WATER RESOURCES RESEARCH INSTITUTE

New Mexico State University

TWELFTH ANNUAL WATER CONFERENCE NEW MEXICO

March 30—31, 1967

THEME: Water Quality- How Does It Affect You?

MILTON STUDENT CENTER

New Mexico State University

Las Cruces New Mexico

NEW MEXICO WATER CONFERENCE
Sponsored By
NEW MEXICO STATE UNIVERSITY DIVISIONS

of

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Agricultural Extension Service
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College of Engineering
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Cooperative Agent, USDA-ARS, SCS

Water Resources Research Institute
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Arthur L. Ortiz, Director
State Planning Office
Santa Fe, New Mexico

FOREWORD

WATER QUALITY - HOW DOES IT AFFECT YOU?, was the general theme of the papers presented by a group of highly qualified and capable speakers at the Twelfth Annual New Mexico Water Conference.

The Water Conference had its origin in a Water Seminar conducted in the Agricultural Economics Department during the Spring Semester, 1956. Eleven water areas were discussed in the seminars, from January 26 to May 24, 1956. The papers were published in limited numbers in a bound volume for reference purposes, under date of September 17, 1956.

The water seminar attracted considerable statewide attention. Many people indicated an interest in attending the seminars. Others asked for any reports which might be available from the meetings. As a result, New Mexico State University, then New Mexico College of Agriculture and Mechanic Arts, sponsored a statewide water conference, held October 31, November 1 and 2, 1956.

At the end of the 1956 Conference, the group agreed that an annual conference should be held. Thus from the beginning as an Agricultural Economics Department seminar, the Twelfth Conference has been held and is reported here.

As a matter of record for those who are interested, the subject of each of the twelve conferences is listed on the following page. The proceedings from several of the conferences are out of print. These conference proceedings have been requested by the Library of Congress and by many college and university libraries and by individuals throughout this country. Also, many requests have been received for proceedings from libraries and others in numerous other countries.

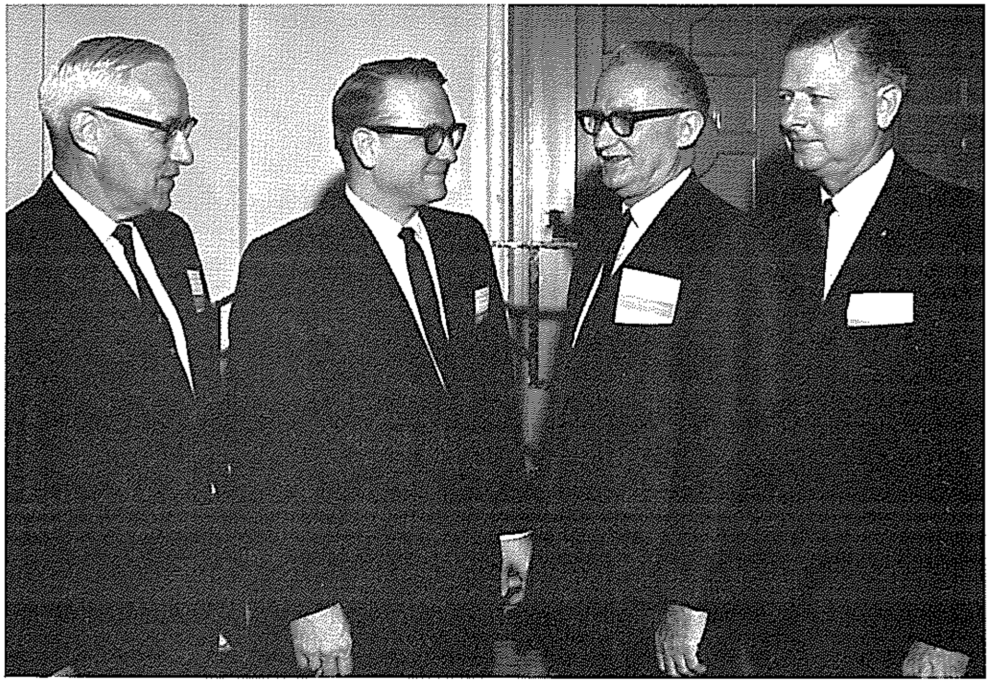
Much credit for the continued success of the conferences is due the members of the Statewide Advisory Committee and the University Water Conference Advisory Committee, as listed inside the cover page of this report. These committees assist in the planning and the presentation of each conference. Several members of the committees have served and given of their time and talents through more than ten conference years.

Part of the funds required for the publication of this proceedings report were provided by the United States Department of Interior, Office of Water Resources Research as authorized under the Water Resources Research Act of 1964, P.L. 88-379.

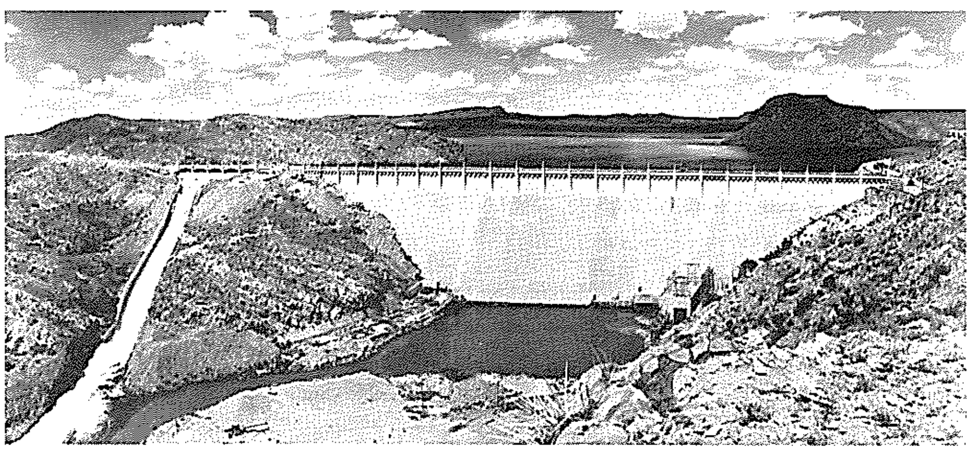
The program which follows will serve as an index to the papers.

H. R. Stucky

H. R. Stucky



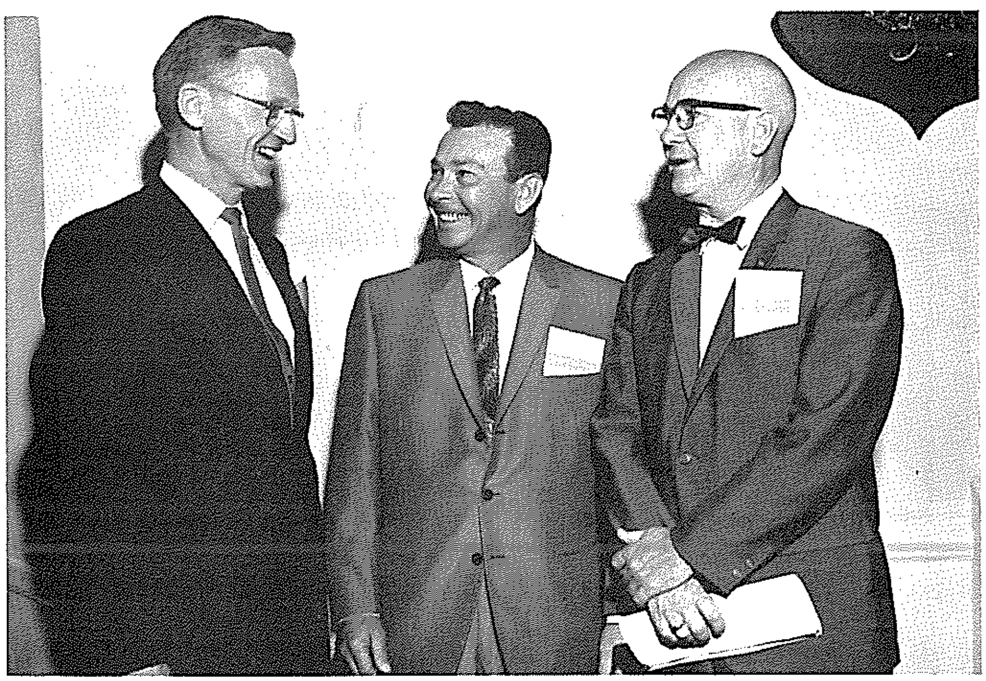
Governor David F. Cargo and Dr. Roger B. Corbett, NMSU President (center left to right) with Dr. H. R. Stucky, Director of the Water Resources Research Institute and Chairman of Conference (left), and Rogers Aston, NMSU regent from Roswell (right). Aston chaired the morning session of the conference at which Dr. Corbett welcomed guests and Governor Cargo presented an address on "New Mexico's Interest in Water."



EL AGUA ES REY EN LAS REGIONES ARIDAS
(Water is King in Arid Regions)

Photo of Elephant Butte Reservoir, taken in 1942, was referred to in Dr. Leyendecker's paper, Agricultural Career Opportunities in the Water Resources Areas," p. 56. Dr. Fabian Garcia, Director of the Agricultural Experiment Station (1913-1945) had this picture hanging in his office with the title "El Agua Es Rey En Las Regiones Aridas" and as Dr. Leyendecker stated in his paper "Dr. Garcia knew full well the true and deep meaning of the statement."

E. D. Eaton, Associate Director, Office of Water Resources Research, Department of Interior in Washington, D. C., attending the New Mexico Water Conference at New Mexico State University, gets a hearty handshake from Fred A. Thompson (right center) of the Department of Game and Fish in Santa Fe. Looking on are Benjamin C. Hoy of the Bureau of Indian Affairs, Ignacio, Colorado, and Ladd S. Gordon (right) Director, New Mexico's Department of Game and Fish.



Enjoying a joke before the beginning of the Friday morning session of the Conference are (left to right) Harold Dregne, Professor of Soils, NMSU; M. L. Wilson, Associate Director, Agricultural Experiment Station, NMSU; and Haskell Street, El Paso Water Utilities. Dr. Wilson served as chairman, Mr. Street was one of the speakers, and Dr. Dregne is a member of the University Water Conference Committee.

NEW MEXICO WATER CONFERENCE

March 30 - 31, 1967

THEME OF THE CONFERENCE - WATER QUALITY--HOW DOES IT AFFECT YOU?

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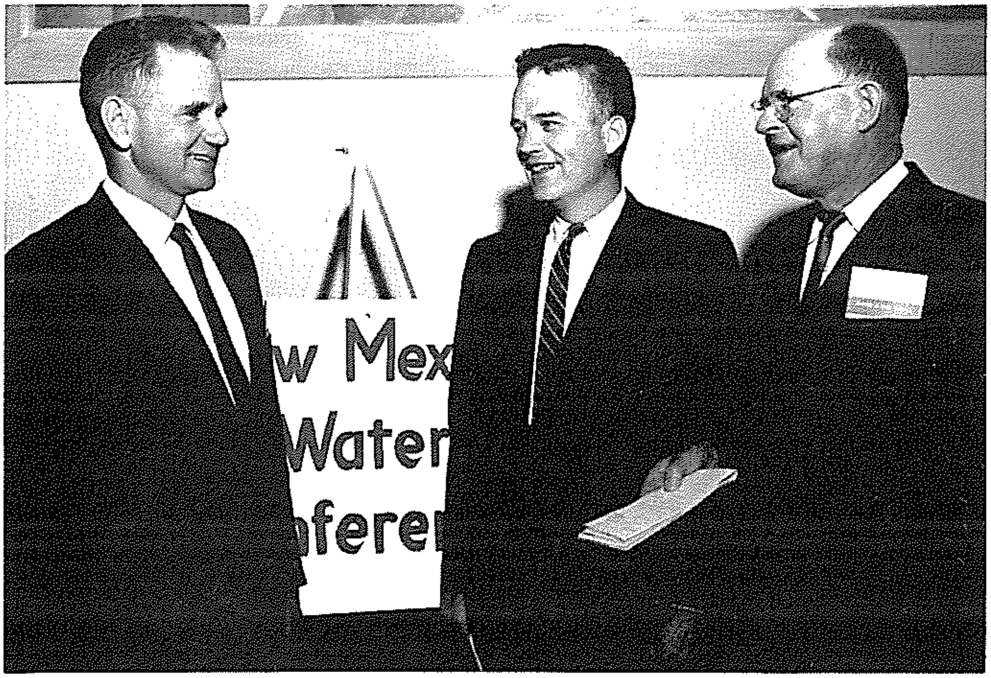
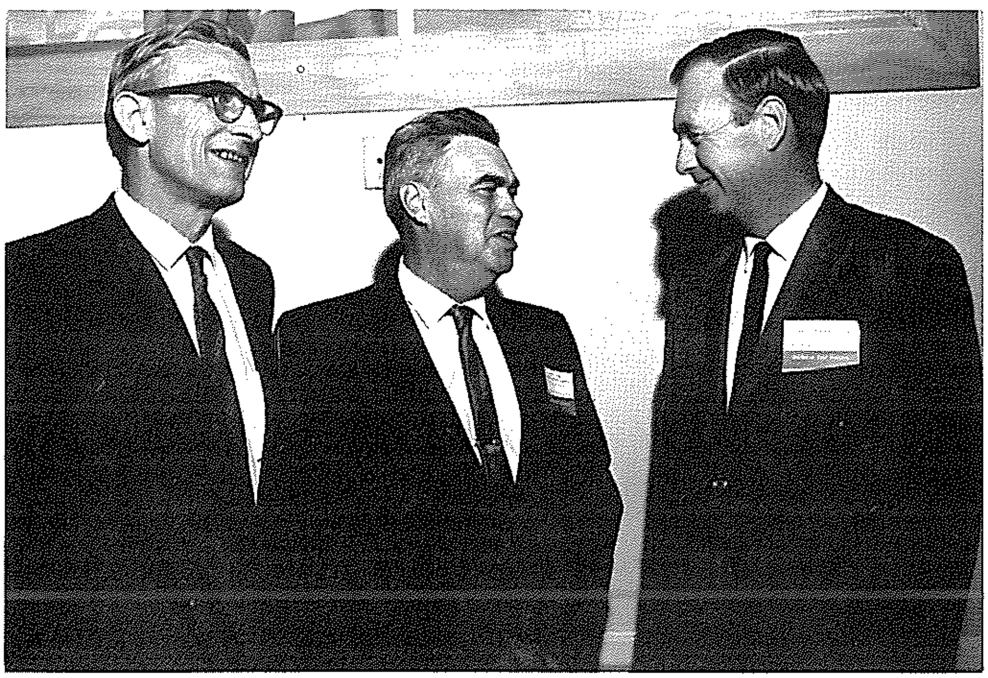
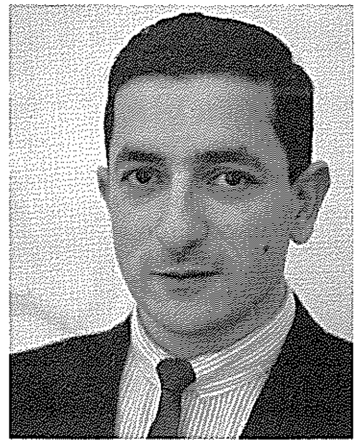


State Representative Hoyt Pattison, Curry County; Willis Ellis, Professor of Law, University of New Mexico; and John Gregg, Elephant Butte Irrigation District, Las Cruces (left to right), discuss the problems of water law and water management. Mr. Pattison and Professor Ellis were speakers during the special sessions - Recent Water Legislation.



Three of the speakers in the special sessions on Recent Water Legislation were (left to right) State Engineer Steve Reynolds; Senator James Kirkpatrick, Dona Ana County; and Harlan Flint, Special Assistant Attorney General.

Dr. Donald E. Longenecker
Texas Agricultural Experiment
Station, Isleta, Texas



Dr. Allen Lazrus
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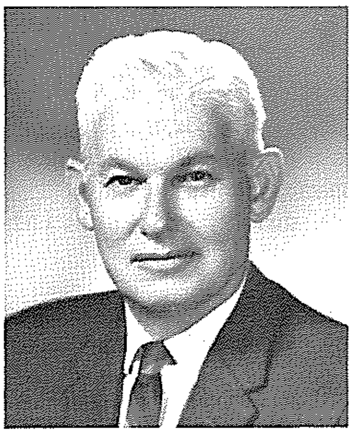

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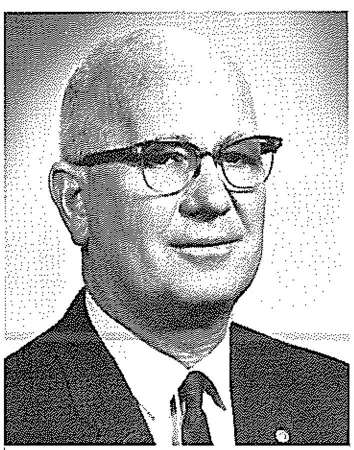
New Mexico State University



Haskell Street
El Paso Water Utilities
El Paso, Texas

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New Mexico Institute of Mining
and Technology, Socorro, NM

THE DEVELOPMENT OF WATER QUALITY STANDARDS

James L. Agee[1]

The water quality standards that are being developed by the State and which must be approved by the Secretary of the Interior will go considerably beyond the application of water quality criteria for water uses in specific streams. The Water Quality Act of 1965 which requires the establishment of water quality standards calls for the States to adopt: (a) water quality criteria applicable to their interstate waters, and (b) a plan for the implementation and enforcement of the water quality criteria. All fifty States, the District of Columbia, Guam, Puerto Rico, and the Virgin Islands have indicated their intent to meet the June 30, 1967, deadline for submitting their water quality standards. The standards will then go to the Secretary of the Interior for review and approval. In the event a State's proposed standards are adjudged unsatisfactory, the Secretary may initiate action to adopt suitable water quality standards.

Last May the Federal Water Pollution Control Administration issued "Guidelines for Establishing Water Quality Standards for Interstate Waters." A memorandum, "Necessary Supporting Material and Implementation Plan Contents," was developed in December. These two documents provide the States basic guidance for developing their standards. Today, with less than three months before the deadline for submitting their standards, most States have demonstrated good progress and apparently will complete the job by June 30.

Over the past two months we have had the opportunity of meeting with most of the States in Regional meetings. To date the Federal Water Quality Standards Staff has reviewed the standards of approximately 25 States as submitted on a preliminary basis.

With this as background, I want at this time to report on items of special interest in the development of water quality standards. Specific attention will be given to Guidelines Numbers 1, 6, 7, and 8.

GUIDELINE NO. 1

Water quality standards should be designed to "enhance the quality of water." If it is impossible to provide for prompt improvement

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1/ Director, Water Quality Standards Staff, Office of Program Plans and Development, Federal Water Pollution Control Administration, U.S. Department of the Interior, Washington, D.C.

water quality at the time initial standards are set, the standards should be designed to prevent any increase in pollution. In no case will standards providing for less than existing water quality be acceptable.

This Guideline can be applied to moderately or heavily polluted waters by establishing criteria which would improve existing water quality and prevent any increase in pollution. Rigid application of this Guideline to high quality natural waters is more difficult, especially in areas where future development is likely to occur. Under these circumstances the Administration is encouraging the States to adopt standards which will provide for the preservation of all existing water uses, but which in fact may be less than existing water quality. The acceptability of standards providing for less than existing quality can be determined by asking two questions:

1. Are all existing water uses being preserved? and,

2. Are waste discharges which are amenable to treatment or control being treated or controlled?

If the answer to both questions is "yes" - the standard would normally be acceptable.

GUIDELINE NO. 6

The plan for implementing and enforcing the water quality criteria should be submitted in sufficient detail to describe the nature of the actions to be taken to achieve compliance, a time schedule for such compliance, the controls and surveillance for measuring compliance, and the enforcement authority and measures for ensuring compliance. It is recognized that there are a number of ways that the water quality standards can be effectively implemented and enforced by the States; achievement of the purposes of the Act, rather than the methods by which this is done, is paramount.

The Administration is asking the States to develop a detailed plan for implementing and enforcing their water quality criteria. The plan should include a construction timetable for the needed municipal industrial waste treatment facilities, scheduled over the next five years. The States have generally not given sufficient attention to the needs of each municipality or industry. The Administration, through its Regional Offices, is currently advising each State regarding the detailed implementation plans required.

GUIDELINE NO. 7

The plan should include consideration of all relevant pollutional

> sources, such as municipal and industrial wastes, cooling water discharges, irrigation return flows, and combined sewer overflows.

Obviously, this Guideline is troublesome. We cannot expect that presently uncontrolled sources of pollution such as heat discharges, irrigation return waters and combined sewer overflows can be corrected or eliminated in a short period of time. However, the Administration is requesting the States to consider all relevant sources of pollution in adopting both their criteria and plans of implementation. Criteria for many interstate waters will specify numerical limits for bacteria, dissolved oxygen, temperature, toxics, salinity, sediment and other water quality parameters applicable to a particular river basin. The plan for implementation must include all relevant sources of pollution--municipal and industrial wastes, heat discharges, agricultural drainage, and others. Of particular concern here in the Southwest is the application of water quality standards to irrigation return flows. The Administration has recommended that States where irrigation does have an impact on water quality adopt criteria and a plan of implementation to deal with this type of pollution. It is recognized that the final answer to pollution from irrigation is not available today. Nevertheless, positive steps can be taken to initiate control measures.

GUIDELINE No. 8

> No standard will be approved which allows any wastes amenable to treatment or control to be discharged into any interstate water without treatment or control regardless of the water quality criteria and water use or uses adopted. Further, no standard will be approved which does not require all wastes, prior to discharge into any interstate water, to receive the best practicable treatment or control unless it can be demonstrated that a lesser degree of treatment or control will provide for water quality enhancement commensurate with proposed present and future water uses.

This Guideline requires secondary waste treatment by municipalities and an equivalent high degree of watertreatment or control by industries. Adequate treatment for industrial wastes can only be handled on an industry-by-industry basis. The best practicable treatment or control for a pulp mill's waste might include chemical recovery, fiber collection, primary settling, and aeration, plus lagooning of wastes during low stream flows with release of the stored wastes during high stream flow. Any lesser degree of treatment for municipal or industrial wastes can be accepted only where it can be demonstrated that a lesser degree of treatment or control will provide for water quality enhancement commensurate with present and proposed future water uses.

This Guideline has been criticized on the premise that it requires "treatment for treatment's sake." The best answer to this charge is "that, if we are serious about maintaining water quality, we must be serious about waste treatment, control and preventive measures." Applying waste treatment technology after waters have become polluted is generally too late and certainly not in keeping with the preventive approach of water quality standards.

The four Guidelines which I have discussed are no more important than the others, but these are the ones that have generated many questions from the States.

It is important to point out that the "Guidelines" which were developed are meant to be used for guidance, and rigid application is not always practicable. The basic thrust of the water quality standards effort is enhancement and/or preservation of water quality to provide for present and future uses.

Significant in the water quality standards effort has been the appointment of five National Technical Advisory Committees for water uses. The five Committees are:

Public Water Supplies
Industrial Water Supplies
Recreation and Aesthetics
Agricultural Uses
Fish, Aquatic Life and Wildlife

The basic charge to these committees is twofold:

(a) To recommend specific water quality requirements for respective uses named, and

(b) To identify the specific research needs to develop meaningful water quality criteria.

Unfortunately, much of the data and information being developed by these Committees will not be available for use by the States before the June 30 deadline. The point of real importance, however, is that a water quality criteria program has been initiated by the Federal Water Pollution Control Administration and that the program will have the back-up of the technical committees as well as laboratory and field research.

The water quality standards program is well underway. It is anticipated that most States will meet the June 30, 1967, deadline and that Secretary Udall will proceed post-haste with review and approval of the State standards as submitted.

CONSEQUENCES TO NEW MEXICO OF WATER QUALITY STANDARDS ON INTERSTATE STREAMS

John W. Hernandez[1]/

The October 1965 Federal Water Quality Act gave the states until June 30, 1967, to develop (1) water quality criteria applicable to the interstate waters, or portions thereof, within each state, and (2) a plan for the implementation and enforcement of the water quality criteria adopted. The fast approaching dead-line for the adoption of water quality standards placed many of the states in the extremely difficult position of having a single year in which to formulate fundamental policy for the future uses of their water resources--this policy, by its very nature, to have long-term consequences. Unfortunately, because the time made available was so short, standards for many states will be based on inadequate technical information with little regard given to the economic implications of particular provisions.

Standards have now been proposed for three of New Mexico's five major interstate streams. To assess the significance of the proposed quality standards in the development, and redevelopment, of New Mexico's water resources, three steps will be followed in this paper:

1. A review of the structure, intent, and administration of our current water-rights legislation.

2. A review of the nature, intent, and language of the proposed standards.

3. After comparing their similarities, a deduction of the consequences of the administration of quality standards based on certain parallelisms with water-rights law.

IMPORTANT ASPECTS OF WATER-RIGHTS LAW

In New Mexico water-rights legislation, and in its interpretations by the courts, there is the repetition of the concepts of beneficial use, of admonishments against the waste of water and of efficiency of use. The State Constitution (1) specifies that "beneficial use is the basis, the measure, and the limit of the right to the use of water." Beneficial use has been interpreted to include recreational uses and fish and wildlife propagation as well as agricultural, mining, industrial, municipal and domestic applications. It is interesting to note that

1/ Associate Professor of Civil Engineering
New Mexico State University

the Colorado River Compact (2) specified the relative importance of various beneficial uses of water as follows:

1. Uses for navigation are subservient to domestic, agricultural, and power purposes.

2. Impoundment for electrical generation is subservient to agricultural and domestic purposes.

The language of a number of New Mexico (3,4) and California (5) court decisions may be interpreted to show that beneficial use implies efficient use and that an appropriator is not entitled to waste water. New Mexico statutes (6) require that the amount of water used for irrigation "shall not be in excess of the limits imposed" and shall be "consistent with good agricultural practices" that will result "in the most effective use of available water in order to prevent waste".

One of the three major purposes of the Pecos River Compact between Texas and New Mexico is specified (7) to be "the more efficient use of water". With a slight variation, this same phrase also appears in the Costilla Creek Compact (8) between New Mexico and Colorado. In addition to requirements for the efficient use of water is its reasonable use. Hutchins (9) reports the following:

> The supreme court has adopted the rule that in contests over water rights, prior appropriators who complain of injury must prove that their use of water is reasonable and beneficial----------.

There are a number of phrases in these citations from New Mexico water-rights law that have bearing on the implications of water quality legislation--these are (a) beneficial use, (b) efficient use, (c) most effective use, (d) non-wasteful use and (e) reasonable use.

In general, the State Engineer has responsibility for the apportionment and efficient use of the public waters of the State. The right to appropriate these waters is administered through a system of use permits and licenses issued by his office and through court decrees upon adjudication proceedings. Based on hydrologic and hydrographic studies, the State Engineer must establish the amount of water available for appropriation at a particular site on a stream system and must resolve questions of the efficiency and reasonableness of use.

CHARACTERISTIC PROVISIONS OF THE PROPOSED QUALITY STANDARDS

In establishing water quality standards, factors which should be considered are the costs incurred by the water user to meet a particular standard; the value of damages to stream life and downstream users resulting from violation of the standard; and the dollar value added to the water (or the benefits to society) through the application of the water to beneficial use. Thus economics, by implication, are an integral part of all standards. Professor Harold A. Thomas (10), in his widely quoted paper "The Animal Farm: A Mathematicl Model for the Discussion of Social Standards for Control of the Environment", states that

> It may be shown that without exception every quality criterion or rule whether it pertains to health, to aesthetics or to property damage is always equal to a function of a cost: benefit ratio----. To set a criterion is to impute a cost: benefit ratio.

The following are selected sections from the Standards for the San Juan River in New Mexico and are cited as examples of the intent and language of the proposed standards:

1. Pollution is defined as the addition of materials or substances of other than natural origin to the stream in concentrations which will impair or adversely affect the application of the water of the stream to beneficial use with pollution deemed to be preventable by practical, conventional waste-water treatment and disposal techniques.

2. Degradation is used to describe the deterioration of water quality which results through beneficial uses, but which is not readily preventable by economical treatment methods. The appropriative right to water does not include the right to pollute, but concomitant to use is the degradation of quality to some degree. Thus, inherent with the beneficial use of water is some deterioration of its quality.

3. The term "conventional waste-water treatment" is intended to indicate one of the many economically feasible waste-water treatment and disposal techniques which have been evolved in sanitary engineering practice. The application of such treatment methods to waste-waters prior to their discharge to the stream is implied in these standards. No wastes, amenable to conventional treatment, should reach the stream prior to the application of appropriate treatment techniques, with the requirement for treatment imposed so as to limit the waste materials reaching the stream to a minimum.

4. The Department will also take appropriate measures to avoid unreasonable stream deterioration that is readily preventable by economical treatment methods but will not apply these standards to prohibit degradation resulting from the development and use of waters within the limitations of the Colorado River Compact, the Upper Colorado River Compact and the La Plata River Compact.

5. Turbidity introduced in the stream, other than that which occurs naturally, shall not reduce light transmission to the point that existing aquatic life in that section of the stream is inhibited or that will cause substantial visible contrast with natural appearance of water. Naturally occurring turbidity caused by silt and suspended sediment or by the operation of irrigation or flood control facilities are not subject to these regulations.

6. The stream bottom shall be free of debris and sediment of other than natural origin, that will adversely inhibit the growth of normal stream flora and fauna or significantly alter the physical and chemical properties of the bottom.

7. The stream shall be free of objectionable floating solids, oils, and grease where these materials come from other than natural sources.

8. Toxic substances and chemicals such as, but not limited to, pesticides, herbicides, heavy metals, and organics, shall not be introduced into the stream in waste-water flows in concentrations which (1) are toxic to plants, fish, aquatic or wildlife; or (2) will change the ecology to an extent detrimental to these forms of life.

CONSEQUENCES OF QUALITY STANDARDS

The concepts of beneficial use, of reasonable use, of efficient use, and of the elimination of waste appear in the proposed standards. Consciously, or perhaps unconsciously, the concepts incorporated in standards have been carried over from the water-rights area. Just as consumptive use is recognized in water-rights law as a consequence of beneficial use--the quality standards consider degradation to be inherent with beneficial use.

Just as the waters of a stream system are shared by the users, the degree of degradation brought about through beneficial use must be shared. Just as the State Engineer must decide on the amount of water available for appropriation, the water pollution agency must establish limits on the degree of degradation which will be permitted at a particular place on the stream.

New Mexico is now in the process of adopting water quality standards for our major interstate streams and I believe that the State will establish similar standards for all our streams and tributaries as the federal share of the cost of new water pollution control facilities is increased for states willing to do this. I also believe that a system of effluent standards and permits for effluent discharge will be instituted in the next ten years.

Because of the tremendous growth potential of our state, I believe that the administration of water quality programs will have the same far reaching consequences as water-rights administration--and because of the similarity of basic intent, both will be administered in much the same fashion in the future.

The administration of the water-rights system has been successful over the years because of the high calibre of our present and past State Engineers and because of the availability of a well-trained technical staff. We have just as big a stake in water quality as we do in water quanitity and it behooves all of the water users to support the development of a strong water pollution agency in New Mexico, and this can best be brought about by the provision of a separate, identifiable budget for this agency.

REFERENCES

1. New Mexico Constitution, Article XVI, Section 3.

2. Colorado River Compact, Article I and IV, approve August 19, 1921.

3. Snow V. Abalos, 18 N. Mex. 681, 694, 695, 140 Pac. 1044 (1914).

4. Stroup V. Frank A. Hubbell Co. 27 N. Mex. 35, 37-39, 192 Pac. 519 (1920)

5. Gibson V. Puchta, 33 Calif. 310, 316-317, (1867).

6. N. Mex. Stats. 1953 Ann., Ses. 75-5-17 Amended by Laws 1955, Ch. 91.

7. Pecos River Compact, Article 1, signed December 3, 1948.

8. Costilla Creek Compact, Article 1 between New Mexico and Colorado, signed Sept. 30, 1944.

9. Hutchins, Wells A., The New Mexico Law of Water Rights, Technical Report No. 4, New Mexico State Engineer Office, 1955.

10. Thomas, Harold A., "The Animal Farms: A Mathematical Model for the Discussion of Social Standards for Control of the Environment", The Quarterly Journal of Economics, Vol. LXXVII, pp 143-148, February 1963.

NEW MEXICO'S INTEREST IN WATER

Governor David F. Cargo1/

As I came down here by plane this morning, I can assure you that I took a renewed interest in water. All the way down here, I have never seen such a collection of dust in my life. I think this illustrates at least one thing--that the most important thing to New Mexico, without question, is water.

I am sure you have speakers here today who will go through a very exhaustive discussion on what has taken place in our water laws in the past; and what will take place in the future. I would say this, that I think that we are really privileged to have a man like Steve Reynolds as State Engineer in the State of New Mexico. I have a lot of respect for him and I am sure Steve will go through and explain many of the pieces of legislation which went through the last legislature, some of which have been signed and some have not, and some bills were defeated. There is one thing about water, it always is good for a little controversy and the controversy sometimes doesn't have a great deal of logic to it.

I was reminded the other day of controversies. I'd gone back to the White House a week ago, and we had 49 governors there. We had one lady governor and her escort, George Wallace. George is a most interesting fellow, you know, and my wife gets a kick out of him. I am not always sure that I do. At least I like to listen to him and at noon they restricted all of the spouses from coming with the governor, so George couldn't appear. At night he appeared, and the President had him sitting in a part of the room where he couldn't see, no matter which way he turned, but as I sat there I listened to the Governor of Mississippi, who was a fellow by the name of Paul Johnston, and he was talking to George Wallace and they got to talking about foreign aid and Johnston looked at him and said, "It's the damnedest thing I ever saw in my life, this foreign aid." He said, "We are just giving away all of our resources and all of our assets, and there has just got to be a halt to it." Wallace said, "Well, I certainly agree with you, we gotta get a man in there that can hold things down. We need a President that really knows the issues." Johnston looked up again and said, "You know, we are giving foreign aid now to Arabia, and, he said, "you know what they are doing with it? They are going out there on the desert and they are putting up water troughs for camels, and they are building back-houses for camel drivers, and they are building rest places so thay can all sit down and rest out in the desert." Wallace looked at him and he said, "Paul, do you know that to be a fact?" Johnston looked at him and he answered, "No, but it is a hell of an issue down in Mississippi." So, I think sometimes when we go after our water problems, it sometimes is more a "hellof an issue" than a reasoned approach.

1/ Governor, State of New Mexico

Sometimes what may be a real issue, may not be very well thought out and it seems to me that we in the State of New Mexico must be more circumspect in the way we approach our water problem.

I am sure we are going to find new ways to develop sources of water. I am sure that if we took just five percent of what we spend on destroying mankind, and spent it on water research, that we wouldn't have a thing to worry about. I doubt that this is going to happen, but sooner or later I am sure we are going to go into different types of research that, at least I feel, will be beneficial to mankind and the people that follow us.

We are already converting salt water, or saline water, into fresh water, and I am sure much more will be converted. It's a matter of cost. I think that probably something which is equally important is the redistribution of our sources of water. New Mexico should be in the forefront when it comes to examining the problems of redistribution. I think we should be prepared for that day, and I personally do not believe that a proliferation of control over the uses of water is something that is going to help us as we approach this problem. New Mexico has become one of the leading states in the nation when it comes to the control and use of water. We have some very progressive water laws. We have been very careful in trying to control this. But one place where we have been remiss, has been in the field of water pollution.

New Mexico has less by way of water supplies than any other state in the Union, and yet we have been willing to sit back on many occasions and say, that we are not going to do what we should do when it comes to controlling water pollution. Now, either we control pollution, or it's going to control us. I know we can sit back and rest in peace knowing that Uncle Sam is giving us until the 30th day of June this year to solve our problems, but we should have been solving these problems many years ago, and we weren't doing it. We leaned back and adopted a Rip Van Winkle attitude towards it. We viewed state's rights as being a defense mechanism rather than being a laboratory of democracy. We thought that all we had to do was just simply not act and we would solve our problems, and now they are upon us.

I am happy to say that we did pass a measure which is a substantial first step towards controlling water pollution in the State of New Mexico. The bill is not exactly what I wanted, but then the legislature didn't give me everything I wanted the last time around, so we recognize that. However, it is an important piece of legislation because it's the first step and I think we have to then take the second step. We have to very carefully approach the entire problem of air pollution. We have to do this rather forcefully. Someone today will discuss the water pollution bill which we passed. I can briefly run over a part of it for you. It sets up a Water Quality Control Commission and it includes the following agencies, and I am sure someone else will go into this in depth, but the State Engineer, the Interstate Stream Commission, the Department of Public Health, the Oil Conservation Commission, the Department of Game and Fish, the State Parks and Recreation Commission and the Department of Agriculture are named on the board. Now, if there can be nothing else gleaned from this list, it is that among other things we need to reorganize state government.

We need a Department of Conservation and Natural Resources, and we need one very badly. When it takes an act of legislation to bring together all of these departments, and I am not saying that they don't cooperate because many times they do; but when it takes an act of legislation to bring them together on a board, I think you can realize part of the problem that we have in New Mexico. One of the problems is that we have 214 boards, commissions and agencies plus innumerable departments of government. In the next session of the legislature, I am going to present a plan of reorganization and it will reorganize the executive branch of government into no more than 20 departments, and one of those departments hopefully will be a Department of Conservation and Natural Resources. It's my hope by doing this, that we can intelligently approach many of our problems of conservation--using conservation in the broad sense of the term.

Now, as I say, the law will be explained to you so I don't want to dwell upon it except to note in passing that it's a tragedy when we have to have federal laws that say that if we refuse to do what we know we should do, then they are going to preempt the field, and this is what has happened. It's happening in many other areas.

Things we should do because they are morally right, we are being compelled to do because somebody in Washington says we should do, or which should have been done a long time ago. The State of New Mexico will be taking an interest in many other areas, and one thing that concerns me greatly, and I'm not being critical of the legislature, but I am just sorry that we spent so much more time in the legislature discussing the price of liquor, and we didn't spend more time discussing the future of the natural resources of water in the Capitan reef or other such important water issues. Now, we take a great deal of time to figure out what Old Crow is going to do for us, but darn little as to what is happening on the Capitan Reef. Now, I admit that some need a little Old Crow now and then to get along in the world. I have nothing against Old Crow, but its a tragedy, when you watch something happen as happened in the last legislature where they were considering a bill that was of critical importance to the State of New Mexico; and there was very little debate on it, as a matter of fact, almost none at all. And there was so little information available that I had to go out and seek most of this on my own. Steve Reynolds gave me a good deal of information, but I went out and sought additional information. But, on the basis of the testimony of others involved, that is outside of government, people extrinsic to government, there is virtually no argument in connection with this bill other than the arguments for the bill. Now, I think that our legislature is going to have to become cognizant of the fact that you cannot sit back in state government and with a shrug of the shoulders disregard basic issues. Many times this is what has happened. They have got to be alert, and they have got to be knowledgeable. I must admit that it would help me a great deal, if the legislature would debate these things. We had many bills that came before the legislature that were somewhat less significant, although there were some things that, of course, made sense. We appropriated some $6,000, which is not much, but it was appropriated directly here to New Mexico State University to study water requirements for agriculture and I think this was much needed. We have many other bills that were introduced, some of them important, many others were pretty much--well, somebody up the road wanted a piece of legislation so they gave it to them, which is all right. It doesn't always do great harm.

My thought is this, that New Mexico as a State has to take a greater interest; we have a terrible system. New Mexico is really outstanding in this. We limit our governors to two two-year terms. We deliberately prohibit anyone who has had vast experience in state government from running. We have developed a most unique system in New Mexico, whereby one who can get out and spend all of his time running for office has a good chance of being elected. I will be very frank with you. I have an interest in water, but when you take office as Governor of New Mexico, you are running, and that is probably one reason I am down here. If I had a four-year term, I would probably get more concerned about traveling around about a year before election, but you have to take an interest in these things because in New Mexico you are running for Governor from the time you get elected until they toss you out of office, and sometimes they don't leave you there very long.

One of the great difficulties in New Mexico is that we do not have a constitution that's geared to meeting the type of problems we are trying to solve here today. You have got to give state government a little insulation so that people can stand up, and they can do what they should do without worrying about being reelected. The only way you are ever going to have measures that amount to a hoot in the field of conservation or water quality control, or anything else, is if you have state government that has a little continuity to it and at least a couple of years to get it going.

One of the things that I would like to do is to have state government get busy. Now I may seem a little impatient now and then, and I am, because I don't have much time; and I've got to get it done in a hurry, and that is why I don't always have the patience to sit back and listen to these fellows that are going to get going next fall. Well, I don't have time to wait until next fall. We have got to go into various areas.

One thing the State of New Mexico should be doing, and I approached Governor Connally of Texas on this, we should be entering into an interstate compact on the Capitan Reef. I think we should be very seriously thinking about the consequences of a new era where atomic energy is going to be used as it will be I am sure, to convert water into a state whereby we can use it not only for agricultural purposes, but use it for recreational purposes and industrial purposes. We have got to sit down now and figure out how it is that we want to divide up our water. How much of it should go to agriculture, how much to industry, how much to municipality, how much for recreation? We have got to decide that now, and it won't wait for tomorrow. We have got to sit down and we have got to review our water laws. We have got to decide whether our children should be permitted to till the soil and have the water available to do it, or whether we want to use it all up today. We have to determine whether or not we want to use fresh water, or saline water for the secondary recovery of oil. We have got to find out the answers to many of these problems, and I want to congratulate all of you that are here today for having an interest; I want to congratulate you for taking the time to sit down and think, because if we don't do the thinking now, there isn't going to be an awful lot left for the next generation.

We excel in every field of government except that of self preservation; and apparently we are working very hard to see whether we can do one of two things. Are we going to be permitted to feed the world before we destroy it? Whichever one comes first is going to be a real problem. And, I am not sure that we are going to make it. But the key to all of it is the judicious use of water. This is one of the first steps and, if we can solve that problem, maybe we can keep ourselves alive until we are ready to push the button. I congratulate you for setting up this conference. I congratulate everyone that is involved in it, and with it, and in closing I would just like to say that I'd like to thank you for the privilege of seeing people that are willing to think. Thank you very much.

STREAM POLLUTION AND MEASUREMENT

J. W. Clark[1]/

Not many years ago, few people gave serious thought to water. Save for certain arid areas, there was usually an abundance of it, and water in the rivers and lakes was generally pure and perfectly fit for most normal uses. There has been a great change. In general, most of the nation has enough water though acute shortage problems have developed. The quality of our available water has become a matter of universal concern. Contamination is the rule rather than the exception in most areas. It is apparent that we can no longer dump our refuse into water without inviting grave perils.

We have learned to cope with a host of natural enemies in the world of water, but man has found that he is unable to cope with man himself. In terms of water, man's worst enemy is no longer nature but products of his own activity. Thus we may question whether man can extricate himself from water problems he has created through negligence and waste. Therefore, in order to face up to this problem we must be prepared for a period of development of new concepts in the fields of the social sciences as well as in the technical aspects of water pollution control.

The national problem of water pollution is complex and involves many facets. Water is withdrawn over and over again as it moves towards the sea. This water is being freely used for all purposes, including the disposal of waste materials and thus is becoming heavily polluted. The alarming thing about pollution is that the water may be rendered unfit for future use unless means can be found to cleanse it. This situation is further complicated by the popular feeling that water once soiled must be thrown away. There is of course, normally no more logical reason for throwing away dirty water than for throwing away a dirty shirt. Both dirty shirts and dirty water can be washed and reused.

Pollution may be defined as the adding to water of any substance, or the changing of water's characteristics, such as the heating of water in a cooling process, in any way which interferes with its uses for beneficial purposes. Thus, the addition of significant amounts of harmful chemicals or the presence of substances that aggravate taste and odor problems in drinking water supplies must be considered pollution. The introduction of harmful bacteria and a host of noxious substances by improperly treated sewage is pollution.

Water polluting substances may be classified according to seven general categories: (1) domestic sewage and other organic materials that serve as a bacterial food, (2) organisms that produce disease, (3) substances that serve as food for aquatic plants, (4) chemical substances dissolved in water, (5) suspended sediments, (6) radioactive substances, and (7) heat.

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This first category, domestic sewage and other organic materials that serve as bacterial food, covers the traditional putrescible organic substances which come mainly from man's body discharges, food processing wastes, and garbage. This type of waste provides food for the bacteria in water. When oxygen is present, the so-called aerobic bacteria reduce these waste materials to stable compounds. This is a highly desirable process in nature because no noxious odors are given off, the principal products are carbon dioxide and pure water. The harm that develops from placing too much waste in water is brought about by depleting the dissolved oxygen normally present in natural surface waters. When the demand for oxygen by the bacteria exceeds the rate at which oxygen can be supplied to the water, the water becomes septic. Under this septic condition, no dissolved oxygen remains in the water and fish and many other normal aquatic organisms die. By dying, these fish and other forms of life add to the pollutional load of the water and the condition is made considerably worse. Bacteria, no longer able to obtain oxygen from the water must derive this element from the food they eat. This changes their whole life process so instead of giving off so much carbon dioxide and water, they also produce methane gas, hydrogen sulfide and many other interfering substances. The river not only ceases to support fish life but it gives off odors that are offensive to smell and produces a dark colored water that is evil appearing. This decreases the value of the river as a source of water for other uses down stream.

Hardly anyone disagrees that the nation, its communities, and individuals incur losses or damages because of water pollution. Some of these losses or damages are reflected directly in increased costs for the operation of water treatment facilities. By far the larger share of the total damage is not directly accounted for at all. The detriment to health, the loss or reduction of fishing and recreational uses, and depreciated property values all have an adverse economic effect. This is paid through reduced utility of the water resource and the retardation on economic growth. Unfortunately, these indirect consequences of pollution are real and constitute a handicap to the fulfillment of economic and social goals.

The second of the water polluting substances, organisms that produce disease, are carried into rivers, lakes, and ground water by wastes from cities and certain kinds of industry such as slaughtering plants, which contain animal wastes. These microorganisms can cause the occurrence of diseases such as typhoid fever or infectious hepatitis. These organisms may be ingested directly by drinking or indirectly through water contact sports such as swimming and other activities.

It has been demonstrated that effective waste treatment reduces the number of disease-producing organisms in water. Conventional methods of sewage treatment will reduce the microbial content by about 95 percent. Additional treatment by other feasible processes including disinfection will increase the removals even more. How much do these pollution damages cost? Various figures have been used; they are difficult to contest. A conservative figure is greater than $3.00 per person per year for direct costs. The indirect costs, of course, would be much higher than this. The total costs of water pollution is measured in billions of dollars annually.

The third category, substances that serve as food for aquatic plants, are minerals in solution such as nitrogen and phosphorus. These substances occur to some extent in streams under natural conditions but are introduced in much larger quantities by discharges of sewage and industrial wastes. They are also washed from farmlands and lawns in increasing quantities as agricultural use of chemical fertilizers expands.

These minerals in solution are fertilizers and stimulate extensive growths of water plants such as algae. When plants die and decay, they require oxygen from the water and in some cases produce objectional tastes and odors. Not the least of the problems associated with aquatic plants is the possibility of toxic reactions developing in lakes and rivers resulting from the decay of certain algae. A poison generated in some algae accumulations, which resembles strychnine, has on occasions killed water foul, sheep, dogs, and cattle that have used such water. Every indication points toward needs for water pollution control at a rate not thus far experienced in this country. The real question is whether this stress will be met by response to crises or whether it is met by advance foresight and planning.

The fourth group of pollutants, chemical substances contained in waste water, include exocits such as synthetic organic chemicals and other chemical and mineral substances that result from various industrial processes. They synthetic materials will increase manyfold in significance in the future. These chemicals include such substances as detergents used in household washing and this problem still exists, insecticides, pesticides, and weed killers which are receiving widespread usage in agriculture, and other synthetics from the booming organic chemistry industry.

Insecticides, pesticides, and herbicides may be washed off vegetation and land surfaces by rain or irrigation water. These chemicals are relatively new and their effects upon human beings, animals, and aquatic wildlife are as yet little understood. There have been several hundreds of different pesticides registered for the U.S. market and these are available in many thousands of different formulations. The problem lies not only with the individual chemical substance as it is placed in nature by man but with the possible toxic effects of combinations of these chemicals and their products. Synthetic chemicals may act on man or animals individually or in combination with other substances or through their chemical breakdown products as they are changed in nature.

The Fish and Wildlife Service and the Public Health Service experiments with various insecticides indicates "that there may be insidious consequences from prolonged exposure to small quantities of insecticides in small mammals and birds". Research indicated a large percentage of bird eggs were not fertile and chicks were often weak, resulting in a material reduction of the population. Insecticides were even more harmful where they were introduced through the water. They were especially destructive to fish, snakes, and frogs.

Common table salt in water is a serious problem in certain areas of the country. Salt is particularly troublesome in arid areas of the southwest. These salt problems may arise from leaching of natural salt deposits, the disposal of brines from oil wells, or return flows from irrigation. When irrigation water is applied to the field, a large percentage of the water is evaporated or transpired into the atmosphere. This leaves the remaining smaller volume of water to carry the large amount of salt originally contained. This remaining water seeps into the ground carrying with it the salt load. These waters contaminate the ground water and rivers materially increasing their salinity.

Other chemical industrial problems arise from acids being drained to the rivers. These acids are contained in many industrial wastes from metal processing and mining. The principal source of acids is coal mining. Sulfuric acid is formed at exposed surfaces in coal mines where sulfur bearing minerals come into contact with air and water. Water flowing through mines or pumped from them carries strong acids to rivers. This problem is very serious and many miles of streams have had their aquatic life destroyed. Acid drainage was curtailed in the 1930's but is on the increase again. It has been estimated by the Public Health Service that 2.7 million tons of sulfuric acid are produced annually by mines. Present information indicates that a large measure of correction of mine acid problems could result from a comprehensive control program.

Six Russian engineers and industrialists are on trial in Volgograd for causing a catastrophe in a river there. They are accused of allowing effluent from a chemical plant to escape into a stream where it killed thousands of caviar-rich sturgeon and other fish. If found guilty, they might be sent to Siberia where snow and ice constitute the primary natural resources.

The fifth pollutional problem, suspended sediments, are primarily soil and mineral particles washed from the land by rain. These sediments fill reservoirs, increase the cost of water treatment, and reduce fish populations. There are as yet no clear cut answers to sediment problems. Additional research and analysis of existing data is necessary before conclusions may be reached. In general, any slowing down of water velocities, especially in overland flow before it reaches the river will reduce sediment loads.

The sixth category, radioactive substances, are produced from several sources. Possible points of contamination range from the original mining of naturally occuring radioactive minerals to waste products of reactors. Utilization of the products and properties of fissionable material has created an industry that is expected to expand rapidly in the next few years. As this industry grows, there must be a parallel expansion of research into the disposal of its related waste products. Unless significant breakthroughs provide needed new methods for waste disposal, it is possible that this will be a difficult and hazardous problem.

The present method of containing radioactive by-products is a temporary one. This system provides for storage of these wastes under the ground or at the bottom of the sea. This problem is of paramount importance and must be solved before large reactors are constructed for the processing of sea water as proposed by the government.

The exposure of human beings to radiation is cumulative over their respective lifetimes. Therefore, the fundamental problem of radioactive waste disposal is the control of the total radiation exposure of the earth. The expected volume of waste products that will require disposal will run into millions of gallons per year. The magnitude and cost of such a waste program suggests the need of a very substantial effort to find better ways of disposal or utilization of these by-products.

Problems encountered at the 200,000 acre Savannah River plant of the Atomic Energy Commission located at Aiken, South Carolina, illustrate the difficulty in disposal of relatively small amounts of atomic wastes.

Low-level radioactive waste probably would be harmless if kept in a shoe box but the AEC has a much more elaborate process for the disposal for tons of items brought here each month as being contaminated.

"We're becoming famous as a garbage dump," declared Howard Kilburn, deputy plant manager, referring to plans to bury 1500 tons of Spanish soil and tomato vines at the Aiken site.

The soil was polluted January 17, 1966, when a U.S. Strategic Air Command bomber collided with a tanker plane over the Spanish coast and dropped four atomic bombs. Two of the hydrogen bombs burst open when they hit the ground in a tomato field. Officials ordered the soil and plants dug up and shipped to the Savannah River plant for burial to relieve fears of Spanish fisherman and farmers.

This material, along with other nuclear weapons debris, will be placed in 55 gallon drums under at least 10 feet of red clay and sand. Since the plant was built in 1953, AEC and E.I. du Pont personnel operating the plant have filled many holes 300 feet long and 20 feet deep with solid waste.

Liquid waste undergoes an even more elaborate disposal process. It is kept in deep underground steel and concrete tanks. Some of these tanks must be refrigerated to keep the temperature down. Also wastes with a long life will require that tanks be replaced at some future point in time.

Wells are regularly drilled in the area to sample the soil and water to insure that no leakage has occurred. Wind is important and no material is buried if the wind velocity is over 10 miles an hour. Radiation checks are made on highways where wastes are hauled and new pavement is placed over the old if any contamination is noted.

Workers at the site wear special outer clothing which never leaves the plant area and this clothing is constantly checked for radioactivity.

Junk to be buried includes mops that have been used in contaminated areas, metal scraps, worn equipment, reactor parts, and even newspapers. A buried item may be anything such as a magazine or book some one brought into a restricted area to read.

The last pollutant listed, heat, has a direct detrimental affect upon water quality and its other associated uses. Large quantities of water are withdrawn daily from rivers, lakes, and ground water for cooling purposes. This water is used in power plants, steel mills, petroleum refineries, and various other industries. After use, these waters are normally returned to their original source from which they were withdrawn. Substantial amounts of heat are, therefore, transfered to these original water sources. The temperature of the water in rivers and lakes is materially increased in this process.

The amount of oxygen that water can hold is reduced as the temperature increases. Biological and chemical processes of the water are accelerated by a temperature increase. The net result is a more rapid depletion of the oxygen reserve of the water. This reduction in oxygen content of the river decreases its ability to assimilate organic material and can completely destroy the value of the stream. Some fish can withstand only a few degrees of temperature rise and in many instances, this condition will result in a virtual elimination of all aquatic life. Furthermore, the water is unfit for other industrial cooling operations or as a source for domestic water.

Growth of industry in the United States in recent years has been phenomenal and this growth is expected to continue into the foreseeable future. Industry will require 80 percent or more of the expected increase in total water requirements. This is not only because of rising production but because many new processes are requiring more water than the previous ones. Therefore, industry should directly pay an increased share of the total water pollution control cost.

Water supply and pollution trends show that one of the most pressing problems in the future water crisis is the need to develop new treatment processes which will remove more of the contaminants from waste. Present methods now remove only 75 to 90 percent, each, of the suspended solids and the oxygen demanding wastes of domestic sewage. Little of the nitrogen and phosphorous is removed and their availability for algae growth is normally increased by waste treatment. Unless new methods are employed, the volume and complexity of future wastes will only compound the problem. An all-out research effort is needed to investigate existing ideas and to develop completely new concepts in the area of waste treatment. Research will require financial support of the federal government. Such a program must be free of political influence in order to attract fresh ideas. Many competent scientists and engineers do not desire to work on a project housed in the political arena. These scientists are in a position to choose their area of activity and a sound scientific base of project selection rather than the power of a senator must be employed to make a career in water pollution control attractive. The present trend over the past two years since the transfer of the water pollution control administration out of the Public Health Service has increased the political activity in the area of research. This is a step backward at a time when all available energies are needed to meet present needs and prepare for the future.

Direct use of treated sewage for all municipal purposes is unusual but the concept is not new. Experiences of Chanute, Kansas, is a striking example of what has been done. During a water shortage over a period of five months--October 1956 to February 1957--this city recycled its sewage 8-15 times. Sewage was also used by the City of Lyndon, Kansas, during the fall of 1956 as a source of water for all municipal purposes including drinking. These examples of direct recycling of sewage for water supply are rare but the indirect use of sewage as a water source is quite common in the United States. Most cities that draw water from rivers are using a portion of their upstream neighbors' sewage as part of their water supply. It is an oddity that we are content to drink our neighbors' sewage but the thought of drinking our own is upsetting.

Water reuse can be expected to increase for one simple reason, the population is increasing. If you don't want to drink water from sewage, you had better start making your plans now by providing more and better research. The present state of technology indicates that it may become feasible to practice complete recovery of the water component of municipal sewage.

Many researchers believe that waters recovered from sewage will be made completely safe by application of modern waste and water treatment procedures. The Chanute water supply met the bacteriological requirements of the U.S. Public Health Service Drinking Water Standards after approximately a dozen passages through the sewage plant and then the water treatment plant. There are, however, a number of problems pertinent to the question of water reuse and public health. Much research will be required to adequately answer these questions and some of the research is time dependent, therefore, we must increase our activity in this area of need in order to solve the problem in time.

One of the difficult areas of technological need is for a better surveillance of natural water quality. We must have water quality facts to develop and put into effect sound management policies and programs.

A river (and I will confine my remarks to surface waters) from its upland source to the ocean is subject to a series of withdrawals for use and inflow contributions. Some withdrawals involve consumptive use and flow is reduced. Other withdrawals are essentially returned, some hardly impaired in quality and some grossly polluted and many between these extremes.

Of the seven water polluting substances previously classified, all but number one, organic material that serves as bacterial food, can be continuously monitored or periodic checks are sufficient for present needs. The standard method for evaluating the BOD, biochemical oxygen demand that is a measure of the biodegradable organic pollution, requires 5 days. This is hardly satisfactory to measure the BOD on a river and determine the answer when the water evaluated has traveled 260 miles downstream. Preliminary results of a research project at this University indicates that this five-day time may be reduced to approximately four hours on a continous measurement for some biodegradable materials. Unfortunately, the Federal agency supporting this work has substantially reduced its university research program in this field for fiscal 1967-1968. At the same time, their inhouse research and industrial contract work has been expanded. This is difficult for me to understand in other than a political light.

Costs of renovating waste waters and disposal of contaminants is still subject to considerable discussion. Current thoughts on cost goals are rather vague but there is ample evidence to support some computation. In considering waste reuse, water and wastewater treatment must be considered together in a realistic water-use cycle. In order to be meaningful, all costs presented in this discussion represent total costs, including operation and maintenance plus amortization of the original investment.

The first cost in the water use cycle is for development of the raw water source and averages about 8 cents per 1,000 gallons. The next cost is water treatment and averages about 5 cents per 1,000 gallons. The most expensive item is water distribution to homes and industry and averages about 15 cents per 1,000 gallons. Waste collection costs about 6 cents per 1,000 gallons and for complete treatment 10 cents.

Total cycle cost for water and waste appears to be about 44 cents per 1,000 gallons of water. Water distribution and waste collection will always be necessary whether we use recycled water or not, therefore, this figure may be reduced from the cost comparison. This results in a cost of water of 23 cents per 1,000 gallons utilizing a portion of the sewage over again each time.

Other benefits would be the immediate results of such a reuse program. Water based recreation in non-polluted, asthetically acceptable surroundings would come into being. Better assurance that some chemical, biological, and radiological pollutants would not be exerting subtle cumulative effects on the health of man. Direct benefits of complete waste treatment of all liquid wastes gives the greatest potential for a long-range solution to our water problem based on present technology.

There is justifiable concern among planners that the increase and shift of the U.S. population in the next 20 years will result in widespread and serious water supply and pollution problems. These extremely complex problems of waste treatment, stream sanitation, and water reuse must be solved now. Conventional water treatment and pollution control techniques are fast become obsolete. Problem areas present new challenges that can be met only through expanded research and the environment in which this research is to be conducted is of primary importance. Leave politics to the politicians and the scientist elbow room to work.

WATER REQUIREMENTS FOR CROP PRODUCTION WITH SALINE WATERS AND SALINE SOILS

D. E. Longenecker[1]/

The following statement was made by Dr. C. A. Bower, Director of the U.S. Salinity Laboratory, in a paper presented at Lahore, Pakistan, in November, 1964, "By its very nature, irrigation agriculture is an intensive form of agriculture that cannot survive without a full supply of water". What Dr. Bower inferred here was that any extended period of deficient water supply could be disastrous to any irrigated area because gradual salinization of soils would be almost certain to occur, either through inadequate leaching or by upward movement of salts from ground water, or both.

The supply of water should be adequate to irrigate all cultivated soils within the project, because even fallow soils will gradually become salinized unless periodically irrigated. In any full irrigated area, therefore, it is not enough to consider only the water requirements of crops. The water needs of the entire project must be borne in mind. This includes periodic water needs of idle or fallow land, as well as cropland, for these need irrigation occasionally, if only for control of salinity.

Dr. Bower's remarks are particularly applicable where irrigation waters are saline and where underground waters are saline and quite shallow, as in the middle and lower Rio Grande Valleys of New Mexico and Texas. There is no actual lack of water in the Elephant Butte project, and there will be none within the foreseeable future. When surface water supplies become inadequate they can be supplemented by ground water pumping. What is lacking is an adequate supply of good quality water. Soil and water salinity can rapidly become an acute problem where surface supplies are undependable. We witnessed this during the four-year period, 1952 to 1956, in this area. The Pecos River Valley of Texas is another good example of an area always troubled by salinity because of unpredictable amounts of surface water.

Encroachment of salinity is usually a gradual process, and for this reason the more to be guarded against. Familiarity breeds contempt, and farmers in saline areas sometimes neglect to practice proven salinity control measures. We see local farmers pre-irrigating with salty ground water when project water should be used for this purpose, regardless of its scarcity. They have been told that germinating seedlings are more sensitive to salt injury, but they forget. We see

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farmers irrigating back after planting to be sure their seedbeds do not dry out. They have been told that irrigating back after planting will add salt to the beds, and cooler soils will make seedling disease worse, but they forget.

There is no way to estimate the annual income losses due to the subtle and often unrecognized effects of salinity in this area, but they probably are considerable. Many farmers in West Texas and New Mexico are casually applying waters considered by salinity experts to be so high in salt as to be unusable except supplementally or under special conditions. In other words, we have lived with the salinity devil so long that many have grown careless, and often fail to recognize salt injury until the situation becomes serious.

With this introduction I will try to devote my remarks more closely to the assigned title of my paper. Based on its contents, the title should more properly be "Limitations in Determining Water Requirements for Crop Production with Saline Waters and Saline Soils". As you will see, there is a lot more about this subject that we don't know than what we do know. The phrase "Water Requirements" is easy to say and extensively spoken but far more difficult to determine with any degree of accuracy. Presumably, "Water Requirement" takes in all of the water necessary for normal crop growth, together with provision for adequate leaching plus a suitable allowance for evaporation losses. Let us examine each of these separately.

First, how much water is necessary for "normal" crop growth, and how does salinity affect this situation? Before this can be answered, we need to define "normal" in terms of crop production, and this, too, defies precise definition. Is "normal" the average yield of a partular crop in a given area over a period of years, or does it refer to the production <u>capability</u> of that crop within the climatic limitations of the area? Since average yields are often far below what could be expected to be "normal", I prefer the latter definition. If we choose this, we assume that growth and yields are not being limited by a large number of other factors such as soil, physical and chemical conditions, fertility, insects and diseases, to name a few. To show how just one of these can affect normal growth and therefore water requirement, let us look at upland cotton <u>with</u> and <u>without</u> seedling disease damage on a deep, medium-textured soil.

Without seedling disease, cotton is a tap-rooted crop whose roots can penetrate to depths of 6 to 7 feet if root development is not limited. With deep root systems, research has shown that the crop will be (1) more drouth resistant, (2) will make more total vegetative growth, and (3) will use up to 30 per cent more water during the season than the same crop would use if its root system were restricted to the top 3 feet of soil. This restriction does occur where seedling disease destroys the taproots during the early seedling period, or where nematode damage is serious. With shallow roots, the crop suffers more quickly from water stress, and therefore must be irrigated more often, with consequent higher evaporation losses. The same situation can occur if rooting depth is restricted by other factors such as adverse soil physical conditions, excess salinity at deeper depths, or inadequate preplant irrigation.

Now let us examine the effect of two different varieties of the same crop species upon this thing called "Water Requirement".

Let us take a short-growing grain sorghum as compared to a tall-growing forage sorghum. Transpiration here is largely proportional to total leaf area. The tall forage sorghum has 10 to 20 times as much total leaf area as the small grain sorghum, and will therefore transpire much more total water over the season. Its overall water requirement would be much higher because of this, and because it must be kept in a succulent condition almost until harvest, whereas the grain sorghum would benefit from some moisture stress during the head maturity stage.

Crops which have different lengths of growing season would also have different water requirements, for obvious reasons. Alfalfa requires hugh amounts of water for maximum production because it is growing vegetatively from early spring until late fall. Cotton also falls into the category of a long season crop, but its water requirements could be reduced 1/4 to 1/3 if evaporation from the soil can be retarded. A two-bale crop of cotton actually requires only about 20 inches of water--for growth alone--twice this much usually has to be applied.

Water requirements for plant growth are therefore difficult to define, even in the absence of soil and water salinity. With salinity the situation becomes even more complex. Individual salt ions, absorbed by plants in excess quantities, each have some specific physiological effects. Some effects may be bad, but we also believe some effects may be good, depending upon the particular crop and the particular ion. Plant scientists are only now beginning to realize that these specific effects do exist. As yet not enough is known about this subject to draw any definite conclusions.

In addition to specific ion effects, soluble salts act upon all crops to render soil moisture less available to the plants. In a saline situation, the osmotic pressure of the soil solution is higher than in a non-saline situation. In order for roots to extract moisture from the soil, the osmotic potential of the plant must be higher than that of the soil solution. If it is not higher, moisture can actually move from the plant back into the soil. All plant species have the capability to adjust the osmotic pressures of their tissue fluids within a limited range. Near the upper limit of this range, so much of the plant energy is devoted to moisture extraction from the soil that vegetative growth is greatly reduced. Thus, within this range of osmotic variability, there is no sharp point above which plant growth ceases entirely. Vegetative growth of all species is gradually more restricted as salt concentrations in the soil solution increase. At restrictively high salt levels, growth will be short, and leaves will be thicker, more brittle, and of a darker green or blue-green color. Transpiration will be greatly reduced because leaf stomata will not be fully open and because high salt levels of leaf tissue fluids will physically retard evaporation. Plants in this condition often show little tendency to wilt, and farmers can be deceived into thinking the crop does not need water, when in reality it does.

Different crop species vary greatly in their ability to tolerate salinity. This is related partly to their varying ability to alter the osmotic pressure of their tissue fluids, but partly to other reasons not yet precisely determined. Some salt tolerant species apparently have a more or less selective root permeability, whereby they are able to largely exclude certain salt ions while at the same time absorbing other ions and water with little or no restriction. All of this is lumped together and called "salt tolerance", which term presently hides a great deal of ignorance on the part of plant scientists.

Salt concentrations in the soil can only be controlled by leaching. This is the process of removal of salts by carrying them below the bottom of the root zone in the drainage water. The more saline a water or soil, the more water must be applied to do an adequate job of leaching. This, of course, is water over and above the needs of the crop.

The U.S. Salinity Laboratory has developed a formula for determining leaching requirement based upon salt tolerance of the crop. At best, however, this formula is only a rough approximation because it involves assumptions that may or may not be valid. One of these assumptions that the farmer has to make concerns rooting depth of the crop to be grown. We have already discussed how root depth can be highly variable depending upon many factors.

Soil salinity, under conditions of good internal drainage, usually increases with depth. Highest salt levels therefore are usually found at the bottom of the root zone. Salt levels at this depth are synonymous, by definition, with salt levels in the drainage water. The leaching requirement formula is based upon permissible levels of salt at the bottom of the root zone. But if root depth varies greatly due to other factors, it becomes very difficult to apply this formula. An example will help to show what I mean.

For fair yields of cotton, the permissible level of soil salinity at the bottom of the root zone has been established at approximately 12 millimhos per centimeter conductivity in the soil extract. Keep in mind that this too is only an approximation, at best. Now let us suppose that, under a bed-and-furrow type irrigation, the salt levels at the one-to-five foot depths are 5, 6, 7, 9 and 12 millimhos <u>under the furrow</u>, and 7, 9, 11, 13 and 15 millimhos <u>under the bed</u>. If we choose the salt levels under the furrow, and if the cotton root is 5 feet deep, then the requirements of the leaching formula have been met. If we choose the salt levels <u>under the bed</u>, or if the cotton is 3 feet deep or 7 feet deep, then more or less leaching is required, but how much is difficult to determine.

Another shortcoming of the leaching requirement formula is its assumption of uniform water application across a field. With surface irrigation, uniform application is impossible.

New and better methods need to be devised to predict leaching requirement for salinity control. These should, in some way, be related directly to physiological conditions within the plant itself. The soil and water portions of the plant-soil-water integral unit are primarily physical-chemical systems which can vary considerably both vertically and laterally throughout the root zone. The combined effects of the soil-water system are reflected in physiological responses within the plant itself. The plant, therefore, will be the only reliable indicator of its water needs and its salinity status as well. Up until now, such methods have not been developed.

The best measurements we have of water needs <u>other than for leaching requirement</u> are found in consumptive use data. These data have been compiled for various crops in various parts of the country, and include the combined needs of the plant plus evaporation losses from the soil. They have also been called evapo-transpiration data.

Presumably, water requirements of any crop in a saline situation would therefore consist of consumptive use needs plus whatever is needed for leaching requirement to control salts. But consumptive use data also are approximations at best, and may involve many errors. Here again, a specific root depth must arbitrarily be selected for each particular crop. Moisture leaching below this depth is assumed to be unavailable to the plant. In river valley areas with shallow ground water tables, this error may be considerable. Many deep rooted species such as cotton, alfalfa, grapes, and most trees can obtain a good part of their water from upward movement of moisture from shallow water tables. Difficulty of determining root depth, however, is probably the biggest source of error.

Consumptive use measurements also assume the existence of upper and lower available soil moisture limits called "field capacity" and "wilting plant", which actually may or may not exist depending upon internal drainage characteristics of the soil. At best, these soil moisture values are ranges rather than specific points on the soil moisture curve. Calculations of available water for consumptive use data are based upon the amount of moisture held by the soil between field capacity and wilting point, and can involve considerable error, particularly on texturally stratified soils such as we have in most valley areas.

Consumptive use also is in <u>no</u> way directly related to yields. It is related, rather, to moisture uptake by the plant and therefore only to <u>vegetative</u> growth. Most of you know there is no good relation between seed cotton yields, for example, and total vegetative growth of the cotton plant. Quite often there is an inverse relationship--too much vegetative growth and too little fruit set.

Consumptive use values are useful therefore only as general guides to moisture use by crops. Researchers in the Salt River Valley of Arizona have reported that the mean annual consumptive use of water by cotton over a 9-year period averaged 41.2 inches per year. However, this value varied between years from 27 to over 50 inches. With such great variability between years, how is it possible to come to any valid conclusions concerning water requirements of crops?

Evaporation, too, can vary widely, even from field to field depending upon soil texture, crop management, and climatic variability. Evaporation from soil depends to a great extent upon the amount of total plant cover, air movement near the soil surface, and relative humidity. A low-growing or slow-growing row crop will lose much more water by evaporation because of less shading of the soil. Also, a soil which shrinks and swells badly will lose more water than one which does not, or one that is mulched properly by cultivation.

In conclusion I can only say that it is easy to find fault with existing methods of doing things, but sometimes this becomes necessary in order to show how little we know. Regarding water requirements of crops, we hate to admit it but we must still deal with approximations and generalizations. In order that I might leave you with at least something constructive, I will close with a few of the generalizations. Most of these are simply common sense.

1. A summer-grown crop will require much more water for both transpiration and evaporation than a crop grown in cooler parts of the year.

2. A fast-growing or highly vegetative crop will require more water for transpiration and require more frequent irrigation than a slow-growing crop or one with less total leaf area.

3. The greater the total leaf cover, and the denser the shade, the lower will be losses by evaporation.

4. Evaporation is in proportion to the total wetted and unshaded soil area. Therefore, using double beds or irrigating alternate furrows would result in less evaporation loss because some of the unshaded area would not be wetted.

5. A long-season crop will require more water than a short-season crop of the same type.

6. Deep-rooted crops will consumptively use more water than shallow-rooted crops, but shallow-rooted crops will need irrigation more often. Sprinkler irrigation of shallow-rooted crops could save a lot of water over a season. Surface irrigation of these crops, such as lettuce or onions, is very wasteful of water because too much is usually applied at each irrigation.

7. Crops on coarse-textured sandy soils will usually require water more often than the same crops on finer-textured soils because sandy soils do not hold as much available water.

8. With water of any given salinity, salt-tolerant crops will require less water for leaching purposes than crops with lower tolerance to salt.

9. The saltier the water, the greater the amounts which must be used to control salinity in addition to crop needs.

10. The pre-plant irrigation is by far the best time to apply the extra water needed for salinity control.

And finally, crops grown for seed or seed products, such as cotton, can be considerably stressed for moisture during the seed maturation period without appreciable losses in yield.

A COMPARISON OF MINOR TRACE CONTAMINANTS IN ATMOSPHERIC PRECIPITATION AND IN WATER SUPPLIES

A. L. Lazrus1/

In recent years there has been increasing concern over the allowable concentrations of minor trace contaminants in drinking water. One source of these elements is the atmosphere, from which aerosols may be deposited in surface waters either by dry fallout or by entrapment in atmospheric precipitation. A survey of the concentrations of some minor contaminants in precipitation should indicate the possible importance of this second mechanism.

The National Precipitation Sampling Network is maintained by the National Center for Atmospheric Research, in cooperation with several other agencies. The network consists of approximately thirty stations fairly evenly distributed throughout the mainland United States, plus one station at Mauna Loa Observatory, Hawaii. At each station an automatic precipitation collector remains open during periods of precipitation only, thereby excluding dry fallout from the sample. The collected precipitation is mailed from each station to NCAR, where pooled monthly samples are analyzed.

Chemical analyses for the trace elements discussed are performed by atomic absorption preceded by an extractive concentration procedure (4).

Figures 1 through 4 show nationwide distributions of the elements from September 1966 to January 1967. The symbol representing a station indicates the grams of contaminant, as the metal ion, deposited on one hectare by one centimeter of precipitation. This figure, having the dimensions of concentration, is relatively independent of the total amount of precipitation and is representative of the contaminant concentration in the air. It is, however, not completely independent of the amount of rainfall since frequent showers keep the air cleaner and since contaminant concentration decreases with duration of a rainfall. The numeral under the symbol represents grams of contaminant deposited per hectare per month averaged over the five month sampling period. This figure is directly proportional to both concentration and quantity of rainfall.

Certain generalizations are evidently applicable to those metals. The northwest portion of the U. S. is conspicuously low in contamination. The northeast is relatively quite high. The southeast and southwest vary from low to moderate in contamination, depending upon the particular metal. The maps suggest that the concentration patterns of these minor trace contaminants could be engendered primarily by human activity. Concentrations tend to increase in areas of mining and manufacturing.

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Figure 1, 2, 3, 4

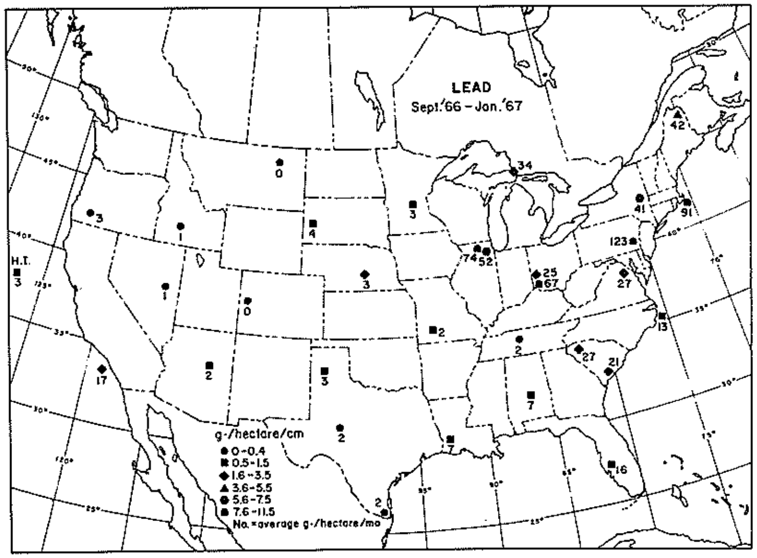

Fig. 1

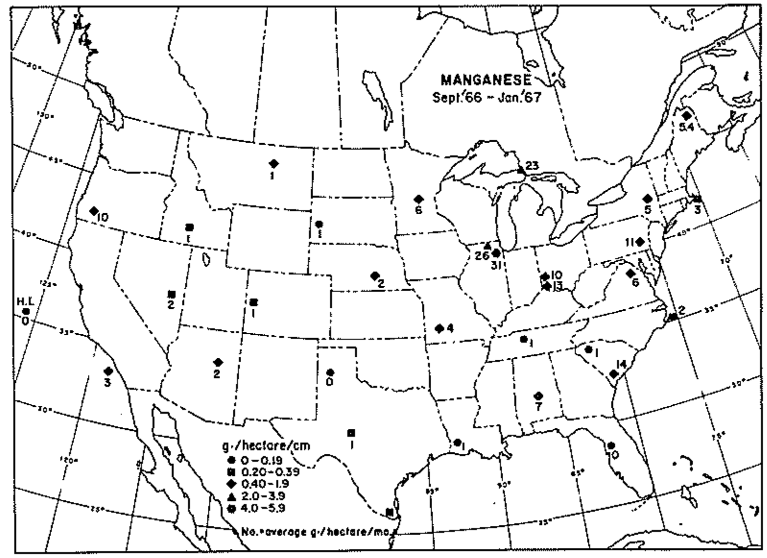

Fig. 2

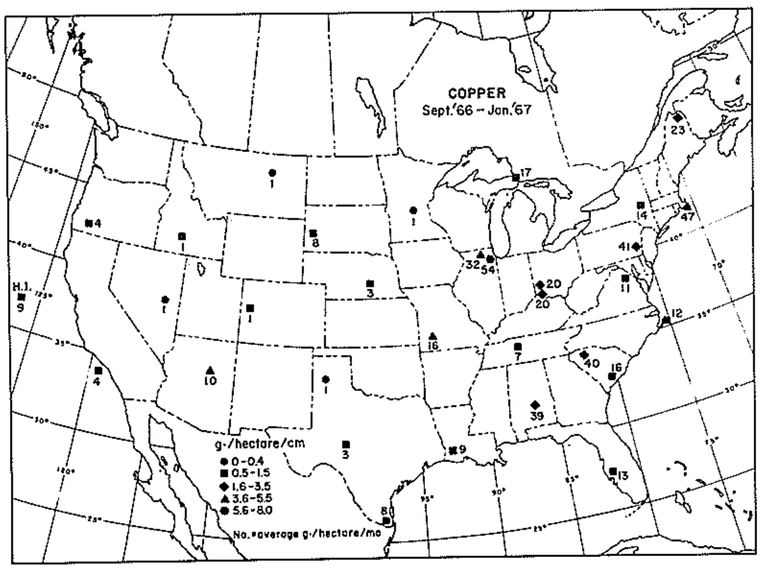

Fig. 3

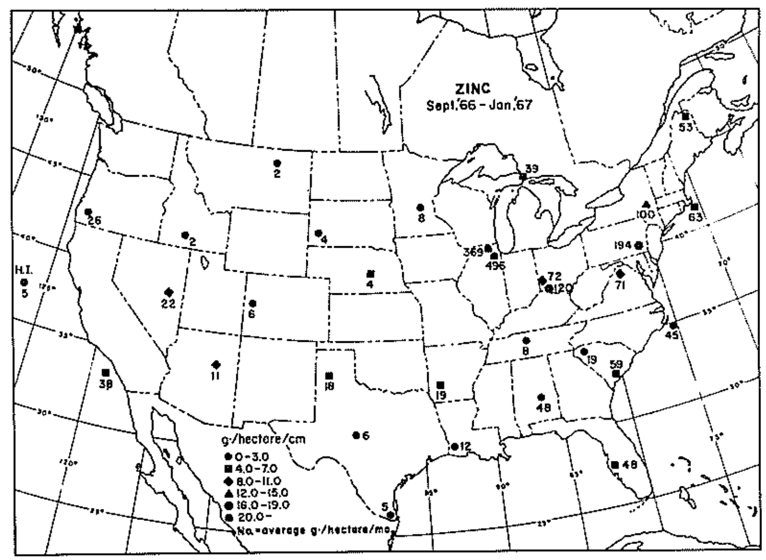

Fig. 4

Table 1 compares the average concentrations found in precipitation with those in surface water supplies before treatment (1). There is, on the average, twice as much lead in atmospheric precipitation as in the water supplies. This ratio implies the existence of a process whereby lead is depleted after precipitation reaches the surface. In the case of copper, the quantity found in precipitation could account for the average value found in surface water. Nickel and manganese, however, must have other sources in addition to atmospheric precipitation.

Only the lead average in precipitation comprises a significant percentage of the limits established by the U. S. Public Health Drinking Water Standards of 1962 (5). A plot of average lead values for the five month period against the quantity of leaded gasoline consumed in the county in which the sampling station is located, though showing considerable scatter, indicates a definite correlation, as might be expected, samples from areas where much gasoline is consumed tend to exert a large influence on the total lead average in precipitation. If median values, rather than averages, are compared the result is somewhat less startling. Both precipitation and the untreated water supplies have median lead concentrations of approximately 0.01 ppm.

Table 1

Trace contaminants in precipitation and in untreated water supplies

Element	A Average conc. in precipitation ppm	B Average conc. in untreated water supplies ppm	C U.S.P.H. conc. limits (1962) ppm	$\frac{A}{C} \times 100$ %
Pb	0.034	0.017	0.05	68
Cd	0.0011	---	0.01	11
Mn	0.012	0.070	0.05	24
Cu	0.021	0.021	1.0	2
Zn	0.107	---	5.0	2
Ni	0.0043	0.0065		

A - Average of samples collected from Sept. 1966 through Jan. 1967

B - Average computed from data presented (1)

The appreciable lead contamination in precipitation is plausible in view of earlier investigations. Environmental lead contamination is widespread. Tatsumoto and Patterson (7) found lead concentrations in snow 10^4 greater than the amount attributable to naturally formed dust, in a remote area

500 miles east of the Los Angeles complex, at an altitude of 7,000 ft. The same authors estimate that the concentration of lead in the surface layer of the Pacific Ocean off the coast of southern California has increased tenfold during the past three or four decades. Their calculations indicate that the input of lead into the atmosphere by combustion of leaded gasoline could account for this observation (6).

Ettinger has previously discussed likely sources of lead contamination in water supplies (3). Large industrial complexes, with associated high consumptions of coal and leaded gasoline, do not necessarily cause appreciable dissolved lead enrichment of nearby water supplies. Samples showing high lead concentration had been exposed to contamination by metal-working and chemical industries. Apparently, natural processes control the concentration of dissolved lead in surface water. Ettinger concluded that only a fraction of lead in surface water remains dissolved, and that low turbidity of drinking water reduces the likelihood of the consumer's exposure to lead.

The median value for lead in drinking water, according to Durfor, is only 3.7 ppb (2). Our observations indicate that lead content of rainfall in urban areas may exceed the limit for drinking water by several hundred percent.

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C A R E E R   O P P O R T U N I T I E S

A joint panel on Research Needs and Career Opportunities in the Water Resources Area was conducted to call the attention of students to these fields.

The following men presented papers in this panel discussion:

Career Opportunities in the Water Resources Field:

Lloyd Calhoun
New Mexico Electric Service, Hobbs

Frank O. Elliott
New Mexico Oil and Gas Association, Roswell

Francis C. Koopman
Water Resources Division, U. S. Geological Survey, Albuquerque

Conrad G. Keyes
Civil Engineering, NMSU

Career Opportunities in the Water Research Field:

E. D. Eaton
Office of Water Resources Research, Department of Interior, Washington, D. C.

P. J. Leyendecker
Director, Agricultural Experiment Station, NMSU

C. E. Jacob
Coordinator of Research, NMIMT, Socorro

Frank B. Titus
Graduate Student, University of New Mexico

CAREER OPPORTUNITIES IN THE WATER RESOURCES AREA
(With Emphasis on the Area of Petroleum)

Lloyd A. Calhoun[1/]

Third in size, outranked only by agriculture and the investor-owned utilities, the petroleum industry now has investments in the U.S. in excess of $71 billion. With an investment per employee at nearly $78,000 petroleum ranks number one in the nation which is far ahead of the country's average of $17,000 for all industry.

No other single industry offers such a wide range of career opportunities for today's college graduates. Oil companies employ some 1,500,000 people or nearly one out of every 50 employed in the United States.

The President of Humble Oil and Refining Company, Dr. Charles F. Jones, recently was quoted by Oil and Gas Journal on this very point when he said, "I know of no other industry, whose manpower needs cut across so many educational backgrounds of people emerging from the nation's colleges and universities."

Gulf Oil Company, one of the industry's majors, in a recent ad directed to college employables listed that firm's needs for graduates in agriculture and agronomy, engineering, chemistry, physics and geophysics, petroleum technology, geology, accounting, business administration, marketing, mathematics, data processing, and liberal arts. This broad field of professional offerings is matched by virtually every one of the fifteen or more major oil companies listed in the 1967 College Placement Annual. Altogether, there are more than 40,000 companies operating in some phase of activity in the petroleum industry.

The scope of activity within the industry is far too varied to do more than list the major phases in the time alloted. Most of the large, integrated companies are engaged in exploration, drilling, production, refining, transportation, petrochemicals, research and development and marketing. Allied activities, also offering countless career opportunities, are supply, service, and consulting firms which depend exclusively upon the oil industry for their existence.

By no means a complete listing of talents sought after by the petroleum industry--for there are some 2,000 occupations altogether--the following are given as examples of opportunities to be found in the industry: Accounting, Biology, Business Administration, Chemistry, Chemical Engineering, Civil Engineering, Economics, Electrical Engineering, Finance, Geology, Geophysics, Industrial Engineering, Industrial Relations, Liberal Arts, Law, Marketing, Mechanical Engineering, Metalurgical Engineering, Physics, Statistics, and Tax Specialist.

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Hobbs, New Mexico

In years past, the list of professional talents needed by the industry would not have been nearly so extensive for the technology had not yet developed to its present sophisticated status.

The great bulk of duties arising in the petroleum industry's water resources fields has fallen upon the shoulders of the omniscient petroleum engineer to perform in most instances. Water uses in the oil industry encompass a multitude of problems and applications most of which are not to be found in other technologies. Off-shore drilling and production practices, secondary oil recovery by waterflooding, waste water disposal and pollution control requirements are only a few of the recent industry developments which result in the urgent need for professionals in other than the strictly geological and petroleum engineering disciplines. Oil companies and their affiliated chemical, transportation, research and development and service activities have developed a myriad of career opportunities for chemical, civil, electrical, mechanical engineers and hydrologists. There are even naval architects and marine engineers working in the industry in the specific practice of their professions.

Demands for petroleum engineers, per se, were never so great as they are today. The supply cannot satisfy demand nor is it apt to in the foreseeable future. There is no competition from the petroleum engineering profession to any of you here today who seek career opportunities in the oil industry in the practice of your chosen professions. Your talents are being sought as well as those of the petroleum engineer.

The evolution of the applied science of petroleum engineering saw its Genesis at the University of Pittsburgh in 1910, according to Arthur E. Uhl of the Institute of Gas Technology, and consisted of seven courses in oil and gas geology, technology and law. Uhl reports in the April 1965 issue of the Journal of Petroleum Technology that the first petroleum engineering degrees were granted in 1915.

During the half-century from that time to this, the state-of-the-art has seen great technological changes. Uhl, in his manuscript on petroleum engineering education, has cataloged the ten year period from 1910 to 1920 as "The Emergence of a Discipline," the next decade, "The Development of a Curriculum," the thirties as "The Shift to Engineering" era, from 1940 to 1950, "The Rise of Reservoir Engineering" and the latest ten-year epoch as "The Change to Fundamentalism." By 1940, almost 3000 students were enrolled in petroleum engineering disciplines in a dozen American universities.

Enrollments continued to grow through the years and by 1956 numbered nearly 5000 petroleum engineering undergraduates. Then followed, beginning in 1958, a precipitous decline to fewer than 1000 enrollees in 1963 from which point a slight increase has developed to the present count of 1335 in 27 U.S. colleges.

The past 10 years' general downward trend of graduating petroleum engineers has brought forth such industry alarm signals as the news headline in the

January 23, 1967 Oil and Gas Journal issue "PE-Grad Shortage Growing Acute", followed by the warning that "the shortage of petroleum-engineering graduates is fast moving from the serious into the critical stage" and "Oil companies desperately need PE graduates, and the 1967 supply will be at an all-time low".

Only 176 PE graduates will come out of U. S. colleges this year. So great is the demand for their services that the average salary offering is reported to be at least $750/month.

What makes this picture all the more somber is the dim prospect of meeting engineering needs to supply the nation's future petroleum products requirements. Industry estimates tell us that per capita consumption of petroleum products will have increased from an average of 21 barrels annually to 26 barrels by 1975.

The growth rate of individual petroleum products promises to be even more dramatic. For instance, gasoline consumption will increase over the next 10 years by 44%, kerosene by 55%, distillate oil by 16.8%, residual oil by 32.7% and other products including lubricants by nearly 51%. The Oil and Gas Journal also forecasts petrochemical markets to double during the next decade.

Whether the supply requirements of these greatly increased demands can be met depends in large measure on the availability of engineering and other professional manpower.

There should be no question in the minds of educators, graduates or undergraduates concerning the promise of career opportunities in oil.

Now, let us turn again to the conference theme, "Water Quality - How Does It Affect You?" and to the specific assignment of "Career Opportunities in the Water Resources Area" as they may apply to the oil industry.

Secondary recovery of oil by waterflooding is on an accelerated course throughout large segments of the industry. In Lea County, New Mexico, the number one U. S. county in the production of oil and gas annually, a number of systems are now in operation and many more are planned. As primary production of oil wells decline it becomes necessary to turn to secondary methods to maintain economic production of oil properties. Primary methods normally recover no more than 20 to 30 percent of the reservoir oil in place. Recoverable volumes vary with different reservoir types and conditions.

In Southeastern New Mexico, where approximately 90 percent of the State's oil is produced, production is declining at an average annual rate of 15 percent. Unless supplemental recovery operations are put into effect, approximately 80 percent of the oil in place will not be recovered.

Oil operating companies in this area estimate that 604 million barrels of additional oil can be recovered by waterflooding, 103 such projects already being in operation. The first such system was begun in April 1952. Total oil recovered through 1965 by waterflood is reported by the New Mexico Oil Conservation Commission to be 104,076,000 barrels.

The Economic Subcommittee, appointed by the New Mexico Oil and Gas Committee, reported in June 1966 that total water requirements extending over the next 20 years for secondary recovery of oil in the area described above would be 45,600 acre-feet per year. Only 22 percent of this volume is expected to be potable water, 53 percent would be re-cycled produced water and the remaining 25 percent would be non-potable water. The possible sources for such large volumes of water of the character contemplated will not be speculated upon in this paper. However, it is clearly evident that water treatment methods plus transportation, storage and pumpage problems altogether will require the talents of several engineering classifications. This is just one such development in the oil industry. It is not a particularly unique development nor is it the largest.

With the passage of the Water Quality Act of 1965, the Congress, as a consequential by-product, created many new career opportunities in the water resources field. However, the petroleum industry finds itself in perhaps a more favorable position than other industries when the subject of pollution is brought up. The American Petroleum Institute has had, for the past 36 years, a committee collecting, developing and publishing information on pollution problems of the industry. The petroleum industry has been deeply concerned with the nation's water resources, being one of its major users. Petroleum refineries have an intake of about 3.6 billion gallons of water per day, used primarily for cooling, 92.8 percent of which is returned to the source.

Dayton H. Clewell, Senior Vice President of Socony-Mobil Company recently told the National Water Conference of the U. S. Chamber of Commerce, that the petroleum industry is spending more than $30 million each year for water treatment of all types. As disposal of oil field brines, waterflooding, petrochemical manufacturing and refining operations and thermal secondary recovery of oil by steam flood, requiring large volumes of water of high quality continue to grow at the present rapid rate, water treatment costs within the industry will increase proportionately.

Career opportunities for graduates in many fields of endeavor will likewise grow in the water resources field within the petroleum industry in the years ahead.

CAREER OPPORTUNITIES IN THE WATER RESOURCES AREA AS RELATED TO THE OIL INDUSTRY

Frank O. Elliott1/

I am appearing on this Water Resource Panel representing an industry that has spent billions of dollars in research on "How Not to Find Water" yet experience, technology and research has now proven that we, too, must have water to obtain maximum recovery of our State's most valuable natural resource. We have found that a large percentage of the oil reservoirs will recover only 20% of the available oil in place by natural gas expansion and pumping, but if additional energy is supplied in the form of waterflooding, up to 80% of the oil can be recovered. There are many problems involved in waterflooding.

Problem No. 1, and certainly not the least of the problems is the availability of water of the proper quality delivered to the oftentimes remote oil field at a cost that will make the flood economically feasible. You will note, I stated -- water of proper quality.

This brings up Problem No. 2. Obviously we do not require this water for drinking or irrigation purposes so in a large percentage of our floods a non-potable water is satisfactory; however, we have found that water containing a particular chemical make-up is not always compatible with a particular reservoir formation or the oil in the formation, resulting in an emulsion that blocks the permeability, eventually causing the failure of the project unless a successful treatment is found to eliminate the emulsion problem.

Problem No. 3 concerns the injection technique to prevent a breakthrough of the water to the oil producing wells, bypassing the oil and leaving it unrecovered in the reservoir.

Waterflooding for secondary recovery of oil is comparatively in its infancy, with much to be learned in the coming years. Although it is rather difficult to create in the laboratory, conditions that exist three to twenty thousand feet below the surface, it certainly presents a challenge to men of research in this field.

Up to this point, I have not specifically mentioned career opportunities. Certainly, it is obvious to see that hundreds of jobs are and will be available with the established companies in the field of secondary

1/ President, New Mexico Oil and Gas Association
Roswell, New Mexico

recovery of oil but I am sure there are those present who have the vision and ambition to seek more than a job, the opportunity is here for this person with the proper technical training, vision and ambition to earn his first million within ten years as there are hundreds of minor oil fields throughout the United States that will, within the next ten years, reach their economic limit of primary production, many of which are suitable for secondary recovery by waterflooding but due to the diverse ownership and other factors, may well be abandoned unless the man with the necessary ability and ambition furnishes the catalyst to assemble the field into a workable secondary recovery project.

In recent years, the nerve center of research for both industry and government has evolved at a very rapid pace to our universities and colleges. A recent article in Readers Digest stated that in 1951, the Federal Government spent 295 million dollars in the colleges and universities for research and development, by 1965 that figure had grown to 1.7 billion dollars, if this trend continues, certainly the research departments of our colleges and universities are going to face a very awesome responsibility as it has been and will continue to be through research in all fields, and this is particularly true in the oil and gas industry, that our free enterprise system and our Government receive the tools to keep our country in its enviable economic position that it holds today.

GOVERNMENT CAREER OPPORTUNITIES IN WATER RESOURCES

F. C. Koopman[1/]

Billions of dollars are spent yearly toward solutions to the problems and projects pertaining to water. It has been estimated (1) that by the year 2000, less than 35 years from now, water needs will have reached crisis proportions. It is the intent to plan so that such a crisis could be lessened, averted, or at least forestalled by planning and initiating programs to conserve or develop our water reserves. The importance of the research and development activity in water resources cannot be underestimated. A considerable number of government agencies are engaged in projects involved with the optimum use of water resources in the future and the conservation of the present supplies. A recent review (2) of the functions of federal agencies found that only the Post Office Department, of the eleven cabinet-level departments, lacked responsibilities in the field of water resources. Within the Federal

1/ Hydrologist, Water Resources Division, U.S. Geological Survey
Albuquerque, New Mexico

complex there are 38 agencies and 25 commissions or committees, that have functions pertaining to water resources. Add to this the number of State agencies and that portion of private enterprise that deal with water and it becomes evident that water is an important part in our present national economy.

Water studies by colleges, industry, and government demand a steady increase in scientific manpower. The manpower working with water is not composed only of hydrologists, but includes other professionals such as geologists, geochemists, oceanographers, physicists, mathematicians, lawyers and others. The actual number of professionals assigned as hydrologists account for less than 5 percent of those active in Earth Science.

Hydrology is a young science and it uses the talents and abilities of engineers, and geologists, as well as those trained in basic and life sciences. Because of its significance, the search continues for those with education or experience in hydrology. The demand has caused a shortage of "water based" scientists and engineers. Those with sufficient academic background in related subjects, and who can qualify as hydrologists, are considered to be within a shortage category for Federal employment. An on-the-job special training program for those meeting entrance requirements as hydrologists has been initiated so that these individuals can accelerate their professional participation in water resources programs. The professional advancement depends upon the individual's ability and initiative.

Because hydrology is one of the young sciences, it offers many challenges in research and investigation. Because of the diversified nature, solutions to most of the problems in water resources can be obtained only by physicists, chemists, mathematicians and statisticians working together with engineers and earth and life scientists.

Engineers and scientists who choose Federal service in the Water Resources Division of the U.S. Geological Survey have the opportunity to work in their field of interest in research or development within an atmosphere of intellectual freedom. Employment benefits including annual and sick leave, insurance and retirement, compare favorably to those offered by industry. Because of the world wide shortage of experienced hydrologists, there are opportunities to work in foreign countries after a relatively few years of experience in water resources.

There is a great deal of satisfaction in working with water resources and water problems because of the urgent need for this work. Solutions to problems and development of new water resources projects that are so vital to the future will be a stimulating challenge.

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CAREER OPPORTUNITIES IN THE WATER RESOURCES FIELD AS THEY APPEAR TO STUDENTS AND SPECIFICALLY IN THE EDUCATIONAL FIELD

Conrad G. Keyes, Jr.[1/] ScD

Career opportunities in the Water Resources field as they appear to students is a function of the year, the time of the year, and the degree which the student has obtained. During the past five years, most students have had sufficient opportunities for job employment. Some of New Mexico State Universities' students have had anywhere from five to ten offers during one year. Since most students graduate during May or June, job opportunities at this time seem to be in greater number than during the fall semester.

The degree which the student has obtained is the most important variable as far as the educational field career opportunities are concerned. A student with a bachelor's degree in Water Resources has only a few opportunities in the educational field. The largest number in the educational field will go on for a master's degree in Water Resources. He can either obtain a fellowship (full-time graduate courses) or he can work half-time on a teaching assistantship or on a research assistantship. The following is a comparison of the salaries earned and the time required for completion of the degree.

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1/ Assistant Professor, Civil Engineering Department, New Mexico State University, Las Cruces, New Mexico.

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CAREER OPPORTUNITIES IN WATER RESOURCES RESEARCH

E. D. Eaton1/

Water resources research, and the opportunities it offers for a professional career are such stimulating subjects that they often tempt me to talk for longer than my allotted share of the program. To avoid that temptation, this afternoon I will touch only briefly on "why, what kind, and how much water resources research?;" and use a few illustrative examples to indicate the scope of opportunity.

The "why" of water resources research, it seems to me, has been well demonstrated by the three previous papers by Dr. Agee, Professor Hernandez, and Professor Clark. Their papers have made evident the importance and urgency of developing improved answers for many problems of water quality management. Although certainly it is true that action to protect water quality need not, and should not, be deferred awaiting completion of research, it also is clear that effective economically practicable water quality management for many of the streams in the Southwest, as well as elsewhere in the United States, requires greatly increased knowledge and understanding of the processes involved. This also is true of virtually all other aspects of water resources management from urban hydrology to waterfowl protection. Research, in a sense, is among the most needed and the most promising activities in water resources conservation and utilization.

It is always difficult to estimate quantitatively the justifiable magnitude of research effort, but one or two business-type computations may be indicative. For example, a recent paper by Hands and Kube in the *Harvard Business Review* for October 1966 estimates that in the next 30 years investment by industries and municipalities in water quality protection facilities will be not less than $110 billion. Comparable estimates of investment in major engineering facilities for streamflow regulation and water storage exceed $200 billion during about the same period of years. Research to increase the effectiveness of investment in water facilities by no more than 3 percent, therefore, justifies research expenditures averaging over $200 million a year. This alone is substantially greater than current expenditures for all water research. Without pursuing further such calculations (which all too easily might degenerate into a mere numbers game), there is evident need and justification for substantial increase of the current level of water resources research effort.

The excellent paper just presented by Dean Leyendecker has clearly stated the importance both of research that seeks to provide fundamental

1/ Associate Director, Office of Water Resources Research, United States Department of the Interior, Washington, D. C.

understanding of physical processes, and of research that is readily transferable to practice--something confusingly termed "applied research." As Dr. Leyendecker has indicated, both kinds of research are needed in the fields of physical sciences such as hydrogeology and hydraulics, and also in many of the life sciences that deal with biological processes. Professor Hernandez' discussion this morning exemplified the involvement of civil and sanitary engineering, and also the involvement of social sciences in seeking definition of "feasible means of treatment." Usable concepts of such criteria call for employment of operations research and systems engineering as well as of the conventional technical disciplines.

The "systems" may be macro-systems such as river basins or major metropolitan areas; they may be micro-systems such as individual industrial or agricultural enterprises; and, in fact, they may be systems of public administration, laws, and regulations. There now is wide consensus that as we engage increasingly in problems of water resource management in a complex physical and social environment, operations research and systems engineering are increasingly productive approaches.

Against that background, what are current estimates of water resources scientific personnel requirements? At the present time, water resources planning, facilities construction and operation, research and university teaching are the principal activity of approximately 10,000 professional-level people in the United States. Of these, the largest number are engaged in facility planning, design, and construction; while about one-fourth of that number are engaged in water resources research. These numbers may be expected to double within the next 5 to 10 years, depending to considerable degree on the capability of universities to produce professionally qualified people.

Research activities are of major significance in this connection because they have twofold effect. In addition to producing the scientific knowledge and understanding needed for the effective and practical solution of water resources problems, research also is a principal means for production of high quality technical practitioners. The association with senior faculty members that is afforded to advanced students engaged as research assistants is an important element in trained manpower development.

Broadened technical participation is becoming increasingly evident in water resources activities, especially so in water resources research. In addition to physical scientists and engineers, water resources planning, operations, and research now involve significant numbers of the life scientists and social scientists. Furthermore, although water resources activities may continue in the future, as they have in the past, to be preponderantly the responsibility of Federal and state agencies, there is already evident an increasing industry concern that enlarges participation of consulting engineers, private research institutions, and in the case of certain industries, significant numbers of professional corporate employees.

By and large, professional water resource career opportunities in public agencies, private industry, and universities are likely to remain preponderantly in the traditional professional categories of engineering, physical, life, and social sciences, and law. There is, however, increasing recognition of the need for professional personnel to have understanding of and capability in multi-disciplinary approaches to resource problems, and also of the relationships of natural resources to urban environments.

I hope that these brief comments convey to you my conviction that there are promising opportunities for careers in water resources research which will be professionally rewarding and personally stimulating.

AGRICULTURAL CAREER OPPORTUNITIES IN THE WATER RESOURCES AREA

Philip J. Leyendecker[1/]

I should like to share with you a quotation which I shall always remember. It appeared below a photo of Elephant Butte Reservoir in the office of the late Agricultural Experiment Station Director Fabian García. Below the picture were the words, "El Agua es Rey en las Regiones Aridas," (water is king in arid regions). Director Garcia, who was responsible for directing much of the early irrigated agricultural research in New Mexico, knew full well the true and deep meaning of this statement.

In the arid Southwest, only about 10 per cent of our precipitation finds its way into streams and underground water storage. The other 90 per cent is transpired by vegetation, which means that it is lost to human, industrial, or agricultural uses. Much of this vegetation is of little economic value, and much of it interferes with, and seriously reduces, grass and timber production.

Competition for the 10 per cent of available water is by far the most serious problem which faces Southwestern agriculture. To reduce this competition, we must find ways and means to decrease drastically the critical loss of 90 per cent of the water which falls on our watershed areas. Exotic plants must be found to replace those with high water requirements and low economic value.

Research teams which cut across the engineering and biological disciplines will be required to combine all possible vegetation combinations, special site preparation and management manipulations to increase watershed water production. To be fully effective, this figure must be increased from at least 15 to 25 per cent. As an example, it has been estimated that watershed yields can be increased from 10 to 20 per cent, by simply replacing brush and trees with grass vegetation, which will at the same time increase the economic grazing potential of the watershed.

Unless the amount of available water can be increased soon, water now used by agriculture will be transferred to urban, industrial and recreational uses, where the financial returns are far greater.

Of the 10 per cent which finds its way into streams and underground storage, agriculture presently utilizes about 92 per cent. Research projects must be developed that will assure the most effective and efficient use of available water. Since agriculture uses the most water, it is our responsibility to discover ways and means of conserving it.

1/ Dean of Agriculture and Home Economics
Director of the Agricultural Experiment Station and Extension Service
New Mexico State University, Las Cruces, New Mexico

A considerable amount of the water reaching underground reservoirs is very high in alkaline salts and is not suitable for industrial or agricultural use. In addition, many acres of potential agricultural land contain high amounts of similar salts which preclude the production of agricultural crops. Research is needed to develop new crops and grasses which are tolerant to alkaline water and soils. Concurrently, soil and water management irrigation regimes must be developed to fully exploit the use of highly alkaline water which cannot be put to a higher use without expensive treatment. We also must know more about the irrigation of high alkaline soils and its effect upon the quality of underground water supplies which are used for urban and industrial uses.

Once a water supply is contaminated, the cost of purification usually far exceeds its highest economical use. As agricultural technology moves into the concentrated use of chemicals to maintain and produce higher quality food stuffs and yields, the danger of altering the quality of secondary water sources becomes greater. Teams of soil scientists, sanitary engineers, biologists and bio-chemists must direct their attention to the half life and bio-degradation of agricultural chemicals which are used to increase yields and control weeds, insects, and diseases. To guard against contamination of underground water supplies, detailed studies must be made by the soil scientists to determine the utilization and movement of fertilizers in the soil. The maintenance of water quality for multiple uses is the prime responsibility of all consumers of this precious commodity.

Further attention must be given to the consumptive use of water for row crops and forage grasses. Much of our native grassland could be reseeded to grasses and forbs of high nutritive value and low water requirements, which in turn would increase watershed water production. New water requirement levels for most irrigated crops must be reestablished in light of modern technology. Recent work in the Pecos Valley of New Mexico indicates that we can grow crops successfully with less water than which is now customarily being used.

It may also be necessary in the future to abandon the growing of certain crops that have high water requirements and replace them with more efficient water users. Crop breeders must also be searching for, or breeding new varieties that require less water per pound of salable product. The development of dwarf feed grains which produce the same amount of grain with a much smaller percentage of leaf and stalk could well be the answer. Plant physiologists and bio-chemists also may assist in reducing water consumption by developing chemicals that can be absorbed by the plant which increase surface tension, thereby reducing transpiration and in turn, reducing the amount of water required for normal yields. This phenomenon should hold a great fascination for the basic scientist.

Coupled with consumptive use and breeding for lower water consumption is the discipline of micro-climatology. Research in this area is yet to be exploited. We know little about the micro-climate which exists in a cotton, grain or alfalfa field, yet we apply moisture as if we were fully aware of those inter-actions which control water loss and consumption. Precise instrumentation must be developed, both for above and below ground readings, accompanied by accurate interpretations and applications to irrigation ecology and regimes.

Detailed micro-climate studies might well require a complete reevaluation of irrigated agriculture. Despite the fact that the irrigation art is as old as man's first attempt to control the environment about him, we know little about the basic principles underlying the application of water to cultivated crops. More efficient means must be found for applying water to soils which supply moisture to the delicate absorbing root surfaces of food and fiber producing crops. Flooding and furrow irrigation, which have been used for centuries, are probably the most inefficient means of supplying moisture to growing crops. We must look into underground and sprinkler irrigation where minimum amounts of moisture can be applied for maximum crop production.

Recent research work by the Agricultural Experiment Station at New Mexico State University has shown that it is practicable to apply irrigation water from underground piping systems. Preliminary results indicate efficiency of a very high order can be obtained without sacrificing yields. Greater fertilizer efficiency also accrues with an underground system, because leaching is cut to a minimum.

As we look down the road, it is apparent that scientists from allied fields, especially the physical sciences, must be attracted to water research to assist in generating new and fresh ideas that can be used in increasing the efficiency of water use and maintenance of quality, if agriculture is to compete successfully with the many users of water. For in the final analysis, the allocation of available water will be determined by those activities which produce the highest financial returns. It follows then that the water which is available to agriculture at a price we can pay will have to be utilized in the most efficient, effective manner if agriculture is to compete successfully as a major water user.

In closing, may I say again, "EL AGUA ES REY EN LAS REGIONES ARIDAS."

GEOLOGIC AND HYDROLOGIC RESEARCH RELATING TO WATER RESOURCE RESEARCH IN NEW MEXICO

C. E. Jacob[1]

As a basis for understanding and describing the surface and subsurface hydrology of major basins in New Mexico and neighboring states, refinements must be made in the geologic knowledge of those basins. An investigation, now underway jointly by the University of New Mexico, New Mexico State University, and New Mexico Tech, concerns the water supply of the Pecos Basin. Certain sub-basins of the Pecos have been studied for many years; there is need now for an integrated approach to hydrologic problems in the basin.

The Roswell Basin is being modeled by electrical analog techniques. The Roswell and Carlsbad subsurface geology is being restudied. "Feedback" between the laboratory model studies and field geology should lead to a sharpening of the model and increased reliability of predictions based thereon.

Interrelationships between surface water and ground water involve return flows from irrigation, seepage losses from streams and canals, and natural influent seepage. The hydrometeorology of the Pecos Basin is also important, not only in the upper reaches where seasonal snow melt feeds the Pecos headwaters, but also in the lower reaches where runoff from high intensity storms is particularly great. Modeling of the surface-water basin in mathematical terms, and ultimately by electronic analog, should enable more accurate prediction of water yield under operational conditions differing from those of the present.

The integrated treatment of the Pecos Basin by the methods of systems analysis and dynamic programming would include interrelationships between hydrology, economics, and agriculture. The techniques developed in the study should find application later to other major basins of the state, including the Rio Grande.

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Socorro, New Mexico

EDUCATION AND RESEARCH NEEDS IN HYDROLOGY

Frank B. Titus[1/]

The recently developed awareness by governmental and other authorities of impending need to increase useable water supplies in the United States and throughout the rest of the world has brought a surge of interest in the general field of hydrology. Whereas few departments of hydrology have existed before in institutes of higher learning, within the span of a few years, as a result of this surge, many universities and colleges have added educational programs that cover all aspects of natural water occurrence and availability. Right now there is a search for qualified teachers to staff new or expanding departments, particularly in the area of ground-water hydrology.

The institutes of higher education in New Mexico, in line with the national trend, are developing and expanding their efforts in this area. Using three of our major schools as examples, the University of New Mexico has made major strides in the study of economic and legal aspects of water supply, New Mexico State University has expanded rapidly in the study of water use in agriculture, and the well established Department of Ground-Water Hydrology at New Mexico Tech has significantly enlarged its activities in the study of scientific aspects of hydrology. (This is not to suggest that these institutes are restricting themselves to development only in these areas of special interest.) Thus, a student in New Mexico who is interested in preparing for a profession in any area of water supply can find a school which will provide him with excellent training.

The several individual and inter-university cooperative research projects in hydrology that are being pursued in New Mexico colleges and universities provide important information to State action agencies, such as the State Engineer Office and the Department of Development. Cultural development in New Mexico, as elsewhere, has shown the general state geographic areas where potable and non-potable water is found, and the areas where great or small quantities of water are available for development. It is now the task of both the research agencies and the action agencies to refine this general knowledge, to encourage optimum use of available water, and to discourage practices that will be detrimental to the state's "hydrologic health."

Thus, we wish to apportion water in the most benefical manner, to administer water supplies most equitably, and to use water most efficiently. We wish to find and develop new water supplies where they exist, to improve

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the quality of water where economically feasible, and to find new and beneficial applications for water while at the same time protecting existing water rights. Finally, we wish to better understand the occurrences of water; that is, the relation between water and the environments in which it exists.

I want to emphasize the need for continuing fundamental research that is implicit in the last statement above, not because it is any more important than any of the others, but because this need can sometimes be overlooked in the press for rapid economic development of water supplies. A project which today may seem to provide merely for the satisfaction of intellectual curiosity, can tomorrow provide the required knowledge or insight for a new type of water development.

An example of fundamental research in one area of hydrology is a project in Estancia Valley, New Mexico being carried on by New Mexico Tech in cooperation with the New Mexico Water Resources Research Institute. Part of this study is concerned with the hydrologic and geologic history of the basin as a means of explaining the presence of highly mineralized shallow ground water. In this basin changing meteorological conditions in the geologic past have strongly influenced the evolution of the basin to its present hydrologic and geologic condition. To obtain information in this "hydrologic" study, we are collecting data on meteorology, geology, paleontology, limnology, and archeology.

What the study will produce immediately in the way of "useful" information, I can only speculate on at this point; except, I hasten to add, that the graduate students involved in the study will, I hope, develop a "feel" for basin hydrology, a mental picture of a water basin as a dynamic system, and a recognition of the manifold interrelationships that exist between water and its environments. And these after all are the things that we as students must hope to learn. This is the essence of the science of hydrology that must be comprehended before we can speculate on what effects man's beneficial use of water will be.

WATER QUALITY RELATIONSHIPS IN IRRIGATION DEVELOPMENT

Harris McDonald[1]/

INTRODUCTION

Irrigation has been practiced since prehistoric time. Early civilizations were centered in irrigated areas and some have fallen because certain basic principles of irrigation science were either unknown or were not followed. Today, we know some of the principles and practices essential to permanent and profitable agriculture under irrigation.

Since plants function much like miniature distillation cells, an amount of water in excess of the net consumptive use must be applied and allowed to percolate through the root zone in order to leach the salts left by the evapotranspiration process. This saline water must have an outlet, either natural or artificial, in order to maintain optimum plant growth. This deep percolation usually contains in solution as much salt as was contained in the water applied, although profound chemical changes may have taken place.

Water quality is an important factor in irrigation development, and in this paper we briefly describe the basic principles involved and some of the problems encountered in projects planned, designed, and operated by the Bureau of Reclamation.

WATER QUALITY AS RELATED TO SOURCE OF SUPPLY

Typically, the water from the high mountain areas is principally from snowmelt and is very low in total dissolved solids. Farther down in the basin where the rivers emerge from the mountains we find the best potential reservoir sites. The natural streamflow at this point usually exhibits an inverse relationship between discharge and concentration of total dissolved solids, the low flows being the more mineralized because these are supplied principally by ground water.

EFFECT OF RESERVOIR OPERATION

With streams which exhibit wide variations in rate of runoff, irrigation water quality can be greatly improved by reservoir storage, inasmuch as the low salinity floodflows are mixed with the more saline low flows. A typical example is the quantity and quality of inflow to and releases

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from Lake Mead on the Colorado River, as shown in Figure 1, for the period 1941-58. The average monthly concentration of total dissolved solids at the Grand Canyon gaging station upstream from the reservoir varied from about 0.5 to 1.5 tons per acre-foot during this period. The average monthly discharge varied from 0.5 to almost 5 million acre-feet. The water released from Lake Mead varied from 0.5 to 2.0 million acre-feet, and the concentration of total dissolved solids varied from 0.8 to 1.2 tons per acre-feet. As a result of the regulation provided by the reservoir, the irrigation projects downstream received water of better quality than would have been received without the reservoir.

COLORADO RIVER BASIN

In recent years emphasis has been placed on integrated river basin planning rather than the planning of individual projects. The authorizing legislation for the Colorado River Storage Project and participating projects required a report on the effect of the projects on quality of water in the Colorado River Basin.

The third report was furnished to the Congress by the Secretary of the Interior on December 17, 1966. This report gives the historical, the present modified and the anticipated quality of water of the Colorado River down to Imperial Dam. The past is represented by a tabulation of the determined or estimated historic condition at 17 quality-of-water stations for the period 1941-64. These stations are shown in Figure 2. The present modified condition includes adjustments of the historic condition based on the assumption that new developments begun during the 1941-64 period were in operation for the full period. The anticipated quality condition is an estimate of the quality situation after the presently authorized developments and some projects proposed for authorization are placed in operation. The effects of these developments are presented in 5 different increments, as shown in Figure 3.

Studies of chemical trends indicate that under historic conditions the average concentration of dissolved solids of the Colorado River at Lees Ferry was about 0.74 ton per acre-foot, below Hoover Dam about 0.93 ton per acre-foot, and at Imperial Dam about 1.01 tons per acre-feet for the 1941-61 period.

Under the present modified conditions, that is, assuming that the recently constructed projects were in operation for the entire period, the concentrations would have been about 0.79, 0.98 and 1.10 tons per acre-foot, respectively, at the three stations.

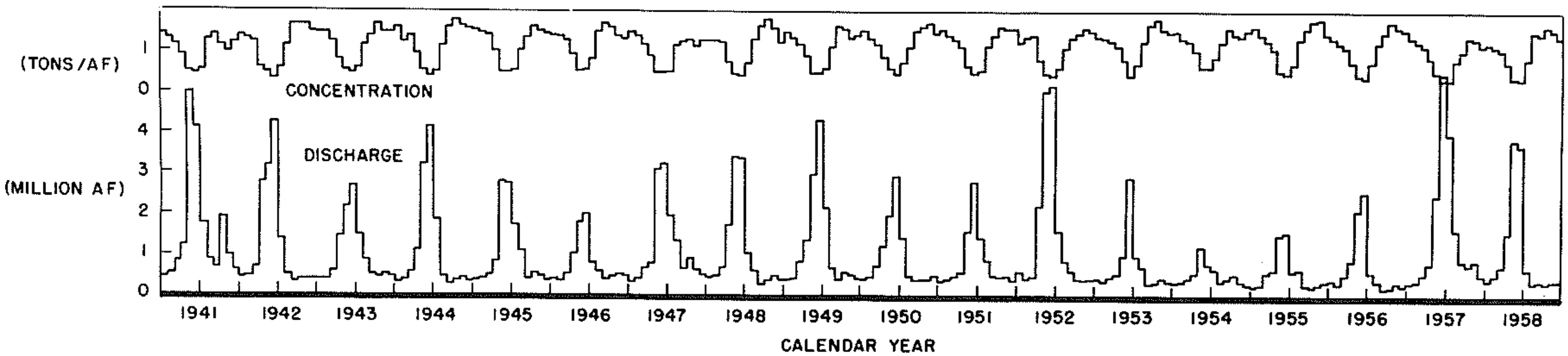
Since only a limited amount of data are available on the effect of irrigation on water quality, it has been assumed for the purposes of this study that the return flow quality will reflect a salt balance and an additional pickup from 0 to 2 tons per acre. Limited data on several areas indicate these additional pickup rates would embrace most of the irrigation projects in the Upper Colorado River Basin.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

QUALITY OF WATER STUDY

COMPARISON OF QUALITY OF WATER ABOVE AND BELOW LAKE MEAD

COLORADO RIVER NEAR GRAND CANYON, ARIZONA.



COLORADO RIVER BELOW HOOVER DAM, ARIZONA-NEVADA.

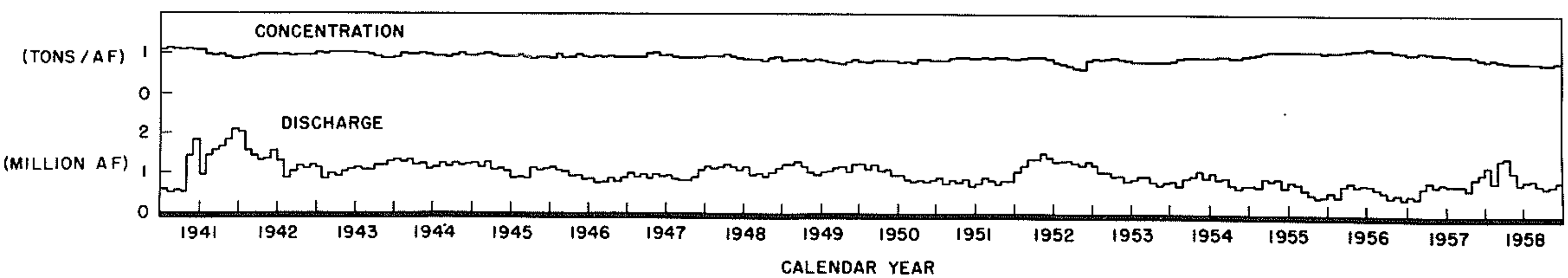


FIGURE 1

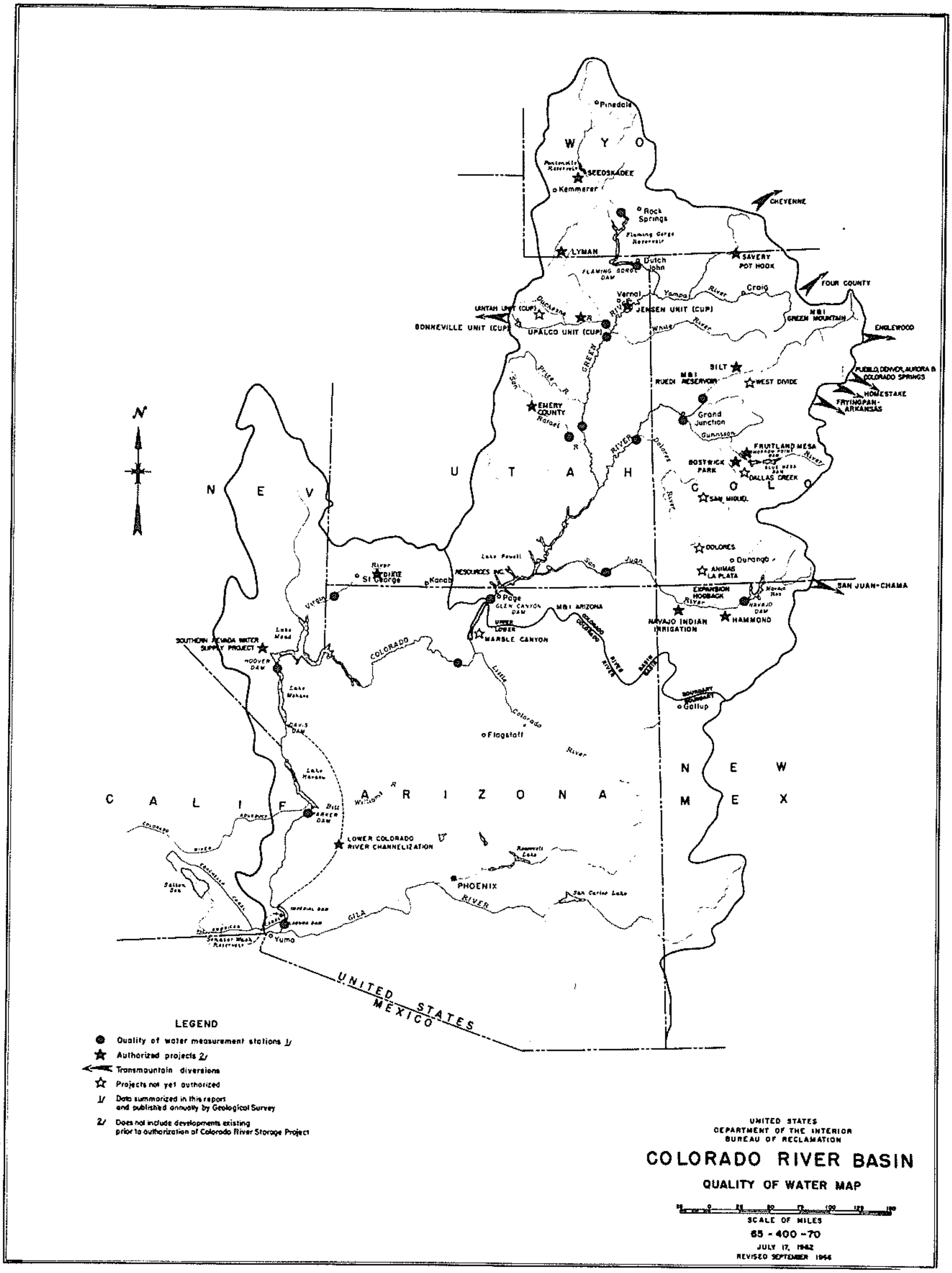

LEGEND
Quality of water measurement stations 1/
Authorized projects 2/
Transmountain diversions
Projects not yet authorized
1/ Data summarized in this report and published annually by Geological Survey
2/ Does not include developments existing prior to authorization of Colorado River Storage Project
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER BASIN
QUALITY OF WATER MAP
SCALE OF MILES
65 - 400 - 70
JULY 17, 1962
REVISED SEPTEMBER 1966
W Y O
U T A H
N E V
C O L O
A R I Z O N A
N E W M E X
C A L I F
UNITED STATES
MEXICO
Pinedale
SEEDSKADEE
Kemmerer
Rock Springs
CHEYENNE
LYMAN
Dutch John
SAVERY POT HOOK
FOUR COUNTY
Vernal
Craig
JENSEN UNIT (CUP)
UINTAH UNIT (CUP)
BONNEVILLE UNIT (CUP)
UPALCO UNIT (CUP)
GREEN RIVER
ENGLEWOOD
SILT
RUEDI RESERVOIR
WEST DIVIDE
HOMESTAKE
EMERY COUNTY
Grand Junction
FRUITLAND MESA
BOSTWICK PARK
DALLAS CREEK
SAN MIGUEL
DOLORES
Durango
ANIMAS LA PLATA
SAN JUAN-CHAMA
St George
Kanab
Page
GLEN CANYON DAM
NAVAJO INDIAN IRRIGATION
HAMMOND
MARBLE CANYON
SOUTHERN NEVADA WATER SUPPLY PROJECT
HOOVER DAM
Gallup
Flagstaff
LOWER COLORADO RIVER CHANNELIZATION
PHOENIX
GILA RIVER
Yuma

FIGURE 2

Summary of Anticipated Effects of Additional Developments on Quality of Water at Seventeen Stations

Colorado River Basin

(Units: 1,000 except concentrations)

Station (1)	Present Modified condition: Flow (AF) (2)	Concentration (T/AF) (3)	T.D.S. (T) (4)	Effects of storage unit operations - Increment No. 1: Project	Flow adjustment (AF) (5)	Flow (AF) (6)	Concentration (T/AF) (7)	T.D.S. adjustment (T) (8)	T.D.S. (T) (9)
Green River at Green River, Wyoming	1,255	0.42	532						
Green River near Greendale, Utah	1,513	0.55	829	Flaming Gorge Unit	16	1,529	0.57	43	872
Duchesne River near Randlett, Utah	398	0.98	389						
Green River near Ouray, Utah	3,967	0.54	2,124	Flaming Gorge Unit	16	3,983	0.54	43	2,167
Green River at Green River, Utah	3,995	0.62	2,493	Flaming Gorge Unit	16	4,011	0.63	43	2,536
San Rafael River near Green River, Utah	95	2.20	210						
Colorado River near Cameo, Colorado	2,643	0.58	1,529						
Gunnison River near Grand Junction, Colorado	1,700	0.87	1,471	Curecanti Unit	-6	1,694	0.87	-2	1,469
Colorado River near Cisco, Utah	4,810	0.88	4,234	Curecanti Unit	-6	4,804	0.88	-2	4,232
San Juan River near Archuleta, New Mexico	915	0.22	197	Navajo Unit	42	957	0.22	10	207
San Juan River near Bluff, Utah	1,580	0.62	973	Navajo Unit	42	1,622	0.61	10	983
Colorado River at Lees Ferry, Arizona	10,455	0.79	8,230	Increment No. 1	120	10,575	0.79	120	8,350
Colorado River near Grand Canyon, Arizona	10,714	0.88	9,380	Increment No. 1	120	10,834	0.88	120	9,500
Virgin River at Littlefield, Arizona	153	2.27	348						
Colorado River below Hoover Dam, Arizona, Nev.	10,681	0.98	10,447	Increment No. 1	120	10,801	0.98	120	10,567
Colorado River below Parker Dam, Ariz., Calif.	9,100	0.96	8,780	Increment No. 1	120	9,220	0.97	120	8,900
Colorado River at Imperial Dam, Ariz., Calif.	8,363	1.10	9,232	Increment No. 1	120	8,483	1.10	120	9,352

Station (1)	Effects of developments - Increment No. 2: Project	Zero pickup: Flow adjustment (AF) (10)	Flow (AF) (11)	Concentration (T/AF) (12)	T.D.S. adjustment (T) (13)	T.D.S. (T) (14)	T.D.S. pickup at 2T/A: T.D.S. adjustment (T) (15)	Concentration (T/AF) (16)	T.D.S. (T) (17)
Green River at Green River, Wyoming	Seedskadee	-165	1,090	0.49	0	532	118	0.60	650
Green River near Greendale, Utah	Seedskadee, Lyman, Westvaco, and other M&I	-211	1,318	0.66	0	872	118	0.75	990
Duchesne River near Randlett, Utah	Central Utah	-186	212	1.65	-39	350	2	1.66	352
Green River near Ouray, Utah	Seedskadee, Lyman, Westvaco, and other M&I Central Utah, Savery-Pothook, Hayden Steam Plant	-457	3,526	0.60	-34	2,133	164	0.65	2,297
Green River at Green River, Utah	Seedskadee, Lyman, Westvaco, and other M&I Central Utah, Savery-Pothook, Hayden Steam Plant	-457	3,554	0.70	-34	2,502	164	0.75	2,666
San Rafael River near Green River, Utah	Emery County	-17	78	2.69	0	210	2	2.72	212
Colorado River near Cameo, Colorado	Colorado East slope diversions and Silt Project	-340	2,303	0.65	-32	1,497	4	0.65	1,501
Gunnison River near Grand Junction, Colorado	Fruitland Mesa and Bostwick Park	-32	1,662	0.88	0	1,469	36	0.91	1,505
Colorado River near Cisco, Utah	East slope diversions, Silt, Fruitland Mesa, and Bostwick Park	-372	4,432	0.95	-32	4,200	40	0.96	4,240
San Juan River near Archuleta, New Mexico									
San Juan River near Bluff, Utah	Hammond, Utah Construction, Expansion Hogback	-40; 36 (Salvage)	1,582	0.62	0	983	4	0.62	987
Colorado River at Lees Ferry, Arizona	Increment No. 2	-850	9,725	0.85	-66	8,284	210	0.87	8,494
Colorado River near Grand Canyon, Arizona	Increment No. 2	-850	9,984	0.94	-66	9,434	210	0.97	9,644
Virgin River at Littlefield, Arizona									
Colorado River below Hoover Dam, Arizona, Nev.	Increment No. 2	-850	9,951	1.06	-66	10,501	210	1.08	10,711
Colorado River below Parker Dam, Ariz., Calif.	Increment No. 2	-850	8,370	1.06	-66	8,834	210	1.08	9,044
Colorado River at Imperial Dam, Ariz., Calif.	Increment No. 2	-850	7,633	1.22	-66	9,286	210	1.24	9,496

Station (1)	Effects of developments - Increment No. 3: Project	Zero pickup: Flow adjustment (AF) (18)	Flow (AF) (19)	Concentration (T/AF) (20)	T.D.S. adjustment (T) (21)	T.D.S. (T) (22)	T.D.S. pickup at 2T/A: T.D.S. adjustment (T) (23)	Concentration (T/AF) (24)	T.D.S. (T) (25)
Colorado River near Cameo, Colorado	Fryingpan-Arkansas	-70	2,233	0.67	-4	1,493			
Colorado River near Cisco, Utah	Fryingpan-Arkansas	-70	4,362	0.96	-4	4,196			
San Juan River near Archuleta, New Mexico	San Juan-Chama and Navajo Indian Irrigation	-618	339	0.21	-135	72			
San Juan River near Bluff, Utah	San Juan-Chama and Navajo Indian Irrigation	-360; 18 (Salvage)	1,222	0.79	-18	965	220	0.97	1,189
Colorado River at Lees Ferry, Arizona	Increment No. 3	-412	9,313	0.89	-22	8,262	220	0.93	8,692
Colorado River near Grand Canyon, Arizona	Increment No. 3	-412	9,572	0.98	-22	9,412	220	1.03	9,842
Colorado River below Hoover Dam, Arizona, Nev.	Increment No. 3	-412	9,539	1.10	-22	10,479	220	1.14	10,909
Colorado River below Parker Dam, Ariz., Calif.	Increment No. 3	-412	7,958	1.11	-22	8,812	220	1.16	9,242
Colorado River at Imperial Dam, Ariz., Calif.	Increment No. 3	-412	7,221	1.28	-22	9,264	220	1.34	9,694

Station (1)	Effects of developments - Increment No. 4: Project	Zero pickup: Flow adjustment (AF) (26)	Flow (AF) (27)	Concentration (T/AF) (28)	T.D.S. adjustment (T) (29)	T.D.S. (T) (30)	T.D.S. pickup at 2T/A: T.D.S. adjustment (T) (31)	Concentration (T/AF) (32)	T.D.S. (T) (33)
Duchesne River near Randlett, Utah	Uintah Unit	-20	192	1.82	0	350	0	1.83	352
Green River near Ouray, Utah	Four County, Colorado; Cheyenne, Wyoming	-71	3,455	0.61	-14	2,119			
Colorado River near Cameo, Colorado	M&I Ruedi Reservoir and West Divide	-116	2,117	0.70	-2	1,491	38	0.72	1,533
Gunnison River near Grand Junction, Colorado	Dallas Creek	-37	1,625	0.90	0	1,469	30	0.94	1,535
Colorado River near Cisco, Utah	M&I Ruedi Reservoir, West Divide, Dallas Creek, Dolores, and San Miguel	-378	3,984	1.04	-34	4,162	120	1.07	4,282
San Juan River near Bluff, Utah	Animas-LaPlata and Dolores	-93; 29 (Salvage)	1,129	0.88	34	999	157	1.22	1,380
Colorado River at Lees Ferry, Arizona	Increment No. 4	-674	8,639	0.94	-124	8,138	277	1.02	8,845
Colorado River near Grand Canyon, Arizona	Increment No. 4	-674	8,898	1.04	-124	9,288	277	1.12	9,995
Colorado River below Hoover Dam, Arizona, Nev.	Increment No. 4	-674	8,865	1.17	-124	10,355	277	1.25	11,062
Colorado River below Parker Dam, Ariz., Calif.	Increment No. 4	-674	7,284	1.19	-124	8,688	277	1.29	9,395
Colorado River at Imperial Dam, Ariz., Calif.	Increment No. 4	-674	6,547	1.40	-124	9,140	277	1.50	9,847

Station (1)	Effects of developments - Increment No. 5: Project	Zero pickup: Flow adjustment (AF) (34)	Flow (AF) (35)	Concentration (T/AF) (36)	T.D.S. adjustment (T) (37)	T.D.S. (T) (38)	T.D.S. pickup at 2T/A: T.D.S. adjustment (T) (39)	Concentration (T/AF) (40)	T.D.S. (T) (41)
Colorado River near Grand Canyon, Arizona	Marble Canyon	-14	8,884	1.05	0	9,288	0	1.12	9,995
Virgin River at Littlefield, Arizona	Dixie Project	-62	91	3.80	2	346	23	4.05	369
Colorado River below Hoover Dam, Arizona, Nev.	Increment No. 5	-329; 28 (Salvage)	8,536	1.21	2	10,353	23	1.30	11,083
Colorado River below Parker Dam, Ariz., Calif.	Increment No. 5	-201; 85 (Salvage)	6,983	1.24	2	8,686	23	1.35	9,416
Colorado River at Imperial Dam, Ariz., Calif.	Increment No. 5	-216	6,331	1.44	2	9,138	23	1.56	9,868

FIGURE 3

Under the expected condition, with all authorized projects and projects proposed for authorization in operation and with an assumed pickup of 2 tons per acre on the new irrigated lands, the concentrations are estimated to be 1.02 tons per acre-foot at Lees Ferry, 1.30 tons per acre-foot below Hooever Dam, and 1.56 tons per acre-foot at Imperial Dam.

Estimates are that these depletions would occur by the year 2030. However other developments, as yet not identifiable, are expected to occur and will reduce the quantities of water shown for the various stations. The further reductions in quantities of water will cause slightly greater concentrations and these are estimated to be reflective of conditions in the year 1990.

These studies indicate an overall increase in the concentration of total dissolved solids under the conditions of development outlined, but the new depletions described leave the remaining water acceptable for further use. The concentration of total dissolved solids at Imperial Dam will increase 34 percent under conditions of no pickup of salts from new irrigated lands and about 45 percent if the 2-ton per acre pickup is assumed for new land.

GARRISON DIVERSION UNIT

The Garrison Diversion Unit of the Missouri River Basin Project originally authorized by the Flood Control Act of 1944, was approved for construction on August 5, 1965. The initial stage provides for irrigation of 250,000 acres in North Dakota, a municipal and industrial water supply for 14 towns and cities, fish and wildlife enhancement of 36 major areas, and recreation developments at 9 major water impoundments. Other project functions include flood control and incidental drainage.

One of the most interesting features of this project is the plan to restore Devils Lake. At one time, this lake was an attractive summer resort, having a water surface area of 142 square miles. The lake has no surface outlet. During a series of dry years evaporation reduced the area of Devils Lake itself to only 4-1/2 square miles and greatly increased the concentration of salts in the remaining water. Several other shallow lakes were formed and these collect the runoff and the upper lakes must fill and overflow before the water reaches Devils Lake as shown in Figure 4. The Garrison Diversion Unit will supply water from Garrison Reservoir on the Missiour River. Deliveries will be made at the rate of 400 cfs through the New Rockford Canal, Warwick Canal, and Devils Lake Feeder Canal. The Bureau of Sport Fisheries and Wildlife proposes four impoundments in the west arm of Devils Lake, with water surface elevations ranging from 1430 at the upper pool to 1427 in the lower pool. Water will be pumped from Six Mile Bay and conveyed through a canal to the west arm of Devils Lake in order to maintain the water surface elevations in the upper lakes.

A significant item in restoration of Devils Lake is the disposition of saline water presently in the lakes and that required to flush the lakes.

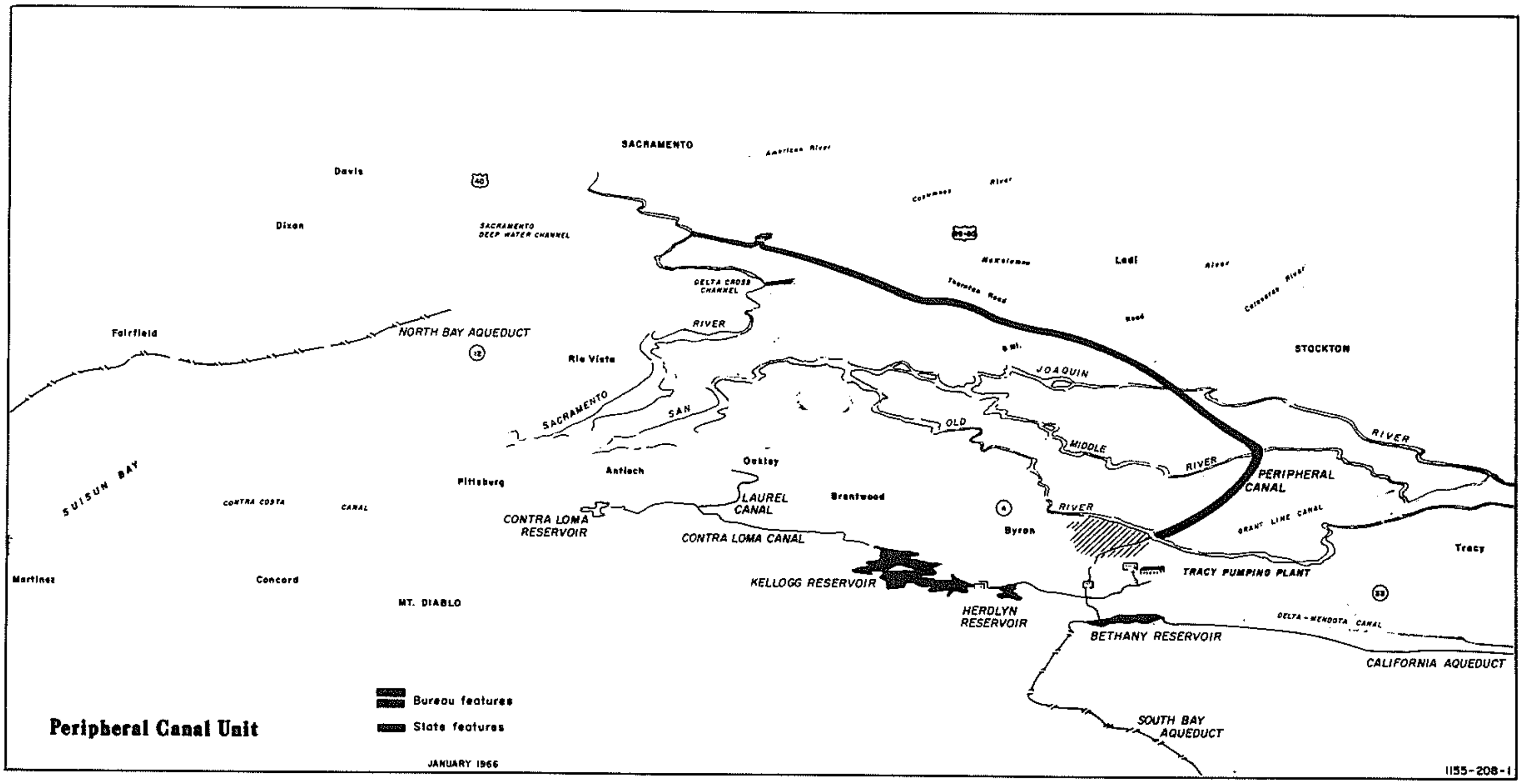

SACRAMENTO
Davis
Dixon
SACRAMENTO DEEP WATER CHANNEL
DELTA CROSS CHANNEL
RIVER
Lodi
STOCKTON
Fairfield
NORTH BAY AQUEDUCT
Rio Vista
JOAQUIN
SACRAMENTO
SAN
OLD
MIDDLE
RIVER
RIVER
SUISUN BAY
Pittsburg
Antioch
Oakley
LAUREL CANAL
Brentwood
PERIPHERAL CANAL
CONTRA COSTA
CANAL
CONTRA LOMA RESERVOIR
CONTRA LOMA CANAL
RIVER
Byron
GRANT LINE CANAL
Tracy
Martinez
Concord
MT. DIABLO
KELLOGG RESERVOIR
HERDLYN RESERVOIR
TRACY PUMPING PLANT
DELTA-MENDOTA CANAL
BETHANY RESERVOIR
CALIFORNIA AQUEDUCT
Bureau features
State features
Peripheral Canal Unit
SOUTH BAY AQUEDUCT
JANUARY 1966
1155-208-1

FIGURE 4

The 160,000 acre-feet of water stored in the lakes contain an estimated 4 million tons of dissolved solids. The lakebeds also contain up to 3 million tons of additional salts which could be dissolved during the flushing and restoration of the lakes. Diluting the brackish waters and wasting them via the Sheyenne River (North Dakota) would take about 11 million acre-feet of imported water and nearly a half century to empty, flush, and refill the lakes. These estimates are based on imported water of 500 ppm and discharge to the Sheyenne River of water at 1,000 ppm. Another scheme of rehabilitation that was studied and is the preferred solution would be to store the 160,000 acre-feet of brackish water and the required flushing water in East Stump Lake. Imports would then be continued at the rate required to fill and maintain the proposed lake level. An outlet would be provided to discharge excess inflow into the Sheyenne River and to permit circulation in the lakes. Recreation and fish and wildlife benefits from the Garrison Diversion Unit amount to more than $1,700,000 annually.

CENTRAL VALLEY PROJECT

Complex water quality problems also have been encountered in the Central Valley Project of California. More than 70 percent of the total streamflow in California occurs north of an east-west line drawn through Sacramento (1), and 77 percent of the present demand for water is found south of this line. The geographic disparity in supply and demand is expected to be greater under ultimate development than at present. The California State Water Plan involves the transfer of surplus waters of the Sacramento and other rivers in the northern part of the state to the south, including the San Joaquin River Basin and the South Coastal Basins. The water so transferred must be conveyed around or across the Sacramento-San Joaquin Delta. The Delta area in California is roughly triangular, lying just to the east of Suisan Bay. Under natural conditions it was a marsh with a network of channels extending 50 miles north and south and with a maximum width of about 25 miles. It was the terminus for the entire Central Valley Basin drainage system where an average of about 30,000,000 acre-feet of water was discharged to the ocean annually. Soon after the gold rush of 1849, a settlement was begun in the Delta by the construction of low levees to hold back the Delta waters. Today, 584,000 acres of Delta lands are irrigated. This unique area has now become one of the richest agricultural areas in the Nation. The lands are located on about 50 separate islands or tracts interlaced with 700 miles of meandering waterways.

Historically, the Delta was flushed during winter and spring periods of high runoff from upstream basins. Water of good quality was usually available to Delta water users, except during periods of low streamflow. During such periods, intrusions of sea water, local return drainage, and drainage from outside the Delta area contributed to a degradation of local water supplies. The maximum recorded extend of salinity intrusion occurred in 1931 when ocean salts reached Stockton and Sacramento on the eastern edge of the Delta. With the beginning of operation of Shasta Reservoir by the Bureau of Reclamation in 1944, controlled releases to the Sacramento River have been sufficient to maintain a hydraulic barrier for the repulsion of saline water and permit the stabilization of the agricultural development.

Initial development for export of Delta water began in 1940 with Bureau of Reclamation operation of the Contra Costa Canal. This canal presently diverts about 76,000 acre-feet of water annually.

Tracy Pumping Plant began operations in 1951 to deliver up to 4,600 cfs to the Bureau's Delta-Mendota Canal. Present normal exports through this facility are about 1,390,000 acre-feet per year.

Recent, authorized, and planned development for the use of water in the tributary basins and export from the Delta will further drastically alter natural Delta conditions. These developments will reduce the Delta outflow to only some 1,000,000 to 2,000,000 acre-feet annually. The situation has been studied extensively and several plans have been presented for maintaining the riparian rights of the Delta users, and for providing suitable water quality for the large Delta export. These are (1) hydraulic barriers, (2) physical barriers, (3) Delta waterway control, and (4) a peripheral canal. All of the plans have received extensive study and are reported upon in numerous reports. The complexity of the interlocking problems and possible solutions indicated the need for a high degree of coordination among Federal, state and local Government agencies. For this reason, an Interagency Delta Committee was formed to formulate a concept for the integration of the various Delta programs and arrive at a mutually acceptable coordinated plan. The objective of the plan is a comprehensive optimum development, recognizing the economics of agriculture, industry, recreation, navigation, fish and wildlife, and water development.

The recommendation from this coordinated study was the Peripheral Canal plan, shown in Figure 5. The canal, with an initial capacity of 21,800 cfs, will provide for conveying 16,800 cfs to the south side of the Delta for export and for releasing 5,000 cfs to the various Delta channels.

WATER QUALITY RELATIONSHIPS AT POINTS OF AGRICULTURAL USE

Water quality and its relationship to crop production is of primary importance to the irrigators and the irrigation planners. In appraising the suitability of the available water in a particular situation, many variables must be considered. For this reason, we do not believe that a numerical rating system can be established for irrigation water which would be valid for the many conditions found throughout the West. Because of this, the suitability of the available water must be determined for each individual area.

Dregne ( ) has summarized the factors that are important in determining the suitability of water to a particular land area. These include the concentration and chemical nature of the water, and the influence of soils, crops, climate, irrigation practices, and drainage. The first

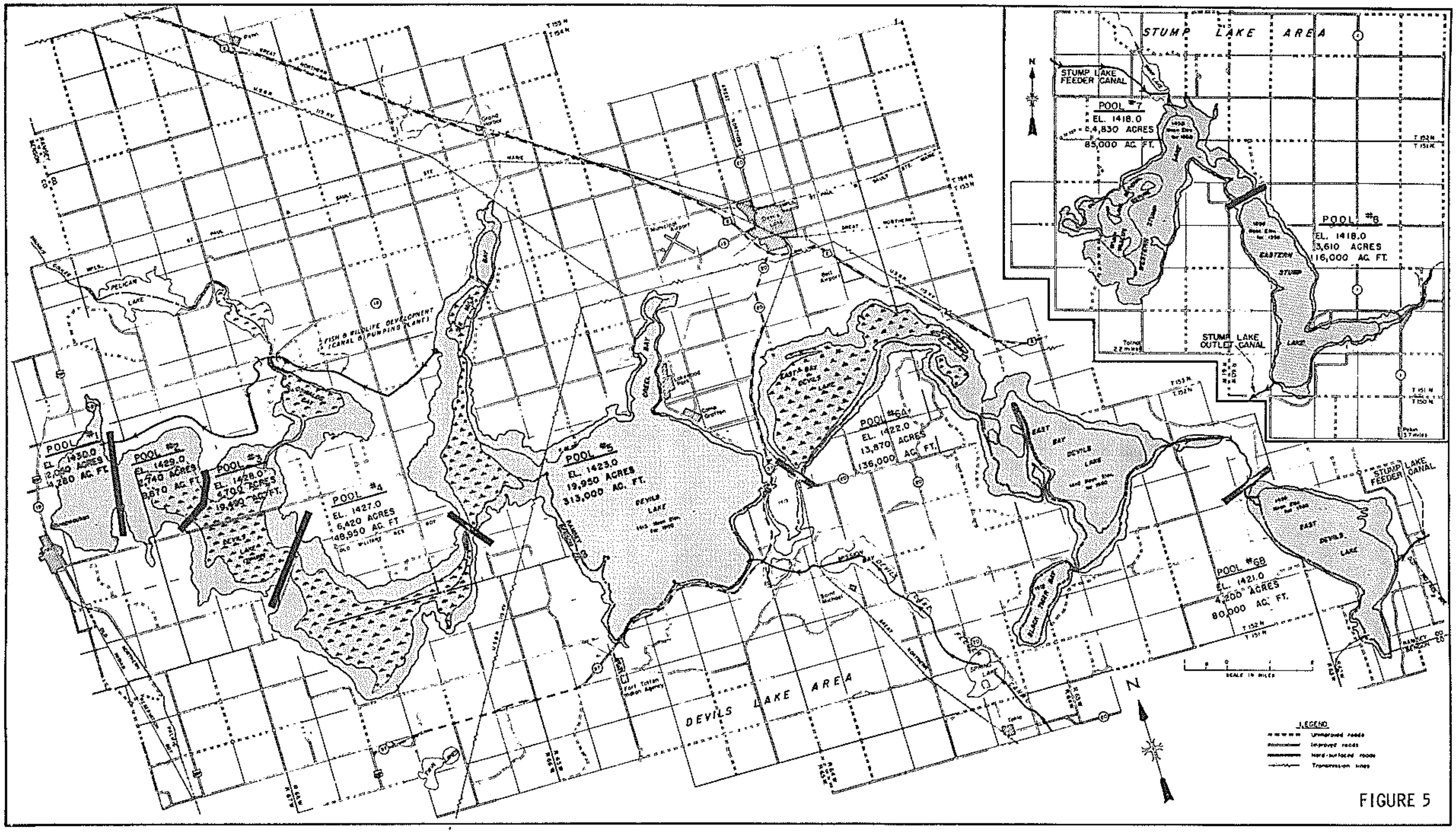

STUMP LAKE AREA
STUMP LAKE FEEDER CANAL
POOL #7
EL. 1418.0
4,830 ACRES
85,000 AC. FT.
POOL #8
EL. 1418.0
3,610 ACRES
116,000 AC. FT.
STUMP LAKE OUTLET CANAL
PELICAN LAKE
FISH & WILDLIFE DEVELOPMENT (CANAL & PUMPING PLANT)
POOL #1
EL. 1430.0
2,050 ACRES
4,280 AC. FT.
POOL #2
EL. 1429.0
2,740 ACRES
8,670 AC. FT.
POOL #3
EL. 1428.0
4,700 ACRES
19,490 AC. FT.
POOL #4
EL. 1427.0
6,420 ACRES
48,950 AC. FT
POOL #5
EL. 1423.0
19,950 ACRES
313,000 AC. FT.
DEVILS LAKE
POOL #6A
EL. 1422.0
13,870 ACRES
136,000 AC. FT.
EAST BAY DEVILS LAKE
POOL #6B
EL. 1421.0
4,200 ACRES
80,000 AC. FT.
EAST DEVILS LAKE
STUMP LAKE FEEDER CANAL
DEVILS LAKE AREA
N
LEGEND
Unimproved roads
Improved roads
Hard-surfaced roads
Transmission lines

FIGURE 5

consideration is the concentration and chemical composition of the dissolved solids in the water and the presence of ions such as boron which is toxic to plants even in low concentrations. Although high total dissolved solids are detrimental to plant growth, the cation distribution may also have a very significant long-term effect on land productivity.

Suitability of water for irrigation is closely related to soil characteristics. Soil with a moderate to high hydraulic conductivity can be successfully irrigated with waters of lower quality than soil with a low hydraulic conductivity. Water containing a high proportion of sodium to calcium and magnesium ions can reduce the rate of movement of water through soil. An exchange of sodium ions in the water with calcium and magnesium ions of the soil clay may destroy soil structure and cause swelling of the soil upon addition of water. This dispersion of colloids usually reduces the rate of water infiltration into or percolation through the soil and in some instances may result in a completely impermeable condition. The opposite effect results from use of water with high concentrations of dissolved solids. Henderson showed that soil permeability increased in direct relation to the concentration of the water. This principle was forcefully demonstrated by the results of an exchange of water in the San Joaquin Valley of California under the operation of the Central Valley Project. Waters containing 175-350 ppm dissolved solids were exchanged for water containing 40-60 ppm. The exchange water greatly increased the permeability of the soils which resulted in a shorter time being required to irrigate the crops, better internal drainage, reduction of tendency to develop salinization and an overall increase in production. Enlargement of ditch structures, and drains are necessary.

Climatic factors further influence the suitability of water for irrigation which can be used successfully on a particular area. Using saline water of the same quality affects crops less in cool regions than in hot, dry areas. Water of poorer quality can be used in a subhumid climate than in arid regions. Rainfall which adds little or nothing to the salt load, dilutes salt added to the soil by irrigation water and is often sufficient to leach the salts out of the root zone.

Selection of the method of irrigation and degree of land development may be influenced by the need to use water of poor quality. Although certain irrigation practices are likely to increase the salts less than other methods, the proper use and handling of water is probably more important than the method used to distribute it. Inadequate or improper leveling may result in soil salinization from use of saline water regardless of the irrigation method used.

WATER QUALITY RELATIONSHIP AT POINT OF RETURN

Some of the most important processes which influence quality of water in its journey from the farm turnout to the drain are precipitation or dissolution within the soil, concentration due to evapotranspiration,

ion exchange between the water and soil, accumulation of sediments due to soil erosion, pollution from other sources, and heat exchange with the soil.

Concentrations of dissolved solids may increase from 2 to 10 times in the return flows from irrigated lands compared to the irrigation water. This may be due primarily to evapotranspiration, although the dissolution of residual salts in the soil may also be an important factor. The pickup of salt from the soil occurs primarily during the early years of irrigation, and if the substrata materials are saline may be an important factor affecting return flow quality. The salt balance concept described by Wilcox (*) is the relation between the quantity of dissolved salts carried to an area in irrigation water and the quantity of dissolved salts removed by the drainage water. To maintain a favorable salt balance in the soil, as much or more salt must normally be removed in the return flows as is introduced in the irrigation water.

As water percolates through the soil, the chemical composition of dissolved salts may change. Exchange of cations in the water and those of the soil result in the gain of some and loss of others.

Nitrates are often picked up by percolating waters, chiefly from commercial fertilizers and manure applied to crops. Phosphates and potassium applied as fertilizers usually do not leach readily from the soil. Other sources of nitrates which are picked up by return flows are those from barnyard and silo effluents, a small amount from precipitation, nitrogen fixation in the soil, and surface drainage waters.

Other factors are involved when water percolates through the soil. The soil acts as a filter and removes suspended solids, as well as coliform bacteria, thereby reducing or eliminating turbidity and improving the potability of the water.

Pesticides or other agricultural chemicals may be a source of water pollution, and are frequently found in the surface runoff from treated irrigated fields. Current knowledge about the extent of pesticide residues in water resources is meager and knowledge about the significance of these residues and their effect on water supplies is even less.

There are several practices which could be carried out to maintain or improve the quality of irrigation return flows. Lining of canals and laterals and increasing irrigation efficiency, reducing percolation losses, may be beneficial under certain circumstances. The percolating water often displaces the more saline ground water which comprises return flow thereby increasing the salt load returning to the stream.

Some promising techniques to reduce leaching of nitrate fertilizers involve the use of slow-release nitrogen compounds, coating of fertilzer to slow the rate of release, and incorporation of nitrifying inhibitor in fertilizers. Reduction of the quantity of nitrate lost by leaching may be achieved by use of anhydrous ammonia fertilizers, since these are mostly in the ammonium form and will be fixed to clay particles after reacting with the soil moisture.

Other means of improving water quality in streams is control of nonbeneficial consumptive uses of water. Control of phreatophytes along irrigation distribution systems, drains, reservoirs, and flood plains may increase the quantity of water without an increase in the total salt load.

The ability to predict water quality changes resulting from irrigation is desirable if not essential. Prediction of return flows is complex and involves a number of factors. A computer program is being developed to meet Bureau of Reclamation needs in predicting the chemical composition including ion exchange and concentration of the solution phase of the soil. Another program is being developed to predict the quality of water leaving the bottom of soil column. If successful, this will provide one of the critical parameters needed to obtain an estimate of the quality of the return flow. Other research is being undertaken on the value of desalted water for irrigation use.

The effect of irrigation depletions on the quality of stream discharge may be small depending on the proportion of available supply which is diverted for irrigation and other factors. Sylvester and Seabloom calculated the water quality for lower Yakima River if irrigation had not been developed. Their findings showed an increase from 40 to 210 ppm dissolved solids during the irrigation season and an increase from 80 to 160 ppm during the nonirrigation season as a result of irrigating 375,000 acres. The increase in dissolved solids and the increase in concentration of individual ions was not enough to make the water less desirable for most downstream uses.

In summary, the increased emphasis being placed on water quality control and the requirement for the development of standards for interstate streams presents a real challenge to those engaged in irrigation planning to develop procedures for predicting the influence of irrigation on water quality. Such predictions will become the focal point for development of the structural and nonstructural measures needed for maintaining and improving water quality.

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SEDIMENT AND ITS EFFECT ON WATER QUALITY

Elliott M. Flaxman[1]/

INTRODUCTION

This paper describes the water uses that are affected by sediment, how these uses are affected, the impact of sediment on water quality in New Mexico and the factors which contribute to its presence.

The word "sediment" has several meanings, depending upon its use. To the geologist it is usually considered to be finely divided rock fragments; however, the common visual test for the degree of pollution in terms of turbidity does not distinguish one source of the material from another when it is in suspension. Turbidity is defined as the degree of opaqueness of water due to the amount of fine matter in suspension. Sediment is defined in this paper as inorganic or organic particles originating from weathering, chemical precipitation, or biological activity, and transported, suspended, or deposited by water, air, ice, gravity, or combinations of these agents.

Turbidity tests measure the amount of light penetration in water, usually in terms of Jackson turbidity units. The standard unit of turbidity is that produced by one part per million of silica diatomaceous earth or fullers earth) in distilled water (1). The depth at which a light image from a candle or other artificial source disappears is the calibrated level of turbidity. The turbidity test does not correlate with determination of sediment concentrations. In this determination, the sediment in a representative sample of a water-sediment mixture is dried and weighed. The percentage of this weight to the total sample is reported in parts per million. Reasons for a lack of correspondence include the fact that color can affect the amount of light penetration without the presence of suspended particles and that finer particles intercept light more effectively than coarser particles even though the weight of sediment in two samples is the same.

WATER QUALITY PARAMETERS AFFECTED BY SEDIMENT

The following is a brief description of standards for good quality water pertaining to sediment content. These standards are based on experience in the use of water affected by sediment.

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1. Water Supply, Drinking, Culinary and Food Processing.

Water for these purposes should have a clarity equivalent to less than 5 Jackson turbidity units (2) or no greater than 10 parts per million by weight (3). The small amount of sediment that could be present to keep within this standard would not usually be visible to the eye. Reasons for high standards include the aesthetic value of clear water, greater palatability, and greater ease of ridding water of bacteria when it is nearly free of suspended solids.

2. Industrial Water Supply.

The American Water Works Association (4) has recommended desirable upper limits of turbidity in parts per million (silica scale) for the following industrial processes:

Brewing	10 ppm	Soda and sulphite	15 ppm
Carbonated beverages	2 "	Light paper	5 "
Paper and pulp		Tanning	20 "
Groundwood	50 "	Textiles	5 "
Kraft pulp	25 "		

3. Bathing, Swimming and Recreation

The two factors which determine limits on the presence of sediment for these purposes are safety and aesthetics. Inability to see the bottom of swimming pools and lakes when diving or wading can result in serious injury, while muddy water reduces the enjoyment for both swimming and boating. A desirable objective is that Jackson turbidity units be less than 25 under conditions where quality control can be exercised. In swimming pools, the water should have sufficient clarity for a black disk, 6 inches in diameter, to be readily visible when placed on a white field at the deepest place in the pool. (5)

4. Growth and Propagation of Fish and Other Aquatic Life.

The problems of identifying and describing the influence of sediment on aquatic life is indicated by the variety of data on this subject. Certain degrading effects on spawning and habitat have been clearly established, without necessarily providing qualitative values. The effect of sediment on the aquatic environment includes inhibition of photosynthesis, destruction of benthonic organisms and damage to fish, as described by Hoak (6). Sunlight is essential for the synthesis of organic matter by plants and chlorophyll-bearing organisms. Data by Ellis (7) shows that turbid water reduces light penetration about 50 percent and muddy water, about 75 percent. Deposition of sediment on a stream bed can have several damaging effects. It tends to smother both organisms which contribute toward purification of the stream and those which provide food for fish. Fine sediment tends to clog the pores in gravel bed streams. This reduces the circulation of oxygen-rich water which sustains the viability of eggs deposited for spawning by fish. In addition to these effects, Bartsch (8) has pointed out that inert particles in settling to the bottom carry organic flocs and absorb finely dispersed organic matter. This may create anaerobic conditions of an objectional nature, such as the boiling up of gases. Turbid water may provide for slightly cooler bottom temperatures, an advantage to habitat if temperature approaches a critical value.

Many reports have indicated that sediment can clog or cut the gills of fish and mollusks, resulting in serious injury or death. After an intensive study of the literature, Cordone and Kelly (9) have concluded that there is no universal answer as to whether sediment is directly harmful to fish, but that there is no question that it is damaging to feeding and spawning grounds. There is also strong evidence to indicate that the catch in trout fishing streams is small at fairly low suspended sediment load concentrations. Apparently the fish cannot see a lure at moderate or high concentrations.

5. Agricultural Water Supply.

Sediment affects use for irrigation by sprinkler systems or surface application, for injection or spreading of water for underground recharge, and for consumption by livestock.

In sprinkler irrigation, excessive wear of nozzle heads and fittings occurs when sediment of very fine sand (0.074 mm.) or coarser size is present in the distribution system. The extent of wear by concentrations of silt size particles is not known, but a minimal concentration of fine sediment is deemed desirable. In spreading of water for recharge, Schiff (10) has reported that a sediment concentration up to 575 ppm. has been handled when a grass cover maintained an open, friable surface soil, but that water with the same sediment concentration reduced infiltration rates drastically on nearly bare ground with the same soil. Other experience has indicated that extended application of water with concentrations exceeding 200 ppm. tends to clog pore spaces and lowers the efficiency of application. In the use of injection wells for ground water recharge, even a small amount of sediment may reduce the intake rate substantially.

In diversion of irrigation water, the water-sediment mixture is frequently in the same concentration as in the stream flow. The coarser sediment sizes then deposit in canals and diversions and the fine materials in laterals, farm ditches and fields. A minimum cost of maintenance for these installations would require relatively clear water, particularly exclusive of all sand sizes and gravel.

THE EFFECT OF SEDIMENT ON WATER QUALITY IN NEW MEXICO

According to an inventory by the U. S. Public Health Service (11), there are about 6 communities in the State where a major or exclusive supply of water is from surface diversion or storage. The population served by these facilities is about 53,850, of which 25,000 are in the City of Farmington. The other approximately 250 communities and industrial users obtain their water from wells or springs. The subsurface supplies being used as the principal source in New Mexico are free of sediment. Each of the communities using surface supplies, with the exception of Las Vegas, have sedimentation treatment installations to eliminate both inert particles and flocs of dissolved solids. Sediment concentrations are relatively low where surface runoff is used, except in the northwest part of the State.

Sediment is one of several causes of limited recreational use, including swimming and fishing, of many New Mexico streams. The intense storms that occur during the summer when enjoyment of the streams is possible produce by far the heaviest sediment yields of the year. In addition to high concentrations of suspended sediment which move through the system, stream beds are covered by an undesirable layer of soft sand which has been brought in over geologic and modern times. According to the Proposed Water Quality Standards for the Rio Grande River in New Mexico (12), the river above the mouth of the Chama and the Chama above El Vado Reservoir are good to excellent fishing streams; Elephant Butte Reservoir and downstream to Percha Dam are excellent for warm water fishing. The stream reaches that make for good fishing and other recreational pursuits also coincide with contributing watersheds that have the lowest erosion in the State. The major reservoirs provide sufficient capacity for stored water to become clear through deposition of incoming sediment.

Sediment probably has its greatest impact in New Mexico on the quality of water used for irrigation. Accumulation in canals, laterals, and farm ditches requires cleanout, and deposition on fields reduces permeability or requires releveling for efficient water application. A sampling of the cost of cleaning sediment from farm ditches in the Rio Chama-Espanola watershed indicated that the cost per cubic yeard averages about 76¢ for earth lining and $2.00 for concrete lined ditches. A cubic yard is equivalent to about one ton of sediment.

Figure 1 shows the location of principal areas irrigated by surface water or a combination of surface and ground water as related to major sediment source areas. The data were obtained from maps prepared at New Mexico State University (13) and by Thorp (14).

An analysis is being made to determine the principal factors which contribute to reservoir sedimentation in the western part of the country. Preliminary results that have been published (15) point up the reasons why much of New Mexico is highly vulnerable to erosion. These include

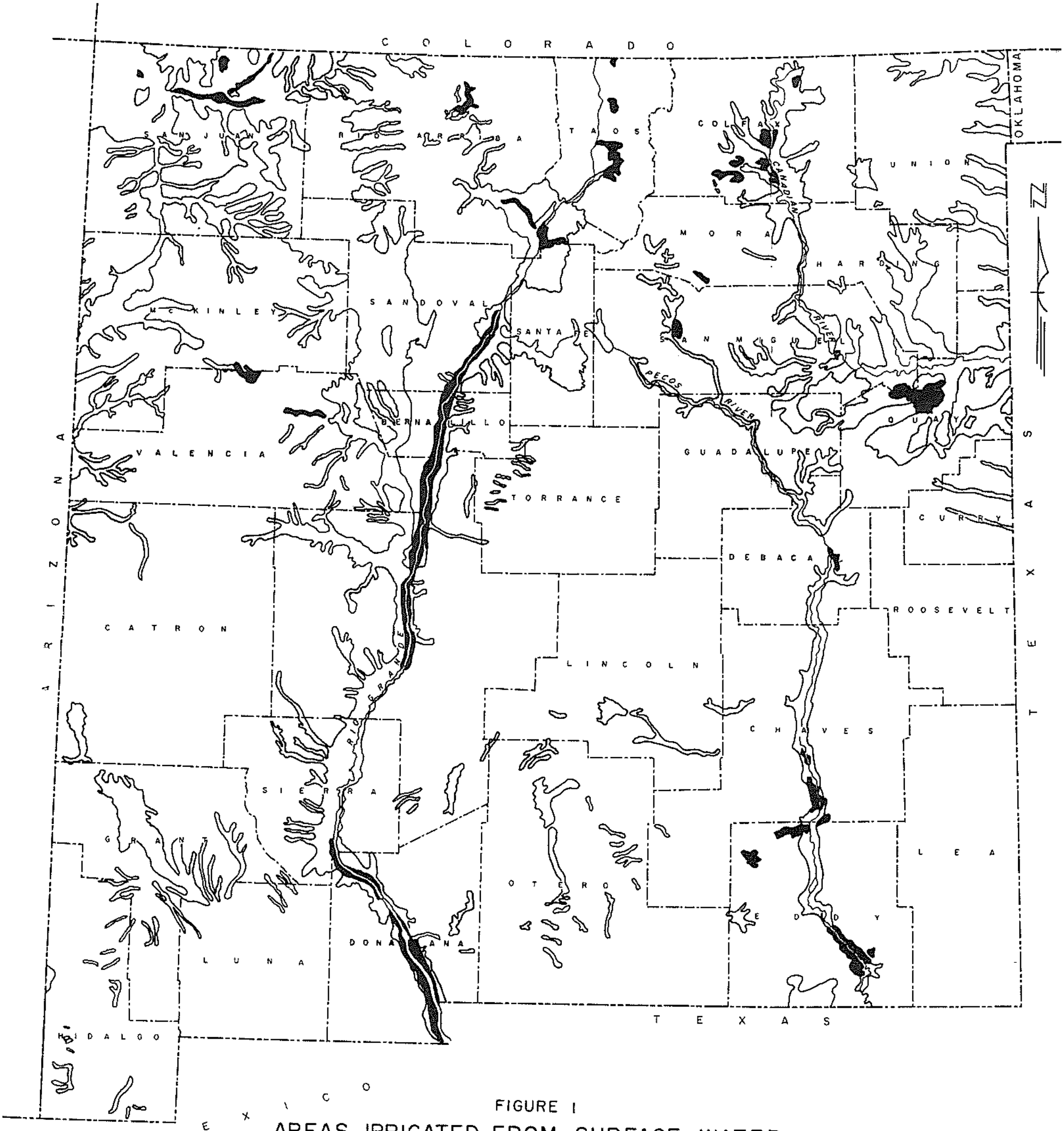

FIGURE I

AREAS IRRIGATED FROM SURFACE WATER RELATED TO MAJOR SEDIMENT SOURCE AREAS

NEW MEXICO

MARCH 1967

LEGEND

Land irrigated with surface water or with surface and ground water.

Major sediment source areas.

a limited amount of moisture for plant growth, moderate to steep terrain with a relatively high drainage density, and very unstable soils. The studies indicate that salts in the soils contribute to their erodibility. It is suggested that the marked increased in dissolved solids in water of the Rio Grande during the summer storm season is linked to the high erosion that occurs over most of the basin. This cause of increase would be in addition to removal of the salt crust which develops on the soil surface from capillary action. Erosion exposes new layers of underlying salty subsoil and parent material. Dortignac (16) has pointed out the attendant relationship between increased salt content and increased sediment concentration in streams. The climate, topography and soils which are the major elements contributing to the high sediment load of New Mexico's streams create a watershed condition highly sensitive to relatively minor disturbances.

The proposed Water Quality Standards for the Rio Grande excludes from pollution subject to regulation, turbidity which is naturally caused by silt and suspended sediment or from the operation of irrigation or flood control facilities. The proposed standards for the Pecos River (17) exclude silt and suspended sediment but not other "significant sources of turbidity" as subject to abatement. These recommendations understandably recognize the problem of abating sediment concentrations by attempting control of natural phenomenon with regulation. The Soil Conservation Service in December 1966 suggested changes be considered for the proposed Water Quality Standards for the Rio Grande. These changes include a recommendation that "Naturally occurring turbidity caused by silt and suspended sediment or from operation of irrigation, flood control facilities, or land treatment measures are not subject to regulations unless more efficient and economical measures could be instituted to alleviate the turbidity conditions. Then the turbidity would be subject to these regulations."

The above proposal recognized that there is a potential for reduced sedimentation in New Mexico streams. In evaluating the effects of land treatment, it is generally assumed that the best one can do in reducing erosion is to return it to the so-called normal geological rate. As one facet of the effort to make such an interpretation, much has been written and discussed about the origin of valley trenches which have contributed so substantially to high sediment yields of watersheds such as the Rio Puerco. Speculation on such topics does not rule out the fact that the potential for sediment control can be classified by sites in such categories as those subject to agronomic or management measures or subject to structural measures, or combinations of these, and finally those sites not subject to control.

It is possible to estimate quantitatively the reduction in sediment yield by installation of measures for stabilization or control of sources. Evaluation of benefits in terms of improved water quality may be simple or complex, depending upon the physical conditions and the standards which must be met for specific water uses. Benefits of treating an identifiable source of water-born sediment depositing in a canal or entering a domestic water supply system may be easily determined. As the types and sources for degrading sediment become more numerous it is necessary to determine the proportionate contribution of each source to the problem. Benefits would be reduced costs of removal or of water treatment. However, certain uses require that water quality be of a specific standard on arrival at the place of use. Stream recreation and fish habitat are of this type. The option of treatment immediately before or sediment removal after the use may not be available. In these instances it will be necessary to first determine whether watershed treatment can reduce sediment concentrations to acceptable standards for the specific use. The economic feasibility of physically effective measures must be judged on the basis of their downstream impact, of which water quality is one, and on their on-site benefits.

SUMMARY

Water quality standards pertaining to sediment indicate that turbidities or concentrations must be very low for municipal and industrial use and only slightly higher for recreational use, including sport fishing and swimming. For supplies of municipal and industrial water New Mexico is fortunate in that the major source, ground water, is generally free of sediment. However, irrigation water, drawn chiefly from surface supplies, is usually high in sediment concentrations and in damage to distribution systems. Opportunities exist for reduction in sediment yield. Certain programs in this field, not otherwise justified, may be feasible with the added benefits of water quality improvement.

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WATER QUALITY RELATIONSHIPS FOR URBAN AND INDUSTRIAL USES

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Quality water has not been defined in simple terms in spite of all that has been said and written about it. There are many classes of water users, each with specific requirements and quite often the characteristics that make a particular water objectionable to one group are unimportant or even desirable to other groups. Perhaps there is no simple definition for the term because it means a different thing to different people. To the sanitary engineer it has one connotation, to the industrial engineer it means something else and to the agriculturist it has still another meaning.

Water quality specifications for cooling the condensers in an electric generating plant or in the manufacture of steel differ greatly from those required for bottling soft drinks, brewing beer or air conditioning. Water that is satisfactory for agriculture is far from adequate for domestic use or for the production of steam. Fortunately, most water users have some flexibility in the specifications which determine the suitability of a water for their particular requirement. For such users, the average domestic quality water will suffice with a minimum amount of treatment. For those uses that have restrictive specifications, it is necessary that extensive treatment be given to the water and close control be maintained over the quality. Boiler feed water for the production of steam to be used in high pressure boilers is an example of a water requiring special treatment. Water required in the manufacture of pharmaceuticals is another example.

The home owner considers water to be of good quality when it is clear, free of odors, tastes or colors, non-staining, cool, safe to drink and reasonably soft. In recent years, with the advent of so many water operated home appliances the domestic user is beginning to demand a few additional qualities. There are inquiries from many sources about the fluoride content, the hardness, the total mineral content, and the sodium content.

One thing is quite certain--water users of all classes are becoming more conscious of water quality if one can judge by the number of inquiries that are received in our offices. These inquiries are from engineers, consultants, business people, motel owners, and most of all, from school children. The ringing telephone quite often heralds some slight change in the quality of water being delivered to the customers. Raymond J. Faust, Executive Secretary of the American Water Works Association, says

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"the people want water that meets the needs of the home much more closely than do our present supplies."

Processing water in a public water utility to meet the needs of the many classes of users is quite impractical. As a result each public utility adopts a set of quality specifications, influenced in some degree by the quality of raw water available for treatment, and attempts to maintain the same quality at all times through constant control methods. The water produced under these conditions should meet the needs of all domestic users, should be safe, sparkling clear and free of taste and odor. It should conform to the U.S. P.H.S. Drinking Water Standards in every respect and far exceed them in most respects. Users that require a water of different characteristics must then supply any additional treatment needed.

Perhaps most of you are not aware that the earliest water system in this country was for the purpose of providing water for fire fighting. No quality controls were necessary for this type of water. As the community grew and the system expanded beyond the one street it originally served, the demand for a water suitable for human use caused the upgrading of the quality of water in the system. This has been the pattern followed through the years. The demands of the customers have resulted in the improvements in quality and in close quality controls. This must continue to be the pattern and when the customers require a higher quality of water and demand that it be furnished, the demand will be met.

Water has a number of characteristics that are quite interesting, some of which are quite beneficial to man and some of which are not so advantageous. As we all know, water travels in a cycle. Nature is constantly freeing water of all its impurities and transporting it from low places to higher elevations and releasing it to flow again toward the low places. It is fortunate for mankind that water is released, free of all impurities, at higher levels. This makes water available to man all over the earth. Unfortunately, water is an excellent solvent and picks up various minerals as it moves through and over the earth's crust. Because water is moving toward the low places, man takes advantage of this fact and puts his unwanted wastes in the stream to be carried along. These minerals and wastes constitute the problems we have in using water.

Fortunately, the water is not permanently affected by any of these minerals it has dissolved or the man made wastes that have been discharged into it. They can all be separated from the water by appropriate methods. Some of the materials can be separated easily and at very little cost. Others can be separated only by use of more expensive methods. From this over-simplified version of the water cycle, it is obvious that the cost of water treatment must be balanced against the desire for higher quality in the water we use.

In the early days there was no knowledge of the germ theory of disease and the quality of the water was judged solely by the physical qualities. With the explanation of the germ theory and the introduction of such devices as the slow sand filter, and later, the rapid sand filter, the sanitary quality of water was improved. Use of coagulating chemicals, and later, the introduction of chlorine as a disinfectant made possible the production of drinking water that was practically free of turbidity and free of harmful bacteria. The health authorities and the water supply agencies have been diligent in their efforts to protect the health of the public. The extent to which they have succeeded is demonstrated by the drastic reduction in water borne diseases over the past 50 years.

In a large measure, the establishment of the U.S. P.H.S. Drinking Water Standards has had a great deal to do with the steady improvement in the quality and safety of the public water supplies. In the U.S. one can drink from a public water fountain anywhere in the country with no fear for the safety of the water. There are very few other countries in the world where this is true.

The drinking water standards were first promulgated in 1914 to protect the health of the traveling public. These standards were not obligatory for use by municipally or privately owned water systems unless they served as watering points for railroads, ships or passenger carriers of some type. The standards have been revised from time to time as changes in the environment have brought about the need for change. Major revisions were made in 1927, in 1942 and again in 1961-62.

The revision of the drinking water standards in 1961-62 was accomplished through the combined efforts of representatives of fifteen major organizations interested in the health and welfare of the public, the quality of water in the streams and the quality of water served to the public. Included in the group were such organizations as the U. S. Public Health Service, the American Water Works Association, and Water Pollution Control Association and the National Committee on Radiation.

The drinking water standards are generally accepted as the minimum standards throughout the U.S. A water supply will, in most cases, far exceed the quality required by these limiting criteria. Water supplies that exceed the limits in more than two or three of the categories are considered unsatisfactory. It has been stated that as many as 1,000 to 1,500 water supplies in the U.S. could be classed as unsatisfactory on this basis.

The criteria are listed in two groupings. Those substances considered toxic and known to have harmful effects upon humans are listed in one group. If a water supply contains one of these minerals in excess of the limiting value, the supply should be rejected as unsatisfactory.

Another group includes substances that are undesirable above the limits shown. Supplies containing one or more of these substances in amounts greater than listed are rated as undesirable.

The substances that are objectionable in drinking water and their limiting value are listed below in the two groups mentioned.

HARMFUL SUBSTANCES

Substance	Concentration-ppm
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Cr^{+6})	0.05
Cyanide (Cn)	0.2
Fluoride (F)	Varies with temp
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

UNDESIRABLE SUBSTANCES

Substance	Concentration-ppm
Alkyl benzine sulfonate (ABS)	0.5
Arsenic (AS)	0.01
Chloride (Cl)	250.
Carbon Chloroform Extract (CCE)	0.2
Cyanide (Cn)	0.01
Fluoride (F)	0.4-1.2 Varies w/ temp
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45.
Phenols	0.001
Sulfate (SO_4)	250.
Total Dissolved Solids	500.
Zinc (Zn)	5.0

Both industrial and community wastes have gone into our streams in the past with little or, at best only partial treatment. No one seemed to feel that this was wrong and full advantage was taken of the diluting effect and assimilative capacity of the stream to hold down capital investments as well as operating costs. In most instances this caused no particular problem until the volume of wastes grew to such proportions that the streams could not assimilate the load. Now, the load of wastes being discharged into our waterways has become so great that many of the streams are virtually open sewers and have no value for any other use.

An alarmed Congress passed the Water Quality Act in 1965 establishing a Water Pollution Control Agency and charged the Agency with the responsiblity for control and abatement of stream pollution. The federal agency has requested each state to prepare suitable stream standards that will prevent further deterioration of the quality in the streams. It will be very interesting to observe the manner in which the Water Pollution Control Agency, the State Pollution Control agencies and local authorities cooperate to bring about the abatement of pollution.

Not only are the streams being overloaded but many new types of wastes are being introduced into the streams. Most of them are of industrial origin but some originate in the domestic wastes. Some are known to be dangerous to human beings, while others are still on the doubtful list. Not enough research work has been done to determine the effect of long time consumption of water containing the substance in question.

Organic compounds constitute the greater portion of these new contaminants. They come from chemicals used as insecticides, fertilizers, detergents, paints, lubricants, automotive fuels, and many others. The identification and detection of these compounds is extremely difficult and in many instances no method is known at this time for positive identification. It is possible for the well equipped and well staffed research laboratories to identify most of them but the average water utility laboratory makes no attempt to detect or measure these compounds. Fortunately, it is possible to get assistance in this work from federal and state agency laboratories for analyses of quarterly or semi-annual samples.

The concentrations involved are very small, being in the order of a few parts per million down to a part per billion. While this may seem like an insignificant quantity to those of us accustomed to thinking in terms of tons per acre foot or grains per gallon, some of these contaminants have caused sizeable fish kills in concentrations of less than one ppb.

The literature does not report any direct or physiological damage to human beings as a result of the consumption of water containing present day low concentrations of these organic pollutants. It is known that they cause objectionable odors and tastes, foaming, high clorine demands, and fouling of ion-exchange media. We have no knowledge yet of the long term effect of consuming water with one or more of these contaminants. Research projects are in progress on this subject as well as many other aspects of the effect of the organic compounds upon human beings.

The method used to extract the organic compounds from the water is based upon the tremendous adsorptive power of activated carbon. Large quantities of water are filtered through carbon and the carbon is then subjected to chloroform to extract those substances soluble in chloroform. Evaporation of the chloroform leaves the extracted materials for possible identification. The method was developed by U.S. P.H.S. research technicians in connection with their water quality network project. More than 150 sampling points covering all the major rivers in the U.S. are taking part in the project and send monthly samples to the Taft Memorial Center at Cincinnati. Quarterly reports of the results of the program are distributed to all participants. Interested persons or agencies can get the reports by requesting to be placed on the mailing lists.

Some of the compounds that have been detected and identified include DDT, Aldrin, orthonitrochlorobenzene, tetralin, napthalene, chloroethyl ether, acetophenone, dephenyl ether, pyridine, nitriles, aldehydes, ketones and alcohols. To date no safe limit for any of these substances has been established.

After chloroform extraction the carbon is then treated with ethyl alcohol and additional organic compounds may be extracted. Frequently there remains a portion of the extracted material from one or both extractions that cannot be identified by known methods. Obviously there must be some concern about the presence of unidentified substances. Much work needs to be done in the development of methods to identify and test these unknown portions of material.

The increased use of insecticides, herbicides and pesticides is another cause for concern. There are over 9,000 compounds of this type manufactured and more than one and one-half billion pounds are produced annually. Some 50,000,000 acres are sprayed each year by airplanes. Wind and air drift causes some of the compounds to enter streams and lakes. Runoff carries more into the waterways. Some of these compounds, such as DDT, are known to accumulate in the body. DDT has been isolated from the bodies of animals in very remote parts of the earth.

The water plant operator and the health authorities need to know more about the effect on the quality of the water when it receives these and other agricultural chemicals. Investigations have shown little to cause concern to date. What we need to know is the effect of increasing concentrations.

Infectious hepatitis is the only virus that is definitely known to be transmitted by means of drinking water. In a few epidemic outbreaks of poliomyelitis, water has been suspected, but not proven, of being the carrier. In outbreaks of other enteric virus diseases where the exact cause was not determined it was stated that water could have been the carrier, along with several other common vectors. Epidemiologists have failed to implicate water as the carrier in these virus disease outbreaks but there are those who continue to point to the possibility.

Investigation has shown that in every case where water was suspected of being the carrier, the public water supply did not conform to the U.S. P.H.S. Drinking Water Bacteriologic Standards. These studies also show that where filter effluent turbidities are kept below 0.2 units consistently and a chlorine residual of one ppm is maintained in the clear water, the incidence of virus disease is very low. On the basis of experience and the evidence obtained in these studies, it seems reasonably safe to say that outbreaks of water borne infectious hepatitis are unlikely where the water conforms with the drinking water standards. The principal concern of the health authorities is that the level of virus pollution may increase to the point that present-day methods are not adequate to prevent the viruses from passing through the plant. Primary sewage treatment does not significantly reduce the virus concentration and the activated sludge process removes only about 90% of the viruses placed in the raw sewage in field experiments.

A few years back there was much written about the effect of fallout of radioactive particles. Research since that time indicates that radioactive material in drinking water can be harmful. Strontium 90 and Radium 226 are both deposited in the bone structure, interfere with the production of blood cells and cause leukemia. The three radio nucleides known to exist in water include the two mentioned and gross beta particles which include the other radioactive substances.

Samples have been collected from the Rio Grande at El Paso for about eight years for the water quality network program. You may be interested to know that the reports on radioactive substances, the organic chemicals and other harmful substances in the water are shown to be quite low in concentration and much below the recommended levels.

Having discussed briefly the nature of the many new contaminants, let us turn to the water treatment plant and see how well it functions in the removal of these impurities. Water plants are being built today on much the same principles as 30 years ago. Coagulation and flocculation, sedimentation, filtration and chlorination provide the basic stages of treatment and even the chemicals and the basin sizes are about the same. The organic compounds are not removed by these processes. Chlorination has little effect upon them. They cannot be flocculated and settled out. The only method that has been found to be effective is that of adsorbing the compounds on activated charcoal particles. Research indicates that an effective method of producing a water relatively free of the insecticides, the chlorinated hydrocarbon and the organo-phosphate materials as well as the viruses is to pass the filtered water through a deep bed of activated charcoal. Such a procedure would require a change in the design of plants. An alternate proposal is to replace the top portion of the filter media with granulated activated charcoal.

There is a great need for improvement in the design and in the operation of water treatment plants to meet the challenge imposed by the presence of new pollutants in the raw water.

Why has the philosophy regarding the treatment of water remained essentially unchanged so long? There are at least three groups involved in the building of a water plant. The municipality engages a design engineer to build a plant. The engineer prepares plans which the health department officials must approve prior to construction. All three of these groups must share the blame for the delay in accepting new ideas. The municipality does not want to risk large capital outlays on untried procedures and methods. The health department official, feeling all the responsibility for a mistake in judgment will fall back on his shoulders, takes a very conservative attitude and approves only what he knows will work. The design engineer, the only one of the three with enough background and experience to properly evaluate new methods of treatment, is reluctant to take the time and incur the expense to research the new proposals. Of the three, the design engineer is most fitted by training, experience and knowledge, to be in a position to advance the art of water treatment.

Ironically, the responsibility of the health department officials for the health of the public may eventually be the very thing that will force these officials out of their conservative position. To maintain their present attitude is certainly not entirely in the interests of public health.

The A.W.W.A. endorses the U. S. P.H.S. Drinking Water Standards and has participated in the revisions of these standards. Nevertheless, there is a considerable number of A.W.W.A. members who feel that minimum standards are not sufficient to provide a stimulus that will cause the water utility operators to strive for a higher quality product. They feel there should be a set of criteria for drinking water of sufficient excellence that few, if any, waters could qualify as this "ideal" water. There should be a goal to attain.

There are over 20,000 water systems in the U.S., 90% of which serve communities of less than 10,000 population, and 80% of them serve less than 5,000 people each. It is not likely that all these systems have the facilities and the personnel to properly safeguard the water being served. It is the plan of the A.W.W.A. Task Group 2225M to devise a plan of rating each water system. The basis for rating would be the quality of the water, the facilities available and the qualifications and abilities of the personnel. The rating plan is designed to encourage the updating of facilities, the training of personnel and the improvement of quality of water.

The criteria are set up as guides or goals and are not intended as standards. Some of the criteria are limited at present by the sensitivity of the methods used in testing. Some will change as more information becomes available relating to the physiological effects of trace elements after long-time consumption.

The criteria for the "ideal" water are listed below and the limit for each is given in ppm except where otherwise indicated.

IDEAL WATER QUALITY - CHARACTERISTICS AND CONCENTRATIONS

Physical Characteristics	Maximum in Ideal Water
Turbidity	Less than 0.1 unit
Non-filterable residue	0.1
Microscopic & Nuisance Organisms	None
Color (true)	3 units
Taste	None
Odor	None
Chemical Characteristics (Toxic)	
Lead (Pb)	0.03
Barium (Ba)	0.5
Arsenic (As)	0.01
Cyanide (Cn)	0.01
Silver (Ag)	0.02
Selenium (Se)	0.01
Cadmium (Cd)	0.01
Chromium (Cr^{+6})	0.01
Insecticides, Total	None
Chemical Characteristics (Non-toxic)	
Aluminum (Al)	0.05
Iron (Fe)	0.05
Manganese (Mn)	0.01
Copper (Cu)	0.2
Zinc (Zn)	1.0
Nitrate - Inorganic (N)	5.0
Filterable Residue	200.0
Phenolic Compounds (as phenol)	0.0005
Chloroform soluble - Carbon Absorption	0.04
Alcohol soluble - Carbon Absorption	0.10
ABS	0.20
Hardness (as $CaCO^3$)	80.0
Coliform Organisms	Not more than one/1
Radioactive materials	
Grosbeta activity	100 pc/1
Radium	3 pc/1
Strontium	5 pc/1

In order to supplement existing supplies some communities may find it advantageous to remove excess salt from brackish waters rather than transport a better quality water long distances. There are several processes available to remove this excess mineral.

The Office of Saline Water is a government agency that is directing research and operating pilot plants to test several methods of converting saline waters to usable drinking water. The methods being tested include various versions of evaporating the water to separate it from the salts; freezing water and evaporation under partial vacuum. To date they have been quite successful in producing a good quality water but the cost of operations have been quite high. The costs have been dropping as experience has helped solve some of the problems but they still are quite high when compared with present-day prices for treated water from other methods. The lowest cost figures obtainable have ranged from $0.80 to $1.00 per 1,000 gallons as compared to the cost of about $0.10 per 1,000 gallons for a treated surface water and about one-third that for pumping well water

The use of electrically charged membranes to separate mineral salts from water is a patented process. Several smaller installations are in successful use, one being the plant at Buckeye, Arizona. Water is passed between layers of thin membrane material which bear a DC charge. The metallic ions in the water are attracted to the membrane that possesses an electrical charge opposite its own. Many of these ions pass through the membrane causing the water in alternate channels to be supercharged with salt particles and the remaining channels to have water with reduced mineral salts. The water costs about $0.40 to $0.60 per 1,000 gallons, depending upon electrical costs and membrane maintenance figures, and upon the amount of salt reduction required.

In the Industrial Engineering Journal an ion exchange process was reported which uses lime and sulphuric acid as regenerants to reduce 2,300 ppm solids to 500 ppm. Operating costs were stated to be in the order of $0.11 to $0.22 per 1,000 gallons with the cost of a one million gallon per day plant estimated at $300,000.

One of the more promising processes uses the ion exchange method. Instead of a fixed bed of resin, a closed loop with quick operating valves has been devised that permits continuous operation. Part of the loop contains a portion of the resin that is treating water to remove salts. Another portion of the loop contains resin that is being regenerated with an appropriate regenerant. A third portion of the loop is used to wash the regenerated resin. On a pre-arranged time schedule, the valves open, the resin is hydraulically shifted from one portion of the loop to the next and in less than a minute the flow of water is being treated with freshly regenerated resin. A one million gallon per day plant can be erected in a day or two after delivery and occupies a space of about 10' by 10'. Everything is automatically timed and chemical costs are greatly reduced over other ion exchange units. The cost of treating a 2,000 ppm brackish water to produce a 500 ppm quality water is estimated to be in the order of $0.10 per 1,000 gallons.

One of the newest processes proposed for reducing salt solids in water is called reverse osmosis. In the process of osmosis, if two solutions are separated by a semipermeable membrane, the liquid from the more dilute solution moves through the membrane into the more concentrated solution. The differential in pressure developed between the two solutions is called osmotic pressure. The reverse osmosis process consists in the application of sufficient pressure on a saline liquid to force it through a membrane. The liquid which passes through the membrane contains considerably less dissolved salt. Inasmuch as no change in form is required as in the standard saline conversion technique, it has promise of being much less expensive. Its success depends primarily upon the development of a suitable membrane.

In summary, it would appear that two opposing trends are involved in the problem of maintaining and improving the level of quality in our drinking water. The demand for a water which must steadily improve in quality is being made more difficult by the increase in population, the increase in pollution and rapid change in the kinds of contaminants. The problem of supplying a potable, safe and desirable water for domestic and industrial users has become a problem for both the waste treatment agencies and the water treatment operators. The responsibilities of the waste treatment plant operators must be extended and correlated with those of the water utility operator in order that the whole job of water treatment can be effectively accomplished.

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WATER QUALITY REQUIREMENTS AND RELATIONSHIPS FOR RECREATIONAL USE

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Mr. Chairman and conferees, the Bureau of Outdoor Recreation is pleased to make its interests known concerning water quality requirements and outdoor recreation. When I started this study of water pollution and its relationship to outdoor recreation, I hastily concluded that the title of this paper drew forth an obvious comment, "Of course we need clean water for all forms of water-oriented recreation activities." This statement is generally true. However, after reading numerous recent papers on the broad subject of water pollution and the specific aspects of quality standards for recreation waters, I learned that pat answers are not necessarily the best ones and that much remains to be done to obtain adequate solutions. It is also obvious that there are few experts in this relatively new field.

The Bureau of Outdoor Recreation is currently building a Nationwide Outdoor Recreation Plan as a general guide for future planning and action in the field of outdoor recreation. The Plan is intended to serve as an instrument for assuring that a variety of recreation opportunities desired by our people of present and future generations will be available in sufficient quantity and quality to serve them adequately within the range of available resources. An important phase of the Plan involves a comprehensive inventory of the supply of outdoor recreation resources in the United States. Federal, State, county, municipal and private recreational lands, waters and facilities will be recorded. The study will disclose the amounts, types and location of all present recreation lands, waters and facilities, what additional recreation development is now planned, and what potential areas can be identified for recreation development in the future.

This inventory of supply will be matched with a Nationwide demand survey in order to determine the types and location of resources and opportunities which will be required by present and future generations. Determination of the need for available water for outdoor recreation will be an important aspect of this analysis.

One of the most pressing needs in outdoor recreation planning is an expanded research program. Research is one of the important responsibilities of the Department of Interior as well as the Bureau of Outdoor Recreation. When expanded research becomes a reality, one of the priority study items should be the determination of standards for recreation waters. Presently, some of our potentially finest recreation waters are polluted to the point where recreation is restricted or dangerously close to this point. We all

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know that an increasing population will place increasing demands on our fresh water resources. However, we need not go to a future-demand situation. Our current needs are not being met in some areas because of pollution of outstanding rivers and lakes.

Among our Great Lakes, Lake Erie is rapidly losing its value as far as recreation is concerned. Commercial and sport fishermen know this is true. So do swimmers, boaters, lakefront property owners and many naturalists. Walleye pike and cisco have been virtually replaced by less desirable fishes. The commercial fish catch from Lake Erie has dropped from over half the Great Lakes total to less than the catch from Lake Michigan alone. As a result, many commercial fishermen are destitute. Huge algae growths die and wash ashore to form enormous odorous masses around boat docks, lakefront property, and bathing beaches. To make a bad situation worse, debris, logs, lumber and numerous other floating materials litter the shoreline.

All major Lake Erie tributaries are heavily polluted at their mouths and many throughout large reaches of their lengths. Winding through the center of Cleveland, Ohio, the Cuyahoga River flows north to Lake Erie. It is a torpid ribbon of gray sludge marked with large irridescent splotches of oil. Much of the American shoreline of Lake Erie out one to two miles is polluted. The most serious damage in this zone is to recreational uses, particularly swimming and water skiing. It has been estimated by some that even with total pollution control, it would take 25 years to clean up Lake Erie.

No fish can live in the mighty Hudson for ten miles downstream from Albany --just sludge worms, fly larvae, leaches, and maggots. The beautiful Hudson is a fetid dumping ground for 217 major sources of waste.

The Merrimack River in New England is perhaps the most polluted river in the history of man. Through its entire length it averages less oxygen than fish need to live, and below Lowell, Massachusetts, its oxygen content is zero.

To further illustrate, Chicago, with modern treatment facilities, pours wastes into the Illinois Waterway which have a pollution effect equivalent to the discharge of sewage from about 1 million persons and contain solids --natural and synthetic, organic and mineral--amounting to about 1,800 tons per day.

As though to emphasize the seriousness of water pollution in our country, the Potomac River in our Nation's Capital and in its tidal estuary is grossly polluted. The river and estuary are unsafe for water-contact sports. All of the State health and water pollution control agencies, as well as the Federal agencies involved, are deeply concerned for the continued safety of the metropolitan water supply. On October 2, 1965 President Johnson at the signing of the Water Quality Act of 1965, pointed specifically to the Potomac River, recalling that President Theodore Roosevelt used to swim there earlier in the century. "Today, he said, "the Potomac is a river of decaying sewage and rotten algae. Today all swimmers are gone. They have been driven from its banks."

Getting closer to home in Colorado our own South Platte River is seriously polluted. It will require much time, effort and money before this river is sufficiently cleaned up to support a warm-water fishery and fishing and other outdoor activity along its banks.

I have cited only a few examples, but water pollution is a National problem. Across the land, rivers once sweet and unsullied are now so polluted they are good for little more than carrying away the human and industrial wastes that made them that way. Except for the headwaters, almost all of America's rivers are seriously polluted.

Equally destructive is the silent killing of estuaries and their associated fish, plants and animals by pollution. Just as fresh water life, marine life lives precariously close to death. The slightest environmental change can spell doom. And the hand of man has been applied heavily to our estuaries. Factories on or near our shores, cities at the mouths of rivers, and thousands of resort hotels, motels, and summer homes find coastal marshes and tidewater flats convenient places to dispose of garbage, industrial wastes, litter and other debris.

We read and hear much about pollution of recreation waters by industry, municipalities and agriculture. This is understandable, for these are the most common and obvious sources of pollution of recreation waters. However, little has been said about the pollution caused by recreationists and Federal installations. Recreationists themselves often overlook the effect they and their activities have on the quality of recreational waters and associated land areas. Summer homes and cottages in the vicinity of lakes, reservoirs, and streams often present a vexing problem. Many are located in areas remote from adequate sewage treatment facilities. Pollution occurs by seepage from septic tanks, overflow of drainage fields and in some instances, direct discharge of sewage into recreational waters. Pleasure boating has also caused water quality problems, principally through the discharge of sewage in anchorage areas. Deposition of trash, garbage and other materials from pleasure craft is also a source of pollution. Winter sports activities, particularly ice fishing, have proved detrimental to water quality through the deposition of debris on the ice and snow. This problem will become more acute as winter sports activities increase.

Another little recognized source of pollution of recreational waters are Federal installations. Compared to the total of untreated discharges of municipalities and industry, pollution by Federal agencies is very small, less than three percent. However, it is disturbing that there is any, especially when this pollution by government facilities is serious in some locations. Fortunately, Federal installations are making substantial and accelerating progress to end water pollution but the problem still remains in some locations.

What are the effects of water pollution on outdoor recreation? The extreme effects, of course, are prohibition of water-contact activities. This can be caused by a high count of coliform bacteria, indicating the presence of organisms from the digestive tract of warm-blood animals. Or plant nutrients introduced through pollution can cause excessive growth of aquatic plants, which by their presence prevent swimming, water skiing, and boating. When these plants die and decay, they cause secondary oxygen-demanding pollution accompanied by disagreeable tastes and odors. The possibility of the development of toxins from the high density growth, death, and decay of certain types of algae is also very real.

When organic pollution reduces the dissolved oxygen in a stream below four or five parts per million, only rough fish can exist, thereby eliminating any sport-fishing value that might have been present. When the oxygen count reaches zero, anaerobic bacteria take over the job of reducing organic pollutants to inert materials. We then have a septic condition with the familiar dark, evil-appearing, foul-smelling condition characteristic of grossly polluted water in which no fish can live.

Siltation is another common source of pollution. Pollution in the form of silt can change the water environment and in turn, the type of recreation activities engaged in. Silt caused by logging, overgrazing, or farming can change a cold-water fishery to a warm-water fishery.

Pollution can and has caused a considerable loss in recreation activity days and associated economic benefits. In many areas, some of our prime recreational waters have been lost to pollution. With their loss has gone swimming, water skiing, boating, fishing and yes, picnicking, camping, and sightseeing opportunities. Camping, picnicking and sightseeing, while not directly water-oriented activities, are considerably enhanced as an experience by aesthetically pleasing water. Pollution robs the water of its aesthetic value for such activities.

Economic losses associated with the loss of recreation areas are significant. Concessions for boating, swimming, food, drink, and lodging are seriously affected. Service and supply businesses developed to support those water-centered recreation activities are also severely affected. Probably the most damaging effect of polluted recreation waters has been the loss of prime areas near large metropolitan areas where the need is greatest.

At this point, then, I think there is general agreement that water pollution poses a serious threat to the future of water-based recreation. At present the supply of usable recreation water meets the needs of American citizens in many areas. However, there are already sections of the Nation where the supply is severely limited. For example, in the crowded eastern seaboard, opportunity is rapidly being restricted in variety and reduced in quality. There are not enough recreation waters in the right places to meet the demands. This is also true of several large metropolitan pockets elsewhere in the Nation. When water needs for outdoor recreation are projected in the Nationwide Plan, it will refer to water of a quality suitable for outdoor recreation. This is the crux of the problem. Will sufficient recreational water be available to meet the needs in 1980, 2000, and 2020? These are the years for which the Plan will attempt to ascertain the needs. At the present rate of pollution control and abatement, we may not be able to meet our future requirements. I suspect that most of our presently polluted waters will have to be cleaned up if we are to have adequate acreages in the future. It will require increased and closely coordinated planning of Federal, State, and local governments and the private sector if the task is to be accomplished. The Bureau of Outdoor Recreation is committed to play an important role in this planning. By the year 2010 our national population will double and the overall need for outdoor recreation facilities will triple. Not only will there be more people, but they will have more free time, more money and be more mobile than ever before. Already the increase in need for outdoor recreation developments is surging ahead of population growth. The types of outdoor recreation most people participate in today are rather simple -- walking and driving for pleasure lead the list. However, swimming, picnicking, fishing and boating are among the most popular. What people do now is not necessarily what they want to do in the future. The ORRRC report indicates that more than 20 percent of those surveyed said that while they do not participate in fishing, they would like to. Other activities for which there is a large unsatisfied desire include swimming, boating, and "just going to the beach."

In recognition of the importance of conserving some of our purest of recreation waters, legislation has been introduced in Congress calling for establishment of a National System of Scenic Rivers. This legislation has been introduced in Congress calling for establishment of a National System of Scenic Rivers. This legislation is designed to preserve, reclaim, and make available for the benefit of all the American people, specifically chosen segments of the Nation's diminishing free-flowing rivers. This program would guarantee for America a remnant of her heritage of unspoiled, <u>unpolluted</u>, free-flowing rivers. In this area a portion of the Rio Grande is one such river being considered.

It is thus apparent that water is a focal point for outdoor recreation. Most people seek water in which to swim or fish; or which to boat; along which they can walk, picnic, or camp, or just look at. People also want to recreate close to home. Two out of three Americans now live in metropolitan areas and by the year 2000, three out of four will. It is here that the need for most types of outdoor recreation is centered. It is here where the greatest need for recreation waters is and will be. It is here where most of the pollution occurs. It becomes obvious then, that we cannot afford polluted recreation waters if we are to meet our recreation needs.

Ridding our recreation waters of pollution is one of our primary tasks. But an equally important task which should be undertaken as soon as possible is the establishment of uniform standards for quality of recreation waters. Currently we are faced with a maze of conflicting regulations and standards. It is an understatement to say that there is a lack of agreement among research and management people about what constitutes clean recreation water. Refinement of water quality standards for the various water-oriented recreation activities and their adoption by all agencies concerned is necessary before a workable solution can be found to pollution control in recreation waters. Water quality standards for recreation vary considerably among agencies responsible for determining whether certain types of water-oriented recreation is permissible. Some beaches are allowed to remain open through the water quality may be lower than that at other beaches which have been closed by another agency. Why do public officials permit water-skiing in waters polluted to the extent that swimming is prohibited? The answer lies in increased research by Federal, State and local governments and private industry. Our universities could also do much to help in this problem. Once adequate criteria are developed, then they must be applied effectively and uniformly. One of our principal problems concerning the use of standards is the reluctance by regulatory agencies, particularly at the local level to apply them effectively, if at all. The best standards will accomplish nothing without effective application!

Pollution of recreation waters is serious and its future effect could be even more damaging. What then is needed? First of all, one level of government or one agency cannot solve the problem. It will require an untiring effort on many fronts. Federal, State and local government, private industry, the educational community and an overwhelming grass roots support of the people are needed to effectively clean up our recreation waters and to prevent further pollution.

It is not enough to maintain the status quo. Right now the clean water advocates are running neck and neck with the polluters. We must greatly increase our efforts and plan on cleaning up those potentially fine recreation waters that have been allowed to deteriorate for far too many years. This must be done to meet our future needs. Continued degradation of water resources in urbanized areas will place greater recreational use pressure on the fewer remaining acceptable water areas. People will have to travel even greater distances in quest of suitable water oriented recreation activities. These trends must be reversed if suitable recreation waters are to be found in the future.

Much closer coordinated planning of Federal, State, and local governmental agencies, and private enterprise is necessary if the program is to succeed. You, the states, the Federal Water Pollution Control Administration and the Bureau of Outdoor Recreation should play a major leadership role in this planning. Real coordinated planning is necessary to avoid confusion and expensive duplication of effort. However, if this program is to be fully effective it must have the support of a large segment of the population. This support can only be gained through an accelerated program of information and education by all levels of government, schools, industry, agriculture, and conservation groups. The public must be shown the wisdom of clean recreation water in the clearest of terms. The people should be encouraged to learn how municipal and industrial wastes are handled in their community. They should be urged to let elected officials at local, State and Federal levels know they want strong anti-pollution laws, and want them enforced. Lastly, they should be encouraged to join action groups to foster pollution controls.

Control of pollution of recreation water is not impossible. Many fine examples of what can be done are available.

For a century, Pennsylvania's 130-mile Schuylkill River, which empties into the Delaware River at Philadelphia was described as "too thick to navigate and too thin to cultivate." Some ship captains refused to dock at Philadelphia because of corrosion from this contaminated stream.

A dozen years ago, Pennsylvania started to rehabilitate the Schylkill. In two years the 47 coal mines which poured two million tons of coal washings into the headwaters of the river each year had installed desilting systems. From Reading downstream, every city along the Schuylkill put up a new sewage plant or enlarged existing ones. Philadelphia invested 80 million dollars, and local industries spent an additional 40 million to complete the job.

Now, they are swimming and boating on the Schuylkill once more. Municipalities using the river for their water supply report more economical operation of their purifying plants; industries which formerly were forced to develop their water supplies from wells are using Schuylkill water again.

Water pollution abatement on the North Platte River in Wyoming is probably one of the most outstanding examples in the Nation. Wyoming cleaned up this river in a decade. In this experience, we have proof that the cities and industries of any State can achieve clean water if they have the will to do so, and if the State's leaders show the way.

The effort began in 1955 under Governor Simpson, now a United States Senator. Governor Simpson appointed Arthur E. Williamson as the State's pollution abatement chief, and strongly supported his persuasive efforts to clean up the North Platte.

In 1948, the Public Health Service stated that the North Platte was so grossly polluted that it was doubtful that recovery ever could be made. By 1954, the river had deteriorated further. However, through Mr. Williamson's persistent efforts, Wyoming improved the quality of the North Platte without intervention by Federal authorities, and without legal abatement enforcement proceedings.

The cost to industry has been high but residents and businessmen have found that the investment was sound. Land values along the river have increased from $240 an acre 10 years ago to $1,500 an acre. Residents now are proud of their river and recreation activities have returned.

Other important examples can be shown. Dramatic progress has been made along the Missouri River, where 10 years ago not one major city treated its sewage. Today, Sioux City, Omaha, Kansas City and St. Joseph all have treatment plants operating or under construction, and meat packing plants have done a significant clean up. St. Louis a few years ago voted a $95 million bond issue for waste treatment. The Shell Oil Company plant at Anacortes, Washington has installed a complete treatment system to avoid polluting waters in the area and to protect local commercial and sport fisheries. Kaiser Steel at Fontano, California, reclaims mill wastes in a settling and recycling system which keeps its water needs to a minimum. The beautiful Willamette River in Oregon is being cleaned up; even the grimy Ohio is getting a bath.

The Water Quality Act of 1965 has been an important factor in accelerating the program by (1) establishing the Water Pollution Control Administration, (2) requiring each State to signify its intent within a year, to establish water quality standards by June 30, 1967, and to submit a plan for enforcing those standards, and (3) permitting the Federal Government to step in with its own rules if the State fails to set standards or sets standards deemed unsuitable by the Water Pollution Control Administration. The Act also authorized $150 million a year in Federal grants to help States and communities to build sewage treatment plants--an increase of $50 million over the presently authorized ceiling.

Still, with all these efforts, much more is needed if we are to truly control water pollution in the United States.

If, as predicted, outdoor recreation activities triple in the next 50 years and if future recreationists are to fully enjoy their outdoor experiences, we must have clean water. Yes, there is and will be an increasing need for truly clean recreation waters.

The Nation must work harder if we are to succeed. Much more money must be invested in city and industrial waste treatment plants. We need intensive research to develop more efficient techniques of water treatment. And equally important, we need better enforcement of strong pollution laws at the Federal, State and local level.

President Johnson, in his speech at the signing of the Water Quality Act of 1965, said, "I believe that with your help and your continued cooperation, water pollution is doomed in this century." He also said with the signing of the Act, "I pledge you that we are going to reopen the Potomac for swimming by 1975. And within the next 25 years, we are going to repeat this effort in the lakes and streams and other rivers across this country."

I am certain all of us share in the President's views. His remarks must offer a real challenge to all of you who work so closely with the problem of water pollution. Your accomplishments in developing new waste treatment systems and control methods have been clearly proved. The challenge that faces you is the same as that facing the Nation. America has the capability; it must redouble its efforts.

RECENT WATER LEGISLATION - 1967

A special session on Recent Water Legislation was arranged since the New Mexico State Legislature had recently adjourned after having considered many water proposals and passing several of them.

Mr. Harlan Flint, Special Assistant Attorney General, assigned to the State Engineer Office, and Mr. Hoyt Pattison, State Representative from Curry County, presented many of the high points in connection with this legislation. The two papers were followed by discussion periods on the various aspects of water law and the application of the law to the management of the water of New Mexico.

The papers presented on the following pages are:

1967 Water Legislation
by F. Harlan Flint
General Counsel, State Engineer and
Interstate Stream Commission
Santa Fe, New Mexico

Water Legislation - 1967
by Hoyt Pattison
Representative from Curry County -- New
Mexico State House of Representatives,
Farm Operator, Farm Manager, and Registered
Professional Engineer
Clovis, New Mexico

1967 WATER LEGISLATION 1/

F. Harlan Flint2/

This will be a brief resume of the 1967 Water Legislation considered by the First Session of the Twenty-eighth Legislature presented on the evening of March 30, 1967 at the New Mexico Water Conference in a panel chaired by Dr. Ralph Stucky, and also participated in by Representative Hoyt Pattison.

We have had quite a few rather formal debates on the subject of legislation during recent weeks in the course of the legislative session. In most instances Representative Hoyt Pattison, who is also at the head table here this evening, participated in these discussions with enthusiasm and effectiveness. As our moderator has indicated, Mr. Pattison was the sponsor of a large share of the water legislation considered.

It has been one of my greatest pleasures to be involved in a field of activity where things are happening. And things of importance are happening in the many disciplines that are devoting their efforts to water problems. It is fascinating to participate in and watch the functioning of the machinery of water politics, particularly in the context of the First Session of the Twenty-eighth Legislature.

There are an increasingly large number of groups and interested individuals who are participating in the most important field of legislative effort. We see irrigation farmers, dry land farmers, ranchers, representatives of the oil and gas industry, recreationists, sportsmen, conservationists, members of federal, state, municipal government and other political subdivisions, domestic water users, public health representatives and a multitude of industrial interests too numerous to list. It is a fascinating process and I would like to discuss it sometime but we are not here tonight to discuss the process but rather to review the product of this process.

In the interest of briefly reviewing this product and particularly the successful legislation produced by the recent legislature, I have taken the liberty of dividing up the water bills that our offices were most concerned with into six categories. These categories are necessarily somewhat arbitrary and it has been necessary to leave out some legislation which I feel to be of less general interest.

1/ Considered by the First Session of the Twenty-eighth New Mexico Legislature.

2/ General Counsel, State Engineer and Interstate Stream Commission, Santa Fe, New Mexico.

DITCH REHABILITATION

I have denominated the first category "Ditch Rehabilitation," a category in which four bills were introduced as reflected by the following table:

Comm. Sub HB 34	/$100,000 appropriation, statewide, for rehabilitation of irrigation facilities_/	signed (Chapter 67)
SB 174	/Appropriation for rehabilitation of irrigation facilities, Grant County_/	died
SB 175	/Appropriation for rehabilitation of irrigation facilities, Santa Fe County_/	died
SB 312	/Appropriation for rehabilitation of irrigation facilities, San Miguel County_/	died

The several bills shown in the above table are successors to similar bills introduced in previous sessions. The purpose of these bills has been to appropriate moneys to the State Engineer from a trust fund created under the Ferguson Act, the federal act under which the State of New Mexico received grants of federal land for the purpose of improving irrigation. The legislature has directed the State Engineer to use these moneys for the purpose of rehabilitating community ditches and other public irrigation facilities within the State. The practice has been to make these funds available on a matching basis to the local entity, so that a grant from these moneys in the amount of 15% of project cost will be matched by a 15% contribution by the local entity and by as much as a 70% grant from the federal government. The net effect has been to generate substantial expenditures in the interest of conservation with a relatively small contribution from the State.

INTERIM STUDY

The second category of legislation is "Interim Study." The legislation in this category is shown in the following table:

Comm. Sub. HB 116 & HB 179	/Interim study of water law and administration_/	died
HB 396	/Study of agricultural water requirements_/	signed (Chapter 220)

The committee substitute for HB 116 and HB 179 received considerable attention by the legislature and represents the consolidation of features of two bills introduced by Representatives Hoyt Pattison and Richard B. Edwards and others. The bill passed the House but was unsuccessful in the Senate, where it died in the Senate Conservation Committee. It would have provided a $20,000 appropriation for the purpose of financing an interim legislative committee to study water laws and institutions.

The second bill, HB 396, authorized an appropriation of $6,000 to the New Mexico State University for the purpose of undertaking a two-year study of agricultural water requirements through the year 2060.

WATER POLLUTION

A third category of bills dealing with water pollution are summarized in the following table:

HB 201	/Water Quality Act, creating water quality control commission_/	signed (Chapter 190)
HB 83	/Water Pollution Act_/	died
SB 476	/Water Pollution Act_/	died

The successful bill in this category represents the first substantial New Mexico legislation in the field of water pollution.

CAPITAN REEF PACKAGE

One of the largest categories of water legislation includes the bills that I have chosen to call the "Capitan Reef Package." All of these bills died except one, Committee Substitute for SB 396, but the category represents one of the most important areas of legislative concern. The bills are summarized in the following table:

Comm. Sub SB 396	/Excluding certain water from underground water basins_/	signed (Chapter 86)
HB 321	/Regarding secondary recovery of oil, provides if water injected and withdrawn in equal amounts there is no appropriation_/	died
HB 357	/Required no fresh water be used when brackish water available_/	died
SB 188	/Similar to HB 321_/	died
SB 189	/Similar to SB 188_/	died
SB 314	/Withdraw New Mexico from Pecos Compact_/	died
HB 292	/Same as SB 314_/	died

SB 394	/Repeal existing State Engineer jurisdiction ground water_/	died
SB 395	/Procedures for declaring underground water basins_/	died

All of the bills in this group are related to the concerns of different people with the use of brackish water from the Capitan Reef, particularly in Lea County, New Mexico. Several of these bills including the successful Committee Substitute for SB 396, constituted efforts by representatives of the oil industry to exclude the Capitan Reef from the State Engineer's jurisdiction. More detailed consideration will be given to SB 396 at the conclusion of this paper.

WATER RIGHTS AND ADMINISTRATION

A fifth category of water bills entitled "Water Rights and Administration" are summarized in the following table:

SB 335	/Soldier's exemption_/	signed (Chapter 182)
HB 27	/Similar to SB 335_/	died
SB 162	/Permitting use of water rights on all or part of lands_/	died
HB 89	/Exempts mineral wells from metering_/	died
HB 315	/Procedure for adopting State Engineer regulations, etc._/	signed (Chapter 246)
HB 148	/Create water commission, make State Engineer employee thereof_/	died
SB 393	/Authorize leasing of water rights_/	signed (Chapter 100)
HB 133	/Require permission of land owner prior to well application_/	died (incorporated in HB 306)
SB 381	/Same as HB 133_/	died
Comm. Sub. HB 306	/Eliminates State Engineer hearings in most ground water applications_/	signed (Chapter 308)

SJR 7 /Require de novo hearings in appeals from State Engineer_/ adopted (Constitutional Amendment No. 5)

The bills in this category all deal in some fashion with the modification of water rights statutes or with the method of administration, authority and jurisdiction of the State Engineer. First there were a sub group of two bills (SB 335 and HB 27) which had as their purpose the exemption of persons on active military assignment from the requirement of statute that an application must be filed for extension of time within which to use water in order to avoid the possibility of forfeiture. SB 335 became law and protects a person in the above category against any possibility of forfeiture for non-use of water. SB 335 also incorporated elements of HB 27 and SB 162, authorizing water right owners to use all their water right on a portion of their land without filing an application with the State Engineer.

HB 315 is a rather important piece of legislation dealing with the administrative procedures to be followed by the State Engineer Office. It requires the State Engineer to hold hearings before adopting rules and regulations and requires that a hearing be held following the declaration of a basin, at which hearing the State Engineer shall put on evidence to justify the act of declaration of the basin.

Another bill in this category, HB 148, would have abolished the Interstate Stream Commission and would have rather seriously modified the authority and jurisdiction of the State Engineer. The bill proposed the creation of a 13-man commission whose members would have been appointed by the Governor to represent geographical areas substantially paralleling our present judicial districts. The State Engineer would have been an employee of the commission and the commission would have been given the same authority now enjoyed by the Interstate Stream Commission plus broad supervisory control over the State Engineer Office. The bill died in committee.

SB 393 authorized the leasing of water rights. This bill passed without substantive objection, our only reservation being to its necessity. In my opinion farmers already enjoyed the right of temporarily transferring water rights.

HB 306 is one of the most important bills to pass and I will discuss its primary purpose in a little more detail below. It had the secondary purpose of incorporating the provisions of HB 133 to the effect that nobody may file an application to drill a well on the land of another without securing the prior permission of the owner of the land.

SJR 7 is among the more significant measures adopted since it had the purpose of providing that any appeals from State Engineer decisions shall be de novo. It this proposed constitutional amendment were adopted by the people, it would have the effect of establishing a different method of appeal in water matters than prevails in all other areas of administrative law.

MISCELLANEOUS

A final category of legislation is, or course, "Miscellaneous" and a summary of these bills follows:

SJM 10	/Urges an interim study leading to draft of uniform administrative procedures act_/	adopted
HB 227	/Appropriated $60,000 for measuring devices within the Gila River System and its tributaries_/	signed (Chapter 192)
Comm. Sub. HB 205	/Geothermal Resources Act_/	signed (Chapter 158)
SB 311	/Severance Tax Bonds, Canadian River Dam_/	died
SB 426	/Requires plugging of mine drill holes_/	signed (Chapter 128)
HM 3	/Memorialized Congress to study Pecos River Flood Control Dam_/	passed
SM 10	/Same as HM 3_/	passed
HB 263	/Las Cruces arroyo flood control_/	signed (Chapter 156)

SJM 10, while not having the force of law, urges the Legislative Council to conduct a study of administrative procedures on a statewide basis during the interim and to report back to the legislature at a later date. I am advised that this study will be undertaken and feel that this is the proper way to undertake the evaluation of problems of administrative procedures and administrative law. HB 227 appropriating $60,000 for measuring devices, will relieve water users in the Gila-San Francisco Stream System from the economic burden of complying with the decision of the United States Supreme Court in Arizona v. California, 373 U.S. 546, which determined the relative rights of New Mexico and Arizona to the waters of that stream system. I will not take the time to further describe the other miscellaneous bills.

EVALUATION

It is always dangerous to evaluate the importance of legislation in advance but I will risk it to the extent of suggesting that Comm. Sub. SB 396, Comm. Sub. HB 306 and SJR 7 are the three most important water measures passed by the recent legislature. I will conclude my remarks by briefly describing and evaluating these bills.

SB 396 was probably the most controversial water legislation introduced in this session. It is the sole survivor in the category that I described as being introduced to permit the appropriation of the waters of the Capitan Reef for secondary recovery without the necessity of making application to the State Engineer and without requiring the applicant to bear the usual burden of showing that the new appropriation will not impair existing rights. What the bill says is that "No present or future order of the State Engineer declaring an underground water basin...shall include water in an aquifer, the top of which aquifer is at a depth of twenty-five hundred feet or more below the ground surface at any location at which a well is drilled and which aquifer contains non-potable water." Non-potable water is defined by this act as containing not less than 1000 parts per million of dissolved solids. While the bill was of general application, the intent of its sponsors was to permit the oil industry to proceed to develop water from the Capitan Reef at points where the top of the reef is at least 2500 feet below ground surface, and to do so without having to file an application. There is a serious possibility of fatal ambiguity in the language of the bill. This possible ambiguity was suggested in committee hearings but was not considered seriously enough so that amendment of the language was contemplated. I want you to listen to and read the language of the bill carefully if you will and see if you don't agree that at least two diametrically opposed constructions can be placed upon the language. Under one reading it seems to say that if at any place you drill a well into this aquifer you first encounter non-potable water at 2500 feet or more, then that entire aquifer and the water therein must be excluded from any declared underground water basins. The significance of this interpretation can be suggested by pointing out that if so read the legislation would prevent the State Engineer from having any jurisdiction over the waters of the Roswell Artesian Basin, since the San Andres formation is found in some locations at a depth of 2500 feet or more.

Another construction of which the language is susceptible is to the effect that the water in an aquifer need not be excluded from a declared underground water basin unless water is first encountered at more than 2500 feet in depth at every location where a well is drilled into that aquifer. Given that construction the bill would not apply to the Capitan Reef since there are some locations at which water is first encountered in the Capitan Reef at less than 2500 feet.

I will not extend my discussion of this bill except to say that serious concerns for the constitutionality of the bill and for its practical effects were expressed during the hearings and debate on Comm. Sub. SB 396.

May I next refer to HB 306. This is the one that had the principal purpose of taking the State Engineer part way out of the hearing business, at least as to hearings arising out of applications involving ground waters. The bill eliminates State Engineer hearings in certain instances where this legislation provides that the hearing will be held in the district court instead. Several sections of the new law provide that after an application has been filed and the State Engineer has caused an advertisement to be made of the application, then, if there is no protest, the State Engineer is directed to consider the application. If he decides that he would have to deny it, he is required to so advise the applicant. If, on the other hand, the application has been protested, the State Engineer is directed to advise the applicant that the application has been protested. The law then provides that "Unless the applicant files within 30 days after receipt of notice...an action for hearing in the district court...the State Engineer may proceed to deny the permit." It is also stated that "The application shall be heard and tried as cases originally docketed in the district court and the State Engineer shall be a party thereto." In other words, under the two circumstances described, no State Engineer hearing is held. It appears that this legislation puts the district court in the position of the State Engineer in deciding applications. Objections to the constitutionality of this legislation were expressed in committee hearings on the grounds that this legislation would require the court to perform what has been denominated by our courts as an administrative function. The risk exists that the legislation will therefore be held to authorize a violation of the separation of powers doctrine. It also runs the risk of failing for the same reason that de novo appeals were rejected by the New Mexico Supreme Court in the case of Kelley v. Carlsbad Irrigation District, 71 N.M. 464.

HB 306 is also subject to some confusion regarding which applications are covered by the new rule. As a matter of law, however, the constitutional objection is the most serious one. As a matter of policy, we feel that there are inherent dangers in the patch work legislative modification of administrative legal procedures contemplated in this law. You have heard this afternoon and this morning considerable emphasis placed on realistic appraisal of the relationship between the disciplines involved in water resources development and an acceptance of the relationship between ground and surface water. This law yields the indefensible result of applying a different administrative procedure to ground waters than is applied to surface water. As such, it constitutes a step backwards in administrative law.

SJR 7. The final measure to be discussed is SJR 7 which will be voted upon by the people of New Mexico as Constitutional Amendment No. 5. This resolution provides that "in any appeal to the district court from a decision of a state executive officer charged with administering water rights, the proceeding appeal is by de novo as cases originally docketed in the district court." This constitutional amendment is stimulated by what must be the most widely known water case in recent time, Kelley v. Carlsbad Irrigation District, supra, which held that appeals from administrative agencies must be based upon the record made at the hearing before the administrative agency. In considering such an appeal, the district court is limited to determining whether, based upon the legal evidence, the administrative officer acted fraudulently, arbitrarily or capriciously and whether his action was substantially supported by the evidence. Two years ago the legislature adopted a resolution substantially identical to the one which will now be submitted to the voters. That resolution was voted upon and rejected by the people less than two years ago. This bill will result in the issue being submitted to them again.

Several objections to the proposed amendment should be stated. It is inappropriate to establish one rule for appeals from the State Engineer hearings and another rule for all other administrative appeals. Second, a similar constitutional amendment was rejected by the people of New Mexico less than two years ago and it therefore seems premature to ask that the matter be submitted for their approval or rejection again. Third, efforts are now under way in both the executive and legislative branches of government to secure the creation of a constitutional convention. The nature of appeals from administrative agencies is one of the items that should be considered in a comprehensive study of our New Mexico constitution. Also, the Constitutional Revision Commission has had these matters under consideration and is preparing to submit recommendations to the Governor and the Legislature, probably including proposed changes in the area of appellate review of administrative decisions.

The trend of the law is in the direction of increasing the responsibility of administrative agencies and relieving the courts from the burden of hearing the large amount of technical evidence that can be required in cases involving areas such as water. There has been a tremendous growth and refinement of administrative functions and procedures during the last several decades. No one would claim that administrative law has always served the public interest as best it might have. However, it is here to stay and we should attempt to improve it, not abandon it.

The First Session of the Twenty-eighth Legislature has been an important one for water law and water rights administration. The significance of legislation adopted and, indeed, of legislation which failed, may not be known for many years. It is probably sufficient for the moment to describe what has happened and to limit evaluation to the few interpretative remarks contained in this report.

WATER LEGISLATION - 1967

Hoyt Pattison[1/]

"You don't miss the water until the well runs dry." And if you are wise you don't wait until the well runs dry to do something about it. A Fort Worth consulting engineer recently told some 60 Deaf Smith County Texas farmers they had until 1985 to do something about their wells running dry. He said:

> "By the year 2020 the High Plains of Texas would need 15-18 million acre feet of supplementation water annually.
>
> Suggested Mississippi River importation.
>
> State it would not be impossible, but it must start with people like you--interested groups, beginning work now!"

New Mexico--particularly Eastern New Mexico--must begin work now in order to participate in this work and effort. We must do our part and take care of our responsibilities if we are to benefit from usage of this water.

I begin this talk about Water Legislation in the 28th New Mexico Legislature in this manner in order to point out the growing realization among many New Mexicans that perhaps our water laws need updating in some areas. This fact was emphasized by the introduction in this session of some 37 bills and memorials pertaining to water primarily and indirectly effecting water law and its administration.

I am a little familiar with the subject of water as I make my living as an irrigation and dryland farmer. I know what it means to use a shovel and irrigate from a ditch--the convenience of underground tile and gated pipe--and the use of sprinkler irrigation systems. We use all these methods where I farm in Curry County. I also know a little about water engineering and hydrology as I have a degree in Agricultural Engineering from New Mexico State University. I remember taking a soils course under Dr. Harold Dregne and being in school with Dr. George Dawson--both of whom are here tonight. I have become acquainted with water law and water legislation as I am now serving my third term as a State Representative of the rural area of Curry County. So, you see, I know the essential importance of water--what it means--its value from the text book, to the ditch bank, to the law book.

In the New Mexico House of Representatives for the past five years, I have had the opportunity to debate quite often with Mr. Harlan Flint, my

1/ Representative from Curry County--New Mexico State House of Representatives, Farm Operator, Farm Manager, and Registered Professional Engineer, Clovis, New Mexico.

district court and makes the State Engineer a party on the same basis as the other participants. I believe our District Judges are very capable of rendering fair judgment based on the facts presented in cases of this type.

House Bill 133 stated that if an applicant applies for a drilling permit on private land he does not own, and the applicant does not have mineral or oil and gas rights under the land, or is not a governmental body, then the applicant must submit a statement that he has the land owners permission.

House Bill 396 is very important to the future of New Mexico. It appropriates $6000 for the first year of a two year study to the Agricultural Economics Department of New Mexico State University for the purpose of making a study of the agricultural water needs of New Mexico to the year 2060. Texas has already made such a study to the year 2020. Other states have done this and are doing this as a part of an overall water plan for their areas. New Mexico needs this done as soon as possible so that we will have available information on which to base our requirements for participation in water importation projects. This bill states that the Agricultural Economics Department of New Mexico State University shall cooperate with county agricultural extension agents and county water planning committees in making this study. You people need to help with this study in your individual counties.

It has been a pleasure to present this information to you tonight. Only time will tell if everything we did in Santa Fe this year was the best for New Mexico. I believe that a lot has been accomplished in the area of water law and I hope it will be for the good of those concerned.