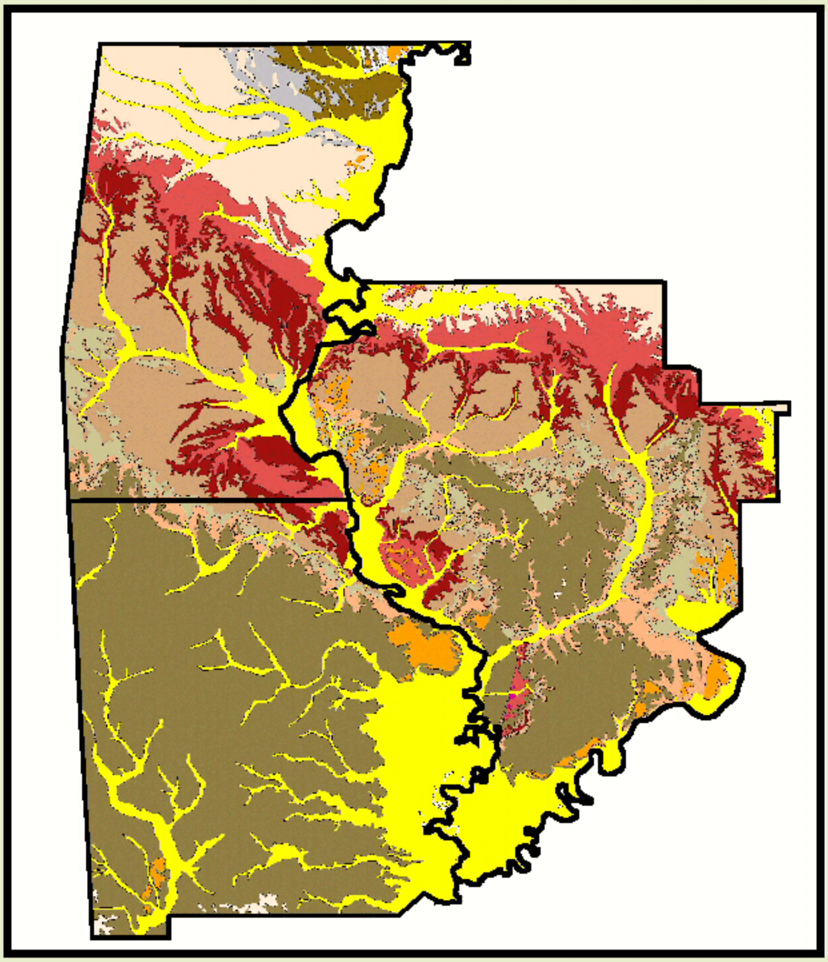
HYDROGEOLOGY AND VULNERABILITY TO CONTAMINATION OF MAJOR AQUIFERS IN ALABAMA: AREA 10



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COMPACT DISC 2

GEOLOGICAL SURVEY OF ALABAMA

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HYDROGEOLOGY DIVISION

COMPACT DISC 2

HYDROGEOLOGY AND VULNERABILITY TO CONTAMINATION OF MAJOR AQUIFERS IN ALABAMA: AREA 10

By
Dorothy E. Raymond, Blakeney Gillett,
and James D. Moore

Prepared by the Geological Survey of Alabama in cooperation with
the Alabama Department of Environmental Management

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GEOLOGICAL SURVEY OF ALABAMA

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The Honorable Don Siegelman
Governor of Alabama
Montgomery, Alabama

Dear Governor Siegelman:

It is with pleasure that I make available to you and the citizens of Alabama the publication "Hydrogeology and Vulnerability of Major Aquifers to Contamination: Area 10," by Dorothy E. Raymond, Blakeney Gillett, and James D. Moore. The report, published as Compact Disc 2, is one of a series of reports that describe all major aquifers in the state. They are the first publications offered on compact disc by the Geological Survey of Alabama.

This publication presents information on the geology and characteristics of the major aquifers and public-supply wells in Choctaw, Clarke, and Washington Counties. Information contained in this report is critical to engineers, resource managers, city planners, and others responsible for conserving and protecting Alabama's ground water resources.

Respectfully,

Donald F. Oltz
State Geologist

Science and Service for the People of Alabama

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HYDROGEOLOGY AND VULNERABILITY TO CONTAMINATION OF MAJOR AQUIFERS IN ALABAMA: AREA 10

By

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ABSTRACT

The Geological Survey of Alabama (GSA), in cooperation with the Alabama Department of Environmental Management (ADEM), is revising and expanding a series of reports that delineates the major aquifers in Alabama and characterizes their vulnerability to contamination. The original reports were prepared by the U.S. Geological Survey in cooperation with ADEM. The state is divided into 13 areas that are addressed in separate reports. The hydrogeology and vulnerability to contamination of the major aquifers in Area 10, which includes Choctaw, Clarke, and Washington Counties, are described in this report, which currently is available only in digital format.

The aquifers in the study area are the Nanafalia aquifer, the Lisbon aquifer, the Crystal River aquifer, the Miocene-Pliocene aquifer, and the watercourse aquifer. The Nanafalia aquifer includes the permeable units of the Midway and Wilcox Groups in the subsurface. The Lisbon aquifer consists of the upper part of the Tuscahoma Sand, the Hatchetigbee Formation, the Claiborne Group, and the Moodys Branch Formation. The Crystal River aquifer includes much of the Vicksburg Group, although a few beds of the Jackson Group may be productive locally. The Miocene-Pliocene aquifer consists of the Citronelle Formation, the undifferentiated deposits of the Miocene Series, and the Paynes Hammock Sand and Chickasawhay Limestone of Oligocene age. The watercourse aquifer includes alluvial and terrace deposits.

The Nanafalia aquifer is widely used for public supply in the northern part of Area 10. The Lisbon aquifer is used in the central part of the study area, and the Miocene-Pliocene aquifer is used in the southern part. The Jackson Water Works and Sewer Board in Clarke County is the only system in Area 10 that uses the Crystal River aquifer as a water source.

The recharge areas for all the aquifers in the study area are highly vulnerable to contamination. The presence of impermeable beds (aquicludes) above the well completion zones and the fact that most public supply wells are drilled some distance from recharge areas may provide protection from surface contamination in the immediate vicinity of the wells. Aquifers become less vulnerable to contamination from surface sources with an increasing degree of confinement by clay layers. However, even deep aquifers can be vulnerable to natural sources of contamination such as mineralized ground water.

Pumping of public water supply wells and irrigation wells can increase the potential for contamination of aquifers if not properly planned, managed, and monitored. Pumping of large quantities of ground water creates cones of depression, increases flow gradients, and draws ground water and any associated contamination toward pumping wells.

The permeable terrace and alluvial deposits of the watercourse aquifer overlie the major aquifers along the Tombigbee and Alabama Rivers. Ground water flow in most of these areas is toward the rivers. In southern Washington County the watercourse aquifer and the underlying Miocene-Pliocene aquifer are used extensively by industries located adjacent to the Tombigbee River. Owing to extensive pumpage, the natural ground water flow direction in this area has been reversed. Ground water moves from the river toward the pumped wells. This reversal of flow direction increases the possibility of recharge of the aquifers by infiltration of river water.

INTRODUCTION

The U.S. Geological Survey, in cooperation with ADEM, conducted a series of geohydrologic studies in Alabama to delineate the major aquifers and their recharge areas and to define areas susceptible to surface contamination. Each of the 13 areas of the state was studied by different authors. DeJarnette (1989) summarized the characteristics of the aquifers in Area 10, which includes Choctaw, Washington, and Clarke Counties. The present study is a cooperative effort between GSA and ADEM to update and supplement the results of the previous study and to provide the hydrogeologic information in a digital format on a CD-ROM that can be easily accessed by computer. In addition to the document you are now reading, the CD-ROM for Area 10 also contains a GIS database and a copy of the program ARC Explorer from ESRI, Inc. The GIS database includes all of the data used to make the maps that appear as plates in this report. The file Readme, located in the root directory of this CD-ROM, provides information about how to access the GIS database using ARC Explorer.

The dependence on ground water in this three-county area of southwest Alabama is not fully covered in this report, which is limited primarily to public supply wells. About 34 percent of the population in Area 10 is supplied by privately owned water wells (Mooty and Richardson, 1998).

ACKNOWLEDGMENTS

The authors thank the well drillers and managers and operators of water-supply systems in Choctaw, Clarke, and Washington Counties for the information they provided on their wells. In addition, Sonja Massey, Fred Mason, and Enid Bittner of ADEM provided assistance and suggestions in the preparation of this report. Geographic Information Systems (GIS) support was provided by Ruth T.

Collier, Douglas R. Taylor, and Gary Crawford of the GSA. Their efforts are greatly appreciated.

PURPOSE AND SCOPE

The purposes of this report are to (1) describe the hydrogeology of the study area; (2) delineate, redefine, and describe the major aquifers and their recharge areas; (3) delineate areas that are vulnerable to contamination; (4) delineate the Source Water Assessment Areas or Wellhead Protection Areas as defined under §335-7-5 and §335-7-12 of ADEM's administrative code and as currently identified in the study area; (5) identify the locations of public supply wells in the study area; and (6) provide all hydrogeologic data in a digital GIS format that can be readily accessed by scientists and the public.

The Geologic Map of Alabama (Szabo and Copeland, 1988) at a scale of 1:250,000 provides new geologic data from which to update the previous aquifer susceptibility map (DeJarnette, 1989). In the study by DeJarnette (1989) all wells used for municipal and rural public water supplies were inventoried. For the present study, water-level data from the GSA's regular monitoring program and historical water-level data were used to prepare generalized potentiometric surface maps of the aquifers. Areas vulnerable to contamination from the surface were delineated from topographic maps and geologic maps. Wellhead protection area boundaries came from reports submitted to ADEM by public water supply systems that have completed wellhead protection projects.

LOCATION AND EXTENT OF THE STUDY AREA

Area 10 is in southwestern Alabama and includes Choctaw, Clarke, and Washington Counties (plate 1). These counties have a combined land area of about 3,220 square miles (Alabama Department of Economic and Community Affairs, 1984) and had a population of 61,450 in 1995 (Mooty and Richardson, 1998). The area includes the towns of Butler, Gilbertown, Thomasville, Grove Hill, Jackson, McIntosh, Coffeeville, and Chatom, and numerous other small towns and communities. Ground water is the sole source of drinking water for these towns, with the exception of Jackson, which uses the Tombigbee River as a back-up supply.

PREVIOUS INVESTIGATIONS

Numerous reports describe the geology and hydrology of the study area. Information on the geology of the area was published as early as 1858 in the second biennial report of the Geological Survey of Alabama (Tuomey, 1858). Adams and others (1926) provide a detailed description of the geology of Alabama including a geologic map of the state. The most current geologic mapping for Area 10 is found in Szabo and Copeland (1988) (plate 1).

The earliest information on ground water in the study area was published in 1907 (Smith, 1907). Other reports that contain information on the geology and ground water resources of the area are *Geology and Ground-Water Resources of Choctaw County, Alabama* (Toulmin and others, 1951); *Water Availability of Clarke County, Alabama* (Causey and McCain, 1971); *Geology of Clarke County, Alabama* (Causey and Newton, 1972); *Water Availability of Washington County, Alabama* (Newton and others, 1972); *Water Availability of Choctaw County, Alabama* (Newton and McCain, 1972); *Geology of Choctaw County, Alabama* (Turner and Newton, 1971); *Water Content and Potential Yield of Significant Aquifers in Alabama* (Barksdale and others, 1976); *Map of Fresh and Slightly Saline Ground-Water Resources in the Coastal Plain of Alabama* (Ellard, 1977); *Configuration of the Base of the Miocene Series* (Moore and Raymond, 1985); *Watercourse Aquifers in Alabama* (Moore and Hunter, 1991); and *Aquifers in Alabama* (Moore, 1998).

PHYSICAL FEATURES

Area 10 lies within the East Gulf Coastal Plain section of the Coastal Plain physiographic province (fig. 1). The northern half of Choctaw County and extreme northern Clarke County are in the Southern Red Hills physiographic district (Sapp and Emplaincourt, 1975). The northern part of this district is called the Flatwoods subdistrict, which extends only into the northeastern tip of Choctaw County. The central part of the district is a southward-sloping upland of moderate relief. The southern part of the district, which extends from Choctaw County into Clarke County, is the rugged Buhrstone Hills subdistrict.

South of the Southern Red Hills district is the Lime Hills physiographic district that includes most of the remainder of Choctaw County and a large part of central Clarke County. The Lime Hills district is characterized by a rugged topography developed on resistant limestone and includes the Hatchetigbee anticline in the southern part (figs. 1, 2).

The Southern Pine Hills district is south of the Lime Hills district and includes most of Washington County and southern Clarke County. This district is a southward sloping upland with as much as 250 feet of relief.

Valleys of the Alabama and Tombigbee Rivers occupy parts of all three counties in Area 10. These valleys are characterized by broad, flat flood plains and terraces and are in the Alluvial-Deltaic Plain district.

STRATIGRAPHY

Geologic units strike northwestward and dip southwestward about 40 feet per mile in Area 10 except where affected by folding and faulting. Structural features in the study area include the Jackson fault, the Hatchetigbee anticline, and several other major faults (plate 1; fig. 2). The Hatchetigbee anticline was formed by the upward movement of salt in the subsurface that lifted the overlying

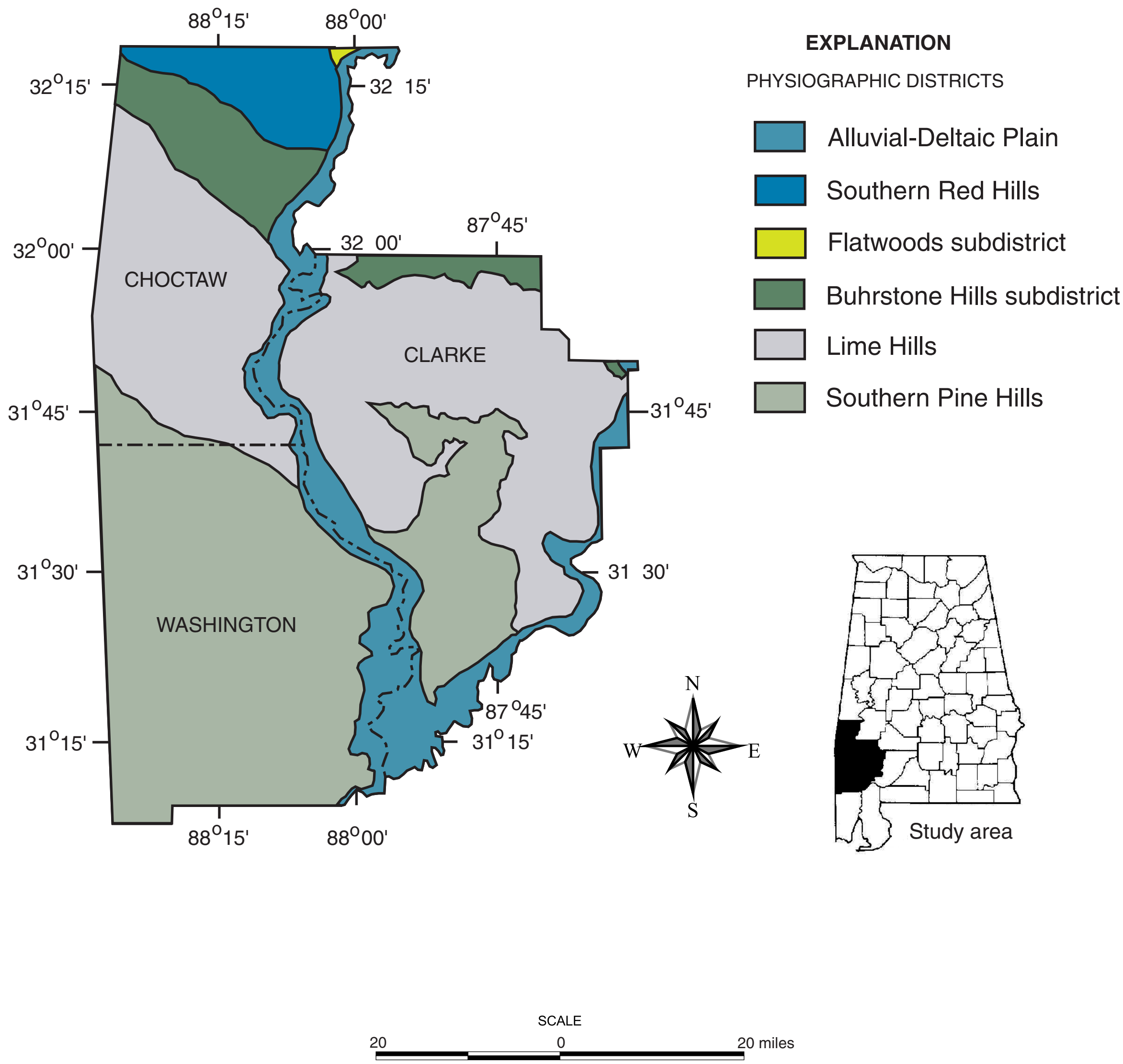


Figure 1.--Physiographic divisions in Area 10 (from Sapp and Emplaincourt, 1975).

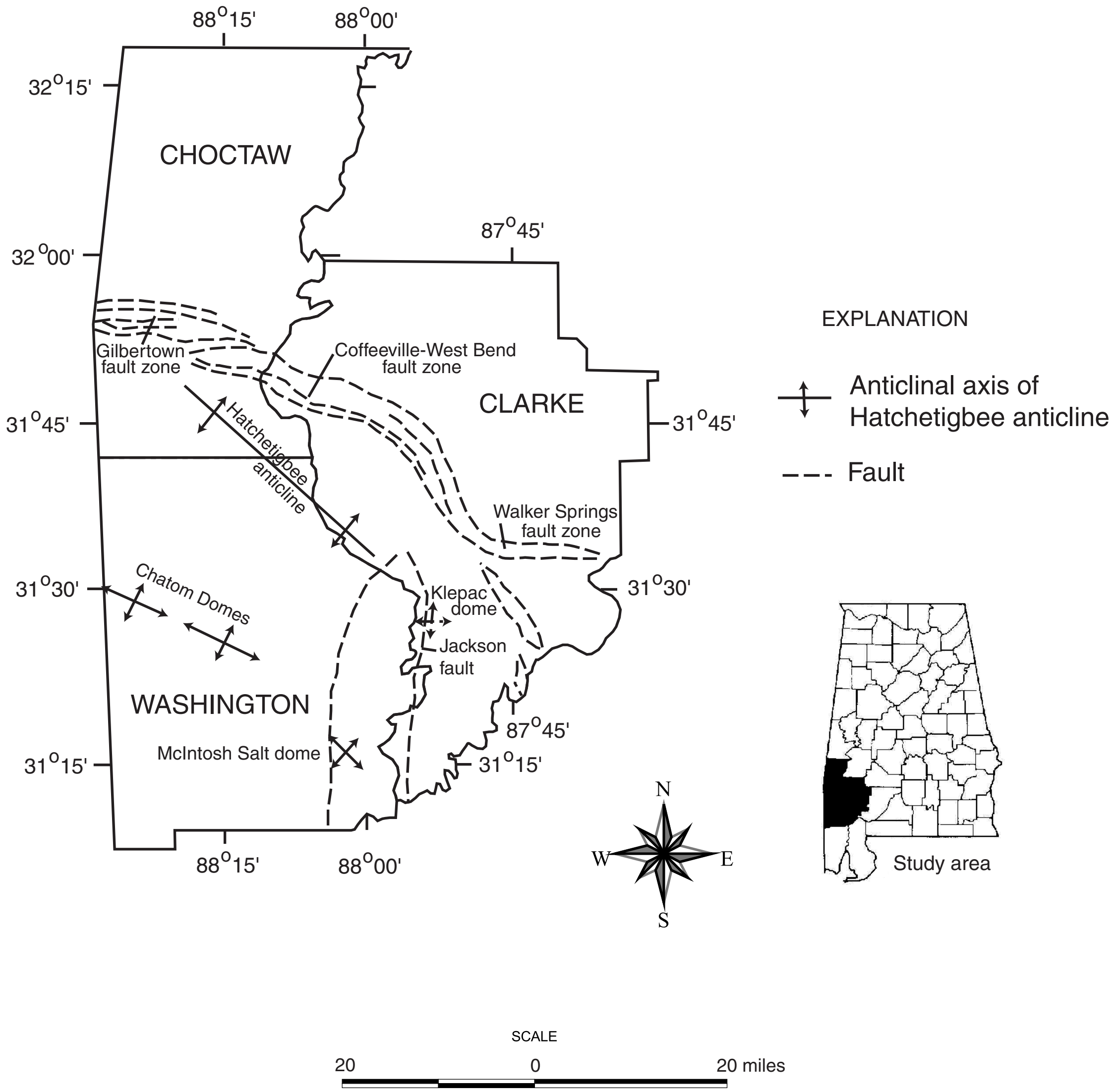


Figure 2.--Major structural features of Area 10 (from Moore, 1971).

sediments into a large fold. Erosion has cut through the fold layers to expose older rocks in the center of the fold.

Geologic units that crop out in and immediately underlie the study area range in age from Tertiary to Quaternary (table 1; plates 1, 2, 3, 4). Unconsolidated sedimentary deposits of Tertiary age crop out in all three counties of Area 10. Quaternary alluvial and terrace deposits overlie older units in and adjacent to the flood plains of the Alabama and Tombigbee Rivers and other large streams in the study area. Stratigraphy of the units that serve as aquifers or aquicludes in Area 10 is given below.

TERTIARY SYSTEM

A thick sequence of Tertiary sediments underlies the study area. Tertiary units cropping out and underlying the study area include the Midway, Wilcox, Claiborne, Jackson, and Vicksburg Groups, the Chickasawhay Limestone, the Paynes Hammock Sand, and the Miocene Series undifferentiated. For the sake of this report, the Vicksburg Group, the Chickasawhay Limestone and the Paynes Hammock Sand are referred to as the Oligocene Series undifferentiated (plates 1, 2, 3). Quaternary rocks include the Citronelle Formation and alluvial and terrace deposits. The cross sections in plate 2 illustrate the general structural and stratigraphic relationships of the Tertiary units in the subsurface in the study area.

PALEOCENE SERIES

MIDWAY GROUP

The Midway Group of Paleocene age, crops out in the northeastern part of Choctaw County and includes the Porters Creek Formation and the Naheola Formation (table 1) (MacNeil, 1946). In the subsurface the Midway is a major confining unit rather than an aquifer.

The Porters Creek is a massive dark-brown to black marine clay that fractures subconchoidally. Outcrops of the formation are exposed in the Flatwoods area in the northeastern corner of Choctaw County in Area 10 (fig. 1). In Choctaw County, the Porters Creek is about 350 feet thick.

The Naheola Formation overlies the Porters Creek and crops out southwest of the Porters Creek in Choctaw County. The Naheola also is exposed in Clarke County on the upthrown side of the Jackson fault. The lower part of the Naheola consists of interbedded brownish-gray laminated sandy silt and silty clay and greenish-gray sand. The upper part consists of sand, sandy marl, lignite, and silty clay. Thickness of the Naheola in outcrop is about 200 feet.

Table 1.--Geologic units in Area 10 and their water-bearing properties (modified from DeJarnette,1989)

System	Series	Group	Geologic units	Aquifer	Thickness (feet)	Lithology	Water-bearing properties	Quality of water
Quaternary	Holocene and Pleistocene		Alluvium and terrace deposits	Watercourse	0-60	Silt, clay, sand, and gravel, varicolored, unconsolidated.	Will yield 10 gpm or more locally where saturated sands are of sufficient thickness. Potential source of large supplies in southernmost part of Clarke County and eastern Washington and Choctaw Counties.	Water is soft, generally has a dissolved solids content less than 50 mg/L, and commonly contains iron in excess of 0.3 mg/L. Water quality is suitable for most uses.
Tertiary	Pliocene and Miocene		Citronelle Formation and Miocene undifferentiated	Miocene-Pliocene	0-300	Sand and gravel, yellow, pink, and tan; light-gray and varicolored clay; blue to green sand, clay, and sandy clay; bluish-gray fossiliferous marl; light-gray sandstone; bluish-green fossiliferous sandy clay at base of series.	Will yield 10 gpm per well in Choctaw County. Will yield 1 Mgpd per well in southernmost part of Clarke County and most of Washington County. May yield up to 2.0 Mgpd in southern half of Washington County.	Water is soft, generally has a dissolved solids content less than 75 mg/L, and commonly contains iron in excess of 0.3 mg/L. Locally the water is sufficiently acidic to be corrosive.
Tertiary	Oligocene	Vicksburg	Oligocene Series	Miocene-Pliocene; Crystal River	70-140	Limestone and marl, gray and pale-olive, sandy, fossiliferous; gray and greenish-gray clay; yellow hard fossiliferous limestone with indurated fossiliferous ledges; greenish-gray fine sand and yellowish-green fossiliferous marl with limestone ledges at base of series.	Solutionally enlarged openings in limestone are a potential source of large supplies in Clarke and Washington Counties. The Bucatunna Clay serves as an aquiclude separating the Crystal River and Miocene-Pliocene aquifers.	Water is moderately hard to very hard and low in dissolved solids. Locally contains iron in excess of 0.3 mg/L.
Tertiary	Eocene	Jackson	Jackson Group	Crystal River	100-150	Clay or clayey limestone, light-greenish-gray and white, calcareous; light-gray fossiliferous marl; yellow, orange, and light-gray, fine to medium sand; bluish-gray clay and sandy clay; indurated glauconitic, fossiliferous sandy marl and limestone.	Yazoo Clay is generally impermeable. Some thin beds will yield 10 gpm. Potential source of larger supplies.	Water is soft to very hard and generally is low in dissolved solids. Locally contains iron in excess of 0.3 mg/L.
Tertiary	Eocene	Jackson; Claiborne	Moodys Branch Formation of the Jackson Group, Gosport Sand, and Lisbon Formation	Lisbon	125-310	Sand, yellow, light-tan, pink, and brown, fine-grained; light-gray and greenish-gray silty clay; very fine to coarse glauconitic sand; glauconitic fossiliferous green sand with indurated calcareous layers of sandstone; white to very light-greenish-gray claystone; fine to coarse cross-bedded glauconitic sand at base of formation.	Yields 10 gpm in Washington County. Yields 100 gpm at Coffeeville, Clarke County. Potential source of 0.1 to 0.5 Mgpd.	Water is soft to very hard, but generally is hard. Dissolved solids are generally less than 500 mg/L, except locally in southern Choctaw County where bicarbonate is the principal constituent. Commonly contains iron in excess of 0.3 mg/L.

Table 1.--Geologic units in Area 10 and their water-bearing properties-Continued

System	Series	Group	Geologic units	Aquifer	Thickness (feet)	Lithology	Water-bearing properties	Quality of water
Tertiary	Eocene	Claiborne	Tallahatta Formation	Lisbon	20-150	Claystone, white to very light-greenish-gray, thin-bedded to massive, siliceous, aluminous, interbedded with thin layers of clay, sandy clay, and sand; 5 to 8 feet of white to gray fine to coarse sand and fine gravel at base of formation.	Will yield 10 gpm where basal sand is present and is a potential source of larger supplies where generally thin saturated sands thicken in subsurface. Lower part generally impermeable.	Limited data indicate water has a low dissolved solids content and is hard to very hard.
		Wilcox	Hatchetigbee Formation	Lisbon	250-300	Sand, gray to yellow, cross-bedded; varicolored laminated clay and sandy clay; pale-olive to greenish-gray, abundantly glauconitic fossiliferous fine sand and marl containing calcareous sandstone concretions in lower part of formation.	Will generally yield 0.2 Mgpd per well and may yield as much as 0.5 Mgpd per well.	Water is soft to very hard and commonly contains iron in excess of 0.3 mg/L. Highly mineralized in Washington, southeastern Choctaw, and southern Clarke Counties.
	Paleocene		Tuscahoma Sand		350-600	Clay, silt, and very fine sand, gray, laminated to thin-bedded, carbonaceous; fine to coarse cross-bedded sand, fossiliferous, glauconitic, sandy marl; lignite.	Some sands will generally yield 0.1 to 0.3 Mgpd per well. Most sands are relatively impermeable. Potential source of larger supplies. Not used as a source of supply in Washington County.	Water is soft to very hard but generally is soft to moderately hard. Locally contains iron in excess of 0.3 mg/L.
			Nanafalia Formation and Salt Mountain Limestone	Nanafalia	100-250	Clay and claystone, gray; greenish-gray glauconitic fossiliferous sand, sandstone, marl, limestone, and some lignite; white or light colored micaceous sand. Salt Mountain Limestone is equivalent to part of the Nanafalia Formation and occurs primarily in the subsurface.	Potential source of 1 Mgpd per well in northern parts of Clarke and Choctaw Counties.	Water is soft and has a dissolved-solids content of less than 1,000 mg/L in northernmost part of Clarke County. Locally contains iron in excess of 0.3 mg/L. Not utilized as a source of water in Washington County.
		Midway	Naheola Formation and Porters Creek Formation		190-500	Sand, green and gray, clayey, glauconitic, and gray finely sandy glauconitic micaceous clay in upper part of Naheola Formation; gray micaceous carbonaceous sand, clay, and silt in lower part. Porters Creek is gray marine clay.	Relatively impermeable. Upper half of Naheola where sandy will yield 10 gpm if sufficiently thick.	Water is highly mineralized, has chloride content of 21,000 mg/L at depth of 200 feet near Rockville in the southern part of Clarke County.

WILCOX GROUP

The Wilcox Group of Eocene and Paleocene age consists of the Salt Mountain Limestone, Nanafalia Formation, the Tuscahoma Sand, and the Hatchetigbee Formation. The Nanafalia and the Hatchetigbee are aquifers in the study area, but most of the Tuscahoma is an aquiclude.

The Nanafalia Formation, which consists of sand, sandy marl, sandy clay, massive clay, and lignite, crops out southwest of the Naheola Formation in northeastern Choctaw County. The basal part of the Nanafalia, the Gravel Creek Sand Member, consists of coarse gravelly micaceous sand. Overlying the Gravel Creek is a unit informally named the "*Ostrea thirsae* beds" (plates 3, 4). This unit contains abundant fossils of the oyster *Odontogryphaea thirsae* (Gabb). At the top of the Nanafalia is the Grampian Hills Member, which consists of siltstone, silt, sand, and calcareous sandy clay. Thickness of the Nanafalia ranges from about 100 feet in outcrop to about 250 feet in the subsurface.

The Salt Mountain Limestone crops out only in the southern part of Clarke County where it has been uplifted along the upthrown side of the Jackson fault. Elsewhere in Alabama, the Salt Mountain, which is laterally equivalent to the middle part of the Nanafalia Formation, is restricted to the subsurface.

The Tuscahoma Sand crops out southwest of the Nanafalia Formation in northern Choctaw and northern Clarke County. The formation consists of clay, silt, very fine to coarse sand, lignite, and fossiliferous glauconitic marl. Thickness of the Tuscahoma ranges from about 350 feet in outcrop to more than 600 feet in the subsurface.

EOCENE SERIES

HATCHETIGBEE FORMATION

The Hatchetigbee Formation of the Wilcox Group overlies the Tuscahoma Sand and crops out in central Choctaw County, northern Clarke County, and northeasternmost Washington County and on the crest of the Hatchetigbee anticline (fig. 2; plate 1). The formation consists of gray, brown and olive-green very fine to fine sand and interlaminated carbonaceous clay and silt. Thickness in outcrop is about 250 feet, and thickness increases to over 300 feet downdip.

CLAIBORNE GROUP

The Claiborne Group of Eocene age consists of the Tallahatta Formation, Lisbon Formation, and Gosport Sand. These formations, along with the overlying Moodys Branch Formation, make up the Lisbon aquifer, a major aquifer in the study area.

The Tallahatta Formation crops out in central Choctaw County, in north-central Clarke County, and around the Hatchetigbee anticline (plate 1). The outcrop of the Tallahatta is characterized by rugged topography with steep hills forming a north-facing escarpment. Thickness of the Tallahatta ranges from 20 to 150 feet. The formation consists of gray clay, siliceous claystone, and thin interbeds of sandy clay, sand, and siltstone. The indurated claystone beds contrast sharply with the underlying Hatchetigbee Formation. The Meridian Sand Member at the base of the formation consists of 5 to 8 feet of sand and gravel.

The Lisbon Formation overlies the Tallahatta and has a similar distribution. The Lisbon is a light- to yellowish-gray calcareous glauconitic sand and sandy clay that is about 100 to 220 feet thick in Area 10.

The Gosport Sand, which overlies the Lisbon, is a calcareous, fossiliferous, glauconitic sand that ranges from 10 to 30 feet in thickness.

JACKSON GROUP

The Jackson Group of Eocene age includes the Moodys Branch Formation and the Yazoo Clay. The Yazoo Clay serves as an aquiclude in Area 10. The group crops out in south-central and southwestern Choctaw County, northeastern Washington County, and central Clarke County. Total thickness of the group is 110 to 160 feet.

The Moodys Branch is a greenish-gray glauconitic, calcareous sand, limestone, and sandy marl that is 10 to 15 feet thick. The Yazoo Clay is primarily clay and contains interbeds of sand and marl.

OLIGOCENE SERIES

The Oligocene Series crops out in southwestern Choctaw County, central Clarke County, and northeastern Washington County. The Oligocene Series includes the Red Bluff Clay, Forest Hill Sand, Marianna Limestone, and Byram Formation of the Vicksburg Group and the Chickasawhay Limestone and Paynes Hammock Sand. These sediments are mapped as the Oligocene Series undifferentiated on plate 1. Total thickness ranges from 70 to 140 feet.

The Red Bluff Clay consists of 10 to 25 feet of interbedded greenish-gray clay, limestone, and sand in Washington and Choctaw Counties; in Clarke County, thickness ranges from 10 feet in the eastern part of the county to 60 feet in the western part of the county. The Forest Hill Sand is a thin carbonaceous clay with lenses of sand. The Marianna Limestone is 30 to 80 feet of white soft fossiliferous limestone. The Byram Formation consists of interbedded marl, limestone, and clay and averages 15 feet in thickness. The Bucatunna Clay Member of the Byram Formation, an aquiclude, is present at the top of the Byram and ranges from 5 to 30 feet in thickness. Exposures of the Bucatunna are poor and generally covered. The Chickasawhay Limestone is about 19 feet of sandy marl and limestone. The Paynes

Hammock Sand consists of locally fossiliferous, calcareous, argillaceous medium to coarse sand; pale-bluish-green clay; and thin-bedded sandy limestone.

MIOCENE AND PLIOCENE-PLEISTOCENE SERIES

Sediments of the Miocene Series undifferentiated crop out in a large part of Clarke and Washington Counties and the southwestern corner of Choctaw County. The unit is about 300 feet thick in Washington and Clarke Counties and consists primarily of light-gray and varicolored clay, varicolored sand, gravel, marl, and sandstone. The Pliocene-Pleistocene Citronelle Formation, which includes white, yellow and red sand and gravel, overlies the Miocene sediments in the southern part of Area 10.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

HIGH TERRACE DEPOSITS

High terrace deposits unconformably overlie older sediments along the major rivers. These deposits are remnants of older alluvial deposits that now form relatively flat uplands in several parts of the study area. The high terrace deposits are about 40 feet thick and consist of varicolored silt, sand, clay, and gravel; they are considered a part of the watercourse aquifer.

PLEISTOCENE AND HOLOCENE SERIES

ALLUVIAL AND LOW TERRACE DEPOSITS

Alluvial and low terrace deposits overlie older sediments along streams in the study area. These deposits, mapped as a single unit on plate 1, underlie the flood plains or former flood plains of the streams and consist of sand, silt, gravel, and clay. The sediments make up most of the watercourse aquifer in Area 10, although they are not presently used as a source of public water supply. The alluvial deposits generally range in thickness from 30 to 60 feet.

HYDROGEOLOGY

Geologic units that crop out in and underlie Area 10 contain beds of permeable sand and limestone. These permeable beds, called aquifers when saturated with water, dip southwestward and supply water to wells in and downdip from their outcrop areas. The major aquifers in the study area are the Nanafalia aquifer, the Lisbon aquifer, the Crystal River aquifer, the Miocene-Pliocene aquifer, and the watercourse aquifer (plate 5; table 1). Water in these aquifers, with the exception of the watercourse aquifer, generally exists under water table conditions in outcrop areas and becomes confined downdip. The watercourse aquifer is unconfined. In their outcrop areas, aquifers also provide the base flow to streams.

Ground water of adequate quantity and quality for domestic use generally can be obtained at depths of 100 feet or less in most parts of Area 10. To produce larger yields (greater than 50 gallons per minute (gpm)), wells in Area 10 may need to be as deep as 300 feet. The deepest well (CHOS-03, plate 1) in Area 10 is 1,242 feet deep and is located at Gilbertown.

The occurrence and quality of ground water in the study area is affected by structural deformation of the underlying geologic units (plates 2, 3, 4; fig. 2). Two major structures in Area 10 that affect ground water movement are the Hatchetigbee anticline and the Jackson fault (fig. 2). Anomalous occurrences of ground water with high chloride content are present adjacent to the Mobile and Tombigbee Rivers and in the folded and faulted areas of Choctaw County (fig. 2).

NANAFALIA AQUIFER

The Nanafalia aquifer consists of sands of the Naheola and Nanafalia Formations and the lower part of the Tuscahoma Sand in the study area (table 1). The Nanafalia aquifer is separated from the overlying Lisbon aquifer by the relatively impermeable middle part of the Tuscahoma Sand and is immediately underlain in Area 10 by impermeable clays of the Porters Creek Formation.

Units comprising the Nanafalia aquifer crop out only in the extreme northern part of Choctaw County and have an average thickness of 120 feet. The Nanafalia is a water source in both northern Choctaw and Clarke Counties, but only in Choctaw County is it used for public supply. High-yield wells (>50 gpm) completed in the Nanafalia range in total depth from 200 to 600 feet, with the noted exception of Gilbertown's well, CHOS-03 (plate 1), which is 1,242 feet deep. Most public supply wells completed in this aquifer pump at rates between 200 and 500 gpm; however, higher yields are possible.

LISBON AQUIFER

The Lisbon aquifer includes sands of the upper part of the Tuscahoma Sand, the Hatchetigbee and Tallahatta Formations, the Lisbon Formation, the Gosport Sand, and the Moodys Branch Formation. The Lisbon aquifer is confined between the impermeable sediments of the overlying Yazoo Clay of the Jackson Group and the basal Oligocene Series and the underlying clays in the Tuscahoma Sand. Part of the Tallahatta Formation is impermeable in Area 10 and serves as an internal aquiclude within the Lisbon aquifer. Thus, the Lisbon aquifer is separated into upper and lower aquifers in Area 10 (table 1).

The Lisbon aquifer is used extensively in both Clarke and Choctaw Counties for public supply and in northern Washington County for many private wells. Wells range in depth from about 200 to 600 feet. Reported yields are as high as 200 gpm.

CRYSTAL RIVER AQUIFER

The Crystal River aquifer in Alabama consists of limestones of the lower Oligocene Series. While the Crystal River Formation is absent in western Alabama, laterally equivalent water-bearing limestones are present in Area 10. Because of its limited occurrence, the Crystal River aquifer is rarely utilized as a source of water in Area 10. The exception is Hoven Spring which supplies water for the town of Jackson in Clarke County (plate 1). Hoven Spring's (CLAHH-6, plate 1) discharge, 1,000 to 1,500 gpm, is not derived solely from the Crystal River aquifer but is supplemented by the overlying Miocene deposits, which indirectly contribute to the spring's flow.

MIOCENE-PLIOCENE AQUIFER

The Miocene-Pliocene aquifer includes the Citronelle Formation, the Miocene Series undifferentiated, the Paynes Hammock Sand, and the Chickasawhay Limestone, and is hydraulically separated from the underlying Crystal River aquifer by the relatively impermeable Bucatunna Clay Member of the Oligocene Byram Formation. To the south in Mobile and Baldwin Counties the Miocene-Pliocene aquifer is restricted to sediments of Miocene and Pliocene age, but in Area 10, the Chickasawhay Limestone of Oligocene age is hydraulically connected to the overlying Miocene and Pliocene sediments, and therefore, the Chickasawhay is included in the Miocene-Pliocene aquifer. The Miocene-Pliocene aquifer ranges in thickness from 0 feet at the northern outcrop limit to approximately 1,000 feet in southern Washington County.

The Miocene-Pliocene aquifer is used extensively as a source of water in Washington and Clarke Counties but is generally very thin or absent in Choctaw County. Depths of wells completed in the Miocene-Pliocene aquifer range from less than 100 feet to about 850 feet. Yields are generally 100 to 200 gpm.

WATERCOURSE AQUIFER

Quaternary alluvial and terrace deposits consisting of interbedded sand, gravel, and clay comprise the watercourse aquifer (plate 5, table 1). Properly constructed wells in the watercourse aquifer have the potential to yield from 0.5 to 1.0 million gallons per day (Mgpd) where sand is sufficiently thick. Most high-yield wells are completed in sand and gravel deposits and buried river sediments. These buried sand and gravel channels are surrounded by silty and clayey sediments that do not yield significant amounts of water, but do allow slow infiltration of water to recharge the sand and gravel beds. Individual buried channels may be connected directly to the Mobile River. In the McIntosh area of southern Washington County, industrial wells ranging from 100 to 340 feet in depth produce 500 to 1,000 gpm. The watercourse aquifer is hydraulically connected to the underlying Miocene-Pliocene aquifer in the southern part of the study area (plate 2) and provides it with recharge.

The sand and gravel beds in the watercourse aquifer and those at shallow depths in the Miocene-Pliocene aquifer are unconfined. Discontinuous clay lenses retard the vertical movement of water but do not completely separate the sand units over large areas.

While the watercourse aquifer can provide large quantities of water to wells, none of the public supply wells are completed in this aquifer because of its vulnerability to contamination.

RECHARGE AND MOVEMENT OF GROUND WATER

The source of recharge to the aquifers is rainfall, which averages 55.0 inches per year (in./yr) in the study area. A large part of the rainfall, about 20 in./yr, runs off the land surface or is returned to the atmosphere by evaporation and transpiration. A small amount of rainfall infiltrates the subsurface as recharge to the aquifers. The recharge areas for the major aquifers in Area 10 generally correspond with their outcrop areas (plates 6, 7, 8). The recharge area for the Nanafalia aquifer is primarily in northern Choctaw County; the recharge area for the Lisbon aquifer is in central Choctaw and northern Clarke Counties; and the recharge area for the Miocene-Pliocene aquifer is in Choctaw, Clarke, and Washington Counties. The recharge areas for all three aquifers consist largely of sloping uplands and some rugged hills, and are a mix of forested and cultivated areas. These aquifers also may receive recharge from the watercourse aquifer where it overlies their outcrop area (plates 6, 7, 8).

Where the aquifers are overlain by relatively impermeable beds, the water in the aquifers becomes confined under pressure. The elevation to which water rises in a tightly cased well is determined by the confining pressure in the aquifer and defines the potentiometric surface for the aquifer. The direction of ground water movement in the aquifer generally is perpendicular to the potentiometric contour lines for that aquifer. Plates 6, 7, and 8 show the potentiometric surfaces and recharge areas for each of the three major aquifers in Area 10. Water moves away from recharge areas to areas of natural discharge and areas of ground water withdrawals.

The amount of water that infiltrates the soil depends on the hydraulic conductivity and permeability of the soil, the amount of water present in the soil during rainfall, and the slope of the land surface. Infiltration is greater in a flat area underlain by gravel and coarse sand than in a sloping area underlain by dense clay.

Remnants of high terrace deposits overlie parts of the recharge areas. These terrace remnants form relatively flat, permeable landscapes and probably contribute to the recharge of underlying aquifers. Alluvial deposits also supply recharge where they overlie major aquifers along the flood plains of the Alabama and Tombigbee Rivers.

NATURAL DISCHARGE AND GROUND WATER WITHDRAWALS

Ground water discharges are primarily to streams, springs, lakes, and wells. A large part of the ground water discharges are through seeps and springs that provide the base (dry weather) flow of streams. A significant amount of ground water also is discharged directly to the rivers where they flow through the outcrop area of the aquifers. Ground water flow toward the rivers is illustrated on the potentiometric maps of the major aquifers by the lowering of the potentiometric surfaces along major rivers (plates 6, 7, 8). Ground water moves perpendicular to the potentiometric contours. Discharge to streams also can occur by upward leakage through confining beds between aquifers. Most of the remainder of the ground water is discharged through wells.

Average ground water withdrawal by public water supply systems in 1995 was 1.06 Mgpd for Choctaw County, 0.98 Mgpd for Clarke County, and 1.09 Mgpd for Washington County (Mooty and Richardson, 1998). Records of public supply wells in Area 10 are given in table 2, and the locations of the wells are shown on plate 5. The remaining discharge from wells is used for domestic, stock, industrial, and irrigation purposes. The amount of water withdrawn by private wells for domestic use in Area 10 was estimated to be 1.58 Mgpd in 1995 (Mooty and Richardson, 1998). The same authors report that 0.15 Mgpd of ground water was withdrawn for agricultural use.

EFFECTS OF WITHDRAWALS FROM THE AQUIFERS

Large withdrawals may cause a depression in the potentiometric surface of an aquifer. The extent of the depression depends on the amount of water withdrawn and the water-bearing characteristics of the aquifer. Long-term withdrawals have caused localized lowering of the potentiometric surfaces of major aquifers in Area 10. Potentiometric surfaces of major aquifers are shown on plates 6, 7, and 8. In western Choctaw County near Melvin, the GSA maintains a continuous recording water-level monitoring station at a well (Cho-1, plates 6, 9) completed in the Nanafalia aquifer. Figure 3 shows that the water level in Cho-1 has declined from about 110 feet to 135 feet below land surface since 1986. Gilbertown has a public supply well in the immediate vicinity of this well; however, Gilbertown's well is completed in the shallower Lisbon aquifer, while Cho-1 is completed much deeper in the Nanafalia aquifer.

In addition to the water-level declines in the Nanafalia aquifer in western Choctaw County (plate 6), depressions in the potentiometric surfaces of the watercourse and Miocene-Pliocene aquifers have occurred in the vicinity of McIntosh in southeastern Washington County (plate 8). In this area, industrial supply wells pump almost continuously.

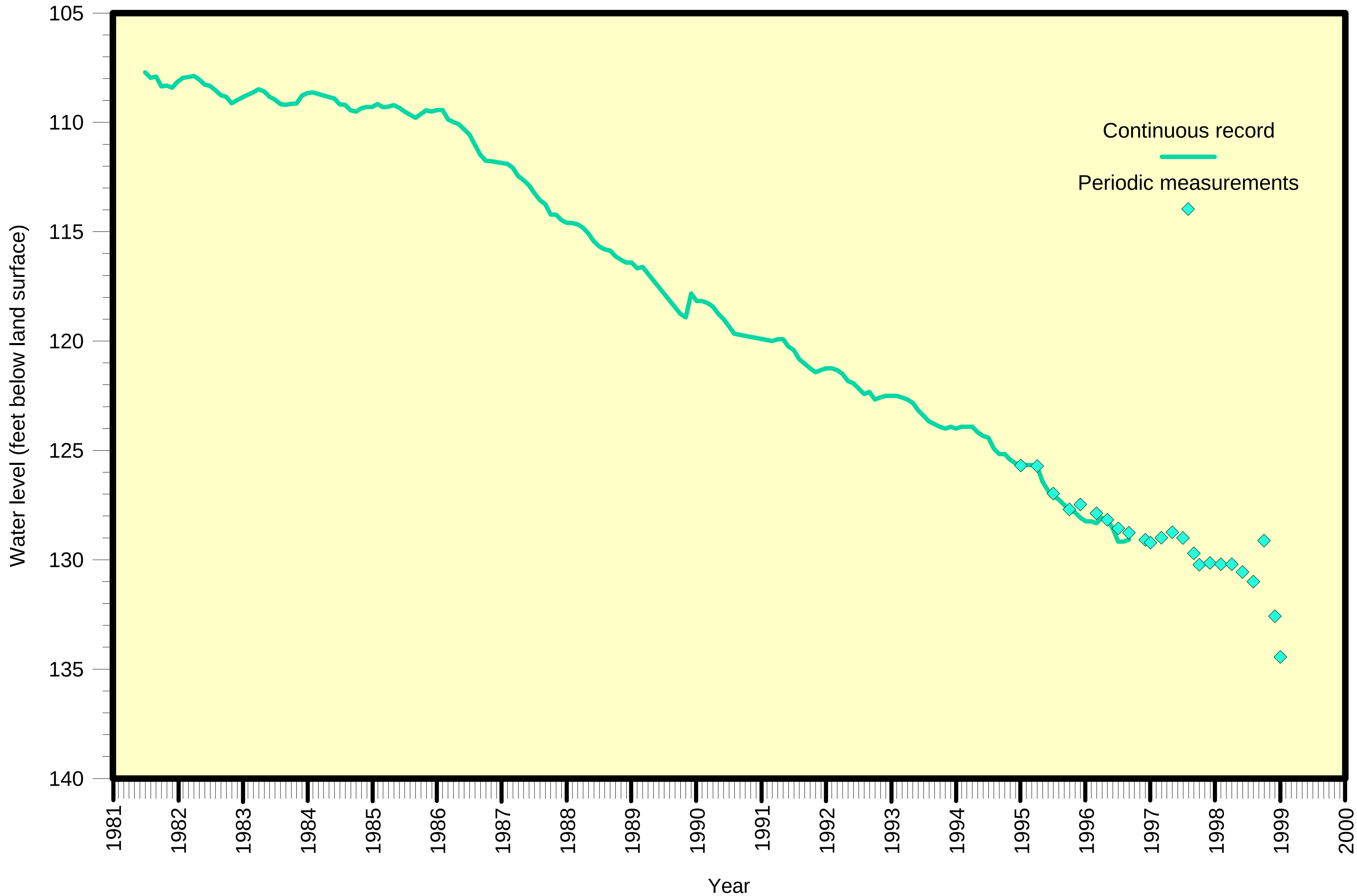


Figure 3.--Hydrograph of monthly low water levels for well Cho-1, Chotaw County.

GROUND WATER QUALITY

Aquifers in the study area generally yield water of suitable quality for most uses. The dissolved solids content is generally less than 500 milligrams per liter (mg/L) and is less than 75 mg/L in the shallow Miocene-Pliocene aquifer, the principal source of ground water in Washington County. Locally, however, iron content may exceed 0.3 mg/L. In Area 10 the water is generally soft to moderately hard except in calcareous units such as the Lisbon and Crystal River aquifers where the water is hard to very hard.

Highly mineralized water is present in lowland areas in the Tombigbee River basin in Washington and Clarke Counties. The principal constituents in the water are sodium, bicarbonate, and chloride. Locally, chloride contents may reach 28,000 mg/L at a depth of only 200 feet (Causey and McCain, 1971). Salt seeps occur at the surface in parts of northern Washington County and in southern Clarke County. Several abandoned salt works are present along the eastern edge of the Tombigbee River and adjacent to the Jackson fault. The total dissolved solids content of water from wells in this area exceeds 20,000 mg/L (Barksdale, 1929; Newton and others, 1972; Raymond, 1981).

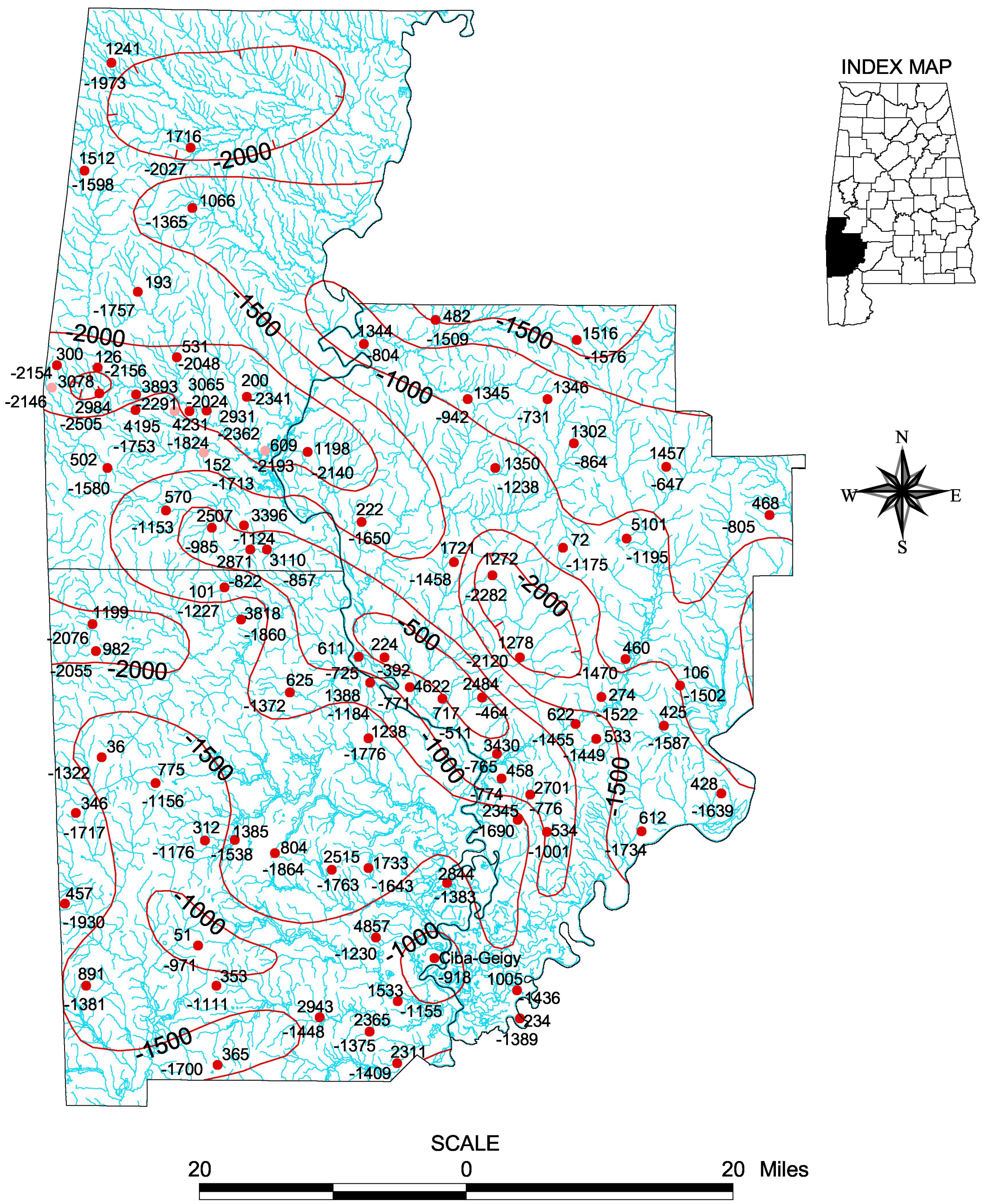
The depth relative to mean sea level at which total dissolved solids content in ground water exceeds 10,000 mg/L in Area 10 is illustrated in figure 4. Generally, water beneath this depth is not suitable for most uses.

VULNERABILITY OF THE AQUIFERS TO CONTAMINATION

Aquifer vulnerability is a difficult concept to evaluate owing to the complexity and variability of the geology and aquifers involved. Aquifers are vulnerable to contaminants from both surface and subsurface sources.

Numerous surface sources of potential contamination include point sources such as gasoline tanks, chemical spills, pipeline and sewer leaks, treatment lagoons, and industrial sites. Potential nonpoint sources of pollution include chemicals applied to agricultural fields, on-site sewage system discharges, chemicals applied to lawns and gardens, and urban runoff.

Some types of contaminants such as petroleum products are lighter than water and float on the water table. These are referred to as light nonaqueous phased liquids (LNAPL's). Other chemicals such as chlorinated hydrocarbons are denser than water and can sink through the aquifer and accumulate and migrate on subsurface confining units. These chemical contaminants are referred to as dense nonaqueous phased liquids (DNAPL's). Some contaminants dissolve in or mix with water and neither float nor sink but move with the ground water. Also, naturally occurring contamination such as saline ground water may encroach into freshwater aquifers from downdip or from other water-bearing units.



EXPLANATION

3299 State Oil and Gas Board Permit Number and other identifiers

-1534 Elevation, in feet below mean sea level, of ground water with about 10,000 mg/L of total dissolved solids as NaCl at 25°C (77°F).

● Elevation calculated from borehole geophysical logs.

● Elevation interpolated from calculated values which were derived from borehole geophysical logs of permeable units above and below a thick (>100 ft) unit with low permeability.

-1500 Elevation in feet below mean sea level, of ground water with about 10,000 mg/L of total dissolved solids as NaCl at 25°C (77°F). Contour interval 500 feet.

Figure 4--Elevation below which ground water contains more than 10,000 mg/L of total dissolved solids in Area 10 (modified from Hinkle and Sexton, 1988).

Outcrops of all aquifers in Alabama are vulnerable to contamination from surface sources of pollution. The extent to which an aquifer can become contaminated depends on the nature of the contaminant and on the hydrogeologic characteristics of the aquifer. These hydrogeologic characteristics are highly variable from aquifer to aquifer and even within individual aquifers and are largely controlled by the permeability of the units comprising an aquifer. Unconfined aquifers with high permeabilities have high recharge rates (typically more than 6 in./yr) and contaminants from the surface may not be filtered adequately as water moves towards the water table. The most vulnerable aquifers in Alabama are either unconsolidated sand and gravel or carbonate rocks that contain numerous solutionally enlarged joints and fractures. Aquifers least vulnerable to contamination are typically overlain by thick relatively impermeable units such as clay or chalk. These impermeable units are either aquicludes (confining units) or aquitards (units that retard the vertical movement of ground water).

Vulnerability may also vary within aquifers. Aquifers are most vulnerable in their outcrops where water-table conditions exist. Where aquifers become confined downdip, their vulnerability to surface contamination decreases as they are protected by aquicludes or aquitards that retard the vertical downward movement of contaminants. Although this confinement affords some protection to the aquifer, no aquifer is immune to contamination from poorly constructed wells and bad management practices. Pumping of large quantities of ground water by public supply wells, industrial supply wells, or irrigation wells creates cones of depression, increases flow gradients, and draws ground water and any associated contamination, where present, toward the pumping wells. In south Alabama and coastal areas, some aquifers are especially vulnerable to natural sources of contamination such as salt water from the Gulf of Mexico and mineralized ground water in other parts of the aquifers.

General guidelines (shown below) have been established to assist in identifying aquifers that have either a high vulnerability, moderate vulnerability, or low vulnerability to contamination. These guidelines are different from those used by U.S. Geological Survey in the original report. Most of the factors listed below apply particularly to the vulnerability of the aquifer in the outcrop area. Not all factors are required for any one aquifer to be assigned to a particular vulnerability category. A few factors pertain only to possible contamination from natural sources of contamination at depth or downdip.

<u>High vulnerability to contamination</u>

- Aquifer is unconfined, unconsolidated, highly permeable, and has high recharge rates (typically greater than 6 in./yr)
- Aquifer is not confined by thick homogeneous impermeable units or is semiconfined
- Aquifer is comprised of rocks that contain solution cavities and/or fractures that allow rapid ground water movement and high recharge rates

- Aquifer has a freshwater/salt-water interface in close proximity to the area of concern
- Aquifer is penetrated by faults that provide an avenue for entrance of contaminated water from the surface or from another aquifer

Moderate vulnerability to contamination

- Aquifer is unconfined, is consolidated rock, has low permeability, and/or has low to moderate recharge rates (typically 1 to 6 in./yr)
- Aquifer has no solution cavity development
- Aquifer is overlain by thick, several thin, or discontinuous impermeable units sufficient to afford some protection to the aquifer
- Aquifer is comprised of fractured rock but fractures are of limited extent and connectivity and are not enlarged
- Aquifer is confined by aquitards that transmit water, but not in quantities sufficient for development

Low vulnerability to contamination

- Aquifer is well confined by aquicludes that are laterally continuous, are homogeneous, are thick, lack connected fracture networks, have low recharge rates (less than 1 inch per year), and are incapable of transmitting significant quantities of water
- Area of concern is a significant distance from the freshwater/salt-water interface of the aquifer

Detailed site-specific hydrogeologic investigations should be conducted to accurately determine an aquifer's vulnerability to contamination. Long-term aquifer testing is needed to determine the aquifer's hydrologic characteristics and the hydraulic properties of confining beds.

Shallow aquifers in Area 10 are highly vulnerable to contamination from surface sources because of the unconsolidated nature of the aquifers, their exposure at the surface, and absence of overlying continuous protective clay layers. The outcrops of the nonwater-bearing formations, Tuscahoma Sand and Porters Creek, are considered moderately vulnerable to contamination from surface sources. Thick homogeneous clay units in these formations provide some protection from contamination. Other geologic formations in Area 10 have interbedded clay units, but the clays are thinner, are less homogeneous, and are laterally discontinuous. Therefore, these formations are considered highly vulnerable to contamination from the surface. Runoff from these clay units could easily infiltrate the more permeable sand and limestone units downgradient from the clay outcrop. Therefore, all areas of recharge for the major aquifers in the study area are considered highly vulnerable to contamination from the surface (plate 5). The depth of the water-producing zone commonly tapped (table 2) and the horizontal distance from the tapped part of the aquifer to the aquifer's outcrop (plate 5) may provide some buffer from surface sources of contamination.

Terrace and alluvial deposits along the Alabama and Tombigbee Rivers overlie and are hydraulically connected with all the major aquifers in the study area. Pumpage from the alluvial deposits in the flood plains of the Alabama and Tombigbee Rivers is limited to the McIntosh area (plate 8). Pumpage in this area has reversed the natural flow direction, which is toward the river, and created large cones of depression in the potentiometric surface. Owing to heavy pumpage, river water now moves into the aquifers adjacent to the river instead of the aquifer discharging into the rivers. The reversed hydraulic gradient between the shallow aquifers and the rivers could result in vertical leakage from the rivers to the aquifers; thus, the areas along the flood plains of the Alabama and Tombigbee Rivers are highly vulnerable to contamination.

PUBLIC SUPPLY WELLS

Thirty public water supply wells and one spring yield water to 19 water systems in Area 10 (table 2; plate 5). Depth of public supply wells ranges from 130 feet for Grove Hill's no. 3 well (CLACC-2) to 1,242 feet for Gilbertown's newest well, CHOS-03.

WELLHEAD PROTECTION AREAS

Public water supply systems that use ground water supply about 40 percent of the population of Alabama (Mooty and Richardson, 1998). Programs that protect ground water sources from potential contamination are known as Wellhead Protection Programs (WHPP's). Alabama's WHPP is the result of 1986 amendments to the Safe Drinking Water Act originally enacted by Congress in 1974. The 1986 amendments directed the states to develop plans and programs to protect areas providing ground water to public water supply wells and springs. The 1996 amendments established Source Water Assessment requirements for public water supply systems using either ground water or surface water sources. Local wellhead protection plans (LWHPP) are not required. The Source Water Assessment Program (SWAP) requires a Source Water Assessment Area (SWAA) delineation, potential contaminant source inventory within each SWAA, a susceptibility analysis of each potential contaminant source in the inventory, and public notification of the condition of raw water supplies, including their susceptibility to contamination. The SWAA's are identified surface areas where potential contaminants are most likely to infiltrate the ground resulting in contamination of public water supply wells or springs. SWAA's are delineated by using hydrogeologic conditions or time of travel criteria. The revised WHPP is a voluntary program that builds on the SWAP by providing guidance for developing protection strategies in the delineated areas. Protection strategies include building a local team of concerned citizens, developing an educational and outreach program, and developing management and contingency strategies. The terms SWAA and wellhead protection area (WHPA) can be used to identify the same area around a public water supply well or spring and are used synonymously in this report.

Five WHPA's currently have been delineated in Area 10 (plate 9) in three communities: Gilbertown, Coffeeville, and McIntosh. Gilbertown's wells 2 and 3 and McIntosh's single well have been given waivers to the WHPA II requirements by ADEM because of the depth of the wells and the presence of significant aquicludes between the well screens and the surface. Locations and boundaries of the WHPA I's are shown on plate 9. The WHPA I is defined by a fixed radius of 400 to 1,000 feet or a 180-day time-of-travel, while a WHPA II boundary is based on a 10-year time-of-travel or flow boundaries.

SUMMARY AND CONCLUSIONS

The major aquifers in Area 10 are the Nanafalia, Lisbon, Crystal River, Miocene-Pliocene, and watercourse aquifers. The recharge areas for these aquifers lie partly within Choctaw, Clarke, and Washington Counties. The aquifers underlie most of the study area and consist of sand and gravel beds and some limestone. Water in the aquifers generally occurs under artesian conditions, excluding the watercourse aquifer.

The Nanafalia aquifer is a source of public water supply in Choctaw and Clarke Counties. The Lisbon supplies public water in Clarke, Choctaw, and Washington Counties. The Miocene-Pliocene aquifer is a public water supply source in Washington and Clarke Counties.

The recharge areas for the major aquifers are considered highly vulnerable to surface contamination throughout the study area. Downdip, the presence of a relatively impermeable clay unit between the surface and the screen location in a well may provide a well with some protection from contamination from the surface.

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EXPLANATION FOR TABLE 2

SYSTEM, water system name.
PWS ID, public water system identification numbers as assigned by the Alabama Department of Environmental Management.
SE ID, source identifications number assigned by the Alabama Department of Environmental Management. New wells may not have SE ID’ s assigned at press time.
WELL NO, well identification number used in Water Resources Investigation Report 88-4077 and shown on plates.
GSA ID, well identification number assigned by the Geological Survey of Alabama (GSA) and shown on plates.
DEPTH, total depth of well in feet. Number in parentheses denotes total depth of test well drilled at the same location.
YEAR DRILLED, the year the well was completed and ready for operation.
DRILLING CONTRACTOR, name of driller.
ALTITUDE, elevation of land surface in feet above mean sea level.
WATER BEARING UNIT, Qalt, alluvial and terrace deposits of Quaternary age; Tmu, undifferentiated Pliocene, Miocene and Oligocene deposits of Tertiary age; Tcr, Crystal River Formation; Tl, Lisbon Formation; Tgl, Lisbon and Gosport Sand; Tnf, Nanafalia Formation.
WATER LEVEL, water level in feet below land surface. The date the measurement was made is shown below the measurement.
WELL CONSTRUCTION, YIELD, REMARKS, gpm in gallons per minute.

Table 2.–Records of public water supply wells in Area 10

CHOCTAW COUNTY

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Pennington Water Works	244	1	CHOL-01	240	1979	Griner Drilling Service Inc.	55	Tnf	11.58 01/18/79	Casing: 8-in. from 0 to 187 ft; 6-in. from 169 to 200 ft. Screen: 6-in. from 200 to 240 ft. Drawdown 5 ft when pumped at 224 gpm for 18 hrs on1/18/79. Town well 3.
North Choctaw County Water Works	243	1	CHOH-01	391 (440)	1980	Graves Drilling Co.	214	Tnf	64.5 08/20/80	Casing: 12-in. from 0 to 41 ft; 6-in. 300 to 341 ft. Screen: 6-in. from 341 to 396 ft. Drawdown 52 ft when pumped at 400 gpm for 19 hrs on 11/05/80.
Butler Water Works	232	2	CHOM-2	708	1981	Layne Central Co., Inc.	160	Tnf	46 01/01/82	Casing: 16-in. from 0 to 570 ft; 8-in. from 510 to 575 ft, 590 to 637 ft, and 642 to 678 ft; 6-in. from 698 to 708 ft. Screen: 8 in. from 575 to 590 ft, 637 to 642 ft, and 678 to 698 ft. Drawdown 103 ft when pumped at 780 gpm for 26 hrs in 1982.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Butler Water Works	232	1	CHOM-01	663	1961	Layne Central Co., Inc.	202	Tnf	64.2 06/06/67	Casing: 16-in. from 0 to 545 ft; 8-in. from 485 to 548 ft and 563 to 606 ft. Screen: 8-in. from 548 to 563 ft and 606 to 641 ft. Drawdown 60 ft when pumped at 548 gpm for 8 hrs in 1961.
Gilbertown Water System	237	1	CHOBB-01	220	1975	Holland Well Co.	250	Tgl	118 02/02/76	Casing: 12-in. from 0 to 190 ft, 10-in. from 180 to 192 ft. Screen: 10-in. from 192 to 220 ft. Drawdown 70 ft when pumped at 200 gpm for 24 hrs in 1976.
Gilbertown Water System	237	2	CHOZ-01	573	1975	Griner Drilling Service Inc.	360	Tgl	198.45 07/31/79	Casing: 16-in. from 0 to 317 ft; 10-in. from 70 to 322 ft. Screen: 8-in. from 322 to 382 ft. Drawdown 58 ft when pumped at 200 gpm for 1.5 hrs in 1979. Also known as the Melvin well.

Table 2.–Records of public water supply wells in Area 10–Continued

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Gilbertown Water System	237	3	CHOS-03	1,242	1993	Donald Smith Company	480	Tnf	304 04/26/93	Casing: 16-in. from 0 to 1,140 ft; 8-in. from 1,040 to 1,158 ft, 1,208 to 1,232 ft, and 1,242 to 1,252 ft. Screen: 8-in. from 1,158 to 1,208 ft and 1,232 to 1,242 ft. Drawdown 20 ft when pumped at 300 gpm for 24 hrs on 4/26/93.
Gilbertown Water System	237		CHOCC-010	1,455 (1,588)	1997	Donald Smith Company	185	Tnf	flows 07/22/97	Casing: 16-in. from 0 to 1,360 ft; 8-in. from 1,300 to 1,395 ft. Screen: 8-in. from 1,395 to 1,445 ft. Drawdown 166 ft when pumped at 450 gpm for 10 hrs on 5/21/97.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

CLARKE COUNTY

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Coffeeville Water Works	252	1	CLAU-2	287	1963	Acme Drilling Co.	172	Tgl	109.9 10/18/85	Casing: 12-in. from 0 to 247 ft; 6-in. from 196 to 247 ft. Screen: 5-in. from 247 to 287 ft. Drawdown 62 ft when pumped at 108 gpm for 8 hrs on 9/25/63. Town well 1.
Coffeeville Water Works	252	2	CLAU-01	287	1967	Acme Drilling Co.	180	Tgl	93 08/03/67	Casing: 12-in. from 0 to 255 ft; 8-in. from 214 to 256 ft. Screen: 6-in. from 256 to 282 ft. Drawdown 103 ft when pumped at 108 gpm for 8 hrs in 1967. Town well 2.
Coffeeville Water Works	252	3	CLAR-012	179	1992	Weldon Drilling Co.	280	Tl	104.25 05/07/92	Casing: 12-in. from 0 to 163 ft; 10-in. from 0 to 166 ft; 6-in. from 134 to 166 ft. Screen: 6-in. from 166 to 179 ft. Drawdown 42 ft when pumped at 125 gpm for 24 hrs on 5/7/92.
Fulton Utilities Board	254	1	CLAO-12	296	1974	Layne Central Co., Inc.	290	Tl	63 1974 96.5 04/18/86	Casing: 18-in. from 0 to 257 ft; 10-in. from 200 to 262 ft. Screen: 8-in. from 262 to 292 ft. Drawdown 94 ft when pumped at 300 gpm for 12 hrs in 1974.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Grove Hill Water System	255	3	CLACC-2	130	1965	Layne Central Co., Inc.	478	Tmu	84.2 04/14/67	Casing: 16-in. from 0 to 110 ft. Screen: 12-in. from 110 to 130 ft. Drawdown 33 ft when pumped at 250 gpm for 8 hrs in 1965.
Grove Hill Water System	255	2	CLAX-9	154	1980	Layne Central Co., Inc.	500	Tmu	98.5 06/30/80	Casing: 18-in. from 0 to 106 ft; 10-in. from 0 to 107 ft. Screen: 10-in. from 107 to 137 ft. Drawdown 6 ft when pumped at 190 gpm for 24 hrs on 8/17/80. Well behind jail.
Grove Hill Water System	255	1	CLAX-01	150	1953	Layne Central Co., Inc.	491	Tmu	86.3 01/10/67	Casing: 24-in. from 0 to 100 ft; 16-in. from 0 to 130 ft. Screen: 12-in. from 130 to 150 ft. Drawdown 33 ft when pumped at 152 gpm for 8 hrs in 1952. Town well 3.
Grove Hill Water System	255	4	CLACC-02	147	1935	Gray Artesian Well Co.	505	Tmu	105 01/01/35	Casing: 18-in. from 0 to 100 ft; 8-in. from 0 to 100 ft. Screen: 8-in. from 100 to 145 ft. Drawdown 12 ft when pumped at 210 gpm in 1940.
Jackson Water Works & Sewer Board	256	1	CLAHH-6				34	Tmu, Tcr		Hoven Spring. Measured flow 1,485 gpm on 10/26/66 and 1,250 gpm on 11/06/86.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

WASHINGTON COUNTY

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Chatom Utilities Board	1358	2	WASP-3	298	1961	Layne Central Co., Inc.	165	Tmu	54.6 04/18/67	Casing: 12-in. from 0 to 246 ft; 6-in. from 178 to 248 ft. Screen: 6-in. from 248 to 273 ft and 283 to 298 ft. Drawdown 17 ft when pumped at 250 gpm for 8 hrs in 1961. Town well 2, Gordy Road.
Chatom Utilities Board	1358	3	WASP-4	349	1950	Layne Central Co., Inc.	185	Tmu	71.8 04/18/67	Casing: 10-in. from 0 to 22 ft; 8-in. from 0 to 259 ft; 6-in. from 259 to 79 ft. Screen: 6-in. from 279 to 299 ft and 329 to 349 ft. Drawdown 63 ft when pumped at 107 gpm for 8 hrs in 1950. Town well 3.
Deer Park/Vinegar Bend Water Authority	1368	1	WASII-01	464	1982	Graves Well Drilling Co.	150	Tmu	52.6 05/11/82	Casing: 12-in. from 0 to 410 ft; 6-in. from 360 to 403 ft. Screen: 6-in. from 403 to 464 ft. Drawdown 30 ft when pumped at 300 gpm for 21 hrs on 5/18/82.
Frankville Water & Fire Protection Authority	1357	1	WASI-01	190	1985	Holland Well Co.	210	Tmu	118 05/02/85	Casing: 16-in. from 0 to 160 ft; 8-in. from 130 to 170 ft. Screen: 8-in. from 170 to 190 ft. Drawdown 18 ft when pumped at 300 gpm for 24 hrs in 1985.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Fruitdale Water System	1360	1	WASEE-1	273	1966	Acme Drilling Co.	245	Tmu	88 1966	Casing: 6-in. from 0 to 250 ft; 4-in. from 217 to 255 ft. Screen: 4-in. from 255 to 273 ft. Drawdown 70 ft when pumped at 60 gpm for 8 hrs in 1966.
Leroy Water & Fire Protection Authority	1362	1	WASM-7	167	1966	Acme Drilling Co.	1362	Tmu	60.4 04/17/67	Casing: 7-in. from 0 to 151 ft; 4-in. from 130 to 151 ft. Screen: 4-in. from 151 to 167 ft. Drawdown 30 ft when pumped at 115 gpm for 8 hrs on 10/03/66.
Leroy Water & Fire Protection Authority	1362	2	WASM-01	174	1972	Acme Drilling Co.	100	Tmu	40 09/21/72	Casing: 12-in. from 0 to 152 ft; 8-in. from 115 to 151 ft. Screen: 6-in. from 151 to 171 ft. Drawdown 24 ft when pumped at 183 gpm for 8 hrs on 09/04/72.
McIntosh Water & Fire Protection	1363	1	WASKK-02	765	1992	Griner Drilling Service Inc.	205	Tmu	159.1 02/17/92	Casing: 12-in. from 0 to 666 ft; 6-in. from 605 to 676 ft. Screen: 6-in. from 676 to 757 ft. Drawdown 338 ft when pumped at 302 gpm for 10 days in Oct. 1991.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Millery Water Works	1364	1	WASC-5	265	1963	Layne Central Co., Inc.	120	Tmu	flows 1963	Casing: 12-in. from 0 to 223 ft; 6-in. from 183 to 228 ft. Screen: 6-in. from 228 to 248 ft. Drawdown 69 ft when pumped at 108 gpm for 8 hrs in 1963. Town well 1, behind town hall.
Millery Water Works	1364	2	WASD-01	266	1975	Holland Well Co.	120	Tmu	flows 1975	Casing: 8-in. from 0 to 226 ft; 6-in. from 220 to 230 ft. Screen: 6-in. from 230 to 260 ft. Drawdown 70 ft when pumped at 120 gpm for 8 hrs on 1/24/75. Town well 2, on County Road 34 West.
South Alabama Utilities/Fairford	1354	1	WASKK-01	823	1987	Holland Well Co.	230	Tmu	186.70 03/30/87	Casing: 12-in. from 0 to 743 ft; 6-in. from 575 to 743 ft. Screen: 6-in. from 743 to 823 ft. Drawdown 5.6 ft when pumped at 220 gpm for 8 hrs on 3/30/87.
South Alabama Utilities/Calvert	1356	1	WASNN-01	232	1971	Holland Well Co.	150	Tmu	90 01/18/71	Casing: 8-in. from 0 to 200 ft; 4-in. from 191 to 212 ft. Screen: 4-in. from 212 to 232 ft. Drawdown 17.66 ft when pumped at 120 gpm for 6 hrs on 1/5/71.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

System	PWS ID	SE ID	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
St. Stephens Water System	1366	1	WASN-02	290	1971	Holland Well Co.	180	Tmu	130 01/01/72	Casing: 8-in. from 0 to 261 ft; 4-in. from 260 to 270 ft. Screen: 4-in. from 270 to 290 ft. Drawdown 62 ft when pumped at 105 gpm for 72 hrs on 6/1/72.
Wagerville Water System	1367	1	WASN-01	385	1967	Holland Well Co.	65	Tmu	23 1967	Casing: unknown. Screen: 4-in. from 368 to 385 ft. Yield 100 gpm.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

Inactive wells

CHOCTAW COUNTY

System	Well no.	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Town of Pennington	2	CHOJ-02	30	1968	Acme Drilling Co.	100	Tnf	2 03/07/68	Casing: 12-in. from 0 to 20 ft; 6-in. casing from 0 to 20 ft. Screen: 4-in. from 20 to 30 ft.
Town of Pennington	3	CHOJ-01	40	1968	Acme Drilling Co.	100	Tnf	2 03/07/68	Casing: 12-in. from 0 to 30 ft; 6-in. casing from 0 to 30 ft. Screen: 4-in. from 30 to 40 ft.
Town of Riderwood	5	CHON-1	137	1917	J. E. Harmon	185	Tnf	39.9 06/07/67	Casing: 4-in. from 0 to 80 ft. Open hole below casing.
City of Butler	6	CHOM-3	415	1936	Gray Artesian Well Co.	192	Tnf	72.7 06/13/67	Casing: 8-in. from 0 to 382 ft; 6-in. from 382 to 393 ft. Screen: 6-in. from 393 to 415 ft. Drawdown 46 ft when pumped 8 hrs at 40 gpm in 1936.
City of Butler	7	CHOM-4	707	1950	Peerson Drilling Supply Co	192	Tnf	73 06/06/67	Casing: 10-in. from 0 to 580 ft; 6-in. from 580 to 647 ft. Screen: 6-in. screen from 647 to 689 ft. Drawdown 37 ft when pumped 8hrs at 200 gpm in 1950.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

CLARKE COUNTY

System	Well no.	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
City of Thomasville	11	CLAJ-4	702	1944	Layne-Central Co.	361	Tnf	327.3 10/10/66	Casing: 10-in. from 0 to 660 ft; 6-in from 607 to 663 ft. Screen: 6-in. from 663 to 698 ft. Drawdown 42 ft when pumped at 125 gpm on 9/05/44.
City of Thomasville	12	CLAJ-3	738	1949	Layne-Central Co.	366	Tnf	333 10/10/66	Casing: 12-in from 0 to 670 ft; 6-in. from 595 to 674 ft and 734 to 738 ft. Screen: 6-in. from 674 to 734 ft. Drawdown 86 ft when pumped 2 hrs at 324 gpm in 1950.
City of Thomasville	13	CLAJ-5	766	1964	Layne-Central Co.	371	Tnf	295 1964	Casing: 12-in. from 0 to 691 ft; 6-in. from 641 to 696 ft and 756 to 766 ft. Screen: 6-in. from 696 to 756 ft. Drawdown 85 ft when pumped 8 hrs at 225 gpm on 5/28/64.
Town of Fulton	17	CLAX-2	173	1955	Layne-Central Co	239	Tnf	3.5 10/10/66	Casing: 18-in. from 0 to 119 ft; 10-in. from 0 to 123 f. Screen: 8-in. from 123 to 163 ft. Drawdown 41 ft when pumped 8 hrs at 160 gpm in 1955.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

System	Well no.	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Town of Whatley	21	CLABB-01	238	1971	Burrell Drilling Co.	145	Tmu	30 09/14/71	Casing: 12-in. from 0 to 63 ft; 8-in. from 0 to 107 ft. Open hole below casing. Drawdown 77 ft when pumped 24 hrs at 107 gpm on 9/15/71.
City of Jackson	29	CLAPP-4	263	1965	Layne-Central Co.	246	Tmu	125 11/27/65	Casing: 24-in. from 0 to 155 ft; 12-in. from 100 to 159 ft; 10-in. from 189 to 229 ft. Screen: 10-in. from 159 to 189 ft and 229 to 239 ft. Drawdown 66 ft when pumped 3 hrs at 151 gpm in 1965.
City of Jackson	30	CLAPP-3	171	1941	Gray Artesian Well Co.	227	Tmu	125 07/19/45	Casing: 20-in. from 0 to 80 ft; 10-in. from 0 to 131 ft. Screen: 10-in. from 131 to 156 ft. Drawdown 19 ft when pumped 8hrs at 123 gpm in 1945.
City of Jackson	31	CLAPP-2	152 (446)	1923	Gray Artesian Well Co.	227	Tmu	107 09/20/66	Casing: 20-in. from 0 to 10 ft; 10-in. from 0 to 142 ft. Screen: 10-in. from 142 to 152 ft. Drawdown 18 ft when pumped 8 hrs at 137 gpm in 1945.

EXPLANATION

Table 2.–Records of public water supply wells in Area 10–Continued

WASHINGTON COUNTY

System	Well no.	GSA ID	Depth	Year drilled	Drilling contractor	Altitude	Water bearing unit	Water level Date measured	Well construction, yield, remarks
Town of Leroy	25	WASM-02	168	1979	Acme Drilling Co.	100	Tmu	45 05/16/79	Casing: 12-in. from 0 to 146 ft; 8-in. from 101 to 146 ft. Screen: 6-in. from 146 to 166 ft. Drawdown 61 ft when pumped 8 hrs at 250 gpm on 5/16/79.
City of Chatom	32		456	1937		170	Tmu	32	Casing: 8-in. from 0 to 211 ft; 6-in. below; 6-in. screen at 294 ft. Drawdown 145 ft pumping 50 gpm.
Town of McIntosh	37	WASBB-02	245	1967	Holland Well Co.	50	Tmu	23 6/67	Casing: 6-in. from 0 to 218 ft; 4-in. from 211 to 225 ft. Screen: 4-in. from 225 to 245 ft. Drawdown 10 ft when pumped 8 hrs at 100 gpm on 6/20/67.
Town of Calvert	40	WASNN-01	232	1971	Holland Well Co.	150	Tmu	90 01/18/71	Casing: 8-in. from 0 to 200 ft; 4-in. from 191 to 212 ft. Screen 4-in. from 212 to 232 ft. Drawdown 17.7 ft when pumped 6 hrs at 120 gpm on 1/5/71.

EXPLANATION

RELATED LINKS

http://www.adem.state.al.us/
Alabama Department of Environmental Management (ADEM)
ADEM administers all major federal environmental laws, including the Clean Air, Clean Water and Safe Drinking Water acts and federal solid and hazardous waste laws. Information regarding ADEM news, regulations, funded programs, and status of filings are available on this site.

http://www.epa.gov/OW
United States Environmental Protection Agency (EPA)
This is the home page of the EPA Office of Water. Information includes America's water resources, environmental programs and partnerships, monitoring, data, and tools, you and clean water, regulations and legislation, information resources, etc. Pages for EPA Water are maintained as well: Wetlands, Oceans, and Watersheds, Science and Technology, Wastewater Management, Groundwater and Drinking Water, etc. The various regional programs are also covered as well as EMAP Estuaries.

http://www.ga.nrcs.usda.gov/al/
United States Department of Agriculture (USDA)
The Natural Resources Conservation Service (NRCS) is the USDA agency that works at the local level to help people conserve all natural resources on private lands. USDA provides soil information and other agricultural information, including maps of soil types.

http://www.ngwa.org/
National Ground Water Association (NGWA)
NGWA operates the National Ground Water Information Center ®, the largest non-governmental clearinghouse on ground water science and well technology in the world, with more than 40,000 volumes. Ground Water On-Line ®, a nearly 80,000 citation bibliographic database of ground water literature is available at no cost to NGWA members. A database of standards, guidelines, criteria, practices and procedures is also available at the Web site.

http://www.gsa.state.al.us
Geological Survey of Alabama (GSA)
The Geological Survey of Alabama, established in 1848, is a data gathering and research agency that explores and evaluates the mineral, water, energy, biological, and other natural resources of the State of Alabama and conducts basic and applied research in these fields as a public service to citizens of the State.

http://water.usgs.gov/
United States Geological Survey (USGS)
This site is the http server Water Division home page. It contains links to information from the water, geologic, and mapping divisions. USGS fact sheets, information releases, publications, data products, etc. are available. Information on GIS and the National Spatial Data Infrastructure is also included. Contact information for USGS resources (maps, etc.) Is given as well as the USGS telephone book. Links to other USGS sites on-line are available.

http://www.uwin.siu.edu:80/dir_search/index.html
Universities Water Information Network (UWIN)
UWIN maintains several databases for providing water information. Over 100 different water related links are listed by categories.

http://gwpc.site.net/
Ground Water Protection Council (GWPC)
The Ground Water Protection Council is a nonprofit (501(c)3) organization whose members consist of state and federal ground water agencies, industry representatives, environmentalists and concerned citizens, all of whom come together within the GWPC organization to mutually work toward the protection of the nation's ground water supplies.

http://www.gwrtac.org
Ground-Water Remediation Technologies Analysis Center (GWRTAC)
The Ground-Water Remediation Technologies Analysis Center compiles, analyzes, and disseminates information on innovative ground-water remediation technologies. GWRTAC prepares reports by technical teams selectively chosen from Concurrent Technologies Corporation (CTC), the University of Pittsburgh, and other supporting institutions, and also maintains an active outreach program.

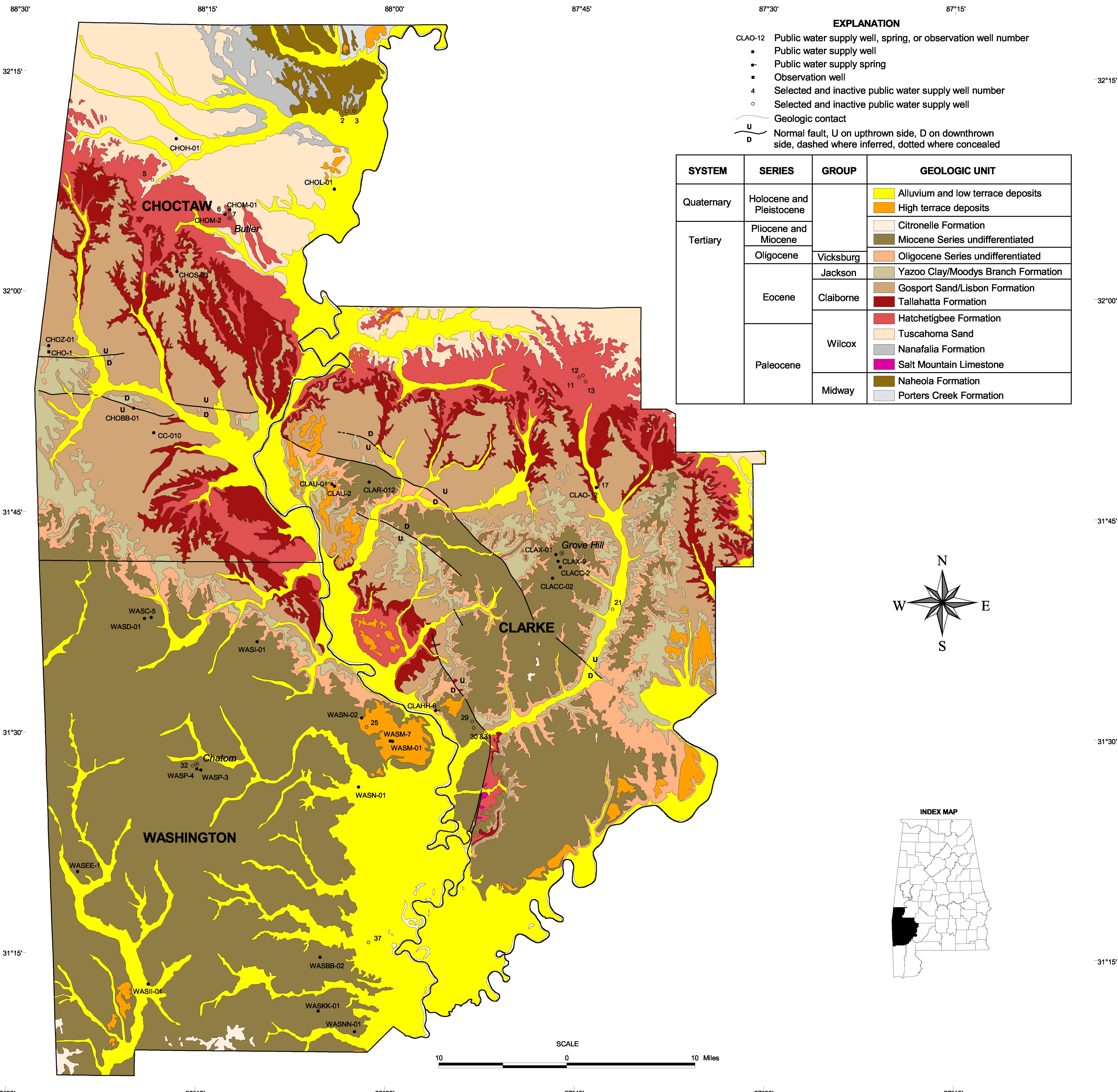
http://www.fws.gov/
U.S. Fish & Wildlife Service (FWS)
This site has general information, news releases, and employment information for the Fish and Wildlife Services. Pages on FWS activities such as Conservation Programs, Endangered Species, Contaminants, Federal Aid to States, Fire Management, Fisheries, Migratory Birds and Waterfowl, National Wildlife Refuge System, Wetlands, Wildlife Law, and Wildlife Species are included. Pages for the various FWS Regions are also incorporated.

http://hermes.ecn.purdue.edu:8001/server/water/water.html
National Extension Water Quality Database
This site allows for searches in a database that has 2,500 abstracts and 1,500 documents on all aspects of water quality. The documents are full text and list available contacts. Also available are Quick Time Movies.

http://www.TheHydrogeologist.com/
This page is a collection of hundreds of links to hydrogeological organizations, software and data repositories, publications, and other resources of potential use to hydrogeologists.

http://www.nws.noaa.gov/oh/

The Office of Hydrology serves as a primary link between the National Weather Service Headquarters and the hydrologic field service programs. Activities include development of hydrologic models, hydrologic data for rivers and flood forecasts, warnings, and water supply forecasts. Current and Historical Data include floods, hydrologic conditions, and water supply outlooks. Data systems available online are HADS (a real time hydrological and meteorological data acquisition and distribution system) and INFLOWS (Integrated Flood Observing and Warning System). Full text handbooks, reports, and user manuals are available. Information on forecast systems are also available.



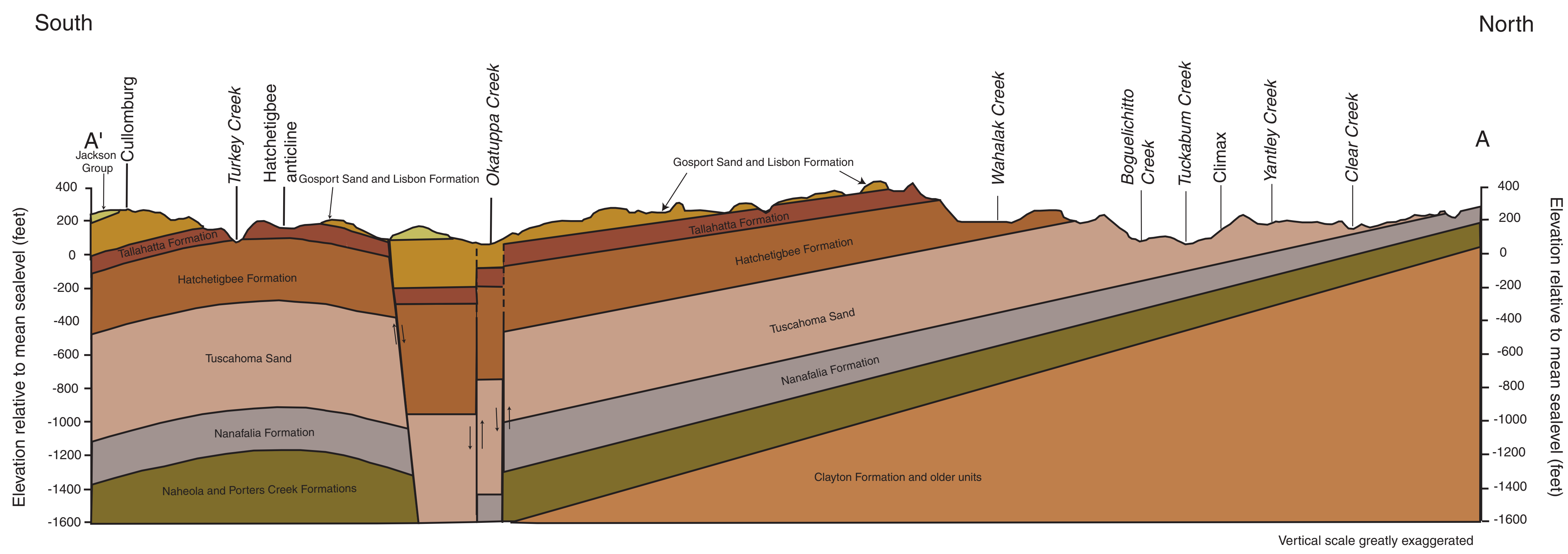
GEOLOGY AND LOCATIONS OF PUBLIC WATER SUPPLY WELLS IN AREA 10

Geology from Szabo and Copeland (1988)

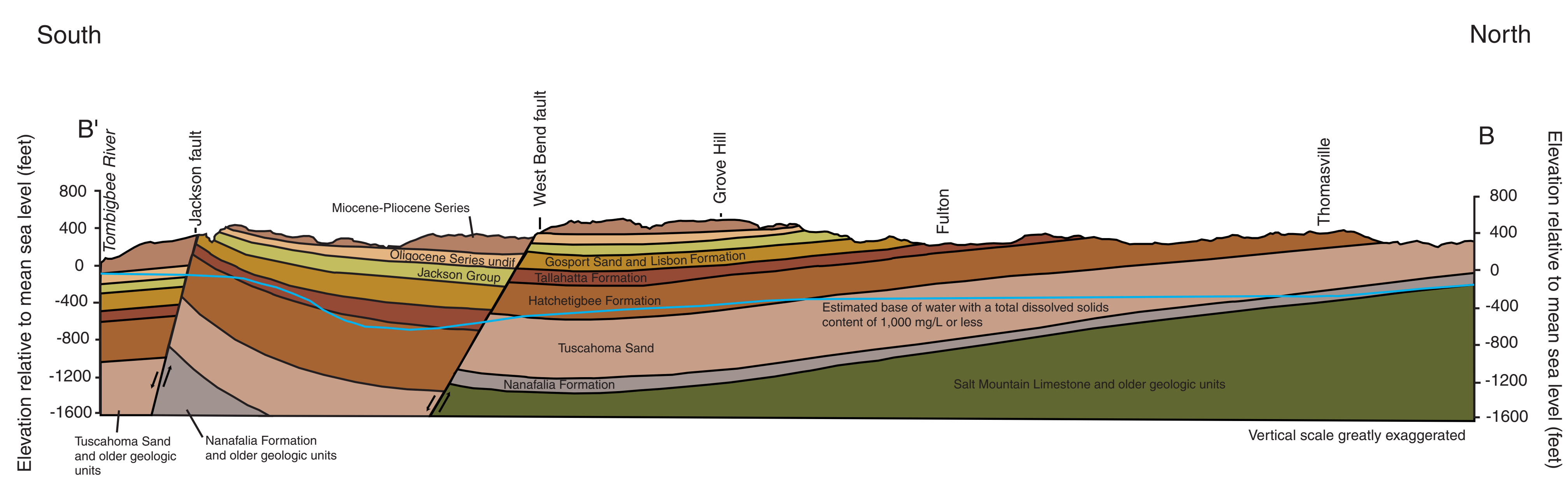
2000

STATE OF ALABAMA
GEOLOGICAL SURVEY
DONALD F. OLTZ
State Geologist

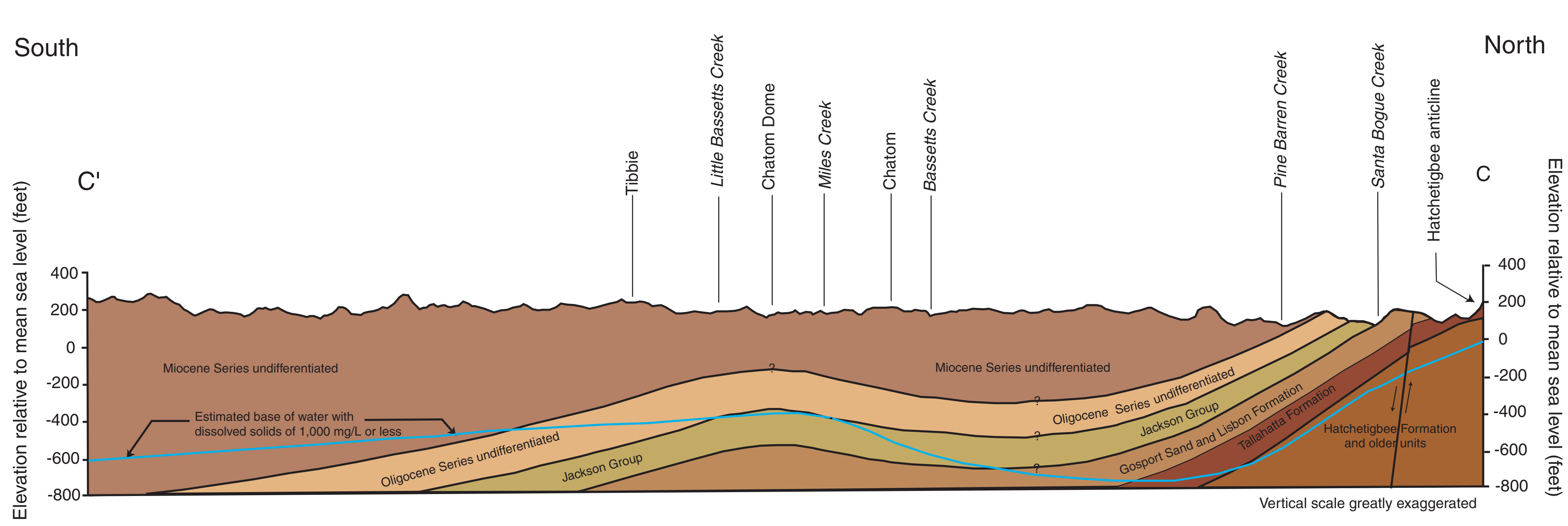
GIS by Ruth T. Collier and Douglas R. Taylor



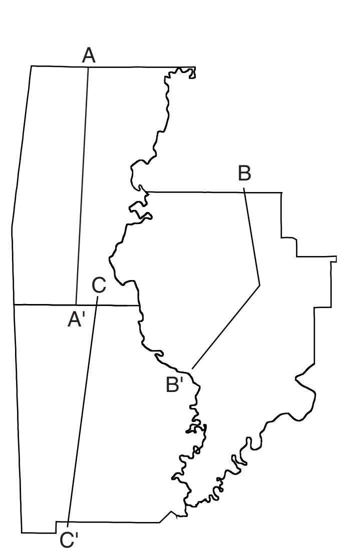
Hydrogeologic Cross Section of Choctaw County, Alabama



Hydrogeologic Cross Section of Clarke County, Alabama



Hydrogeologic Cross Section of Washington County, Alabama



Index map

EXPLANATION

Fault: arrows show relative movement

0 1 2 3 4 5 6 miles

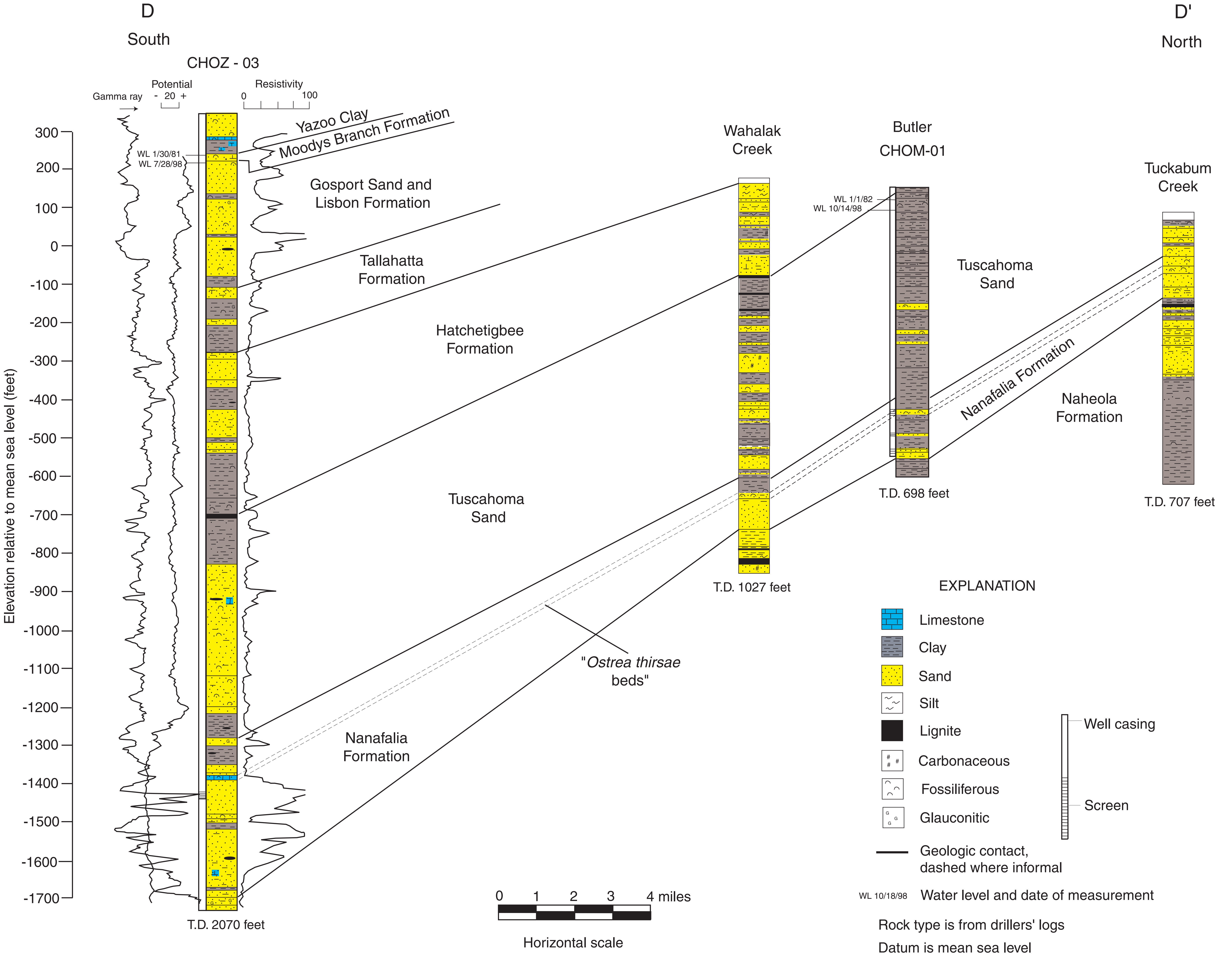
Horizontal scale

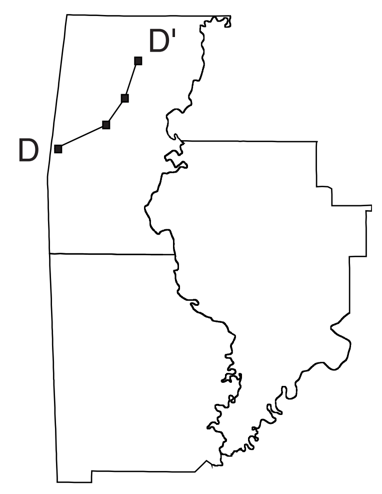
STATE OF ALABAMA GEOLOGICAL SURVEY

Donald F. Oltz
State Geologist

HYDROGEOLOGIC CROSS SECTIONS IN AREA 10

Modified from Causey and McCain (1971, 1972) and Newton, McCain, and Turner (1972)
Compiled by Dorothy E. Raymond
1999





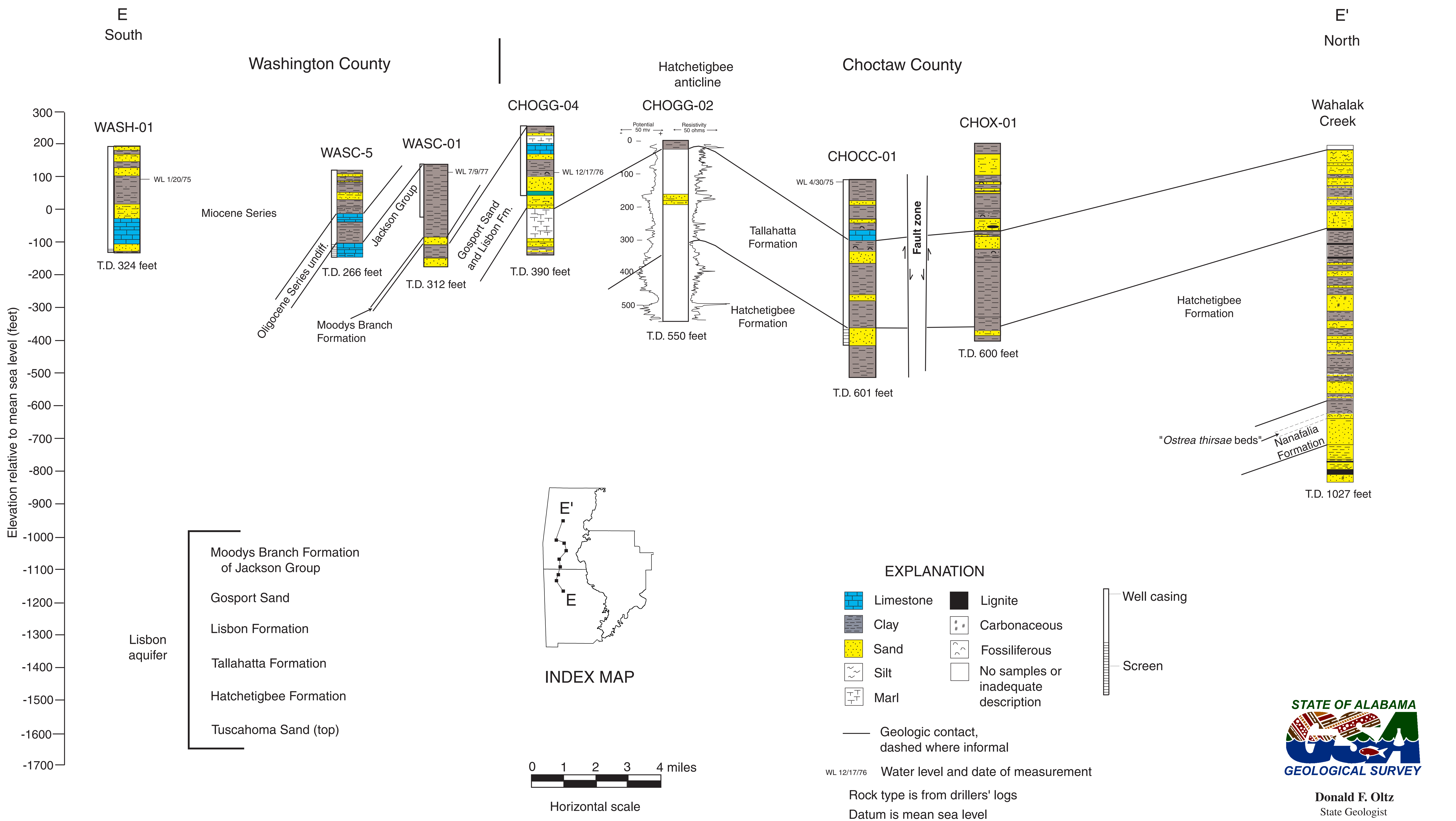
INDEX MAP

STATE OF ALABAMA
GEOLOGICAL SURVEY

Donald F. Oltz
State Geologist

HYDROGEOLOGIC CROSS SECTION OF THE NANAFALIA AQUIFER IN AREA 10

By
Dorothy E. Raymond and Blakeney Gillett
1999

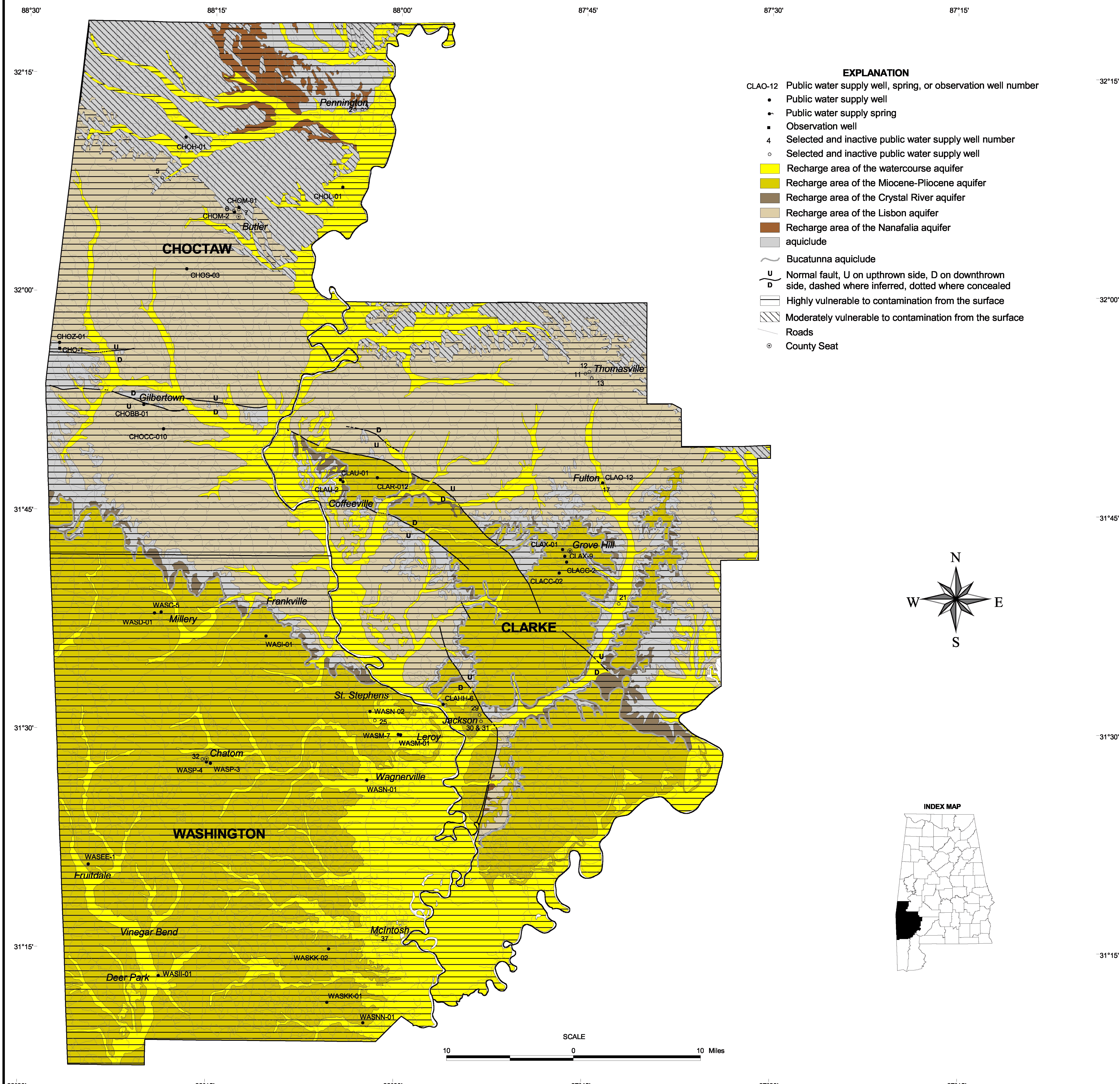


STATE OF ALABAMA GEOLOGICAL SURVEY

Donald F. Oltz
State Geologist

HYDROGEOLOGIC CROSS SECTION OF THE LISBON AQUIFER IN AREA 10

By
Dorothy E. Raymond and Blakeney Gillett
1999



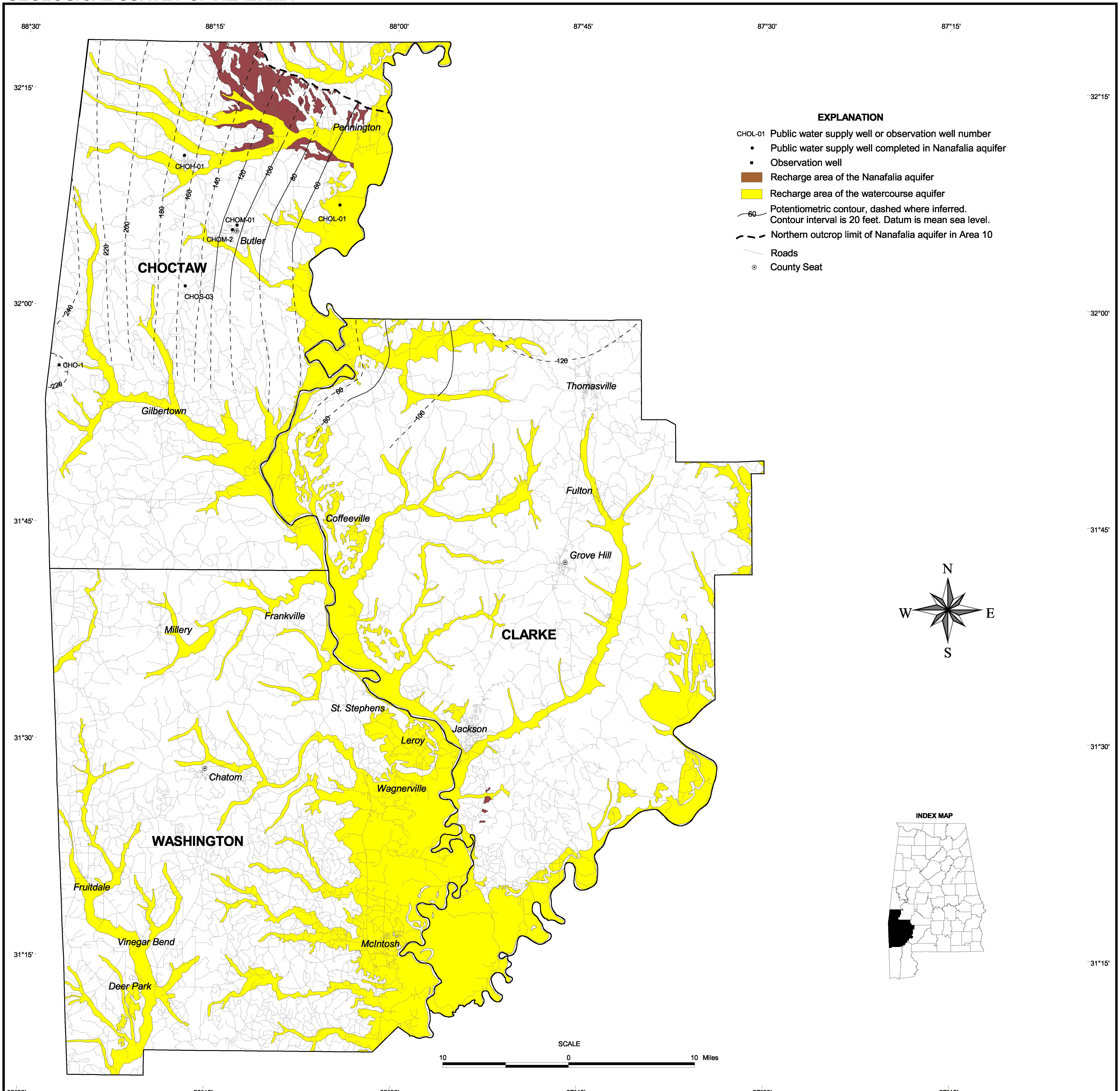
AQUIFER RECHARGE AREAS, LOCATIONS OF PUBLIC WATER SUPPLY WELLS, AND AREAS OF VULNERABILITY IN AREA 10

By Blakeney Gillett and Dorothy E. Raymond

2000

STATE OF ALABAMA
GEOLOGICAL SURVEY
DONALD F. OLTZ
State Geologist

GIS by Ruth T. Collier and Douglas R. Taylor

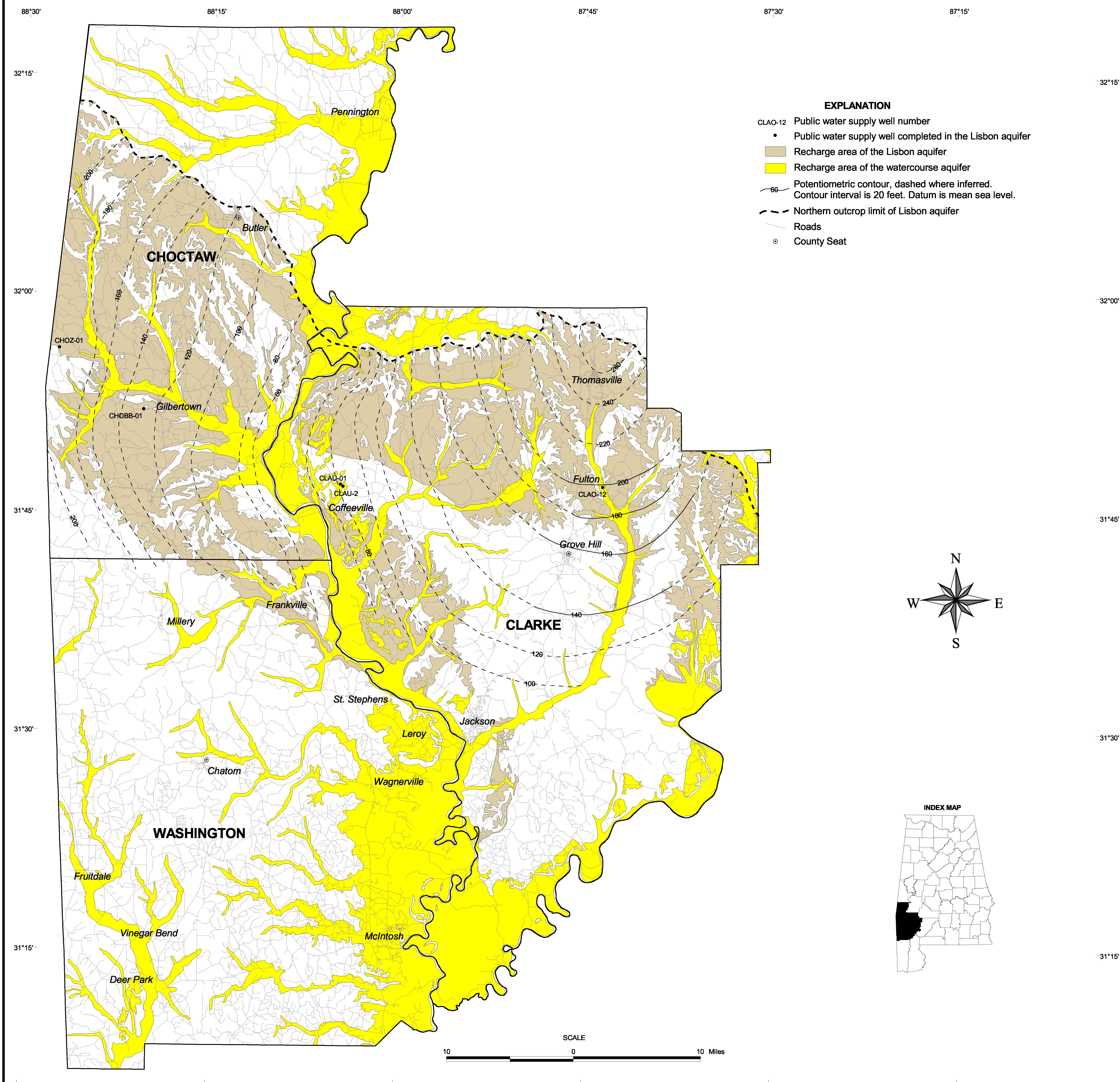


POTENTIOMETRIC SURFACE AND RECHARGE AREA OF THE NANAFALIA AQUIFER AND RECHARGE AREA OF THE WATERCOURSE AQUIFER IN AREA 10

By Blakeney Gillett

2000

STATE OF ALABAMA
GEOLOGICAL SURVEY
DONALD F. OLTZ
State Geologist
GIS by Ruth T. Collier and Douglas R. Taylor



POTENTIOMETRIC SURFACE AND RECHARGE AREA OF THE LISBON AQUIFER AND RECHARGE AREA OF THE WATERCOURSE AQUIFER IN AREA 10

By Blakeney Gillett

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GEOLOGICAL SURVEY
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State Geologist

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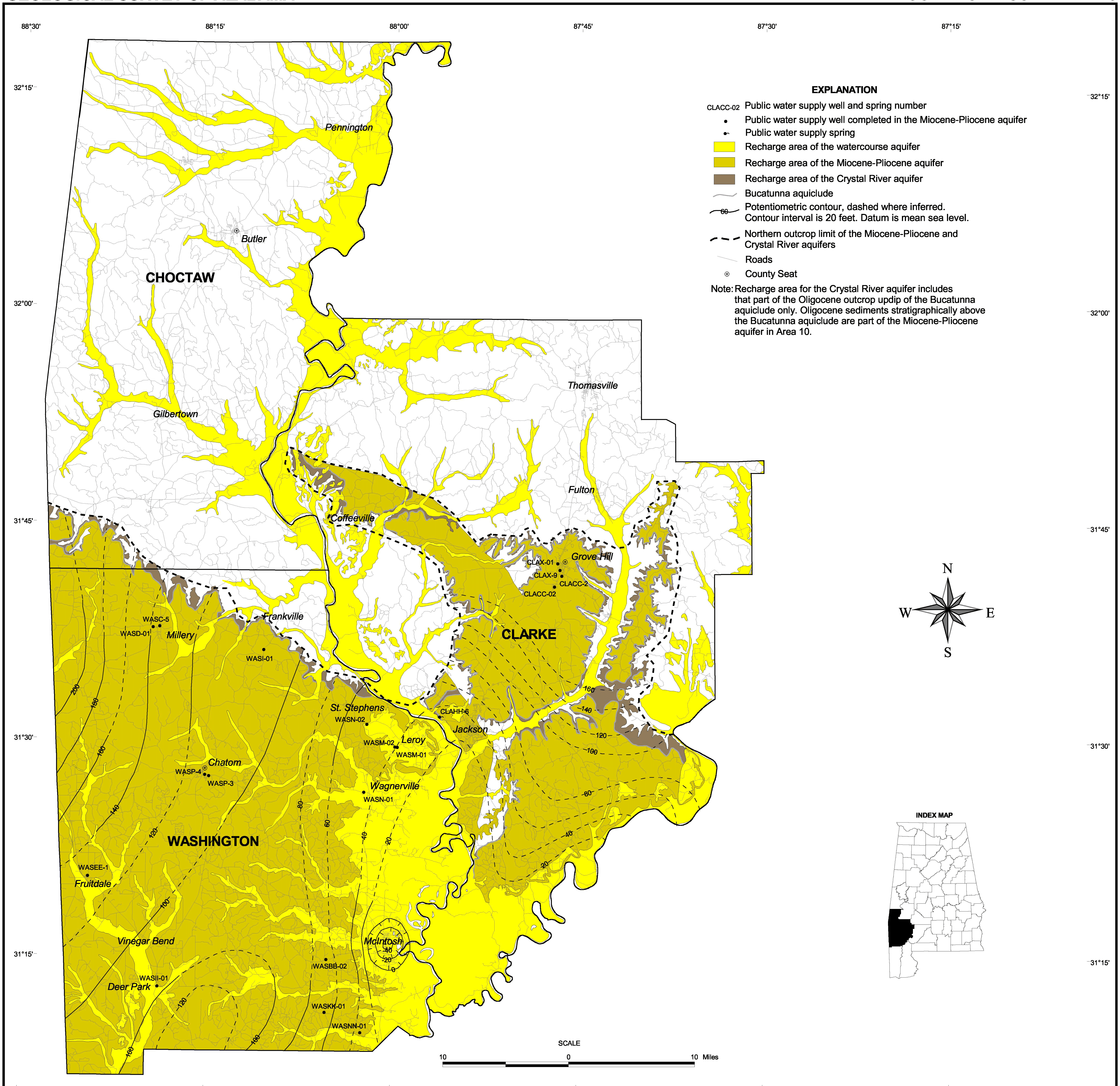

POTENTIOMETRIC SURFACE AND RECHARGE AREA OF THE MIOCENE-PLIOCENE AQUIFER AND RECHARGE AREAS OF THE WATERCOURSE AND CRYSTAL RIVER AQUIFERS IN AREA 10

By Blakeney Gillett

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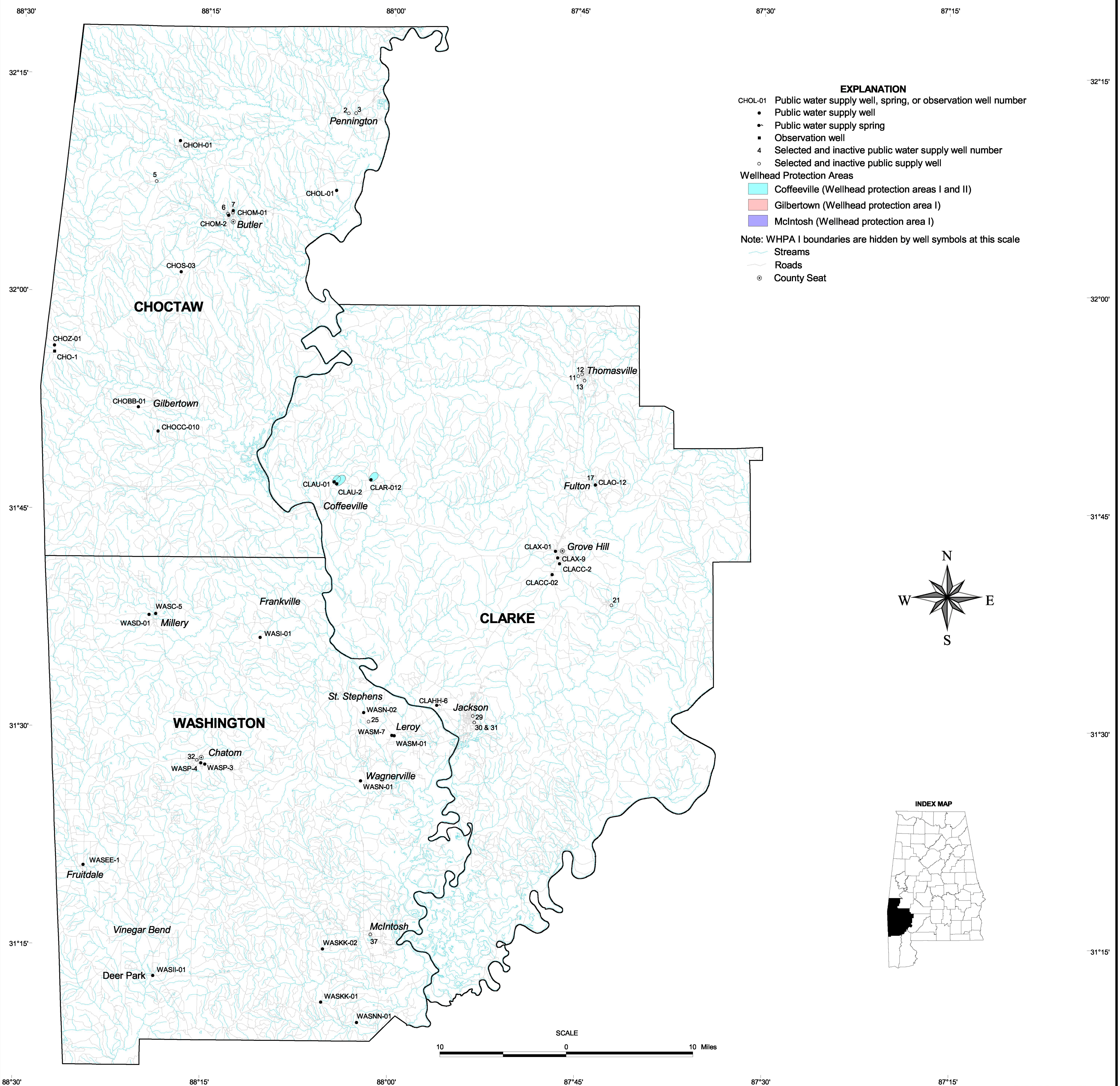

LOCATIONS OF PUBLIC WATER SUPPLY WELLS AND WELLHEAD PROTECTION AREAS DELINEATED IN AREA 10

By Blakeney Gillett

2000

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GEOLOGICAL SURVEY
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GIS by Ruth T. Collier