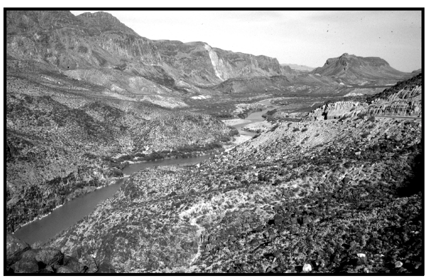
Background

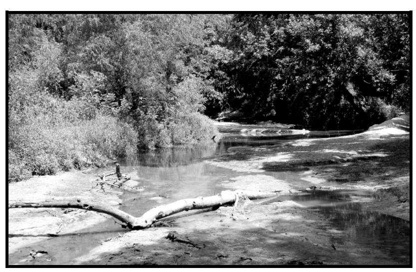
North Texas: Canadian River



West Texas: Rio Grande

Central Texas: Little Blanco River

East Texas: Black Cypress Bayou



South Texas: West Mustang Creek

Background

Land surface form, natural vegetation, soil types, and land use are highly variable in different areas of Texas. When these variables are grouped according to similarities and mapped, 12 distinct Texas ecoregions result. (Figure 3-1)(Omernik and Gallant, 1987). Texas has more ecoregions than any other state due to diversity in these mapped features.

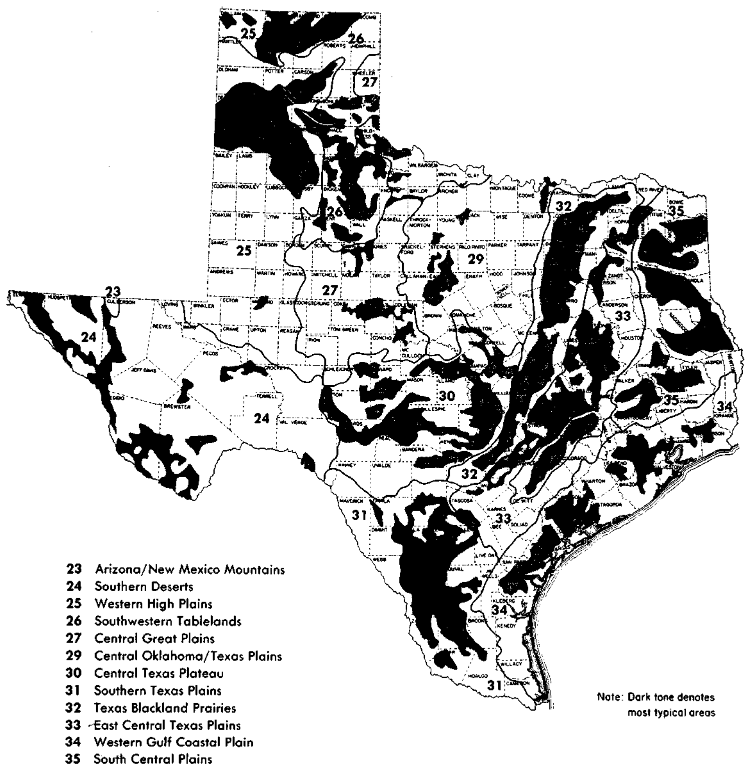


Figure 3-1. Texas Ecoregion Map

The ecoregion map is based on the presumption that streams and rivers derive their character primarily from the watersheds they drain. One only needs to travel across Texas from east to west along IH-10 to realize distinct spatial differences in land form, soil types, natural vegetation, climate, and land uses. The Piney Woods of East Texas slowly transform to the Post Oak and Blackland Prairie areas, where richer, deeper soils promote agricultural activities. In sharp contrast to these areas, farther west one finds the rolling, rough topography and thin rocky soils of the Edwards Plateau. The Trans-Pecos area of Far West Texas, with its arid climate and harsh terrain, produces only sparse, drought-resistant vegetation without irrigation. Land forms in the plains of the northern and southern areas are similar; the treeless high plains in the Panhandle region and Lower Rio Grande Valley are both very flat.

Streams that cross these natural areas, and the reservoirs found within them, are just as distinct (photographs of some examples are shown on the opening page of this section). As water flows over and through the land to the stream channels, it acquires and integrates characteristics from the land, especially from its soils, topography, and vegetation. The bayous and sloughs of the Piney Woods typically have a sluggish flow due to low stream gradients, and are highly-colored dark brown to black due to abundant natural organic matter. The streams that traverse the Post Oak and Blackland Prairie areas, while faster flowing, tend to carry higher suspended inorganic sediment loads due to the erosion of deep soils. The rocky terrain of the Hill Country tends to produce fast-flowing, clear streams due to high stream gradients and thin soils. As a result of the arid West Texas climate, few streams cross the Trans-Pecos area; those that do resemble the Hill Country streams, but often have sandy bottoms and high salt content due to high evaporation rates and flow over salt-bearing strata. The streams of the high plains and Gulf coastal plains typically have low stream gradients, sandy bottoms, and shallow water that spreads out over wide stream channels.

Texas is dominated by a network of 15 major river basins that generally flow from north to south, eventually entering seven coastal bay systems that line the Gulf of Mexico shoreline (see map of major river basins at the opening to the Introduction Section). Portions of the Red, Sabine, and Rio Grande form parts of the borders on the north, east, and south, respectively, that give geographic definition to the State. Large quantities of water are also hidden beneath the ground in a system of aquifers. The State has developed a comprehensive water plan to alter this network of surface and groundwater in order to meet the needs of a growing population (TWDB, 2002).

Texas is the second-largest state in the United States, occupying about 7 percent of the total U.S. water and land area. Texas includes 267,277 square miles, of which 5,363 square miles are covered by water. The 4,959 square miles of inland water ranks Texas first in the 48 contiguous states, followed by Minnesota (4,780 mi^2), Florida (4,683 mi^2), and Louisiana (4,153 mi^2)(Ramos, 2002). Groundwater resources are stored in nine major aquifers and 20 minor aquifers that underlie approximately 76 percent of state's surface area. Texas population ranks second in the U.S., totaling 20,851,820 (2000) residents. The Texas population has shown steady

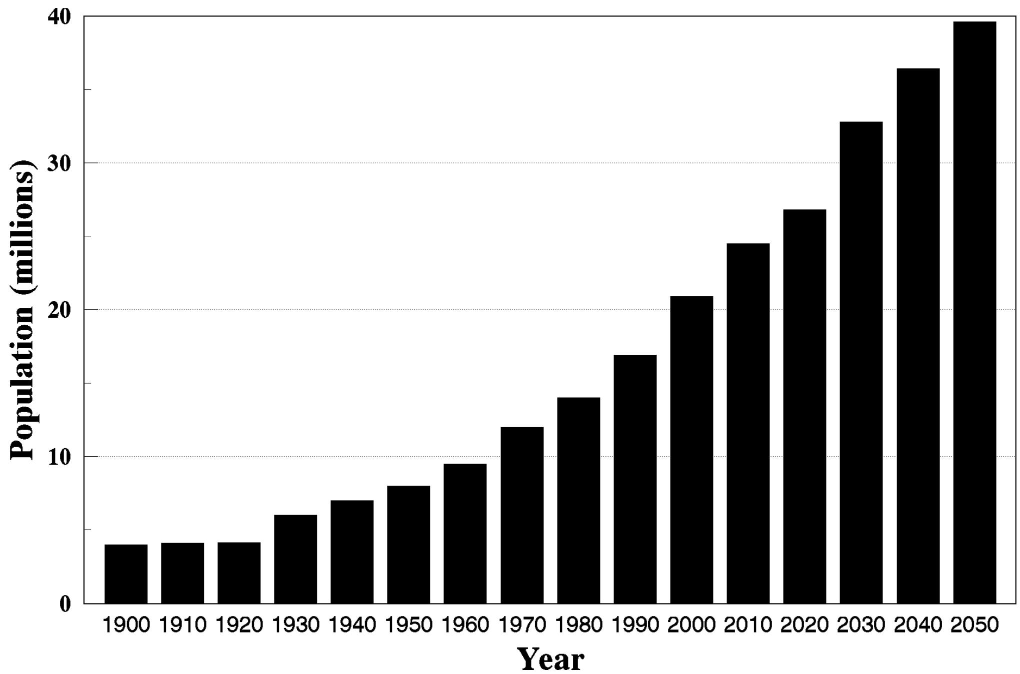


Figure 3-2. Historical and Projected Texas Population, 1900-2050

growth from 1900 (3,480,710) to 2000 (Figure 3-2) (TWDB, 2002). In the ten years1990 to 2000), Texas has experienced a growth in population from 16,986,510 to 20,851,820, an increase of 22 percent. In part, due to the favorable climate, robust economy, clean air and water, and diversity of natural features, the Texas population is forecasted to show strong trends for increasing numbers. Using present moderate trends in growth, the Texas population is projected to nearly double, increasing to 39,600,000 by 2050.

Water used by the growing Texas population is stored in underground aquifers and surface reservoirs. Precipitation which supplies both ground-water and reservoir systems is highly variable across the State due to changing climatic conditions. The eastern third of the state experiences high relative humidity, abundant rainfall, warm to hot summers, and mild, wet winters. The middle third of the state typically has moderate humidity, moderate amounts of precipitation, hot summers, and dry winters. The western third of Texas is characterized by low relative humidity, episodic rainfall, hot, dry summers, and mild, dry winters.

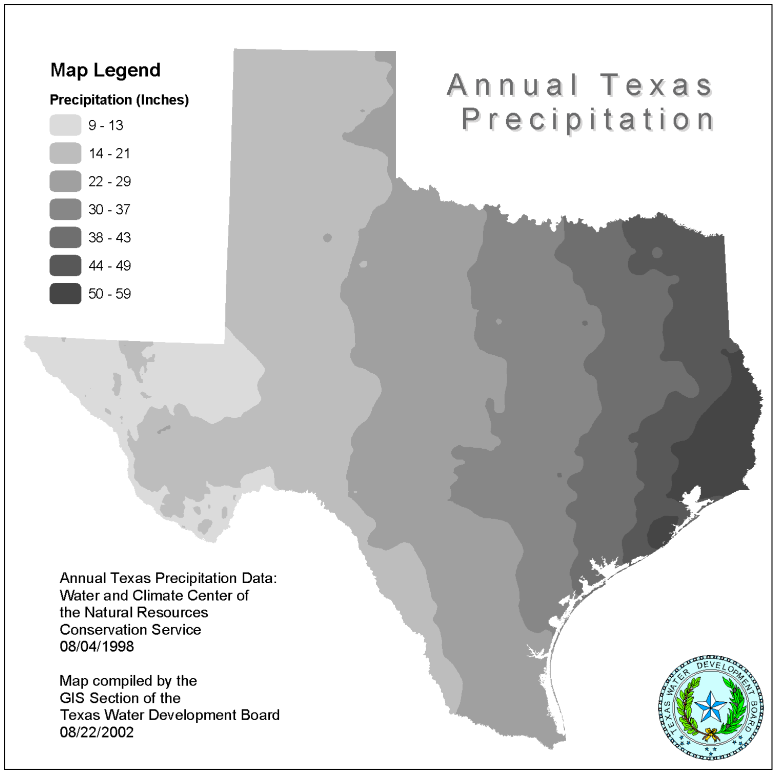


Figure 3-3. Map of Annual Texas Precipitation

The rainfall distribution ranges from 9-13 inches on average in the desert mountains in the western portion of the state to an average of 50-59 inches annually in the coastal plains and coniferous forests in the southeast (Figure 3-3)(TWDB, 2002). Yearly average rainfall varies little from the Texas Panhandle in the north to the Lower Rio Grande Valley of extreme south Texas. In the northern Panhandle region rainfall averages 14-21 inches per year and in the Lower Rio Grande Valley, annual rainfall typically averages between 22 and 29 inches.

Unfortunately, rainfall is not equally distributed throughout the year in any region of Texas. April and May are generally the wettest months in most regions, except for the High Plains and Trans Pecos areas where rainfall is most plentiful in the summer. The eastern and central portions of the State typically receive secondary spikes in rainfall near the onset of autumn. September rainfall in these areas usually approximates that which falls in April. This pattern reflects the influence of tropical weather systems that migrate out of the Gulf of Mexico in late summer and early fall. These

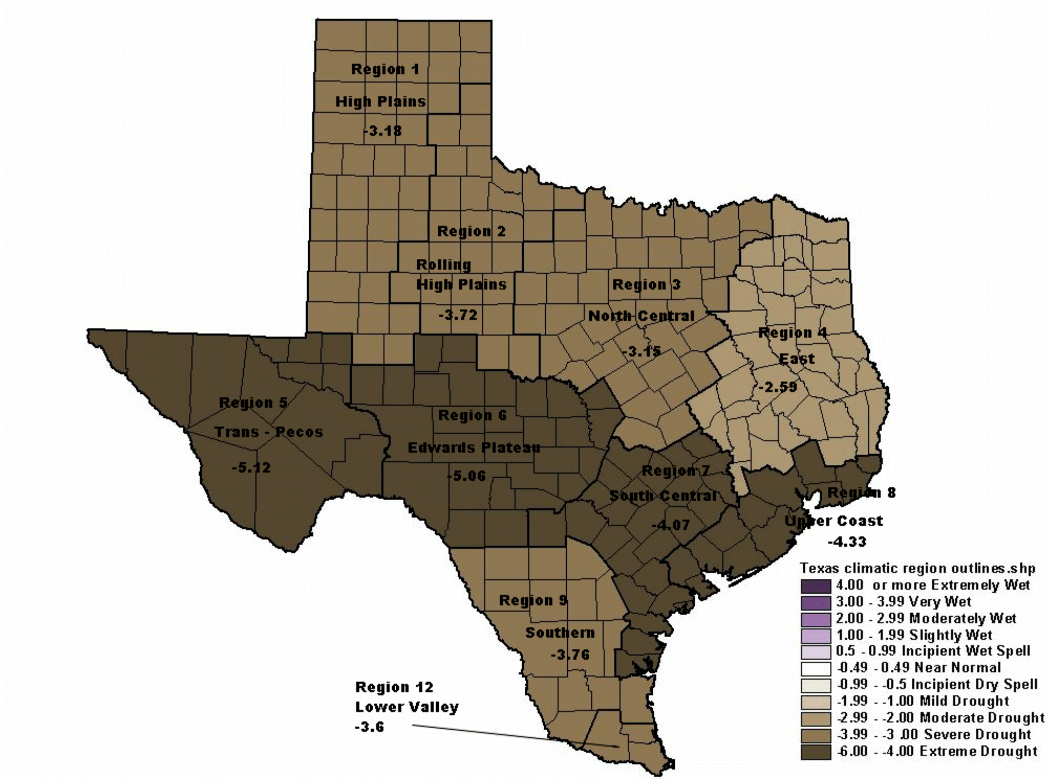


Figure 3-4. Palmer Drought Index Values for Texas, September 2000

tropical systems often produce heavy, sustained rainfall and can become real drought busters.

During most Texas summers, due its geographic location, a huge dome of hot, dry air envelops the State, affording few opportunities for significant cloud cover. During these clear days, high, often triple-digit, temperatures and deficient rainfall may contribute to extensive damage to agricultural crops and shortfalls of streamflows, reservoir levels, and groundwater may occur. The large mileage of intermittent streams in most regions of Texas is largely due to the lack of summer rainfall and high evaporation rates brought on by the elevated, incipient temperatures. Reduced streamflows and falling reservoir and aquifer levels are exasperated when lack of rainfall extends into other seasons and drought conditions develop.

Moderate to severe drought conditions commonly occur in one or more regions of the State each year as revealed by the Palmer Index for September 2000 (Figure 3-4). The Palmer Index takes into account the amount of moisture required to have normal weather for a specific region, and

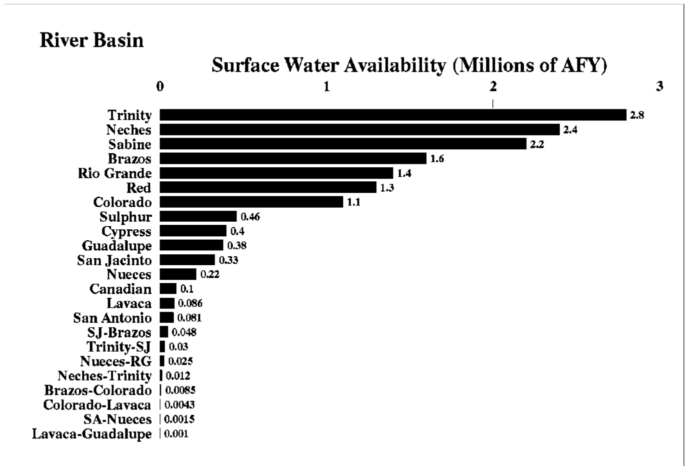


Figure 3-5. Surface Water Availability in Major Texas River Basins

describes departures from normal conditions by a simple numerical scale. Positive values indicate wetter than normal conditions, while negative values represent varying degrees of drought. Although the Palmer Index is primarily an index of meteorologic drought, it also takes into account hydrological factors such as precipitation, evaporation, and soil moisture.

Most of Texas' major river systems originate and drain eastern and middle portions of the State, paralleling average annual rainfall patterns. In terms of surface water availability, the Trinity River is the largest in the State, followed by the Neches, Sabine, and Brazos (Figure 3-5)(TWDB, 2002). Most of the major river systems have been dammed to form reservoirs and provide water for domestic and industrial uses. Reservoir development has been emphasized as a means for providing surface water to meet the growing Texas population since the early 1900's. In 1900, only one major reservoir existed in Texas; by 1940 there were 41; by 1960 105 existed; by 1980 there were 184; and by 2000 there were 211 (TWDB, 2002). Development of reservoirs began to slow in the 1970's and reached a plateau in 2000 due to environmental issues, increased construction costs, and reduced number of potential sites.

In 2000, Texas had enough water supply in surface and groundwater sources to meet major demands for water. Major demands on water supplies come from six primary sources: (1) agricultural irrigation, (2) municipal, (3) manufacturing, (4) steam-electric generation, (5) livestock watering, and (6) mining. With a growing population, it is no surprise that demand for water in Texas is expected to increase substantially over the next 50 years with the total increasing from 17 million acre feet per year (AFY) to 20 million AFY (Figure 3-6). By the year 2050, municipal

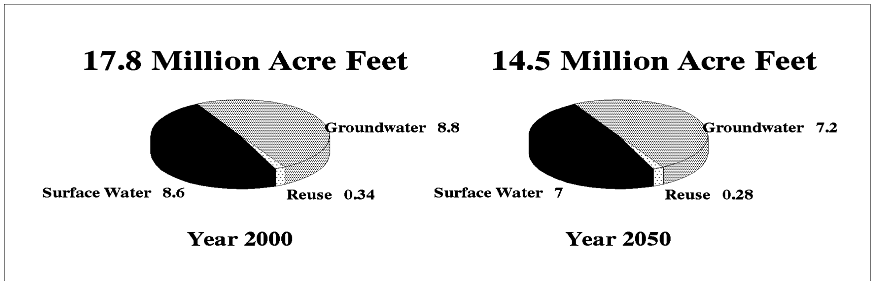


Figure 3-6. Comparison of Major Demands on Texas Water Supplies

demand for water is expected to increase from 4.3 million AFY to 7.1 million AFY, an increase of 67 percent. Similarly, manufacturing demand for water is expected to increase from 1.8 million AFY to 2.7 million AFY, an increase of 47 percent. Irrigated agriculture has historically been the largest user of water across the State. However, due to improved irrigation practices that improve irrigation efficiency, declining groundwater supplies, and voluntary transfer of water rights from irrigation to municipal uses, irrigation demand is forecasted to decline from 9.7 million AFY to 8.5 million AFY, decrease of 12 percent. Despite the decline in demand over the next 50 years, irrigated agriculture, at 8.5 million AFY, will remain the largest user of water in the State.

The amount of water available, the condition of facilities to convey water to users, and water rights and contracts determine current and forecasted

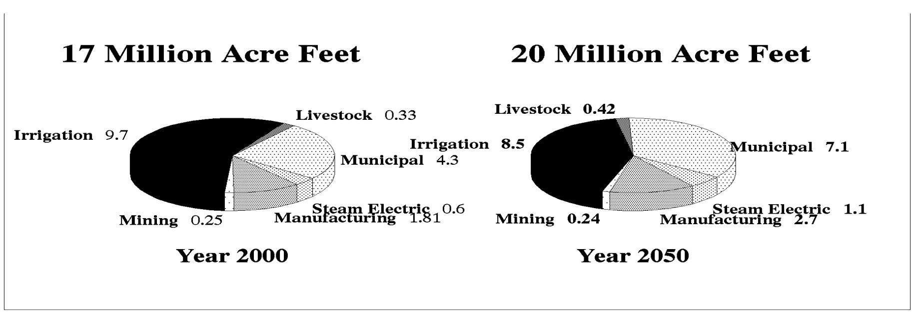


Figure 3-7. Comparison of Texas Water Supplies to Meet Demands

water supplies. In 2000, Texas had approximately 14.9 million AFY of total surface water available, but only 8.6 million AFY could be used due to restrictions in infrastructure conveyance capacity, water permits, and contracts (Figure 3-7)(TWDB, 2002). By 2050, total surface water available and water supplies are expected to be 14.4 million AFY and 7 million AFY, respectively. These respective declines of 500,000 AFY and 1.6 million AFY are expected unless conveyance systems are changed and contracts that are in the planning cycle are renewed.

Groundwater is stored in nine major and 21 minor aquifers in the State. Major aquifers are generally large, regional aquifers that can produce large quantities of water. Minor aquifers are considered more localized and produce less water. The occurrence of major aquifers does not parallel patterns in annual precipitation across the State. In terms of availability, the Ogallala, located in the Texas Panhandle, is by far the largest (6.4 million AFY), followed by the Gulf Coast (1.6 million AFY), Carrizo-Wilcox (1.6 million AFY), Edwards-Trinity Plateau (0.98 million AFY), and the Queen City (0.68 million AFY)(TWDB, 2002).

Total groundwater available in 2000, estimated by planning groups for the state water plan using differing development scenarios, was about 14.9 million AFY. The amount of groundwater available as supply, based on existing wells and pipeline conveyance systems was estimated at 8.8 million AFY in 2000. The total groundwater available and amount of supply are expected to decline to 13.1 million AFY and 7.2 million AFY, respectively, in 2050, due to declines in the Ogallala, Gulf Coast, Hueco-Mesilla Bolsum, and Carrizo-Wilcox aquifers(TWDB, 2002).

The bottom line is that new management strategies will have to be emphasized and implemented in Texas where the population and demand for water are forecasted to continue moderate growth for the next 50 years, while surface and groundwater supplies are expected to decline. According to the newly adopted Texas Water Plan, traditional approaches for surface water (construction of eight new major reservoirs and ten smaller ones) and groundwater (installation of new wells and additional pumping of existing wells) will fall short in providing supplies needed in 2050 (Figure 3- 8)(TWDB, 2002). However, the plan indicates when new strategies are emphasized for groundwater (artificial recharge and groundwater transfer through pipelines) and surface water (conservation, reuse,

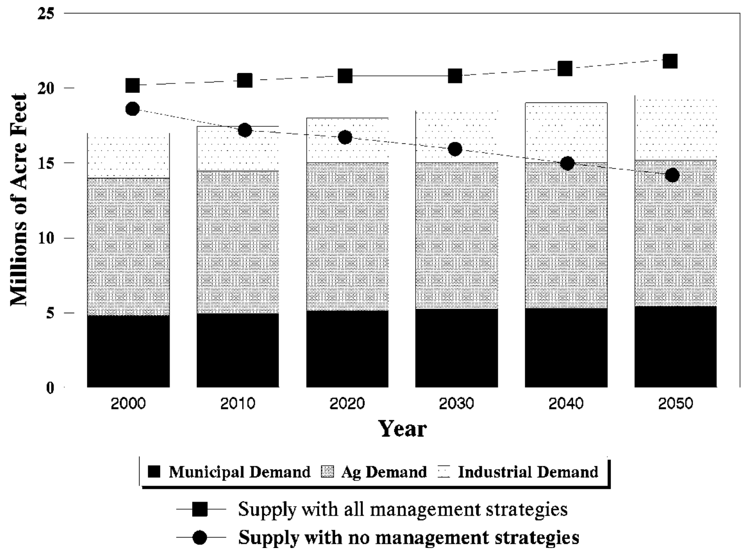


Figure 3-8. Projected Texas Water Supplies and Demands, 2000-2050

desalination, brush control, and new conveyance systems), then at least on a volumetric basis, available water supplies will be greater than projected demands for water in 2050 (Figure 3-8)(TWDB, 2002).

One problem with the newly developed water plan is that it does not recognize environmental water needs as a separate demand. The need to provide minimum base flows for streams and rivers and freshwater inflows to coastal estuaries to preserve and protect indigenous flora and fauna must be considered and factored into the equation to balance water supply and water needs in Texas. The Texas Parks and Wildlife Department (TPWD) and Texas Water Development Board (TWDB) are spearheading studies to determine these minimum flows. As the Texas population has continued to grow, pushing it to the second most populous state in the nation, the need to conserve, protect, and restore surface and groundwater supplies has never been more paramount.

Water quality management programs administered by the TCEQ have one basic goal, that of protecting and restoring Texas' surface and groundwater resources. The TSWQS provide the framework for accomplishing this goal. The TSWQS recognize the hydrologic and geologic diversity of the state by dividing major river basins (see map on the opening page of the Introduction section), reservoirs, and bays into defined segments. The TSWQS recognize 225 stream and river segments, 100 reservoir segments, 48 bay segments, and the Gulf of Mexico, which is treated as one segment

(Table 3-1) (TCEQ, 2000). All other streams and rivers, reservoirs, and estuaries are unclassified.

Rivers and Streams

Streams and rivers are characterized by flow. Perennial streams and rivers flow continuously, all year around. Intermittent streams and rivers become completely dry for a period of a week or longer during most years due to dry climatic conditions or upstream withdrawals. Some intermittent streams and rivers become completely dry in shallow portions of their channels, but maintain perennial pools in deeper areas. Many streams and rivers in Texas originate as intermittent streams that flow only following heavy rain showers. Others originate from abundant spring sources and are perennial.

Pollutants discharged from municipal and industrial point sources or contained in diffuse nonpoint source runoff often directly affect the health of streams and rivers. Occurrence of depressed dissolved oxygen concentrations, elevated fecal coliform densities, and excessive nutrient loading are often associated with the discharge and assimilation of point and nonpoint pollutants in streams and rivers.

The health of streams and rivers is directly linked to habitat integrity instream, on the banks, along the riparian areas, and in adjacent wetlands. Stream quality may be altered if activities damage shoreline and wetland vegetation, which filter pollutants from runoff and bind soils. For example, riparian vegetation is often removed during channelization projects aimed at improving flow characteristics in streams and rivers. Removal of the vegetation eliminates shade that moderates stream temperature. Stream temperature, in turn, affects the availability of dissolved oxygen in the water column for fish and other aquatic life.

In order to accurately determine the magnitude and extent of the nation's total waters, the EPA has developed the river reach file and database. The computerized digital line graph and database reflect hydrologic features found on 1:100,000 scale U.S. Geological Survey (USGS) hydrologic maps. For instance, since 1990, the estimated number of Texas stream miles has increased from 80,000 to 191,228 due to improved resolution of map measurement techniques (Table 3-1).

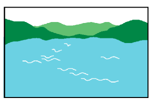
Texas has approximately 191,228 miles of streams and rivers, with 2,475 miles forming portions of the borders with adjoining states and Mexico (Table 3-1). Some 11,247 Texas streams and rivers have been named; their

Table 3-1. Atlas of Texas Surface Waters

State population (2000)	20,851,820
State land surface area (square miles) State water surface area (square miles	261,914 5,363
Total number of river and stream miles Number of intermittent stream miles (subset) Number of perennial river miles (subset) Number of ditches and canals (subset) Number of border miles (subset) Number of named streams and rivers Number of named stream and river miles Number of TCEQ classified stream and river segments Number of TCEQ classified stream and river miles Number of TCEQ unclassified stream and river segments Number of TCEQ unclassified stream and river miles	191,228 144,603 40,194 6,431 2,475 11,247 80,000 225 14,238 319 6,048
Number of reservoirs ($\geq$ 10 acres)	9,933
Number of total acres of reservoirs > 10 acres	1,994,600
Number of major reservoirs (> 5,000 ac-ft)	211
Total acres of major reservoirs	1,690,140
Total number of TCEQ classified reservoir segments	100
Total number of TCEQ classified reservoir acres	1,552,827
Total number of TCEQ unclassified reservoir segments	29
Total number of TCEQ unclassified reservoir acres	34,024
Square miles of bays	2,394
Number of TCEQ classified estuary segments	48
Square miles of TCEQ classified estuary segments	2,001.6
Number of TCEQ unclassified estuary segments	9
Square miles of TCEQ unclassified estuary segments	2.4
Square miles of TCEQ classified Gulf waters	3,879
Number of classified Gulf segments	1
Number of Gulf coastline miles	624
Acres of inland wetlands	6,471,012
Acres of coastal wetlands	1,648,400

* EPA RF3\DLG estimates

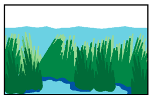
combined length is approximately 80,000 miles. Of the total stream and river mileage, 144,603 miles (76%) typically have intermittent flow (stream channel becomes completely dry) in some portion of the water body for at least one week during most years. Approximately 40,194 miles (21%) of stream and river miles are perennial, meaning that they have sustained flow throughout the year. A small portion of stream and river miles (6,431 miles; 3.4 %) are canals and ditches. Most of the classified stream and river segments, which comprise 14,348 miles, have been established by the TCEQ on larger perennial water bodies. The mileage of classified streams and rivers accounts for about 36 percent of the total perennial miles.



Lakes, Reservoirs, and Ponds

Lakes, reservoirs and ponds are depressions that hold water for extended periods of time. These water bodies may receive water carrying pollutants from streams and rivers, runoff, direct discharges from domestic and industrial sources, and groundwater discharges. Pollutants become trapped in ponds, lakes, and reservoirs because relatively low current velocities, long storage times, and lack of shading by riparian canopy encourages uptake of dissolved materials by algae and bacteria, and their subsequent sedimentation, along with much of the particulate load delivered through tributary inflows. Therefore, they are especially vulnerable to additional pollutants from human activities in their watersheds. Even under natural conditions, sediment, nutrients, and organic materials accumulate in ponds, lakes, and reservoirs as part of a natural aging process called eutrophication. Unnatural sources of nutrients (such as point source domestic discharges and nonpoint source runoff) may overload lake and reservoir systems and accelerate eutrophication. Excessive growths of algae and macrophytes, depressed dissolved oxygen concentrations, and elevated pH values are often symptoms of eutrophication from anthropogenic sources.

Texas has approximately 9,933 reservoirs and lakes that cover 10 surface acres or more. Collectively, these reservoirs and lakes cover approximately 1,994,600 acres. Major reservoirs having more than a 5,000-acre-foot capacity number 211 and together cover approximately 1,678,708 acres (Table 3-1). The TCEQ has established 100 reservoirs as classified segments; their surface acreage accounts for about 93 percent of the total acreage for major reservoirs and about 78 percent of the acreage for all reservoirs and lakes.



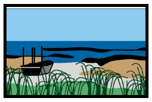
Estuaries

Estuaries are coastal waters where inflowing stream or river water mixes with, and measurably dilutes, sea water. In Texas, estuaries are the lower tidal portions of rivers and streams that directly enter the Gulf of Mexico or its bay systems. For this report, tidal portions of streams and rivers, although estuaries, are considered part of the stream and rivers category. Tidal streams and rivers are usually confined by stream banks and they are characterized in miles rather than area (square miles).

Estuaries serve as important nursery areas for many commercial fish and most shellfish populations, including shrimp, oysters, crabs, and scallops. The Texas fish and shellfish industry relies on productive estuarine waters and their adjacent coastal wetlands to provide healthy habitat for important life stages of fish and shellfish development. Recreational anglers also enjoy harvesting fish that reproduce or feed in estuaries, such as red drum, spotted seatrout, and flounder.

Pollutants from both local and distant sources tend to accumulate in estuaries. Most pollutants that enter streams and rivers eventually migrate toward the coast. As rivers approach the coast, their mouths broaden and stream velocity decreases. The reduction in stream velocity and fluctuation of tides from the Gulf reduce flushing and entrap nutrients and pollutants at the head of estuarine waters. This natural trapping process establishes the basis for highly productive estuarine ecosystems, but also makes estuaries vulnerable to excessive pollutant loading from point and non-point sources.

Historical development patterns along the Texas coast have amplified natural trapping functions and overloaded the estuaries. Industrial development and population centers have clustered around estuaries and bays with access to shipping and barge transport. Adjacent water bodies are used for waste disposal. The Galveston Bay Estuaries Program and Coastal Bend Bays and Estuaries Program were created by the TCEQ and EPA to address a wide array of problems (for example, contaminated sediment, nutrient enrichment, depressed dissolved oxygen concentrations, and declining fish, shellfish, and sea grass populations) and develop management strategies to deal with them. Texas has 2,394 square miles of bays and estuaries (Diener, 1975) (Table 3-1). Forty-eight bay systems have been classified by the TCEQ. Classified bays cover approximately 2,002 square miles and account for about 84 percent of all the bay and estuary area.

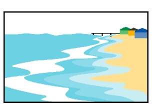


Wetlands

Wetlands are generally considered as a transition zone between land and water where the soil is occasionally or permanently saturated with water. In Texas, there are approximately 6,471,012 acres (10,108 mi^2) of inland wetlands and 1,648,400 acres (2,575 mi^2) of coastal (saltwater) wetlands (Table 3-1). Wetlands are populated with plants that are specially adapted to grow in standing water or saturated soils. There are many different types of wetlands, including marshes, bogs, swamps, mangroves, prairie playas, and bottomland hardwood forests. Wetlands may not always appear to be wet. Many wetlands dry out for extended periods of time. Other wetlands may appear dry on the surface but are saturated with water beneath the surface.

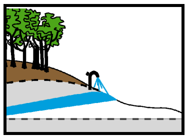
Saltwater wetlands fringe estuaries; freshwater wetlands border streams, rivers, and reservoirs or occur in isolation. Generally, wetlands improve water quality, provide critical habitat for a wide variety of fish and wildlife, provide storage for flood waters, and stabilize shorelines. Wetlands filter nutrient and sediment from water before it enters adjacent water bodies and underlying groundwater aquifers.

Wetlands can be physically destroyed by filling, draining, and dewatering. Wetlands can also be damaged by the same pollutants that degrade other water bodies, such as nutrients, toxic substances, and oxygen demanding wastes.



Ocean Shoreline Waters

Gulf of Mexico shoreline waters in Texas provide critical habitat for various life stages of commercial fish and shellfish (such as shrimp), provide habitat for endangered species (such as sea turtles) and support popular recreational activities, including sport fishing, swimming, surfing, and boating. The Gulf of Mexico encompasses an area of approximately 3,879 square miles within Texas' jurisdiction, from Sabine Pass on the north to Brazos Santiago Pass on the south (Table 3-1). About 624 miles of the Gulf form the Texas coastal shoreline. Despite its vast size and volume, the Gulf of Mexico is vulnerable to impacts from pollutants, especially in the near shore waters that receive inputs from treated domestic and industrial waste discharges, adjoining water bodies, and offshore dumping. Oil spills from tankers or offshore drilling facilities may also generate persistent adverse impacts on the shoreline of the Gulf.



Ground Water

Beneath the land's surface, water resides in two general zones, the saturated zone and the unsaturated zone (Figure 3-9). The unsaturated zone lies directly beneath the land surface, where air and water fill the spaces between soil and rock particles. Water saturates the pore spaces in the saturated zone, which lies beneath the unsaturated zone in most cases. The term "groundwater" applies to water in the saturated zone. Surface water replenishes (or recharges) groundwater by percolating through the unsaturated zone. Therefore, the unsaturated zone plays an important role in groundwater hydrology and may act as a pathway for groundwater contamination.

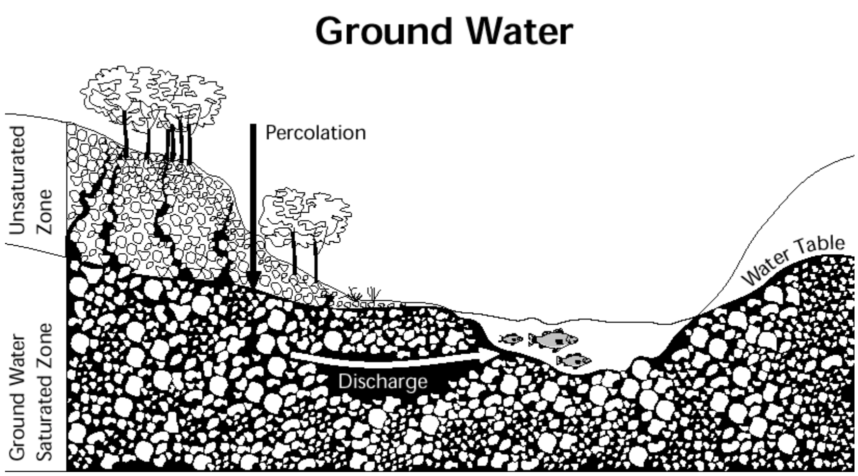


Figure 3-9. Groundwater Schematic