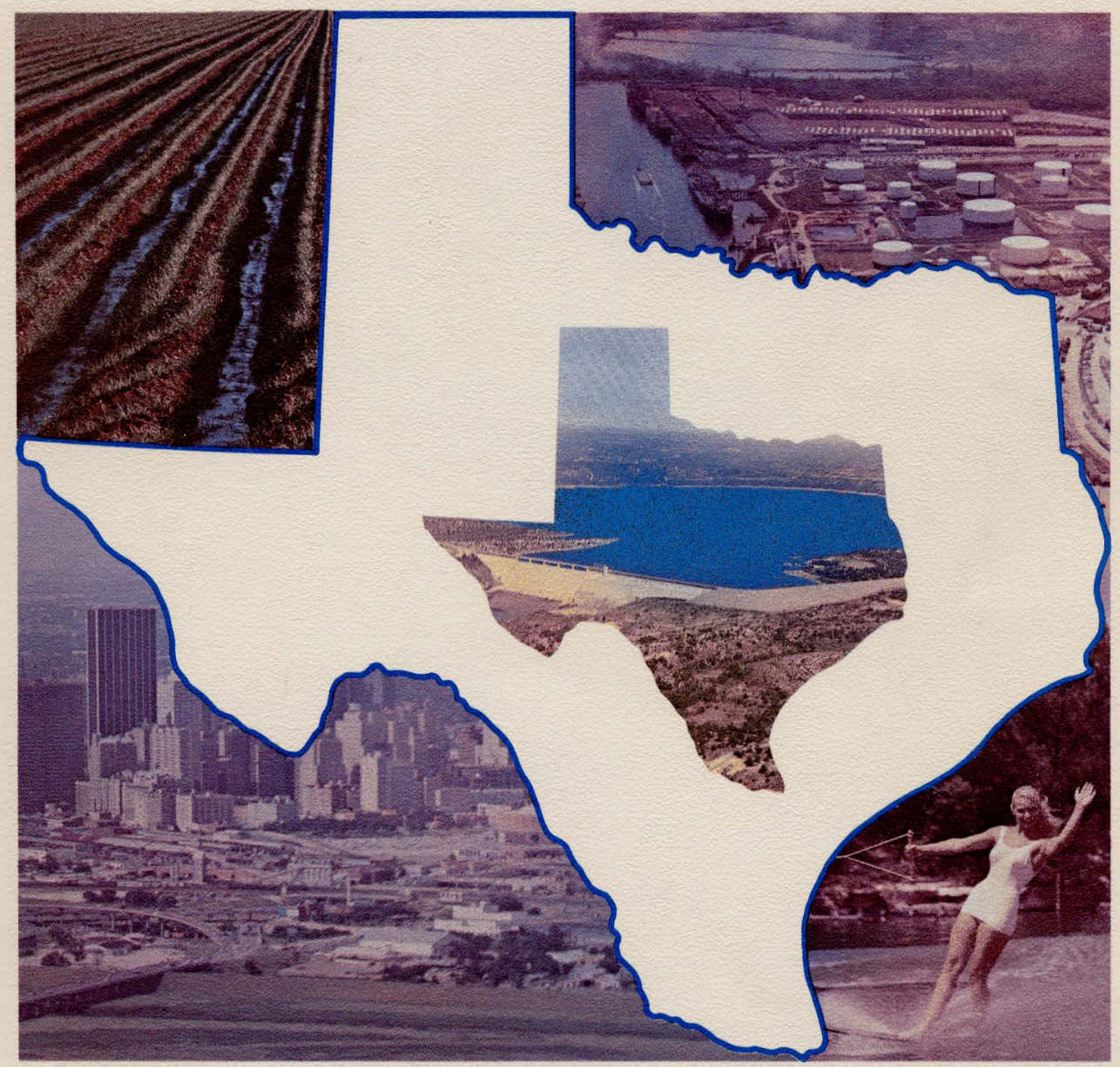
THE TEXAS WATER PLAN

Summary



TEXAS WATER DEVELOPMENT BOARD

NOVEMBER 1968

THE

TEXAS WATER PLAN

SUMMARY

THE TEXAS WATER DEVELOPMENT BOARD

November 1968

TEXAS WATER DEVELOPMENT BOARD

P. O. BOX 12386
CAPITOL STATION
AUSTIN, TEXAS 78711

The People of Texas

The Honorable John Connally
Governor of Texas

The Honorable Preston Smith
Lieutenant Governor of Texas

The Honorable Ben Barnes
Speaker of the House

The Legislature of the State of Texas

Transmitted herewith is a summary of the Texas Water Plan, a flexible guide for the orderly development, conservation, and wise management of the State's water resources to meet the needs of our expanding State to the year 2020. Since Texas does not have enough water within its boundaries to meet all its needs beyond 1985 it will be necessary to seek supplementary water from outside its borders. The Plan includes the possibility of importation of large quantities of surplus water from the lower reaches of the Mississippi River to areas of greatest need in Texas, in order to meet our requirements after 1985.

The Texas Water Plan recognizes the importance of the roles of local, State, and Federal agencies in the development of our water resources, and the need for the continuation of the cooperation and harmony that has been manifest in the preparation of the Plan.

Water is vital to sustaining the people of Texas and their economy. Full development and conservation of all our water resources is essential if Texans are to meet their responsibilities for a rapidly expanding population and for supplying the accompanying demands for water for domestic and municipal uses, industry, agriculture, mining, hydroelectric power, navigation, and recreation. If we are to meet these responsibilities and provide the water so essential to our well-being, we must begin now. To delay the full development of our water resources will place a burden upon the future of Texas from which it might never recover.

Respectfully submitted,

Texas Water Development Board

Mills Cox, Chairman

Marvin Shurbet, Vice Chairman

W. E. Tinsley, Member

Robert B. Gilmore, Member

Milton Potts, Member

Groner Pitts, Member

Howard B. Boswell, Executive Director

FOREWORD

NEED FOR ACTION

The preparation and release of the Texas Water Plan is only the beginning insofar as the effective protection, conservation, development, distribution, and utilization of Texas' water resources is concerned. The Texas Water Plan precipitates a moment of critical decision for the Legislature, for the people of Texas, and for the future of Texas. Similarly, immediate major decisions will be required of the Federal Government.

Action by and within the State of Texas alone, even on a large scale, is not enough, because the water resources now available to Texas are not sufficient to meet the economically justified future water needs of the entire State no matter how efficiently they may be conserved, distributed, and administered. Thus, the only solution for this shortage of water supply is the import of water into Texas from out-of-State sources, possible only through the coordinated efforts of Federal agencies, governmental agencies of other States, the State of Texas, and local Texas agencies. The urgent need for additional water will impose a time schedule which will be extremely difficult to meet even with the fullest effort. Delay by the State, or by any other concerned level of government, would have irreversible results.

Present water developments and those of the future will be extremely costly. Therefore, the maximum degree of efficiency in planning, financing, design, construction, and management is imperative. The State has a major responsibility for achieving this objective. By prompt effective action, whatever immediate costs may be involved will be returned many times to the State as a whole.

With the heavy demands on the Federal budget, it is completely unrealistic to expect that the United States would fully finance construction of all of the works needed to meet Texas' urgent water needs. The State of Texas, and its political subdivisions, must provide significant portions of the funds required. Further, in order that Texas may have full control over the development and utilization of its water resources, it is essential that the State be a major participant in financing and directing the Texas Water Plan into actuality and in its management once construction is completed.

The magnitude of the job and the tremendous long-range commitment of State resources involved must not be underestimated, nor the tragic consequence of delay. There is not a water resource plan of this magnitude or complexity in existence in the world today or even in the planning stage, yet Texas' water needs for the future can be met with nothing less sweeping.

STATUTORY AUTHORIZATION

Planning for long-range water resource development for Texas has been conducted by the Board in compliance with a series of statutory enactments. These Legislative and Executive directives have reflected the response by the State to the increasing complexity of its water problems.

Acting under the stimulus of prolonged drought, broken by heavy rains and flooding in the Spring of 1957, the Legislature in special session adopted the Water Planning Act of 1957. Complying with provisions of that Act, the Board prepared and submitted to the 56th Legislature a progress report titled "Texas Water Resources Planning at the End of the Year 1958."

In May 1960, Governor Price Daniel requested that the Board assume State leadership in coordinating water planning in Texas, and that it prepare a Statewide plan to meet municipal and industrial water requirements. Cooperating with river authorities and cities, the Board prepared a report titled "A Plan for Meeting the 1980 Water Requirements of Texas," May 1961.

The United States Study Commission--Texas was authorized by Congressional Act on August 28, 1958. Its assignment was to formulate a basic, comprehensive, and integrated plan for development of the land and water resources for a defined area of study, which included only about 62% of Texas.

The Bureau of Reclamation and Corps of Engineers subsequently completed several reports on specific projects. The Corps of Engineers reports included multiple-purpose reservoir projects, local flood control, navigation primarily along the Texas Gulf Coast, hurricane protection, and comprehensive reports on the Sabine and Trinity River Basins. The Bureau distributed its Preliminary Report on the Texas Basins Project in 1963.

Local entities—cities, river authorities, and water districts—were also suggesting projects in their areas, some of which conflicted with proposals of Federal agencies.

Governor John Connally recognized the need for a more orderly and longer range analysis of the State's water problems, water needs, and solutions to these problems on a Statewide basis, and by letter dated August 12, 1964, requested that a comprehensive State Water Plan be prepared. He said:

> *"I am increasingly concerned about drought conditions in Texas and progress of our efforts to develop adequate sources of water for all our State. I'm sure the members of the Texas Water Commission share this concern with all our citizens.*
>
> *The Bureau of Reclamation and the Corps of Engineers have proposed broad water development projects for Texas far beyond the plans of the Texas Water Commission report, "A Plan for Meeting the 1980 Water Requirements of Texas." In my opinion, these plans fall short of satisfying the water needs for all of Texas.*
>
> *Furthermore, the Congress is presently considering a Federal water pollution control bill which will supplant state authority in this field. I have long been concerned that the State exercise its responsibility in all areas of water conservation and development. The recently enacted Water Resources Act of 1964 does provide an opportunity for state participation in federal water research programs.*
>
> *As you know, it is my responsibility, with the help of the Texas Water Commission, to review major federal projects and formally approve or disapprove them on behalf of the State. I cannot properly evaluate some proposed federal projects without a longer-range State Water Plan for Texas.*
>
> *Therefore, by authority granted me under Article V, Section 22, House Bill 86, 58th Texas Legislature (The General Appropriations Act), I hereby*

request the Texas Water Commission to use any available moneys appropriated under the Act to begin at once to develop a comprehensive State Water Plan. In the public interest and to aid the economic growth and general welfare of the State, I urge that you explore all reasonable alternatives for development and distribution of all our water resources to benefit the entire State, including proposals contained in preliminary reports of the federal agencies."

The State's planning programs have been conducted in accordance with the Texas Water Planning Act of 1957 (V.A.C.S. 7472d-1) through August 1965, and in accordance with V.A.C.S. 8280.9(b) as amended by acts of the 59th Legislature since September 1, 1965.

Acceleration of the planning effort, and the development of a longer range Texas Water Plan, was begun with Governor Connally's authorization of August 12, 1964, under authority given the Governor in Acts 1963, 58th Legislature, Chapter 525, p. 1393, Article 5, Section 22.

Emergency funds were allocated for key planning staff for the accelerated program in October 1964 from appropriations to the Governor for the purpose of deficiency grants.

The 59th Legislature provided additional funds for the accelerated program in a special emergency appropriation in Acts 1965, Chapter 4, p. 7. In addition, the 59th Legislature realigned the functions of the several Texas water agencies. This realignment assigned planning for water development in Texas, including financing, as a responsibility of the Texas Water Development Board.

The 60th Legislature provided continuing support for the planning program in its regular appropriations to the Board.

ACKNOWLEDGEMENTS

Many individuals and organizations, both public and private, have participated in the formulation of the Texas Water Plan. It would be impossible to acknowledge the individual contribution of every person and every group playing a part in bringing Texas to the position of strength in managing its water resources that this Plan makes possible. With sincere appreciation, however, the Board recognizes this tremendous reservoir of support. The special and dedicated assistance of the following merit special mention:

The Governor of Texas
The Honorable John Connally

The Lieutenant-Governor of Texas
The Honorable Preston Smith

The Speaker of the House of Representatives
The Honorable Ben Barnes

The Legislature of the State of Texas

whose untiring support has made possible this Plan for sound water development in Texas.

The staff of the Board, both past and present, who have unstintingly worked toward the completion of the Texas Water Plan.

Members of the then Texas Water Commission, who provided initial direction for the planning program.

Joe D. Carter, Chairman
Otha F. Dent
H. A. Beckwith
William E. Berger

Consulting Advisory Panel, which performed an incalculable service to the Board and the State by setting the planning program on a firmly marked road of achievement.

Joe M. Kilgore, Chairman
Harvey O. Banks
William F. Guyton
Allen V. Kneese
Mason Lockwood

The U.S. Army Corps of Engineers and the Bureau of Reclamation for their very able and invaluable assistance in the Texas Water Plan, and to the U.S. Geological Survey for the very valuable studies it is making of ground waters.

Universities and colleges that have prepared reports and conducted studies vital to the development of the Plan.

University of Texas at Austin
Texas A&M University
Texas Technological College
University of Texas at El Paso

Leeds, Hill and Jewett, Inc., General Consultant to the Board, through guidance, assistance, direct participation, preparation of reports, and staff training, have played an essential part in every phase of the planning program.

Harvey O. Banks, President
Raymond A. Hill

Consultants and consulting firms who have prepared reports used by the Board in the many facets of formulating the Plan.

A. C. Bowden

Brown & Root, Inc.

Bryant-Curington, Inc.

Forrest & Cotton, Inc.

Freese, Nichols and Endress

Wm. F. Guyton and Associates

Harza Engineering Company

McDonnell Automation Company

Hydrocomp International

International Business Machines Corporation

Lockwood, Andrews, & Newnam, Inc.

National Engineering Company

The Ralph M. Parsons Company

Reagan & McCaughan

Southwest Research Institute

Texas Instruments, Inc.

Bechtel Corporation

Dr. Paul D. Torrey

Turner, Collie & Braden, Inc.

Water Resources Engineers, Inc.

All of the many State and Federal agencies who have cooperated and assisted in countless ways in making possible development of the Plan.

River authorities, water districts, and other political entities that have supplied invaluable advice and assistance on the water needs and problems in the areas they represent.

The Texas Water Conservation Association and private organizations that have provided unfailing and generous encouragement and support.

All of those individuals and organizations who, through testimony at hearings held by the Board in 1966, contributed to the development of the Plan.

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INTRODUCTION

Water planning is a means to an end and not an end in itself. Its objective is the development of water resources as effectively and economically as possible to meet man's needs while at the same time protecting him from flooding and periodic drought. The high dams and man-made rivers that stand as monuments to man's ingenuity and technical skills conserve and distribute the water which is vital to his life and well-being, and shield him from its detriments. These works are conceived and planned to overcome the sometimes severe disparities between water resources as provided by nature and the timing and places of man's needs for water supply.

In the past, Texas citizens generally have been able to live wherever they chose without concern for the availability of water. Where other resources were available, a water supply was also generally available, either in the immediate vicinity or at relatively short distances. People settled, developing these supplies where they were found; investments were made, economies developed, and social and cultural values accumulated to the benefit of all citizens of the State.

Texans now, however, are able to see the limits of the State's developable water resources. Seeing these limits, recognition has also come that wise use of the available water resources is vital to the continued expansion of Texas population, economy, and culture.

By far the bulk of the water resources remaining available for development in Texas is found in the East Texas river basins. By contrast, large future water needs will be felt in areas to the west and southwest, several hundred miles distant, and for some areas, over 3,000 feet higher in elevation, where available water supplies are limited and diminishing. Cities and industries in many areas throughout the State will need more water or water of better quality than can be made available from local fresh water sources.

Furthermore, studies for the Texas Water Plan show conclusively that presently available water resources are grossly inadequate to meet Texas' future economically justified water needs. Importation of water from out-of-State sources will be essential. Without it, retrogression must inevitably occur in some sectors of the State's economy, particularly agriculture and associated agribusiness, with attendant severe social problems of unemployment and forced population relocation, and loss of financial investments.

As a result of the Texas Water Plan studies, the Congress has authorized the U.S. Corps of Engineers and the U.S. Bureau of Reclamation to investigate a possible import of water.

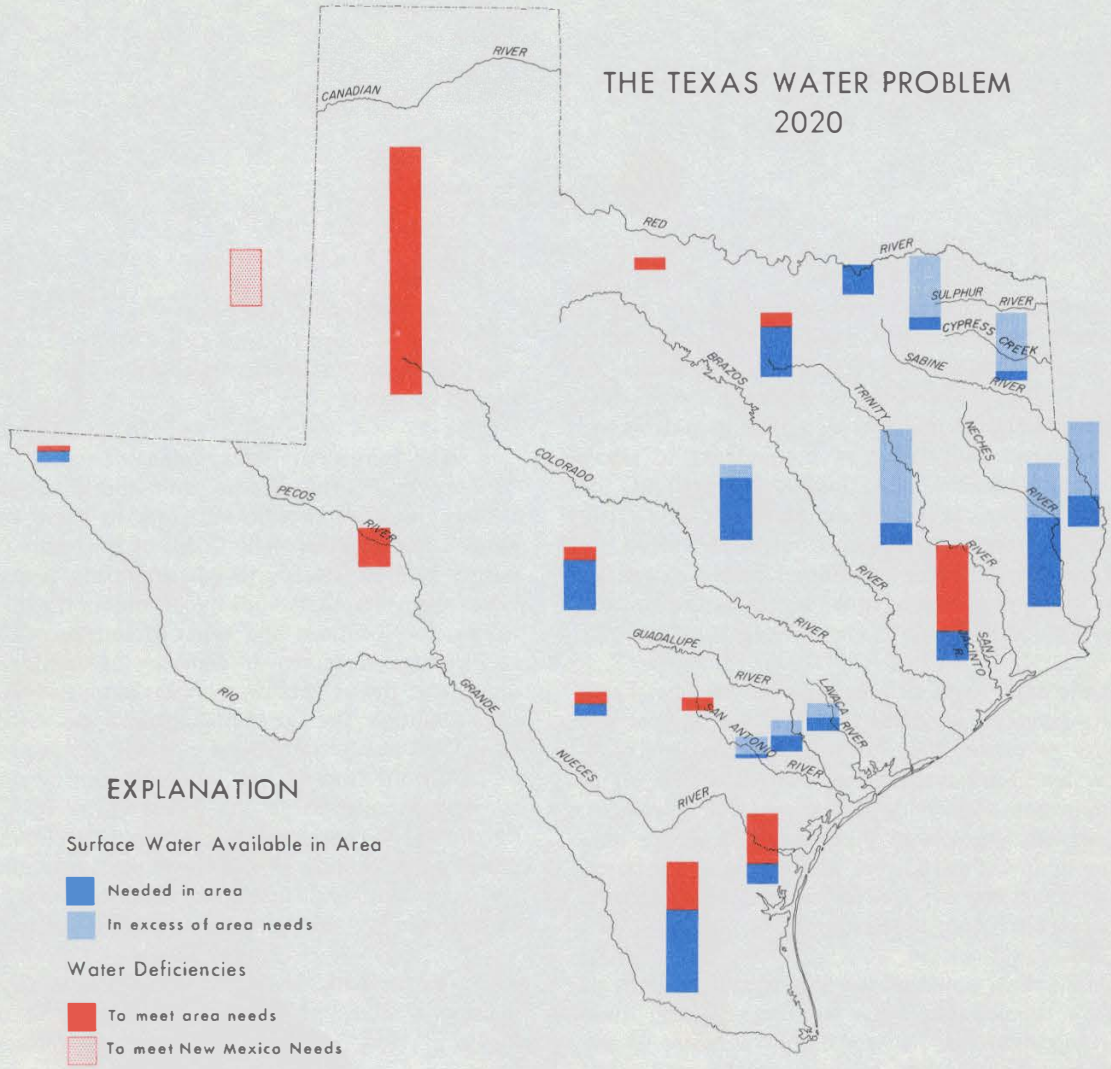
The Bureau of Reclamation is conducting studies of importing surplus water from the Mississippi River System into water-deficient areas in West Texas and eastern New Mexico. The Corps of Engineers is participating in these studies to determine the availability of water from the Mississippi in coordination with affected States, the locations and types of conveyance channels required for movement of water to these water-deficient areas, and the effects of such withdrawals and conveyance facilities. The Corps of Engineers was authorized in May 1966 also to determine whether any modifications or additions should be made in proposed Federal projects in relation to the Texas Water Plan, and to determine the effects of upstream developments on pollution or changes in salinity in the bays and estuaries and to recommend such improvements as are necessary to maintain or improve the quality of water in the bays.

Concurrently the U.S. Geological Survey is conducting a study of the Ogallala Aquifer in the High Plains of West Texas to determine the hydraulic and hydrologic conditions in the aquifer important to its effective utilization in conjunction with an imported water supply.

By 1972 the above Federal agencies, the Water Resources Council, and the Office of Water Resources Research will have spent several million dollars for studies and investigations—including the potential import of water to Texas and eastern New Mexico, and the Ogallala Aquifer.

Texas must continue to bear its full share of responsibility for developing and implementing plans for water import, and providing for the equitable distribution within Texas of waters now or potentially available for use. Since August 1964, the State has expended approximately $10 million in these planning activities. The time has now come to decide whether this investment in the future is to bear fruit or to be thrown away.

Statewide planning on a comprehensive long-range basis provides a guide for problem solving in advance of need; it is essential in a water-short area such



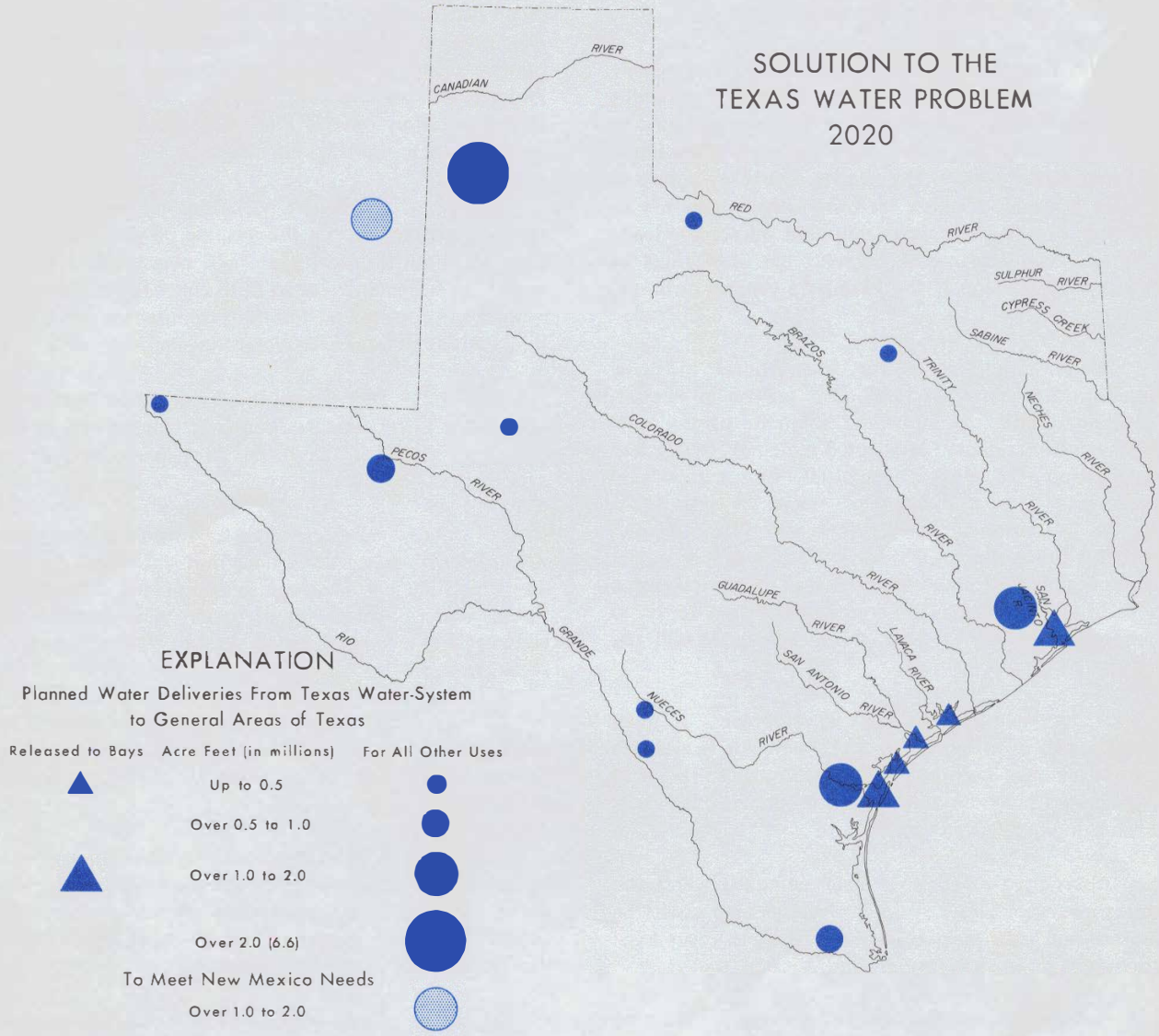
as Texas. The Texas Water Plan has been prepared as such a guide for water policies and development, and for intergovernmental relationships affected by or affecting water resource development. The coordinated progressive Statewide development proposed will enhance the effectiveness of the large investments of capital, labor, and materials and of water related land resources required to meet Texas' water needs. It will allow a thorough and systematic evaluation of those projects which are to receive State financial aid, and will provide a basis for selection of those which are in the Statewide interest.

Water requirements have been projected for a 50-year period and means of satisfying these requirements are proposed. It is recognized that if this Plan for water development, completed in 1968, is to provide for water to meet people's needs to the year 2020, it must be subjected to continuing study, refinement, and alteration as changing needs, priorities, and wishes of the people of the State may dictate. Thus it is a Plan that is flexible, retaining freedom of choice as to future actions as long as possible.

In developing the Texas Water Plan, the Board has used all historical data that could be accumulated; the resources of a qualified and dedicated staff; and the advice of Federal and State agencies, universities, in-State and out-of-State consultants, river authorities, cities, water districts, and representatives of the various economic segments of the State, as well as the opinions of the citizens of the State expressed during the hearings held by the Board in the summer of 1966.

Recognizing that continuing study and investigation will be needed of future water needs and problems in Texas, the Board nonetheless believes that sufficient information is now available on which to base this comprehensive Statewide Water Plan.

The document has been organized to facilitate its use both by the general public and by technical readers. The supporting data are available in files of the Board, as



are the reports prepared for the Board's use as a part of the planning document by universities, State agencies, and private consultants. This summary describes the Texas Water Plan and proposes a means for its implementation. Additionally, the Board has prepared a detailed description of the Texas Water Plan providing substantive detail and supporting data on its various aspects.

PLANNING CONCEPTS

Planning is the process by which a prudent society directs its activities to achieve goals it regards as important. It involves more, however, than the formulation of a physical plan—a means of implementation is necessary if planning is to be meaningful. The Board was directed to develop a comprehensive long-range flexible water plan for Texas. Recognizing the complexity of this task—the Board first defined the goals such a plan must acheive through the coordinated activities of Federal, State, and local levels of government. This conceptual framework has guided planning activities and formulation of the Texas Water Plan, and forms the basis for Plan implementation.

1. The Goal

The objective, or goal, of the Texas Water Plan is to provide in the most effective and economic manner the water supplies and the other benefits to be derived from water development necessary to meet the needs of Texans for all purposes throughout the State as the population grows and the economy expands. National, State, and local interests must be fully considered. Social, cultural, and economic values will be recognized. To the maximum extent possible, the Plan will assure that water supplies of good quality are made available so that the future of Texas will not be limited by lack of water.

2. The Plan to be a Flexible Guide

The Texas Water Plan is a guide for the extremely complex solution to the difficult problem of matching water development to demand. It has been designed to meet water needs for all purposes throughout the State, retaining options as to the proper course of action as long as possible. It must be progressively adapted to changing conditions, recognizing that all economically justified water demands throughout the State must be met as they develop if the Plan is to achieve optimum results.

Water requirements for all purposes must be frequently reviewed, updated, and revised as needed. Feasibility studies of individual elements of the total Plan must be conducted in selected sequence. Design and construction of physical facilities for storage and conveyance of water must be staged at times that provide the optimal balance between water supply, needs for flood control and other purposes, and project economics. A time schedule for action must be adopted to meet Texas' water requirements in time to avoid economic detriment. This time schedule will be extremely difficult to meet.

A framework of project development to meet water needs is proposed in the Plan. All reasonable alternatives have been examined, and must continue to be evaluated with the objective of minimizing the costs of achieving the desired results.

Alternative intrabasin projects compatible with the long-range objectives of water development could be incorporated into the fabric of the Plan to meet local preferences or changing conditions.

Changes in water resource availability resulting from instream development, shifting land use patterns, changes in storage in ground-water bearing formations, effects on flow in streams, flood and drought incidence, and changes in water quality must all be continually analyzed within the context of the Plan. Maximum use must be made of waste waters which can be reclaimed and renovated for beneficial purposes.

The whole range of the State's economy—the effects of water availability and water pricing on location of industry, municipal development, and irrigation expansion--must be evaluated periodically so that water development can be phased to meet changing needs. Opportunities for water-oriented recreation must keep pace with the expanding population.

3. Water Rights

Formulation of the Texas Water Plan has been based upon the premise of no interference with vested rights under existing water right permits. The basin of origin provisions of the Texas Water Development Board Act provide legal bases for protection of intrabasin rights. There is no comparable legal protection in Federal laws or policies nor in other State statutes. Implementation of the Plan is to be based on these tenets of water rights administration:

(1) Intrabasin needs for all beneficial purposes developing within the ensuing 50-year period will have an absolute priority of right over exportation for out-of-basin demands, as to both water rights for locally sponsored projects and the right to purchase water from the facilities of the Texas Water System.

(2) Demands on the Texas Water System for reasonable intrabasin requirements will be met at any point of time on a 100% firm basis before any exportation.

(3) Water temporarily surplus to intrabasin requirements and to the satisfaction of existing rights at any time, will be conserved and exported through the Texas Water System only under valid permit and contract arrangements, and subject to right of recapture when needed.

(4) All rights under permits to be held by the Board will be obtained through full compliance with rules and procedures of the Texas Water Rights Commission.

(5) Where operation of the Texas Water System might conceivably interfere with beneficial uses under existing rights, appropriate protective terms and conditions will be imposed in water permits granted by the Texas Water Rights Commission.

(6) Agreements will be executed as necessary with holders of existing rights and with operators of other projects, defining such rights as against the Board, and specifying project operational criteria for the Texas Water System to protect usage under such rights, and its operation with that of other projects to maximize overall benefits.

4. Federal-State-Local Relationships

Implementation of the Texas Water Plan and the Texas Water System is to be a coordinated and cooperative effort of the Federal Government, the State of Texas, political subdivisions of the State, and private interests, each acting within the scope of its authority and policies, and within the objectives and framework of the Plan. This arrangement is designed to further the interests of each to the maximum feasible extent. The State will be a major participant, on a partnership basis with the United States, in bringing the Texas Water System into being and in subsequent operation and management of the System.

5. Water Quality

Water quality control is an integral part of water resource development to enable maximum beneficial use, maximum reuse of waste waters, and to preserve the bays and estuaries. At the same time, the necessity to use streams, coastal waters, and ground waters for the final disposal of adequately treated waste effluents is recognized.

For purposes of planning, the achievement of the following goals of water quality management have been assumed: Pollution of Texas' water resources from both man's activities and natural sources will be abated as rapidly as possible, and future pollution prevented. Large-scale regional systems for the collection, treatment, and disposal of municipal sewage and industrial wastes will be planned and constructed where necessary to achieve quality control at reasonable cost. Control of wastes at the source may be necessary in some instances in order to maintain the quality of effluents discharged at levels that will permit reuse.

The compelling factor in water quality control is the health and welfare of Texas citizens. Water quality criteria must be based upon the total use that will be made of the water resource. Low flow augmentation, or low flow control, may be used to bring water quality to levels that will satisfy water uses of the stream on an interim basis, but not as a substitute for the highest economically feasible treatment of wastes.

Reservoir storage space and water will not be permanently and irrevocably allocated to quality control. However, under some circumstances water may be provided for low-flow augmentation, where such water can be used downstream to meet other requirements or to provide fresh water inflows to the bays and estuaries. Where so used, the necessity of continuance will be reviewed at intervals in the light of advances in waste treatment technology, economics, and the need for the storage and use of water for other purposes.

Control of natural sources of quality impairment will be diligently investigated and control measures undertaken where feasible as a means of enhancing usable water resources.

Water development will be undertaken so as to assist the Texas Water Quality Board in achieving effective pollution control, and in assuring fulfillment of the established water quality standards.

6. Multipurpose Development

Dam and reservoir sites in Texas are becoming scarce and costly to develop, and must be preserved and developed to maximum advantage. In general, each water basin, source, site, and facility will be developed on a multipurpose basis, and to its optimum limits. In examining such multipurpose possibilities, all functions and problems related to the site and the requirements it is to meet will be considered. If it is not economic to build facilities to optimum limits initially, initial development will be planned so that subsequent enlargement is not precluded.

7. Ground Water Use and Conjunctive Use With Surface Water

Whenever feasible, ground water resources will be developed and used on a safe-yield basis. In ground water aquifers subject to overdraft, ground water pumpage will be reduced to safe yield as rapidly as possible by substitution of surface water supplies. Where applicable and feasible, alteration in the pattern of excessive pumping will be considered.

The underground resources of natural ground water and of storage and transmission capacity will be utilized conjunctively with surface water supplies and facilities where such complementary operation will minimize the cost of providing adequate water supplies.

8. Progressive System Development and Coordinated Operation

The Texas Water System is considered as a single integrated unit to be planned, designed, constructed, and operated in such a manner as to minimize the costs of achieving the desired multipurpose results. To achieve this cost minimization objective, elements of the System will be staged and constructed progressively as water demands build up.

The most advanced techniques and automation will be used to operate the system of reservoirs, pumping plants, aqueducts, power plants, and other facilities in a coordinated manner to achieve optimum results.

9. Bays and Estuaries

The coastal bays and estuaries are of great importance to the State of Texas and to the Nation. Adequate fresh water inflows will be provided and other actions taken to preserve and enhance these resources. Comprehensive studies of all bays and estuaries are necessary to determine the proper actions.

10. Intangible Values

Future water development will have a profound impact on the State, politically, economically, socially, and culturally. The full range of impacts and benefits or detriments must be evaluated, even when not measurable in monetary terms. In planning and in project development, therefore, the benefits of esthetic and recreational enjoyment of the water resources of the State will be given full consideration, although these benefits cannot be quantified with precision. Sites of historic and

archeological value will be examined, and measures taken to the fullest possible extent to minimize loss of any of these values as the result of water development. River reaches and springs of great scenic and scientific value will be preserved whenever possible and feasible. All feasible measures will be taken to mitigate any damage to fish and wildlife resources resulting from construction and operation of facilities of the Texas Water Plan, and wherever possible the enhancement of these resources will be included as a project purpose.

11. Need for Equity in Resolving Problems

The construction of the massive impoundment and conveyance facilities of the Texas Water System will have an adverse, although temporary, impact upon the civil functions and economic stability of some local areas. Schools, hospitals, police, fire protection, and other administrative functions will be affected by the large-scale influx of construction personnel. Offsetting these detriments and costs of local communities, to the extent they cannot be handled with local financial resources without hardship, and insofar as the costs are not borne as a Federal responsibility, will be an obligation of the State as part of the construction cost of the System.

12. Master Districts

The reimbursable costs of the facilities of the Texas Water System allocated to water supply will be secured in full by water service contracts executed by the State with legally and financially viable master districts. Such districts must be formed in areas where no such entity presently exists, and must have adequate powers to raise sufficient revenue through water charges or taxation to assure that costs of providing water to the district through the System will be repaid. Where irrigation is a use to be served, a master agency or conservancy district will contract for the delivery of water to one or more wholesale delivery points within the area involved. Distribution of the water to retail consumers will be accomplished by the master agency or district or under ancillary contracts with other political subdivisions within the master agency.

Such agencies or districts will have adequate revenues, derived either from executed water sales contracts, or tax revenues, or both, to assure that the Federal and State investment for capital costs and the annual costs will be repaid insofar as these costs are reimbursable under Federal and State laws and policies. It will be important to assure economically effective farm units within irrigation areas to meet the costs of water supply.

13. Master Plans and River Basin Comprehensive Plans

The Texas Water Plan has been formulated incorporating previous master plans and comprehensive plans for river basin development to the fullest possible advantage.

All elements of such plans not in conflict with the overall objectives of the Statewide comprehensive Plan can be developed as a part of the on-going development of water resources of the State.

In the resolution of any conflicts that may arise, consideration of means for enhancement of the economic and social well-being of the river basin will be a principal objective as well as consideration of the Statewide interest.

14. Interstate Compacts

The apportionment of water from sources flowing along or across the boundaries of Texas will be made on the basis of jointly conceived compacts between the States involved and approved by the United States. On streams where compacts have not yet been consummated, it is expected that continued efforts will be made to reach agreement on the equitable apportionment of the waters.

15. Energy for Pumping

Extremely large amounts of energy for pumping will be required for the Texas Water System, and costs for energy will be a major component of cost of supplying water under the System. New generating facilities and expanded transmission systems will be necessary, and should be the lowest cost facilities feasible for supplying these needs. These will be fully integrated with the regional power systems. Surplus capacity and energy available from the regional systems will be used where financially advantageous.

16. Water Service Contracts

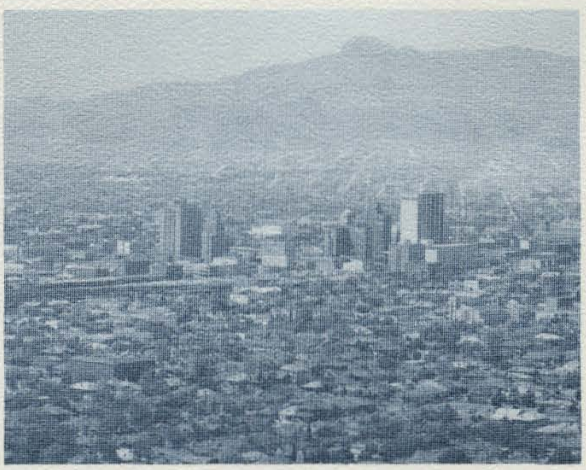
The water service contracts to be executed between the State and local political subdivisions served by the Texas Water System will convey a contract right to a water supply of suitable quality without specifying the exact source or sources from which the water will be obtained. The contracts will specify the amounts, timing and places of delivery, and the amounts and manner of payment and will contain such other terms and conditions as necessary to protect the interests of the United States, the State, and the contracting agency.

17. Water Pricing and Repayment Policy

The formula for payments for water under water service contracts will be such as to assure the State, as operator of the Texas Water System, of sufficient revenues to meet its financial obligations to the United States to the extent these pertain to water supply, to repay the State's investment allocated to water supply, and to operate and maintain the water supply components of the System.

Pricing and repayment for water for irrigation will be in accordance with the provisions of Federal Reclamation Law, as an investment by the United States. Other pertinent Federal laws and policies will apply with regard to reimbursement of the remainder of the Federal investment. The State's investment will be repaid with interest.

Pricing and repayment for municipal and industrial water supplies will be by zones, with the price for water increasing as the distance of conveyance increases.



The
Texas Water Plan

THE TEXAS WATER PLAN

Its Objectives

The Texas Water Plan is a flexible guide to the coordinated, long-range management, development, and redistribution of Texas' water resources, and for the importation of water from out-of-State for the benefit of Texans throughout the State.

The several regions of the State are interdependent economically, financially, and politically. One region with water surpluses cannot retain those surpluses in excess of its own needs to the detriment of other regions less fortunately endowed with water resources without loss to its own well-being and to the State as a whole. Concerted, aggressive action is required if adequate funds are to be available for the full development of water and facilities that will be necessary throughout the State. The Texas Water Plan will provide a sound basis for such action.

The Plan is based on the premise of the following accomplishments being achieved effectively and economically through cooperative coordinated action by the Federal agencies, State agencies, local political subdivisions, and private interests.

(1) Satisfy vested water rights with proper modes and procedures to be followed for the equitable adjustment of any water rights that might be affected by the program, including continuance of vested riparian rights now supplied by direct diversion from streams.

(2) Provide the projected 2020 municipal and industrial water requirements throughout the State.

(3) Provide for the importation of an estimated 12 to 13 million acre-feet per year from out-of-State sources by 2020 to meet Texas' water needs, and deliver 1.5 million acre-feet to New Mexico through joint use of facilities.

(4) Deliver about 7.5 million acre-feet of supplemental water annually for irrigation in North Central Texas, the High Plains, and the Trans-Pecos area. Planning will continue as to possible import of water to supply additional economically justified water needs throughout the State, as those needs arise.

(5) Deliver 727 thousand acre-feet of water annually for irrigation in the Coastal Bend area and 700 thousand to the Lower Rio Grande Valley through the Coastal Canal; and make available 200 thousand acre-feet annually for irrigation in the Winter Garden area and 190 thousand acre-feet annually for irrigation in Webb and Maverick Counties by releases from Amistad Reservoir, with water supplied to the Lower Rio Grande Valley through the Coastal Canal in replacement for these releases.

(6) Based on best available estimates of need, provide regulated fresh water inflows to the bays and estuaries, and participate as justified in other measures such as structural modifications to obtain better tidal circulation, with the objective of maintaining suitable quality conditions for fish and shellfish.

(7) Supply projected water requirements for wildlife management areas and refuges.

(8) Meet projected water requirements for secondary oil recovery programs.

(9) Recognize interstate compact commitments.

(10) Use return flows and reclaimable waste waters to the maximum feasible extent.

(11) Through conjunctive use of surface and ground water and other measures, make possible a decrease in ground water extractions from aquifers to the safe yield, thus minimizing subsidence and other adverse effects of overdraft.

(12) Decrease loss of the State's water resources through control of phreatophytes and salvage of phreatic non-beneficial consumptive uses.

(13) Provide flood control through storage in proposed reservoirs, and by channel improvements and levees where necessary.

(14) Coordinate hurricane protection projects along the Gulf Coast with other actions in order to minimize the adverse effects of those projects.

(15) Support projects to provide drainage where feasible for land reclamation and where necessary for maintenance of agricultural productivity.

(16) Alleviate degradation of the State's fresh water resources from sources of naturally poor quality water, such as saline springs.

(17) Develop means to provide regional systems for the collection, treatment, and disposal of municipal sewage and industrial wastes that will be necessary to maintain the quality of the State's waters at requisite levels.

(18) Develop other necessary means for quality protection and management.

(19) Preserve and protect river reaches and springs of great scenic beauty or scientific value.

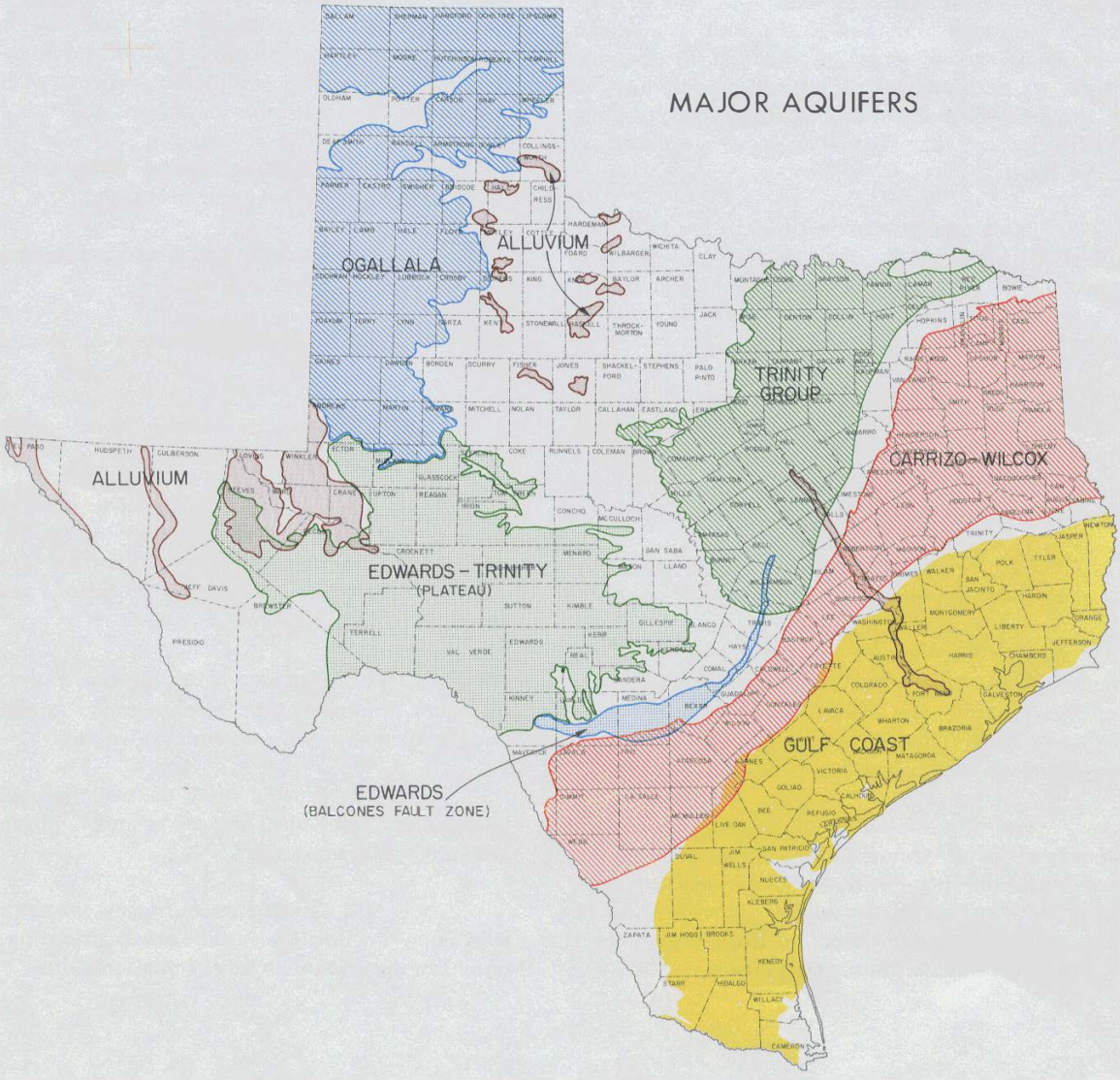
(20) Preserve and protect sites and natural phenomena of historic and archeological importance.

(21) Provide additional water-associated recreational opportunities.

(22) Integrate feasible navigation projects on Texas streams with other water development objectives, and provide necessary water requirements for navigation purposes.

(23) Provide for expanded upstream watershed programs for erosion control and land treatment, and additional floodwater retarding structures and channel improvements.

(24) Generate electrical energy for pumping to the extent that energy cannot be made available from other sources at requisite prices.



(25) Develop hydroelectric power where feasible.

(26) Protect and enhance fish and wildlife resources to the maximum feasible extent.

(27) Provide increased financial assistance to qualified local agencies for necessary water facilities.

Water Resources

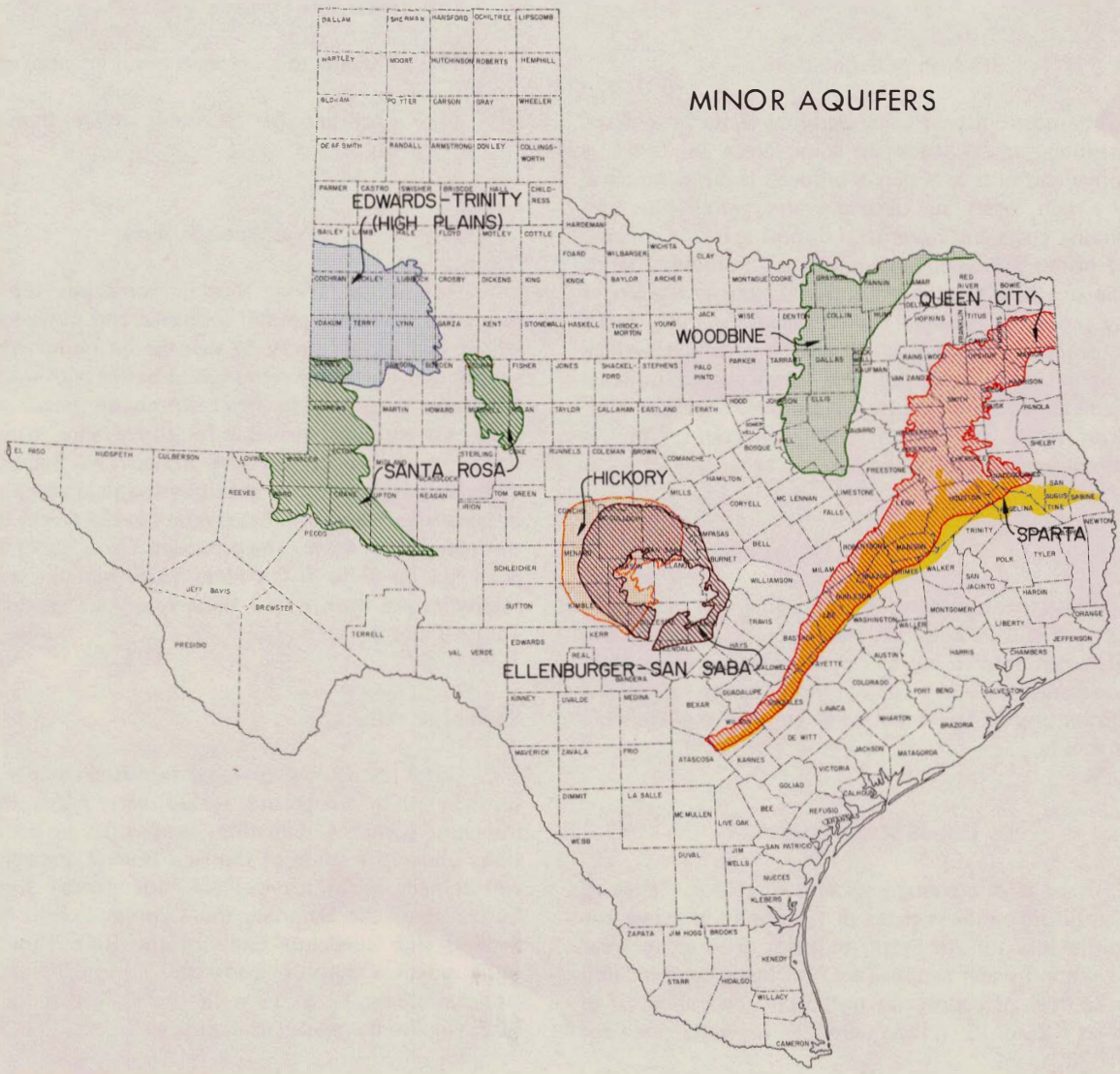
The total water resources of the State have been evaluated in planning studies, including waters from surface streams of Texas (surface waters); water from underground formations (ground water); treated or untreated waste waters (return flows); brackish and saline waters; and atmospheric water for possible increases in rainfall. Studies have also been undertaken of possible importation of water from out-of-State sources.

Surface Water

The amount of water flowing in Texas streams ranges widely from east to west as does the amount of water falling as rain or snow. The average annual runoff is about 39 million acre-feet, with about three-fourths of this total coming from the eastern one-fourth of the State. The annual amount of runoff varies widely also. For the period 1940-46, the average annual amount was approximately 59 million acre-feet, dropping to about 24 million acre-feet annually for the dry period 1950-56.

Ground Water

Ground water is a significant resource throughout much of the State, supplying about 75% of the total water used for municipal, industrial, and irrigation purposes. Many areas now supplied by ground water are depleting the available supply because the rate of pumping grossly exceeds the rate of replenishment. As



ground water is depleted, those areas must meet their needs through a supplementary source. In areas where serious overdrafts occur, corollary problems of land subsidence and intrusion of poor quality water may impose additional hazards.

Return Flows

Much of the water diverted from a stream or pumped from underground formations for municipal and industrial use is returned to a stream channel as treated waste water. Some of the water used for irrigation also returns to the stream or aquifer. As water uses increase in the future, the volume of return flows will increase. As the new sources of water which can be exploited are strictly limited, methods of renovating return flows for reuse must necessarily be employed.

Present municipal and industrial waste-water releases are estimated at 0.8 and 1.3 million acre-feet per year, respectively, and are projected to reach 5.9 million acre-feet by 2020.

Brackish or Saline Waters

The possibility of using desalted water as a means of meeting water needs in some areas in Texas is attractive and one to which the Board is directing close study. High costs of desalting the water plus the continuing costs and hazards of disposing of the concentrated brines produced under present technology tends to rule out desalting as a solution to large-scale water supply problems. However, in local areas desalting shows great promise. Technological advances which reduce costs and solve some of the waste brine disposal problems could offer additional promise in the future. Brackish water will supply a large percentage of the water requirements for secondary oil recovery.

Weather Modification

Research studies of the potential for modifying rainfall are still in relatively early stages. Although the Board is not foreclosing this potentiality, present planning does not rely upon weather modification as a means of augmenting in any substantial amount the available water supply.

Out-of-State Import

There is not enough water available in Texas to supply future water needs. If we are to prevent the economic loss to the State of major geographic areas where ground water supplies are now being depleted and other sources of supply do not occur, an import of as much as 12 to 13 million acre-feet of water per year must be sought. Water in these quantities appears from preliminary planning estimates to be available from the Mississippi River at a point below diversions from the River in Louisiana. For purposes of planning, it was assumed that this diversion of water could be made possible.

The New Mexico State Engineer's office has indicated that import of approximately 1.5 million acre-feet of water per year will be required by the year 2020 to maintain existing irrigation development and the associated expanding economy in Eastern New Mexico. It has been assumed that this need could also be met from the Mississippi.

Description of Physical Works

The physical works required to accomplish the objectives of the Texas Water Plan are categorized as:

(1) The Texas Water System,

(2) Interstate System,

(3) Projects to meet local requirements, and

(4) Facilities for purposes other than water supply.

Texas Water System

The Texas Water System comprises the dams, reservoirs, pumping plants, conduits, and other facilities which will be necessary to manage an imported water supply and the water resources of basins with interim or long-term surpluses to meet intrabasin needs and to make the surpluses available for conveyance to areas of deficiency elsewhere in the State. The System also includes the conveyance facilities and regulatory storage necessary to transport these waters to the places of need throughout the State. The proposed Texas Water System is shown on Plate 2. On Plate 3 existing and proposed reservoirs are shown, and these reservoirs are listed on Tables 1 and 2.

Sources of Water

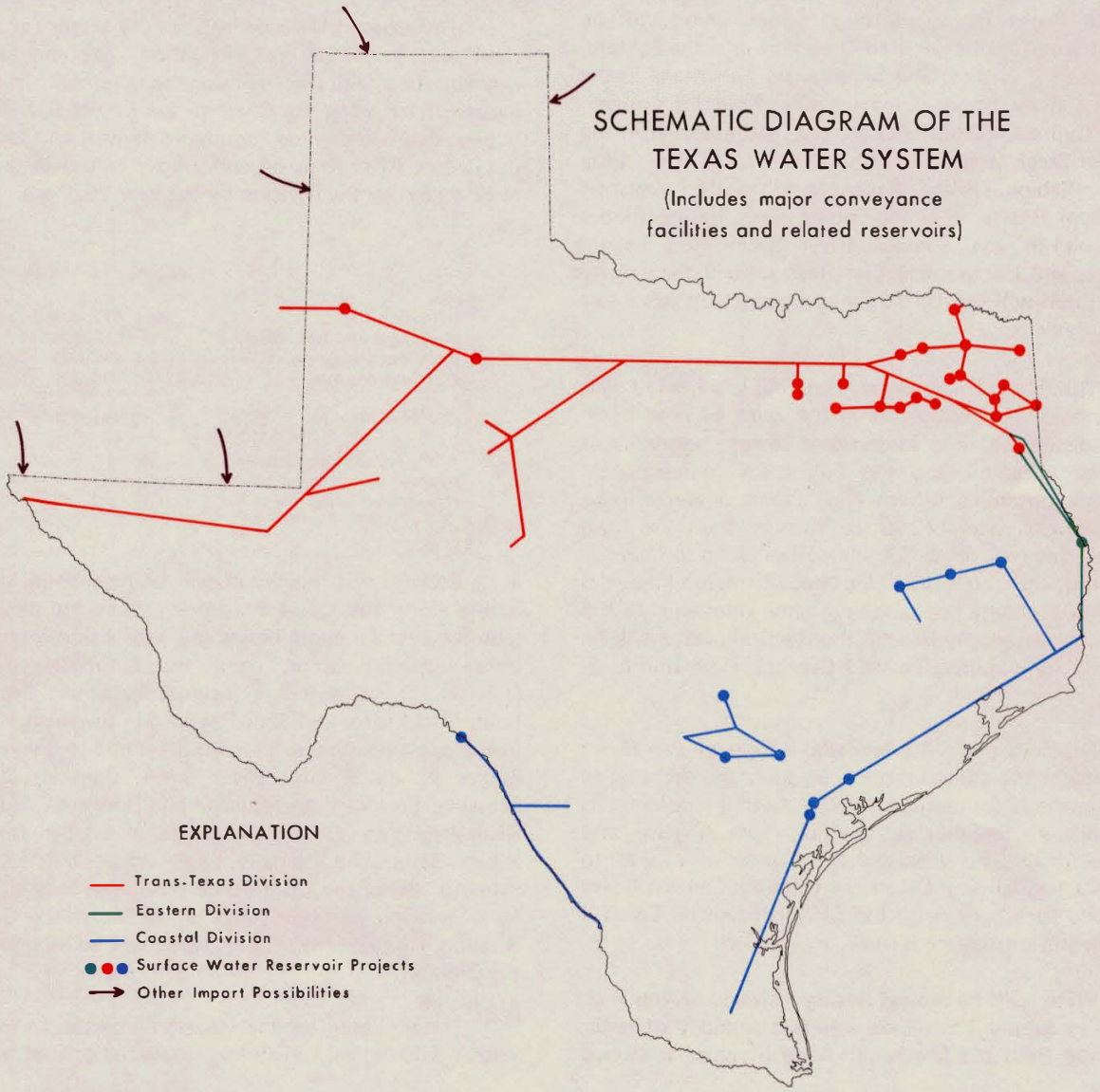
After satisfying all local intrabasin water needs through 2020, recognizing vested water rights, meeting interstate compact obligations, and satisfying the obligations under the draft of the Red River Compact, there will remain a surplus available for export from the Lower Red, the Sulphur, the Cypress Creek, Neches, Sabine, and Guadalupe-San Antonio River Basins, and some possible surplus from the Trinity River Basin. Approximately 12 to 13 million acre-feet of water per year will also be needed as import to Texas.

Some supplies of water may be available on an interim basis from basins where water supplies are in excess of present water requirements or water requirements projected to 2020. Use of these waters on an interim basis when intrabasin supplies are in excess of requirements will permit the most economical and efficient phasing of construction, and result in a lower unit cost of water to all concerned including intrabasin users. Some of these basins where temporary interim use is proposed will ultimately need supplemental water through the System to meet intrabasin requirements in excess of intrabasin supplies.

Physical Elements and Purposes

The physical facilities comprising the Texas Water System shown on Plate 2 are: (a) the **Trans-Texas Division,** including the storage and regulating reservoirs and the interconnecting conduits and pumping plants in the Northeast Texas basins, the Trans-Texas Canal, and the terminal reservoirs and wholesale distribution systems; (b) the **Coastal Division,** including the Coastal Canal, storage and regulating reservoirs from the Sabine River to the Lower Rio Grande Valley, conveyance from the Rio Grande of releases from Amistad Reservoir to the Winter Garden area, and the storage and conveyance complex in the Guadalupe and San Antonio River Basins; (c) the **Eastern Division,** comprising those works in the eastern basins required to move water from the point or points of delivery to Texas of water imported from out-of-State sources to the Trans-Texas and Coastal Divisions.

Distribution systems to supply irrigation users will be constructed from wholesale delivery points by the master districts to be served with water for irrigation purposes under the Texas Water System. These systems for distribution will be a local area responsibility. Their design and repayment of their costs will be subjects for local decision.



The **Trans-Texas Division** will supply all municipal, industrial, and irrigation requirements in the Northeast Texas basins and the Dallas-Fort Worth area. The following amounts of water will be transported through the Trans-Texas Canal for Dallas-Fort Worth, North Central Texas, the High Plains, the Trans-Pecos area and El Paso, and to New Mexico.

	ACRE-FEET PER YEAR
Municipal & Industrial	950,000
Irrigation	7,584,000
New Mexico	1,500,000*
Total	10,034,000

* Water imported from out of Texas.

Storage and regulating capacity will be developed in reservoirs in the Northeast Texas basins to provide fully the projected requirements of those basins, and to supply water to the Trans-Texas Canal. These reservoirs include Pecan Bayou, through which water will be moved from the Lower Red Diversion into the System; Parkhouse I, Naples, and an enlarged Texarkana in the Sulphur River Basin; Titus County, Franklin County, Black Cypress, Caddo enlargement, and Marshall in the Cypress Creek Basin; and Mineola and Lake Fork in the upper Sabine River Basin. Additionally, existing Tawakoni Reservoir in the Sabine River Basin, Cooper Reservoir in the Sulphur River Basin, and Lavon, Forney, and Garza-Little Elm Reservoirs in the Trinity River Basin will be utilized for conveyance by this water supply system.

The Trans-Texas Canal, concrete lined, will begin at Northeast Texas Junction at the upper Sulphur River Basin divide and end at terminal storage reservoirs at Caprock Reservoir and the Bull Lake complex near Lubbock on the Southern High Plains. Water will be lifted approximately 2,700 feet through the Canal from Cooper Reservoir in the Sulphur River Basin to Caprock Reservoir, ultimately requiring about 5 million kilowatts of electric energy for pumping when operating at full capacity. An additional 950 thousand kilowatts will be required for pumping beyond Caprock Reservoir to El Paso.

Southwest of Wichita Falls, a pipeline can divert water from the Canal to supply 95 thousand acre-feet of water annually for municipal and industrial requirements of Abilene, Sweetwater, Snyder, San Angelo, and Colorado City as it is needed and if these cities elect to contract for delivery. Diversions from the Canal will also be made to supply irrigation in North Central Texas if contracting entities are formed.

Water will be moved through storage on the High Plains to supply 1.5 million acre-feet annually of water imported from the Mississippi River by canal westward from Bull Lake Reservoir to New Mexico. South from storage, Caprock Reservoir and Bull Lake, water will be conveyed by canal to supply 505 thousand acre-feet of water annually for municipal and industrial use—80 thousand acre-feet for Lubbock, 140 thousand acre-feet for Midland-Odessa, 45 thousand acre-feet for Big Spring, 40 thousand acre-feet for Pecos, and 200 thousand acre-feet by pipeline from Pecos to El Paso—and 933 thousand acre-feet annually for irrigation in the Trans-Pecos. Additional water can be supplied in the El Paso area and Hudspeth County for irrigation purposes by enlargement of the capacity of the System.

Distribution systems will be needed in North Central Texas, the High Plains, and the Trans-Pecos for irrigation water. The canal conveying water from a point near Lubbock to the Trans-Pecos will be a main artery of the distribution system on the High Plains. Other than this main canal, these distribution systems will be constructed and operated by districts formed in the area they serve.

The **Coastal Division** will supply water for municipal and industrial uses, irrigation, bay and estuary augmentation, and wildlife refuge requirements from the Sabine River along the Coast to the Lower Rio Grande Valley. Estimated water requirements west and south of the Brazos River, plus needed inflows to Galveston Bay, to be served by the Division by the year 2020 are:

	ACRE-FEET PER YEAR
Irrigation	1,817,000
Municipal and Industrial	518,000*
Bays and Estuaries	2,450,000
Fish and Wildlife	60,000
Total	4,845,000*

* Does not include San Antonio and Houston supply, which may be met by any one of several alternatives.

Storage and regulation will be developed in river basins along the Coast to provide both the projected requirements for those basins and, where interim or long term surpluses occur, some water for the Coastal Division. These reservoirs include Blackburn Crossing, Ponta, Rockland, and Sam Rayburn in the Neches River Basin; some possible surplus from Tennessee Colony and Bedias in the Trinity River Basin; Canyon, Cloptin Crossing, Lockhart, and Cuero I and II in the Guadalupe River Basin; and Cibolo and Goliad in the San Antonio River Basin. Additionally, salt water barriers and Palmetto Bend and Confluence Reservoirs may be used for regulation or conveyance of water in the Coastal Division. Additionally, import water will be brought into the Division.

Water supply for the Houston area can be met by several alternatives, including combinations of supply

from the Trinity, San Jacinto, and Neches River Basins, ground water, and water from the Coastal Canal. These alternatives include diversion from the Neches River Basin through the canal system of the Lower Neches Valley Authority under appropriate water permits and contracts; water from the Coastal Canal; diversion of water from Rockland Reservoir to Bedias Creek Reservoir and into the San Jacinto System; or treatment of Trinity River water and its direct municipal use.

Fresh water inflows needed for Galveston Bay, now estimated at 1.5 million acre-feet annually, may be revised by studies now underway. These needs can be supplied from the Coastal Canal, in whole or in part.

Cuero, Cibolo, and Goliad Reservoirs and a pipeline conveyance system are a part of the Coastal Division. Through systems operation, San Antonio can be supplied from this source with 220 thousand acre-feet of water annually to supplement available ground water from the Edwards (Balcones Fault Zone) Aquifer. Further, these reservoir developments will allow early use of interim basin surpluses in the lower coastal areas.

Conveyance of releases of water out of Amistad Reservoir to the Winter Garden area will be down the river channel, then through canal and pump station across the divide to terminal regulating storage. Delivery point in the Winter Garden area will be determined by feasibility and design studies conducted in coordination with local interests. Water supplied from Amistad to irrigators in this area and in Webb and Maverick Counties will be replaced in the Lower Rio Grande Valley by deliveries through the Coastal Canal. Areas thus supplied will be required to assure the repayment of the reimbursable costs for the delivery of the replacement water from the Coastal Canal and for diversion facilities from the Rio Grande. Distribution systems, constructed and operated by local master districts, will be needed in the Coastal Bend, Lower Rio Grande Valley (except where existing systems are adequate), Webb and Maverick Counties, and the Winter Garden area.

The **Eastern Division** includes those works required to move water imported from out-of-State sources to the Trans-Texas and Coastal Divisions. At the time of release of this report, planning for such an import must, of necessity, be adaptable to any one of several alternative points at which such an import supply might be delivered to the Texas State line. Final decision will be conditioned by the results of feasibility studies by the Corps of Engineers, studies by the Mississippi River Commission, and by the future water needs of the State of Louisiana which might also be served by works carrying an import supply to Texas and New Mexico.

Principal alternatives being considered are a coastal routing which would bring import water to the State line at the eastern terminus of the Coastal Canal on the Sabine River; a combination of import with the authorized Red River navigation project; or some combination of these or other routings.

If the water is brought along the coastal route, then works of the Eastern Division would convey water northerly into the Trans-Texas Division. Alternatively, water imported to a northerly point, such as the Red River, would supply water to the Trans-Texas Division, and south to supply the Coastal Division (See Plate 2).

Design studies of some eastern basin reservoirs will be guided by the operational requirements imposed by the direction in which water ultimately is moved through the Eastern Division.

Staging

Before construction of any conveyance unit of the Texas Water System is begun, there must be assurance of an import water supply. This is necessary to avoid the risk of constructing System units or committing interim water surpluses to meet water needs for which there might not be a sufficient assured long-term water supply.

Once an import of water from the Mississippi River has been assured through appropriate agreements and Congressionall authorization and funding, maximum efficiency at minimum cost can be achieved by staging construction of storage, conveyance, and irrigation distribution facilities over time as water needs increase. Constraints of design and construction capability and the availability of funds are key factors in determining the rate at which facilities can become operational.

Subject to the results of feasibility studies, the Board proposes that design and construction should begin in the following sequence, and proceed concurrently on:

A. (1) Storage facilities in Southwest Texas and the Coastal Canal from the Lower Rio Grande Valley, utilizing temporary surpluses in basins west of the Guadalupe River on an interim basis, and building eastward as intrabasin demands and requirements of service areas absorb these temporary surpluses. Construction on the Coastal Canal will continue progressively eastward from the Guadalupe River as rapidly as possible to assure delivery of water through the Canal from the east by the time interim surpluses are required for inbasin users and additional supplies are needed as a supplement to meet total water requirements within these basins and to supply their service areas.

(2) Storage and conveyance facilities in the Northeast Texas basins.

B. The Trans-Texas Canal and storage and distribution facilities in the High Plains and North Central

Texas areas. As the construction on the Trans-Texas Canal to Bull Lake is completed and construction begins on the Canal southward toward Pecos, construction should begin on the distribution system in the Trans-Pecos and on the pipeline to El Paso.

C. The conveyance facility from the Mississippi River to the State line.

Water available as surplus from the Northeast Texas basins would move westward first, supplying the requirements in the Dallas-Fort Worth area as needed, and initiating deliveries through the Trans-Texas Canal.

As facilities from the Mississippi River are completed, additional water to West Texas, plus the 1.5 million acre-feet annually for New Mexico, would be moved through the Trans-Texas Division facilities as rapidly as municipal demands increase and as irrigation distribution facilities are constructed to serve the land.

When the Coastal Canal is completed east to the Sabine River, Mississippi River water can be brought directly into the Coastal Division to supplement eastern basin water providing 2020 projected requirements in the areas supplied by the Coastal Division.

At this phase the Texas Water System would be fully operational.

Energy for Pumping

The total power and energy requirements for pumping under the Texas Water System will exceed the present requirements of any region of the State. Although natural gas engines may supply smaller installations, most of the energy must come from electrical generation.

The alternatives for supply of electrical energy for System pumping include:

(a) Purchase from existing utility systems.

(b) Construction and operation by the Board of a State-financed generating plant(s).

(c) A Federally financed and constructed generating plant or system. This would produce the lowest cost energy, particularly for pumping irrigation water since no taxes or interest component would need to be included in the cost.

(d) A very large capacity nuclear or mine-mouth generating plant(s) financed in part with public funds, Federal and State, and in part by private investment, and constructed and operated by the investor-owned utilities.

Of these alternatives, the last appears to be the most feasible because it would achieve the economies of large scale; cost of energy for System pumping would not include a component for taxes or profit, nor, in the case of irrigation pumping energy, an interest component; and the required Federal and State investments would be held to a minimum.

Transmission and distribution of energy for pumping would be accomplished by:

(a) A publicly financed system, Federal or State or both, designed and constructed for the purpose; or

(b) Wheeling (conveying) over the existing utility systems, expanded and reinforced as necessary; or

(c) A new system financed and operated similar to the provisions of alternative (d) for providing electrical energy.

Interstate System

In its preliminary plan released early in 1966, the Board described the imperative need for an out-of-State import of water if a major loss of irrigated agriculture were to be avoided in the West Texas area, notably the High Plains. With the support of the Board, local interests, the Texas Congressional delegation, and widespread support throughout Texas, the Congress of the United States authorized preliminary studies of importation sources and routes from the Mississippi River for these water-deficient areas by the Mississippi River Commission and the Lower Mississippi Valley Division of the U.S. Corps of Engineers participating with the Bureau of Reclamation.

Extremely preliminary indications, plus reconnaissance water studies and economic analyses made by the Board, suggest that feasibility studies of an import routing to Texas and eastern New Mexico from the lower Mississippi River are warranted. The route through Louisiana for such an import might follow the channel of the Red River, entering Texas in the Cypress Creek Basin, or might be a part of a fresh water coastal channel constructed westward to the lower Sabine River from the Mississippi River, or a combination of these two or other routings.

No decision on the relative merits of the routes, or a combination thereof, is possible at this time, and the Texas Water Plan is, therefore, so designed as to be compatible with alternative possibilities.

Projects to Meet Local Requirements

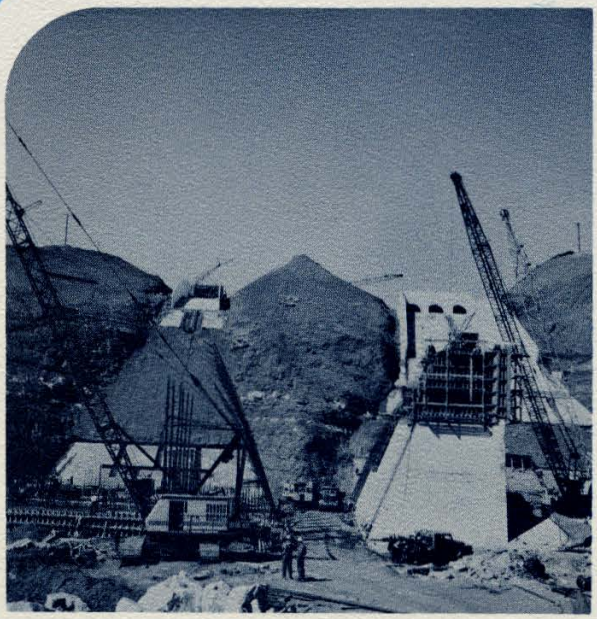
These facilities are shown in summary form in Tables 1 and 2 and are illustrated on Plate 3. The selection of the projects shown here was based on the premise that ground and surface water in each river basin would be developed to the maximum practicable extent, that exports from basins of surplus would be limited to those quantities of water available over and above reasonably foreseeable 50-year basin needs, and that import to areas of deficiency would be limited to that water needed to supplement locally developed supplies. In the studies leading to completion of the Plan, the Board examined the feasible alternatives available and made exhaustive studies of new alternatives proposed by various interests.

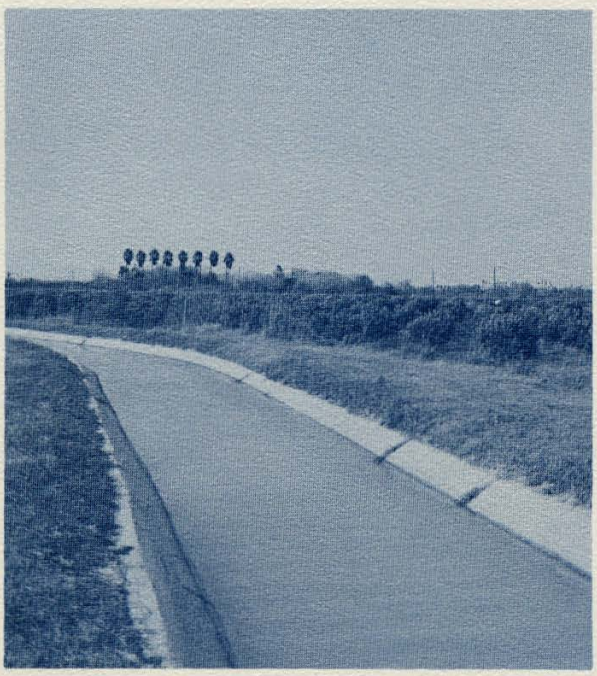
The omission of a local project from Plate 3 or Tables 1 and 2 does not preclude the possibility that that project may ultimately be constructed. By the same token, the inclusion of a project does not mean that it is the only project to be considered. Rather, each such project must be examined on its own merits on the basis of its potential for meeting the basic objectives of the Texas Water Plan, and its merit from the standpoint of Statewide planning for optimum water resource development.

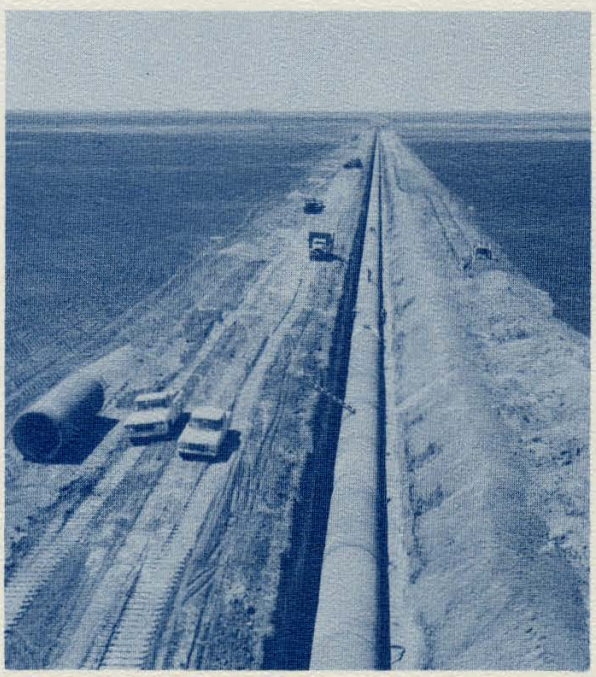
It is envisioned that most of these projects will be constructed under local sponsorship, either by one of the Federal agencies or by a local agency with financial assistance when necessary from the Board.

Water Projects Other Than Water Supply

These projects include navigation, both along the Coast and on inland rivers, flood control facilities other than reservoirs providing water supply storage, hydroelectric power generation, hurricane protection projects, upstream watershed-protection programs, drainage of wetlands, natural salinity alleviation projects, and phreatophyte control projects.







Implementing the Texas Water Plan

IMPLEMENTING THE TEXAS WATER PLAN

This document will not provide a single drop of additional water to Texas water users, unless it is translated into a concerted vigorous action plan supported by all Texas citizens and responsible levels of government to finance and construct the needed facilities for water storage and conveyance. Requirements for making the Texas Water Plan a reality include:

Intergovernmental Relationships and Responsibilities

The State's participation in water planning and development is essential if Texas is to have a voice in the management of its water resources. The facilities required to supply water to Texas involving directly the State of Texas and the United States are:

(1) *The Interstate System*—those works required to divert from the Mississippi River and convey water to the Texas-Louisiana State line.

(2) *The Texas Water System*—those facilities within the State of Texas required to protect, conserve, transport, and distribute Texas' intrastate water resources and Texas' share of interstate waters for various purposes throughout the State, and to regulate and transport water from out-of-State sources brought to the State line through the Interstate System to users in Texas. The conveyance works of the Texas Water System would also transport water from the Mississippi River to the State of New Mexico.

Federal-State-Local Actions

(1) The Board should complete the planning for the Texas Water System and participate in the preparation of feasibility reports with the Federal agencies.

(2) The Interstate System should be designed and constructed by such agency or agencies as Congress may direct.

(3) The most economical pumping energy for the Texas Water System should be provided, possibly by nuclear-fueled generating plants, and transmission systems jointly financed by the United States, the State of Texas, and the investor-owned utilities.

(4) Most of the units of the Texas Water System should be designed and built by the Corps of Engineers and the Bureau of Reclamation; some may be designed and constructed by the Board and/or by local agencies. The Board's involvement in design and construction will be minimal, but the Board must maintain liaison with the Federal and local agencies in design, and must monitor work on design and construction to insure that Texas' interests are properly taken into consideration and protected.

(5) For those units of the Texas Water System designed and constructed by the Federal agencies, the State of Texas must provide a substantial portion (20-35%) of the funds required for engineering and construction on a partnership basis with the United States. This partnership arrangement would be on the basis of investments in the total System by the United States and by the State of Texas, rather than on the basis of ownership of a specific facility or of a particular portion of a facility. One possible solution to this complex financial arrangement would be the establishment of a "Texas Water System Construction Fund" by the Congress, into which Federal appropriations and State monies from the Texas Water Development Fund for construction would flow and from which payments for engineering work by the Federal agencies and for construction would be made. This Fund would be administered by the United States.

(6) For those units to be designed and built by local agencies (or by the Federal agencies for local interests) but from which some water is to be derived for interbasin transfers through the Texas Water System either on an interim or long-term basis, the Board would participate financially either by purchase of storage, or by purchase of water. This would necessitate the negotiation and execution of purchase and operating agreements with such local agencies.

(7) The Board would hold appropriate rights to water conveyed through the Texas Water System.

(8) The Board would execute the base contract with the United States for repayment of that

portion of the reimbursable Federal investment in the intrastate facilities allocated to Texas. The Board would in turn execute contracts with local agencies for their purchase of water, thus obtaining revenues to meet its obligations to the United States, to repay the State's investment, and to cover operation, maintenance, and management expenses. These water contracts would provide the financial security for the base repayment contract with the United States. Federal laws and policies regarding reimbursability and repayment will apply except as to the interest rate to be charged on the investment from the Texas Water Development Fund.

(9) The Board would assist local interests in the formation of master districts with adequate powers to enter into water service contracts with the State of Texas in those areas where such political subdivisions do not now exist.

(10) The Board would purchase water at the State line from the United States, or from some agency thereof, for conveyance and sale through the Texas Water System.

(11) Under agreement with the United States and the State of New Mexico, the Board would convey the water to be imported into New Mexico from the Mississippi River through the Texas Water System.

(12) The Board would operate and maintain, and be responsible for administration and fiscal management of the Texas Water System as elements thereof are completed by the Federal agencies, except for those units which are to be operated, maintained, and managed by local agencies. Fulfillment of this responsibility will entail the negotiation and execution of a master agreement with the United States, and of operating agreements with holders of existing and authorized projects on streams on which Texas Water System conservation units are to be built.

(13) Responsibility for operation, maintenance, and management of the Interstate System should be vested in such agency as Congress may direct.

The key element in carrying out the above actions is the assurance of an effective responsible relationship between the United States and the State of Texas within which each level of government can assume its proper authority and discharge its appropriate obligations. Similarly, responsible relationships between the Board and other State agencies, between the Board and local political subdivisions, and between the Board and water agencies in other States must be established and actively maintained.

These relationships should be formally organized in such a way that effective working partnerships are possible. This organization might be formulated along these lines:

(a) Memoranda of understanding with the Bureau of Reclamation and the Corps of Engineers, the major Federal construction agencies, establishing institutional arrangements required to achieve coordination of planning, and the policies and criteria under which the Texas Water System is to be presented to the Congress and the State of Texas as a joint Federal-State-Local project.

(b) Permanent committees with representatives of the Board, the Bureau of Reclamation, the Corps of Engineers, and of other States or agencies as appropriate. A Policy Committee is needed for review and decision making; a Planning Committee to formulate objectives, policies, and criteria under which the Texas Water System will be developed for consideration of the Policy Committee; and staff committees responsible to the Planning Committee for analysis of hydrology, water requirements, economics, and design.

(c) The Congress to set forth in the authorization for Federal participation in the Texas Water System and in the Interstate System the basic policies under which cooperative Federal-State implementation will proceed. These policies would establish the terms under which the Board would assume responsibility for operation, maintenance, and management of the Texas Water System and guarantee repayment of the reimbursable Federal costs allocated to Texas. Since out-of-State elements will be involved, a special commission or agency, with specifically defined powers and duties should be created by parallel or complementary actions of the Congress and the States to oversee the construction, operation and maintenance, and management of the Interstate System, and to insure that the interests of both the United States and the States are protected.

(d) For projects not a part of the Texas Water System, the Board will maintain active liaison with the Federal construction agencies (Corps of Engineers, Bureau of Reclamation, and Soil Conservation Service), and with concerned local entities, and will take appropriate actions on pre-project planning, investigations, authorizations, final planning, and construction.

State Coordination

The Board will coordinate the interests and participation of other State agencies in planning for construction and operation of the Texas Water System and related projects, by direct liaison between the executive head of the Board with other State agencies, or by designated staff principals of the Board with other State agencies.

The Board will work closely with river authorities, major cities, and other entities. Continuing communication and coordination is essential with these regional and local interests regarding immediate and long-range

planning, operational criteria of local projects consistent with objectives of the Texas Water Plan, contractual agreements on various features, and joint participation in project financing.

This continuing communication and coordination is especially important on projects not directly related to the Texas Water System such as channeling for flood control, hurricane and tidal flood protection, coastal navigation, upstream watershed protection programs, and drainage facilities.

Interstate Coordination

The Board will continue to participate in programs of interstate cooperation including:

(1) Necessary activities relating to interstate and international streams bordering or crossing Texas;

(2) National or regional water associations or councils such as National Rivers and Harbors Congress, the National Reclamation Association, Interstate Conference on Water Problems, the Council of State Governments, the Southern States Water Conference; and

(3) Interstate groups such as the Western States Water Council and cooperation with the States adjacent to Texas with regard to importation of water from out-of-State, including continuing interest and cooperation in regional systems which have been proposed such as the North American Water and Power Alliance.

System Management

The planning, design, construction, operation, and management of the facilities proposed in the Texas Water Plan will require the application of the most advanced concepts and methods of analysis to solution of problems and to aid in management decisions. The mass of data involved in this complex System of dams, reservoirs, power plants, diversion facilities, pumping plants, and navigation facilities is so massive that application of advanced techniques of data management and processing are essential. When all of these facilities are in place, their integrated operation and management will require a completely automated system.

Master Districts

No construction will begin, and no water can move to any area to be served by the Texas Water System, until there is a firm commitment on the part of a responsible political entity to contract for the repayment of the reimbursable System costs allocated to the area. Where irrigation is to be served by the Texas Water System, master districts must be available to make contract commitments. Although these master districts may take varying forms—creation of a new district, combination of a group of districts, or the enlargement of areas and functions of existing districts—a number of broad powers will be needed. These powers, not necessarily all applicable to any given area, include but are not limited to the following:

(1) Power to contract for a water supply and to assure repayment of the costs for such a supply.

(2) Power to contract with local entities or subdistricts for "retail" distribution of water.

(3) Power to borrow money and incur indebtedness, issue bonds, levy taxes, and take all other required responsible financial actions necessary to repay obligations for the delivery of water.

(4) Power to charge direct water tolls and charge indirect beneficiaries who obtain water from underground sources recharged as a consequence of delivery and use of water through the Texas Water System.

The Board, appropriate to its statutory duties, will assist local areas in any way in establishing viable political entities with authority and financial competence to assume contractual obligations required under the Texas Water System.

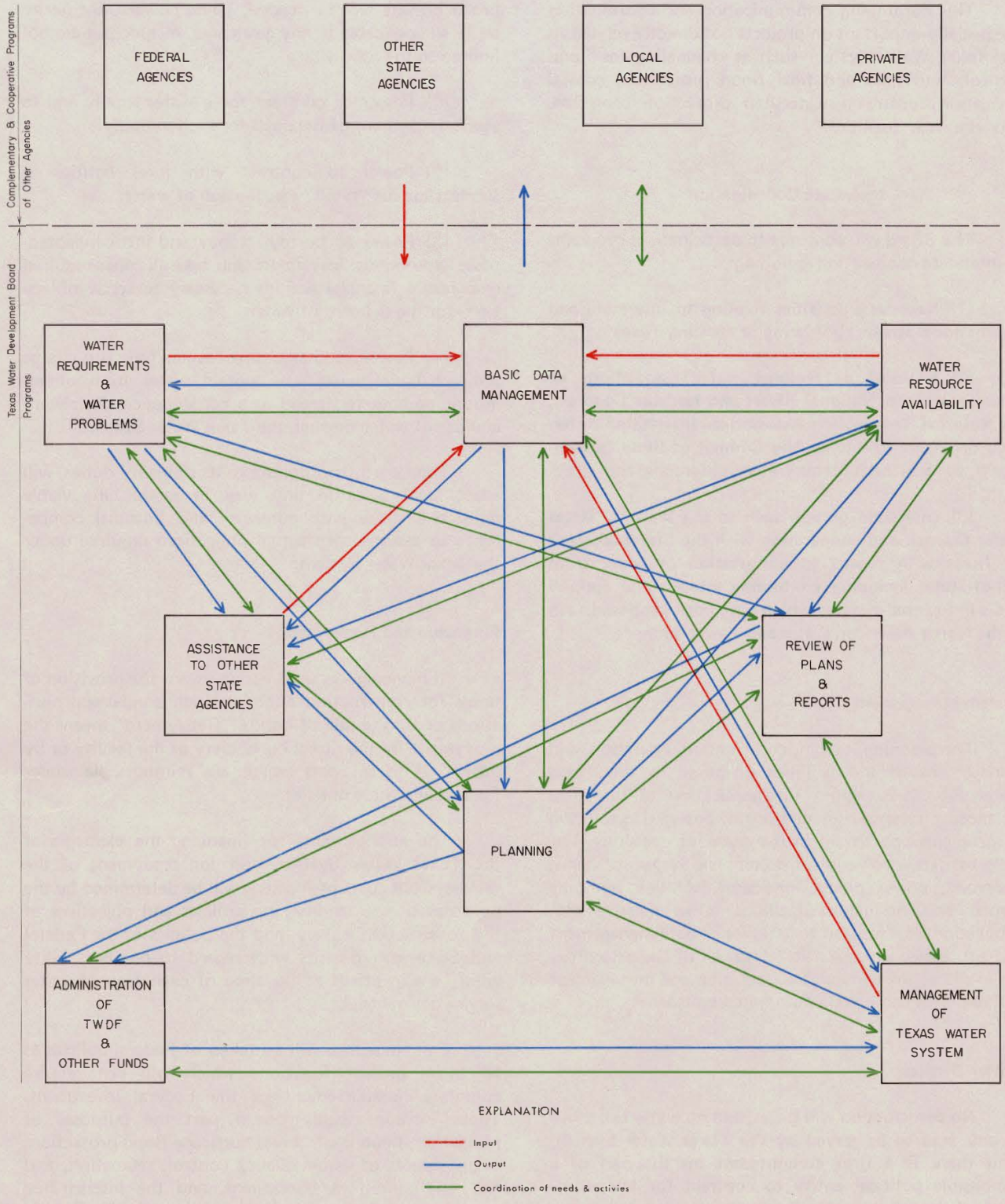
Financing and Repayment

"Financing" as used herein means the provision of funds for construction either through annual appropriations or by the sale of bonds. "Repayment" means the repayment by the direct beneficiary of the facility or by others of those costs which are reimbursable under Federal and State policies.

The arrangements for financing the elements of the Texas Water System, and for repayment of the reimbursable costs of facilities will be determined by the purposes of the facility, the policies and objectives of the construction agency, and the policies of the Federal and State governments with regard to reimbursability which are in effect at the time of execution of water service contracts.

Full advantage will be taken of Federal policies as to those project functions which will not require complete reimbursement of the Federal investment. These include wholly or in part the purposes of navigation, flood control and hurricane flood protection, some aspects of water quality control, recreation, and fish and wildlife enhancement, and the interest-free provisions of Reclamation Law as regards the Federal investment allocated to irrigation.

MAJOR PROGRAMS OF TEXAS WATER DEVELOPMENT BOARD



Cost of other project functions will be financed jointly by the Federal Government and the State, and in some cases by local interests.

The Texas Water System will be financed as a joint Federal-State and local enterprise. Water delivered into the System from out-of-State sources will be purchased at the State line by the Board from the Interstate System.

The Board will operate and manage the principal facilities of the Texas Water System as these facilities are constructed. This will require the negotiation of a master agreement with the United States. The Board will also guarantee repayment of the reimbursable Federal costs under the terms of this master agreement, including guarantee of payment for water purchased from the Interstate System. The obligations incurred by the State in this agreement with the United States will be underwritten by contracts negotiated by the State with master districts receiving water delivered through the System.

Board Program

Plate 1 outlines the steps that must be taken by the State and Federal governments if the Texas Water Plan is to become a reality. The controlling time schedule is keyed to times at which essential actions must be taken to assure that first deliveries of water to the High Plains and other areas through the Texas Water System will meet critical times of water demand. The Board has scheduled each of its major programs to meet the target dates shown on Plate 1.

The following summary of major programs is descriptive only, rather than inclusive of every task. Detailed schedules and budgets will guide each program.

Water Requirements and Water Problems

This program involves the continuing evaluation of water requirements and water problems throughout the State of Texas.

Required are projections of future population and economic development, both for local areas and the State as a whole; future State and National demands for irrigated crops; soil classification studies, particularly as these relate to application of water for irrigation; land use plans; projections of future irrigated acreages and locations; unit use values for municipal and industrial demands; consumptive use of water by irrigated crops; studies of irrigation efficiency; future recreation demands; fish and wildlife demand studies; and hydraulic, hydrologic, biologic, and economic studies of the bays and estuaries.

Basic Data Management

This program relates to compiling, collecting, storing, retrieving, presenting, and publishing basic data obtained under other Board programs, from other State agencies, from Federal and local agencies, and from private interests. The Board is actively working with other State agencies in inventorying and evaluating all available water-oriented data and in determining future requirements for basic data of all kinds to effectively implement the Texas Water Plan.

All of these data are essential to sound water planning and for the effective and economic development and utilization of the limited water resources which are now or may become available to Texas. To proceed without adequate basic data and a proper data management program would cost the water users of Texas hundreds of millions of dollars.

Because water resource systems are dynamic and continually changing due both to natural phenomena and to the effects of man's activities, the longer, more continuous and complete the historical records, and the greater the frequency of observations, the more valuable and useful the data will be.

Water Resource Availability

The collection, analysis, and use of data relating to the occurrence and quality of all sources of water is essential to determining the location and quantitative and qualitative characteristics of the available resource.

Hydrologic studies have been made for all present and proposed reservoirs in the Texas Water System. Their physical characteristics, operational effects upon one another and on the System as a whole, quality of water now and under future conditions, and their yields under present and future conditions have been examined. These refined studies must be conducted for all of the river basins of the State.

Studies providing information on the geology, hydrology, and hydraulic characteristics of ground water basins at a level suitable for general planning have been completed for approximately 40% of the State. These studies, however, must now be refined, and new techniques of analysis applied for each of the ground water basins upon which the State must rely.

Assistance to Other State Agencies

The Board is necessarily involved in this Plan with all State agencies and colleges and universities whenever related functions touch on water resource matters. Individual Board programs provide necessary assistance to PACT—Planning Agency Council for Texas—Texas

Water Rights Commission, Texas Water Quality Board, Parks and Wildlife Department, Railroad Commission, and Water Well Drillers Board.

This structured relationship between State agencies engaged in corollary activities is essential to an effective State management system designed to avoid duplication of effort while meeting fully the State's governmental needs. Conceptually, these relationships must be flexible and responsive to the increasing need for a multidisciplinary approach to common problems which does not penalize the State by duplicating either services or professional competence.

Review of Plans and Reports

The Board will review reports prepared by Federal, State, and local entities on water projects and analyze their import to the State's total water development picture in the context of the Texas Water Plan.

Planning

Sound continued planning is especially important in Texas where internally available water resources are inadequate to meet rapidly expanding Statewide demands, and where the cost of water development and conveyance will be high.

Texas water planning studies described in this report have been, of necessity, conducted at a reconnaissance level. These plans must now be refined and detailed so as to serve adequately for feasibility level reports, as a basis to proceed with design at the proper time, and to provide the basis for decisions which will insure the most efficient use of intrastate waters.

Economic and financial analyses must be refined prior to the presentation of feasibility reports to the Congress for authorization of Texas Water Plan facilities, and to form the basis for execution of water service contracts. These analyses, which the State must assume the responsibility of preparing and supporting to the Congress, must be adequately detailed to provide assurance to the Congress that the benefits to the State and to the Nation justify the costs of the Plan; and that the repayment capability of those areas to which water will be taken is adequate to reimburse the Federal investment to the extent required by Federal laws and policies.

Administration of Texas Water Development Fund and Other Funds

The Texas Water Development Fund was created by Constitutional amendment in 1957. The purpose of the Fund's establishment was to make loans to local governmental entities sponsoring construction of projects for the conservation and development of the State's water resources. Further Constitutional amendments in 1962 and 1966 broadened the authority of the Board in administering the Fund to include powers to acquire conservation storage facilities in reservoirs to be constructed on Texas streams and for any system or works necessary for the filtration, treatment, and/or transportation of water by Federal or local governmental agencies to the end that the remaining reservoir sites in Texas may be developed to their optimum potential. The program administered by the Board is currently limited by Constitutional provision to $400,000,000 provided that the last $200,000,000 be approved by a two-thirds majority of each House of the Texas Legislature. By Constitutional provision, the Board is limited to a maximum investment in any one local project, and further restricted to an aggregate investment of $100,000,000 in all reservoir conservation storage facilities.

The State of Texas must continue to share in the costs of Texas water development throughout the period of implementing the Texas Water Plan if it is to provide the assistance that will be needed in water development.

The authorization by the Legislature and the citizens of Texas of an augmented Texas Water Development Fund will be necessary before feasibility reports for the Texas Water System go to Congress for authorization in order that Texas can be in a strong position to say that the State is ready to accept its share of the responsibility for meeting its water needs.

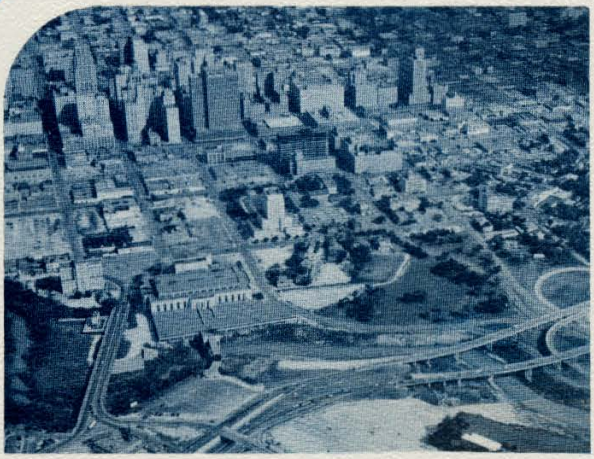
Management of Texas Water System

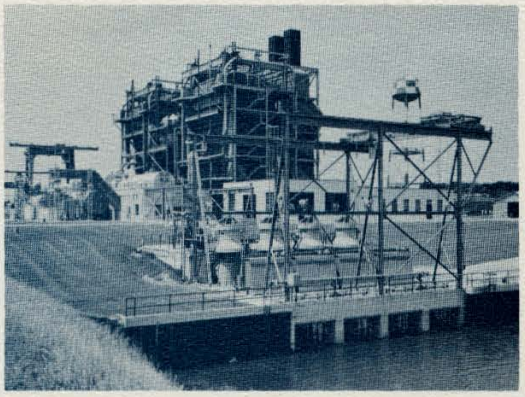
This is a new program designed to carry out Board responsibilities for operation, maintenance, and administrative and fiscal management of the Texas Water System.

While actual operation, maintenance, and administrative and fiscal management of specific elements of the System will not start until 1979, certain necessary preliminary actions must be initiated now as indicated on Plate 1.

Operation of any system as complex as the Texas Water System must be fully automated to achieve maximum efficiency and economy. Only one similar system, the California State Water Project, which is much less complex, has been designed for automated operation. The Board must provide the design concepts and the research needed for automated operation.

Hundreds of millions of dollars in revenue will be generated annually by sales of water from the Texas Water System. Millions of acre-feet of water will be moved through the System to a wide variety of water users. There is no precedent for the management of a complex water resource system on this scale, and experienced management capability must, therefore, be developed over time to assume control as the elements of the System become operational.





Water Uses, Needs, and Problems

WATER USES, NEEDS, AND PROBLEMS

Major water uses in Texas are for domestic and municipal supply, industry, and irrigated agriculture. Other beneficial uses of water include mining and secondary oil recovery, hydroelectric power generation, navigation, and recreation. Additionally, plans for comprehensive water development must consider fresh water inflows necessary for the bays and estuaries, flood and hurricane control, drainage, water quality management, fish and wildlife enhancement, intangible values derived from preservation of scenic areas and scientific values, and problems of land surface subsidence and salt water intrusion.

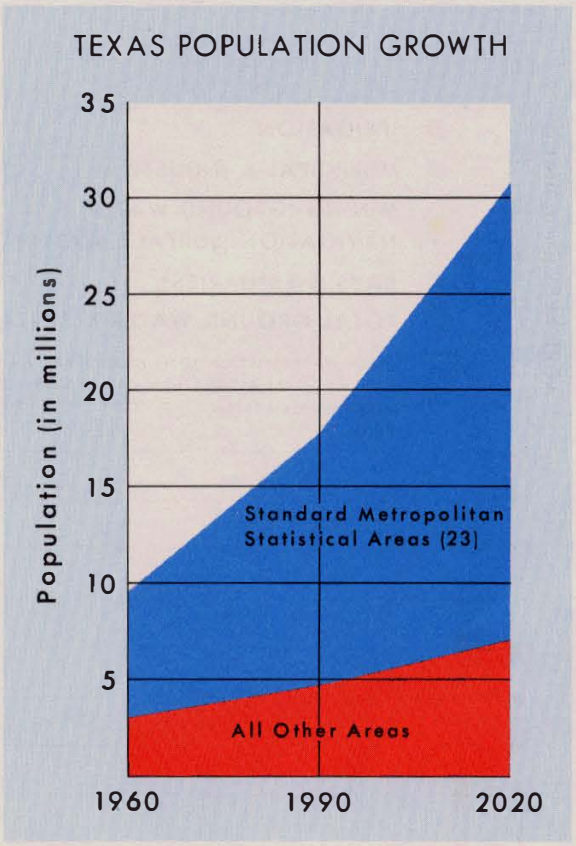
Intrastate supplies are not equal to these needs, either as they occur geographically, or as the needs for water increase over time. Water supply for municipal use will be an acute problem in two decades in some major Texas cities. A supply for presently existing irrigation will be needed where available water is rapidly dwindling, and fresh water inflows will be needed for the bays and estuaries. Flood and hurricane damage and poor drainage are creating severe problems now in many parts of the State.

Projections of water requirements have been made by the Board for all beneficial uses. These requirements were reported in detail in the river basin summaries printed and released by the Board in 1966. These requirements will be continually reviewed and updated as a part of the continuing planning activity of the Board. The basin summaries will be revised and reprinted in 1971, using data from the 1970 census. Thereafter, updated summaries will be released every five years.

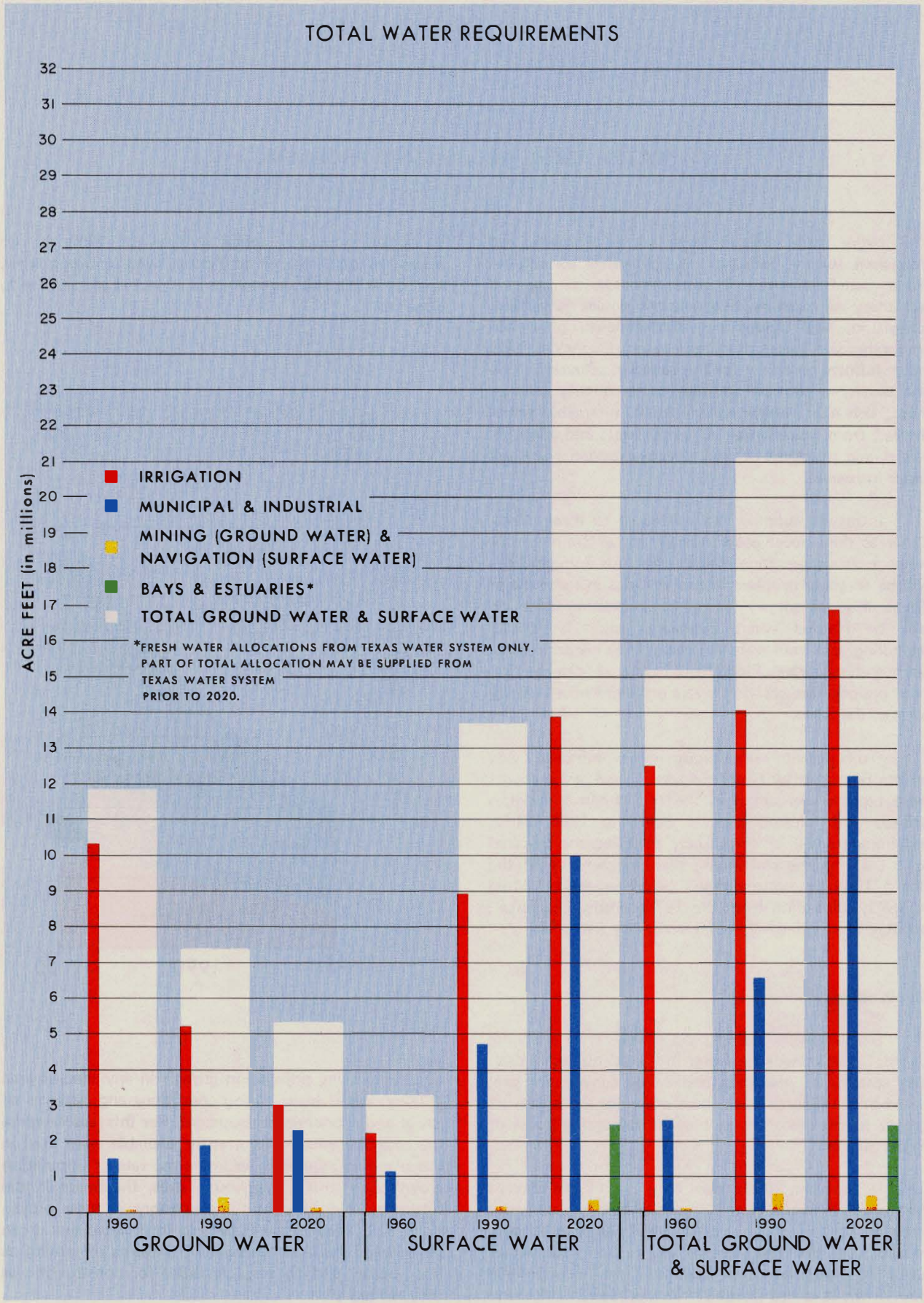
Municipal and Industrial

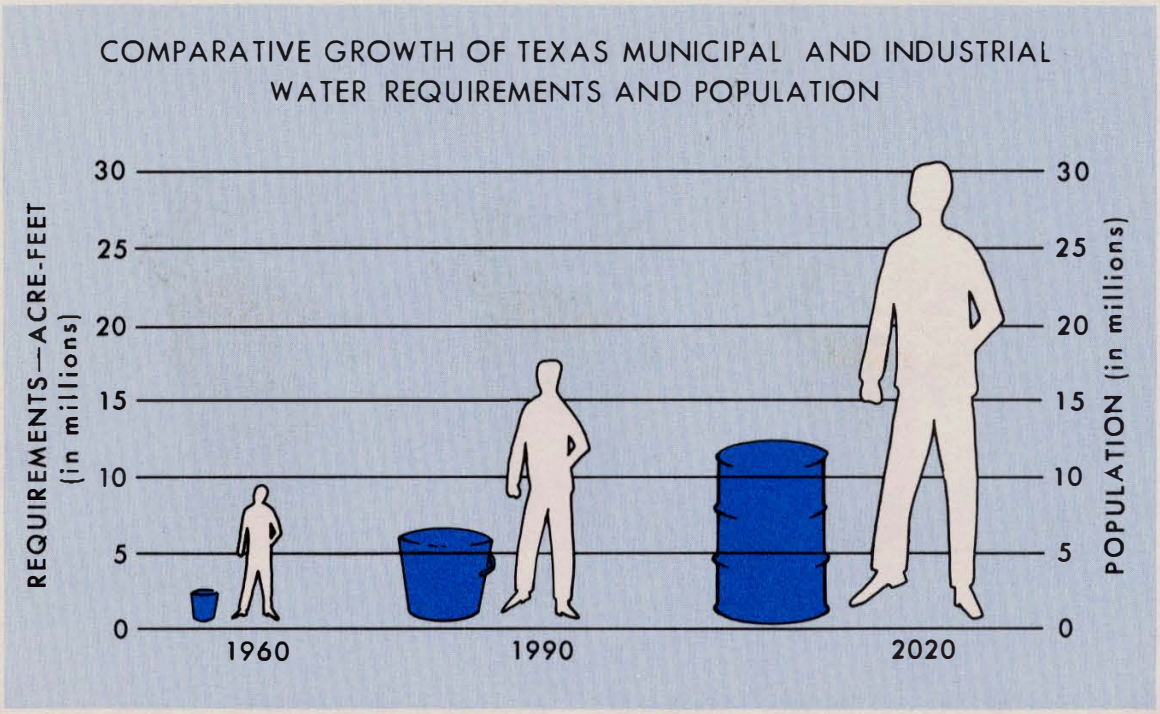
Shallow wells, springs, and streams were adequate to meet man's needs for water in Texas' historical past. The systems of reservoirs and water conveyance proposed in the Plan to meet these needs for the future are simply extensions through time of the spring house or oaken bucket.

In the year 2020, more than 30,500,000 Texans are expected to use over 12 million acre-feet of water annually for municipal and industrial purposes as contrasted with the 1960 use of 2½ million acre-feet of water by a population of 9,579,677. As Texas population grows, it is also shifting from a predominantly rural to a predominantly urban pattern. In 1960, it was estimated that 75% of all Texans lived in urban areas, and by 2020, this percentage is expected to increase to about 84%.



Projecting population growth in any specific area is complicated by changing conditions and patterns of social and economic development. For this reason, while the soundest practices currently available were used in the planning studies to estimate the rate of population growth and shift throughout Texas, the Board in the future must make continuing revisions in these projections. The Texas Water Plan is so formulated that it can be adapted to meet changes in patterns of growth as they occur, and to stage facilities for construction as they are required.


TOTAL WATER REQUIREMENTS
ACRE FEET (in millions)
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
IRRIGATION
MUNICIPAL & INDUSTRIAL
MINING (GROUND WATER) & NAVIGATION (SURFACE WATER)
BAYS & ESTUARIES*
TOTAL GROUND WATER & SURFACE WATER
*FRESH WATER ALLOCATIONS FROM TEXAS WATER SYSTEM ONLY. PART OF TOTAL ALLOCATION MAY BE SUPPLIED FROM TEXAS WATER SYSTEM PRIOR TO 2020.
1960
1990
2020
GROUND WATER
1960
1990
2020
SURFACE WATER
1960
1990
2020
TOTAL GROUND WATER & SURFACE WATER



This projected growth assumes that water supplies can be made available at economically supportable costs to provide for diverse municipal and industrial water demands. Present evaluations of available water supplies indicate that of the 23 Standard Metropolitan Statistical Areas (major population centers) the following will need supplemental water from the Texas Water System by 2020, most of them long before 2020: Abilene, Brownsville-Harlingen-San Benito*, Corpus Christi, Dallas, El Paso, Fort Worth, Galveston-Texas City, Houston, Lubbock, McAllen-Pharr-Edinburg*, Midland, Odessa, San Angelo, and San Antonio.

Proposed storage and conveyance systems in the Texas Water Plan will make it possible to provide these long-range requirements on a dependable basis. Cost of water of such quality as to be suitable for the various needs of these areas will be generally less than the costs that would be incurred by each city if it had to compete for the available resources on a piecemeal basis.

The pattern of industrial growth, and projections of the use of water by industry, cannot be predicted with absolute certainty. These projections must respond flexibly to changes in technology and industrial concentration. They must be subjected to continuing review and refinement to assure this response if industrial water supply is to be available as needed in local areas.

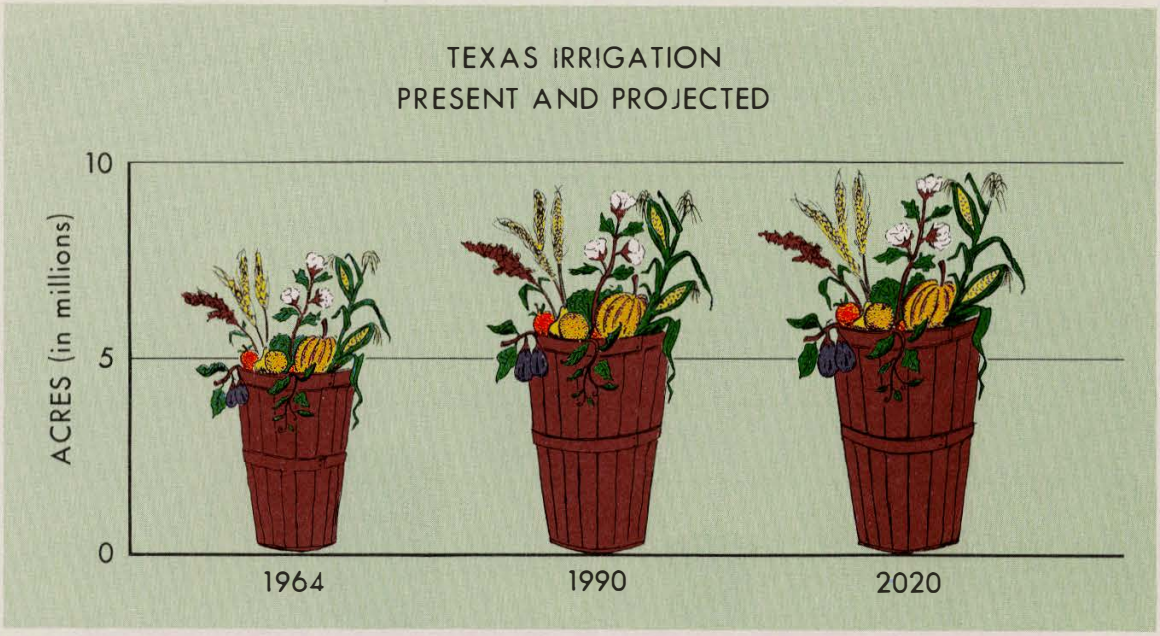
Irrigation

The present level of Texas irrigation—7.7 million acres in 1964 (and still growing)—has developed rapidly, mostly since World War II. Detailed studies conducted for the Board by Texas A&M University of projected National and State food and fiber demands indicate that in 2020 these demands will fully justify the more than 9.7 million acres proposed to be irrigated under the Texas Water Plan.

Nearly 83 percent of all present irrigation is supplied with ground water. However, many presently irrigated areas—the High Plains, Lower Rio Grande Valley, Winter Garden, Trans-Pecos, and elsewhere—face the prospect of returning to dryland farming as available water supplies are exhausted. There is not enough water in Texas available, even through redistribution, to avoid this occurring. These needs for water for irrigation in excess of available supplies do not occur in eastern and central river basins of the State where present and projected irrigation will be supplied by direct diversion or under existing water rights.

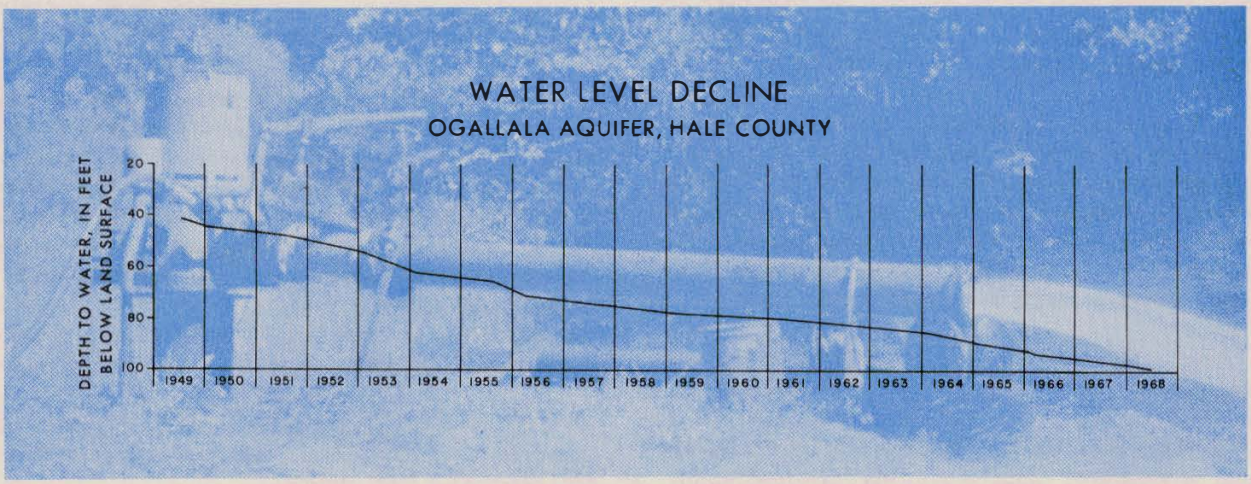
By 1985, if a supplemental surface supply of water has not reached the High Plains, this vast area will have begun an area-wide retrogression to dryland farming which will have profound economic consequences throughout the State. The North Central Texas, Trans-Pecos, Lower Rio Grande Valley, and Winter Garden areas face equally crucial time-phasing problems. The 5.1 million acres of land irrigated in the High Plains is supplied by water from the Ogallala Formation, where water levels are declining as the result of prolonged

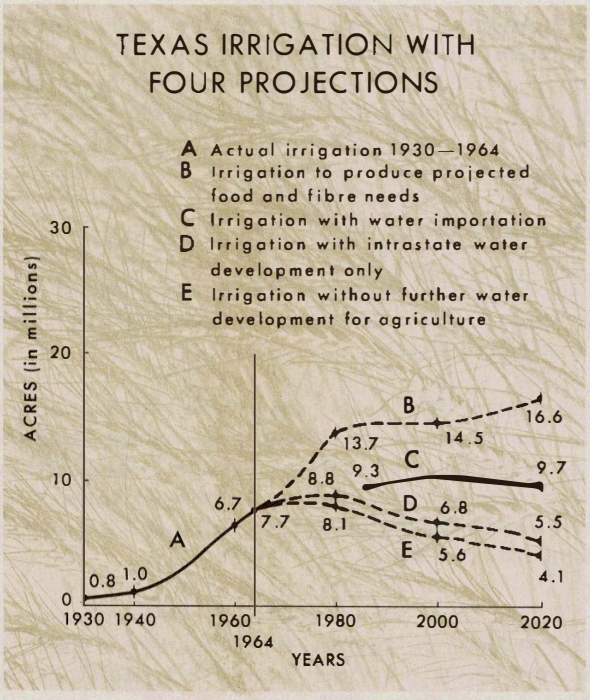
* These cities are included in the Texas Water Plan with other Lower Rio Grande Valley communities, some or all of which will need supplemental water supplies.



pumping at rates far exceeding the rates of replenishment. Studies by Texas A&M University indicate a potential economic demand of 6.7 million irrigated acres in the South High Plains if water can be made available at costs which would leave irrigators an economic incentive to irrigate their lands rather than dry farm. Without an import of water from outside the area, however, irrigation will have begun a severe decline by 1985, to a predicted 2.2 million acres supportable by ground water in 2020. Present irrigation of 350 thousand acres in North Central Texas will decline to about 168 thousand acres supportable by local water supplies in 2020. Planning studies by the Board indicate that only about 650 thousand acres of the 824 thousand acres historically irrigated in the Lower Rio Grande Valley can be supported by Rio Grande water, and there is an irrigation potential of 1.4 million acres in the area with an adequate water supply. An added complexity in providing an adequate irrigation water supply in the Lower Valley area results from the as yet unresolved legal questions relating to allocation of Rio Grande water. In the Winter Garden about 200 thousand acres of the 300 thousand acres irrigated will be dry farmed or out of production by 2020 without additional water supplies, and this is an area where economic incentives are projected to create an irrigation potential of more than 900 thousand acres. Declines in irrigated acreage will occur elsewhere throughout the State without a systematic program for supplying supplemental water.

The reimbursable costs of water supply to these areas will have to be borne by the areas. The cumulative cost to the entire State of their loss as irrigation areas will be formidable if it is not possible to supplement their locally available supplies through the Texas Water Plan.





Agriculture generates more of Texas' wealth, supporting a related annual $6 to $7 billion commerce and industry, than any other factor in the economy with the exception of petroleum and petro-chemicals. One yardstick of this contribution is in cash receipts from farm marketings which reached $2.5 billion in 1964, and are expected to reach $9.3 billion by 1990. Irrigation accounts for over half of this agricultural wealth.

The contribution of irrigated agriculture to the economy of the entire State, however, goes far beyond the direct returns for the value of crops. Utilities, gas pipelines, transportation, navigation, investments through loans and mortgages, bank deposits, canneries, food processing plants, livestock and poultry production, fertilizer and pesticide manufacturers, farm equipment manufacturers and distributors, and wholesale and retail commerce are all direct beneficiaries of a healthy and expanding irrigated economy.

Mining

Water used in the State for mining purposes is almost entirely for the purpose of petroleum production. Sand and gravel operations and recovery of other minerals use very minor amounts of water.

Improved technology has had a tremendous impact on the oil industry through secondary recovery of oil by water injection. Fluid injection operations have increased production from 20 percent in 1953 to around 30 percent in 1965 of the total volume of oil produced within the State. Within the next 15 years up to one-half of the oil produced in Texas will probably come from fluid injection projects.

Calculations indicate an estimated cumulative total 15 million acre-feet of water will be required in Texas through the year 2020 for secondary recovery of oil. Either brackish, saline, or fresh water can be used for injection operations, and the choice is usually dictated by the economics of water supply and operation and maintenance costs. The projection of water requirements for secondary recovery operations for this Plan was based on an evaluation of the amount of oil available which can be produced by water injection.

The largest reserves of oil in Texas susceptible to recovery by water injection are in arid areas of the State. Water to meet mining needs will be met by local surface and ground water resources as the demands on these local resources by higher priority uses are met through water of better quality imported through the Texas Water System.

Hydroelectric Power Potential

Conventional hydroelectric power projects appear improbable in the future in Texas, although pump-back storage projects may be developed in some areas. Further planning studies may show the feasibility of such pump-back projects separate from, or coupled with, projects of the Texas Water Plan.

Navigation

Navigation was important to the exploration, colonization, and early development in Texas. Major rivers, flowing roughly parallel courses from northwest to southeast, provided early routes from the Coast to the interior. Subsequent advances in overland transportation slowed river navigation development except in the tidewater area along the Gulf, where navigation has been steadily expanding, and contributing to the growth of that highly industrialized region.

Texas now has 12 ports for deep-draft (30-40 feet) vessels and 13 shallow draft (6-14 feet) ports. The intracoastal waterway connects the entire coastal area with a protected shallow draft route between Texas and other Gulf and south Atlantic ports. The Houston Ship Channel enables this inland area to receive and ship the third largest tonnage of all U.S. seaports.

Constant expansion of coastal facilities for domestic and overseas commerce has accelerated efforts to connect inland industrial areas with them by development of Texas rivers for navigation. Navigation on the Trinity and Red Rivers has been authorized. Proposals have been made for studies on other streams to

determine the engineering and economic feasibility of navigation. The Texas Water Plan is compatible with any such development found to be economically feasible.

Recreation

Demands for recreation, particularly for water-oriented recreation, are increasing rapidly in Texas, as the continuing concentration of the State's population in the cities adds immediacy to the urgent need for recreational facilities away from the cities. Lakes and camping and picnic areas are jammed with crowds on weekends and throughout the spring, summer, and fall. Broad based recreational planning now underway must recognize this urgent need.

Recreation is, increasingly, a big business, both for the State and for private investors. Economic analyses by the Board indicate recreation benefits of $1.1 billion with a cumulative potential of two billion visitor-days to the year 2020 at the reservoirs proposed in the Texas Water Plan. These analyses have shown that benefits from water-oriented recreational developments exceed their costs by a wide margin. It should be recognized also that esthetic and recreational enjoyment of water development projects is not accurately measurable by dollar value.

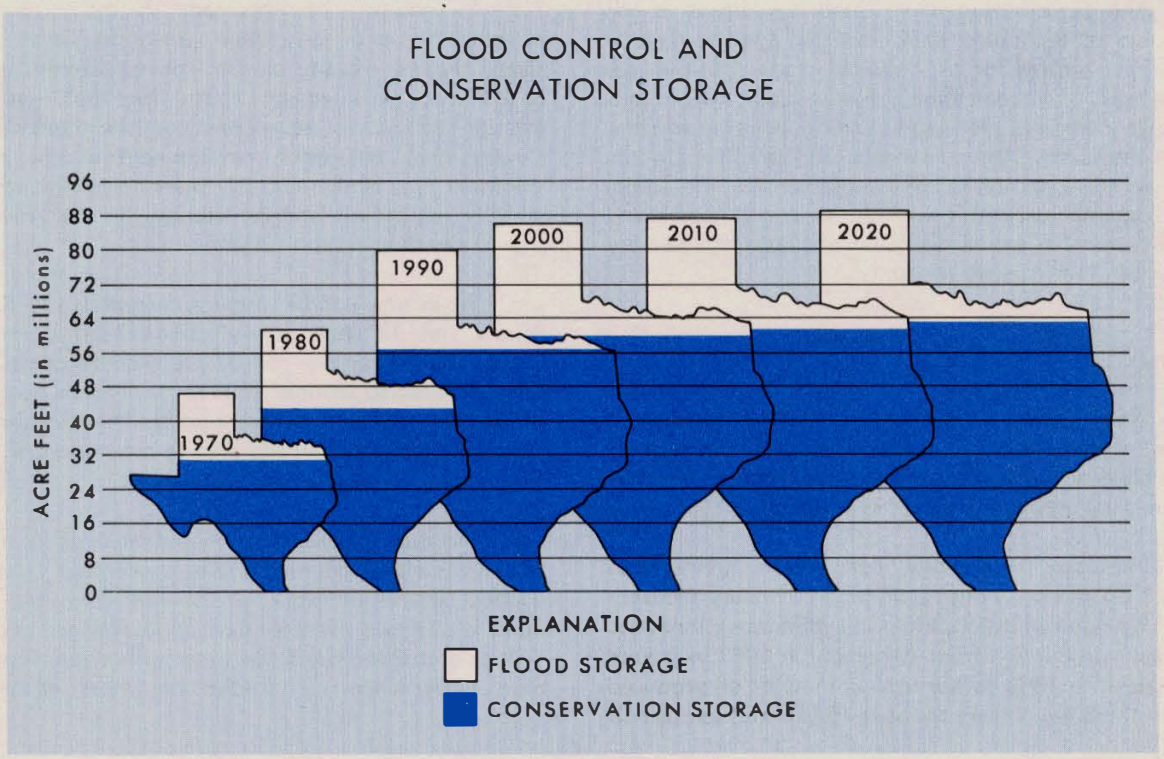
Recreation has been an important factor in planning for Texas water resource development. Water planning by the Board, developed concurrently with the formulation by the Parks and Wildlife Department of a comprehensive outdoor recreation plan for Texas, takes full cognizance of the recreational value of potential reservoir development proposed under the Texas Water Plan.

Flood Control

Floods in Texas have historically caused widespread suffering, major losses of life, and damage in both urban and rural areas.

Some 320 Texas cities have flood problems resulting from stream overflow, local drainage, or coastal floods. One hundred of these cities have stream overflow flood problems, 112 have local drainage problems, 20 have coastal flood problems, and another 88 have some combination of these.

The worst general floods of recent years were in 1957 when every major river and tributary in the State flooded during the spring months between April and June. In late April 1966, intense flooding occurred in northeast Texas where 20 to 24 inches of rain fell in some areas in a relatively short period of time. Flash flooding in the Sanderson area in 1965 cost 24 lives in a period of hours. Severe flooding occurred in South Texas from heavy rainfall accompanying Hurricane Beulah in 1967.



The Federal Flood Plain Management Program, enacted by Congress in 1960, is directed toward assisting cities to alleviate flood problems. The purpose of the Program is to provide a basis for sound zoning ordinances and subdivision regulations in cities with flood problems by defining the flood plain limits under flood conditions. The Board examines applications for assistance under the Program, assigns priorities for project formulation, and the studies are made by the Corps of Engineers. As of August 31, 1968, seven such studies had been completed and seventeen were underway.

Flood control measures proposed in the Texas Water Plan, developed cooperatively with the U.S. Army Corps of Engineers, include flood control storage in reservoirs, channel improvements and modifications such as levees, and other measures adapted to particular flood problems in specific areas.

Upstream Flood Retardation and Watershed Protection

Two-thirds of all agricultural lands in the State are subject to serious erosion or the threat of erosion. Effective land use and soil, water, and plant conservation measures are essential to protect agricultural production capacity, and to reduce sedimentation in reservoirs, stream channels, and coastal waters.

Under the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, as amended), the Soil Conservation Service of the U.S. Department of Agriculture provides technical and financial assistance for land treatment, flood prevention, and the conservation, development, utilization, and disposal of excess water on watersheds up to 250 thousand acres.

Watershed plans developed to implement this and other Acts include land treatment measures as well as structural control measures. The soil and water conservation measures on the land must precede or accompany installation of floodwater-retarding structures and drainage and irrigation facilities.

The State agency with responsibility for the land conservation program is the State Soil and Water Conservation Board. That agency and the Board have closely coordinated their activities and those of the Soil Conservation Service since the passage of the Texas Water Planning Act of 1957, including the studies of the current planning program.

As of April 1, 1968, watershed plans had been approved and work had been completed or was in progress on land totaling about 13½ million acres. Plans have been authorized by Congress for work on additional watershed areas totaling about 1¼ million acres.

Drainage

Many areas of the State have drainage or wetland problems, particularly in the Lower Rio Grande Valley and in the coastal areas of other river basins, including the intervening coastal basins. Many small coastal cities—Rockport and Aransas Pass, among others—have serious urban drainage problems. Investigations made by the Soil Conservation Service in 1961 and 1965 indicate a total of 16.6 million acres of wetlands. Much of this area is frequently flooded bottomland, marshlands, and tidewater swamps situated too low in relation to possible outlets to drain properly or to be drained. No drainage improvement is contemplated for such areas, their most beneficial uses being as natural habitat for fish and wildlife species. Other lands are subject to frequent inundations from river and creek flooding and will require extensive protection facilities to prevent flooding before drainage improvement measures can be installed.

Summary drainage reports by the Soil Conservation Service show that drainage improvement is considered to be feasible for a total of over 7.8 million acres in Texas. About 11.5% of this total has had adequate drainage improvement to April 1968.

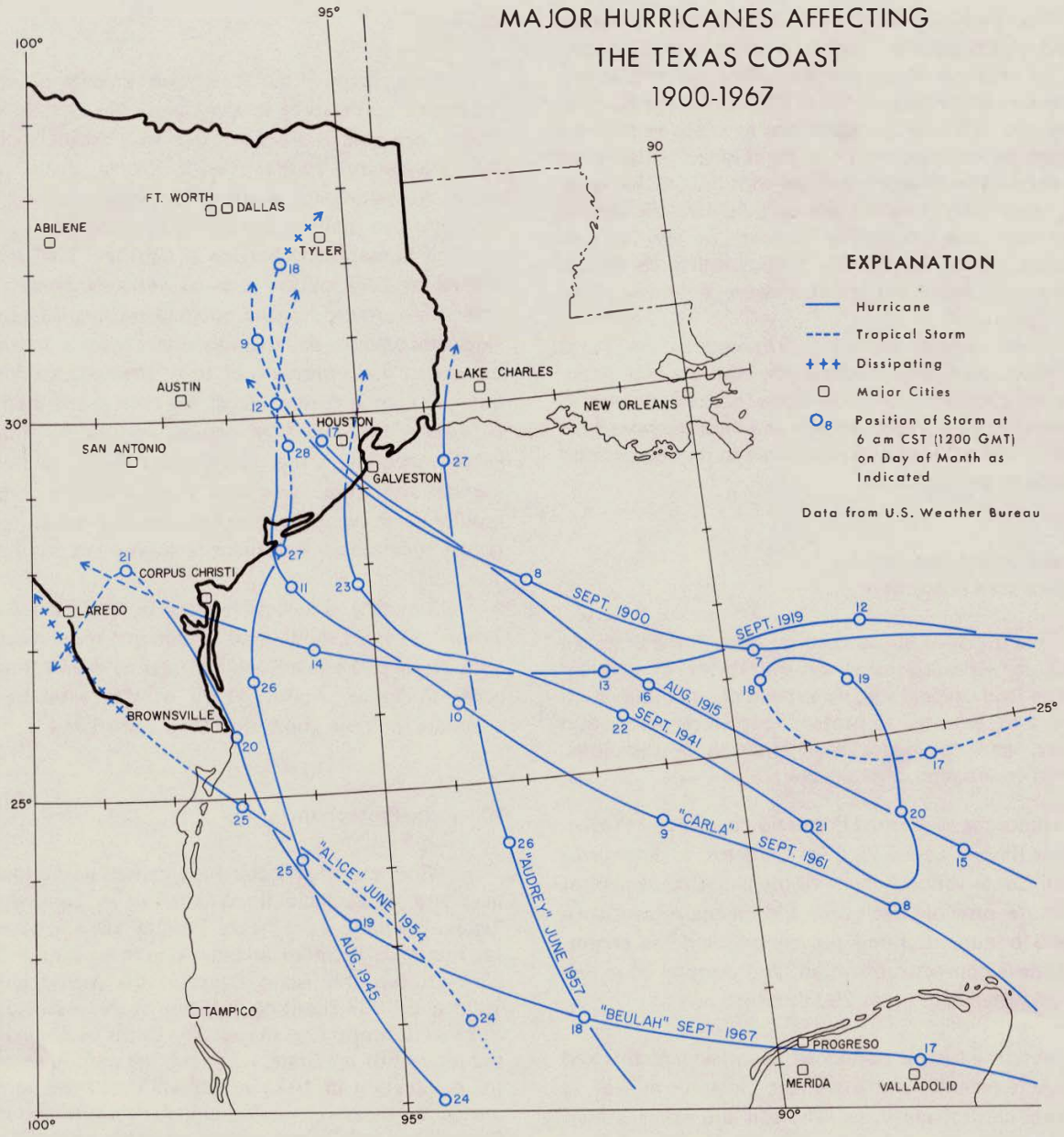
Hurricane Protection

Wind and high water have caused heavy losses of lives and incalculable flood damages in Louisiana and Texas. Flooding from heavy residual rains is often felt for hundreds of miles inland. A total of 33 hurricanes have crossed the Texas Coast in the period between 1900 and 1967 resulting in losses of thousands of lives and severe property damages. The Corps of Engineers, at the request of the State, is conducting a study scheduled for completion in 1973 which will detail the hurricane protection measures needed along the entire Texas Gulf Coast. This study, designed to result in measures which will reduce hurricane damage along the Coast, is extremely important to continued urban and industrial development.

Water Quality

Presently available water quality data indicate some areas of Texas streams and ground water aquifers where quality of water is impaired. Inorganic pollutants, both natural and man-made, probably now constitute a more widespread problem than do organic materials from municipal and industrial wastes.

In planning, those areas were defined where water quality problems exist and which must be corrected in



whole or in part, and other areas where water quality problems do not presently occur but where full stream development may have adverse effects on quality. Serious degradation of sanitary quality occurs in parts of four river basins—the Trinity, San Jacinto, San Antonio, and the Rio Grande.

It has been assumed as a concept of planning that the highest economically feasible techniques of municipal and industrial waste treatment will be utilized, that pollution resulting from oil field brines will be eliminated over time, and that agricultural practices will be improved to eliminate pollution problems to the extent feasible under existing technology.

Conventional waste treatment techniques in some areas may not meet this conceptual premise, and may be inadequate to maintain established stream quality standards. Centralization of all urban sewage treatment systems in a large city, or consolidation of the systems of several smaller cities probably offers more promise than any other approach to effective pollution control. Whatever alternative or level of treatment applied, it is apparent that use of the full assimilative capacity of streams is not a practical long-term solution for the final treatment of municipal and industrial waste effluents. Increasingly, this assimilative capacity will be required to accomodate pollution from land runoff which is beyond practical control.

Capital costs for treatment of municipal wastes at a level adequate to combat pollution problems throughout the State are estimated as high as several hundreds of millions of dollars during the next decade. Although only limited estimates are available of the costs to industry and cities for water treatment processes required to make water suitable for use, there is no question that they run into the hundreds of millions of dollars also.

Bays and Estuaries

The Board is aware of an impact from the changes in volumes of water from streams entering the bays resulting from upstream reservoir development and water utilization, continually increasing return flows, and changing conditions of surrounding land development on water quality in the bays and estuaries along the Texas Gulf Coast.

The economic urgency for finding meaningful solutions to these problems is demonstrated by the increased value of commercial and sports fishing in the estuarial environment, now estimated at more than $150 million annually, more than 99% of which is derived from the catch of species dependent on the estuarine environment at some point in their life cycle. The related economic return to the State from tourism attracted to the bay areas is estimated at $300 million annually. All of this can be lost to the State if some solution for preserving the ecology and esthetic quality of the bays is not found.

Studies to find feasible solutions and concepts compatible with maximum upstream development of Texas water resources have shown that fresh water inflows and reduction of pollutants are not the whole solution. Other factors, including circulation within the bays themselves, land runoff, and hydraulic interchange with Gulf waters, all have profound effects on bay conditions.

An intensive study has been undertaken of the Galveston Bay complex by the Texas Water Quality Board in cooperation with many Federal and State agencies. The results of this study, and detailed studies on the other bays, may provide long-range solutions to the complex bay and estuarial needs. In 1967, the Board and the U.S. Geological Survey began a three-year comprehensive data collection program designed to aid in defining the quality and hydraulic characteristics of the bays. The total cost of this program is in the order of $400,000. Meanwhile, reasonable fresh water inflows are provided to the bays and estuaries on an interim basis while their long-range needs are determined by these detailed studies.

Fish and Wildlife

Traditionally Texans have enjoyed access to excellent fishing and hunting opportunities. Cultural developments such as cities, highways, airports, and reservoir projects may intrude on valuable ecological areas and habitat. Whenever damage occurs, measures for mitigating these damages must be assessed. Where possible, the potential of water development for enhancing the fish and wildlife resource must be achieved. Most importantly, programs of fish and wildlife management and cultivation will provide a continuing increase in the hunting and fishing potential.

Scenic and Scientific Areas

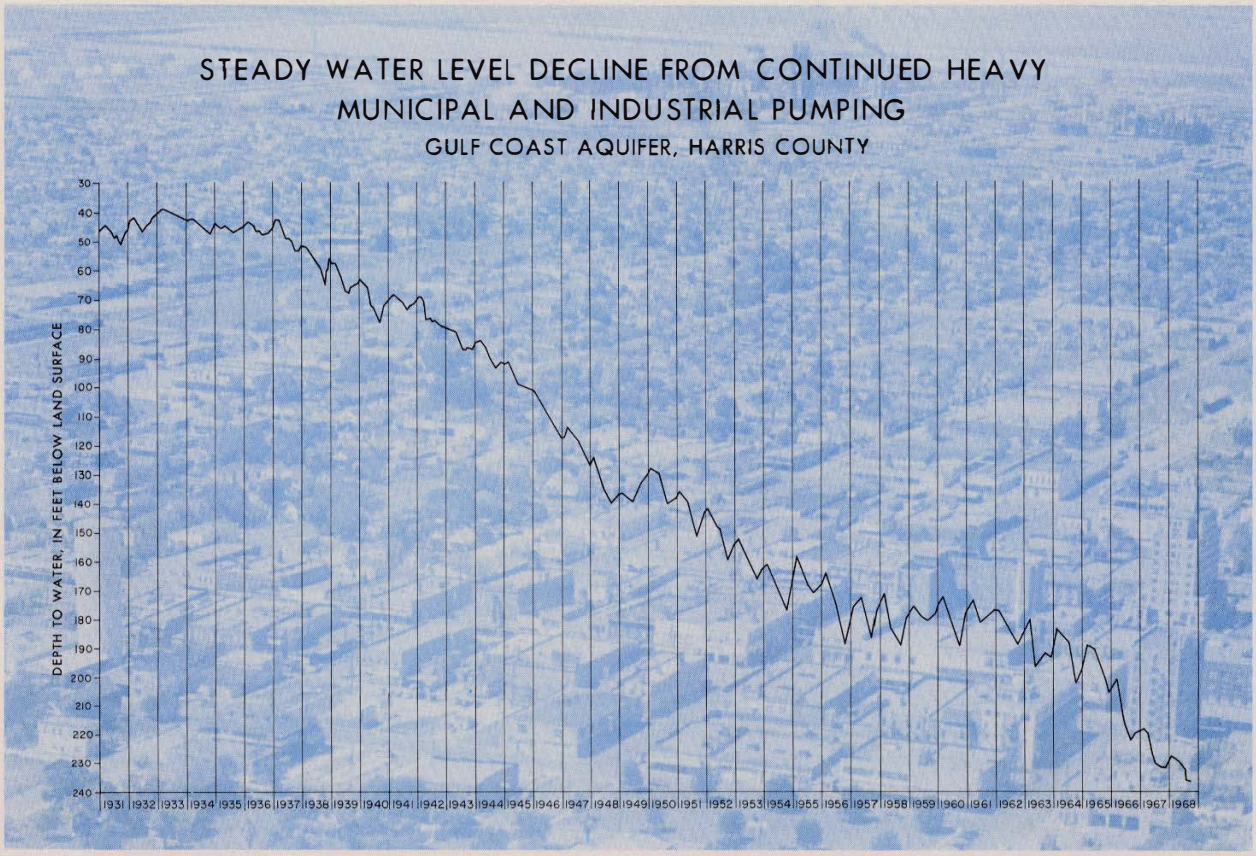
Texas is endowed with extremely beautiful scenic areas and areas of unique scientific value. Some of these areas have been lost by urban expansion, highway and utility development, or may be threatened by development of reservoirs or water conveyance facilities.

The Board recognizes its responsibility to minimize this loss of natural beauty and scientific value to the State as it might result from water development. As a part of the Texas Water Plan, therefore, the Board recommends that a systematic effort be made to preserve these assets for future generations.

Subsidence and Saline Water Intrusion

In some areas of Texas, withdrawals of large volumes of ground water have resulted in adverse effects. Major effects which may limit further ground water development in these areas are: (1) the intrusion of saline water into the areas of heavy withdrawal, a problem in many areas of the State; and (2) land subsidence, which is principally of concern in the Gulf Coast area.

Many fresh water aquifers are closely associated with saline water aquifers which may either overlie, underlie, or occur in areas downdip of the fresh water aquifers. Where such fresh water aquifers are heavily pumped, saline water has moved towards pumping wells, resulting in the deterioration of the quality of fresh water. A significant example of saline water encroachment is in the Texas City-Galveston area where deterioration in water quality already has been noted in some wells. It is important that the positions and rates of movement of saline water in problem areas be given careful study. Studies are underway to optimize ground water withdrawals to limit saline water encroachment in order to extend the useful life of the aquifers.



Subsidence of the land surface as a result of pumpage of large volumes of ground water has already become a particularly acute problem in several areas along the Texas Gulf Coast. As the artesian pressure head in these deeply buried aquifers is reduced by large withdrawals of ground water, the skeletal framework of the aquifers is altered and the beds compressed by the weight of the overlying rocks. Land subsidence is presently most pronounced in local areas near Pasadena, Baytown, and Texas City where as much as five feet of subsidence has occurred. Loss of freeboard on hurricane protection facilities may result from such subsidence. Drainage and flooding problems during periods of wet weather have resulted in many places as a consequence of subsidence. Damage to municipal utility lines and other facilities has occurred. Studies will be continued to define the relationship between ground water withdrawals, pressure head decline, and subsidence so that more accurate projections of the magnitude of future subsidence problems can be made and both saline water encroachment and land subsidence can be minimized in these areas.

Conclusions and Recommendations

CONCLUSIONS

1. Texas' Potential for Growth

Texas has the capability for great population growth and industrial and agricultural expansion, provided adequate water supplies of suitable quality can be made available at reasonable and equitable costs. With ample supplies of water, it is anticipated that the population of Texas in 2020 will have grown to 30,500,000, more than 3 times the population in 1960. Corresponding industrial and agricultural expansion to support this growth is expected to occur.

If adequate water supplies are not available in time, however, this future population growth and economic development will be severely curtailed. Agricultural production in the western half of the State must inevitably decline, with Statewide adverse economic impact, particularly to the associated agribusiness and financial interests in the major metropolitan centers.

For example, supplemental water supplies must be made available in the following areas no later than the dates shown:

San Antonio area (municipal and industrial)—1985
Corpus Christi area (municipal and industrial)—1987
El Paso area (municipal, industrial, and irrigation)—2000*
High Plains (irrigation)—1985
Trans-Pecos area (irrigation)—1990
Lower Rio Grande Valley (municipal, industrial, and irrigation)—1980

If this time schedule can be met, water needs in other areas of the State can and will be adequately met. To meet this schedule, however, coordinated and cooperative action in planning, feasibility studies, authorization, financing, design, and construction among all levels of government is essential.

2. Water Resources Now Available to Texas

Water supplies can be developed to meet all reasonably foreseeable long-term intrabasin needs and provide surpluses for interbasin transfers under the Texas Water Plan in the Lower Red, Sulphur, Cypress Creek, Sabine, and Neches River Basins. Some interim surpluses will exist in the Guadalupe-San Antonio River Basins and possibly in the Trinity River Basin. Pending full development of the intrabasin needs, the surpluses available for interbasin transfers on an interim basis will be substantially larger.

These water resources available to Texas from intrastate sources and from interstate sources flowing along or across the State boundaries are grossly inadequate to meet the future water needs of the State.

3. Importation From Out-of-State

Importation of water from out-of-State sources is essential to the future development of Texas, and must begin no later than 1988. Planning indicates that by 2020 as much as 12 to 13 million acre-feet per year may need to be imported. Planning estimates indicate that water of suitable quality, in these quantities, can be made available from the Lower Mississippi River.

Such estimates are based on full consideration of the needs of the Mississippi River Basin States now, and in the future, including maintenance of quality and navigation. It is also planned that any project for exportation of Mississippi River water would yield benefits to the exporting State(s), as well as to Texas and New Mexico. Further, this source appears to offer the most economic benefits. In light of these factors the assumption has been made that water could be made available to meet Texas' requirements, and planning has proceeded on this basis.

It is probable that additional importation of water from some source may be required by 2020.

4. The Texas Water Plan

The Plan, the most extensive and complex water resource System yet conceived, is the most effective and economic means for meeting the future water needs of Texas for all purposes on a Statewide basis.

* Needed whenever can be made available. Year 2000 projected in present planning as earliest feasible data for delivery.

5. Participation by the State of Texas

The State must be a major participant with Federal and local agencies in planning, feasibility studies, financing and design, and in operation, maintenance, and management of the Texas Water System in order that the State's interest in its resources may be fully protected.

6. Cost

The cost of construction of the Texas Water System, at current construction cost levels, exclusive of out-of-State facilities for importation and appurtenant irrigation distribution systems, is estimated at about $6.3 billion. Irrigation distribution systems, a local responsibility, are estimated to cost $250-300 per acre to be irrigated.

These expenditures will be spread over a period of 50 years, with most of the capital costs incurred between fiscal years 1975 and 1990. The anticipated rate of cost escalation will be a significant factor in long-range financing planning.

7. Acreage Limitation

The present acreage limitation provisions of Federal Reclamation Law will need to be revised if the State is to have an economically viable agriculture in Texas under Reclamation projects.

8. Economic Justification and Financial Feasibility

The Texas Water System, including import from out-of-State sources, is economically justified on the basis of reconnaissance level studies. The financial resources of the irrigation areas to be served appear to be adequate to repay their share of the costs under current Federal repayment policies through water charges or a combination of water charges and general taxation.

RECOMMENDATIONS

The Board recommends that the following actions be taken by the Governor and Legislature of the State of Texas, the President and the Congress of the United States, and local governmental agencies:

THAT THE GOVERNOR AND THE LEGISLATURE OF THE STATE OF TEXAS:

1. **Adopt a plan for financing the State's share of the cost of the Texas Water System as a joint Federal, State, and local partnership undertaking and to provide additional financial assistance to local political subdivisions for water supply projects; such plan to be submitted for approval by the voters at the 1970 general election.**

2. Amend the Texas Water Development Fund Act to:

   (1) Eliminate the present provision for termination in 1982 of Texas Water Development Fund investments.

   (2) Remove the present limitation on the total amount of the Water Development Fund, the limitation on the permissible investment in a single project, and the limitation on the maximum aggregate investment in reservoir conservation storage facilities.

   (3) Remove the limitation on the coupon interest rate for Water Development Fund bonds from the present maximum of 4%.

3. Empower the Board to implement the Texas Water Plan, including authority to:

   (1) Participate in partnership with the United States Government, pursuant to appropriate statutory and contractual arrangements, in the design, construction, operation and maintenance, and management of the Texas Water System; such participation to be on the basis of ownership by the State of an undivided interest in the total System.

   (2) Enter into contracts with Federal, or with Federal-State agencies, to purchase water from out-of-State sources delivered at the State line.

   (3) Enter into cooperative agreements with the United States, local public agencies, and investor-owned utilities for financing, constructing, and operating facilities to generate and deliver pumping energy required for the Texas Water System.

   (4) Acquire by eminent domain lands necessarily required for water development project purposes proposed in the Texas Water Plan.

   (5) Preserve lands necessarily required for water development project purposes

proposed in the Texas Water Plan under terms providing equitable return to the landowner.

(6) Use lands necessarily acquired for project purposes prior to initiation of construction, and on an interim basis. Purpose of use would include leasing for agricultural use, leasing for recreational development, or development cooperatively with the Parks and Wildlife Department for wildlife and fishery management, or for other purposes not inconsistent with ultimate reservoir development. Since acquisition of lands by the State removes the tract from local tax rolls, lease contracts may contain provision for contribution by the lessee to units of local government, of an amount equivalent to former ad valorem taxes or special assessments.

(7) Act as sponsor of water development projects proposed for Federal authorization when the Board is acquiring storage in a reservoir project as a part of the Texas Water System, or when a local sponsor is not available for a needed water development project, whether or not it is a part of the Texas Water System.

4. Amend Article 7470 which lists the purposes for which water may be appropriated, by adding a provision to authorize the appropriation of water for other beneficial uses which may be defined from time to time in Rules and Regulations of the Texas Water Rights Commission, to enable the Commission to consider the allocation of waters of the State for water quality control purposes, mosquito control, fish and wildlife, maintenance of fresh water inflows to the bays and estuaries, and such other purposes as it may deem beneficial to the State. Many of these uses are already specifically included as project purposes in the Federal reservoirs in Texas.

5. Provide additional funds to the Texas Water Quality Board, under its authorized program of State grants for planning and constructing sewage collection and treatment systems, by establishing a Texas Clean Water Fund to complement the construction grant provisions of the Federal Water Pollution Control Act as amended.

6. Establish a Texas Water Projects Recreation Fund, to be administered by the Parks and Wildlife Department as a part of its long-range recreation plan for Texas, to provide the funds in excess of those available from user fees necessary to repay the reimbursable Federal investment allocated to recreation, and to enhancement of fish and wildlife resources under the Federal Water Project Recreation Act, to provide on-shore facilities and to operate and maintain such facilities for elements of the Texas Water System.

7. Provide adequate funds for the concerned State agencies, designating specific interagency responsibilities, to complete comprehensive studies of the bays and estuaries and to prepare recommendations for Legislative consideration for long-range conservation of these resources.

8. Establish State policy as to the degree of State responsibility for the costs associated with providing fresh water inflows to the bays and estuaries to complement Federal policy when established; appropriate funds, or establish other funding procedures for payment of those costs; and designate the responsible State agency for administering such funds.

9. Mitigate the effects of the influx of workers for construction of the facilities of the Texas Water System upon communities which must provide school, police, fire, hospital, and other services for those workers during the period of construction; adopt a formula for assessing those effects; and make funds available to assist such communities in defraying the short-term costs of providing these additional local services where such mitigation is not a Federal responsibility.

10. Authorize creation of master districts for purposes of contracting for purchase of water under the Texas Water System; such districts to be created where needed and as local interests reach agreements on the areas to be encompassed.

11. Establish and fund a program to be administered by the Texas Parks and Wildlife Department to designate and preserve river reaches and springs of historic, scenic, and scientific value to complement and supplement Federal legislation.

12. Appropriate to the Board adequate funds to carry out its duties and responsibilities for future water development in Texas in a timely manner as shown on Plate 1.

THAT THE PRESIDENT AND THE CONGRESS OF THE UNITED STATES:

1. **Continue to fund the feasibility level studies now being conducted by the U.S. Bureau of Reclamation and U.S. Corps of Engineers of the import to Texas of surplus water from the Mississippi River and its conveyance to points of need within Texas and adjacent States, and approve the concept of such importation as soon as agreement has been reached among the non-Federal interests involved.**

2. **Accept and implement the concept of Federal-State relationships with responsibilities at both levels of government generally as defined in this Plan for the planning, design, financing, construction, operation, maintenance, and administration of the Texas Water System and other projects of the Texas Water Plan.**

3. **Recognize the Texas Water Plan and subsequent modifications as the general guide for future water and related land resource development in Texas.**

4. **Authorize the Texas Water System and its projects, and appropriate funds for engineering and construction of elements of the Texas Water System upon submission of feasibility and survey reports, so that the time schedule presented herein for the Texas Water Plan may be met.**

5. **Authorize the Corps of Engineers and the Bureau of Reclamation to enter into contracts with the State of Texas as the principal contracting agent for repayment to the United States of the reimbursable Federal costs allocated to water supply incurred in the design and construction of the facilities of the Texas Water System, with the State of Texas securing its obligations under such contracts through ancillary repayment contracts executed by the State with local political subdivisions.**

6. **Amend the provisions of Federal Reclamation Law relating to acreage limitations so that economically productive farming units can be developed or sustained under Reclamation projects.**

7. **Establish policy as to the national interest in protection of the coastal bays and estuaries and the criteria for evaluating benefits and detriments to the bays and estuaries from water and related land resource development.**

8. Empower Federal construction agencies, for reservoir and water conveyance projects authorized now or in the future, to:

   (1) Immediately acquire necessary interests in project lands and take necessary actions to preserve the future project sites from encroachment.

   (2) Enter into agreements with the State of Texas and local agencies to provide for credit or reimbursement for the costs of lands acquired, land-taking surveys made, or other project costs incurred by the State or local agencies when such expenditures are sound contributions to the projects.

THAT LOCAL INTERESTS:

1. **Take steps immediately to form master districts, where necessary, covering the areas which desire to be supplied with water for irrigation and other purposes under the Texas Water System, with adequate powers to contract with the State of Texas or the United States for a water supply and other purposes; to raise the revenues necessary to repay the reimbursable costs involved; and to accomplish the other actions necessary to put the water to beneficial use in the most effective manner.**

2. **Examine the desirability of forming, and form where feasible, regional organizations or entities such as a metropolitan water district covering major metropolitan areas in order to minimize the cost of treating and distributing water supplied through the Texas Water System.**

3. **Examine the legal authority of the local and regional agencies to participate in the Texas Water Plan with the Federal and State agencies, and where such authority is lacking, seek authorization from the Legislature.**

4. Immediately undertake studies of the amounts and timing of supplemental water to be contracted for under the Texas Water System, the point(s) of delivery, and the necessary legal and financial arrangements to assure the capability of meeting the contractual repayment obligations. Initiation of these studies should not await the formation of master districts or regional organizations.

5. Expand, in cooperation with Federal and State agencies, programs of basic data collection and planning.

6. Cooperate in further planning for the Texas Water Plan and in preparation of feasibility reports for elements of the Plan.

7. Cooperate with the Board in preparing and presenting unified programs to the Federal agencies and the Congress for Federal authorization and appropriations.

GLOSSARY OF TERMS

Some of the terms used in this document have a restricted meaning or may not be familiar to the general reader, and are therefore described below. Included in the glossary is a diagram showing selected distinctive geographic areas.

Acreage limitation.—Under Federal Reclamation Law, water from a project thereunder generally cannot be furnished to irrigable lands in excess of 160 acres in single ownership, or 320 acres held in joint ownership by a husband and wife, unless the owner agrees to dispose of the excess land within 10 years under terms and conditions satisfactory to the Secretary of the Interior.

Acre-foot.—The volume required to cover 1 acre to a depth of 1 foot. Equivalent to 325,851 U.S. gallons or 43,560 cubic feet.

Aquifer.—A geologic formation, group of formations, or part of a formation that is water bearing. The term is usually restricted to water bearing units capable of yielding water in sufficient quantity for a usable supply.

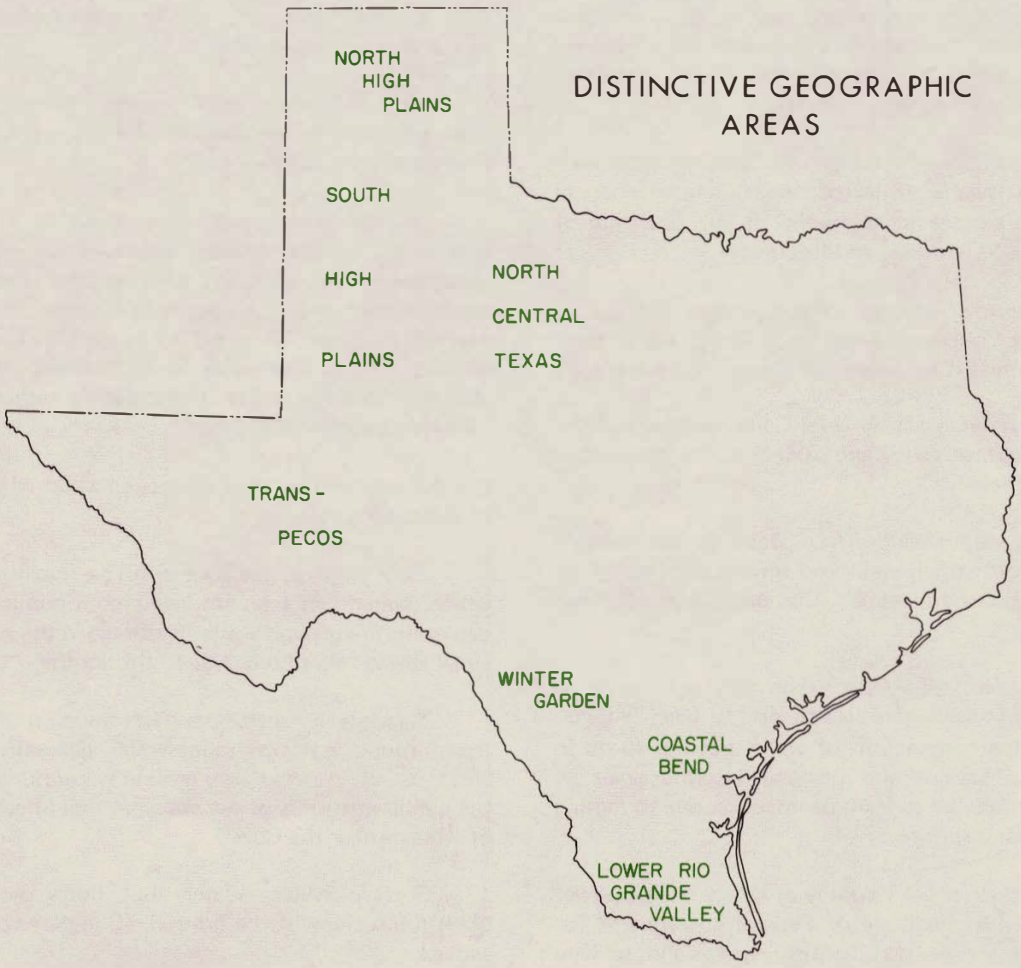
Artesian aquifer, artesian pressure.—Artesian pressure occurs where an aquifer is overlain by rock of lower permeability (such as clay) so that the water is confined under pressure greater than atmospheric. In a well penetrating an artesian aquifer, water will rise above the level at which it is encountered; it may or may not rise sufficiently to flow at the ground surface.

Base flow.—The sustained low flow in a stream, supplied by ground water discharge.

Brackish water.—Water that is undrinkable due to excessive mineral content, although not as mineralized as sea water.

Conservation storage.—Water impounded for later release or withdrawal for beneficial uses. (Compare with Flood-control storage.)

Dead storage.—That part of a reservoir capacity below the lowest outlet level from which water can be released by gravity flow.



Eutrophication.—The process of nutrient enrichment in waters of lakes, reservoirs, and estuaries, commonly accompanied by an increase in algae and depletion of dissolved oxygen in the water.

Feasibility studies.—Studies to determine the technical, economic, and financial feasibility of a project. In the case of Federal projects, feasibility studies are necessary to support Congressional authorization for project design and construction. These studies are generally made following reconnaissance level studies.

Federal Water Pollution Control Act.—The purpose of the Act is to enhance the quality and value of the Nation's water resources and to establish a national policy for the prevention, control, and abatement of water pollution. Under it, the Secretary of the Interior is empowered, after consultation with the States, to establish water quality criteria for the streams, rivers, and other bodies of water in the United States. Federal agencies are required to consult with the Secretary concerning the effects of construction of Federal projects on water quality.

Federal Water Project Recreation Act.—The Act recognizes recreation and fish and wildlife as purposes in the planning and construction of multiple-purpose water development projects. Under the cost-sharing provisions of the Act, a non-Federal entity must agree to administer, operate, and maintain the recreation and fish and wildlife features of the project, and to pay a certain portion of the costs of such features.

Flood control.—Protection of lands from stream overflow, by means of levees, walls, stream channel modification, storage in reservoirs, or by diversion of flood waters into bypasses and floodways.

Flood-control storage.—Water impounded during floods to be released later as rapidly as channel capacities permit. (Compare with Conservation storage.)

Flood plain.—Nearly level land occupying the bottom of a stream valley and subject to flooding unless protected artificially.

Ground water.—Subsurface water in the zone of saturation, from which wells and springs are fed. Often called underground water. (Compare with Surface water.)

Land surface subsidence.—The general lowering in elevation of a considerable area of land surface. This can result from the compaction of water bearing strata in some areas of major and prolonged withdrawals of ground water, as well as from compaction due to mining of petroleum and sulfur.

Master district.—An agency or entity having power to contract with the State or Federal government for repayment of reimbursable project costs, and to levy taxes or make water charges to assure repayment of these costs.

Mine-mouth generating plant.—An electrical power generating plant which is located where the fuel (usually coal) is mined.

Non-reimbursable costs.—According to Federal law and policy, project costs advanced by the Federal government and allocated to purposes such as flood control and navigation, the more direct or immediate beneficiaries of which cannot be readily identified, are non-reimbursable. (See Reimbursable costs.)

Nuclear generating plant.—An electrical power generating plant in which the source of heat energy is nuclear fuel. (See Thermal generating plant.)

Ogallala Formation, Ogallala Aquifer.—The Ogallala Formation covers most of the High Plains of Texas—about 35,000 square miles. The water saturated part of the formation, called the Ogallala Aquifer, is the principal source of usable water supply in this area.

Recharge of ground water.—The *process* by which water enters the zone of saturation in a geologic formation, either naturally, as by rainfall or seepage from streams and lakes, or artificially, as through wells. Also, the term may refer to the *amount* of water added to the zone of saturation.

Reconnaissance level studies.—Studies to determine whether further analysis of a project is warranted. (See Feasibility studies.)

Reimbursable costs.—According to Federal law and policy, project costs advanced by the Federal government and allocated to municipal and industrial water supply and to hydroelectric power, as well as a portion of those allocated to recreation and fish and wildlife, are reimbursable with interest; those costs allocated to irrigation are reimbursable without interest. (See Non-reimbursable costs.)

Runoff.—That part of precipitation which appears in surface streams.

Safe yield of an aquifer.—The maximum rate at which water can be withdrawn continuously without depleting the ground water in storage in the aquifer. It is equal to the rate of recharge to the aquifer.

Saline water intrusion.—The invasion of a body of fresh ground water by saline water, generally in coastal areas, usually due to heavy ground water pumpage. Also, the cyclic intrusion of sea water in tide-affected reaches of streams near the Coast.

Surface water.—Water that flows over or rests upon the surface of the ground. (Compare with Ground water.)

Terminal regulating storage.—Water stored in a terminal reservoir after conveyance so that fluctuating demands for water can be met despite varying rates of supply.

Thermal generating plant.—An electrical power generating plant in which the source of heat energy is coal, lignite, or natural gas. (See Nuclear generating plant.)

Water service contract.—A contract whereby water is furnished for municipal, irrigation, or other purposes at rates sufficient to produce revenues that will cover reimbursable costs.

Table 1.--Incremental Capacities of Reservoirs, Existing or Under Construction

Storage Capacity in 1,000 Acre-Feet

BASIN & RESERVOIR	FLOOD CONTROL	CONSERVATION	DEAD	TOTAL
CANADIAN–				
Rita Blanca	0.0	12.1	0.0	12.1
Meredith	544.0	821.0	0.0	1,365.0
RED–				
Bivins	0.0	5.1	0.0	5.1
Buffalo	0.0	18.1	0.0	18.1
Greenbelt	0.0	50.3	9.5	59.8
Baylor Creek	0.0	9.2	0.0	9.2
Kemp	200.0	245.8	80.2	526.0 5/
Diversion	0.0	40.0	0.0	40.0
Santa Rosa	0.0	11.6	0.0	11.6
Buffalo Creek	0.0	13.8	1.1	14.9
Kickapoo	0.0	98.0	8.0	106.0
Wichita	0.0	11.1	3.0	14.1
Arrowhead	0.0	211.5	16.5	228.0
Farmers Creek	0.0	20.3	5.1	25.4
Moss	0.0	21.6	1.6	23.2
Texoma	2,615.0	1,730.0	1,047.0 1/	5,392.0
Randall	0.0	5.4	—	5.4 2/
Brushy Creek	0.0	6.2	10.6	16.8 2/
Timber Creek (Bonham Lake)	0.0	12.0	1.0	13.0
Coffee Mill Creek	0.0	10.0	0.0	10.0
Pat Mayse	64.6	124.5	4.6	193.7
Crook	0.0	7.2	0.0	7.2
SULPHUR–				
River Crest	0.0	7.2	0.0	7.2 2/
Texarkana	2,509.0	145.3	0.0	2,654.3
CYPRESS–				
Franklin County (Big Cypress Creek)	0.0	71.8	1.2	73.0
Ellison Creek	0.0	23.9	0.8	24.7
Johnson Creek	0.0	10.1	0.0	10.1
Lake O' the Pines	587.2	243.2	11.7	842.1
Caddo	0.0	136.5	38.5	175.0
SABINE–				
Tawakoni	0.0	907.2	29.0	936.2
Holbrook	0.0	7.8	0.2	8.0
Quitman	0.0	7.4	0.0	7.4
Hawkins	0.0	10.0	0.3	10.3
Winnsboro	0.0	6.6	0.0	6.6
Gladewater	0.0	6.2	0.7	6.9
Cherokee	0.0	43.6	3.1	46.7
Murvaul	0.0	43.7	2.1	45.8
Toledo Bend	0.0	3,790.8	686.2 4/	4,477.0
NECHES–				
Flat Creek	0.0	27.0	5.8	32.8
Palestine Enlargement 6/	0.0	401.4	8.6	410.0
Tyler (Including Tyler East)	0.0	85.5	1.9	87.4
Jacksonville	0.0	29.8	0.7	30.5
Striker Creek	0.0	23.9	2.8	26.7
Kurth	0.0	16.2	0.0	16.2 2/
Sam Rayburn	1,148.9	1,400.6	1,452.0 1/	4,001.5
B. A. Steinhagen	0.0	40.3	28.4	68.7
TRINITY–				
Amon G. Carter	0.0	16.0	4.0	20.0
Bridgeport	0.0	396.1	37.0	433.1
Eagle Mountain	0.0	135.5	47.2	182.7
Worth	0.0	30.6	3.0	33.6
Weatherford	0.0	15.2	4.4	19.6
Benbrook	76.5	77.5	10.8	164.8
Arlington	0.0	43.0	2.7	45.7
Walnut Creek	0.0	2.9	1.1	4.0
Mountain Creek	0.0	11.2	15.9	27.1
Garza-Little Elm	520.9	481.8	0.2	1,002.9
North	0.0	17.0	0.0	17.0

Table 1.--Incremental Capacities of Reservoirs, Existing or Under Construction--Continued

BASIN & RESERVOIR	FLOOD CONTROL	CONSERVATION	DEAD	TOTAL
TRINITY (Cont'd.)–				
Grapevine	238.3	165.1	23.4	426.8
White Rock	0.0	8.2	4.1	12.3
Lavon Enlargement	412.5	95.8	47.8	556.1
Ray Hubbard	0.0	483.7	6.3	490.0
Trinidad	0.0	7.8	0.0	7.8 2/
Terrell	0.0	7.3	1.0	8.3
Joe B. Hogsett	0.0	661.1	17.9	679.0
Turkey Creek	0.0	3.6	1.1	4.7
Waxahachie	0.0	12.6	1.0	13.6
Bardwell	79.6	49.5	5.4	134.5
Halbert	0.0	6.6	0.9	7.5
Navarro Mills	143.2	53.2	7.7	204.1
Houston County	0.0	18.8	0.8	19.6
Livingston	0.0	1,675.0	75.0	1,750.0
Wallisville	0.0	46.7	12.4	59.1
Anahuac	0.0	35.3	0.0	35.3 2/
SAN JACINTO–				
Conroe	0.0	420.5	9.8	430.3
Houston	0.0	116.7	41.6	158.3
Sheldon	0.0	5.4	0.0	5.4
Addicks	204.5	0.0	0.0	204.5
Barker	207.0	0.0	0.0	207.0
BRAZOS–				
Buffalo Springs	0.0	5.4	0.0	5.4
White River	0.0	36.4	1.8	38.2
Sweetwater	0.0	8.2	3.7	11.9
Abilene	0.0	8.0	1.8	9.8
Kirby	0.0	4.8	2.8	7.6
Fort Phantom Hill	0.0	67.0	7.3	74.3
Stamford	0.0	47.6	12.4	60.0
Hubbard Creek	0.0	277.8	40.0	317.8
Daniel	0.0	3.0	7.0	10.0
Cisco	0.0	6.5	2.4	8.9
Leon	0.0	17.5	9.8	27.3
Graham	0.0	47.0	5.6	52.6
Possum Kingdom	0.0	188.1	536.3	724.4
Palo Pinto Creek	0.0	39.5	4.6	44.1
Mineral Wells	0.0	5.0	3.4	8.4
DeCordova Bend	0.0	105.4	44.6	150.0
Proctor	314.8	37.5	21.9	374.2
Pat Cleburne	0.0	18.3	7.3	25.6
Whitney	1,372.4	381.9	245.2 1/	1,999.5
Waco	553.3	104.1	69.0	726.4
Belton	640.0	398.5	59.1	1,097.6
North San Gabriel 5/	87.6	29.2	14.0	130.8
Laneport 5/	162.2	37.9	44.1	244.2
Stillhouse Hollow	394.7	218.2	17.5	630.4
Lake Creek	—	—	—	—
Mexia	0.0	0.0 3/	10.0	10.0
Trading House Creek	0.0	37.8	0.0	37.8
Camp Creek	0.0	7.7	0.9	8.6
Alcoa	0.0	10.5	0.0	10.5
Somerville	347.4	16.0	9.2	372.6
Smithers	0.0	18.0	0.0	18.0
William Harris	0.0	11.1	0.9	12.0 2/
Eagle Nest--Manor Lake	0.0	18.0	0.0	18.0
Brazoria	0.0	21.3	0.7	22.0 2/
COLORADO–				
J. B. Thomas	0.0	172.1	31.6	203.7
Colorado City	0.0	21.6	9.4	31.0
Champion Creek	0.0	36.8	5.8	42.6
Robert Lee	0.0	454.8	34.0	488.8
Oak Creek	0.0	34.5	4.8	39.3
San Angelo	277.2	107.0	12.2	396.4
Twin Buttes	454.4	171.9	14.3	640.6
Nasworthy	0.0	12.4	0.0	12.4
Coleman	0.0	36.9	3.1	40.0
Hords Creek	0.0	8.5	0.2	8.7
Brady Creek	0.0	28.6	0.5	29.1
Brownwood	0.0	133.2	10.2	143.4
Buchanan	0.0	756.9	235.2	992.1
Inks	0.0	17.0	—	17.0

Table 1.--Incremental Capacities of Reservoirs, Existing or Under Construction--Continued

BASIN & RESERVOIR	FLOOD CONTROL	CONSERVATION	DEAD	TOTAL
COLORADO (Cont'd.)–				
Lyndon B. Johnson	0.0	117.3	21.2	138.5
Marble Falls	0.0	8.8	—	8.8
Travis	778.0	1,172.0	—	1,950.0
Austin	0.0	20.0	1.0	21.0
Decker Creek	0.0	33.9	0.0	33.9
Bastrop	0.0	16.6	0.0	16.6
Eagle Lake	0.0	9.6	0.0	9.6 2/
GUADALUPE–				
Canyon	354.7	383.3	2.9	740.9
Dunlap	0.0	3.6	2.4	6.0
McQueeney	0.0	5.0	0.0	5.0
H-4	0.0	5.4	1.3	6.7
SAN ANTONIO–				
Medina	0.0	251.7	2.3	254.0
Victor Braunig	0.0	26.5	0.0	26.5 2/
Calaveras Creek	0.0	63.2	0.0	63.2
Olmos	15.5	0.0	0.0	15.5
NUECES–				
Upper Nueces	0.0	7.6	0.0	7.6
Corpus Christi	0.0	259.1	42.9	302.0
RIO GRANDE–				
San Esteban	0.0	18.8	0.0	18.8
Red Bluff	0.0	307.0	3.0	310.0
Balmorhea	0.0	5.9	0.5	6.4
Amistad	1,775.0	3,000.0	550.0	5,325.0
Texas Share	997.6	1,686.0	—	2,683.6
Casa Blanca	0.0	20.0	0.0	20.0
International Falcon				
Summer Storage	909.5	2,112.3	258.9 1/	3,280.7
Texas Summer Share	533.0	1,237.8	—	1,770.8
Winter Storage	509.5	2,512.3	258.9 1/	3,280.7
Texas Winter Share	298.6	1,472.2	—	1,770.8
COASTAL–				
Big Hill	0.0	32.0	0.0	32.0
Highlands	0.0	5.6	0.0	5.6
Austin	—	—	—	—
Alice Terminal	0.0	7.0	0.0	7.0
Tranquitas	0.0	6.0	0.0	6.0
Monte Alto	0.0	25.0	0.0	25.0
Valley Acres	0.0	7.8	0.0	7.8
Loma Alta	0.0	26.5	0.0	26.5
TOTAL 7/	17,587.9	28,653.4	6,275.7	52,517.0

1/ Minimum pool for hydroelectric power generation.

2/ Off-channel reservoir.

3/ Reservoir will be sedimented by 2020.

4/ Minimum pool for thermal power generation.

5/ Land acquisition initiated.

6/ Land clearing.

7/ For reservoirs on boundary streams, the total storage (not the Texas share) has been included. For International Falcon the winter storage figures have been included.

Table 2.--Incremental Capacities of Reservoirs, Proposed and Potential

Storage Capacity in 1,000 Acre-Feet

BASIN & RESERVOIR	FLOOD CONTROL	CONSERVATION	DEAD	TOTAL
RED–				
Lower McClellan Creek	0.0	22.0	106.0	128.0
Lelia Lake Creek	0.0	17.2	3.0	20.2
Sweetwater Creek	0.0	49.2	16.5	65.7
Ringgold	0.0	413.1	19.9	433.0
Bonham (Bois D'Arc)	48.5	75.1	7.0	130.6
Big Pine	54.7	77.9	6.0	138.6
Pecan Bayou	52.4	564.3	8.3	625.0
Liberty Hill	0.0	89.8	7.9	97.7
Barkman Creek	0.0	10.8	5.1	15.9
SULPHUR–				
Cooper	127.5	273.0	9.3	409.8
Parkhouse I	0.0	548.2	87.2	635.4
Parkhouse II	0.0	750.1	96.9	847.0
Naples (Initial)	0.0	1,466.5	135.8	1,602.3
(Ultimate)	701.7	2,220.0	190.0	3,111.7
Texarkana Enlargement	1,687.7	802.9	125.8	2,616.4
CYPRESS–				
Titus County	0.0	311.3	2.9	314.2
Marshall	0.0	775.0	7.3	782.3
Black Cypress	0.0	820.0	4.4	824.4
Caddo Enlargement	0.0	213.5	38.5	252.0
SABINE--				
Mineola	674.5	370.1	20.4	1,065.0
Lake Fork	413.2	621.5	18.9	1,053.6
Big Sandy	163.7	215.3	6.9	385.9
Kilgore No. 2	0.0	14.0	1.0	15.0 [1/]
Cherokee No. 2	0.0	110.6	1.7	112.3 [1/]
Carthage	636.6	456.5	41.0	1,134.1
Bon Wier	124.5	215.3	23.0	362.8
Salt Water Barrier [6/]	—	—	—	—
NECHES–				
Weches	839.7	1,401.7	26.2	2,267.6
Ponta	517.8	805.8	25.5	1,349.1
Rockland	1,502.5	1,789.9	58.9	3,351.3
Salt Water Barrier [6/]	—	—	—	—
TRINITY–				
Bridgeport Enlargement	0.0	396.1	37.0	433.1
Aubrey	258.3	603.8	37.8	899.9
Garza-Little Elm [2/]	331.6	630.6	40.7	1,002.9
Lakeview	136.7	306.4	45.6	488.7
Tennessee Colony	2,187.8	2,044.6	328.6	4,561.0
Bedias	0.0	488.0	16.7	504.7
SAN JACINTO–				
Cleveland	0.0	479.8	4.2	484.0
Lower East Fork	0.0	330.7	7.3	338.0
Lake Creek	0.0	200.0	6.0	206.0
BRAZOS–				
Millers Creek	0.0	7.4	18.1	25.5
Breckenridge	0.0	550.0	67.0	617.0
Stephenville	0.0	40.6	10.9	51.5 [3/]
Aquilla Creek	111.5	59.7	28.1	199.3
Cameron	0.0	1,200.0	18.0	1,218.0
Navasota No. 2	550.7	1,315.4	69.5	1,935.6
Millican	359.0	1,125.8	72.0	1,556.8
South San Gabriel	46.5	30.2	8.0	84.7
COLORADO–				
Stacy	659.3	650.0	50.0	1,359.3
Upper Pecan Bayou	102.7	93.5	10.1	206.3
Clyde	0.0	4.7	1.0	5.7
San Saba	331.6	195.6	5.0	532.2 [4/]
Mason	433.8	319.9	15.2	768.9 [4/]
Pedernales	212.0	233.4	5.0	450.4 [4/]
Columbus Bend	481.7	483.9	88.1	1,053.7
Matagorda	0.0	61.4	28.6	90.0

Table 2.--Incremental Capacities of Reservoirs, Proposed and Potential--Continued

BASIN & RESERVOIR	FLOOD CONTROL	CONSERVATION	DEAD	TOTAL
LAVACA–				
Palmetto Bend	0.0	230.0	55.0	285.0
GUADALUPE--				
Ingram	36.4	53.5	0.5	90.4
Cloptin Crossing	107.0	146.8	3.2	257.0
Lockhart	0.0	59.9	9.5	69.4
Cuero I and II	843.0	2,816.0	50.0	3,709.0
Confluence	0.0	406.0	33.0	439.0
SAN ANTONIO–				
Cibolo	218.0	172.0	28.0	418.0
Goliad	702.0	958.0	42.0	1,702.0
NUECES–				
Choke Canyon	0.0	686.0	14.0	700.0 5/
R & M	0.0	672.4	—	672.4 5/
Montell	239.3	1.0	12.0	252.3
Concan	141.2	0.0	7.8	149.0
Sabinal	89.1	0.0	4.2	93.3
COASTAL–				
Garcitas	0.0	63.0	4.0	67.0
TOTAL–	16,124.2	33,616.7	2,383.0	52,123.9

1/ Potential alternate to obtaining water from Sabine River.

2/ Capacities after storage exchange with Aubrey Reservoir.

3/ Potential, alternate to obtaining water from Proctor Reservoir.

4/ Alternate for Colorado River development.

5/ Alternate for Nueces River development.

6/ Location and capacity not determined as yet.

Appreciation is expressed to the following for permission to reprint the photographs that appear herein

Texas Parks and Wildlife Department

Texas Highway Department

U.S. Bureau of Reclamation

U.S. Army Corps of Engineers

U.S. Geological Survey

Lower Colorado River Authority

Brazos River Authority

Port of Houston

Nelda Thomas, Photographer