disposition of the 5,100 gpm intake water can be briefly summarized as:

Process consumption	10.2%
Return to atmosphere	69.6%
Disposal to mine reclamation	8.4%
Others	11.8%
	100.0%

It is important to note that about 70 percent of the water will be returned to the regional atmospheric environment, and will eventually become rainwaters. Even the 10 percent converted to hydrogen contained in the product SNG will eventually return to the atmosphere as water, wherever the product SNG is burned as fuel.

TABLE 3

WATER REQUIREMENTS AND DISPOSITION

	GPM	%
Process Consumption		
To supply hydrogen	1,120	
Produced as methanation byproduct	- 600	
Net consumption	520	10.2
Return to Atmosphere		
Evaporation:		
From raw water ponds	420	
From cooling tower	1,760	
From quenching hot ash	150	
From pelletizing sulfur	250	
From wetting of mine roads	730	
	3,310	
Via stack gases[1]:		
From steam blowing of boiler tubes	200	
From stack gas SO_2 scrubbers	40	
	240	
Total return to atmosphere	3,550	69.6
Disposal to Mine Reclamation		
In water treating sludges	100	
In wetted boiler ash	30	
In wetted gasifier ash	300	
Total disposal to mine	430	8.4
Others		
Retained in slurry pond	20	
Miscellaneous mine uses	580	
Total others	600	11.8
GRAND TOTAL	5,100	100.0

1 Does not include water derived from burning of boiler fuel.

It is also important to note that the remaining 20 percent will be disposed of on-site, principally as sludges and wetted ash used in the reclamation of the coal mining area. THERE WILL BE NO RETURN OF WASTEWATER TO THE SAN JUAN RIVER.

A schematic diagram of the "Water Treatment and Reuse Systems" (Figure 4) is also attached hereto, and graphically illustrates the extent to which recycle and water reuse has been designed into the plant:

1. As already discussed, the water used to provide turbine steam is condensed and recycled for 100 percent reuse.

2. The water fed into the Lurgi gasifiers (as steam) provides hydrogen required to convert the coal carbon to methane (SNG), and steam required in the subsequent "shift conversion" of excess carbon monoxide to carbon dioxide and additional hydrogen. The hydrogen is also subsequently used in the methanation step to produce additional methane as well as byproduct water.

   After serving its beneficial use as a gasification reactant, the excess steam is condensed as phenolic gas liquor from which useful byproduct phenols are then extracted. After oil and solids removal, and bio-treating, the recovered water provides 100 percent of the makeup needs for the process cooling water system.

   This water has now served three useful functions:

   (a) Supplied necessary reactant in the conversion of coal to SNG.
   (b) Served as the medium for removal and recovery of byproduct phenols (as well as ammonia).
   (c) Supplied 100 percent of the cooling water makeup needs.

3. The cooling water system is a closed-loop with an evaporative cooling tower. Water is recycled and reused in the system about 3-6 times before the build-up of dissolved salts, because of the evaporative cooling, necessitates a blow-down to maintain a tolerable level of salts within the circulating water.

   Finally, the blowdown is reused again to quench the hot ashes from the Lurgi gasifiers.

WATER TREATMENT AND REUSE SYSTEMS

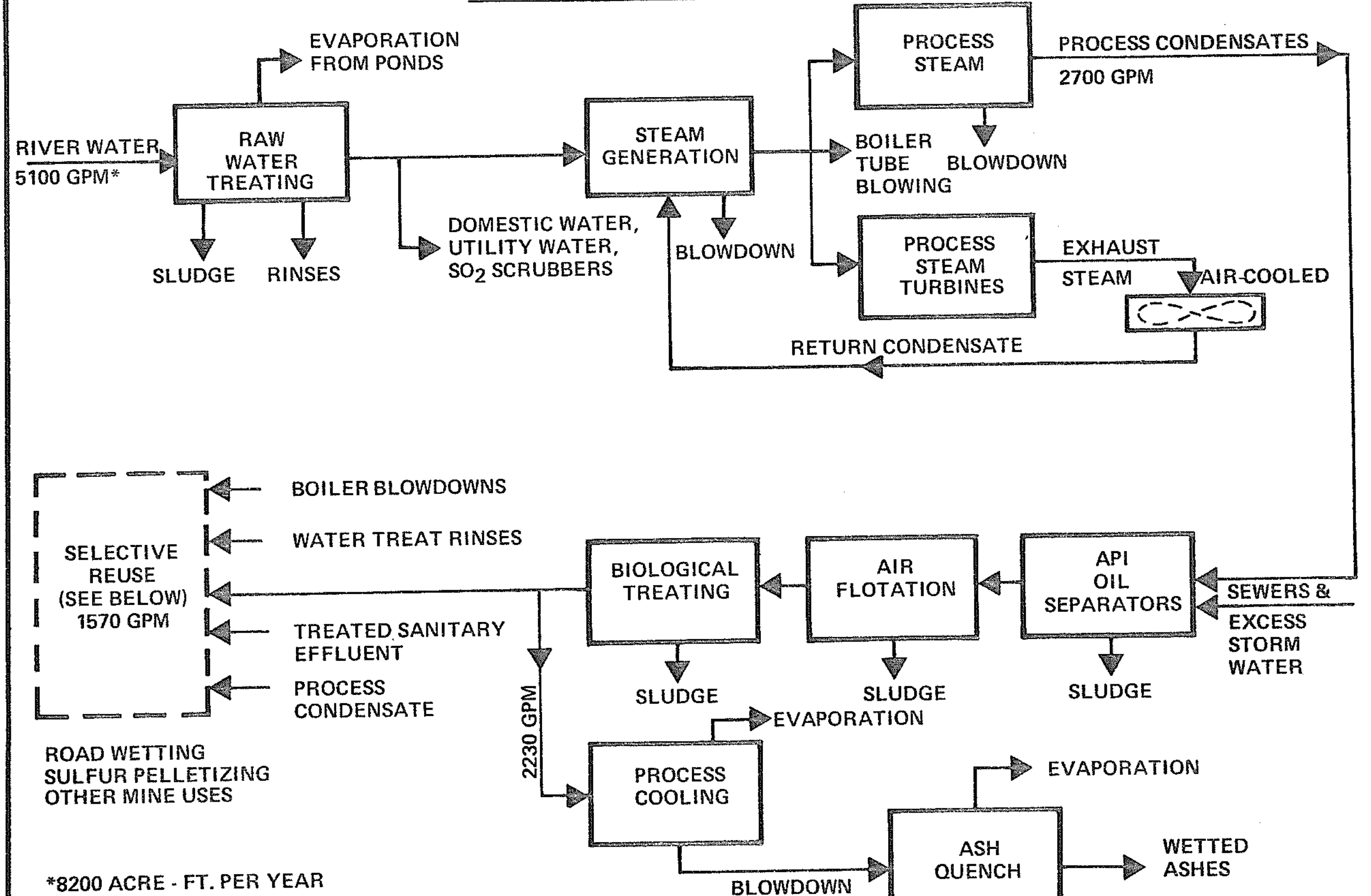

FIGURE 4

4. Boiler blowdown water, rinse waters from the intake water demineralizers, treated effluent from the sanitary system bio-treatment unit, and excess process condensate will be selectively reused to provide:

    a. water for wetting of roads in the mining area (dust abatement).
    b. water for pelletizing the byproduct sulfur; and
    c. other uses in the mining and coal processing operations.

It should be obvious now that the water intake to the plant will be beneficially used and reused many times over, and 80 percent will return to the atmosphere as water vapor.

REPORT BY THE NATIONAL WATER COMMISSION
A Review

Harry P. Burleigh*
Paper presented by Lewis B. Seward**

The duties of the National Water Commission as set forth in Public Law 90-515, 90th Congress, S. 20, September 26, 1968, covered a range of water subjects from a review of present and anticipated national water resources problems to a consideration of economic and social consequences of water resource development and allocation. The National Water Commission faced a monumental task in meeting the charge given it by the Congress. Its task was rendered even more difficult because the Nation is undergoing a period of rapid change in social and environmental preferences, and these preferences have a direct bearing upon the Commission's view of its mission--to determine "what policies the Nation should adopt to ensure that its finite water resources are used in ways which yield the highest measure of welfare to society, now and in the future."

In carrying forward its work, and in the conclusions incorporated in the Review Draft of the Commission's Proposed Report, the Commission has made valuable contributions to the solution of some of the perplexing resource management problems of the Nation, and has addressed some long-needed institutional changes to reflect its view of the proper governmental posture in the light of present conditions.

Particularly significant findings by the Commission include these:

1. The concept of alternative futures as the proper basis for projecting future levels of water use--and the distinction between water "requirements" and water "demands"---is a valid and rational approach to an analysis of the optimal allocation of resources to meet defined social, environmental, and economic goals. This approach, conducted in planning activities at all levels of government, would make possible the presentation of options from which orderly decision-making could then take place.

2. The Commission has made an excellent statement of the proper perspective of the environmental aspects of water resource use and development on page 2-2. The need expressed to "take environmental values and processes into account in selecting among alternatives, so as to accommodate them or, where a conflict of values is necessarily present, to reach an informed and balanced judgment upon what best will serve the public interest" recognizes the dangers in following an either-or kind of evaluation, while at the same time acknowledging the need for realistic and objective environmental impact analysis.

*Executive Director, Texas Water Development Board, Austin, Texas
**Principal Engineer-Project Development, Texas Water Development Board, Austin, Texas

3. The Commission showed a clear understanding of the causes and effects of some of the intergovernmental conflicts that have arisen as a product of the Nation's increasing concern with the degradation of the quality of its water resources. In part, as the Commission notes, these conflicts have resulted from the attempt to improve water quality controls through implementation of antiquated and inappropriate legal and institutional measures. The proper relationship of the authority and responsibility to be exercised by the several levels of government were not clearly defined in legislation enacted to deal with the problem, and, as a consequence, both underlapping and overlapping activities occurred with less than effective results. In its new concern with environmental quality, the public pressed for instant cures for long-standing problems, and there was not a means for quantifying and presenting the effort and cost that would be involved. As a result, the public became disillusioned, and the Administration and the Congress have yet to demonstrate their willingness to assume the very heavy financial burden of the "instant" cure approach. The Commission's entire analysis of the Nation's alternatives in this situation merits the careful attention not only of governmental entities with responsibility in this field, but of the general public as well.

One section of the Commission report dealing with water quality could, however, be improved and expanded to more clearly identify the problem. The discussion of water quality in relation to the estuaries and the coastal zone treated some aspects of quality in this sensitive environment, but failed to include such critical problems as the effects on quality in the estuaries of land runoff; diminution of fresh water inflows resulting from upstream development and use; the changes in estuarine currents and circulation patterns as the result of dredging, and construction of hurricane protection works; and the effects of such offshore activities as drilling and construction of offshore ports. The estuaries are particularly important from the standpoint of critical environmental concern, and it is therefore especially essential that the complex interdependence of all of the factors affecting the water quality in the coastal zone be identified so that quality management and control programs can be interrelated with total coastal zone management.

4. Probably the Commission's major contribution to the Nation's consideration of the proper use of water resources is the very conprehensive cataloging of the many problems, parameters, limitations, constraints, and effects of various water development and allocation alternatives. All of these things need discussion, and the governmental response to these discussions should be informed and deliberate. It is unfortunate, however, that the Commission did not take the two final steps that would have made its very great effort truly meaningful: in the absence of defined national goals and objectives within which its work should have been conducted, the Commission consistently based its conclusions on rather narrow concepts of economic "good," and made no attempt to articulate the broader social and environmental goals that economic efficiency should serve to attain; and secondly--and perhaps this is in part because the first step was not taken--the Commission's Proposed Report appears as a series of analytical statements, prepared from different viewpoints, unrelated in terms of the effect of their implementation on the achievement of national needs for a secure and dignified quality of life.

The Report, as it now stands, is extremely weak with regard to the economic and social consequences of water resource development. The specific discussions about 1) the importance of water in an economic sense, 2) water for irrigated agriculture, 3) transbasin diversion, 4) water to rescue areas where ground-water mining occurs, 5) financing water programs, and 6) the role of the federal government in future water resources programs are inconsistent, paradoxical, and in some instances obviously prejudiced. The Commission uses terms such as "social welfare" and "social costs" which it does not define. Further, it sidesteps important issues, such as social preferences for water amenities and the final determination of the dollar amount of the proposed compensation to basins-of-origin for opportunity losses that would be suffered because of interbasin transfers, by referring them back to Congress.

The Commission exhibits obvious prejudice against water for irrigation by alluding to agricultural surpluses, and takes an unfounded and unexplained position that "unless it is economically feasible, interbasin transfers should not be undertaken to rescue areas which are mining ground water, that is, which are depleting ground water reserves by pumping in excess of recharge."

The Commission's failure to produce rational recommendations regarding interbasin transfers and water resources development to support regional economies appears to be due to the absence of a conceptual framework or model which states, or otherwise incorporates, the Nation's goals and objectives concerning income, employment, income distribution, population dispersion, stable prices, and, in the case of food and fiber, the goal to keep quantities high and hold prices of these necessary commodities at relatively low levels to serve the interests of low income groups. The view is taken that publicly owned water resources should be developed and distributed to water users in a manner analogous to that which is used by the private sector market place for manufactured goods. Throughout the discussion, economic efficiency criteria, from the national viewpoint, are mentioned as being the guidelines whereby water resources investments would be judged. Transbasin diversions would be judged feasible when diversion benefits exceed diversion costs including compensation to basins of origin of diverted water, but no attention is given the effects of such public policies upon income redistribution among regions: i.e.; why should publicly owned water be traded among regions, or shouldn't the national treasury receive the proposed interregional compensations for use in nationwide public programs, if such compensations are to be make.

The matter of compensating regions of origin of diverted water in the amount of the value of opportunity forgone within these regions adds a new dimension to water resources planning. Heretofore, proposals to move water among regions have implicitly rested upon the assumption that only unemployed or unused surpluses would be tapped for such purposes. The Commission's recommendations would apparently permit more widespread selling of waters among basins or regions if favorable prices could be negotiated. There are at least two major problems inherent in these conditions of transfer. One deals with the problem of valuing water in alternative uses within basins of supply, and the other pertains to "real" versus "apparent" opportunity within basins of supply. Carried to its logical conclusion, this compensation principle requires "marketplace optimal allocation" of water within and among basins, or to put it another way, this type of water marketing could result in the selling of water presently in use from basins in which uses have been established. On the other hand, a basin of supply may have water which is not being used but which, if other resources were available and water users were present, would have value within the basin of supply. This apparent but unrealized opportunity could unduly burden transbasin diversion costs in the real sense and might preclude use of the water in other areas that could pay diversion costs but could not pay the "apparent" opportunity forgone part of the cost. This position of the interbasin diversion discussion appears to have been included in the report without having had the benefit of thorough investigation and widespread evaluation and review by water resources professionals. It needs further consideration.

The Commission's discussion of "Water and the Economy" suffers from skepticism about the effects of water resources upon regional economic growth. The importance of water is recognized in the opening hypothesis of Chapter 3, and later a number of regional cases in which water projects were major factors associated with regional growth were presented. In all instances the discussion supports the original hypothesis yet the Commission concludes, without supporting evidence, that "while water resources projects have had very significant impacts on regional economic development and population distribution in the past, their role has now greatly diminished." It is to accept this conclusion. Some of the cases cited are as recent as the decade of the 1960's.

The concept of alternative futures was introduced and applied to agriculture. Similar analyses were not applied to municipal and industrial water using activities even though it is stated at the outset that this would be done. From the analyses of alternative futures of agriculture, the Commission concluded that "the agricultural water problem does not appear to be one of water shortage." This conclusion was based on the Heady studies which were predicated upon the assumption that the Nation's agricultural sector could be managed as a single operating unit in which regional reallocation of production could be freely practiced. This, of course, is not the case. The Nation's agriculture is composed of a large number of farms (management units). Each manager makes his cropping decisions based upon his available supply of land, water, capital, climate, other resources, and management abilities. Thus, in a real sense it is extremely doubtful that the conditions underlying the Heady studies shall ever be present. Thus, the Commission's conclusions about the future need for water for agiculture are subject to question. Given that Heady's assumptions are valid, the question remains, what happens to the farmers and the supporting rural economies? Who compensates the losers here? The Commission failed to recognize this problem. Instead, it inferred in its discussion of the problem of regional economies subject to decline due to declining groundwater irrigation supplies, that farm adjustment was rapid anyway and cited as support of its position the four percent annual decline in farm population during the 1960's. This reviewer sees this trend in farm population decline as having occurred while irrigation water development was taking place. What will be the rate of farm population decline as groundwater for irrigation declines? What will be the rate of non-farm rural area decline as the farm population declines? The Commission failed to consider the social and economic consequence of water shortage except to make the obvious suggestion that more efficient use be made of existing groundwater supplies.

The economic efficiency criteria imposed upon regional economy rescue operations is too severe. The social costs of no rescue should be included in the benefits of rescue.

Perhaps one of the most striking inconsistencies in the report with the Commission's own view of its primary focus is found in the section dealing with interbasin transfers on page 8-6. The report says: "The Commission does not presume to offer suggestions about how much water this should be. The people will decide that question through their elected representatives. It need only be noted that the ultimate authority resides in Congress. . . . Thus, when the economic criteria that should govern an interbasin transfer are discussed . . . water which society has decided should be precluded from developmental activity is not considered. What is considered is water that remains available for producing goods and services in the economic sector."

It would appear that this approach--not unique to this chapter--precisely avoids the key question that was posed to the Commission by the Congress when the Commission was created. That question, clear from even a cursory reading of the National Water Commission Act, is this: What should the Congress consider to be the scope of the water problems facing the Nation, and how can those problems be best resolved in the interests of assuring the quality of life desired for the American people? There is no indication in the Act that the Congress intended that the Commission make its recommendations on the basis of economic efficiency alone, but rather the explicit intent is expressed that the Commission review national water problems in the context of broad national social goals.

It should be noted, indeed, that even on these terms the Commission failed in consistency. "Mining" of ground water is apparently to be regarded as a cardinal sin. However, under any set of criteria for resource management and use, there would appear to be conditions under which such depletion would represent not only a social but an economically desirable decision. The Commission has in its report referenced the Texas High Plains as a region that has unwisely used a depleting ground water resource to the extent that its economic base of irrigated agriculture is now threatened. Irrigation at an intensive level began on the High Plains in the late 1930's as the Nation came out of the horror of the dust bowl years. Production under irrigation increased during World War II and the years following when the Nation's heartland fed the free world and sustained a massive national war effort. Irrigation made possible the production of food and fiber, using substantially less manpower than would have been dreamed possible at the turn of the century. There was not then an awareness of the ultimate consequence to the region if restraints were not imposed. This may have been the result of ignorance, but the Nation as a whole and also the world profited by that ignorance as it resulted in food production.

An interbasin transfer of water surplus to the uses of the Mississippi Basin states has been proposed as a means of bringing a supplemental water supply to the High Plains to sustain the irrigation economy. The Commission has apparently determined in advance of availability of study results that such a transfer would be undesirable, but appears to have based this judgment solely on the criterion of the ability of irrigation farmers within the High Plains area to repay the full costs of moving the water to their headgates. The additional considerations of the social cost to the Nation of a major regional economic disaster; the loss of one of the Nation's most productive sources of food and fiber at a time when millions of our own citizens and millions of people throughout the world are existing on inadequate to starvation diet; and the advantages to the Nation of putting to productive use a water resource that would otherwise be unused appear not to have been included in the Commission's thinking. Yet these are just as real factors as the repayment capacity of individual farmers, and may in the long run have profoundly greater influence on the quality of life in this country.

In the chapter of the report dealing with planning, the Commission very properly stresses the need for planning on a broader scale than for water alone. The intimate relationship between water and land use planning is emphasized, as it indeed should be. This makes particularly questionable the Commission's rather adamant view that allocation of water to the various uses should be made on the basis of use where the water occurs. Water is not a fixed resource but a movable good that can be transported with relative ease over long distances. The Romans knew this and implemented striking programs of water resource transfers. As our Nation's population continues to grow--and there is no indication that such growth is going to be reversed--we may come to a situation where land is our truly limited resource, and land is not movable. It would appear, therefore, that our national planning and thinking for the future should be directed toward realizing the fullest potential of the land and water and energy and other resources available to us without preconceived constraints on ownership by the region or state in which such resources may happen to occur.