2.0 PLANNING BASIS AND METHODS

Webster's Dictionary defines a plan as a "detailed formulation of a program of action." While compiled and presented in a summary report, the State Water Plan is based on literally millions of different data elements and calculations and numerous analytical methodologies involved in formulating a comprehensive and consistent program of action. This section addresses the background, institutional and regulatory setting, underlying data and methods considered in the Plan's formulation.

2.1 PLANNING HISTORY AND PHILOSOPHY

2.1.1 Previous Water Planning Efforts

In 1957, after extremely damaging floods ended the State's most severe drought of record in the 1950s, the Texas Water Development Board was created by the Texas Legislature, and voters subsequently approved a constitutional amendment authorizing the Board to administer a $200 million Water Development Fund to help communities develop reliable water supplies. Also in 1957, statewide water planning was mandated when the Texas Water Planning Act (Acts 1957, 55th Leg., p. 1268, ch. 425, Section 3) was enacted. The authority to prepare a Water Plan is codified as Section 16.051 (Chapter 16, Subchapter C, Planning) of the Texas Water Code.

Although many proposals concerning the State's water resources were prepared between 1904, when voters first authorized the public development of water resources, and today, only six water plans have been officially adopted as State policy. The first two plans, which were adopted in 1961 and 1968, consisted of initial attempts to describe the State's water resources, to quantify future water needs, and to propose water supply projects to meet future uses. The interrelated nature of conventional water development proposals and non-water supply aspects of comprehensive water resources management, such as flood protection, hydropower generation, drainage, water quality, recreation, and fish and wildlife, was recognized and incorporated into the 1968 Texas Water Plan to the extent possible with the understanding and knowledge of the time.

The official adoption of the State's third water plan, Water for Texas - A Comprehensive Plan for the Future, in 1984 signaled a key departure from the earlier plans which relied almost exclusively on water supply development to meet future water uses. The 1984 Plan proposed major new conservation, environmental, and ground-water protection initiatives and included long-term funding needs for water pollution control, in addition to conventional water supply projects. For the first time, the 1984 Plan presented a documented need for, and a more justifiable approach to, developing the State's water resources.

The State's 1990 Plan, Water for Texas - Today and Tomorrow, further exemplifies the continuing evolution of water planning in Texas by building on new directions established in 1984 and by emphasizing improved overall management of the State's water infrastructure systems. The

Board adopted a 1992 update of Water for Texas - Today and Tomorrow that focused on needed policy initiatives with a minor updating of the project recommendations from the 1990 Plan.

2.1.2 Consensus-based Planning Efforts

As previously mentioned, the State Water Plan is statutorily defined as a guidance document. Further, a large portion of the decision-making authority relating to water resources development in Texas occurs at the local level where decisions on which options to pursue, their detailed planning and design, and method of financing is substantially determined. State government, in the initial planning stage and later in this process in the permitting and financing stages, has some ability to influence the proposed action. Given these circumstances, the Plan has, at best, a limited power of persuasion in guiding the State's water future.

In late 1992, the TWDB initiated a process of substantially broadening the participation in the State Water Plan in order to increase its impact and effectiveness. Better consensus of opinion with the assumptions used to develop the Plan and improved cooperation in implementation and policy development was desired with the Texas Natural Resource Conservation Commission (TNRCC or the Commission), Texas Parks and Wildlife Department (TPWD), various other water interests and the general public (see Exhibit 2-1).

The three State agencies support the consensus process used to develop the 1997 State Water Plan, Water for Texas, and believe that it correctly targets the major issues and provides viable recommendations. This support, of course, does not remove the agencies' duties to consider the full details of projects when they come forward for State regulatory, environmental protection, or funding decisions, nor does it constitute a unilateral endorsement of any specific project at this time.

Exhibit 2-1
Consensus Water Planning Goals

✯ Promote consistent planning, policy, regulation, management, and wise use of the State's water resources,

✯ Minimize or avoid any needless and unproductive conflict in the planning and management of such resources, and

✯ Provide an on-going, cooperative planning and policy process for orderly and responsible water conservation, development, and management.

2.2 PLANNING METHODOLOGIES

2.2.1 Legal, Regulatory, and Institutional Considerations

In formulating an appropriate statewide water plan, not only do the statutory provisions of Federal and State law govern the Plan's approach, but also the development of more detailed policy and regulatory execution of statutory duties by State and local agencies and the institutional framework in which water is developed and managed.

2.2.1.1 Texas Water Code

Besides the statutory direction provided the Board and its Executive Administrator in Chapter 16 of the Texas Water Code concerning development of the State Water Plan (see Section 1.1), the Code also addresses other key regulatory issues related to water management. Most notably, provisions in Chapter 11 governing surface water rights and environmental protection are of interest in defining appropriate planning methodologies for forecasting the State's water future.

Water Rights

Texas' legislature and courts have determined that the State of Texas owns, in trust for every citizen, all surface water in defined water courses in the State. Anyone desiring to use the State's water must first apply in writing to the Texas Natural Resource Conservation Commission. A regular permit for the right to use surface water may be granted by the Commission only if a beneficial use of water is contemplated, existing surface water rights are not impaired, unappropriated water is available, water conservation is practiced, and the surface water right is not detrimental to public welfare. Existing Texas law does not establish a similar permitted use system for groundwater in the State, except where ground-water districts have been established with this authority and fully exercise it.

Surface water rights information must be considered in all water planning to safeguard previously approved Certificates of Adjudication and permits to use surface water. In formulating this amended Water Plan, the planning tenets shown in Exhibit 2-2 have been recognized related to surface water rights.

Exhibit 2-2
Planning Assumptions Related to Surface Water Rights

- The Plan will not interfere with vested surface water rights under existing adjudicated certificates, water rights permits, or international or interstate compacts.

- The type of use or location of diversion recognized under a permit may be changed through amendment at some future time as water needs change.

- Surface water rights or contractual water supplies that are likely to go unused may be made available in the planning process for other uses with the assumption that this water would be marketed or the rights subordinated to another use. Where significant, these assumptions will be clearly stated. However, the granting of a new appropriation must still consider the full recorded values of existing water rights.

- Intrabasin needs within the 50-year planning period that can be met with supplies that are economically and technically feasible to develop will have priority over exportation for out-of-basin needs, except where the planned transfer is intended on a temporary basis.

Further methods used in the State Water Plan also considered protection of existing surface water rights and modes and methods of adjustment to rights over time (re: Chapter 16.054 of Texas

Water Code). For instance, only the reuse of wastewater prior to its discharge to a watercourse was considered available for new supply without a new water rights appropriation. Future use of return flows was addressed as a new appropriation. All water marketing and transfers of surface water rights identified in the Plan were assumed to be voluntary and typically would result from conversion of land uses (e.g. farms into subdivisions, etc.), sale of existing unused water rights, sale of existing used water rights, sale of water produced through "conservation trades," and subordination of existing water rights.

In the case of environmental water need considerations affecting water rights, the granting of a new appropriation and amendment to existing water rights may be limited by these considerations, consistent with current State law and policy. The State Water Plan process takes these water rights adjustment mechanisms into account.

In areas of the State outside of ground-water conservation district boundaries, the unrestrained exercise of the legal doctrine of "right of capture" prevails, which essentially allows the private landowner, within his property, the unlimited right or ability to capture as much groundwater as possible for use, so long as it is put to beneficial use. Within the boundaries of groundwater conservation districts, there is typically some level of regulation in the form of well registration, well spacing, or other measures which may somewhat limit the full right of capture.

A projection of expanded ground-water management, both in terms of district geographic bounds and district regulation, was also incorporated into the Water Plan forecasts. In problem areas, future ground-water supply availability was limited to the "perennial yield" or the annual recharge quantity of the aquifer supply. In areas where withdrawals from the aquifer in excess of the annual recharge were not expected to cause deleterious side-effects (such as subsidence, cessation of springflow, or harm to other aquifer users or to the aquifer itself), "mining" of aquifer supplies (withdrawing more water than is naturally recharged) was assumed corresponding to an estimated future time period by which time alternative supplies would need to be developed.

Environmental Regulations

Applicable major Federal and State regulations were considered for new water supply projects in the Water Plan, including regulations related to protection of water quality, threatened and endangered species, critical habitats, and sites of historical importance. A planning methodology for consideration of instream flow needs in Texas' river basins, and freshwater inflow needs in the receiving coastal bays and estuaries, was developed and utilized by the three agencies (see Chapter 2.2.3) to address environmental flows necessary to sustain the State's aquatic resources. Assessment of the physical features and living natural resources of alternative sites for major projects in the updated Water Plan was conducted on a "reconnaissance-level." The results of additional interagency field investigations of potential reservoir sites and detailed studies of freshwater inflow needs of selected bays and estuaries are included in the Plan's findings as completed.

Still, these environmental considerations are only preliminary. Once specific projects are considered for implementation, additional environmental studies must be performed to provide the site-specific data and analyses needed for an adequate ecological assessment and comprehensive consideration of all project impacts.

2.2.1.2 Regulatory Guidance Document

Chapter 11 of the Texas Water Code lays out most of the laws relating to the granting and enforcement of surface water rights in Texas. Ground-water use is not regulated by the State, but rather in some areas, by local ground-water districts. In areas outside of these local districts, the legal doctrine of "right of capture" prevails.

In June 1995, the TNRCC published A Regulatory Guidance Document for Applications to Divert, Store, or Use Water. The purpose of the document was to provide better clarity and consistency regarding the state administration of water rights and to ensure the timely and efficient review of water rights applications. It summarizes the TNRCC's existing policies and rules used to review and take action on applications for new or amended water rights to divert, impound, or use State water.

The Regulatory Guidance Document, for the first time in a consolidated manner, laid out the Commission's policies and guidelines regarding several important aspects of water regulation, including the TNRCC's and case law interpretation of existing statutory authority, needed evaluation of water management alternatives, promotion of less-impacting options, consideration of interbasin transfers, environmental assessment methods, and other issues of importance to water planning.

2.2.1.3 Coastal Management Program

The Texas Coastal Management Program (TCMP) was approved by the U.S. Department of Commerce, Office of Coastal Resource Management, on January 10, 1997. The TCMP provides a networked structure for management of coastal natural resources among various affected Federal and State agencies, using their existing statutory authorities. To ensure that decisions made concerning activities in the coastal region are consistent with the goals and policies of the TCMP, the plan is implemented through the Coastal Coordination Council (CCC) with members from key State agencies and four appointees of the governor representing coastal interests. Representatives of four members of the CCC (TWDB, TNRCC, TPWD, and GLO) have participated in development of the State Water Plan.

The TCMP has several goals for coastal management (see Exhibit 2-3; the 10 goals have been paraphrased into a consolidated list of 5). The TCMP also contains a list of policies for specific activities. Determining consistency of actions with goals and policies of the TCMP is the major tool the CCC uses to ensure sound management of coastal natural resources. Enforcement of consistency is normally handled through administrative procedure, but can result in an attorney general's opinion and lawsuit filed in a district court against a State or local governmental entity. Rather than subjecting every permit or authorization decision to review, the CCC and individual regulatory agencies have developed "thresholds," which are definitions of the magnitude of an action below which the CCC delegates the consistency decision to the agencies and will not review agency actions. For actions above the threshold, the CCC may review consistency if various procedural requirements are met.

For most coastal activities, the TCMP goals and policies apply only to those actions that occur within the program's boundary that generally coincides with the coastal facility designation line in the State's Oil Spill Prevention and Response Act of 1991 (see Figure 2-1). Activities that require permits for freshwater diversion inland of the management boundary may also be subject to the goals and policies of the plan if they fall within 200 river miles of the coast.

Exhibit 2-3
Goals of the Coastal Management Program

✯ Protecting, preserving, restoring, and enhancing coastal natural resource areas (CNRA's) which include wetlands, oyster reefs, seagrass beds, gulf beaches, tidally influenced waters and other sensitive resource areas defined in §33.203 of the Natural Resources Code.
✯ Improving coordination in decision-making among state, local, and Federal agencies.
✯ Establishing clear policies for management of CNRA's.
✯ Decision-making is to be visible, coherent, accessible, and accountable to the public with decisions based upon accurate, objective, and reliable information and scientific data.
✯ Coastal area goals, including allowing compatible economic development and multiple human uses of the coastal zone, minimizing the loss of human life and property due to the loss of the protective function of some CNRA's, and ensuring and enhancing public access and enjoyment of the coast while balancing those objectives with protection of private property rights.
✯ Consideration of other issues of broader statewide importance.

The TCMP may affect the State Water Plan in two ways; through direct consistency review of the Water Plan or through determination of the consistency of actions recommended by the Water Plan. There is a provision in the TCMP that allows an agency preparing a general plan to request a non-binding advisory opinion from the CCC on the plan's consistency. If the CCC finds issues that raise consistency concerns, it must identify the issues and present recommendations for ways to resolve the consistency issues. An agency may also request participation of the CCC in development of a general plan.

The second way the TCMP may affect the State Water Plan is through consistency determination of individual actions that may be recommended by the plan, as they are implemented. Within the coastal boundary, the following activities are subject to consistency review by the appropriate regulatory agencies if the project magnitude is below applicable thresholds, or by the CCC if the magnitude is above applicable thresholds: wastewater discharge permits; levee improvement or flood control projects; declarations of drought or water shortage emergency and requests for emergency release of unappropriated water from TWDB-controlled reservoirs; new permits to store, take, or divert 5,000 or more ac-ft/yr of water; amendments to permits to increase water appropriations by 5,000 or more ac-ft/yr; and amendments to permits to change the purpose to a more consumptive use of 5,000 or more ac-ft/yr. Inland of the coastal boundary but within 200 river miles of the coast, several actions involving water appropriation are subject to consistency review. These include: new permits, except emergency permits to store, take, or divert 10,000 or more ac-ft/yr of water;

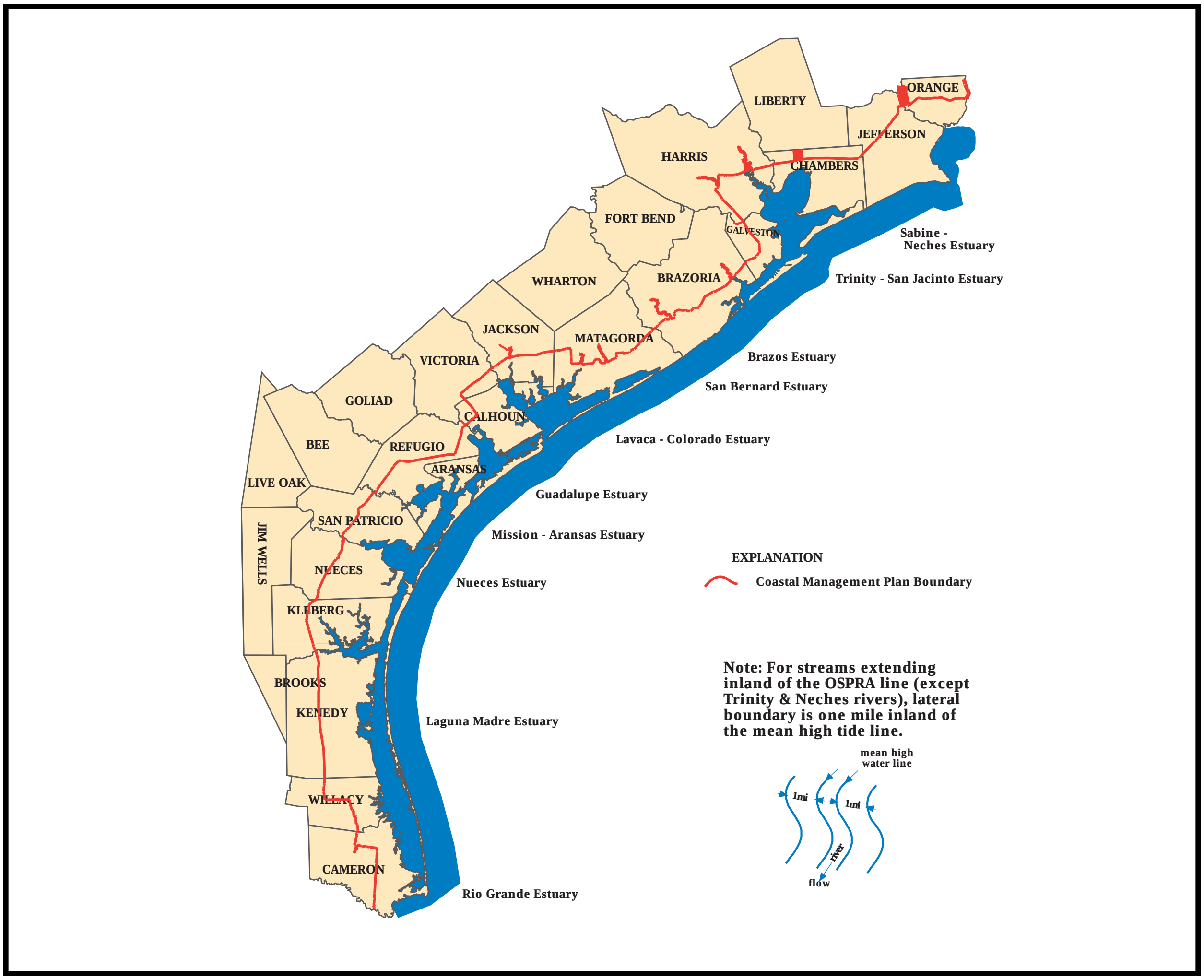

Figure 2-1
Coastal Management Plan Boundary

amendments to permits to increase water appropriations by 10,000 or more ac-ft/yr; and amendments to permits to change the purpose to a more consumptive use of 10,000 or more ac-ft/yr.

2.2.1.4 Federal Law

Several aspects of Federal environmental law can have significant impact on future water resources development in Texas. Section 404 of the Clean Water Act provides for the permitting of discharges of dredged or fill material into waters of the U.S. and has the practical effect of requiring Federal environmental permitting and potentially mitigation for water projects of any substantial size. The Federal actions may support or conflict with State findings of the same nature.

The Endangered Species Act has also shown its affect on water management in Texas with requirements for new water development projects to protect threatened or endangered species, claims or legal actions under the Act which resulted in significant regional ground-water regulation, potential reservoir sites becoming unavailable for development, and operations of existing reservoirs coming under review for their effects on threatened or endangered species. Licensing or re-licensing of hydroelectric facilities by the Federal Energy Regulatory Commission (FERC) can bring about requirements for providing instream flows to maintain affected fish and wildlife habitats. Also in recent years, the awarding of a Federal conservation easement to the U.S. Fish and Wildlife Service has pre-empted development of a water supply reservoir site in East Texas. Any or all of these actions at the Federal level can significantly impact the State's ability to manage and allocate its water resources.

The Federal government may preempt State law and substitute a Federal allocation rule for a State rule under certain circumstances. Primarily, Federal preemption may occur to protect navigable waters under the Commerce Clause of the U.S. Constitution. This power has been construed broadly by the courts to include most water bodies, including wetlands, and the protection of environmental and recreational uses of the water.

Other enumerated constitutional powers under the Property Clause, the War Power, and the General Welfare Power also give Congress the power to regulate and allocate water and to preempt State law. In addition, the treaty-making power and the power to approve interstate compacts are sources of Federal authority.

Notwithstanding these preemption powers, Congress has often required the Federal government to comply with State law in the acquisition and exercise of water rights for Federal projects and in the operation of Federal projects. Such Congressional intent to give State law deference is evidenced, for example in the Reclamation Act of 1902, and the provisions of the Federal Water Act relating to FERC licensing of Federal hydropower projects. However, such intent to defer to State water right law is not found in other Federal laws such as Section 404 of the Clean Water Act or the Endangered Species Act.

Programs under the Safe Drinking Water Act and provisions of the 1996 amendments to the Act provide support for source water assessment and protection. The Source Water Protection, Wellhead Protection, and Comprehensive State Ground Water Protection programs all provide programmatic and financial support to aid in the protection of surface and ground water resources.

The budget constraints and subsequent changing roles of Federal government agencies have also created a gap in their funding of major water supply, flood protection, or chloride control projects, especially when the Federal funding supported broad public purpose initiatives.

2.2.2 Planning Horizon, Study Areas and Measurement Units

To be able to meet a constitutional test on State-supported financing of interbasin transfers and to allow for an adequate planning period given that major water projects can typically take from

10 to 25 years to develop, the planning horizon for the amended Water Plan is designated as the 50-year period, 2000 to 2050, with forecasts presented at ten-year increments.

The State Water Plan is an aggregation of many sub-area analyses and is built piece-by-piece from the local area up. Projections of water use and water supply availability and allocations of supplies to uses are prepared for cities of 1,000 or more residents and for rural areas of counties. The Plan then aggregates this data into 16 defined geographic regions (see Figure 2-2) to describe common water issues and to facilitate presentation of regional and local information.

Texas is such a vast and diverse state, it is difficult to delineate "optimal" regional water planning boundaries given the varying layout of the State's surface watersheds, aquifer boundaries, and socioeconomic and utility development patterns that routinely criss-cross each other. Further, the relative importance of these factors to an area's water management issues also varies from location to location. The planning regions reflect the best professional opinion of the Board staff after several years of consideration.

It is typical in water supply planning for very large quantities of water to be considered, and relating such quantities in gallons results in extremely large numbers. Therefore, it is common for the measure of an acre-foot to be used as a standard unit measure in water supply planning. An acre-foot represents the amount of water it takes to fill one acre of area one foot in depth. In layman's terms, an acre-foot is the approximate amount of water a family of five would use in one year's time.

Table 2-1 provides a series of standard conversion factors for terms and measures commonly used in water management.

Figure 2-2
Texas Water Planning Regions

The Plan also presents data from a resource perspective at an individual river basin and aquifer level. In accordance with the Texas Water Code, each basin has been designated as a separate planning area for the purpose of calculating in-basin water supplies and uses over the designated 50-year planning horizon. There are 15 river basins and eight coastal basins which traverse the State of Texas (Figure 2-3) and are designated as separate planning areas for the purpose of developing long-term basin population and water use projections and calculating basin water supplies. Provisions of Senate Bill 1 (SB 1), enacted by the 75th Texas Legislature, would require the Board to designate such regional and basin boundaries by rule-making (planning regions used in this update to the Water Plan do not reflect the SB 1 boundaries, as these provisions do not take effect until after adoption of the current plan). Also delineated for analyses are the defined nine major and twenty minor aquifers of the State (see Figures 2-4 and 2-5).

Figure 2-3
Texas River and Coastal Basins

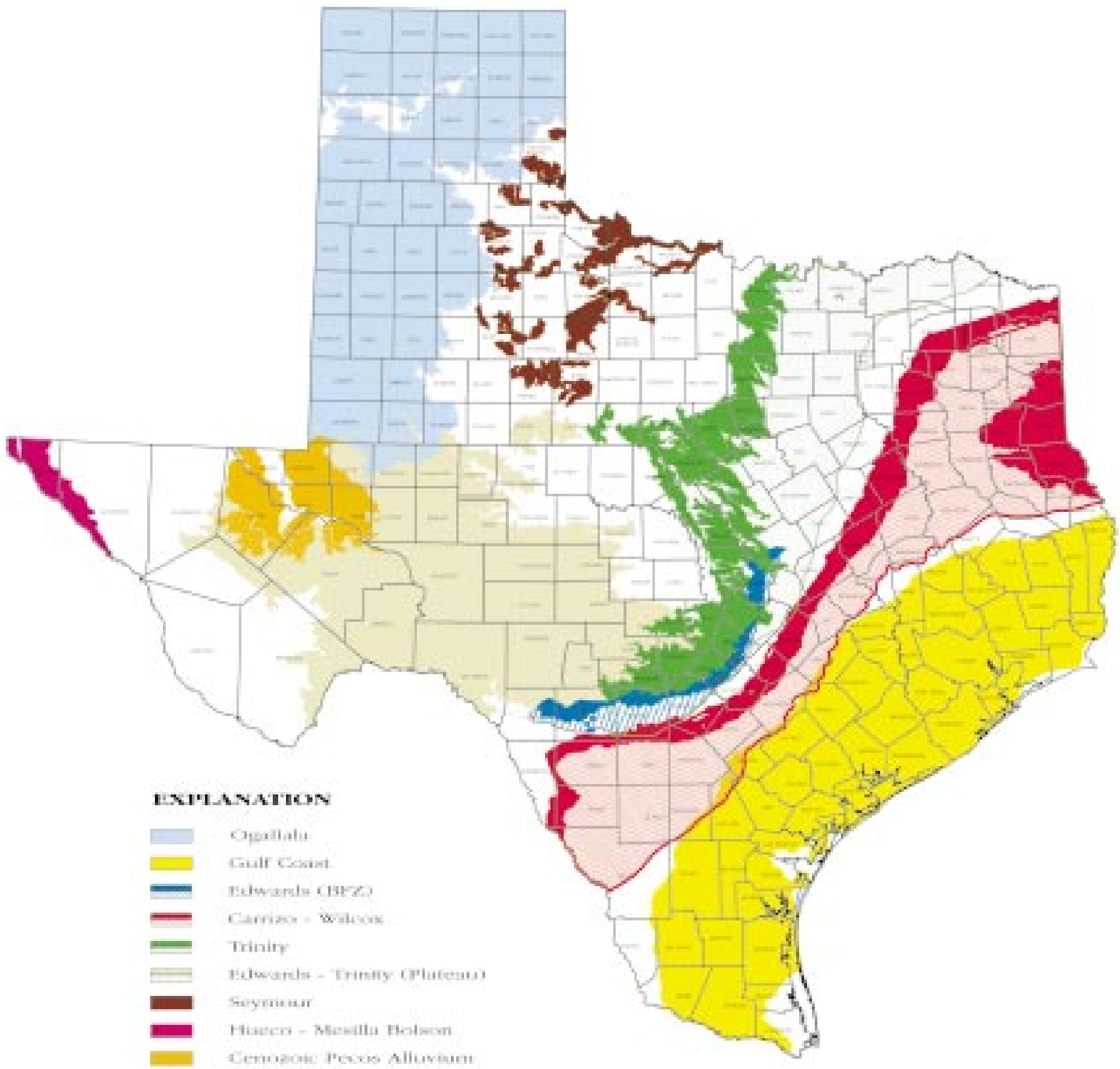

Figure 2-4
Major Aquifers of Texas

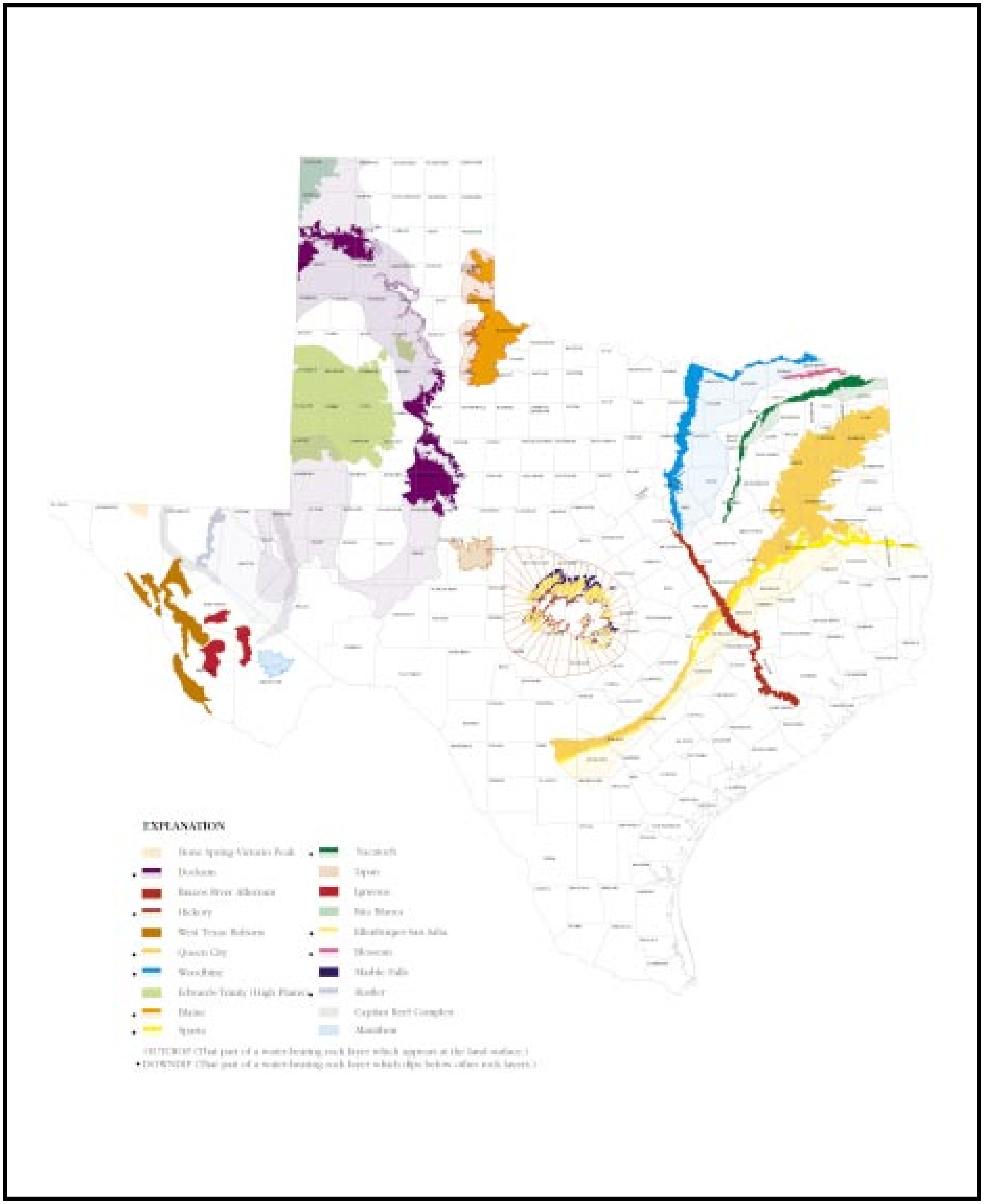

Figure 2-5
Minor Aquifers of Texas

2.2.3 Data Sources, Methodologies, and Limitations of Analyses

Volume III of the State Water Plan provides a more detailed description of the procedures, methods, assumptions, projection scenarios, and data sources used in the development of the population, water use, and water supply allocation projections. This section provides a summary of those methods. The data sources and methodologies referenced in this section were the result of general agreement among the TWDB, TNRCC, and TPWD staff, along with input from several technical advisory committees as to an acceptable basis of modeling the State's water future.

Table 2-1
Unit Measures and Conversion Factors

Amount	Equals
1 acre-foot (ac-ft)	325,851 gallons (gals) 43,560 cubic feet (cf) 1,233 cubic meters (m3)
1 acre-foot/year (ac-ft/yr)	892 gallons per day (gpd) 0.0014 cubic feet/second (cfs)
1 cubic foot (cf)	7.48 gallons (gals) 0.0284 cubic meters (m3)
1 cubic foot/second (cfs)	730 acre-feet/year (ac-ft/yr) 449 gallons per minute (gpm)
1 million gallons (MG)	3.07 acre-feet (ac-ft)
1 million gallons/day (MGD)	1,120 acre-feet/year (ac-ft/yr) 1.55 cubic feet/second (cfs)
1,000 gallons/minute (gpm)	2.23 cubic feet/ second (cfs)

2.2.3.1 Population

The technique used for projecting county population is a cohort-component procedure which uses the separate cohorts (age/sex/race/ethnic groups) and components of cohort change (fertility rates, survival rates, and migration rates) to calculate future populations. Projections of each cohort are then summed to total populations. Cohorts used in the projection process are defined as single-year-of -age (0 thru 75 and over), by sex and race/ethnic groups which include Anglo, Black, Hispanic, and other.

Key assumptions used in developing the population projections are associated with the fertility rates, survival rates, and migration rates (set to the 1980-1990 migration rates for each county and varied from the base set in accordance with the consensus-defined projection scenarios). Four scenarios were defined based on varying the migration rates to allow for a range of alternative future populations (see Exhibit 2-4).

Population projections for all cities and towns of 1,000 or more residents were then developed using the historical population shares of each city in relation to its corresponding county population. Each county's projected population was then used as a control total for all cities within the county and for the rural county population.

The development of the consensus population projections incorporated a number of data files and information based on the 1990 Census, provided by Steve Murdock, Ph.D, Chief Demographer for the State Data Center. A limitation in preparing projections is the quality of the underlying data on which the projections are based. The U.S. Bureau of the Census has acknowledged that they may have under-counted the State, county, and city populations by as many as 560,000 people. Since the consensus population projections are based on the Federally-adopted 1990 Census count information, the alleged undercount could result in conservatively lower forecasts for some areas of the State.

Exhibit 2-4
Population Forecasting Scenarios

Three modeled and one composite forecasting scenarios were identified for use in the State Water Planning process:

- 0.0 migration scenario or 0% of the 1980-1990 migration base rate with only the natural increase in the population being assumed,

- 0.5 migration scenario or 50% of the 1980-1990 migration rate over the projection period,

- 1.0 migration scenario or 100% of the 1980-1990 migration rate over the projection period, and

- Recommended Scenario or one of the above three migration rates which seemed most appropriate for each county given recent growth rates and likely development trends. Regional and State totals termed "recommended" are an aggregated mix of these individual county selections.

2.2.3.2 Water Uses

Municipal Water Use

The municipal water use projections rely on three primary components: (1) population projections for counties, cities, and rural areas of counties; (2) per capita water use projections for cities, towns, and rural areas of counties under varying rainfall conditions; and (3) implementation of indoor and outdoor water conservation practices.

Data sources used in the development of the municipal forecasts included the Board's annual municipal water use summaries for cities and counties (1980-1991), annual per capita water use summaries for cities and counties (1980-1991), the consensus population projections for all counties and cities of 1,000 or more residents, and water conservation working papers prepared by the consensus planning staffs of the three agencies.

Various planning scenarios were modeled to provide a range of potential municipal water demands reflecting differing assumed rainfall conditions and levels of water conservation activities (see Exhibit 2-5).

A key factor in the municipal water use forecasts is the specification of per capita water use statistics. For State planning purposes, municipal per capita water use reflects residential, multi-family, and associated commercial and institutional water uses, but not industrial water use (which is less closely tied to population).
Industrial water use (as discussed later) is projected separately, based on anticipated industrial growth and industry-specific water use statistics.
A likely range of municipal water conservation savings that could be attained over the 1990-2050 planning horizon was then specified. The range of water savings associated with conservation practices and programs was estimated based on: (1) implementation of the 1991 State Water-Efficient Plumbing Act without any additional conservation strategies, (2) an expected water conservation scenario, and (3) an advanced conservation scenario (see Exhibit 2-5).

Each assumed weather-related per capita water use statistic was held constant over the planning period. The conservation savings, measured in gallons per capita per day (gpcd), were then subtracted from each per capita use statistic, resulting in a declining per capita water use for each entity over the 1990-2050 planning period. Estimates of future municipal water use are then computed by multiplying the projected population of a city or community by the entity's projected per capita water use, adjusted for the conservation savings. The projected municipal water use is then converted to an acre-foot measure.

Exhibit 2-5
Municipal Water Use Forecasting Scenarios

In addition to incorporating population forecast scenarios (see Exhibit 2-4), weather and water conservation conditions were defined for developing municipal water use forecasts. Those conditions included:

Varying weather assumptions:

- a below normal rainfall per capita water use statistic was defined as the highest per capita water use recorded over the 1982-91 period, constrained on the upper limit to 25% of the last 5-year average per capita water use, and
- a normal rainfall per capita water use statistic was defined as the average per capita use from 1987-91.

Varying water conservation assumptions:

- plumbing bill only or potential water conservation savings associated with water efficient plumbing fixtures in all new houses and existing housing being retrofitted over time.
- expected case water conservation or the same as above but with some additional savings due to outdoor and other conservation measures, and
- advanced case water conservation or the same as expected case, but with an accelerated implementation of existing housing retrofits and slightly more aggressive savings from outdoor and other conservation measures.

The below normal rainfall and the expected case water conservation scenarios were the basis the State Water Plan recommended forecast. Advanced conservation was then implemented prior to construction of new reservoirs and interbasin transfers.

Municipal water conservation is increasingly recognized by water utilities as a very cost-effective approach for extending water supplies. Additionally, many conservation strategies are simply good management alternatives. The implementation of the 1991 State Water-Efficient Plumbing Act and other conservation measures included in the municipal water use projections will certainly save water over time. The provision of these efficient fixtures in new or existing housing will induce about the same level of per capita water conservation savings whether the housing is in East Texas or West Texas or whether located in urban or rural areas. Not all areas of the State will experience savings from conservation at the same rate or potential amount. For example, rural areas in Texas have historically grown slower and typically have less outdoor water use than urban areas. The Board's per capita forecasting methodology considers the slower population growth rate and lower seasonal (outdoor) water use of these rural areas. However, the forecasts do not reflect the situation where some rural areas being urbanized may experience some upward pressure on per capita water use as land use changes and more intensive development occurs.

Additionally, the potential water conservation savings associated with the municipal water use projections do not take into consideration any potential voluntary or mandatory restrictions of water use during prolonged dry periods. As specified in these planning projections, conservation is an improvement in water use efficiency and applies to everyday water use regardless of weather conditions. Water use restrictions are measures to restrict desired water use resulting from water supply shortages typically associated with emergency conditions (i.e., drought, system delivery capacities or outages, supply contamination, etc.).

Several cautions should be stated in using these per capita water use statistics for water supply planning:

- the assumed normal rainfall per capita water use statistics should only be used for revenue forecasting or evaluation of typical utility systems design or operations, but not be used for water supply planning. Water demands projected using this average weather statistic will likely fall short of what water demands may actually occur during dry times and may result in water supply shortages.

- the assumed below normal rainfall per capita water use statistic reflects a frequently- recurring dry condition (e.g., the driest year of the last ten years of record). This may not be representative of a more severe and extended drought. Consequently, additional supplies or more stringent demand management measures may be required during severe drought, and

- "peak day" utility use statistics should not be used as a basis for raw water supply planning. While appropriate for certain types of utility facilities, using peak day demand can greatly over-estimate raw water supply needs.

Manufacturing Water Use

Three key assumptions underlie the forecasts of manufacturing growth: (1) growth is due to changes in existing manufacturing capacity and/or expansion of capacity due to new or relocated industry, (2) the current locational pattern of industries within the State is assumed to remain the same over time, and (3) historical interactions between oil prices and industrial activity are assumed to continue.

County manufacturing output for the base year 1990 was estimated by distributing projections of state-level two-digit standard industrial classification (SIC) manufacturing output to metropolitan statistical areas (MSAs) and non-metropolitan statistical areas based on each area's estimated share of the state's manufacturing output. Each area's industry output was then allocated to those counties comprising the corresponding MSA and non-MSA area based on reported earnings and employment for each manufacturing facility within the county. County manufacturing output is then projected over time by applying the state industry-specific growth rate to the corresponding county-specific industry base year output, adjusted to the area's projected growth for each industry (SIC).

Exhibit 2-6
Manufacturing Water Use Forecasting Scenarios

Four growth-related scenarios were defined for forecasting manufacturing water use that included:

- No growth where the current real value of manufacturing output is held constant over time.
- Low oil prices affecting Texas industries where prices range from $13 to $17 per barrel.
- Baseline oil prices affecting Texas industries where prices range from $17 to $23 per barrel.
- High oil prices affecting Texas industries where prices range from the $23-$29 per barrel.

The first three scenarios were then projected under with and without industrial water conservation assumptions.

Based on the Board's records of reported water use by county and industry, an industry-specific water use coefficient, defined as acre-feet per unit of output, was calculated for each county industry. Recently updated industrial water-use efficiency projections were applied to each county-specific industry water use coefficient, resulting in a declining coefficient for each of the major water using industrial SIC groups through 2030 and held constant at the 2030 level through the year 2050 (Pequod, 1993).

County manufacturing water use was projected over time by applying each county-specific industrial group's water use coefficient, adjusted for increasing water use efficiency, to the corresponding industrial group's projected output. Four growth-related scenarios were incorporated into the manufacturing water use projections (See Exhibit 2-6). Three of these scenarios vary oil prices which drive alternative manufacturing growth projections. In some cases, high oil prices stimulated some sectors and retarded others, and a similar, but reversed pattern, was seen for the lower oil price scenario. The baseline oil price scenario was selected as the recommended forecast to be used in the subsequent water supply planning efforts.

Data sources used in the development of the manufacturing water use projections included county manufacturing water use summaries by two-digit standard industrial classifications (1980-1991) prepared by the Board, long-term projections of Texas' manufacturing output by two-digit standard industrial classification prepared by Perryman Consultants, Incorporated, metropolitan statistical area projections prepared by the U.S. Bureau of Economic Analysis, earnings and employment data for each reporting manufacturing facility prepared by the Texas Workforce Commission, and manufacturing water use efficiencies prepared by Pequod and Associates.

Investment in water-efficient technology depends to a large extent on the cost of water relative to other production costs, the anticipated economic climate (expansion or contraction), and the fiscal and management strategies of individual production facilities as to the timing for modernizing or re-tooling the production process of a facility. Therefore, the actual scheduling of the anticipated improvements in water use efficiencies for a particular industry may not coincide with that of the many facilities that comprise an entire industry. This scheduling problem could result in a potential over-estimation or under-estimation of an industry's future water use, particularly at the local level. However, the improved water use efficiencies for a particular industry and the scheduling of these efficiencies is the latest and most reliable information available at this time.

Steam-electric Power Water Use

Water use projections for steam-electric power generation have two major components: power generation capacity and water use for that projected capacity. Power generation projections were based on current per capita electric demand for reported residential, commercial, and other sectors on a utility-specific basis. Industrial power water uses were based on each utility's reported sales by Standard Industrial Classification (SIC). A composite growth factor was estimated for the remaining unaccounted-for sales. For existing plants, future water use was assumed to remain constant at the average 1988-1991 historical water use patterns unless information indicated that plants were scheduled for closure. For planned plants and facilities, water use permits and/or plant design data were used to determine future water needs. If permit or facility design information was not available, it was assumed that additional generation would use water at the same gallons per kilowatt-hour rate as the current average use for that utility.

Exhibit 2-7
Steam-electric Water Use Forecasting Scenarios

- Upper case scenario incorporates current generating technology to meet future power demands.
- Lower case scenario incorporates new combined- cycle technology and additional water conservation practices.

In developing the steam-electric water use projections, a number of assumptions were used including (1) power generation demands will grow in direct proportion to population growth for residential, commercial, and other sectors. The power demands are based on the recommended-case population projections; (2) industrial power generation demands are assumed to grow in direct proportion to industrial and manufacturing growth projections for each major electric power use by SIC; (3) no change is assumed in electric power generation capacity for the upper case scenario; and (4) a combination of technological, conservation measures, and other factors are assumed to reduce total water use by five percent by the year 2000, ten percent by 2010, and 15 percent from 2020 to 2050.

Two scenarios were developed to reflect potential technology changes in the electric power industry (see Exhibit 2-7). The advanced combined-cycle combustion technology, if broadly implemented by the power industry, could significantly lower water use in this sector.

A number of data sources were used in the development of the steam-electric power water use projections. These sources included: TWDB's survey of annual water use (1980-1991); the consensus population and water use projections developed by staffs of the three agencies with advisory committee assistance; Public Utility Commission's projections of additions and removals of power generation to the year 2005, fuel use, thermodynamics of existing power plants, co-generation statistics, long-range power needs, and the impact of technology on power generation; water rights permit information from TNRCC; and research on new technologies and related information from the Electric Power Research Institute.

Because it is unknown where future power plants will be located, the methodology assumes that power generation will occur in locations that have historically had power generation or where power companies have announced new locations. However, unforeseen technological advances, changes in market forces, and conservation efforts could affect both power plant locations and water use. Additionally, changes in Federal regulations could have an important affect on steam-electric power generation and water use.

Mining Water Use

Projections of fresh water use for mineral production in Texas were developed for the various fuel and nonfuel categories. Water use in mining activities includes data on actual water use as well as estimates of water needs for each decade through the year 2050. Trends in production, estimated total mineral reserves currently accessible, and rates of water use were derived from historical and more recent data and were then used to develop mining water use projections by basin, region, and county.

Mining water use projections were based on projected future production levels for each mineral commodity. These future production levels were derived from both state and national historic rates, which were constrained by accessible mineral reserves in each region. Projected future quantities of water used in the production of mining activities were based on these projected production levels and historic water use rates. Two key assumptions were used to develop the mining water use projections: (1) that locational concentration of various mining activities within a region would remain much the same; and (2) that each region would retain its share of state mineral production over the projection period. Although mining is an important industry in

Texas, water for mining purposes represents less than one percent of the total water use in Texas. Due to the relatively small quantity of water used in this industry, only one scenario was developed for the mining water use projections.

A number of data sources were used in the development of the mining water use projections. These data sources included published information from the U.S. Bureau of Mines, published reports and information from the Bureau of Economic Geology, annual reports from the Texas Railroad Commission, mineral tax reports from the Texas Comptroller of Public Accounts, and water use information provided by the Board's annual water use survey.

Irrigation Water Use

The Board, with technical assistance from staff of Texas A&M University, developed a linear programming model for use in evaluating and assessing the many factors affecting irrigation water use for the Texas agricultural sector. Linear programming models are based on mathematical techniques for systematically determining solutions for maximizing or minimizing values of linear functions under various variable (resource) constraints. Several types of variables are used in the modeling procedure for determining future irrigation uses by geographical region. More specifically, these variables include crop prices, crop yields, production costs, water costs, and six types of irrigation delivery system costs. These data are crop-specific and reflect the major crops grown within the major agricultural regions in Texas. As part of the revenue stream, Federal farm payments, in the form of deficiency payments, for specific crops and land-set-aside requirements for compliance with Federal farm programs were included in the modeling procedure.

In addition to the variables used in the analysis, specific resource constraints were included to reflect historical acreage, cropping patterns, and water use which correspond to each agricultural region in the state. Constraints developed for each agricultural region included total irrigated acreage, crop-specific acreage, irrigation technology adoption, and the amount of water that could be applied over a specific time. Once the most profitable combination of irrigated and dryland production was estimated, along with the quantities of water required for that level of production, the regional projections were distributed to each county by apportioning a county's share of the regional acreage and water use.

Three forecast scenarios were selected from many scenarios for presentation in the Water Plan (see Exhibit 2-8). Scenario II was selected by the Technical Advisory Committee as the recommended scenario for water supply plan-

Exhibit 2-8
Irrigation Water Use Forecasting Scenarios

Three growth-related scenarios were defined for forecasting irrigation water use that included:

- No new water conservation practices and no reduction in Federal farm program subsidies.
- Expected case water conservation practices and no reduction in Federal farm program subsidies.
- Advanced case water conservation practices and reduction in Federal farm program subsidies by 1/2.

ning purposes. Scenario II includes changes over time in crop prices, crop yields, and production costs, Federal farm payments are held constant over the planning period, and an expected case irrigation technology is assumed.

The model incorporates more efficient water-conserving irrigation technology over time as it becomes economical to do so. In fact in some cases, advanced water conservation measures, such as Low Energy Precision Application (LEPA) irrigation systems, were brought on so quickly by the model (looking purely at economics), it did not well mirror the reality of the recent spread of such technology. The significant capital cost of such irrigation systems, high levels of farm debt, land suitability, lack of knowledge by some farmers of such systems, reticence to change, and other factors have slowed the proliferation of such water-efficient irrigation technology.

For the expected case irrigation forecasts, the rate of implementation of advanced conservation technology was slowed somewhat to reflect these institutional impediments. For the expected case irrigation forecasts, the rate of implementation of advanced conservation technology was slowed to reflect these institutional impediments by allowing a fixed percentage of irrigated acreage to be converted to more efficient technology for each decade. The conversion rate to more efficient technology was determined by irrigation specialists familiar with the irrigation characteristics of each area.

Major data sources used to develop the irrigation water use projections included regional crop budgets prepared by Texas A&M University, Texas historical crop statistics prepared by the Texas Agricultural Statistics Service, surveys of irrigation in Texas prepared through a cooperative effort by the Board, Texas State Soil and Water Conservation Board, and the U.S. Natural Resources Conservation Services, projected crop prices and yields prepared by the Food and Agricultural Policy Institute at the University of Iowa and University of Missouri-Columbia, projected energy prices prepared by the U.S. Department of Energy, and a number of other research publications.

Federal farm programs and policies play a major role in the actions of individual farmers and the decisions that are made in relation to food and fiber production. Changes in farm program policies and payments, set-a-side requirements, quotas, and other policies could deviate from the underlying assumptions of the consensus irrigation water use projections. The consensus planning staff will continue to monitor changes of Federal farm policies and programs in order to maintain an up-to- date series of projections for the Texas irrigated agricultural sector.

Livestock Water Use

Estimating free-range livestock water consumption is a straightforward procedure that consists of calculating water consumption per livestock unit and the total number of livestock. The Texas Agricultural Extension Service provided information on water use rates, calculated as gallons per head per day for each type of livestock including cattle and calves, poultry, sheep and lambs, and hogs and pigs. The Texas Agricultural Statistics Service provided current and historical numbers of livestock by type and county. Water use rates were then applied to the number of livestock by type and county. For those counties where the number of livestock was unavailable, historical livestock distribution patterns were assumed. County livestock water use was then aggregated to regional and statewide totals. Because livestock water use represents 1.7 percent of the state's total water use, livestock production and water use is assumed to remain constant over the projection period.

Data sources used in calculating livestock water use included Texas livestock statistics from the Texas Agricultural Statistics Service, agricultural cash and price receipts from the Texas Agricultural Statistics Service, and published data and information from the Texas Agricultural Extension Service.

2.2.3.3 Environmental Water Needs

Instream Flows

Since water development projects, such as river impoundments and diversions, can alter the natural flow regime of streams and rivers, assessment of fish and wildlife maintenance needs in the affected downstream segments is an important project activity. The primary objective is to minimize development impacts on living resources by managing for environmental flow needs through watershed management. This can best be done on a regional basis. Also, decreasing the flow in streams below a certain threshold can affect the assimilative capacity or dilution ability of streams, thereby leading to increased costs associated with higher levels of wastewater treatment and nonpoint source pollution prevention activities. Therefore, multi-stage rules are needed for environmentally safe operation of these necessary water projects over the normal range of weather conditions experienced in Texas, which is extreme.

The environmental criteria generally have been accepted by State water agencies for use in planning and for use as "default" values in the permitting of certain small projects in the absence of site-specific information. However, they are not intended to replace site-specific information in the permit process, and the TNRCC is charged by law with the final decision in all permit matters.

As part of the State Water Plan process, a team of instream flow and aquatic biology specialists was asked to develop guidelines to be used in planning for water resource projects. The general consensus planning methods developed by the State water agencies attempt to balance human and environmental water needs. These criteria provide instream flow recommendations that serve as initial "placeholders" for instream flow needs until more site-specific assessments can be performed.

Seven basic considerations were recommended by the panel of experts to provide a framework for instream flow needs to conserve riverine ecosystems:

> *Mimic Natural Hydrology.* Median streamflow values, derived from naturalized streamflow data, preferably daily, should be used. For proposed reservoirs, inflows up to the naturalized medians would be the instream flow releases. Diversions, including those to off-channel reservoirs, should not reduce streamflows lower than the naturalized median.

Daily Flux of Streamflows. Diversions should not cause flows to cease. Streams need daily flow at a frequency of occurrence similar to that in the historical record.

Ramping and Diversion Rates. No artificial changes in initial streamflow greater than 50% from day to day and none greater than 12.5% within a six-hour period. Down-ramping (abrupt termination of high dam discharges) is of greater concern than up-ramping.

Channel Maintenance. For within-channel maintenance purposes, at least one peak (flushing) flow event should be allowed to pass each season of the year.

Maintenance of Water Quality Standards. Surface water quality standards for segments and reaches should be maintained except during periods of declared public emergency. The 7Q2 (7-day low flow with a two-year recurrence interval) should be used as a default value unless water quality modeling determinations have been made that specify the instream flows necessary to maintain state water quality standards.

Drought Contingency. In order to maintain the ecological health of the aquatic ecosystems, impoundments and diversions should not artificially increase the severity (frequency and/or duration) of low (drought) flows to a significant degree. Drought contingency triggers and drought relief measures need to be evaluated on a site-specific basis to incorporate the natural variation that occurs within hydrologic regimes in Texas. Drought triggers for water development projects should include both capacity (reservoir content)

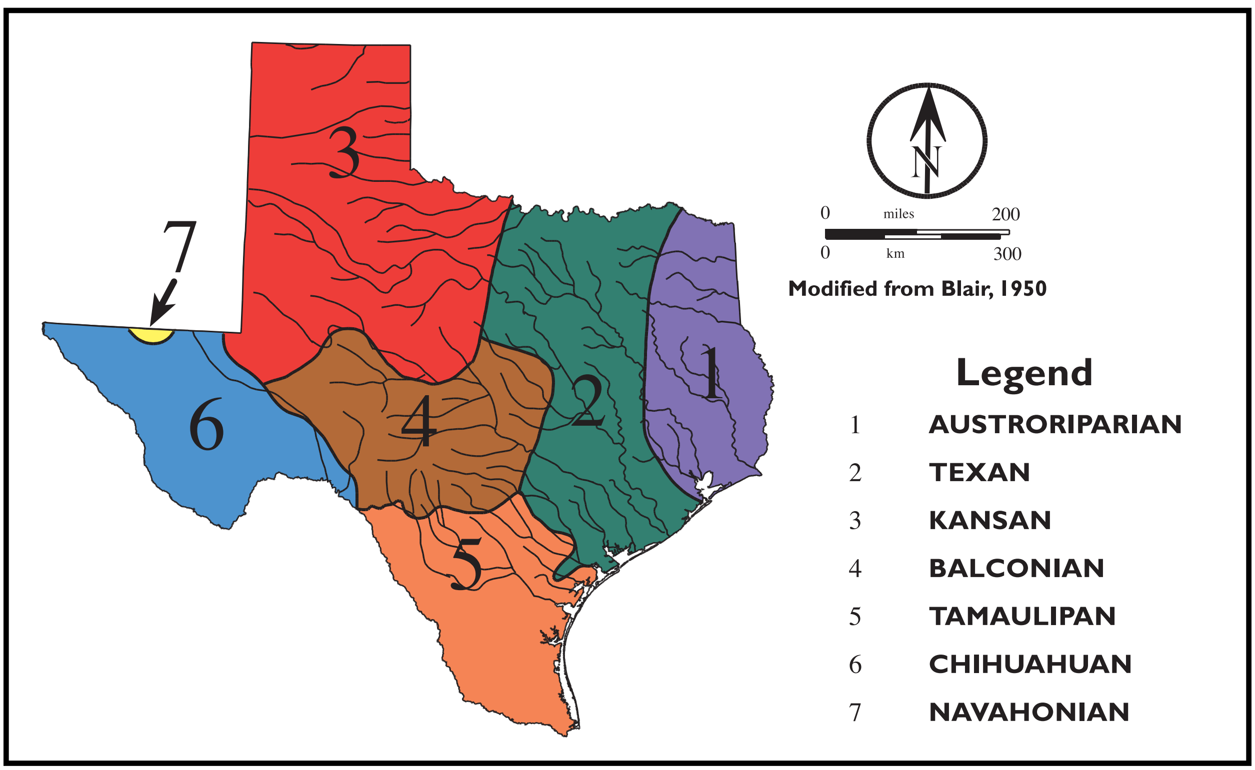

Figure 2-6
Biotic Provinces of Texas

and streamflow levels to incorporate the overall conditions within the watershed into drought planning. Reservoir content is the best indicator for water supply while streamflows are an excellent indicator of the severity of drought conditions. Relief measures should be commensurate with the severity of drought.

Regionalization. Texas climate and hydrology vary extensively among the regions which mandates subdivision of the state for water planning purposes. Biotic provinces (Blair, 1950; see Figure 2-6) should be used in the regionalization process. Blair used the definition of a biotic province developed by Dice (1943). A biotic province is "... a considerable and continuous geographic area and is characterized by the occurrence of one or more ecologic associations that differ, at least in proportional area covered, from the associations of adjacent provinces. In general, biotic provinces are characterized also by peculiarities of vegetation type, ecological climax, flora, fauna, climate, physiography, and soil."

Although there are 3,700 named streams and rivers that flow across more than 80,000 miles of the Texas landscape, there are only eight new reservoirs recommended in this State Water Plan for the next 50 years. However, developing this recommended list required evaluation of a large number of alternative water supply projects early in the consensus planning process. As a result, the three State water agencies agreed to apply non-intensive methods with reasonable ad-hoc criteria which could be used for rapid assessment of instream environmental flow needs and assist in the assessment of potential project feasibility. Specifically, environmental flow criteria were developed for new on-channel reservoirs, direct diversions to off-channel reservoirs or other water storage structures, and direct diversions standing alone with little or no off-channel storage available.

The environmental planning methodology used is based on the concept of passing specified target flows for environmental health purposes, while allowing impoundment and diversion of streamflows for human use when they are greater than the target flows. In addition, the environmental criteria contain drought contingency provisions that require some sharing of the adverse impacts of drought by both humans and the environment. Thus, a balance is achieved early in the water planning process between meeting high priority human needs and maintaining stream water quality and living aquatic resources under dry weather conditions.

The environmental planning criteria concepts described below are intended to approximate the regulatory decisions about environmental flow requirements in State water permits. However, specific project features identified by an applicant during the permitting process may require consideration of more detailed environmental information based on site-specific field studies which were not possible to conduct in the early planning stages. In addition to passage of environmental flows, adequate flows are also passed through the water projects to supply downstream water rights. When the results of intensive freshwater inflow or instream flow studies are available and site-specific criteria have been established, those criteria will be used in the Water Plan instead of the generalized values.

New Project On-channel Reservoirs. The conservation storage of new, on-channel water supply reservoirs can be divided into three zones with provisions for varying levels of instream flows to be passed through to the affected downstream segment (see Figure 2-7).

Zone 1 criteria apply when streamflows are abundant and reservoir water levels are greater than 80 percent of conservation storage capacity. In these "good times," reservoir inflows will be passed through the project in amounts up to the monthly median historic flows, calculated from naturalized daily streamflows occurring at that location in the river basin, to maintain the ecological health and productivity of the stream.

Zone 2 criteria apply when reservoir levels drop to between 50 and 80 percent of conservation storage capacity due to dry weather conditions. In this zone, inflows to the reservoir would be passed through, but only in amounts up to the monthly 25th percentile flow, again calculated from naturalized daily streamflows. Under the emergency conditions we call "drought," Zone 3 criteria apply when reservoir levels fall below 50 percent conservation storage capacity. During such times, reservoir inflows, if any, will be passed through the project in amounts up to the established water quality standard (or 7Q2 value published by the TNRCC) of the affected downstream segment.

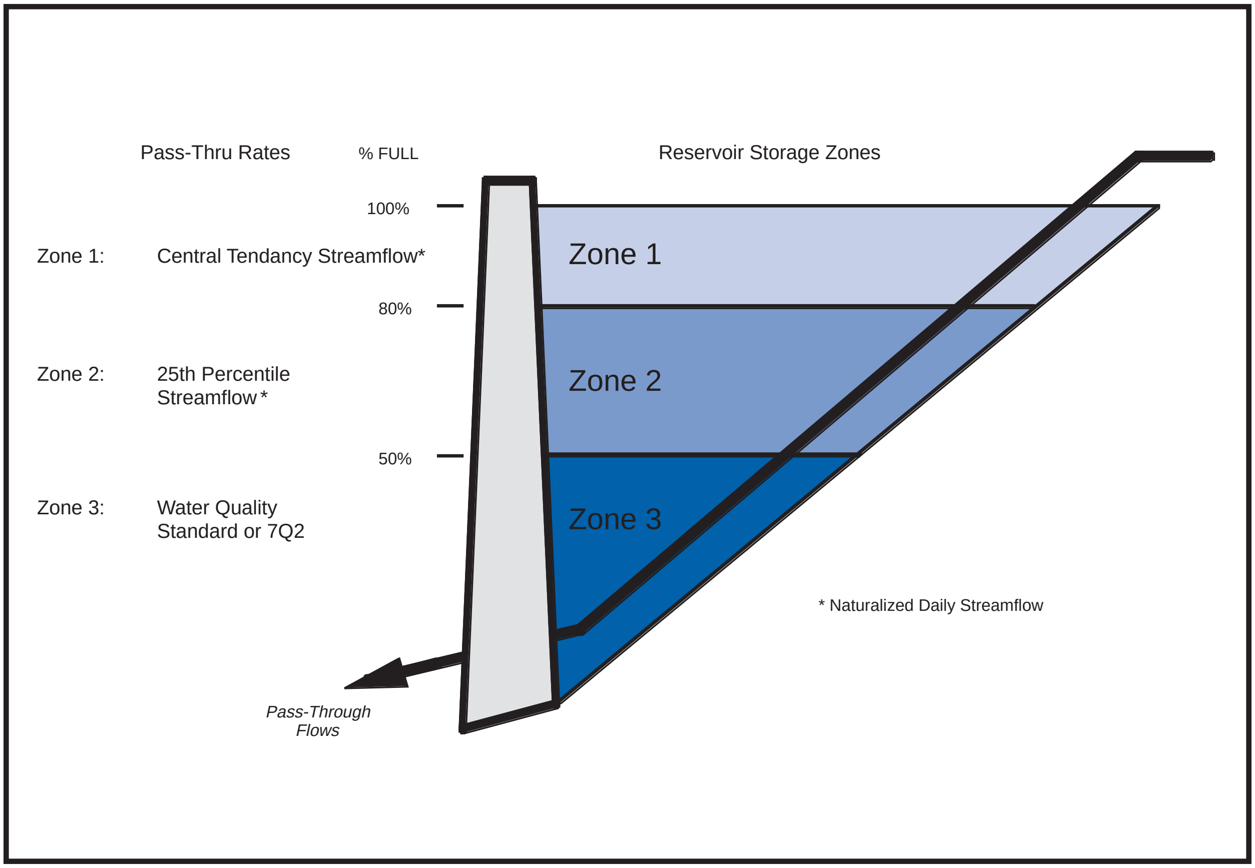

Figure 2-7
Environmental Planning Criteria for New Project, On-channel Reservoirs

In all operational zones, streamflow pass-throughs would not only serve instream flow needs, but would also provide some level of benefit to the associated bay and estuary system at the river's mouth. Flows necessary for the protection of downstream water rights will be added to the instream flows given above and passed through the reservoir. In order to mimic the natural flow regime and safeguard water supplies, no releases will be made from water supply storage to provide environmental flows when natural inflows are below the target values.

New Direct Diversions. Criteria governing direct diversions from a river or stream recommended in the State Water Plan are based on streamflow conditions at the diversion point and on provisions for downstream water rights. Again, three operating zones are defined with respect to the hydrologic conditions (see Figure 2-8). When streamflow is greater than the monthly median value (Zone 1 conditions), as calculated from naturalized daily streamflow estimates, then the minimum environmental flow passed through the diversion project will be the monthly median. When streamflows are greater than the monthly 25th percentile (Zone 2 conditions), but equal to or less than the median (50th percentile), then the minimum environmental flow passed will be the monthly 25th percentile flow, as calculated from naturalized daily streamflow estimates. Finally, when streamflow is less than or equal to the monthly 25th percentile (Zone 3 conditions), then the pass-through flow will be limited to the water quality flow requirement, unless the value is near zero and the diversion could potentially dry up the stream

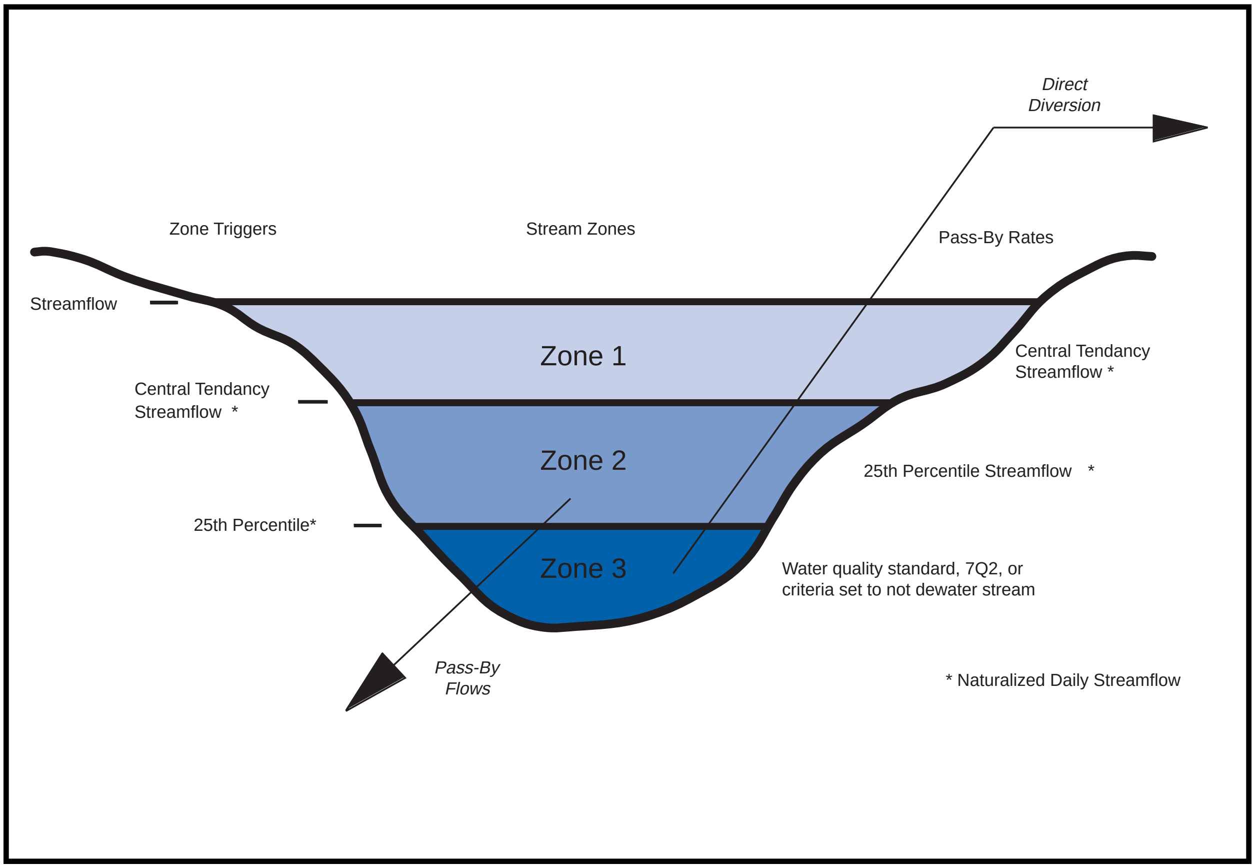

Figure 2-8
Environmental Planning Criteria for New Direct Diversion

itself, at which point a continuous flow threshold (e.g., 15th percentile flow) may be included by consensus planning staff to avoid extreme environmental impacts.

New Direct Diversion Projects into Off-channel Storage. In cases where a recommended water project would divert its water supply from a river or stream into an off-channel storage location, a combination of both the direct diversion and reservoir criteria would then apply to the environmental planning consideration. The direct diversion planning criteria will govern the ability to divert water into the off-channel reservoir, whereas, the separate reservoir planning criteria will address the ability of the project to capture water from within its own watershed, as well as define the reservoir's operation for passing environmental flows to the affected downstream segment in its own watershed.

Bay and Estuary Considerations

For most environmental planning purposes, the Zone 1 instream flow requirements previously described will also provide a "fair-share" of the total targeted freshwater inflows to the bays and estuaries (B&E). However, where "beneficial inflows," as described in Texas Water Code §11.147, have been scientifically determined, those freshwater inflow volumes will be used as the basis for calculating the proportional flow requirement during Zone 1 conditions, and applied to recommended new reservoirs or direct diversions located within 200 river miles of the coast.

No other special B&E provisions would be made in Zone 2 or Zone 3, except that instream flows in these operating zones are assumed to be allowed to pass all the way down to the receiving bay and estuary system. Freshwater inflow needs may be estimated by TPWD until a regulatory determination is made in accordance with Texas Water Code §11.1491.

To address the detailed studies needed to make the above regulatory bay and estuary freshwater inflow determinations, the Texas Water Development Board (TWDB) and the Texas Parks & Wildlife Department (TPWD) have jointly conducted a data collection and analytical study program focused on determining the effects of and needs for freshwater inflows to the state's bays and estuaries.

Results from rainfall-runoff, freshwater inflow, nutrients, and sedimentation models and commercial and coastal fisheries data are placed into the TxEMP optimization model, along with information on salinity viability limits for survival, growth, and reproduction of estuarine plants and animals, and solved mathematically to meet state management objectives for maintenance of biological productivity and overall ecological health. TxEMP was specifically developed as a tool for decision-making on the freshwater inflow needs of Texas bays and estuaries. Feasible solutions from the TxEMP model are verified by TWDB's TxBLEND modeling of resulting circulation and salinity patterns, as well as TPWD's analyses of species abundance and distribution patterns.
Since freshwater inflows affect our estuarine systems at all basic levels of interaction (that is, with physical, chemical and biological effects), the method was designed to include at least the minimum needs for each functional level and a technique for optimizing the freshwater inflow needs across all levels of interaction. Results are displayed as a "response curve" from which decision-

makers can select the point that best balances the needs of man and the environment for the benefit of both (see Figure 2-9).

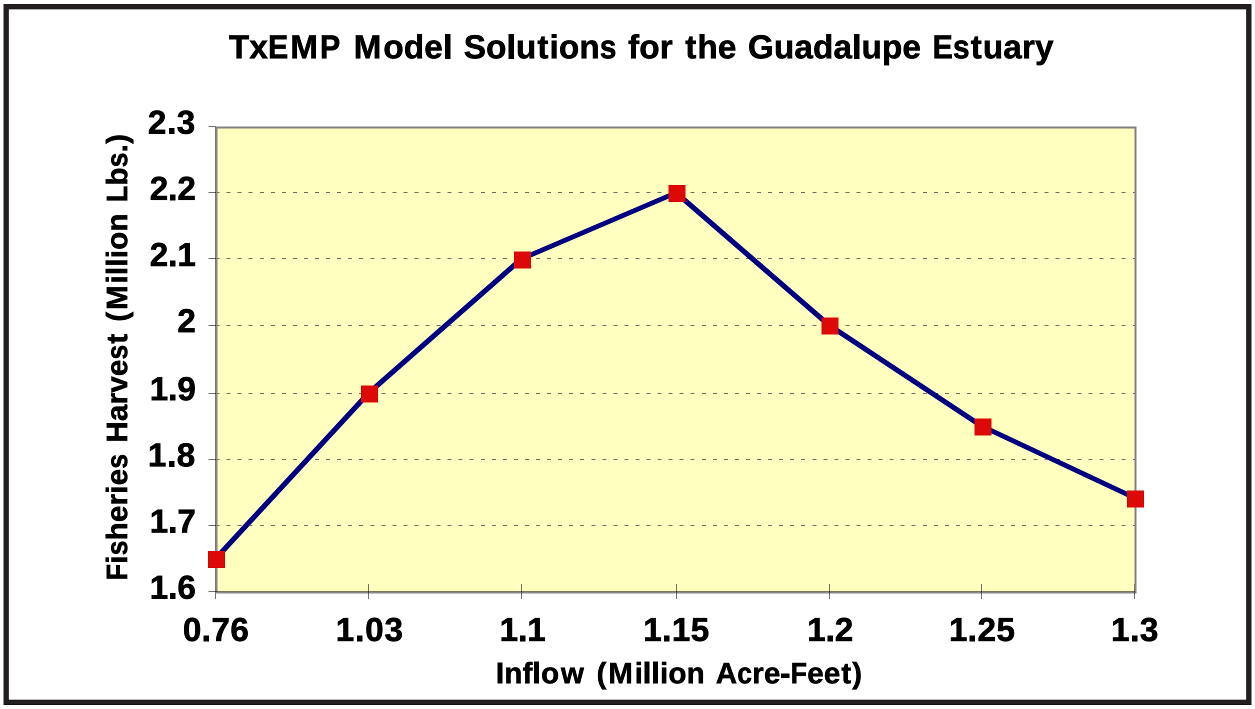

Figure 2-9
Response Curve to Freshwater Inflows
San Antonio Bay and the Guadalupe Estuary

The bay and estuary study methodology was developed by the State water agencies and the prototype tested on San Antonio Bay and the Guadalupe Estuary in 1994. After verifying that the methods and models worked properly, an analysis of this estuary was completed in 1995 and a draft reporting document prepared in 1996, which is currently under review and revision. Similarly, an analysis of Matagorda Bay and the Lavaca-Colorado Estuary was completed by the LCRA, in cooperation with the State water agencies in 1997 and a draft reporting document is currently under review and revision.

While this work was being completed, analyses of Galveston Bay and Sabine Lake were being initiated. Results of these analyses should be available for Galveston Bay and the Trinity-San Jacinto Estuary in 1997, and analyses of Sabine Lake and the Sabine-Neches Estuary will be completed in 1998. Although the State water agencies have already made a preliminary analysis and determination of freshwater inflow needs of Corpus Christi Bay and the Nueces Estuary, work on the Coastal Bend estuaries (including Nueces and Mission-Aransas) is not anticipated to be completed until 1999. Remaining areas, such as Baffin Bay, Laguna Madre, East Matagorda Bay, and the two coastal preserves, Christmas and South bays, are scheduled to be completed by 2002.

Amendments to Existing Permits

The scope of environmental review and permit consideration of an amendment to an existing water right is limited by law. Because of the many varied conditions around the State, and the fact that an applicant may propose a project different than that identified in the Plan, the TNRCC can only provide general guidance as to how the Commission would evaluate applications for water rights and amendments to existing permits.

In general, evaluation of impacts to instream or estuarine ecosystems will occur when there is a significant change in the point of diversion from downstream to upstream, to an adjoining tributary, to an area with endangered species habitat, increase in the amount and/or rate of diversion, or if there is a change of purpose of use from non-consumptive to consumptive. Other changes in place or type of use and changes made by SB 1 to sections 11.122 and 11.085, Texas Water Code, may have limited or no further environmental review. This limited scope of review for proposed amendments to existing water rights was codified by SB 1. Section 11.122 of the Water Code now expressly provides that, except for an amendment that increases the amount of water authorized to be diverted or the authorized rate of diversion, an amendment shall be authorized if the requested change will not cause any greater adverse impact on other water right holders

Table 2-2
Water Rights Permit Amendments and Scope of Environmental Review for Planning

Type of Amendment Environmental Assessment Application of Environmental Criteria Interbasin Transfer with no change in permitted purpose of use, appropriative amount, point of diversion, and rate of diversion.	Environmental impacts considered with respect to the originating basin. Consideration of potential changes in water quality and/or migration of nuisance species, and excessive freshwater inflows to maintain proper salinity levels for B&E may be made for receiving basin. An impact statement may be required to be submitted.	Three-zone planning criteria described previously.
Significant change in point of diversion from downstream to upstream, to adjoining tributary, or to endangered species habitat	Evaluation of impacts to intervening instream or site-affected environmental resources.	Case-by-case basis where level of significance evaluated as per Regulatory Guidance Document.
Change of purpose of use from non-consumptive to consumptive use	Evaluation of impacts to instream and B&E environmental resources.	Three-zone planning criteria described previously.
Change in purpose of use where there is no increase in the consumption of water from that legally authorized in the existing water right.	No environmental review.	not applicable.

or the environment than the full legal exercise of the water right prior to its amendment. An exception to this is provided by changes made by SB 1 to Section 11.085 of the Water Code relating to interbasin transfers. If the water right sought to be transferred is currently authorized to be used under an existing water right, potential environmental impacts shall only be considered in relation to that portion of the right proposed for transfer and shall be based on the historical use of the water.

For planning purposes, proposed amendments, such as conversion from non-consumptive to consumptive use (having the effect of a new appropriation) would have the appropriate environmental considerations described for new projects. For other types of amendments where only the intervening river or stream would be affected, the appropriate reservoir or direct diversion instream flow criteria would be applied. Where applicable, environmental flow criteria would only affect that portion of the existing water right subject to change. A summarization and categorization of the TNRCC's general guidance for determining potential adverse impact to the environment for types of possible water right amendments likely to be considered in the consensus planning process is shown in Table 2-2.

2.2.3.4 Water Quality

As embodied in the environmental planning criteria discussed previously, the water supply yield modeling in the planning process provides that no new major water supply project would alter the rate of streamflow to the extent that it violated numeric water quality standards. Later in the development process when a specific project design for any new reservoir is being evaluated, it will then be possible to model the water quality of the lake's limnological strata and downstream mixing zone [from releases] to ascertain if any further mitigation, such as providing for a multi-level gated release capability or instream aeration devices, may be needed to address any remaining water quality concerns caused by project action.

2.2.3.5 Water Supplies

Surface Water

Water availability from all major existing or under-construction reservoirs was calculated based on either the defined firm annual yield (which is the maximum quantity of water that can be withdrawn from a reservoir each year, on a dependable basis, during a repetition of the most critical drought of record) or the supplies that could be developed under the operating mode of the supply source during drought conditions. For reservoirs without an adequate sedimentation pool, firm yield or available supply was adjusted downward over time as the specific case warranted.

The volume of surface water supplies projected to be available for beneficial use includes the firm annual yield of reservoirs, and direct runoff of rainfall and springflow during the worst year of drought. The available supply from a reservoir that was used in the analysis was the smaller of the calculated yield or the water rights issued for the reservoir. Return flows, defined as discharges into rivers and streams from municipal and industrial wastewater treatment plants and industrial recirculation facilities and irrigation tailwaters, were also used as surface water supply sources, subject to a new water rights appropriation (any reductions due to direct reuse were accounted for).

Provisions of international and interstate water compacts, water supply contracts and surface water permits issued by the TNRCC were reviewed and used as guides for allocating water supplies to uses. It was predicted that contract owners would act as regional water suppliers. The provisions of existing permits establishing specific limits for certain types of use (i.e., municipal, industrial, irrigation, etc.) were not rigidly followed since such limits could be changed in the future through marketing, subordination, or permit amendments. This consideration allowed, for planning purposes, unused water to be made available to those in need.

Groundwater

The estimate of the ground-water supply capability of each area of the State was based on the determination that some form of ground-water management program would be instituted in each area of the State where it was prudent to do so. In areas where natural recharge of the aquifer is significant and in some areas where it is currently believed that groundwater can be "mined" from storage without causing harm to the aquifer or users, ground-water supplies were allocated on a "safe-yield" basis. In parts of West Texas and in the High Plains, where natural recharge to aquifers is negligible and ground-water "mining" or withdrawals in excess of natural recharge is necessary and practical, groundwater was presumed to be "mined" at a decreasing annual rate according to actual use or the hydrologic capabilities of the aquifers.

Both existing and projected ground-water supplies were utilized in many cases in conjunction with surface water supplies and facilities, particularly where such coordinated operation of water supply facilities would be expected to lower the cost of providing adequate water supplies.
The Board, in coordination with ground-water districts and other local ground-water interests, has been conducting efforts to update its information related to the amounts of groundwater in storage, natural rates of recharge, and appropriate best management techniques for use in on-going state and regional water planning processes.

Water Reuse

In developing this update of the State Water Plan, uncertainty over State policy related to (wastewater) reuse made it difficult to forecast the potential contribution of reuse to State water supplies. With the passage of SB 1, reuse policy is now clearer. In this plan, two types of reuse are identified, direct reuse and indirect reuse. In the first case, direct reuse is the reuse of wastewater prior to its discharge back into a river or stream. Once discharged to the river or stream, State law generally provides that wastewater is subject to general appropriation provisions. In order to be used again by the discharger subsequent to its discharge, it must be authorized under an existing appropriation, a "bed and banks" permit for privately-owned groundwater, or a new appropriation (permit) would be required. Current law and policy also provide that unless a return flow requirement is specified in the surface water permit, the surface water user is allowed to utilize up to 100 percent of that effluent in direct reuse as long as the type of use is in compliance with the original permit.

Texas Water Code Section 11.042 also provides for the issuance of a permit for the use of the "bed and banks," whereby permission is sought from the State to use the bed and banks of the State's stream or river simply as a conveyance mechanism to move a defined quantity of water from one location to another where it is removed. Traditionally, this type of permit has been used to convey water in storage to meet a downstream water supply contract. It has also been used to convey groundwater from a well field or contracted State water to a downstream diversion point or allow for conveyance to the point of demand for an interbasin transfer.

Recently, several entities have expressed interest in being able to obtain such permits to "convey" wastewater from the point at which it has been discharged to another point somewhere downstream where it would be diverted and the wastewater again be used. In this manner, the wastewater would be indirectly reused. While reuse of wastewater effluent can potentially be an attractive water supply that could avoid impacts associated with more significant new water supply construction, it is not without its potential impacts and concerns as well. With either direct or indirect reuse, water that was formerly being returned to the watercourse is no longer being discharged (at least in the same volume), thus creating concerns about how this practice might affect downstream water uses of various types and the environment.

Recently-enacted SB 1 generally provides that any request to obtain a "bed and banks" permit for the purposes of conveying return flows for indirect reuse must consider the impacts to downstream water rights and environmental resources. Further, SB1 allows the TNRCC to condition new or amended water rights to provide for a minimum provision of return flows, thus potentially limiting the ability to directly reuse wastewater as well.

2.2.3.6 Allocations of Water Supplies to Water Uses

The allocation of available or new water supplies to future water uses was analyzed at the individual city and county level. Less-impacting and typically more cost-effective water use and supply management measures were first identified to meet future needs, then progressed to more costly, environmentally impacting, or controversial measures.

As a general rule of thumb, this involved modeling expected water conservation savings into all significant water uses as a means of more efficient use of existing water resources and delaying the need for new supply development. Then, expanded use of existing developed supplies, whether under contract or readily available, were identified. Following this typically was expanded use of undeveloped local supplies, such as building the infrastructure needed to access other existing local surface or ground-water supplies or wastewater reuse. Other less-impacting opportunities for additional water supplies were also identified in reallocating reservoir storage or type of use, water marketing, and other such measures.

Finally where still needed, access to additional supply through long-distance conveyance systems, interbasin transfers, or new reservoir development was prescribed. Prior to new reservoir development and interbasin transfers, the entity(ies) in need was expected to achieve an advanced level of water conservation savings.

2.2.3.7 Alternate Water Supplies and Technologies

As conventional water supplies are developed to their economic and environmental limits, alternate supplies and technologies must be considered. These range from water reuse (described previously) to desalination, aquifer recharge, aquifer storage and recovery, and home bases or stand-alone systems. Water supply enhancement techniques such as brush control can also be employed to increase runoff and weather modification can be examined as a possible way to increase precipitation in a given area. The following is a brief description of four of the most commonly found alternative water supplies and technologies.

Desalination of both brackish and saline waters is a proven technology. Texas currently has approximately 16 million gallons of municipal desalting capacity on line or under construction at Bayside, Dell City, El Paso, Fort Stockton, the Lake Granbury area, Kenedy, Lake Possum Kingdom, Robinson, Sherman and South Padre Island. Membrane technologies are being used in Harlingen to treat 4.0 MGD of reclaimed water from that city's wastewater treatment plant for industrial reuse. There are also nearly 30 industrial facilities which use desalting technologies such as reverse osmosis to obtain high purity water. Where brackish ground and surface water (as opposed to water from the Gulf or Mexico or coastal estuaries) is used, desalting costs can be under $2.00 per thousand gallons produced, making desalting of brackish water cost competitive with other more conventional new supplies in some

Exhibit 2-9
Facility Needs Costing Methods

Data sources from:

- Engineering update of previous estimates with later data and cost indices,
- Planning level cost estimates using average cost curves and approximate quantities and routes,
- Existing estimates from the wastewater needs survey,
- Average costs derived from computer analysis of over 5,000 publicly owned water system inventories, future projected populations and deficiencies,
- Cost estimates for flood control projects from Corps of Engineers and TWDB-sponsored studies, and
- Capital improvement plans of larger individual utilities.

Major costing assumptions:

* Current wastewater discharge permit limits, stream standards and waste load evaluations,
* TNRCC design standards for water systems,
* Implementation of approved regional planning studies, and capital improvement programs,
* the Board's most likely series population projections, and
* Conservation will reduce municipal per capita water use, primarily as growth and retrofits occur.

cases. A Federally sponsored planning study in the 1980's identified the potential for desalting at over 500,000 acre-feet per year.

Underground water storage involves the injection or infiltration of water into an aquifer for future use. Such techniques have the advantage over storage in surface water reservoirs because the water is not subject to evaporation and is less easily contaminated. Aquifer recharge holds significant potential for the storage of surplus waters for future use. It is, in effect, making use of an underground reservoir to store water in much the same way in which surface water reservoirs are used. The purpose of aquifer storage and recovery (ASR) projects is slightly different. ASR projects take advantage of unused treatment capacity during off-peak times to treat surface water and store it in an aquifer for recovery during peak times or times of low flow. Both of these technologies hold significant potential to extend both supplies and costly treatment capacity.

Home or stand-alone water systems and on-site technologies for water reuse and recycling also hold potential as supplemental or alternative water supples. The conventional well and septic tank can be replaced by rainwater harvesting systems, gray water recycling systems, and on-site wastewater reuse systems. Even commercial facilities and schools are employing these techniques. For example, several schools in Texas use specially designed recycling systems which collect all wastewater from the bathrooms, treat the water through the use of special equipment and reuse it for toilet and urinal flushing. The result is reductions in water use of over 75% when compared to similar conventional schools. Hundreds of home rainwater collection systems are also being installed in Texas. While none of these home or stand-alone systems provide significant new supplies by themselves, they hold real potential, along with water conservation, to reduce demands on limited conventional supplies or provide water where no conventional sources are available.

2.2.3.8 Facility Needs and Costing

The costs of various types of water, wastewater, and flood protection needs for the State were estimated, using a variety of methods and sources of data (see Exhibit 2-9). A key source of data on major project costing was a recently-conducted study prepared for the Board by Freese and Nichols Engineers, Inc. that updated existing information from previous State Water Plans and incorporated new design and cost information, where available.

Cost estimates were prepared to achieve a level of accuracy adequate for long-range water resource planning at the state level and are not intended to reflect the more exact costs of a final project design, to accurately identify individual utility needs, or to closely specify what the cost of required project environmental mitigation might entail.

2.2.3.9 Regulatory Change

Beyond current legislative action, if the "rule of capture" premise underlying State ground-water law was to change, this would likely affect the ground-water availability assumptions made in the planning process. A more effective means of creating ground-water districts in problem areas could improve water management in those locations. Changes to make the State water rights review and cancellation process more effective could result in some reallocation of existing surface water supplies and would stimulate water marketing. Change in the Federal Endangered Species Act could make it more or less difficult to develop new water supplies. The recent change in Federal requirements for drinking water quality are and will be having significant effects upon water resource needs in requiring the upgrading of water treatment, and in some cases, the development of new higher-quality water supplies.

Regulatory change and changes in other factors underlying the Water Plan's forecasts are inevitable. As directed in statute, the Board is required to periodically review those changed conditions to see if they warrant an update of the Plan's findings and recommendations for the State.

2.2.3.10 Other Issues

Drought

Droughts in Texas are caused primarily by an extensive high-pressure cell called the Bermuda High that drifts latitudinally east to west with the passing of the seasons. When the Bermuda High becomes generally stationary over the southern U.S., the possibility of drought becomes more likely.

Drought is a frequently recurring event in Texas. Texas has experienced severe to extreme droughts in every decade of this century. Five major droughts have occurred statewide since the 1930's, but have differed somewhat in their duration and intensity. The droughts of 1932-34, 1938-40, 1947-48, and 1996, although statewide in extent, were less severe than the extreme droughts of 1950-57 and 1960-67. The U.S. Geological Survey found in most locations in Texas that the probability of the earlier droughts occurring was less than once in about every 25 years (USGS, 1990). The 1960's drought was more severe than the earlier droughts, but less severe than the one in the 1950's. The probability of the 1950-57 drought of record recurring was estimated by the USGS at about once in every 50 to 80 year period. Texas' vast size and differing regional climates mean that hardly a year passes without some portion of the State realizing moderate to severe drought conditions. In fact, the drought of 1996 was so severe that parts of the State recorded lower streamflows than were experienced during the drought of the 1950's. Economic losses associated with this drought were tremendous, owing partly to the fact that the Texas economy is so much larger today than it was forty years ago. The 1996 drought was remarkable for its intensity, but it was fortunately of less duration than earlier droughts.

Drought is a natural part of the hydrologic cycle, but its effects accumulate slowly and can persist over long periods. Drought differs from other natural phenomena, such as floods, hurricanes, and earthquakes, because its presence is often late to be realized. While droughts may not include the dramatic, immediate impacts of floods or hurricanes, they can produce far-reaching consequences of social and economic hardships, environmental perturbations, and population shifts equivalent to or surpassing the effects of most other natural disasters. Because of today's increased demand on water resources, the duration and severity of current droughts reach critical levels much faster than before and may also recover more slowly than in the past.

This natural phenomenon has, in great part, shaped how Texas plans, regulates, and manages much of its water resources. For example, the impetus to form the Texas Water Development Board and develop a State Water Plan was in response to the drought of the 1950s. The 1996 drought provided the impetus for passage of SB 1, which includes legislation requiring drought planning. The very planning basis of the State Water Plan is drought management oriented. For instance, municipal water uses are projected using a “dry-year” or below normal rainfall per capita water use assumption. A reasonable level of water conservation savings are factored into all municipal, industrial, and irrigation forecasts to help minimize water use during both dry and normal periods. Water supplies are planned, wherever possible, to provide a firm or dependable yield that will produce a reliable supply given a recurrence of severe drought. Individual surface water supplies are periodically re-examined by Board staff to ascertain if later history has produced more severe drought conditions (that might produce less reliable supply yield) than for which the project was originally designed. Consideration is also given to other types of management responses such as conjunctive use of surface and ground-water resources and aquifer storage and recovery to help provide for adequate water supplies during dry periods (also see Section 2.2.3.6).

Planning and designing infrastructure to insulate the State against drought effects is only one aspect of needed drought response management. This developed water infrastructure does little to help those human and natural resources depending solely on rainfall and soil moisture (primarily dry-land farming and some environmental water uses) that are most at risk from drought. These resources can suffer discernible effects even with droughts of short duration. Regions underlain by karst aquifers, specifically those that supply 100 percent of an area’s water supply, are especially susceptible to drought. Still at relatively high risk, but somewhat less exposed, are those water uses depending upon instream flows (run-of-river supplied irrigation; aquatic, wetland, and riparian environmental communities; and recreational water uses). Less exposed still are the many urban-type and some agricultural water uses relying on developed surface water reservoir supplies. Typically still less exposed are those water uses (much irrigated agriculture and some urban uses) using certain ground-water resources not dependent upon high rates of aquifer recharge or adversely affected by concentrated high levels of pumping.

In addition to infrastructure approaches to addressing drought, the TWDB and TNRCC have previously required all applicants for State financial assistance or new or amended surface water rights to develop conservation and drought response plans. These local plans provide for a targeted response that, in many cases, is the most effective response to emergency water shortages. However, these efforts have had limited results with only about 15 percent of public water suppliers in Texas having developed such plans. To address these short-comings and provide for a more comprehensive, organized approach to drought response, the recently enacted SB 1 provides for the creation of an inter-agency State body to provide on-going drought monitoring and planning as well as coordinating State programs and drought responses. SB 1 also provides for the development of comprehensive regional water management plans that address drought issues, requires all public water suppliers in the State to develop tailored drought response plans, and requires the larger, existing, surface water rights holders to develop water conservation plans.

Global Climate Change

A series of governmental and academic research efforts and professional workshops around the country have tried to assess the occurrence of global warming, its potential effect upon water resources in the U.S., and what should be appropriate response measures. However, three key factors have previously limited significant action in response to this issue. The first major constraint is the uncertainty and academic debate over the occurrence of global warming. The second constraint is the computational and scientific ability to model its potential effects. Finally, the third issue relates to the potential significant costs of addressing some strategies for response to global warming.

There is a growing body of evidence and general scientific acceptance of the actual occurrence of global warming, hence much of the growing public concern. A series of complex computer models, termed global climate models or GCMs, have been developed in recent years that have been used to assess what might result from global warming. However, due to limited computing capability, data limitations, and a limited understanding of the complex natural forces at work, these models have been somewhat lacking in their analytical and predictive capabilities, particularly incorporating the effect of the world's oceans upon global weather, although modeling capabilities are rapidly improving.

A comparison of the various major GCMs' predictions a few years ago indicated a general concurrence of predictions that global warming would tend to result in overall dryer weather patterns for the interior land masses of the continents. However in the coastal regions, the results were more mixed with several GCMs predicting an overall increase in precipitation, primarily due to increased heat loading into the ocean and resultant increase in hurricane and tropical storm activity. Also given limited computing power, the smallest analytical area (grid cell size) of these models at that time was typically a cell the size of Texas, although more recent advances are shrinking the manageable cell size.

Thus, we have differing forecasts given an area's proximity to the ocean and a predictive result that typically encompasses very large areas. So what does all of this mean to Texas? Will West Texas experience even drier conditions? Will the Gulf Coast be wetter? What will happen in Central Texas? Will the seasonality of wet and dry periods change? Will we experience "monsoon-type" conditions, similar to the Indian sub-continent, where it rains even more intensely during the rainy season and is even drier afterwards?

Due to these uncertainties, various assumed climate change scenarios are sometimes used to evaluate the impacts of climate change on hydrology, water supply, and bay and estuary salinities and communities. Several studies have used an average temperature increase of +2%C and precipitation changes ranging from +20 to -20 percent to assess impacts. A University of Texas researcher (Ward,1992) concluded that land runoff would decrease by 25 percent statewide with a +2%C temperature increase and a 5 percent precipitation decrease; lake evaporation would increase by 12 percent and river flow to the coast would decrease by 35 percent. A TWDB report (Brown et. al.,1993) looked at the climate change effects on 13 reservoirs in the state and evaluated the impacts on water supplies in eight water regions of Texas. With an increase in temperature but no precipitation change, there would be minor water supply problems in the West Central and South Central regions that could be alleviated by expanding water supplies. The Rio Grande and Far West regions would also have minor problems but finding structural solutions such as new water supplies to reduce shortfalls would be difficult. The increased precipitation scenario (+20 percent) would not cause new water supply problems statewide, but the decreased precipitation scenario (-20 percent) would result in significant decreased yield in surface water supplies in every region.

Also in the 1993 TWDB report, several climate change scenarios were used to evaluate climate change effects on river flow and inflow over a 50-year period to five Texas estuaries (Trinity-San Jacinto, Lavaca-Colorado, Guadalupe, Mission-Aransas, and Nueces estuaries). Water use projections for the year 2040 with increased population were included in the analysis and showed that the decrease in inflow resulting from increased water use in 2040 would be less than the decrease in inflow resulting from a 2%C temperature increase (without any change in precipitation or water use). The relationship between precipitation change and estuarine inflow would be decidedly nonlinear: a 20 percent precipitation increase would result in 31 to 64 percent inflow increases for five estuaries while a 20 percent precipitation decrease would result in 39 to 62 percent inflow decreases. Ward (1992) determined that total inflow to the estuaries would be only 16 percent of the 1980 inflows if conditions similar to the drought of the 1950's occurred. However, global climate change is most likely a long-term phenomenon, and its effects may not be manifested within even a 50-year time period.

The 1993 TWDB report also found that freshwater inflow strongly influences estuarine salinity by diluting estuarine water; increases in inflow reduce salinity while decreases in inflow increase salinity. Neither the increase in water use by 2040 nor the small reduction in inflow due to the effect of temperature alone would be great enough to cause a noticeable increase in salinity. However, the ±20 percent precipitation change scenarios would result in noticeable salinity changes. The Trinity-San Jacinto Estuary, with the largest inflow of the five estuaries studied, would have the greatest salinity change: a 20 percent decrease in precipitation would raise salinity in Trinity Bay, close to the Trinity River, from a normal 7.4 parts per thousand (ppt) to 11.8 ppt (ocean water has a salinity of about 35 ppt and freshwater has a salinity of 0 ppt); a 20 percent increase in precipitation would lower Trinity Bay salinity to 5.2 ppt. Salinities at lower Galveston Bay sites near the entrance to the Gulf of Mexico would either increase by 2.8 ppt or decrease by 1.6 ppt from 14.2 ppt. The effect on salinity would be much smaller in the Nueces estuary that currently receives much lower inflows. The 1993 TWDB report indicated that a 20 percent precipitation increase would decrease Nueces and Corpus Christi bay salinities of 22 and 30 ppt by no more than 0.3 ppt while a 20 percent precipitation decrease would raise salinities by no more than 1 ppt.

Global warming may raise sea level by melting polar ice sheets and high mountain glaciers, and by the thermal expansion of seawater, thus potentially inundating large coastal areas and affecting both human infrastructure and ecological resources. An increase in coastal water elevation of 45 cm would increase coastal bay volumes by 25 to 150 percent, with the greatest increase in the shallowest bays (North et. al., 1995). Except for the most optimistic scenarios of precipitation increase, inflows would increase at a lower rate than bay volume, so a general bay salinity increase is likely throughout the coast. Coastal wetland habitat types (freshwater marsh, saltwater marsh, and swamps) would be reduced by the decrease in inflow and increase in salinity, and wind-tidal flats and seagrass beds would increase unless precipitation increased drastically. Oyster reef habitat would decrease under most scenarios in the central and southern estuaries, but would increase in the most northern estuary, Sabine Lake, where salinities are currently too low for good production. In general, the other commercial shellfish species—brown shrimp, white shrimp, and blue crab—would tend to decrease in most bays where salinities increased according to Board research in 1995 (North, et. al.). Climate change conditions that increase temperatures and salinity would tend to favor increased finfish production (spotted trout, red drum, and black drum).

While one can speculate on modeling scenarios and potential outcomes, various studies and professional workshops have debated what are appropriate water management responses given these uncertainties. Some very expensive responses could include redesigning reservoirs to accommodate a shift in climate or its seasonality, or beginning to evacuate coastal areas given potential sea level rise from melting polar ice caps. Most agree that such actions are premature. Most professionals agree that an array of responses to global warming that are appropriate today just happen to be those that additionally make good water management sense in these times (i.e., water conservation, drought planning/response management, diversifying water supplies, systems operations, conjunctive use management, aquifer recharge, minimizing evaporative losses, etc.).

Both computing power and analytical capabilities are improving, and the quality of longer-range climatic predictions will hopefully improve as well as addressing smaller regional areas. Until such time as a preponderance of better information will sway both professionals and the general public alike, it is not probable that a significant public investment will be made to address any unique, expensive effects of global warming beyond the better water management efforts already being implemented today.

Flooding

Given the diverse climatological, physiographic, and socioeconomic features of Texas, the State experiences a wide array of flooding conditions of varying cause, frequency and severity. Serious flooding conditions, ranging from hurricane/tropical storm flooding of flat coastal areas along the Texas Gulf to high-velocity flash flooding in the narrow ravines and gorges of Central and West Texas to the lower velocity, but high volume riverine flooding in North Central, Northeast and East Texas, affect more than a quarter of the State.

Major flooding and erosion damage can occur in urban and rural floodplain areas from coastal, riverine and overland flooding. Flooding can also be caused by the failure of protective measures, ocean shoreline retreat, land subsidence, and by fluctuating reservoir levels along lake shores. An acceleration of the current trend of a relative rise in the sea level along the Texas Gulf Coast could significantly increase coastal and adjacent riverine flooding. Damage can result from sudden flash flooding or be the result of more predictable, gradual rising and receding waters.

Based on the Natural Resources Conservation Service (formerly SCS) findings in 1984, Texas has the greatest acreage of rural floodplain land (slightly more than 20 million acres) of the 48 contiguous states. According to 1985 data for all states from the Federal Emergency Management Agency (FEMA), Texas also has the greatest acreage (18.3 million acres) classified as floodplain land in identified flood prone communities.

Additional flood protection is needed from both structural and non-structural control measures. In 1996, Texas ranked third in the U.S. (behind Louisiana and Florida) in the number of flood insurance policies in effect and the dollar amount of flood insurance coverage (see Table 2-3). From 1978 to 1996, Texas had the second highest number of flood insurance claims paid by the Federal government with many of these damage claims representing repetitive losses for property in chronic flood prone areas.

Table 2-3
Flood Insurance Statistics for Texas
(As of Dec. 1996)

	Amount	National Ranking
Total No. of Policies	260,040	#3
Annual Premiums	$89.665 mill.	#3
Coverage in Force	$28.358 bill.	#3
Historical Claims Paid ('78 to present)	$1.078 bill.	#2

Source: National Flood Insurance Program, 1997.

Flood protection measures are typically costly, involve environmental impacts, provide direct relief to limited beneficiaries in an area, and involve difficult problems with funding, political decision- making, and infrastructure management. At a cost of hundreds of million of dollars, 17.9 million ac-ft of storage capacity for flood protection has been provided in the State's reservoirs, much at Federal government expense. Non-structural flood control measures can, in many instances, be viable, cost-effective alternatives or complementary measures to costly structural flood control measures. In addition to more traditional and typically expensive structural methods of flood damage control, the implementation and enforcement of floodplain zoning restrictions, including the encouragement of greenbelt parks and other low-intensity land uses in flood prone areas and drainages, can be cost-effective in many cases. Implementation of methods to reduce the rate of rainfall runoff through structural and non-structural means can also reduce the severity of flooding events.

As previously mentioned, much of the major flood control improvements in Texas have been funded by Federal (Corps of Engineers) and local interests. In recent years, tightening Federal budgetary considerations have reduced the Federal sponsorship of such facilities, resulting in increasing cost shares for local government when Federal funds can be made available, or in some circumstances, making such projects infeasible when Federal funding is not available. Further complicating factors are the political and institutional impediments of getting broad public funding support at the local level (usually tax-based financing with voter approval required).

Does an institution exist that can "span" the flooding problem area, implement appropriate structural and non-structural controls to mitigate and/or prevent future flooding, and fairly apportion the cost to those benefitting? Will a majority of voters within the political boundary approve typically significant bond debt to directly benefit what may only be a subset of the electorate within the flood plain? These are tough issues.

There is also a growing need for increased State financial involvement in addressing the flooding issue in Texas. While regional flood protection financial assistance is an existing loan program of the TWDB, the significant cost and political difficulties associated with authorizing and implementing such measures at the local level have noticeably limited its use. The State must soon acknowledge the declining Federal role in this area or face even greater exposure to the significant and growing damage potential of chronic flooding in Texas.