A Symposium—

Oil and Water

Related Resource Problems of the Southwest

SOUTHWESTERN FEDERATION OF GEOLOGICAL SOCIETIES

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FOREWORD

This volume presents the texts of papers presented at a Symposium entitled Oil and Water--Related Resource Problems of the Southwest, sponsored by the Southwestern Federation of Geological Societies and The University of Texas in Austin, January 29, 1965. Publication was undertaken by the Bureau of Economic Geology in response to numerous requests for copies. The papers remain in their original form, styled for oral presentation, with only a minimum of editorial changes.

Peter T. Flawn

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RESOURCES AND THE STATE GOVERNMENT

Judge Jim C. Langdon

The opportunity to keynote this symposium on "Oil and Water -- Related Resource Problems of the Southwest" is one I appreciate very much. Certainly, for a member of the Texas Railroad Commission, the subject could not be more pertinent.

Some months ago I made a talk on water pollution with the somewhat facetious title: "Do Oil and Water Mix?" After further study I have concluded that, while oil and water don't mix very well, they surely can get mixed up.

I'm particularly honored to represent Governor Connally on this program today. His deep concern with the problems of oil and water conservation is well known to all of us. He has placed water management and development, along with education, at the top of his list of "Texas Musts."

In fact, the availability of water bears directly upon certain other points in his program including expansion of outdoor recreational facilities and stepped-up drive to attract more tourists and more new industries to Texas.

The acceleration of these particular efforts, of course, does not overshadow the vast and continuing need for water on the part of our swiftly growing cities, our over seven million acres of irrigated farmlands, and the great industries we already have, including oil and gas production and refining.

You gentlemen from West and Southwest Texas and New Mexico are fully aware that one of our major water problems is distribution. You are from an area where the annual precipitation ranges from 30 down to 5 inches, as compared to the 45-to-55-inch averages in East Texas.

Governor Connally had this factor very much in mind last August when he called upon the Texas Water Commission to develop a long-range State Water Plan to the year 2000 and beyond. One of the urgent reasons he cited was the responsibility he will have in the very near future to pass judgment on various federal projects including the proposed construction of a 443-mile canal from the Sabine River to Brownsville.

The Governor said he could not properly evaluate some federal projects without reference to a long-range state plan. The Water Commission moved promptly to project its estimate of water supply and demand at least 20 years past 1980, the end point of its 1961 survey. Helped along by an emergency grant of $46,000 from the Governor's fund and with the invited assistance of the Texas Research League, this vast planning job is now under way.

In his inaugural address last Tuesday, Governor Connally told the Legislature and the people of Texas -- "If we want strong and effective local government we must exercise local responsibility. If we want strong and effective state government we must exercise state responsibility." He stressed the role that education must play in the future of Texas saying: "We can use education to foster the minds and the skills for a more prosperous economy and we can at last devise the plans to assure water for our teeming cities, growing industries, and the farms and ranches which produce our food and fiber."

On Wednesday, in his address to the joint session of the Legislature, he stated that not only was it essential that Texas devise an adequate plan to meet the water needs of the State but that it would be essential for Texas to implement its planning if it is to determine its own destiny in water development. He acknowledged that the federal government has proposed plans for development of major regions of the State but pointed out that these plans do not encompass all our needs and resources, and they still lack the coordination which only the State can provide.

The Governor commented only briefly on oil and gas in his address to the Legislature. However, his interest in this area as one of the State's greatest resources is well known.

We might note that on petroleum matters Governor Connally speaks not only as chief executive of the largest oil-producing state but also as chairman of the Interstate Oil Compact Commission and one of the eight oil-state governors who recently presented an authoritative and detailed report to the IOCC on state conservation practices.

Glancing over your program for this symposium, I see that it is most comprehensive and that various pertinent subjects are going to be discussed by genuine accredited experts. For that reason I shall limit my own comments to the general picture as I see it, with a few footnotes about the Railroad Commission's place in that picture.

Wise and proper water planning involves many considerations, including:

--the amount available, now and in the future;

--an estimate of needs, immediate and prospective;

--the present use and reuse of water resources, and how these might be improved;

--supplemental sources of water;

--what is being done about the water problem; what more needs to be done, and by whom.

Running through all of these factors is the somewhat tangled thread of public and private water rights. Whatever we do about water must be done without unnecessary intrusion upon the legal and traditional claims of individuals, communities and regions. This interesting facet I must leave to Chrys Dougherty and other well-qualified speakers to follow.

Availability of Water -- Future Needs.--Without going into a detailed statistical analysis, we can simply say that we are going to need more water every year as the population of Texas grows at the present rate of 19,000 a month and the per capita consumption of water shows a steady increase. It is estimated that the present demand will be tripled by the year 2000.

At the same time, we recognize that sufficient rain falls each year to meet that increased demand several times over. This remains true even though some 72 percent of rainfall evaporates quickly.

Texas has over 400 million acre-feet of ground water recoverable from storage and an average annual flow in our rivers of 40 million acre-feet.

The problem is not supply; it is distribution and use.

Distribution, Use, and Reuse of Water.--I have already touched upon trans-basin diversion of water for better distribution of available supply. We have been inclined to think of such projects as something belonging in the distant future but I remind you that trans-basin diversion is already an important factor in Texas.

As examples, we can cite:

--the city of Dallas contract with the Sabine River Authority to transfer 184,600 acre-feet annually from Lake Tawakoni to Dallas in the Trinity River Basin through a 32-mile pipeline;

--plans of the city of Houston, in the San Jacinto River Basin, to take 902,800 acre-feet annually from Lake Livingston in the Trinity River Basin by a 40-mile canal;

--and, familiar to all of you from West Texas, the contract made by the cities of Amarillo, Borger, Lubbock, Pampa, and other members of the Canadian River Municipal Authority with the Bureau of Reclamation for a 322-mile pipeline from Lake Meredith that will move 103,000 acre-feet of water a year.

Methods of treating water for reuse must and will be improved, and this means of "stretching" our water resources will be more widely employed than it is today. Water reuse is already extensive, particularly in the industrial centers. A barrel of water reused is the equivalent of the same amount falling from the sky or being siphoned from fresh-water aquifers.

While these and other techniques are important, they cannot replace the standard ways of conserving water by trapping surface runoff in reservoirs, either surface or underground, and by eliminating waste in the production and use of underground water supplies.

Supplementation of Natural Supplies.--Hope is high that new technology can alleviate the water problem, adding to the available supply. Ways may be found to control the weather, so that rainfall can be induced when and where needed. Progress is being made in the reduction of evaporation of our rainfall.

Of current interest are developments in de-salting ocean water. Five demonstration plants, one of them at Freeport, are now in operation. A plant at Los Angeles of much greater capacity is expected to show that costs of de-salinization can be cut from the present $1 to about 35 cents per 1,000 gallons. When desalted water becomes available at commercial prices, the problem of distribution will remain.

The most obvious and urgent means of increasing our available supply of fresh water, and the means nearest at hand, is preventing and overcoming water pollution.

The Water Pollution Problem.--Pollution, or rather the avoidance of it, is the water problem with which the Railroad Commission is most directly concerned.

Indeed, this matter must be a primary concern of everyone connected in any way with the use and conservation of our water resources -- from the individual user to the federal government.

Some contamination is unavoidable from sewage, industrial wastes, salt deposits left from irrigation, and the like. The challenge is to hold contamination within reasonable limits and, at the same time, improve our methods of offsetting it.

The members of the Railroad Commission naturally take such responsibilities seriously. We also have strict requirements and a powerful persuader to use when necessary--namely, pipeline severage. Enforcement so far has been on a case-by-case basis, which we believe has been both fair and effective. For example, in January 1964, employees of the Railroad Commission invested more than 1,500 man hours in pollution control activities. In the critical pollution control area of the Hubbard Creek Watershed in West Texas, the Railroad Commission completed checking 553 oil and gas leases, and 115 leases were severed from their pipeline connections for failure to meet water disposal standards under a "no-pit" order. The Railroad Commission is also acting to prevent pollution problems by having its employees witness well completions, pluggings, and workovers. So you can see that we don't take our responsibilities in this area lightly.

In addition to creating a State Water Commission and a State Water Pollution Board, the Texas Legislature has placed upon the Railroad Commission serious responsibilities of a preventive nature. The Commission's pollution control duties officially began as early as 1899.

As we all know, salt water is the main culprit with which the Commission and the oil industry are concerned. Here in Texas oil wells produce about 2-1/2 times as much salt water as oil. Safely and economically disposing of such a tremendous amount of brine presents a host of problems.

The earliest task given the Commission was to prevent mixing of oil with fresh-water sands. Subsequently, the Commission was ordered to prevent crude oil and natural gas, as well as water, from escaping from their home strata into other strata. In 1955 the Legislature told the Commission to make and enforce operational rules to prevent the pollution of streams and public bodies of surface water, and any subsurface strata.

Both the Commission and the petroleum industry have taken most seriously the responsibility of protecting fresh water from pollution. Disposal of salt water by re-injection, either as part of a pressure maintenance or secondary recovery project or simply to get rid of it, is widespread. Some brine is hauled or piped away for safe disposition or for use in distant waterflood programs.

The use of unlined surface pits has been greatly curtailed and is rapidly being eliminated where there is any danger of fresh-water contamination. All disposal methods are scrutinized as closely, and constantly, as time and personnel permit.

One troublesome problem was created in past years, when abandoned wells were improperly plugged or not plugged at all. The Commission is now moving toward a way of plugging these "lost owner" holes and to make sure that all wells abandoned in the future are adequately plugged.

While granting that oil-field wastes, particularly salt water, have contributed to the pollution problem in the past, the Commission and the industry insist that:

(1) Many of the bad practices of past years have been corrected, often at great expense to the oil producers, and continual progress is being made.

(2) The role of oil wells as pollutants has been exaggerated in many instances.

(3) The amount of fresh water used by the oil industry in waterflooding has been exaggerated.

For example, in the 48-county area overlying the Ogallala Formation in West Texas, surveys show that projected waterflooding will use up less than 1 percent of the water remaining in that aquifer while 96 to 98 percent will go for irrigation at present rates. By the same token, it is felt that oil's share of the pollution blame should be a great deal less than is popularly supposed.

Whatever the facts in a given instance, the industry's brine-disposal problem is a serious one. The Railroad Commission is required by law and the rules of sound administration to take whatever steps are necessary to see that it is solved promptly and adequately.

At the same time, we do not want to make and enforce regulations not actually needed; nor do we want to cause the premature shutdown of marginal-type fields. Expensive and unnecessary requirements should not be made in the name of pollution prevention. A common-sense approach, with proper regard for local conditions, would seem to be indicated. This does not mean, of course, that the Commission will tolerate deliberate delays or flagrant disregard of its control orders.

Finally, let me say that the Railroad Commission is ready and eager to work in cooperation with other State boards, with the federal government, with river authorities, and with local governmental agencies toward the swift and sure elimination of water pollution. We cannot afford the luxury of jurisdictional disputation. There is enough work for <u>all</u> in making sure that Texas retains an ample supply of water for every worthwhile purpose.

Just as surely as an adequate water supply will encourage economic growth, a shortage would just as surely limit growth. The challenge is immediate and inescapable.

OIL AND GAS VERSUS WATER IN THE SOUTHWEST: CONFLICT OR COMPROMISE?

Richard E. Faggioli

Introduction.--It is indeed a pleasure for me again to be in the fine city of Austin. At the risk of jeopardizing my membership in the Corpus Christi Chamber of Commerce, I must say that coming here is an experience to which my family and I look forward with much enthusiasm. Involved with my visits is a particular pleasure in becoming increasingly acquainted with the activities and accomplishments of The University. For their contributions to The University, I congratulate Dr. S. P. Ellison, Jr., and Dr. Peter T. Flawn, and to these gentlemen and their associates involved in the plans and conduct of this excellent meeting I express my gratitude.

A glance at the program for today reveals contributions to follow by representatives of several organizations and professions especially interested in water. As a representative of a company that is part of the oil industry, my remarks are intended to outline the environment in which water is used and conserved during the course of operations, the results of which include a significant economic contribution.

Factors will be discussed relating to historical development, legislative history, depletion and pollution of water supply, industry conservation efforts, and relative economic contributions. With this background the geologist's role in water conservation can be delineated in light of a challenge to prepare further for contributions to industry, community, and governmental activities related to water resources.

Historical Development of Water Needs.--At the beginning of this century and, indeed, as late as 1930, the economy of the State of Texas and the great Southwest was basically agrarian and depended little upon the contributions of industry (other than transportation) to provide the necessities of life for its residents and the tax funds required to sustain the governmental functions demanded by its citizens. However, with the great depression and the revolution in farming and animal husbandry technology, the human resources required to furnish the agricultural products and animals necessary to fill market demand began to decrease drastically. Consequently, there began a tremendous, and still continuing, migration of agricultural and ranch workers to metropolitan areas. This abundant supply of labor, willing and, in fact, eager to work at any wage, became more and more attractive to industry which became concurrently aware of the availability of low-cost dependable fuel supplies, particularly along the Gulf plains of Texas. Little by little industrial plants of substantial importance began to locate in this area. The advent of World War II and consequent construction of military and defense installations in the Southwest contributed to establishment of many defense-related industries and supporting businesses.

Prior to 1930 there was little concern with respect to availability of water except during periods of protracted drouth and in isolated and limited areas where extensive irrigation projects were carried on, such as the Lower Rio Grande Valley. There was little demand for industrial water and, other than the minimal requirements of drilling operations, the oil and gas industry used little water resources except for normal domestic consumption of its employees and cooling tower water for scattered gas plants and refineries.

Simultaneously with the acceleration of the industrial buildup the trend towards conversion from "dry farming" to irrigation quickened. Almost concurrently with these two events the demand for the use of water in oil and gas operations began to increase with the technological advances which led to the institution of pressure maintenance and secondary recovery projects to conserve and produce petroleum more efficiently. These factors, rendered more complex by the tremendous increase in the demand for water in urban areas as the result of the dramatic increase in the population of the area, signaled the beginning of a struggle for priority among the various competing factions which ultimately led, or at least is leading, to cooperative efforts to assure all segments of the economy adequate available water supplies to meet their present and foreseeable needs and to encourage additional industrial development in the area.

The pursuit of this goal has been accelerated during the periods of extended drouth and has ebbed to some extent when rainfall became more abundant. However, during the last decade, there has been almost continuous study by bodies of experts appointed by both private and governmental agencies. When water rights and conservation did begin to receive attention, everyone seems to have gotten into the act, as there are no less than 733 State and local agencies, exclusive of towns and cities, and 23 federal agencies which are interested, to some degree, in Texas water.[7]

Legislative History. --The first water appropriation acts were adopted by the Texas Legislature in 1889 and 1895, but were of little interest except in the arid portions of the State. One of the first, if not the first, act by a Texas legislative body dealing with fresh water in connection with oil field operations was Acts of 1889, page 68 (Article 6004, V. A. C. S., Texas). It provides that any oil well being drilled should be properly cased to exclude any surface or fresh water before penetrating the oil- or gas-bearing rock. This act was aimed at petroleum conservation and water protection and, of course, is in part the basis of some of today's Railroad Commission regulations involving protection of petroleum-bearing and fresh-water sands. Rules 8 and 9 of the Railroad Commission of Texas Statewide Rules provide that all operators of oil and gas wells and waste injection wells shall protect surface waters and fresh-water sands from pollution.

The Board of Water Engineers of the State of Texas (now the Texas Water Commission) was established in 1913, and its historic role has been the protection of the surface and ground waters of this State and the allocation of the available supply among various competing interests. The authority and responsibility of this Commission has been greatly extended and enhanced in recent years.

No comprehensive legislation dealing with preservation and distribution of water resources was enacted until 1917, when the Legislature passed several laws dealing with the subject, one of which (Article 7472) creates priorities among the various competing users of water. Significant amendments and additions to these basic laws were enacted in 1921. There were intermittent amendments of and additions to the water laws of the State during the next forty years but no significant pollution prevention legislation was enacted except Article 6029a which became law in 1955, which was mentioned earlier by Judge Langdon.

As a result of complaints by various special interest groups alleging pollution of underground water supplies and surface waters of the State, the Legislature passed in 1961 a law known as the Water Pollution Control Act and created the Water Pollution Control Board as the regulatory body to administer the provisions of the Act.

Consequently, there now exist four State agencies having basic regulatory jurisdiction over various aspects of fresh-water conservation on a Statewide basis--the Railroad Commission, in connection with the petroleum industry operations; the Texas Water Commission in connection with water matters generally; the Pollution Control Board in connection with contamination of fresh-water supplies; and the Texas Water Development Board which administers the State water loan and investment fund. In addition, there are numerous special districts, created under various laws which have jurisdiction over local aspects of water conservation, such as the High Plains Underground Water District No. 1.

As would be expected, the statutes creating these various bodies have been enacted over a long period of time and not as a comprehensive correlated code covering the conservation and use of water resources; and, as would be further expected, there have arisen conflicts between these agencies concerning their various jurisdictions and prerogatives. For example, a District Court in Travis County recently held that the Railroad Commission, not the Pollution Control Board, has exclusive jurisdiction over the disposition of oil and gas field wastes, but the Board has given notice of appeal.

Under the leadership of Governor Connally, who has expressed deep concern with water development of this State, a decisive beginning has been effected toward the establishment of responsibility of water development in Texas. In August 1964, the Governor asked the Texas Water Commission to expedite a comprehensive long-range State Water Plan. At the joint request of the Texas Water Commission, the Water Development Board, and the Water Pollution

Control Board, the Texas Research League undertook a water study. Recently, the Research League submitted its first report on this study entitled "The Structure and Authority for State Leadership of Water Development in Texas." A total of four reports are planned by the Research League staff to summarize the water study and offer proposals for improvement.

Accelerated planning by the State appears to be particularly appropriate in the face of the increased federal activity in this area of predominantly local interest. In his State of the Union Message on January 4, 1965, President Johnson indicated that he will wage a vigorous campaign for comprehensive water and air pollution control legislation in the 89th Congress.

The "Conflict."--The so-called conflict involves two specific charges which I will attempt to treat separately:

(1) the contribution of oil field wastes to ground water pollution; and

(2) the use of fresh water in oil and gas operations.

Although the disposition of polluted and bacteria-laden effluents by municipalities and industries other than the petroleum industry into water courses and pits probably exceeds substantially the contaminants currently disposed of through surface pits by the petroleum industry, the primary finger of guilt in connection with the pollution problem generally has been pointed at the oil and gas industry.

Surface pit salt water installations have been the object of a variety of exaggerated charges connected with pollution of underground waters, particularly in West Texas, and usually by agriculturally oriented interests. Many of these statements would lead the general public to believe that all of the salt water produced by the petroleum industry is dumped into unlined surface pits, rivers, creeks, ravines and released indiscriminately upon the surface of the earth without regard to protection of potable waters.

Indeed, according to a report which was compiled from a Texas Railroad Commission survey made in 1961 (the latest available complete figures), the Texas oil and gas industry was producing about 2-1/2 barrels of salt water for every barrel of oil produced. Based upon the current calendar day oil allowable, this would mean we are producing over 7-1/4 million barrels of salt water per day. The disposition of this volume of water lends itself to no simple solution. However, it is significant that the petroleum industry, working in cooperation with the Railroad Commission and the Board of Water Engineers, had been diligently pursuing and developing acceptable means of disposition of salt water, where pollution of fresh water might occur, for many years prior to the creation of the Water Pollution Control Board.

It is also interesting to note that the Railroad Commission survey indicates that almost 69% of our total salt water production in the State of Texas was being disposed of through injection wells in 1961, the year the Pollution Control Act was enacted. With the initiation of additional waterflood projects creating a demand for oil field brine and the drilling of a significant number of additional salt water disposal wells since the completion of the survey mentioned, the percentage of the total volume of salt water produced which is disposed of underground at the present time undoubtedly is substantially higher than 69%. In other areas such as Railroad Commission District 9 in North Texas, it was shown by the 1961 survey that 98% of the produced salt water was injected underground and only 2% was disposed of in surface pits. The survey revealed that in four of the eleven Railroad Commission Districts more than 90% of the produced salt water was disposed of through injection wells.

Nevertheless, some newspapers and special interest groups continue to make unfounded or inaccurate statements about the industry in the field of pollution.

That a great majority of the charges leveled at the industry are exaggerated or untrue was recognized by Judge Jim Langdon of the Railroad Commission recently in a discussion of water pollution and conservation before an engineering group when he said:

> "Let me inject one qualifying statement, lest I leave the impression that the oil industry is mainly responsible for water pollution. This is by no means true. In the great overall view of Texas water resources and their conservation, the petroleum industry's share of responsibility is relatively small. . . . "

In reply to charges leveled against the industry to the effect that waterflood operations in West Texas are depleting the Ogallala and surface disposal pits are polluting it, I might make two observations:

First: An editorial in the November 1964 issue of the Cross Section, house organ of the High Plains Underground Water Conservation District No. 1, points out that,

> "Unreliable rainfall, coupled with high rates of evaporation and transpiration, have caused the High Plains farmer to turn to irrigation. Water is being withdrawn from the Ogallala water-bearing sands through thousands of wells at several hundred times the natural recharge rate. A serious ground-water depletion problem is being created by the mining of this vast ground-water supply."

In another editorial in the same publication, the following statement is found:

> "If I could show you how to make an extra year's profit every five years, would you be interested? Studies conducted by the High Plains Underground Water Conservation District show that on an average a

farmer can conserve one year's water out of every five years by using a tailwater return system."

Since more than 96% of Ogallala water is used for irrigation and only about 6/10 of 1% will be used in oil operations, I think the foregoing quotations indicate that the volume of water wasted in irrigation in West Texas in only one to two years will exceed by far the total quantity of fresh water which will be used in waterflood projects in the area over the total lives of the projects.

Second: The 20% evaporation and transpiration rate indicated in the quoted statement would appear to lead to the conclusion that the irrigation cycling operation would increase the chlorides content both by reduction of the total volume of water returned to the formation and by leaching of additional minerals from the soil as the water moves downward to the water table. I feel sure that the oil industry has been blamed in some instances where increased chlorides content has been noted in wells, when in reality the irrigation cycling process itself has been the major cause.

Industry Conservation Efforts.--A number of voluntary industry efforts to protect surface and ground water and determine availability of supplies can be cited. For instance, a central salt water collection and disposal system was constructed in the Darst Creek and Salt Flat fields in the mid- and late 1930's.

The East Texas Salt Water Disposal Company was formed by twelve operators in the East Texas field and first injections through this system occurred October 1, 1942. Today this and other similar systems dispose of an estimated 95% of the produced salt water in Railroad Commission District No. 6. The magnitude of the East Texas system is indicated by the fact that it required an original investment of $2 million which has grown to $7,638,701 today and handles 386,000 barrels of water daily, or 140 million barrels annually.

Many other examples of petroleum industry voluntary action aimed at fresh-water protection, extending back 25 years or more, could be cited.

As most of you no doubt know, the Texas Mid-Continent Oil & Gas Association, with representation from all segments of the petroleum industry, formed a Water Conservation Committee at its annual meeting in 1963. This Committee is composed of top petroleum industry executives and is charged with the duty of dealing with water protection and conservation matters. In addition a Legal Subcommittee, a Technical and Engineering Subcommittee, and a Public Relations Subcommittee were established to function under the policy guidance of the Water Conservation Committee. The actions and decisions of these groups are prescribed by the following policy statement adopted by Texas Mid-Continent:

"RESOLUTION OF TEXAS MID-CONTINENT OIL & GAS ASSOCIATION

WHEREAS, this Association recognizes the importance of fresh water to the economy of the State of Texas and recognizes the obligation of the members of the oil industry as responsible citizens to make contributions in the future as it has done in the past toward the protection of fresh water; and

WHEREAS, the Association recognizes the need for fair and reasonable governmental regulation to protect the State's fresh waters but such regulation may expand unnecessarily so as to constitute a serious economic burden on the industry without significantly advancing the public interest; and

WHEREAS, there have been an increasing number of hearings, investigations, and complaints by State legislative committees, State regulatory agencies, various levels of local government and numerous other groups, all of which involve the disposal of salt water in connection with oil and gas operations and all of which should command the careful attention of industry; and

WHEREAS, it is the belief of this Association that industry can solve any problems it has created by conscientious efforts of members of the industry without compulsion from regulatory agencies and that such voluntary action by industry will produce a greater protection of the public interest and a less severe economic impact on the industry than will result from governmental compulsion:

NOW, THEREFORE, BE IT RESOLVED THAT this Association does hereby adopt the following statement of Association policy:

1. It is the policy of this Association to encourage all operators to recognize the problem of fresh water protection to be of such importance that it deserves the best technical efforts of the industry and is of such importance that each operator should integrate a concept of water conservation in its operations.

2. It is the policy of this Association to encourage operators to be alert for practices that could result in contamination of fresh water, to plan operations in such a manner that fresh water supplies are protected, and to be aware at all times of the need for industry to conduct its operations in a manner that is consistent with the public interest.

3. It is the policy of this Association to encourage operators to seek to develop new techniques for disposals of oil field wastes that economically protect fresh water supplies and encourage operators to share such technical knowledge with one another.

4. It is the policy of this Association to encourage operators to co-operate with regulatory agencies in carrying out their duties with the objective of assisting such agencies to protect fresh water supplies with a minimum of restrictive regulation and burdensome cost to the industry.

5. It is the policy of this Association to urge regulatory agencies, legislators, and the public in general to recognize the importance of the oil and gas industry to the economy of the State and to adopt programs that will protect the public interest without placing undue or unnecessary economic burdens on the industry.

6. It is the policy of this Association to engage in an Association program, through appropriate committees, to study industry problems involving fresh water protection and to furnish to members of industry information on developments in this field."

The Committees I have mentioned have worked closely and co-operated fully with the Water Pollution Control Board and other State and local agencies and private groups on matters dealing with fresh water protection. They have also carried on an extensive and aggressive education program within the industry through its house organs and other news media, giving widest possible dissemination to the Association's policies dealing with water protection and developments in the field of pollution control.

Members of these Mid-Continent Committees have also met on numerous occasions with Chambers of Commerce, governing bodies of water districts, State agencies, and professional and technical associations to review the petroleum industry's role in water protection and conservation.

In these meetings the Committee members have pointed out that for many, many years, the industry has been a leader in this field.

It is common knowledge that for many years oil operators have been furnishing copies of well logs to the Texas Water Commission (formerly the Board of Water Engineers), without which the Commission could not have had available a wealth of information which it now has concerning various fresh-water supplies without expenditure of vast amounts of public funds.

Turning now to other examples of industry water conservation and use projects, several are notable.

Lake J. B. Thomas in Scurry and Borden counties probably could not have been built by the Colorado River Municipal Water District had it not been for water purchase contracts with oil operators. A recent contract negotiated with the District by Sun Oil Company, under the terms of which Sun purchases surplus water from the District and transports it by pipeline to a remote location for use in waterflood operations, may open the way for construction of a new reservoir by the District. In addition, the contract also provides for Sun to intercept and use in its waterflood operations certain salt water which otherwise would change the quality of the water in portions of the Colorado River. The direct benefits accruing to the public from this contract include (1) a reservoir which otherwise might not be constructed, (2) reduction of water cost to other users, (3) reduction of amount of bonded indebtedness required by the District, and (4) a long term water supply for the public, made available partially as a result of financial support from the oil industry to meet its short term needs.

Another dramatic example of the petroleum industry's interest in water protection and conservation is reflected by the construction of a 135-mile, $10 million pipeline engineered by Shell Oil Company and Shell Pipe Line Corporation, and partially underwritten by contracts with 11 other operators, to transport non-potable water produced from Capitan Reef water strata in Winkler County to oil fields in Ector, Andrews, and possibly other counties in West Texas. There it will be used in waterflood projects. One company is purchasing sewage plant effluent from a West Texas city. In another locale an operator is obtaining waste effluents from a butadiene plant for use in a waterflood project.

Surveys made by a Texas Mid-Continent Association Committee in late 1963 of the 48-county Ogallala area showed that since the 1961 survey figures were compiled, 13 of the major operators in the Ogallala area had undertaken 175 water injection projects which would dispose of approximately 200,000 barrels of salt water daily. These projects require an investment of $3.5 million and annual operating expenses of $1.5 million.

My company, Humble, has for some time been conducting studies of the occurrence, characteristics, and availability of fresh and non-potable water supplies in the Permian Basin area of West Texas and New Mexico. These studies use published and publicly available data, for example, that from publications of the U. S. G. S., Texas Water Commission, Texas Railroad Commission, and other reliable published sources. These studies have been initiated in an attempt to develop information on the availability of economically accessible non-potable water supplies satisfactory for use in waterflood operations, thereby avoiding the necessity to use potable water for this purpose.

As a matter of fact, extensive surveys of fresh-water use and projected use by the oil and gas industry in the area of the Ogallala water table--one of the most water-deficient areas of the State--indicate that 96% to 98% of the water produced from this formation each year is used for irrigation and the remainder is used for municipal and industrial purposes. Only a small fraction of 1% is used by the oil industry in waterfloods. Projections concerning the use of this water for oil field waterflood operations indicate that not more than six-tenths of 1% of the total Ogallala water supply will be used for this purpose, and the ultimate total usage for waterfloods will not exceed 1/4th of the total Ogallala water produced in one year. Stated another way, the total amount of Ogallala water to be used in waterflood operation in the area would reduce the projected 40-year life of the Ogallala supply by only three months. Carrying these projections one step further, it is anticipated that the peak use of Ogallala water usage by the petroleum industry will occur in the 7-year period beginning in 1968, during which oil industry usage should not exceed 0.8% of the volume produced each year.

Unfortunately, it is absolutely necessary to use fresh water in some secondary recovery projects or concede that millions of barrels of hydrocarbons must remain unrecovered in the ground. This is true for two reasons. First, in some cases, available adequate supplies of usable salt water are so remote from the area of proposed use or occur at such great depths that it is economically unfeasible to use them. Second, some formations react adversely to economically available salt water because of bacteria or solids indigenous to the salt water strata, and fresh water must be used, therefore, to avoid formation damage which would result in physical waste of hydrocarbons.

Many additional examples of petroleum industry contributions to the protection and conservation of fresh-water resources could be cited, but it is believed that the examples cited fairly depict the interest of the industry in water protection.

Relative Economic Contributions.--On the other hand, I would be remiss if I did not point out briefly the contribution of the petroleum industry to the economy of the State in relation to the small percent of available fresh-water supplies utilized by it. For instance, it has been stated that for every barrel of Ogallala water used in West Texas waterfloods, we can expect to be produced oil having a value more than thirty times that of cotton that could be produced with a barrel of water used for irrigation; and cotton is said to be the most profitable West Texas crop. It is probable that the comparison between the economic values produced by water used in oil production and some farm crops would not be so dramatic, but I feel sure the economics would still remain substantially in favor of oil production.

It has also been stated that, based on statewide total water use by industry, a barrel of water used for waterflood operations produces oil valued at about three times that of products produced per barrel of water utilized in the manufacturing industries.

Therefore, it can be seen that a barrel of water used in petroleum producing mechanisms contributes significantly more to the general economy of the State than does water used in agricultural or manufacturing pursuits. Lest I be misunderstood, let me interject parenthetically at this point that I am not condemning or even criticizing either agriculture or other industries; among their other contributions, they provide a great part of the market for oil, gas, and refined products. It is to the distinct advantage of the petroleum industry that adequate water supplies be developed and conserved within the State to attract new industries and promote expansion of existing industries, as they constitute a primary source of revenue for the petroleum industry through product sales and by providing a market for natural gas.

Returning for a moment to the matter of economics, I would like to cite a few statistics which should indicate, to some extent, the vital role which the petroleum industry plays in the overall economy of the State.

Texas became the nation's number one oil-producing state in 1928; and, in 1932, the value of oil and gas produced in the State exceeded the value of agricultural production for the first time. Currently, the oil and gas industry employs 216,000 people--1 out of every 17 Texans--with a payroll of $1.3 billion a year. The value at the wellhead of oil and gas production is $4.1 billion comprised of: Oil: $2.9 billion; Gas: $0.761 billion; and Gas Liquids: $0.448 billion.

This wealth is shared by thousands of farmers, ranchers, and other owners of land in 209 petroleum productive counties of the State's 254 counties. In 1963 landowners received about $456 million in royalties. The economic benefits derived directly from petroleum industry activities create a demand for many other goods and services which require more plant investments, workers, and additional payrolls.

Taxes paid by the petroleum industry discharge a large share of the cost of education and government in Texas. The industry's tax bill--principally through production or severance taxes--pays about one-third of the State government's total expenditures on public schools. In 1963 oil men paid $223 million in state taxes and another $150 million at the local level to counties, cities, school districts, etc.

Although Texas produces about 35.5 percent of the nation's oil production, only a relatively small part is consumed here. The remainder goes into interstate and foreign commerce, thereby bringing new dollars into the Texas economy and generating new business activity.

Now I realize that I have digressed substantially from my basic topic of water, but I designedly did so with a specific purpose in mind; to show that although the requirements of life, sanitation, and other domestic uses must always have priority in the use of water, the relative contributions to the general economy and public welfare must be taken into account where other uses are concerned. Certainly no responsible oil operator objects to reasonable regulations and laws calculated to protect fresh-water sources and supplies. However, unreasonable and burdensome laws and regulations which may be adopted at the behest of special interest groups whose contribution to the economy is substantially less than the oil and gas industry is not in the interest of either sound resources management or economic expansion. The ultimate result of such a condition would be the premature abandonment of wells and fields because the cost of salt water disposal renders further operations uneconomic or the prohibition of the use of fresh water (where it is the only available or technically usable supply) prevents the institution of secondary recovery or pressure maintenance projects.

The Geologist's Role in Water Conservation. --I have said much about the so-called controversy over fresh-water protection, but nothing about a direct relationship between the petroleum geologist and the problem.

As a matter of fact--and principally through default--there has been little if any relationship between the geologist and water conservation and protection because we have been an inert ingredient in the hydrologic field. We have been content to abdicate our responsibilities and opportunities for service in this vital area of public interest and leave it to the engineers and lawyers.

It has been found during the last decade when long-range water resources planning has reached an all-time peak, that there is a woeful shortage of fully competent hydrologists.

I would like to suggest to you that we geologists--particularly those of us who are actively engaged in the petroleum and hard-mineral prospecting and producing business--are in a position to make really worthwhile and lasting contributions in the field of hydrological research and development if we will only exert the energy necessary to educate ourselves on basic fundamentals of hydrology and apply this knowledge to the hydrologic data which are available to us in our daily activities.

Now let us look at a few examples of the type geological work with which we may be involved as we prepare our studies on water. Mindful of the responsibility of individuals and corporations in the matter of water source and supply, a tremendous amount of work has been accomplished by oil companies. Much of this is in the nature of analyses and consolidation of published reports of federal, state, and local agencies.

For example, in connection with water studies in a portion of West Texas, my company developed a study of an area of approximately 40,000 square miles. Using published and public data the productive limits of known shallow aquifers were delineated with particular emphasis on those areas underlain by more than one potential zone. In the southern part of the High Plains and South Plains, areas can be located where, in a single well, objectives could be reached in the Cenozoic fill, Rustler Dolomite, and Capitan Reef.

The importance of water in the Ogallala Formation of Pliocene age is well known, and a number of maps have been made on the formation. It is a major source of water in West Texas, covering an area of some 24,000 square miles and ranging in thickness from 50 feet to 500 feet. Sixty-five percent of the formation between the water table and base of the unit will yield water to wells. As to the geological character of the formation it is continental in origin, contains gravels and silts, and is thought to comprise coalescing alluvial fans. It is deposited on a surface eroded into Cretaceous and Triassic sediments so maps are desirable on the latter erosional surface as well as on the water table. Since the Ogallala was deposited on an aerially eroded surface, it follows that optimum thickness should be encountered along post-Triassic drainage courses.

Along these ancient stream channels, deposits should contain a higher percentage of coarser material and therefore provide better aquifers than on the old buried divides.

Of course, none of these studies and maps are new to you, but the point which I would like to emphasize is their involvement with geological intervals shallower than those with which we have been primarily involved in the past in our oil search.

In these South and High Plains studies, the technique of block diagram presentation could prove very helpful, particularly in projecting the extent of aquifers into areas of insufficient data. These studies can be extended to include deeper zones, such as the San Andres of Permian age. While waters of the latter have high sulfide content, a knowledge of their occurrence could be very important as a future supplementary source for some oil field uses.

Exploring further the opportunities for geological initiative, the appearance of salt water in a previously fresh-water-producing aquifer is all too frequently attributed to oil field pollution. However, we know that this contamination can occur from below. With many of the aquifers containing salt water below the fresh-water portion, it is easy to demonstrate how high demands on the fresh-water portion with attendant pressure gradients developed will cause salt water to encroach into the low pressure area.

Studies of these facts need not -- in fact, should not -- end with knowledge of them alone. There is great need for the origination of new ideas and solutions. For example, a fresh-water aquifer underlain by encroaching salt water may be made to produce for an indefinitely longer period through a number of wells by injecting fresh water near the salt-fresh water interface. This, in effect, could create a pressure block against salt water encroachment. Geologic ingenuity undoubtedly can develop countless other ideas for methods and mechanisms which may contribute significantly to the water conservation effort.

It would appear that increased attention at the academic level to techniques particularly applicable to geological studies of water-bearing intervals and hydrology would stimulate additional interest in these areas of investigation. Many of us in the past have tended to start our geologic investigation at the top of the first potential oil or gas reservoir. Now we need to extend this upward to the grass roots, so to speak.

After attaining the necessary background and knowledge, it behooves the geologist to take the initiative in making himself available to serve on committees of industry organizations which work closely with the governmental agencies having responsibilities related to water resources. If we are not being included in the committees and studies it is probably because we are not prepared to contribute or because there is inadequate awareness of the contribution a geologist can make. In any event, the geologist must take the initiative to contribute.

Summary and Conclusion.--The transition from a pre-1930 agrarian economy in Texas to current water needs for irrigation, municipal, and industrial purposes has been accompanied by legislative action directed toward conservation of this important natural resource. Numerous federal and state agencies are interested in Texas water, but the four principal organizations for statewide water jurisdiction are: Texas Water Commission, Texas Railroad Commission, Water Pollution Control Board, and Texas Water Development Board. The competition for subsurface water use resolves itself into two principal problem areas: depletion of ground water and pollution of ground water. The major part of the salt water produced in Texas was being injected as far back as 1961. Continued progress, including additional secondary recovery projects, has been accomplished since that time.

Heavy demands on water-bearing aquifers can cause salt water encroachment into the fresh-water-producing interval. Stimulated geological and engineering thinking will contribute programs for control of depletion.

Total oil industry use of potable water is minor relative to other demands, particularly that of irrigation. The relative value attributed to the use of a barrel of water in secondary recovery is as much as 30 times greater than that resulting from other uses, including some irrigated crops. The volume of water used in secondary recovery is minor relative to the other demands in the highly publicized area of the Ogallala Formation.

An industry organization, the Texas Mid-Continent Oil & Gas Association, has established a sound policy for water protection. Dedicated cooperation with the objectives of the policy will lessen competitive water use. Oil industry projects using water unsuitable for other purposes are notable and increasing in number.

A large amount of geological study has been accomplished, but much more can be done using known techniques. Additional data on water-bearing intervals, including shallow brackish and salt water, should be analyzed for water source possibilities.

Additional background in the geology of ground water should be considered on an academic level and in industry application. Prepared with a factual background a geologist can make himself aggressively available to industry organizations which work closely with governmental agencies having responsibilities related to water resources. As a result, the geologist should be in a position to give significant aid toward leading the conflict in water demands through compromise to compatibility.

THE RAILROAD COMMISSION LOOKS AHEAD

George F. Singletary

The very nature of the title suggests that in order to "look ahead" you must "look back" to appreciate the good things and avoid the past mistakes. Certainly you must appraise the present in order to take advantage of all lessons learned.

As one of the more noted Sunday night M. C.'s often says, "But before we hear that," let me assure you that the Railroad Commission is truly a Railroad Commission,

Some of you no doubt are wondering why a member of the staff of the Railroad Commission is appearing before the Southwestern Federation of Geological Societies.

Briefly reviewing the duties of the Railroad Commission, it might be best to state that it was created by a constitutional amendment adopted on November 4, 1890 to set rates on railroads and express companies.

Since then the Commission has been directed by the Legislature to:

-- regulate the motor transportation system in Texas;

-- act as an appellate body in the matter of natural gas utilities when disputes arise between gas companies and municipalities;

-- direct the butane and propane industries in the State insofar as safety and the licensing of dealers and handlers is concerned;

-- regulate the oil and natural gas industry by ascertaining the market demand, setting of allowable production, determining the proper spacing of wells, and performing all duties to prevent avoidable waste and thereby conserving the most valuable natural resource.

Since this meeting is more concerned with oil and gas, with some emphasis on water, my remarks today will be confined primarily to the Oil and Gas Division of the Railroad Commission.

On March 31, 1919, the 36th Legislature enacted the statute requiring the conservation of oil and gas, forbidding waste, and giving the Railroad Commission jurisdiction. By late November of that year the Commission adopted the first Statewide rules, regulating the industry. Among those rules was the first well-spacing rule -- Rule 37 -- to be adopted by any state.

Many problems developed within the industry and the regulatory agency before the early Commissions had much idea of how to cope with them. As an example, it was some years after the discovery of the East Texas field before anyone knew much about the real approach to conservation, the puzzles of the oil and gas reservoirs, or the application of the proper rules and regulations to enforce state laws.

Certainly much knowledge has been gained from the past, and present developments demonstrate the need for continuous learning.

Early in 1962 the Commission realized that much needed to be done in order to "keep abreast" with the oil and gas industry. Accordingly, the first step was to take a look at our organizational structure and our procedures. The Texas Research League was asked to do this job. A more streamlined Oil and Gas Division has evolved, headed by the Chief Engineer with four departments: Engineering and Legal Examiners, Production and Proration, Research and Inspection, and Field Operations.

This was the first step in streamlining the Oil and Gas Division. Immediately following, a tremendous task was undertaken. That was, for the first time, combining the proration of oil and gas (which had formerly been completely separate) and converting from a manual operation to a data-processing operation. Those of you familiar with data processing can appreciate the many headaches and the untold man hours needed to accomplish this undertaking.

The field forces, as a result of conversion to data processing, were relieved of the burden of a mountain of paper work. Therefore, our field inspections have nearly doubled in less than two years.

Accompanying this organizational change the Commission asked industry members to aid and advise on rules and regulations. An Industry Advisory Committee was formed and after many long hard hours, recommended to the Commission the <u>first</u> recompilation of all rules, regulations, orders, and memoranda of Statewide applications. The recommendations were adopted late last year.

Currently, the Commission staff is working with a Texas Mid-Continent Oil & Gas Association Subcommittee on a complete revision of all Commission forms. This will result in updating information, consolidation of various forms and thereby reduce the actual number of forms required, resulting in saving of time and expense without impairing the flow of necessary information to the Commission or for public use.

The Research and Inspection Department is responsible for continuing to examine all rules and regulations to see that those rules and regulations meet the requirements of industry and state; for sound conservation practices are dependent on continuous learning and review.

Another recommendation of the industry was to change to the percentage market demand factor from the old system of scheduled days. To support this change, data presented emphasized that a one-day difference from eight scheduled days resulted in an allowable change of approximately 190,000 barrels per day, whereas 0.5% increments would permit a change of roughly 30,000 barrels per day. The additional flexibility would allow the Commission a method for "inching up" allowables. This method of percentage market demand resulted in an equivalent 5 "producing day" increase in one year's time. It must be noted, however, the same increase would have resulted had the market demand factor for each month been rounded off to the nearest number of producing days.

Accompanying this market demand factor change the Commission more recently adopted a new yardstick for governing the setting of individual well's allowable. Without getting into details of ~~this new yardstick~~, it in effect grants larger allowables to the deeper well and to wells on wider spacing. This tendency, therefore, leads toward larger proration units and wider spacing thereby giving greater weight to productive acreage rather than the well factor which was the older rule that prevailed years ago.

Hand in hand with these changes the Commission just last year amended the Statewide proration unit from 20 acres to 40 acres with an accompanying spacing rule change from 330 feet from lease lines and 933 feet between wells in the same reservoir to 467 feet from lease lines and 1,200 feet between wells.

Inherent with the drilling and producing of wells comes the unpopular and undesirable salt water production. However, rather than speak of the undesirable, let us speak of another valuable resource -- fresh water -- and its protection.

Some groups have reached the hasty conclusion that the Railroad Commission has not used its statutory authority to protect waters and that the industry has been remiss in its duty to avoid pollution. We say that the facts do not justify these conclusions.

Contrary to the beliefs of some, the Railroad Commission has a strong set of rules for the protection of fresh water:

-- one rule sets forth the general requirements of fresh-water protection;

-- another details the casing and cementing regulations for such protection;

-- the third covers the plugging requirements;

-- the fourth provides for protection after abandonment by requiring that surface casing be left in place;

-- of two remaining rules, one contains the regulations relative to protection of fresh water during disposal operations; and

-- the remaining rule requires protection while injecting into producing reservoirs.

Rules and regulations, however, are only effective when there is cooperation and compliance. Lack of compliance is the major cause of our present-day pollution problems.

Recently, a report was made to the legislative committee investigating water uses and water protection that pointed out the Commission's role.

Realizing that salt water production would eventually present problems, the Railroad Commission as early as 1935 assumed its responsibility in the field of pollution abatement when orders were issued to stop surface contamination caused by oil field brines.

Statistics could be quoted showing improvement in both the field of fresh-water protection and pollution abatement. Surveillance has increased until at this time our field personnel spend approximately 44 percent of their time on pollution investigations including the preventative measures of the related work of plugging operations, well completions, and cementing operation. At the end of 1963, more than 85% of the salt water produced in Texas was being disposed of in an approved manner, or was injected into subsurface formations for secondary recovery purposes.

In summary, the Railroad Commission looks to the future in

-- better service to the industry and public by better data and more readily accessible data by employment of the data processing operation.

-- keeping abreast of new techniques, thereby up-dating our rules, regulations, and procedures.

-- stepping up all phases of water protection and pollution abatement.

-- more production in the coming year. The downward trend was reversed in 1963 and the first estimates of total crude oil and condensate indicate that 1964 is the best year since the Suez crisis when total production exceeded one billion barrels.

-- the drilling of wells on wider spacing due to change in the yardstick, change in the Statewide spacing and the "Pooling Bill" which has just been introduced in the Legislature.

WHAT EXPLORATION GEOLOGISTS SHOULD KNOW ABOUT POLLUTION

Earnest F. Gloyna

Introduction.--Water, like oil, is an indispensable resource. When measured in terms of weight, water is by far the greatest resource used by man. Use per capita in the United States is greater by a large factor than all other resource uses combined. The dependency of the Southwest upon production processes and the use of great quantities of water is especially important.

There is an important element in the development of a water resource which distinguishes it from that of other physical systems, namely, man's ability to use water, pollute water supplies, reuse water which has a recent history, recycle slightly used water, and renovate the most objectionable water. Scientific man has developed the means for adjusting the environment to himself or, failing in the quest, to adjust himself to the environment. In the development of modern technology, man has witnessed the synthesis of water resource management. Similarly an affluent society has established a high standard of living. Certainly no one will disagree with the fact that this standard has been accomplished in part through the use of natural water resources and not by keeping the waters pristine pure.

During the interim between the age when the "sanitary idea" became adopted and the present, the yardstick defining pollution was related unequivocally to public health standards. Today, at a crossroads where it is necessary to reevaluate the concept of optimum resource utilization and pollution control, the yardstick must be assigned new dimensions. Just as modern scientific breakthroughs are refining certain physical operations in wastewater treatment and stream flow regulation, it is now necessary to establish new dimensions in water quality maintenance and water use responsibility and to seek the maximization of net benefits that may be derived from the use of water.

It must be agreed that from now on the water needs can best be met by controlling pollution. Water resource management must permit and even direct repeated reuse of the same water. This water may be diluted with relatively pure water as it flows from city to city, from industry to industry, from surface streams to underground formations, from agricultural lands to streams, from wastewater treatment plants to recreational facilities. In essence, water, the vital raw material, must be available in sufficient quantity and usable quality for purposes of furthering the state's affluent society.

The Nature of Pollution.--Water pollution may be very obvious or rather subtle. Pollutants may be classified as conservative or non-conservative. Conservative pollutants are considered to be relatively stable and are not altered by the normal biological processes that occur in natural waters. Typical of this latter category are the inorganic chemicals such as chlorides which, once they enter the receiving water, may be diluted but not necessarily reduced in quantity. Some industrial wastes contain numerous conservative pollutants, including metallic salts and substances which are toxic, corrosive, colored, and taste-producing. Domestic wastes contain chlorides and other dissolved salts. Each time the water passes through a municipality the concentration of chlorides in the wastewater increases approximately 70 to 100 parts per million. Similarly, return flows from irrigation carry dissolved solids, predominately chlorides. Industrial wastes, including oil production, produce wastes containing chlorides in greatly varying amounts.

Non-conservative pollutants are changed in character by the biological, chemical, and physical forces that are exerted in a natural aquatic system. Domestic sewage, a highly unstable, organic waste can be converted to inoffensive carbon dioxide, inorganic materials, and cell substances through the action of bacteria in treatment plants or rivers. Also, some industrial wastes that contain decomposable organic substances and the necessary nutriments can be utilized by bacterial systems. Last but not least, the agricultural runoffs frequently add to the organic load which an aquatic system receives. These wastes may include decomposable material ranging from cellulose to complex chlorinated hydrocarbons. Yet, all of these wastes or waters polluted with these wastes can be treated for use, and as a matter of fact such waters are being used by humans.

Conservative wastes may be broken down biologically by two generally known processes. First, if free oxygen is available specific organisms will proceed aerobically to degrade the waste without producing offensive odors. Second, if dissolved oxygen is not present and the bacteria must utilize oxygen from chemical sources such as sulfates, the process of biological degradation becomes anaerobic and noxious gases such as hydrogen sulfide are produced. Every stream, estuary, and sewage treatment plant contains microorganisms which can initiate aerobic or anaerobic actions. Essentially, a wastewater treatment plant systematizes, controls, and accelerates the processes that would have occurred in any case in a natural aquatic system. A treatment plant can only limit the self-purification burden that may be put on a water body.

A measure of organic pollution, then, is the oxygen that is required to sustain aerobic degradation. This is known as biochemical oxygen demand (BOD). The rate at which domestic or industrial wastes exert this oxygen demand is a function of many factors, including temperature and the chemical characteristics of the aquatic system. At higher temperatures the bacterial action is accelerated, wastes are degraded more rapidly, and the rate at which oxygen must be supplied to the water becomes greater. Furthermore, the amount of dissolved oxygen which can be added to a natural body of water at higher temperatures is less than that at colder temperatures. Therefore, in some cases the summer months are critical periods in handling organic wastes in streams. The introduction of toxins, particularly by industrial and agricultural operations, may appreciably reduce the rate of BOD reduction by inhibiting bacterial action.

Standards for Effluent Quality.--Several countries and various states in the United States have standards of effluent quality which command general acceptance, even if they are not legal in the strict sense of the word. Interestingly enough, for almost half a century many standards have been written following in close detail standards which were proposed in the United Kingdom. These standards suggested that an effluent should not contain more than 30 parts per million suspended solids or have a 5-day BOD greater than 20 parts per million. Although these two tests have been generally recognized, the early British standards were never, in fact, made legal, because their proposers realized that they could not apply in all cases. In almost all instances there are provisions for relaxation when circumstances warrant.

Trends in Pollution.--Trends of industrial effluent production are not easy to assess. Industrial effluents with respect to quantity still seem to be increasing and their limit cannot be foreseen with a high degree of accuracy. New products are continually coming into production, particularly those which produce liquid effluents. Insecticides, pesticides, etc., come readily to mind in this connection.

Problems of wastewater disposal and water quality maintenance go hand in hand. Water and waste treatment facilities will most certainly be more costly in the future. The cheaper water sources have been exploited. In the future water must be treated more thoroughly, managed more efficiently, and transported greater distances.

Do not expect dramatic and inexpensive breakthroughs in solving the water problem. There will be no immediate and inexpensive breakthroughs in weather modifications, desalinization, sewage disposal, industrial pollution abatement, or even agricultural pollution control. To be sure, there will be some technical progress made. However, the degree of progress will be related almost directly to the amount of money put into water resources research efforts.

Pollution control is beginning to receive a considerable degree of evaluation. The proper extent of treatment and the balance among control measures cannot be made rationally on technical grounds alone.[1] Consequently, values must be introduced into the decision-making process. There are many who believe that for a variety of reasons the unregulated market processes cannot deal sufficiently with pollution. As a result, there seems to be adequate grounds for public intervention and planning in this area.

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[1] Allen V. Kneese, Water Pollution, Resources for the Future, Inc., 1962, p. 17.

Pollution is the one aspect of water resources which establishes a technical link between various economic units. An essential element of the pollution problem is that the damages caused by waste disposal into water courses are in most instances external to the polluting unit.

Water Pollution Control Expenditures.--According to the Manufacturing Chemists' Association, to date the water pollution control expenditures for the chemical process industries in Texas amount to about $33 million. The annual operating cost is in excess of $6 million. The projected investment to 1969 is slightly over $6.6 million. This is the reason that modern plants are being designed for minimal waste discharges, so that specific anti-pollution facilities will not be needed.

On the municipal level the picture is pretty grim. According to the Conference of Sanitary Engineers, the estimated backlog of community wastewater treatment plants is so great that it would require almost $2 billion to provide some remedy. This expenditure is based on providing only secondary sewage treatment and will not remedy the problem of nutrient release into streams. Increased releases of phosphorous, nitrogen, and other nutrients cause some of our rivers and lakes to turn green as a result of algal growths. Presently, almost 6,000 communities in the U. S. have some deficiencies in their basic sewage treatment plants or sewer collection systems.

The federal role in water pollution control will continue to be expanded. Senator Edmund Muskie through Senate Bill 4 intends to strengthen the federal role in water pollution control. S.4 is similar to last year's unsuccessful S. 649. Among other things, these federal bills propose to fix stream purity standards. Also, as most of you know, local and state enforcement has become stiffer, sometimes under federal prodding.

Renovation of Polluted Water.--It is becoming obvious that water pollution abatement is necessary and that water renovation is desirable. However, the question arises as to the degree of abatement required. The answer all too frequently depends on which user is supplying the answer. For example, an avid conservationist might have an entirely different outlook from a City Council.

Since it is presently almost impossible to assess economic values on the resources of every watershed, although resource maximization attempts are being attempted on a few large river basins, it may be best to focus attention on some water quality guides. As an example the use-concentration spectrum that has been published recently by the U. S. Public Health Service offers some summary guide lines.[2] Examples of typical use guides are given in figures 1-4 (pp. 29-32). It is noted that the chloride use-spectrum may easily vary by a factor of ten. Coliform organisms, an indicator of human pollution, may vary by a factor of a thousand. Similarly, a moderate biochemical oxygen demand of a water may restrict its use but does not destroy the water for all purposes.

[2] Water Quality Guides, Use-Concentration Spectrum, Water Quality Criteria Practice Section, Technical Services Branch, Division of Water Supply and Pollution Control, U. S. Public Health Service (December 1964).

Indicator or Impurity	Municipal	Swimming	Fish	Livestock Wildlife	Irrigation
Coli $\frac{MPN}{100\ ml}$	$\frac{1}{5000}$ <1	2400 <1	70 * <1		5000 <1
Cr+6 mg/l	0.05 <0.05		5-300 <0.05	5-500 <0.05	3.4-17.3 <0.05
CN mg/l	0.01 0.2 0.01		0.08-0.5 0.01		
Phenols mg/l	1.0 1.0		2700 1.0	15,000 1.0	
Sulfate mg/l	250 1.0		90 1.0	250 2000 1.0	336-960 576 1.0

* SHELL FISH WATERS

FIG. I. WATER QUALITY GUIDES

WATER USE	CONCENTRATION (MG/L)	EXPLANATION
BREWING	60	OBJECTIONABLE ON HIGHER CONCENTRATIONS
BOILER WATER	100	SUGGESTED LIMIT TO REDUCE FOAMING PROBLEM
IRRIGATION	248 - 426	CLASSED AS PERMISSIBLE
FISH, TROUT	400	HIGHER CONCENTRATIONS ARE INJURIOUS
FOOD CANNING AND FREEZING	600-900	HIGHER CONCENTRATIONS MAY CAUSE OBJECTIONABLE TASTE
LIVESTOCK AND WILDLIFE	1500	SAFE CONCENTRATION (INCLUDES CHICKENS, THE MOST SENSITIVE TO CHLORIDE)

FIG. 2. USE-CONCENTRATION SPECTRUM CHLORIDE

WATER USE	BOD (5 DAY) (MG/L)	EXPLANATION
RAW DOMESTIC SOURCE	0.75 - 1.5 *	EXCELLENT SOURCE
RAW DOMESTIC SOURCE	1.5 - 2.5 *	GOOD SOURCE
RAW DOMESTIC SOURCE	> 2.5 *	POOR SOURCE
DRINKING WATER SOURCE	< 4	RECOMMENDED MAX.
STEEL MFG.	< 25	MAX. MONTHLY AVERAGE **

* MONTHLY AVERAGE

** BETHLEHEM STEEL CO. INSTANTANEOUS MAX. = 45 MG/L.

FIG. 3. USE-CONCENTRATION SPECTRUM BOD

WATER USE	MPN PER 100 ML SAMPLE (MONTHLY AVERAGE)	EXPLANATION
DRINKING WATER	1 *	PERMISSIBLE LIMIT
RAW DOMESTIC SUPPLY	50-100	EXCELLENT SOURCE
SHELLFISH PROPAGATION	70-700*	RESTRICTED BY USPHS
BATHING	1000	USUALLY CONSIDERED ACCEPTABLE
RAW DOMESTIC SUPPLY	> 5000	POOR SOURCE

* STATISTICAL LIMITS ARE PROVIDED.

FIG. 4. USE-CONCENTRATION SPECTRUM COLIFORMS

POLLUTION CONTROL: THE RELATION OF WATER QUALITY PROTECTION TO EXPLORATION FOR AND PRODUCTION OF OIL AND GAS IN THE SOUTHWEST

John J. Vandertulip

Introduction.--The production of oil and gas, and the marketing of petroleum products, has had a dizzying impact in this century on the growth and complexity of the political institutions of states in the Southwest and on the economy of the region. As a natural resource providing almost unlimited reserves of energy for all phases of industry, petroleum achieved a pre-eminent position in the economic and industrial growth of this nation within decades after initial discoveries in the Southwest revealed that vast, untapped supplies of oil and gas were available.

In those early days of exploration and production, there was little awareness of the potential water quality problems which were developing in oil-and-gas-producing areas. This lack of awareness was the result of the limited technology in the early days of oil production and the little emphasis on water needs, water conservation, and water development. Some of the problems which were later to plague all of us had not made themselves apparent, and time has compounded their gravity.

In part, this water quality problem was obscured because the use of water--even in the relatively water-short Southwest--was limited, and the supplies appeared ample early in the century for our future needs. Thus, the loss of a water well here and there from increased salinity of the water, or the alteration of quality in the water of a stream, was felt only locally. Additionally, however, is the sad fact that time has been a diligent enemy in compounding the problem. Equipment in old wells has deteriorated, resulting in subsurface leakage of brines. Over many years, brines which have entered ground-water aquifers have moved with the hydraulic gradient of the aquifer to points of discharge in surface-water courses and water wells so that pollution is detected at points which may be many miles from the source and impossible to trace. The ratio of brine production to oil production is increasingly unfavorable in many old fields. Operators responsible for drilling and abandoning many wells have moved on or disappeared, leaving unplugged or improperly plugged wells discharging brines into ground and surface waters. In Texas, legislation will be considered in the present session of the Legislature dealing with some of these problems of old wells, but the legal and economic difficulties in finding adequate solutions are great.

Water Use in Texas.--As water use has multiplied, it has become evident that our supplies of water from all sources are ample only within the framework of certain rigid conditions, and important among these conditions is that all reasonable treatment and handling of wastewater discharges be carried out to maintain water quality and limit or control pollution.

Not only has the use of water grown by leaps and bounds--in Texas from 4-1/2 million acre-feet in 1943 to 15 million acre-feet in 1963--but the variety of uses has also multiplied. Water quality standards imposed by this multiplicity of uses are high, and industrial and municipal growth are dependent on the availability of good quality sources of supply.

In Texas, water is obtained from 23 river basins and intervening coastal areas and from 7 major aquifers underlying about 65 percent of the State. Additional important supplies of water are obtained from minor aquifers in local areas. Quality of water in these streams and subsurface aquifers ranges within fairly wide limits, and changes in quality of either ground or surface water in a local area potentially affect the entire water body involved.

Water Pollution Control Agencies.--Each of the states of the Southwest has moved to combat the problem of brine pollution of its waters in response to events within its own boundaries, and as a consequence, progress toward solution of the problem is not uniform in the several states. I would like, therefore, to sketch for you the water pollution control structure in Texas. I will discuss briefly the part our water agency, the Texas Water Commission, plays in this structure. Then I shall move to the question of the relationship of pollution control to oil and gas exploration and production.

Although there are a number of State and Federal agencies, and local political entities, involved with one phase or another of water resource development in Texas, there are only a few agencies directly responsible for control of water pollution by oil and gas brines through statutory directive. These include the Texas Railroad Commission, the Texas Water Pollution Control Board, the Texas Water Commission, and the Red River Authority. Agency interrelationships in the area of water pollution control have been the subject of careful study in the past few months, and a realignment or redefinition of the pollution control structure in Texas may receive legislative attention in the next few months. It appears probable, however, that such attention will be directed toward strengthening--rather than weakening--overall water pollution control responsibilities and activities of the State agencies.

Responsibilities of the Texas Water Commission.--The Texas Water Pollution Control Board is composed of representatives from three State agencies concerned with pollution control as well as three members of the public appointed by the Governor. The Texas Water Commission is one of the agencies represented on the Board and is charged in the Pollution Board statute with the responsibility for investigating those situations in which the underground waters of the State are being polluted or are threatened with pollution and reporting its findings to the Pollution Board with its recommendations.

In addition to its connection with the Water Pollution Control Board, the Water Commission has other duties related to prevention of pollution of ground water. These duties include: recommending depths to which fresh ground water should be protected by casing in the drilling of oil and gas tests by the petroleum industry; hearing applications for permits to drill injection wells for the disposal of industrial and municipal wastes; reviewing applications to the Texas Railroad Commission for permits to dispose of salt water with the purpose of determining that the proposed injection zone does not contain fresh water, and that the proposed injection operation will not endanger fresh water strata in the area; and planning for the maximum development of all of the water resources of the State.

1. Surface Casing Program

Participation of the Water Commission in the surface casing program is based upon rules of the Texas Railroad Commission under authority given that agency by the statutes bearing specifically on the drilling and producing activities of the oil industry. These rules require that prior to drilling, an operator obtain a letter from the Water Commission setting out the depth necessary for fresh-water protection in oil and gas tests, seismic tests, or other exploratory wells penetrating "fresh-water strata."

During calendar year 1963 the Water Commission processed 9,705 individual applications for such recommendations, 160 field rule applications, and 18 stratigraphic or core test applications, for a total of 9,883 recommendations to the oil industry and to the Railroad Commission. During 1964 our agency made a total of 10,026 such recommendations. In preparing each recommendation, all pertinent geologic and engineering information relating to ground water in the area is utilized, including electric and other mechanical logs, water well schedules, drillers' logs, chemical analyses of water, evaluations of water-level changes, topographic relief and geology in the area, and the use that is or can be made of the available ground water.

As of September 1, 1964, the surface casing files of the Water Commission contained 31,423 logs of oil and gas wells throughout the State. This log library has been collected in a large measure through the cooperation of the oil industry. Large shipments of logs have been received from many operators, and this continuing cooperative program has contributed to the technical capacity of the Water Commission in providing this service function to the Railroad Commission and the oil industry. It has been estimated that 200,000 logs will be required to prepare detailed maps showing the base of fresh-water occurrence throughout the State. When this mapping task is accomplished, and the Water Commission has requested the Legislature to provide funds and the necessary additional personnel to make it possible, the industry will be able to use the maps in planning long-range drilling programs and will avoid the requirement of individual well recommendations. The development of this series of base of fresh-water maps also will be valuable in quantitative ground-water studies.

2. Subsurface Disposal Program

The pollution control functions of the Water Commission dealing with subsurface disposal are related to the administration of a permit system for municipal or industrial disposal well projects, and with review of applications made to the Railroad Commission for permits to dispose of salt water produced with oil by subsurface injection.

In carrying out these functions the Water Commission's staff determines ground-water conditions in the general area of the proposed disposal well by a review of the same array of information used in the surface casing program. A review is also made of the existing completion record or proposed method of completion of the disposal well, the volumes of fluid to be injected, anticipated injection pressures, and the intended disposal zone as related to ground-water conditions.

3. Ground-water Pollution Studies

In its relationship with the Texas Water Pollution Control Board, the Water Commission investigates those situations in which the underground waters of the State are being polluted or are threatened with pollution and reports these incidents to the Pollution Board. In meeting this obligation, the Water Commission's staff conducts field investigations of ground-water pollution problems and prepares technical reports of the results of the investigations.

In general, the field investigations of these pollution problems include a comprehensive study of the geology in the area of the well and the occurrence, quality, movement, and development of ground water. All potential sources of pollution are located and objectively studied with relation to the problem involved because water quality deterioration results from many waste discharges and natural causes, and the precise cause, or causes, in an individual case is not always easy to determine.

Investigations have been made on a variety of pollution problems. In some instances, suspected oil field salt water contamination was found to be the result of inadequate drainage of agricultural lands. Another alleged instance of pollution of water wells by oil field brines was found to be an iron bacterial problem in the water wells. Industrial wastes disposed of into an unlined surface pit are found to be polluting ground water. Septic tanks are creating significant problems, particularly in the vicinity of communities without a central water system. This variety is touched upon here to indicate that our work is directed toward all types of underground problems and not just those resulting from oil field brines.

4. Water Planning

In addition to its specific statutory assignment of responsibility for ground water, the Water Commission is responsible for Texas' water planning activities and development of a long-range plan is contingent on a realistic appraisal of potential losses of water supplies from pollution or any other cause.

Brine Production.--As a contribution to the state of knowledge of the salt water problem in Texas, the Water Commission in 1962 cooperated with the Texas Railroad Commission in conducting a detailed inventory of salt water production and disposal. The inventory was designed to provide an index to the scope and gravity of the brine problem and to provide an historical record against which future appraisals could be measured. This inventory revealed that a total of approximately 2-1/4 billion barrels of salt water were produced in calendar year 1961 from 67,000 oil and gas leases. Of this total, 68.7 percent was reinjected into the subsurface; 20.6 percent was disposed of into unlined surface pits; 10.1 percent was discharged directly into surface water courses; and the remaining 0.6 percent was disposed of by miscellaneous means such as spraying on leases or county roads.

Oil Production.--During this same calendar year, 1961, crude oil production in Texas was 894,000,000 barrels, and natural gas production from gas wells was more than 5 billion cubic feet. In calendar year 1963, crude oil production had climbed to 915,420,051 barrels, gas production from gas wells had shown corresponding gains, and, although figures are not available, it can be safely assumed that salt water production had also increased.

Pollution Control Related to Oil and Gas Production.--Salt water produced with oil is an economic liability to the industry from the moment it is produced--it costs as much to lift a barrel of salt water as a barrel of oil from the oil-bearing reservoir. The salt water must then be separated from the oil. Finally, the salt water must be disposed of by the operator in some manner. It is in selecting a disposal method that the operator finds himself immediately caught between the unfavorable economics of injection where large volumes of water are concerned, the regulations of pollution control agencies, and the anxieties of the surface landowner that his land and water not be damaged.

In new production, these pressures are lessened somewhat because adequate and prudent subsurface disposal methods can be phased into the initial drilling program, thus minimizing direct out-of-hand costs which arise when it is necessary to go back into a production area to install a salt water disposal system. By converting either an early dry hole for disposal, or a producing well which has been originally completed with this end in view, these later costs have been substantially reduced by prudent operators.

In old or marginal production, in stripper wells, and in areas where initial water production is very great, economic means of disposal are not easy to find nor simple to install. Joint ventures of salt water disposal require gathering systems and continual maintenance which involve the individual operator in very complex legal and engineering problems which he may feel are prohibitively costly in time and money when production of petroleum products is a marginal venture at best. Repeatedly in such areas the industry has raised the argument that this production will be lost if shut-downs are made necessary by unfavorable economics. The argument has also been made that the value of the petroleum products outweighs in many such instances the value of the water or land which might be lost by the disposal of salt water into unlined pits or into surface water cours-

In our view, these arguments deal with the problem in a limited way. We believe that if we first accept the premise that pollution which can be prevented will not be permitted, other alternatives will present themselves in addition to the narrow choice between production with pollution or water protection with production shutdowns. Some of these alternatives include compulsory unitization to eliminate wells producing excessive volumes of salt water, and pooling production through wells making less water; economic assistance by the State working cooperatively with industry to dispose of salt water through sound injection projects in areas where industry action alone is not economically feasible; and State and industry cooperative programs to construct and maintain lined conveyance channels to carry produced brines from areas of production to points of discharge along the coast. In an industry which has developed techniques for solving production problems which are so imaginative that they rank with science fiction, it seems certain that many such alternatives await development.

In areas where strong pollution control measures have been applied, it is of interest to note that very few shutdowns have resulted. Where there is a firm realization that pollution will not be tolerated, it has been the experience of other states such as Kansas and California, and the experience of certain areas of Texas such as the area supervised by the Red River Authority, that threatened losses in oil and gas production as the result of tightened pollution control measures have not materialized.

<u>Summary and Conclusions</u>.--To summarize, then, we find that brine pollution of water is not a new problem nor a simple one. The following points appear important in an objective appraisal of the situation:

(1) Oil and gas production continues to increase, and salt water production goes up as an unavoidable corollary. Salt water production in Texas was reported at approximately 2-1/4 billion barrels in 1961.

(2) Brine pollution of ground and surface water can and has resulted from improper or imprudent practices of exploration, well completion, salt water disposal, and well abandonment.

(3) Brine pollution control must be based upon effective enforcement authority, sound petroleum engineering techniques, and competent evaluations of ground and surface water hydrology.

(4) Texas uses approximately 15 million acre-feet of water each year for consumptive purposes, of which 70 percent is supplied by ground-water aquifers. Oil and gas fields coexist throughout the State with the areas underlain by the major aquifers. Ineffective water protection programs in these areas is a particular threat to water quality and conservation.

(5) While simplification of governmental pollution control is desirable, it is apparent that brine pollution is a problem involving the immediate responsibilities of the oil and gas administrative agencies and the water planning agencies of individual states.

When we look at our situation today, then, we find that both the scope and the cause of the pollution problem is shifting, and there are factors of economics, politics, emotion, and self-interest which must be understood and dealt with. The petroleum industry is concerned with what it regards as the unfairness of the image with which it is saddled as a polluter of the public waters. The industry's spokesmen point out quite reasonably that never before has it devoted so much of its time, money, and top technical brains to the task of water protection. A long-range, continuing program will be necessary to cope with the salt water disposal problem. It behooves us all to work together conscientiously, without rancor, and with our combined technology.

GROUND WATER FOR THE OIL INDUSTRY IN TEXAS AND SOUTHEAST NEW MEXICO

William F. Guyton

The use of ground water in Texas and Southeast New Mexico is about 12-1/2 million acre-feet per year.

For those who prefer to deal in barrels, one acre-foot is about 78 hundred barrels, and the total use of ground water here, therefore, is about 100 billion barrels per year.

This 12-1/2 million acre-feet compares to a total use in the United States of about 55 million acre-feet per year. Thus, the use in our region is about one-fourth of the total in the United States.

Figure 1 (p. 48) shows how the ground-water use in Texas and Southeast New Mexico is divided among the various types of use. Irrigation is by far the greatest, amounting to about 88 percent of the total. Next is the municipal use, which is about 6 percent of the total. Next the self-supplied industrial use, amounting to about 5 percent. This includes use by the oil industry, which is about 3 percent, and use by the remaining industries, which altogether amounts to about 2 percent. Last is the rural use, amounting to about 1 percent of the total.

The 3 percent used by the oil industry amounts to between 350 and 400 thousand acre-feet per year. This is equal to about 3 billion barrels per year. Between one-third and one-half is for refining and allied manufacturing and for such things as pipeline stations, camps, and drilling operations. Nearly all of this is fresh water. The remaining one-half to two-thirds of the water used by the oil industry is for water flood and pressure maintenance operations, and it is estimated that perhaps three-fourths of this is brackish or salt water.

Figure 2 (p. 49) shows the principal areas of ground-water use. The stippled areas show irrigation, the solid areas industrial use, and the open circles show the cities over 1,000 population and the military installations which use ground water. The largest industrial use is along the Gulf Coast and the largest irrigation use is in West Texas and Southeast New Mexico. The largest municipal users are Houston, San Antonio, and El Paso.

The principal uses of ground water do, of course, occur primarily in the areas where the water-bearing formations are most productive. In this respect, note the large areas of irrigation on the High Plains. On figure 3 (p. 50) are shown the positions of the major aquifers; and this irrigation on the High Plains, which requires more than half the total ground water used in Texas and Southeast New Mexico, comes from one of them, the Ogallala formation.

As shown by figure 3 (p. 50), about two-thirds of Texas and Southeast New Mexico is underlain by formations termed major fresh-water-bearing formations. These formations supply more than 95 percent of all the ground water used in Texas and Southeast New Mexico.

The primary productive beds in these formations are sands, gravels, and limestones.

One of the important water-bearing limestone formations is the San Andres. The principal area of large production of water from the San Andres limestone is in the Roswell Basin of New Mexico. In this area some 250 to 300 thousand acre-feet of water is withdrawn annually from wells in this limestone. These wells range in depth from less than 200 to more than 1,400 feet. The aquifer is one of the few in New Mexico which have large amounts of perennial recharge. The withdrawals of water from the aquifer have been regulated by the State Engineer since 1931.

Deposits of alluvium which yield large ground-water supplies occur in several parts of the region, as shown on the map. Not shown, because of pattern conflict on the map, is the alluvium of the Roswell Basin, which overlies the San Andres limestone.

The alluvial deposits consist generally of interconnected, lenticular layers of sand and gravel interbedded with clay and silt.

The alluvium in the Roswell Basin occurs to a depth of about 350 feet and supplies in the order of 150 thousand acre-feet of water per year to wells for irrigation. In the Carlsbad Basin to the south, the alluvium extends to a maximum depth of about 250 feet and is used in conjunction with the reef aquifer to supply the needs of that area.

In the remainder of Southeast New Mexico and in West Texas the alluvial deposits fill ancient valleys or basins and fresh water is found in them to depths up to 1,500 feet. They are the source of most of the municipal and industrial water and much of the irrigation water in the El Paso area and of the irrigation supplies in the highly developed Pecos and Coyanosa areas.

In Northwest Texas the alluvium is known as the Seymour Formation and has a maximum thickness of about 100 feet. It supplies water there for a number of towns and some 50 thousand acres of irrigation.

In the alluvium of the lower Rio Grande water is generally fresh enough for use only at depths of less than 250 feet. There are some 2,000 irrigation wells in this area used principally to supplement water from the Rio Grande when the river water is scarce.

In the Brazos River valley the alluvium is in the order of 100 feet thick, and about 1,000 irrigation wells draw from it.

The Ogallala Formation, on the High Plains, consists of interfingered and intergraded lenses and layers of sand, gravel, silt, clay, and caliche. The formation has appropriately been described as homogeneous in its heterogeneity. It covers the surface of the High Plains and ranges in thickness from zero to more than 800 feet. There are over 50 thousand irrigation wells drawing from the Ogallala in this region.

It has been shown that south of the Canadian River the annual pumpage of water from wells in the Ogallala is some 25 to 30 times as much as the average annual recharge. The total ground-water storage in the Ogallala Formation of the Southern High Plains before pumping has been estimated at approximately 250 million acre-feet. Of this some 45 million acre-feet has now been withdrawn. In time the storage will be used up and the pumpage from wells must be reduced to less than the recharge, which will mean the end of the present irrigation economy on the Southern High Plains. In the meantime, however, the water is being used for the production of income as man would use any other mineral resource. In 1963 the Federal District Court in Lubbock ruled that a landowner in this area is entitled to a depletion allowance in his income taxes as his water level declines. The case is now awaiting a decision by the Court of Appeals.

On the Edwards Plateau are the Edwards Limestone, the term being used here in its broad definition to include the Georgetown and the Trinity sands, or basal Cretaceous sands. Wells up to several hundred feet deep drawing from these formations supply a number of small cities and a moderate amount of irrigation. The very large base flows of the lower Pecos, Devils, Nueces, Frio, and Llano Rivers come from springs discharging out of these formations. Because of the large amount of this natural discharge as compared to pumpage from wells, this aquifer is considered relatively undeveloped. However, all the water flowing from the springs into the streams is needed downstream, and then some. This points up a basic conflict between ground-water and surface-water rights.

In North Texas the Trinity, or basal Cretaceous, sands supply water to numerous muncipal and industrial wells. The sands are fine-grained and the yields of the wells generally are not as large as yields of wells in many other parts of the State. The sands are widespread, however, and have been in much demand as sources of water for the smaller cities and for industries. Some of the wells are as deep as 3,500 feet.

The Edwards Limestone in the Balcones fault zone yields water to irrigation wells and to the large municipal and industrial wells at San Antonio. The wells range in depth from about 200 to 2,000 feet. Some of the San Antonio wells are among the largest in the world in terms of capacity, yielding as much as 17,000 gallons per minute, or 1 million gallons per hour, each. As you know, 1 barrel is 42 gallons, so these yields are about 24,000 barrels per hour.

Before there was any pumping, almost all of the recharge to the Edwards in this area was discharged from the limestone through large springs, including

San Antonio Springs at San Antonio, Comal Springs at New Braunfels, and San Marcos Springs at San Marcos. As pumpage from wells has increased, however, the springflow has decreased. The total average annual recharge to the Edwards Limestone in this area is estimated at about 550 thousand acre-feet per year. The average discharge, which balances the recharge, is now divided about evenly between the wells and springs.

The Carrizo-Wilcox sands comprise one of the most extensive aquifers in Texas. The sands supply water to the irrigation wells in the Wintergarden area of South Texas and to the industrial and municipal wells of East Texas. Some of the deepest fresh-water wells in the State draw from the Carrizo in South Texas, where fresh water is obtained from depths greater than 5,000 feet.

The Gulf Coast sands contain fresh water at depths up to 3,000 feet and supply large quantities to municipal, industrial, and irrigation wells all along the Gulf Coast. These formations include sands of the Catahoula, Oakville, and Lagarto Formations; sands of the Goliad, Willis, and Lissie Formations; and sands of the Beaumont Formation.

The principal water supplies in the Houston area are obtained from wells drawing on the five younger formations. The total pumpage in the Houston area is in the order of 350 to 400 thousand acre-feet per year. Individual wells yield up to 3,000 gallons per minute.

The question of whether or not the ground-water resources in the Houston area have reached optimum development has been raised intermittently for the past 25 years. So far the question is one of economics--pumping lifts have increased with the pumping rate, but pumping costs still are not excessive. The potential for increasing withdrawals without causing uneconomical pumping lifts is at least 50 percent of the present rate of withdrawal. An anticipated future problem, however, is encroachment of salt water from the southeast. This salt water is moving updip through the water-bearing sands as a result of the hydraulic gradient created by the depressed water levels in the Houston area. Another problem created by the depressed water levels is subsidence of the land surface. This subsidence generally has been proportional to the decline of water level, and the maximum subsidence to date has been in the order of 5 feet.

As I mentioned earlier, all of these aquifers which I have described supply fresh water in large quantities. It should be noted also that all of them except the Ogallala and some of the alluvial deposits are capable of supplying, and do supply to some extent, brackish and salt water at deeper levels.

Other aquifers of importance which generally cover smaller areas or supply lower yields include (1) the Capitan and associated reefs, the producing part of which occurs in a narrow belt running from Carlsbad, New Mexico, to Pecos County, Texas; (2) the Rustler limestone, from which water is produced in Southeast New Mexico and several counties of West Texas; (3) the Bone Spring Limestone, which supplies water in the Dell City area; (4) the Santa Rosa Sandstone, which supplies water in Southeast New Mexico and in several counties of West

Texas; (5) The Blaine Gypsum, supplying water in several counties of Northwest Texas east of the High Plains; (6) the Hickory Sandstone, supplying water on the west side of the Central Mineral Region of Central Texas; (7) the Woodbine sands, which supply water through a large part of North-Central and Northeast Texas; (8) sands of the Mt. Selman Formation, which supply wells in a large area running through South Texas, South-Central Texas, and East Texas; and (9) sands of the Sparta Formation, which supply wells in a narrow strip running from South-Central Texas to Louisiana.

A great deal of general, and often specific, information is available on the fresh-water sections of these aquifers from the U. S. Geological Survey, the Texas Water Commission, the Texas Bureau of Economic Geology, the New Mexico State Engineer, and the New Mexico State Bureau of Mines and Mineral Resources. In addition, a considerable amount is available from local water districts, municipalities, drilling contractors, and consultants.

These sources of information also normally have some information on the brackish and salt-water resources, but the amount of such information is small in comparison to that which could be made available by a thorough search of records of the petroleum industry. Therefore, except for data in the zone of transition from the fresh to brackish water, the person desiring knowledge of the brackish and salt-water resources often can do best by turning directly to the petroleum industry.

The planning and development of a ground-water supply for the oil industry, or for any other use, is largely a problem of economics. It is not so much a problem of finding water or not finding it, but one of finding the amount and quality desired at the best price, or at least at an acceptable price. The extent of study needed to answer the questions -- Where?, What quality?, How much?, and What is the cost? -- depends on the complexity of conditions and the amount of data already available. The scope of such studies may range from a very small amount of work to a very extensive and detailed investigation. Such an investigation may involve studies of the positions, thicknesses, character, and extent of the water-bearing beds, their transmissibility and storage coefficients, construction and performance records of existing wells, water levels and artesian pressures, chemical quality and temperature of the water, and the areas and amounts of recharge and discharge. Where sufficient information is not available from existing holes and wells, it is often necessary to drill test holes and construct pilot production wells.

Test drilling is commonplace to most of you, and I need not go into the details of it here. Because of the differences in water well and oil well construction, however, I believe it will be worthwhile to devote the remainder of this paper to a description of the construction of a large water well.

Figure 4 (p. 51) shows the design of an actual large-capacity, gravel-walled well drawing from the Gulf Coast sands. Because a high pumping rate was desired, it was necessary to make the well of relatively large diameter.

Also, for economy purposes, it was necessary to keep the drawdown of water level caused by pumping as small as possible by eliminating as much as possible of the head loss sustained by the water as it moves through the face of the well and up the well to the pump.

The first step in construction of the well was the drilling of a pilot hole. The diameter of this hole was 9-7/8 inches. It was drilled entirely through the group of water-bearing sands to be developed. Samples of drill cuttings were taken at intervals of 10 feet in the sands. The hole was cleaned out before and after drilling each sampling interval. Readings were made with a mechanical drift indicator during the drilling of the pilot hole to make sure that its deflection from vertical remained less than one degree. When the hole reached the bottom of the section, an electric log was made. Based on the drillers' log, inspection and mechanical analyses of the sand samples, and on the electric log, the screen settings were then determined and the size of the screen openings and the type and grading of gravel were selected.

The next step in the construction of the well was the reaming of the hole to a diameter of 24 inches to the depth selected for the 20-inch surface casing. After reaming and before the surface casing was installed, the alignment of the reamed hole was checked by an Eastman continuous alignment survey. The specifications called for the hole to be straight enough so that in any 300-foot section of the hole surveyed the center line of the hole was closer than 5 inches to a straight line connecting the two end points of the 300-foot section.

After the reamed hole was found to meet the alignment test, 20-inch casing was set in the hole, with centralizers located approximately every 80 feet. The casing was then cemented in place from bottom to top.

Next, the hole below the 20-inch surface casing was pilot reamed and subsequently underreamed to a diameter of 34 inches to a depth 10 feet below the lowest water-bearing sand to be screened. After the 34-inch hole was underreamed to the total depth, the wall of the underreamed hole was scraped throughout its length by making another pass through the hole with the underreamer. Below the underreamed section, a 5-foot section of hole was reamed to a diameter of 18 inches.

The liner was then set in the hole. The liner consists of 14-inch blank pipe and 14-inch screen made up so that the screen is opposite the water-bearing sands selected for screening. In this well a total of 337 feet of screen was used. The screen is the bar-lug type, consisting of perforated pipe wrapped with stainless steel wire. On the outside of the pipe between the pipe and the wire, there are bar spacers to hold the wire about one-tenth inch away from the pipe. The bar spacers are also stainless steel.

The blank liner laps 100 feet up into the surface casing. The bottom of the liner consists of 15 feet of blank pipe fitted with a back pressure valve, wooden wash plug, and set nipple. Centering guides were used at approximately 80-foot intervals between the liner and the underreamed hole and also at three places in the lap of the 14-inch and 20-inch pipes.

After setting the liner, the well was gravel walled with specially selected and graded gravel to within 10 feet of the top of the liner. The gravel was placed in the well through a gravel line, which was first set at the bottom of the well and gradually withdrawn as the gravel was pumped with water into the hole.

The mud was then washed out of the well with clear water and the screened sections were agitated by surging and washing with a tandem agitator. A detergent type chemical was agitated into each of the screened sections. Next, a test pump of high capacity was installed and the well was further developed by pumping and backwashing with this pump. In this particular well, after the well had been developed as thoroughly as possible with the test pump, the pump was taken out and the well was agitated again with the tandem agitator. The test pump was then again installed and the well developed further by pumping and backwashing. A total of ten 24-hour days was used in this development process, at the end of which time it was decided that the well was thoroughly developed.

During the placing of the gravel and both prior to and after installing the pump, the well was thoroughly sterilized with calcium hypochlorite. A total of 370 pounds of calcium hypochlorite was placed in the well during construction.

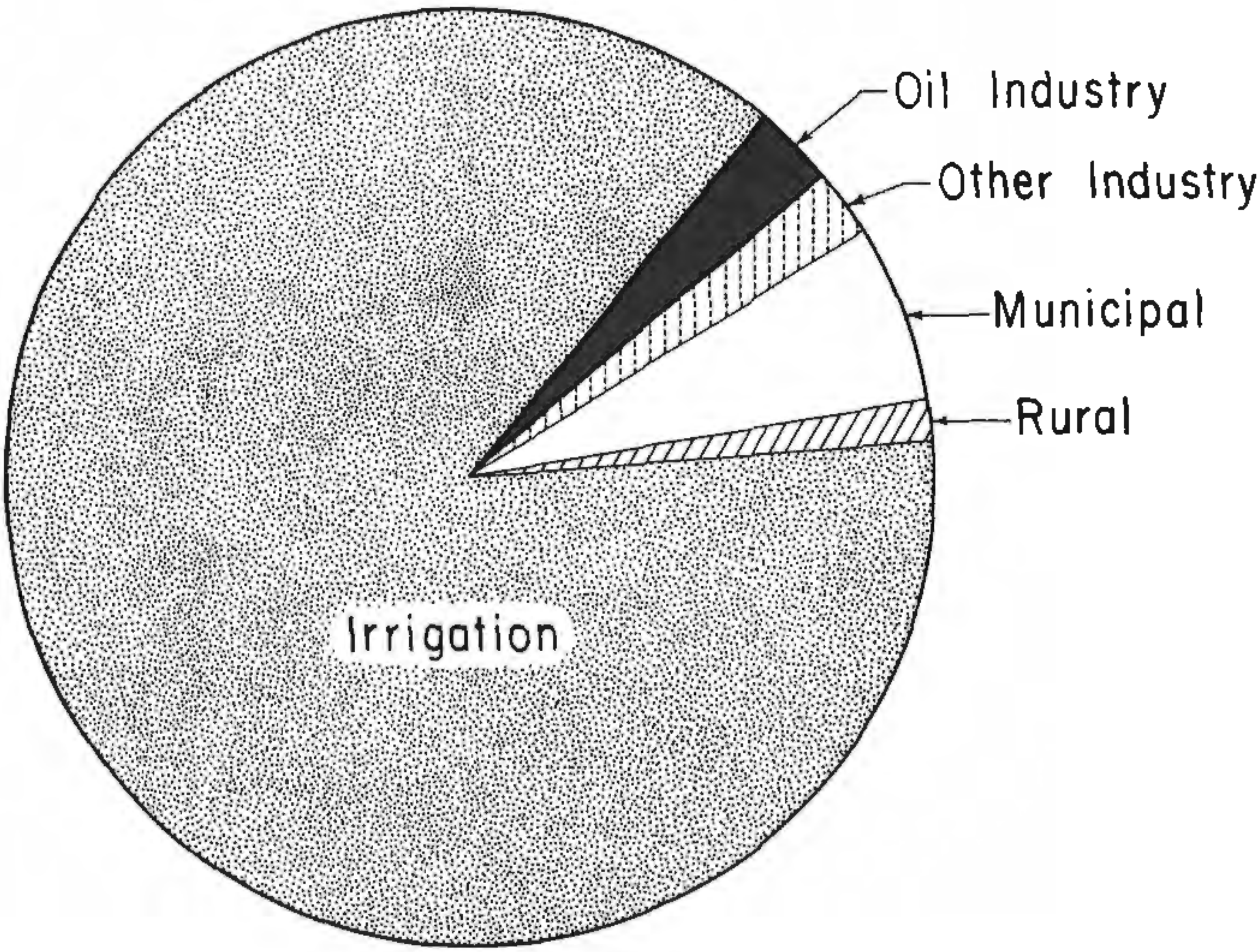
After development, pumping tests were made of the well for a period of five days. Pumping rates ranged from 1,500 to 3,500 gallons per minute.

During the pumping tests, samples of water were taken for chemical and bacteriological analyses, and checks were made of the production of sand with the water. The sand content of the water was found to be much lower than the maximum amount specified of one-half ounce in 200 gallons after 30 minutes of pumping.

Based on measurements of pumping rates and water levels during the tests, the coefficient of transmissibility of the water-bearing beds was determined and a calculation made of the theoretical drawdown of the water level in the aquifer just outside the face of the well. This computed drawdown compared favorably with the drawdown actually measured in the well, indicating negligible head losses as the water moves through the well face and up the well.

The transmissibility coefficient was also used together with other data for computing interference between wells in the well field, determining well spacing, and predicting future pumping levels with given amounts of pumping from the field. With this information, the final design of the well field was determined, and the pump capacity and setting selected for this particular well. The well now produces 2,500 gallons per minute continuously.

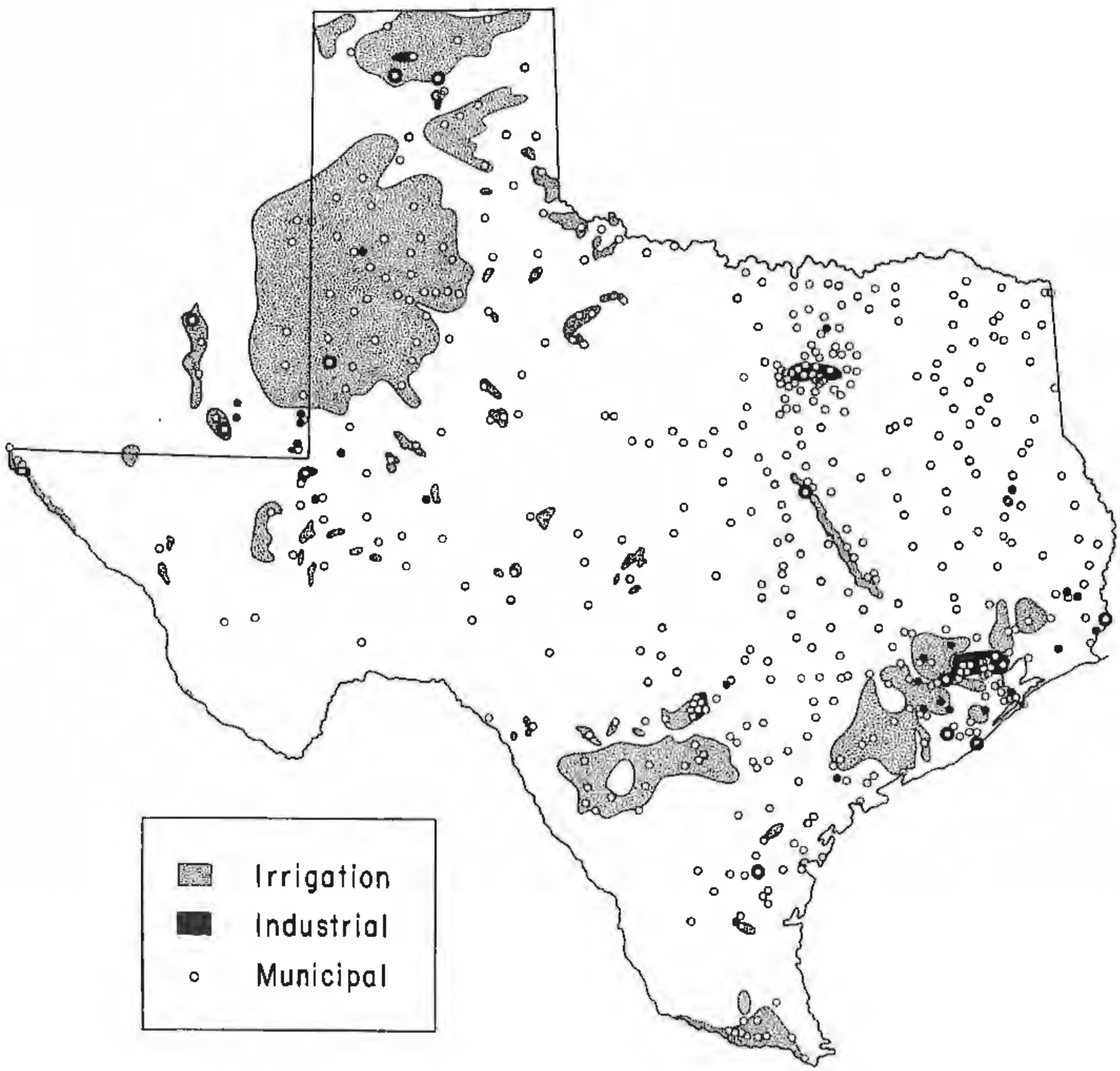
The total cost of the well and pump was approximately $95,000.00. The total cost of the water from the well field, including power, interest on capital investment for wells, pumps, pipeline, etc., and maintenance and depreciation, is a little less than four cents per thousand gallons.



ANNUAL GROUND-WATER USE IN TEXAS AND SOUTHEAST NEW MEXICO

APPROXIMATELY 12,500,000 ACRE-FEET

Figure 1

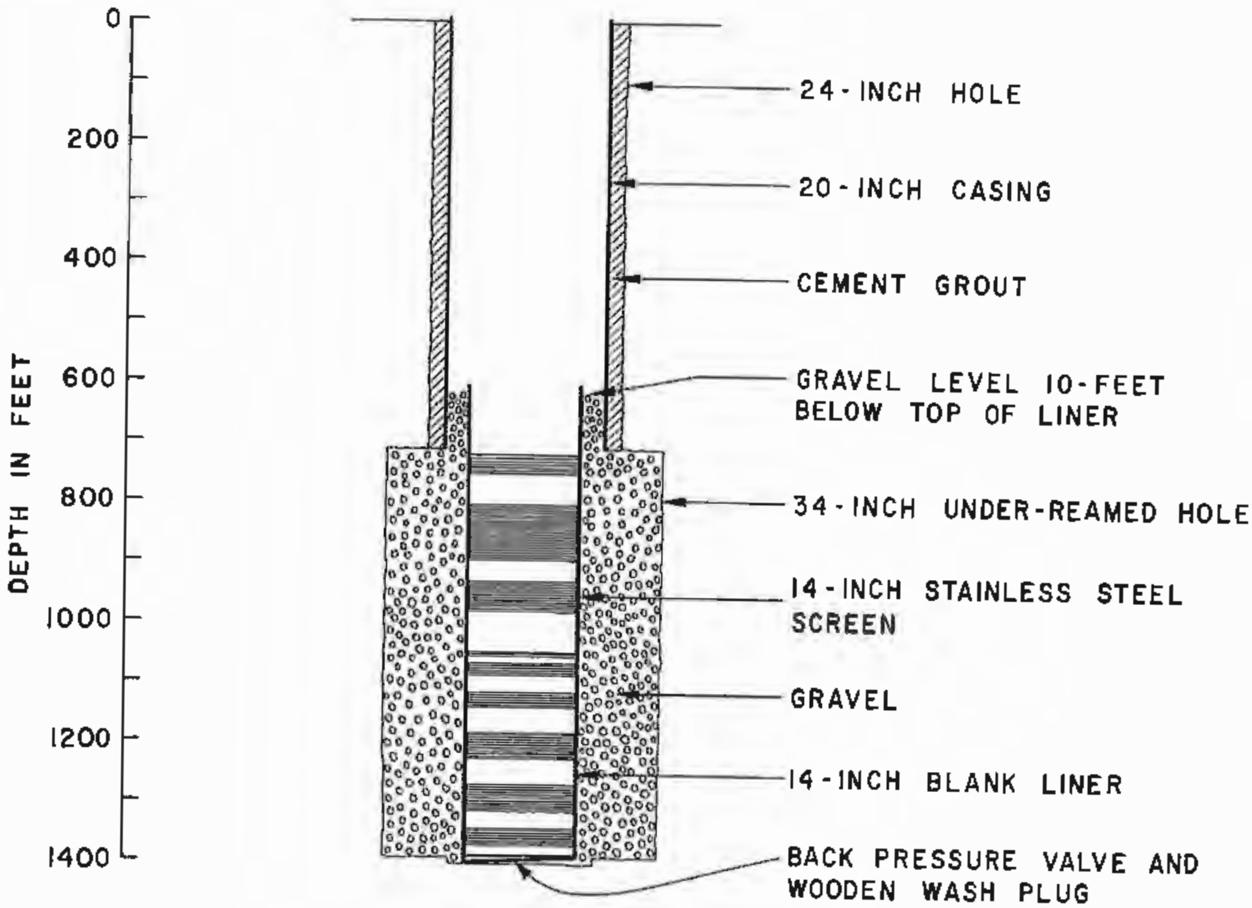


PRINCIPAL AREAS OF GROUND-WATER USE

Figure 2

MAJOR FRESH WATER-BEARING FORMATIONS

Figure 3



TYPICAL WELL DESIGN - GULF COAST

Figure 4

ECONOMIC AND SOCIAL IMPLICATIONS OF WATER AND OIL RESOURCES

Stanley A. Arbingast

The 100th meridian in Texas separates the land of riches from the land of poverty. That statement was made several years ago by my colleague, the late Walter Prescott Webb, professor of history at The University of Texas. What Webb had in mind, of course, was that the 100th meridian sets apart the areas generally deficient in water supply from those with enough water or with more than enough. In the dry lands west of that meridian human occupance has never been easy, and water has seemed a premium resource. Even place names in West Texas reflect the importance of the water supply--Big Spring, Sweetwater, Shallowater, Water Valley, and more. Water has seemed a premium resource, but it has not always been used as such. Today in the 1960's, there is conflict between the producers of oil and those who feel that large-scale use of water by the oil industry is wasteful.

Water in these dry lands has always been scarce enough to inhibit somewhat the growth of water-using activities. Yet, the value of petroleum is so much greater that the liberal use of water in oil-field operations has often appeared justifiable. Water may appear to be scarce on the semiarid plains, but it is still literally dirt cheap. Processed domestic water is still delivered to the West Texas consumer for ten cents or less a ton. A ton of dirt cannot be delivered for that amount, much less a ton of petroleum. Even though the value of water has tended to rise with increase in demand, it has not risen enough to inhibit wasteful use of it.

Water generally has value only in combination with other resources. It is not a primary economic factor; it would be difficult to point to an area where industrial development has been supported entirely or even chiefly by a plentiful supply of water. On the other hand, occurrences of other resources, such as oil, may be primary factors in economic development. If the oil, or the sulfur, or whatever resource, is high enough in value, enough water will surely be made available to complete the resource pattern necessary for its production. For one instance, many underground deposits of potable water in the West would still be undiscovered if the oil industry had not spurred the growth of such cities as Odessa to a stage at which it was essential to augment the water supply, either by construction of reservoirs or by prospecting for new ground sources. The value of water depends on local circumstances, and if that value is high enough, man seems to be ingenious enough to overcome shortages to some degree. It is well known, for example, that sewage effluent from nearby municipalities is used as a source of process water at several West Texas industrial complexes--in Odessa, Big Spring, and Amarillo. Experimentation in lowering the excessive mineral content of ground water with the aim of making it potable or at least satisfactory for industrial or agricultural use in West Texas is proceeding with some encouraging results. There are several other possibilities for augmenting water supply in dry areas, but experimentation is only in the early stages.

Generally, the more advanced the economic activity, the less water is needed. Agriculture, by far the heaviest user of water in the Southwest, siphons out huge amounts for irrigation. Cultivated plants are anything but efficient users of water; it has been estimated that about 1,200 gallons of water are used to produce a pound of cotton. Water use in mining, particularly oil extraction, is also rather high, and the manufacture of bulk materials commonly takes a great deal of water. Fine manufacturing and commerce, on the other hand, require much less, but industry does not use as much water as many persons would have us believe. Frequently, factory discharge is processed and emptied into a stream for the use of other industrial plants downriver. Furthermore, industries which use large amounts of water are actively concerned with minimizing that consumption and often invest rather heavily in systems to enable recycling. It will likely be some years before industrial and municipal water demands approach present demands of agriculture. However, one economist has ventured to say that the High Plains of West Texas and New Mexico would profit most in the long run if the land were returned to pasture and the remaining ground water used for municipal and industrial purposes.

As the economy of the Southwest matures and greater emphasis is placed on the manufacture of consumer goods, it may be anticipated that relatively less water will be required. Nevertheless, there are counter-influences.

Some parts of the Southwest have always been undersupplied with water, yet the demands on their supply may increase disproportionately as economic development goes on. Investigations by the Bureau of Business Research have revealed that per capita domestic use of water is generally higher in the dry areas of Texas than in the humid areas, higher, for example, in Corpus Christi than in Beaumont. The larger amounts of water used on lawns and gardens in Corpus Christi to compensate for the lack of rainfall probably accounts for much of the difference. Also, in the semiarid areas of West Texas a great deal of water is used in domestic and commercial evaporative coolers. By contrast, mechanical refrigeration, which uses little or no water, is much more widely employed in humid East Texas.

Even if Southwesterners use less water in their work, they tend to be using more outside their work, partly in response to rising incomes and living standards. Personal incomes in the drier parts of the region tend to be high, for the land there generally yields greater resource values than elsewhere in proportion to its population. Oil discoveries have been widespread, and extensive and heavily mechanized farming of cotton, grain sorghums, and wheat produces high returns.

Home use of water, particularly in higher income areas, has increased with wider distribution of such appliances as garbage disposal units, dishwashers, and automatic washing machines. In the affluent society, automobiles are washed more often, and the blunt fact is, as incomes increase, people take more baths.

The use of water for domestic landscaping also reflects increasing income. As communities grow, there is also more use of water on parks and on golf courses. Moreover, almost every community wants a lake, often as much for recreational purposes as for municipal use. The fact that the land may be dry and the evaporation rates high seems, if anything, to make recreation lakes even more attractive. Finally, swimming pools are becoming almost as ubiquitous in the Southwest as in California.

Petroleum resources, because they are localized and limited, have stronger primary influence upon economic development than water has. Since the local supply of oil in any particular area is necessarily limited, the day of declining oil activity is inevitable. In fact, the decline of oil exploration and development is already under way in many areas, and the decline of production, even with manipulation by state controls, is a long-range certainty.

This decline of oil flow carries with it several important economic implications. There will be less supplementary income from leases and from royalties to farmers in some parts of the Southwest. When this happens, farming is likely to move in the direction of further consolidation into even larger units than now exist. With loss of economic support, rural population may be expected to decline further. Fifty years ago 75 percent of the people of Texas lived on farms or in rural communities under 2,500 in population. Today, only 25 percent of the population is rural. Some economists estimate that the part of the labor force directly dependent on agriculture may drop to as little as 5 percent. With such a drastic shift in the employment of labor, most kinds of business will be influenced in one way or another.

Oil income has directly supported many professional persons in the Southwest, notably geologists, engineers, and lawyers. Nevertheless, a large number of persons with limited, formal education have realized substantial incomes from oil. With the decline of oil activity, higher education will become even more of a prerequisite to earning a good living, for each year there will be fewer job opportunities for the unskilled and for the uneducated.

The population in many rural areas and in small towns has been sustained for some time by employment in oil production and by income from leases and from royalties. As less oil is produced, this stabilizing influence will weaken, and the trend toward urbanization will have even stronger thrust, especially in those areas which are not attractive to industry or to tourists. One faculty member at The University of Texas has speculated that not only ghost towns but ghost cities will dot the oil country. Ghost towns are already common enough, but the oil-based cities, such as Midland and Odessa, represent far too much investment to be abandoned. It is not reasonable to think that any metropolitan area will develop into a ghost metropolis in this century or in the next. Despite the decline of the coal industry and the mechanization of agriculture, there are still sizable cities in Appalachia. Other activities have replaced, though not always immediately, the waning industries. In this age of technology new types of industry will become important that cannot now even be foreseen; many of the avant-garde industries, even today, are not tied to localized resources but can operate almost anywhere. Electronics manufacture is an example of this type.

Services of all kinds are in increasing demand by the public, and there are far too few adequately trained service workers. Perhaps one rather specialized need may be met by means of a new course in poodle clipping now being offered by a small college in Texas. But there are certainly other more serious needs--the tourist industry, for example. A community does not have to have scenic attractions, gambling, or racing to benefit from tourism. Man no longer is tied to his job ten or more hours a day for six days a week. He has free time, and he has money. Communities which realize that they can no longer depend on minerals and on agriculture to sustain their economy are in the forefront in helping the tourist spend his time and his money.

Resource endowment changes; man's needs change. But, we cannot get along without water. We must plan for its use in such a way that the greatest good for the greatest number will result, and we cannot plan on an emergency basis. Areas of conflict must be resolved, and we must conserve wherever and whenever we can. I am optimistic about the long-range outlook. I think there is plenty of water if we make a conscious effort to conserve it. I believe we will have enough wisdom and foresight to plan in such a way that we can get it to the right place at the right time. Wise use of water will be recognized increasingly as imperative if economic growth is to continue. And I believe we all will recognize that it is our social responsibility.

OIL, GAS, AND WATER LAW--TODAY AND TOMORROW

J. Chrys Dougherty

Comes the end of the day and of the Symposium. Peter Flawn must have thought he ought to have a lawyer to add his usual confusion to an otherwise enlightening and constructive program. Either that or he wanted to remind you how great and satisfying your professional life could really be if you weren't always involved with some legal problem.

There is a bit of tomorrow in the air at this time from the legal arena of courts, administrative agencies, and legislative bodies. The "legal tomorrow" they are in the process of creating seems to me very interesting for geologists and hydrologists and all who work with the earth and its products.

The first of these "legal tomorrows" is the prospect of enactment of compulsory pooling in Texas. Most of you know the problems that have been created in efficient reservoir engineering by the illogical and totally unrelated land surface ownerships which any state regulatory scheme must nevertheless take into account. As the expense of drilling and the complexity of the ownership problems have increased, it has become more and more apparent that some sort of compulsory pooling of interests is required as the only way to give each tract owner his fair share of recoverable production, while at the same time efficiently managing production from the reservoir.

Though Oklahoma had enacted compulsory pooling in the late 1930's, Arkansas in 1947, Louisiana in 1950, and New Mexico in 1953, and 20 other states have such statutes, every effort to enact such a measure in Texas has so far failed. However, matters have now been brought to a head here by four recent Court decisions.

In the 1961 Normanna case[1] the Supreme Court set aside a Railroad Commission gas allowable based on 1/3 per well and 2/3 on acreage where it was shown that such an allowable would permit a well on a 0.3-acre town lot in a 320-acre unit to produce over 200 times as much as a well on the remainder of the unit over the estimated producing life of the reservoir. The Court emphasized that the owner of each reservoir tract was entitled to produce his fair share of the gas from the reservoir.

> "The responsibility rests with the Commission to devise some rule of proration which will conserve the gas in the field in question and at the same time be fair and just to all parties without depriving any of them of his property." 162 Tex. at 290, 346 S. W. 2d at 812.

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[1]Atlantic Refining Co. v. Railroad Commission, 162 Tex. 274, 346 S. W. 2d 801 (1961).

This case seemed to call for a reappraisal of all existing proration orders of the Commission to see if they met the Court's standard of fairness.

This call was repeated in the 1962 Port Acres[2] case where the Court again set aside the Commission's 1/3-2/3 proration formula, this time in a fully developed field, reiterating its Normanna standard. The small tract owners had contended that each small tract was entitled to one well and that to make the well feasible they were also entitled to enough allowable to repay the cost of drilling plus a profit. The Court answered

> "It is to be reemphasized that their permits were granted for the purpose of avoiding confiscation of the minerals underlying their properties and not for the purpose of enabling them to drain the minerals underlying adjoining lands to pay the cost of their operations plus profits." 163 Tex. at 435, 357 S. W. 2d at 376.

But then it immediately added

> "This does not mean and we are not to be understood as foreclosing the power of the Commission, by proper order or exception, to allow the holder of a Rule 37 permit to recover a sufficient amount of oil or gas to repay drilling and production costs and provide a reasonable profit when no other means of recovering the minerals which underlie his land are available. No such problem is before us." 163 Tex. at 435, 357 S. W. 2d at 376.

This left some hope to the small tract operators for relief by Commission action.

Then last year the Court decided two more cases. In the Quitman field case[3] a 50/50 or 1/2-1/2 proration formula was struck down where the proof was that the small tract operators would recover 14 or 15 times their original recoverable reserves by drainage from the large tracts. Note that the productive margin is far below the 200-fold advantage shown in the Normanna case. In response to the small tract operators' plea that any 100% acreage formula would not permit them to pay operating expenses and would force a shut down of their wells, the Court, while reiterating its "fair share" standard, added

> "But in determining the validity of a fieldwide proration order the landowner is not wholly restricted to a recovery of the amount of reserves underlying his land." 380 S. W. 2d at 560.

That is "not wholly" but not 14 times as much as straight acreage. The Court then noted the Commission's broad discretion to prorate in the public interest and its power

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[2] Halbouty v. Railroad Commission, 163 Tex. 417, 357 S. W. 2d 364 (1962).

[3] Railroad Commission v. Shell Oil Co., 380 S. W. 2d at 556 (Tex. 1964).

"to offset the advantage obtained by one who is given an exception to the spacing rule by limiting his allowable production to the extent necessary to overcome this advantage." 380 S. W. 2d at 560.

This looks like definite protection to the larger tracts.

In the Alcoa case[4] decided the same day, the Railroad Commission had refused in 1960 to alter a 1/3-2/3 formula adopted in 1956 for the Appling field. The Supreme Court sustained the Commission's refusal on the ground that Alcoa had acquiesced in the formula over the intervening years and during that period the rights and investments of other operators had intervened and should now be protected. The Court makes it very clear

"The theory of the Normanna decision... is that its holding is to be applied prospective and not retrospectively." 380 S. W. 2d at 602.

"Otherwise not only would confusion and serious injustice result in many instances but an intolerable burden would be cast on the Commission." 380 S. W. 2d at 601.

The Commission is thus left with the job for the future of devising proration orders which will assure to each tract its fair share of the available production but there is a definite limit upon the relief by means of allowable that can be given the small tract operator. Only where he had enjoyed the benefit of an extra allowable for some time could he feel secure of keeping it.

These decisions have precipitated compulsory pooling in Texas because they have made it clear that the small tract operator has much less chance of recovering his cost of drilling plus a profit even if he gets permission to drill a well as an exception to the spacing regulation. While there is some leeway, the Commission's proration formula must approximate his share of recoverable reserves and if this share is not large, he must figure out a way to share the expense of drilling and operation with his large tract neighbor. To effect that sharing on a reasonable basis he must have the aid of State regulation for his bargaining position cannot otherwise be fair.

So now we have the prospect in this current Legislature of a TIPRO-sponsored compulsory pooling bill (S. B. 2 & H. B. 2). This is the group, as you know, that has, in the past, consistently opposed anything that smacked of compulsory pooling. Their very support of such a bill now is most significant. This bill has these interesting protective features:

1. Every effort to pool voluntarily must be tried before forced pooling can occur.

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[4] Railroad Commission v. Aluminum Company of America, 380 S. W. 2d 599 (Tex. 1964).

2. The small tract owner may force his way into a larger adjoining unit.

3. Unfair operating provisions are prohibited from being imposed as a condition of entry, i. e.,

   a. Preferential right of the operator to purchase mineral interests in the unit;

   b. A call on or option to purchase production from the unit;

   c. Operating charges which include any part of district or central office expense other than reasonable overhead charges;

   d. Prohibition against non-operators questioning the operation of the unit.

4. No tract larger than 160 acres for oil or 640 acres for gas may be pooled.

5. No reservoir discovered and produced prior to March 8, 1961 (date of the Normanna case), will have forced pooled drilling units. This conforms to what the Supreme Court said in Alcoa.

6. Non-consenting pooled owners may share in unit proceeds at least equivalent to the acreage basis.

7. Appeals from Commission pooling orders may be tried in the county in which the land is located rather than in Travis County, as at present.

It is my understanding that there is a good chance this bill will pass because both large tract and small tract interests think it a workable bill.

If it does pass, I would guess that a lot more of your productive time will be spent on the scientific facts of reservoir engineering and the search for oil and not so much on trying to justify bizarre solutions to problems generated by fractional ownerships in the pool.

The second "legal tomorrow" relates to jurisdiction over salt water disposal.

The Travis County District Court, in the case of Superior Oil Company v. Texas Water Pollution Control Board, held that control of the disposal oil field waste is under the jurisdiction of the Railroad Commission under Article 6029(a) rather than under the Texas Water Pollution Control Board under Article 7621(d). If upheld on appeal this will give the Railroad Commission full power to regulate where all facets of the oil and gas business are involved. The Texas Water

Pollution Control Board would be relegated to matters of industrial and municipal waste pollution control as the legislative history of its act seems to indicate.

The Federal Water Pollution Control Act relates to interstate streams[5] and its implementation has recently been furthered by Federal statute granting Federal District Courts jurisdiction to hear matters involving interstate compacts.[6] Such cases otherwise would be within the original jurisdiction of the Supreme Court of the United States. The legislative history of this statute shows that it was specifically designed as an aid to the compact between Texas, Arkansas, Oklahoma, and Louisiana for control of pollution of the Red River.[7]

Incidentally, individual liability for the effects of pollution still rest on the principles announced in Landers v. East Texas Salt Water Disposal Co., 151 Tex. 251, 248 S. W. 2d 731 (1952), holding those who contribute to the damages jointly and severally liable. This rule is followed despite any difficulty in determining who was actually responsible, Lone Star Gas Co. v. Thomas, 345 S. W. 2d 844 (Tex. Civ. App. 1961 error ref'd n. r. e.), and irrespective of any evidence of negligence, Gulf Oil Corporation v. Alexander, 291 S. W. 2d 792 (Tex. Civ. App., 1956, no writ).

The third "legal tomorrow" is in the developing guidelines for Commission regulation of the slant hole problem where directional surveys disclose greater than permissible vertical deviation. The Supreme Court here has denied to the Railroad Commission power to devise and assess penalties of its own making not specifically authorized by statute. In the Harrington case[8] the Commission had denied the slant hole driller's application to redrill his wells correctly because (1) he had produced oil in violation of Commission rules, (2) he had not shown legal justification for violating his permit, and (3) he had failed to show diligence in drilling. The Supreme Court held the Commission order void because the statutes prescribe only (a) that the Commission may shut down the well, and (b) that a suit may be brought by the Attorney General to recover penalties for, or to seize, illegally produced oil. Because there was no evidence of overproduction, the Court also held that the Commission would be unauthorized to limit allowable for the straightened well until the amount of illegally produced oil was made up. This holding implies that such a reduction in allowable might be proper where overproduction can be shown.

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[5] 33 USCA Sec. 466 et seq.

[6] P. L. 87-830, 76 Stat 957, 1 U. S. Code Cong. & Adm. News 1125 (87th Cong. 2d Sess. 1962).

[7] 2 U. S. Code Cong. & Adm. News 3282 (87th Cong. 2d Sess. 1962).

[8] Harrington v. Railroad Commission, 375 S. W. 2d 892 (Tex. 1964).

In another slant hole case[9] the Commission was sustained in approving wells which, though found to be slanted, nevertheless did not go outside the proper lease line and where no production advantage was gained as a result of the deviated drilling.

The Commission may be expected to follow these limitations on its powers in such cases. With these guidelines, the slant hole cases can be closed out before too long.

"Legal tomorrows" in the area of water law are seen on every hand. First, as you know, rights of ownership in Texas in ground water have long followed the ownership of the surface.[10] In at least one instance the Legislature has specifically confirmed these rights

> "D. The ownership and rights of the owner of the land, his lessees and assigns, in underground water are hereby recognized, and nothing in this Section 3c shall be construed, as depriving or divesting such owner, his assigns or lessees, of such ownership or rights, subject, however, to the rules and regulations promulgated pursuant to this Section 3c." Article 7880-3c.

Despite this ownership, underground water districts have been given powers to prorate wells and to adjust correlative rights much as in the case of oil and gas.[11] There is no Statewide regulation of ground waters.

In the High Plains area much interest is centered on the Shurbet case now on appeal to the Fifth Circuit. This case sustains a taxpayer's claim to cost depletion for the ground-water supply purchased with his farm land. The trial court found that withdrawals for irrigation in the High Plains come entirely from storage in a vast underground reservoir of definite extent and without any practical recharge. The theory of ground-water ownership in Texas was contested by the Government as a basis for denying that any water or rights in water were obtained by purchase, but the contention was rejected by the Court.

Of course, if this decision is sustained on appeal, it will give new impetus to the development of doctrines of correlative rights in underground water sources as withdrawals from storage are shown demonstrably to affect the water supply of neighbors.

Recent cases in Louisiana and Colorado seem to reach the same net result.

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[9] Stewart v. Humble Oil & Refining Co., 377 S. W. 2d 830 (Tex. 1964).

[10] Houston and Texas Central Ry. Co. v. East, 98 Tex. 146, 81 S. W. 279 (1904); Corpus Christi v. Pleasanton, 164 Tex. 289, 276 S. W. 2d 798 (1955).

[11] Bryson v. High Plains Underground Water Conservation District No. 1, 156 Tex. 405, 297 S. W. 2d 117 (1956).

The Louisiana Supreme Court, in a recent case, has held that underground water is a fugitive sub-surface mineral like oil and gas and is not subject to ownership by the landowner.[12] This is the same rule originally followed in Louisiana oil and gas cases[13] which eventually led to the Louisiana Conservation Act[14] with its protection of correlative rights. Apparently, the Court thought a contrary decision as to water would upset oil and gas law, even though correct scientific knowledge has destroyed the premise on which the oil and gas cases were decided, and that the Legislature ought to adopt a conservation act for water similar to the oil and gas act when Louisiana's water needs become acute.[15]

The Colorado Supreme Court has recently held non-tributary [to a natural stream] ground waters are private property and that a decree recognizing rights to appropriate that [an artesian aquifer] ground-water supply is void.[16] There is a Colorado presumption that all ground water is tributary -- making it subject to appropriation and regulations.[17] Other Western states presume all ground water is percolating and not subject to regulation until the contrary is shown.[18] The Texas, Louisiana, and Colorado rules encourage exhaustion until regulation becomes necessary.

Of course, the whole water problem is becoming more complex and urgent every day. To meet it, we Texans have created so many boards (800 says Vandertulip), commissions, agencies, and special districts that to describe them would take more time than is allotted to me. Each seems to be charged with developing a master plan. The most recent development is the effort to coordinate the work of the Texas Water Commission, the Texas Water Development Board, and the Texas Water Pollution Control Board and integrate them in terms of a long-range State Water Plan. Many of you have seen the first of a four-part comprehensive study being completed by the Texas Research League. I commend their suggestions to your careful study.

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[12] Adams v. Grigsby, 152 So. 2d 619 (La. App.) cert. den. 244 La. 662, 153 So. 2d 880 (1963) noted in 38 Tul. L. Rev. 583 (1964).

[13] Frost-Johnson Lumber Co. v. Salling's Heirs, 150 La. 756, 91 So. 207 (1922).

[14] La. R. S. 30:3 (1950).

[15] 150 So. 2d at 623-624.

[16] Whitten v. Coit, _____ Colo. _____, 385 P. 2d 131 (1963) noted in 16 Stan. L. Rev. 721 (1964).

[17] De Hass v. Benesch, 117 Colo. 344, 181 P. 2d 453 (1947).

[18] Campbell v. Willard, 45 Ariz. 221, 42 P. 2d 403 (1935); Ryan v. Quinlan, 45 Mont. 521, 124 Pac. 512 (1914).

Briefly, they would untangle the principal functions of the Commission and the Development Board in this way.

1. The Texas Water Commission would be restored to the pre-1957 status as a water rights administration agency and freed to pursue additional responsibilities in that field.

2. The separation of water rights administration from planning and development begun under the 1962 reorganization act would be completed by dividing the two functions between the Texas Water Commission and the Water Development Board.

3. The responsibility for negotiations on local and federal projects and for encouraging their development through State investments now jointly shared by the TWC and WDB would be preserved in the reorganized Water Development Board.

4. State financial participation in water resource development would be continued through the Constitutionally authorized Water Development Fund.

Their recommendations for the Pollution Control Board are yet to be published. In any event, you can look for some substantial coordinating changes in the near future, for Texas does not want by its default to permit the Federal Government to fix its water policy.

In the Federal area there is one important development that you should know about, that is, the new Federal Water Resources Act of 1964 under Public Law 88-379, 78 Stat 329. This Act sets up water research centers in the land grant colleges and also appropriates a million a year for ten years to be used for projects selected by the Secretary of the Interior and approved by the President of the United States Senate and the Speaker of the House. Governor Connally envisions a system under which A&M will be the coordinating head of projects at Texas, Texas Tech, and other schools. In addition, the Act sets up a cataloguing center for all Federal water research which will become in time tremendously helpful. The kinds of projects Congress had in mind are set out in the House Report[19] as follows:

1. Reducing evaporation from the surface of reservoirs.

2. Elimination of water-loving vegetation (phreatophytes) along the edges of watercourses and reservoirs.

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[19]H. Rep. 1136, 88th Cong. 2d Sess. p. 2; U. S. Code Cong. & Adm. News Adv. Sheet #2, 2294 88th Cong. 2d Sess. (Aug. 20, 1964).

3. Changing or modifying a forest and vegetative cover on watersheds to reduce evapotranspiration.

4. Reducing seepage losses in irrigation canals and other water distribution systems and other wasteful practices.

5. Reduction of dilution requirements for pollution abatement by development of improved methods for treatment or control of waste materials that are disposed of in water.

6. Waste water salvage.

7. Reuse, recycling, and elimination of wasteful water use by industry.

8. Desalting of saline or brackish water.

9. Weather modification.

10. More accurate quantitative forecasting of meteorologic events.

11. Application of nuclear products in research.

12. Improved use and control of ground water.

As you see, the lawyers, whether on courts, in legislatures, or as individuals, are busy trying to keep up with the problems you earth scientists and engineers have explained to us. Our tomorrows will be interesting and challenging. We hope we do not unnecessarily complicate yours.