DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

HYDROLOGIC INVESTIGATIONS
ATLAS HA–706 (SHEET 1 OF 2)

INTRODUCTION

The Coastal Plain from western Florida to the Rio Grande is an important agricultural area. Pumpage for irrigated agriculture, which is the largest use of ground water in the study area, was more than 4,500 Mgal/d in 1975. Withdrawal of ground water for municipal and industrial uses was estimated to be about 1,300 Mgal/d for the same year. An annual increase in ground-water withdrawal of 30 Mgal/d has occurred in the study area between 1950 and 1980 (Grubb, 1984).

The increasing annual withdrawals of ground water have resulted in lowering of the potentiometric surface, movement of the saline-fresh water interface into parts of the aquifer system that were previously fresh, and land-surface subsidence in areas of municipal and industrial well fields that are pumping large volumes of ground water. Land-surface subsidence also has occurred in some rice-irrigated areas. These changes in the hydrologic system are affecting the availability of suitable quality water for irrigation and for municipal and industrial uses. The availability of suitable quality water will, in part, affect the economy of the area. The suitability of water for irrigation and for municipal and industrial uses is determined in part by the concentration of dissolved solids and by the water type.

In 1981, the U.S. Geological Survey began a study of the Tertiary and Quaternary aquifers, which supply most of the ground water used in the area, for the purpose of defining the geohydrologic framework in which the aquifers exist, describing the chemistry of the ground water, and analyzing the regional ground-water flow patterns within the flow system. The Tertiary and Quaternary aquifers underlie about 230,000 mi^2 in parts of 10 States—Alabama, Arkansas, Florida, Illinois, Kentucky, Louisiana, Mississippi, Missouri, Tennessee, and Texas. The plan of study for the Gulf Coast Regional Aquifer-System Analysis (RASA) was described by Grubb (1984). The geohydrologic framework of the Coastal Plain from western Florida to the Rio Grande was described by Hosman (in press).

The aquifer and confining systems being studied consist mainly of sediments of Tertiary and Quaternary age. In ascending order, the Tertiary sediments consist of the Midway Group and lower part of the Wilcox Group of Paleocene age; the upper part of the Wilcox Group, the Claiborne Group and the Jackson Group of Eocene age; the Vicksburg Group of Oligocene age; sediments of Miocene age; and sediment of Pliocene age. The Tertiary sediments are composed predominately of alternating beds of sand and clay, with some interbedded gravel, silt, lignite, and limestone. Thick clay layers restrict ground-water flow between the Tertiary sediments and to or from the underlying Cretaceous sediments. For the purpose of the study, the multiple aquifers in the Tertiary sediments were divided as follows: (1) Wilcox aquifers, (2) Claiborne aquifers, (3) Jackson aquifers, (4) Miocene aquifers, and (5) Pliocene aquifers. The Quaternary sediments are of Pleistocene and Holocene age and include all alluvial, valley-fill, terrace, deltaic, and natural levee deposits of such age. For the purpose of the study, the multiple aquifers in the Quaternary sediments were not divided into aquifer groups, as was done for the aquifers in the Tertiary sediments, because much of the data in the files either were assigned as Quaternary or the water analyzed was from alluvial or terrace deposits both of which could be of Pleistocene or Holocene age. The multiple aquifers in the Quaternary sediments are referred to as the Quaternary aquifers in this report. A more detailed description of the geology and its areal distribution is presented by Hosman (in press) and by Grubb (1984).

The purpose of this report is to describe the regional variation in dissolved-solids concentrations and primary water types in water from each of the designated aquifers and to relate the concentration of dissolved solids and the primary water type to the suitability of water for irrigation and for municipal and industrial uses. The concentration of dissolved solids, based on median concentrations in 100-mi^2 areas, is described for each of the designated aquifers in ascending order on sheet 1. The statistical mode of the primary water type in individual 100-mi^2 areas is described similarly on sheet 2. The procedure for determining the median dissolved-solids concentrations and the statistical mode of the primary water type is described by Pettijohn (written commun., 1986). Data used in this study were obtained from the water-quality files of the U.S. Geological Survey, files from the petroleum industry prepared by Taylor (1975), and files of the Texas Department of Water Resources.

DISSOLVED–SOLIDS

Because of the solvent property of water, the water in an aquifer can contain many substances in ionic form, that is, electrically charged parts of a molecule. These substances, which usually are minerals in solution, are collectively called dissolved solids. The concentration of dissolved solids in freshwater is, on the average, so small that it is expressed in milligrams per liter (mg/L). However, the concentration of dissolved solids in natural water is not fixed or unalterable. Consequently, the concentration can vary by many orders of magnitude as a result of geochemical and biochemical interaction between water and the geologic material through which it moves. A simple method for categorizing ground water based on dissolved-solids concentration is presented in the following table (Winslow and Kister, 1956):

Water category	Dissolved-solids concentration (milligrams per liter)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	35,000 or more

Dissolved-solids concentration or salinity of water in the aquifer systems in the study area generally increases with depth in the hydropressured (normally pressured) zone. Maximum salinity at most locations occurs near the bottom of this zone or the top of the geopressure zone. The geopressure zone is described by Jones (1968) as that part of the aquifer or aquifer system that has a fluid pressure which exceeds the hydrostatic pressure of a column of water containing 80,000 mg/L dissolved solids. Geopressure may be expressed as a ratio of the measured fluid pressure in an aquifer to the pressure due to the weight of overlying deposits, computed for the depth at which the aquifer occurs.

Geopressure conditions occur in aquifers when water that is released from the compacting aquifer materials is blocked from discharging from the aquifer, thus forming geopressured zones. Three types of blocks or seals that cause geopressured zones to form are: (1) small reservoirs sealed by pinchout; (2) large reservoirs sealed updip by down faulting against a thick shale sequence, and sealed downdip by regional facies changes, and (3) relative position of fault seals in upthrown and downthrown blocks (Dickinson, 1953, p. 423).

Within geopressured zones, the pressure forces saline formation water toward normally pressured aquifers. The intervening clay beds function like membrane filters to freshen the water, which subsequently dilutes the water in the receiving aquifers. Geopressure and trapped radiogenic heat cause diagenesis of montmorillonite to illite in the clay beds. The released freshwater resulting from the diagenesis of montmorillonite either remains in the transformed clay under substantial pressure because the adjacent sand beds are already geopressured, or flows into and dilutes the water in normally pressured aquifers. Osmotic pressures, which are developed by the membrane-like clays and which may be responsible for halting or even reversing those flows, are considered the dominant factor in the preservation of geopressure (Fertl, 1976, p. 16).

Geopressure zones are reported in aquifers in the Wilcox Group, Claiborne Group, Jackson Group, Miocene, and Pliocene deposits and are most prevalent at depths between 5,000 and 15,000 ft. The presence of geopressure zones may affect the water quality in the area of occurrence.

Water for irrigation normally is not treated before it is applied to fields. Therefore the salinity of the applied water is critical for optimum growth of crops. In contrast, modern water management techniques and a variety of available water-treatment processes make possible the use of raw water of almost any quality to produce an acceptable municipal and industrial water supply. However, the cost of producing water of acceptable quality in the volume needed needs to be considered. Following are some general guidelines and recommended limits for dissolved-solids concentration in water that is to be used for irrigation or municipal and industrial supplies.

Acceptable limits of dissolved solids in irrigation water may vary from less than 100 to more than 4,000 mg/L. For example, a sparing application of water with a dissolved-solids concentration of less than 100 mg/L could ultimately damage sensitive crops such as citrus fruit, whereas water with a dissolved-solids concentration of 4,000 mg/L may be used to economically produce salt-tolerant field crops on land with good drainage. This phenomenon occurs because healthy plant growth may be enhanced by one or more of the following: humidity of the plant environment, drainage and mineral characteristics of the soil, water requirements of the plant, duration and frequency of irrigation, the plants' tolerance to salinity, and the presence or absence of sodium ions in the dissolved solids. The relationship of these various factors to each other and to the specific plant needs to be determined before acceptable limits of dissolved solids can be estimated for growing specific crops (U.S. Environmental Protection Agency, 1973, p. 323–338).

The recommended limit for dissolved-solids concentrations in municipal water supplies is 500 mg/L (U.S. Environmental Protection Agency, 1973). In some areas, waters of higher concentration are being used; however, drinking water containing high concentrations of dissolved solids are likely to contain substances that are highly objectionable due to mineral taste, physiological effects, or economic consequence.

The maps on this sheet show the areal distribution of the median dissolved-solids concentrations in water for each aquifer group in the study area. The median concentration of dissolved solids for each 100–mi^2 area was computed and plotted at the center of each 100–mi^2 area. Points of equal dissolved-solids concentration were connected to delimit ranges of dissolved-solids concentrations. In those areas where no ranges appear or are discontinued, that particular aquifer group is most likely not present or is not being used as a source of water. The maps constructed to show the distribution of dissolved solids for each of the aquifer groups are based on chemical analyses of water from about 21,000 sites. The median dissolved-solids concentrations in water from aquifers in each group will be discussed in ascending order (oldest to youngest).

Wilcox Aquifers

Aquifers in the Wilcox Group are separated from the underlying Cretaceous aquifers by the thick clay layer of the Midway Group. Aquifers in this group are the oldest and lower-most aquifers in the gulf coast aquifer systems except for about 25,000 mi^2 in the northern most part of the Mississippi embayment which include some Upper Cretaceous sediments (Grubb, 1984).

The Wilcox aquifers underlie most of the study area. However, water-chemistry data are few in the following parts of the study area—all of Arkansas, south one-half and northeast one-fourth of Louisiana; south one-half of both Mississippi and Alabama; and southeast Texas. There are no data from the coastline to 45 to 145 mi inland because of the depth of aquifers and the excessive salinity of the water. Dissolved-solids concentrations decrease with distance inland from the coastline and nearness to the updip limit, which is approximately at the study-area boundary on the north side.

Median dissolved-solids concentrations in water from the Wilcox aquifers increase markedly in a southerly direction from a line extending from northern Webb County in southwest Texas to southern Cherokee County, Texas, to northern Vernon Parish, Louisiana, to southern West Carroll Parish, Louisiana, to northern Lawrence County, Mississippi, to northern Wayne County, Mississippi, to middle Clark County, Alabama. The increase is from about 3,000 mg/L (upper limit of slightly saline water) at the line to as much as 200,000 mg/L (concentrated brine) northeast of Houston, Texas, and in southwestern Alabama. North of this line, the median dissolved-solids concentration decreases from about 3,000 mg/L to less than 500 mg/L. There are, however, local areas north of the line where the concentrations may be as much as 10,000 mg/L.

Geopressure zones occur along the downdip extent of the mappable data for the Wilcox aquifers (Jones, 1968). The effect of these zones on the concentrations of dissolved solids, however, does not appear to be significant at a regional scale.

Claiborne Aquifers

Aquifers in the Claiborne Group have an areal distribution of dissolved-solids concentrations similar to that of aquifers in the Wilcox Group. The main difference is that the line of markedly increasing concentrations of dissolved solids across the study area is located further to the south or downdip. This has resulted in a slightly larger area of freshwater in the Claiborne Group than in the Wilcox Group even though the updip limit of the Claiborne Group also is located further to the south.

The area of few or no data between the downdip extent of the mappable data for the Claiborne Group and the coastline ranges from 25 to 130 mi, which is a smaller area than that for the Wilcox Group. There also are few data in Missouri and no data in a circular area located in northeast Texas and northwest Louisiana called the Sabine uplift where the Claiborne Group is not present. Other areas of few data occur in the following parts of the study area—Alabama, northern Arkansas, northeastern and southern Mississippi, and southern Louisiana.

Median dissolved-solids concentrations in water from the Claiborne aquifers increase markedly in a southerly direction from a line extending from middle Webb County in southwest Texas to southern Trinity County, Texas, to middle Vernon Parish, Louisiana, to southern Madison Parish, Louisiana, to northern Lawrence County, Mississippi, to northern Wayne County, Mississippi, to middle Washington County, Alabama. The concentrations range from the upper limit of slightly saline water (3,000 mg/L) at the line to concentrated brine (200,000 mg/L) in some areas along the southern extent of the mapped area in Texas. North of the line, the water in the Claiborne aquifers is fresh having less than 1,000 mg/L of dissolved solids and in most of this area having less than 500 mg/L dissolved solids.

There are geopressure zones along the downdip extent of the mappable data for the Claiborne aquifers but like those in the Wilcox aquifers, they do not appear to affect the dissolved-solids concentrations significantly at the regional scale.

Jackson Aquifers

The Jackson Group is predominantly marine sediments of clay and marl and is considered a confining layer rather than an aquifer in most of the study area. However, some water chemistry data is available in two fairly large areas where aquifers occur within the sediments. The areas are in south central Arkansas and in a 40–mi wide area extending from southwest Texas to the Texas-Louisiana border.

Median dissolved-solids concentrations in water from the Jackson aquifers in the area in Arkansas generally are less than 3,000 mg/L. However, in Texas the median concentrations range from less than 1,000 mg/L (freshwater) to greater than 35,000 mg/L (brine).

Vicksburg Aquifers

The Vicksburg Group of Oligocene age is also composed of predominantly marine sediments and is considered a confining layer in this study. However, water is obtained locally from the Vicksburg Group in small areas in Mississippi (Gandl, 1979). Because these aquifers are not significant regionally, the dissolved-solids concentrations were not mapped in this study.

Miocene Aquifers

The distribution of median dissolved-solids concentrations in water from the Miocene aquifers is similar to those for the Wilcox and Claiborne aquifers in the southern part of the study area. Because the Miocene aquifers overlie the Wilcox and Claiborne aquifers stratigraphically, they generally are at shallower depths. Also the downdip extent of data for the Miocene aquifers is beyond the coastline and includes parts of the Continental Shelf. The updip limit of the Miocene aquifers is further south than that for either the Wilcox or Claiborne aquifers. As a result there are data for only the western tip of Florida and the southern one-half of the study areas in each of the following States—Alabama, Louisiana, Mississippi, and Texas.

Median dissolved-solids concentrations in water from the Miocene aquifers increase very markedly in a southerly direction from a line extending from northeastern Jim Hogg county in southwest Texas to middle Colorado County, Texas, to northern Beauregard Parish, Louisiana, to northern Pointe Coupee Parish, Louisiana, to southern Hancock County, Mississippi to southern Mobile County, Alabama. The change from the upper limit of slightly saline water (3,000 mg/L) at the line to brine (greater than 35,000 mg/L) occurs within a short distance in the downdip direction. North of the line, the water in the Miocene aquifers is mostly fresh, with a dissolved-solids concentration of less than 500 mg/L except in the eastern part of Louisiana and in central and southwest Texas where dissolved-solids concentration range from 500 to 3,000 mg/L.

Geopressure zones, which occur along the downdip extent of the mappable data for the Miocene aquifers, appear to have caused a decrease in the concentration of dissolved solids in some areas. This decrease is indicated where water in the Miocene aquifers has a greater concentration of dissolved solids updip from a point than downdip from that same point. Such a phenomenon may occur when the pressure and resultant heat in the geopressure zone cause diagenesis of montmorillonite to illite releasing freshwater that flows into and dilutes the water in the normally pressured aquifers. However, verification of this effect and the significance of it are beyond the scope of this report.

Pliocene Aquifers

The Pliocene aquifers have an areal distribution of dissolved-solids concentrations similar to that of the Miocene aquifers. The main difference is that the updip limit of the Pliocene aquifers is further south than that for the Miocene aquifers and the line of markedly increasing concentrations of dissolved solids apparently is offshore except in Louisiana. The line of markedly increasing dissolved-solids concentrations in Louisiana begins at the coastline in the southwest corner of the State and curves northeastward to about 50 mi from the coast and then curves generally southeastward to the Mississippi Sound.

Water-chemistry data for the Pliocene aquifers, like those for Miocene aquifers, are available for offshore sites on the Continental Shelf as well as for onshore sites. Except for fairly large areas in south-central and southwest Texas, water-chemistry data are relatively plentiful in Texas and Louisiana north of the line of markedly increasing dissolved-solids concentrations. South of this line the data are fewer.

Median dissolved-solids concentrations in water from the Pliocene aquifers increase markedly in a southerly direction from a line extending from the coastline in the middle of Cameron Parish, Louisiana, to the southeast corner of St. Landry Parish, Louisiana to northern St. Bernard Parish, Louisiana. North of this line, the water in the Pliocene aquifer is mostly fresh having dissolved-solids concentrations of less than 1,000 mg/L in Alabama, Mississippi, Louisiana, and east Texas, but more than 3,000 mg/L in some parts of south-central and southwest Texas. South of the line, the water increases in salinity to a concentrated brine (to 200,000 mg/L dissolved solids).

Geopressure zones are reported to occur in the Pliocene aquifers (Jones, 1968). Because of the limited data in the area of the geopressure zones, their effect on dissolved-solids concentrations was inconclusive.

Quaternary Aquifers

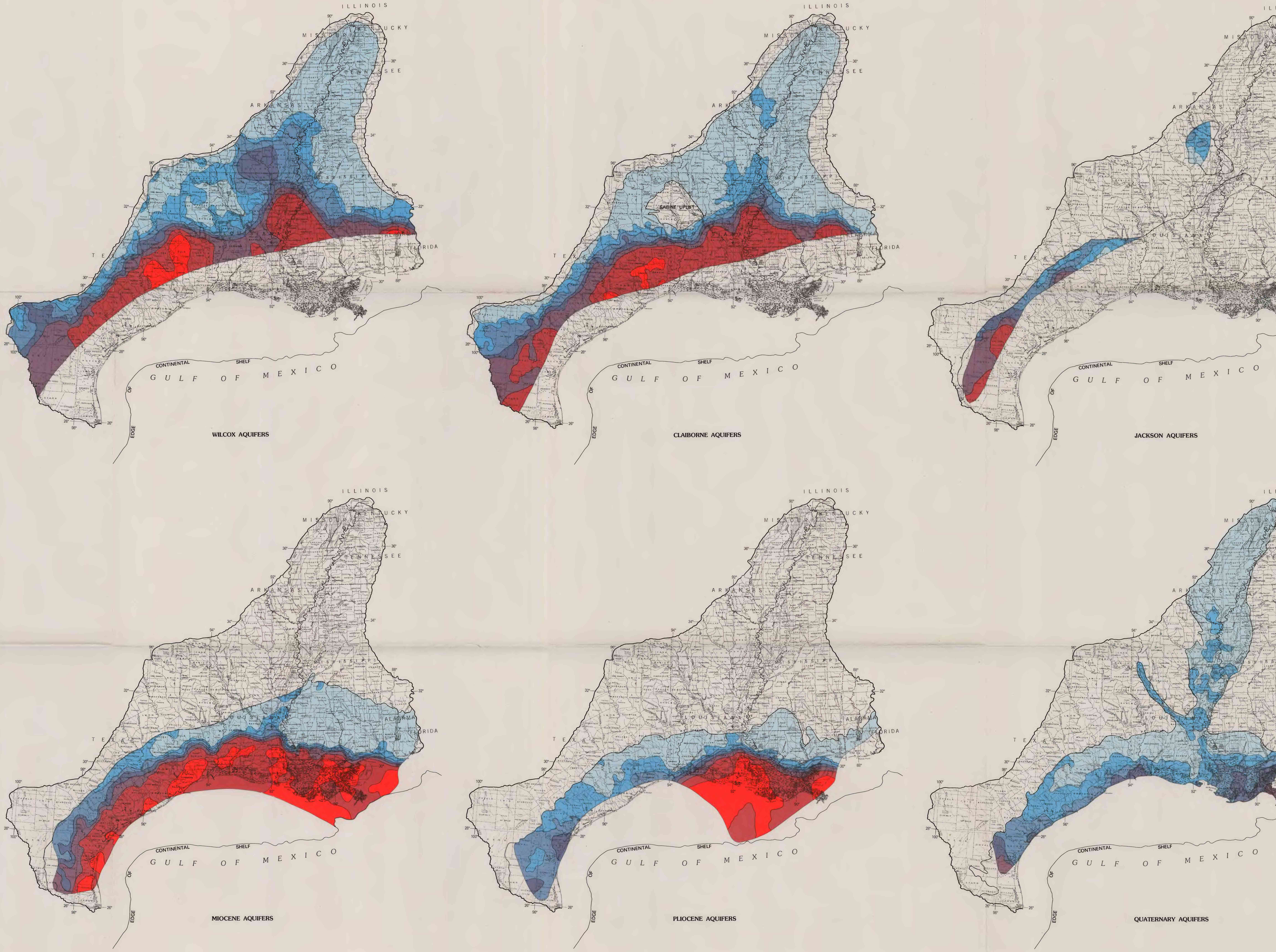
The Pleistocene and Holocene aquifers were combined in this report and are referred to as the Quaternary aquifers. They were combined because much of the data either were assigned as Quaternary or, the water analyzed was from alluvial or terrace deposits both of which could be of Pleistocene or Holocene age.

The distribution of dissolved-solids concentrations in water from the Quaternary aquifers is somewhat different than those in the Tertiary aquifers. For example, the dissolved-solids concentrations in the Quaternary aquifers increase to the southeast and to southwest and generally range from less than 500 to 10,000 mg/L. However the main difference is the absence of a distinct line of markedly increasing dissolved-solids concentration along the southern part of the study area.

The Quaternary aquifers occur in two large bands across the study area. The east-trending band begins in Kenedy County, Texas, at a width of about 25 mi and increases to a width of 130 mi across the southern part of Louisiana. The south-trending band ranges in width from 30 to 120 mi and extends from the tip of Illinois to east-central Louisiana where it merges with the east-trending band in southern Louisiana. Most of the south-trending band, which follows the Mississippi River, is west of the river. Quaternary aquifers also occur on either side of the Red River in Louisiana. In the remainder of the study area, Quaternary aquifers may occur locally along streams, but these are not significant regionally.

Median dissolved-solids concentrations in water from the Quaternary aquifers generally were less than 500 mg/L in all states except Texas and Louisiana. In these two States, the concentrations were generally less than 3,000 mg/L.

The Quaternary aquifers are above the geopressure zones. Thus, dissolved-solids concentrations in water from the aquifers are not affected by them.



WILCOX AQUIFERS

CLAIBORNE AQUIFERS

JACKSON AQUIFERS

MIOCENE AQUIFERS

PLIOCENE AQUIFERS

QUATERNARY AQUIFERS

Base from U.S. Geological Survey
United States base map, 1972

MAPS SHOWING DISTRIBUTION OF DISSOLVED-SOLIDS CONCENTRATIONS IN WATER FROM THE DESIGNATED AQUIFERS BASED ON MEDIAN CONCENTRATION PER 100-SQUARE-MILE AREA

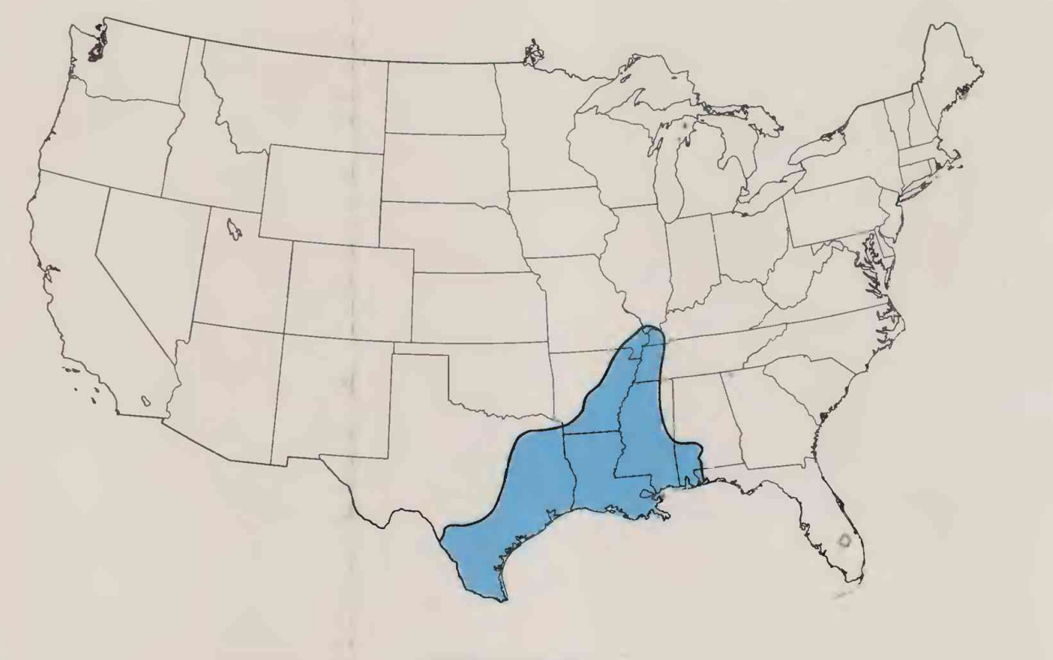
SCALE 1:5 000 000

100 0 100 200 300 400 500 MILES

100 0 100 200 300 400 500 KILOMETERS

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) METRIC UNITS

Multiply inch-pound units	By	To obtain SI units
Foot (ft)	0.3048	Meter
Mile (mi)	1.609	Kilometer
Million gallons per day (Mgal/d)	0.04381	Cubic meters per second
Square mile (mi^2)	2.590	Square kilometer



STUDY AREA

EXPLANATION
DISSOLVED–SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER

▭	0–500
🟦	500–1,000
🟦	1,000–3,000
🟪	3,000–10,000
🟪	10,000–35,000
🟥	35,000–100,000
🟥	100,000–200,000
☐	No data
━	Boundary of study area
─	Boundary of updip limit

DISSOLVED–SOLIDS CONCENTRATIONS AND PRIMARY WATER TYPES, GULF COAST AQUIFER SYSTEMS, SOUTH–CENTRAL UNITED STATES

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