HYDROGEOLOGY
OF THE
NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

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NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Water Resources Special Report 96-4

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December 4, 1996

October 1996

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ACKNOWLEDGEMENTS

Sincere appreciation is extended to the many individuals who have contributed to the understanding of the hydrogeology of the Northwest Florida Water Management District over the years. Thanks are extended to Douglas Barr, Honesto Roaza, Walt Schmidt, Frank Rupert, Gary Maddox and Tom Scott for their meaningful discussions and suggestions. Special thanks are in order for former colleagues who aided in the completion of this project: Tom Allen, John Barksdale, Steve Bedowsky, Brian Caldwell, Linda Clemens, Breck Dalton, Bruce Moore, Wyndy Riotte and Keith Wilkins. The efforts and interests of Aida Bahtijarevic, Maria Culbertson, Peggy Geltman, Diedre Hamil, Valerie Johnson, Elaine McKinnon, Gary Miller, Hank Montford, Paul O'Rourke, Ferdouse Sultana and Patty Wagner are gratefully acknowledged. Their knowledge and talents in producing this publication made the project a success. This study was completed under the general supervision of Douglas E. Barr, Executive Director.

The data and interpretations presented here are the products of programs and activities conducted at the District since its inception. Of particular significance to improving our understanding of ground water resources in northwest Florida has been the contribution of the Ground Water Quality Monitoring Program of the Florida Department of Environmental Protection. This program, created by the Water Quality Assurance Act of 1983 has, since 1985, supported the maintenance and sampling of monitor wells located throughout the District. Many of the interpretations and analyses found in this report were funded, in part, through this program. Rick Copeland, Jackye Bonds, Cindy Cosper, Penn Craig, Tim Glover, Gary Maddox, David Ouellette, Andrew Priest, Jay Silvanima, and, especially, Paul Hansard have, over the years, contributed much to the success of monitoring conducted under the Ground Water Quality Monitoring Program in northwest Florida.

Thanks are also in order for the many individuals who have, over the years, sampled wells for the Ground Water Quality Monitoring Program at the Northwest Florida Water Management District, including Kenny Hamilton, Jean Menne, Brooks Baldwin, Aaron Cohen, Toby Benoit, Steve Davis and J Peterson.

CHAPTER I: INTRODUCTION

Most ground water-related studies in northwest Florida are not comprehensive for the entire panhandle area. Many reports describe the hydrogeology of only a single county or several adjacent counties. These studies often neglect adjacent areas that may significantly influence the ground water conditions within a specific study area. Many reports are outdated, as definition and terminology changes have occurred through the years. It is sometimes difficult to correlate data from reports separated by 10 to 20 years. Most studies that include the entire northwest Florida area are regional in scope, ranging from statewide to the entire southeastern United States. These types of studies necessarily neglect locally significant areas or discrete aspects of the ground water resources of northwest Florida.

The objectives of this report are to integrate local and regional aspects of ground water in the panhandle region and to update related definitions and descriptions. These descriptions and definitions are intended to form the foundation of future work, which will contribute to the database presented in this report. It is expected that these descriptions and definitions will be refined as new data become available.

This report describes and interprets the basic hydrogeologic framework of northwest Florida and provides a rationale for definitions and delineations. The hydrogeologic systems are correlated to stratigraphy as well as to geologic structure. Due to the diversity of ground water settings, many different conditions can impact the resource in a particular area. These settings and impacting conditions are presented and discussed.

Much of this report will focus on the Floridan Aquifer System and the Sand-and-Gravel Aquifer because of their importance as the principal sources of drinking water in northwest Florida. This focus is not intended to de-emphasize the significance of the minor aquifer systems. The characteristics of the minor systems and their relationship to the major hydrogeologic systems are also presented here.

Every attempt has been made to standardize terminology as defined by the Florida Geological Survey (FGS) and the Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition (hereinafter referred to as the Ad Hoc Committee, 1986). Deviations from the recommended terminology have been made to simplify and clarify the terminology of the Ad Hoc Committee and to describe unique conditions within the Northwest Florida Water Management District. These deviations are described within the text.

Location

The Northwest Florida Water Management District (NWFWMD) was created by the 1972 Florida Legislature with the passage of the Water Resources Act (Chapter 373, Florida Statutes). The NWFWMD encompasses an area of about 11,200 square miles. This includes 16 counties, from Escambia County in the west through half of Jefferson County in the east, where it borders the Suwannee River Water Management District (Figure A-1). Seven surface water basins are associated with major rivers within the NWFWMD's boundaries: the Perdido, the Escambia, the Blackwater-Yellow, the Choctawhatchee, the Apalachicola-Chipola, the Ochlockonee, and the St. Marks (Figure A-2). Ground water resources underlying northwest Florida are divided into four major regions: the Woodville Karst Region, the Apalachicola Embayment Region, the Dougherty Karst Region, and the Western Panhandle Region (Figure A-3).

Rules adopted by the NWFWMD govern various aspects of water management including: storage of surface waters, water well construction, consumptive uses of water, and agricultural and forestry surface water management. The NWFWMD has been vested with responsibility for ensuring availability of adequate water supplies and long-term water resource integrity, and must fulfill all other provisions of Chapter 373, Florida Statutes. The primary objectives of the NWFWMD include: (1) to ensure an adequate supply of water for all reasonable and beneficial purposes through the promotion of conservation, resource protection, and development of alternative water supplies; (2) to provide for the protection and enhancement of natural systems through integrated land and water resource management programs; (3) to minimize harm from flooding and otherwise protect the health, safety, and welfare of the residents; and (4) to protect, maintain, and improve the quality of ground and surface water resources. Additionally, the NWFWMD strongly supports public awareness and education regarding water resource management issues.

Climate

The climate of northwest Florida is generally humid to sub-tropical, with warm summers and mild winters. Temperatures average 81°F in the summer and 54°F during the winter (Fernald and Patton, 1984). Normal annual rainfall ranges from about 55 to 67 inches per year. Average annual rainfall is generally highest in the western portion of the NWFWMD and lowest in the eastern portion. Average monthly rainfall ranges between three and eight inches (Fernald and Patton, 1984). There are two distinct rainy seasons each year, the first resulting from frontal storm systems during the winter and early spring, and the second occurring during the summer as a result of afternoon and evening thunderstorms.

Although the NWFWMD generally has an abundant supply of rainfall, droughts periodically occur. Fall and late spring tend to be drier periods. Annual rainfall may vary as much as 50 percent from the average. Many locations have experienced as little as 40 and as much as 80 inches per year. During the past 100 years, the period of the mid-1950s had the lowest rainfall totals, while the mid-1960s had the highest.

Topography and Physiography

The topography and resultant physiography of northwest Florida are the products of stream and sea wave activity over the past 15 million years. The major physiographic features include the Northern Highlands, the Marianna Lowlands (Dougherty Karst Plain, Figure A-3), and the Coastal Lowlands (Figure A-2). The Northern Highlands extend across the northern part of the panhandle and north into Alabama and Georgia. Significant landforms within the Northern Highlands include the Tallahassee Hills, Grand Ridge, New Hope Ridge, and the Western Highlands. The Western Highlands and the Tallahassee Hills are separated by the physiographic province referred to as the Marianna Lowlands. Grand Ridge and New Hope Ridge are remnant highland features bordering the southern edge of the Marianna Lowlands. The southern limit of the Northern Highlands is marked by a regionally-extensive outfacing scarp referred to as the Cody Scarp. Elevations in the highlands area range from 50 to 345 feet above sea level.

The Cody Scarp represents the northern extent of a Pleistocene sea level transgression that removed Miocene and Pliocene sediments to expose the underlying carbonates of the St. Marks Formation and Suwannee Limestone. This area of exposed carbonates is referred to as the Woodville Karst Plain and represents a distinct physiographic subregion of the larger Woodville Karst Region.

The Marianna Lowlands is actually the southern extent of the Dougherty Karst Plain (Figure A-3), which extends into southeast Alabama and southwest Georgia. The Marianna Lowlands is a product of stream erosion and ground water dissolution activity. The highlands that formerly existed in this area have been reduced, primarily by the major rivers and streams: the Chattahoochee-Apalachicola, Chipola and Choctawhatchee rivers, and Holmes Creek (Figure A-2). The karst plain is well drained and contains many visible sinkholes, as well as paleosinks which have no surface expression. Many areas lack well-defined surface drainage patterns due to the capture of runoff by the subsurface through internal drainage. Elevations within the karst plain range from near sea level to 245 feet above sea level.

The Coastal Lowlands lie south of the Northern Highlands and are adjacent to the coastline. Elevations are low, ranging from sea level to about 100 feet above sea level. The land in many areas is poorly drained due to a flat topography and associated high water table. Landforms present within this province include barrier islands, lagoons, estuaries, sand-dune ridges, and relict spits and bars, all of which are the result of marine processes.

Land Use

Approximately 60 percent (6,700 square miles) of the 11,200 square miles comprising the NWFWMD is forested lands (Fernald and Patton, 1984). Forest industries own about 25 percent (2 million acres) of the land in northwest Florida. About 20 percent of the land is owned by state and federal government. These lands include: national forests, state parks and forests, NWFWMD water management lands along major rivers, and several large military bases of which a major portion is forested land.

Agricultural lands comprise about 16 percent of the land in northwest Florida (Fernald and Patton, 1984). Most of the agricultural lands are scattered across the Northern Highlands portion of the panhandle. The remainder of the non-urban land is divided between forested wetlands, waterbodies, and nonforested wetlands and barren lands, covering ten, six, and two percent of the NWFWMD, respectively (Fernald and Patton, 1984).

Urban areas account for about six percent of northwest Florida (Fernald and Patton, 1984). High population densities exist in Pensacola, Ft. Walton Beach vicinity, Panama City, and Tallahassee. The coastal area is extensively developed between Pensacola and Panama City. The panhandle is generally rural, with an overall population density of less than 75 persons per square mile.

Ground Water Monitoring

Ground water monitoring was first initiated in northwest Florida during the early 1930s. Originally, monitoring consisted of observing water-level fluctuations in a few wells in the major urban areas of the panhandle. The NWFWMD has, through the years, expanded and refined the original network due to population growth, the importance of ground water as a source of drinking water, and increasing incidents of ground water contamination. In the earlier days of data collection, the U.S. Geological Survey (USGS) maintained and operated ground water data collection efforts as part of the federal mission. The NWFWMD has been involved in hydrologic data collection since 1976, when it entered into a cooperative agreement with the USGS. This joint agreement remained in effect from 1976 through 1989. In 1983, the Florida Legislature passed the Water Quality Assurance Act mandating the Department of Environmental Regulation (now the Department of Environmental Protection) to establish a statewide ground water quality monitoring network in cooperation with other federal and state agencies, including Florida's five water management districts (Florida Statutes, Section 403.063). The NWFWMD now maintains and operates a part of this network consisting of more than 300 wells distributed throughout northwest Florida (Figure A-4). These wells penetrate and tap all the aquifer systems underlying northwest Florida.

The goals of data collection are to establish baseline ground water quality information, detect and predict trends and changes in water quality, define the hydrogeologic framework, and describe the basic hydrogeologic conditions present for each hydrogeologic system through time. Trends in data can be identified and assessed in order to recognize threats to the resource and to make predictions that allow for management and preservation of ground water resources. Additionally, the dissemination of this data to other government agencies and to the general public assists in solving and supporting local issues.

Limitations on Applicability

The maps presented in this report were prepared at scales that preclude their direct application to site-specific interpretations. Because of the heterogeneous nature of geologic media and the limited geologic control available when these maps were prepared, site-specific conditions may vary from the information presented herein. Accordingly, the maps presented in this report should be used with care when the scale of the area of interest is substantially different from the scale at which the maps were prepared.

CHAPTER II: HYDROGEOLOGIC OVERVIEW

Regional Hydrostratigraphy

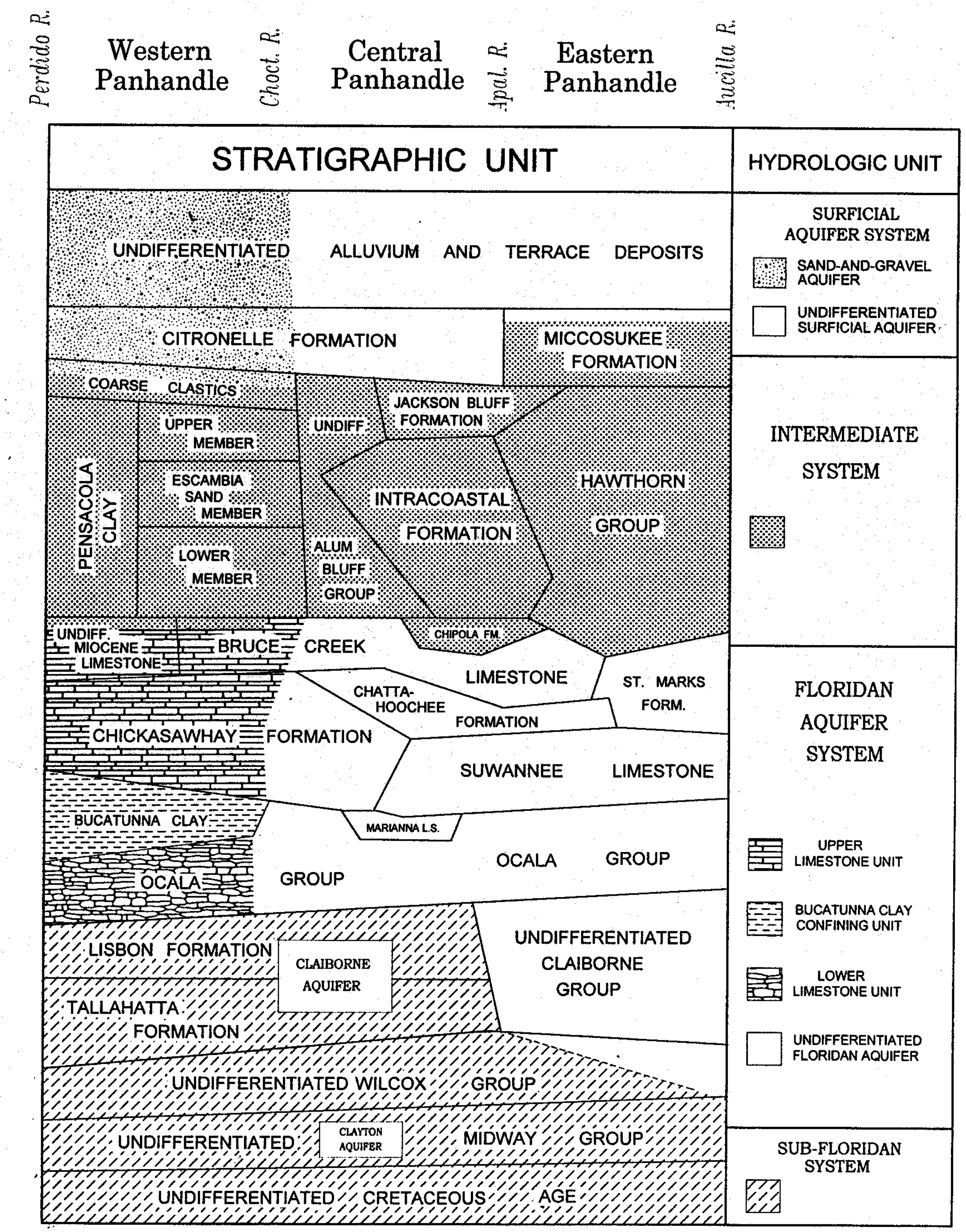
This report is not intended to contradict previous hydrogeologic terminology but to clarify and provide more consistent definitions throughout the panhandle. The inconsistent use of hydrogeologic terminology has long been recognized. Terms such as shallow aquifer, sand aquifer, water-table aquifer, non-artesian aquifer, limestone aquifer, secondary artesian aquifer, deep aquifer, principal aquifer, Hawthorn aquifer, Suwannee aquifer, St. Mark's aquifer, upper confining unit, water-bearing zone of upper confining unit, Pensacola Clay confining unit, Hawthorn confining bed, lower confining bed, etc. have confused understanding of the hydrogeologic framework. Most of the preceding terms are generic and can have a variety of meanings. In northwest Florida, the hydrogeologic framework is divided into four groups of sediments that constitute distinct hydrogeologic systems.

Each system is a collection of lithologic beds that share certain hydrogeologic characteristics. Systems are defined by their ability to conduct or retard the flow of water and, thus, are not constrained by lithologic or stratigraphic boundaries. In general, boundaries between systems separate lithologically distinct units. In some cases, due to variations in a lithologic unit's ability to conduct water, a system boundary may occur within a stratigraphic unit. In descending order from land surface, the four systems are: the Surficial Aquifer System (which includes the Sand-and-Gravel Aquifer); the Intermediate System; the Floridan Aquifer System; and the Sub-Floridan System. Figure 1 correlates regional stratigraphy to the hydrogeologic systems and shows the variability of the hydrogeologic framework across the panhandle. The lithostratigraphic units in the figure are not necessarily shown in correct chronostratigraphic position.

The system definitions presented here are a modification of those presented by the Ad Hoc Committee (1986). In northwest Florida, the Ad Hoc Committee recognized three aquifer systems (the surficial aquifer system, the intermediate aquifer system and the Floridan aquifer system) and two confining units (the intermediate confining unit and the sub-Floridan confining unit). This report modifies the Ad Hoc Committee definitions in two ways. First, the intermediate confining unit and intermediate aquifer system are combined into the Intermediate System. This combination recognizes the fact that the intermediate confining unit and intermediate aquifer system occupy the same hydrostratigraphic position between the Surficial Aquifer System and the Floridan Aquifer System. Accordingly, the complex series of confining and water-bearing lithologies comprising the intermediate confining unit/aquifer system are combined and elevated to system status. Second, the sub-Floridan confining unit is elevated to system status. This recognizes the fact that, in northwest Florida, the Sub-Floridan System contains minor aquifers. This report further deviates from the Ad Hoc Committee recommendations by capitalizing each of the four system names.

Use of the terms "region" and "regionally" are slightly altered from the Committee recommendations. The Committee recommended the use of "region" to specify a spatial extent approximating (or larger than) the size of a water management district. Here the term refers to features that range in size from several counties to the major part of the NWFWMD. This usage most closely corresponds the Ad Hoc Committee's "sub-regional" term.

Due to their lithologic characteristics, the Surficial Aquifer System and Floridan Aquifer System have properties that allow for the storing and transmitting of ground water; however, these aquifer systems are vastly different in that, due to variations in composition and thickness, each has different water-yielding properties. The Intermediate and Sub-Floridan systems function as groups of sediments that retard the vertical movement of ground water. The Intermediate System limits the exchange of water between the Surficial Aquifer System and the Floridan Aquifer System. The Sub-Floridan System forms the base of the Floridan Aquifer System ground water flow regime.



NOTE: LITHOSTRATIGRAPHIC UNITS ARE NOT NECESSARILY SHOWN IN CORRECT CHRONOSTRATIGRAPHIC POSITION.

Figure 1. Correlation of Hydrogeologic Systems to Stratigraphy in the Panhandle Region.

The greater the percentage of continuously occurring clay beds and the thicker the clayey sequence, the more effective the Intermediate System is in retarding vertical movement. Geographically, the Intermediate System displays variable characteristics due to lithologic and thickness changes. Where the system is thin or less clayey, or where the beds are breached by higher permeability sediments, the Intermediate System is "leaky" and vertical movement of water to the underlying Floridan Aquifer System is more effective. In portions of northwest Florida, the Intermediate System contains minor aquifers. These aquifers are sandwiched between clayey sediments. Due to vertical hydraulic conductivity contrasts, discrete hydrostatic heads define each zone.

The Sub-Floridan System, although primarily a confining sequence, does contain aquifers of regional significance. In the north-central portion of the panhandle, the aquifers that occur in this system are the southern extents of more prolific aquifers recognized as the Claiborne Aquifer and the Clayton Aquifer in southeast Alabama and southwest Georgia.

In summary, the subsurface characteristics of each system vary both laterally and with depth. The nature of the variability determines ground water availability or the degree of confinement for the respective system at any given location. Figure A-5 shows the occurrence and extent of the hydrogeologic systems found in the panhandle. Hydrogeologic features of each system within each ground water region and locational reference maps are presented in Appendices B through E.

Surficial Aquifer System

The Surficial Aquifer System is defined by the Ad Hoc Committee as the "permeable hydrogeologic unit contiguous with land surface that is comprised principally of unconsolidated clastic deposits." This system is mainly found under unconfined conditions. However, locally, low-permeability beds may cause semi-confined conditions to exist within the deeper parts of the system. The lower limits of this sequence coincide with the top of laterally extensive and vertically persistent beds of much lower permeability (the Intermediate System). Within northwest Florida, the Surficial Aquifer System varies greatly both in thickness and character.

The Surficial Aquifer System changes from east to west across a transition zone trending from the eastern vicinity of Choctawhatchee Bay in Walton County, extending northeasterly through west-central Washington County, then following Holmes Creek where it divides Holmes County and Jackson County (Figure A-5). East of this transition zone, the Surficial Aquifer System is referred to as undifferentiated and is of relatively minor significance as a source of water, since it is relatively thin, finer grained, and exhibits lower permeability as compared to the area west of the transition. In many areas, the undifferentiated part of the Surficial Aquifer System is absent or highly discontinuous and, thus, is not an important source for ground water withdrawal. On the western side of the transition, the Surficial Aquifer System becomes thicker and contains a higher percentage of coarser-grained beds whose overall permeability is much greater than the corresponding unit to the east. In the western panhandle area, this system is regionally distinctive and is referred to as the Sand-and-Gravel Aquifer. It constitutes the major source of ground water in Escambia and most of Santa Rosa counties. In parts of Okaloosa and Walton counties, the Sand-and-Gravel Aquifer represents a viable supplemental source of ground water to the Floridan Aquifer System.

It should be noted that other hydrogeologic units can be contiguous with land surface and not be part of the Surficial Aquifer System. Commonly, the Intermediate System sediments contain the uppermost water-bearing zones within the system and may be relatively shallow but are confined and do not satisfy definition of the Surficial Aquifer System, which is primarily unconfined. Likewise, in areas where the overburden has been removed, the Floridan Aquifer System is found under unconfined conditions. In some areas, weathered limestone residuum overlies the consolidated limestones of the Floridan Aquifer System. This residuum can be unsaturated, and the Floridan Aquifer System is found under unconfined to semi-confined conditions. Again, this residuum is not part of the Surficial Aquifer System.

Surficial Aquifer System replaces terms such as water-table aquifer, non-artesian aquifer, shallow aquifer, and sand aquifer. Figure 1 correlates the Surficial Aquifer System to the stratigraphy within northwest Florida. In the panhandle, the Surficial Aquifer System is comprised of the uppermost permeable zones of the Miccosukee Formation, undifferentiated terrace and alluvial deposits, the Citronelle Formation, and those portions of the undifferentiated coarse clastics sufficiently permeable to be included in the basal Sand-and-Gravel Aquifer. Figure A-5 shows the occurrence area for the Sand-and-Gravel Aquifer and (by inference) the undifferentiated Surficial Aquifer System.

Intermediate System

The Intermediate System is defined as all sediments that collectively retard the exchange of water between the overlying Surficial Aquifer System and the Floridan Aquifer System (Figure 1). In places where the Surficial Aquifer System is not present, the Intermediate System serves to retard movement of water from land surface to the Floridan Aquifer System. In certain paleokarst areas, the Floridan Aquifer System sequence has been completely removed and the Intermediate System lies directly over the Sub-Floridan System sediments.

Sediments of the Intermediate System generally consist of fine-grained clastic deposits which, in some areas, are interlayered with carbonate beds or coarser-grained clastic sediments (Figure A-6). The interbedded nature of these deposits can result in water-bearing zones contained within the unit. These relatively minor aquifers exist under confined conditions. Due to their discontinuous and variable nature, these individual aquifers cannot be mapped over wide areas. Thus, the aquifers are collectively referred to as the intermediate aquifer regardless of whether one or many water-bearing zones are being discussed. The base of the Intermediate System is marked by a change from predominantly low- permeability clastic sediments to the underlying more permeable carbonate sequence. By definition, confining-bed material must lie between any intermediate aquifer and the underlying aquifer.

Intermediate System replaces terms such as upper confining bed, Pensacola Clay confining unit, and Hawthorn confining bed. Intermediate aquifer replaces terms such as secondary artesian aquifer(s), shallow artesian aquifer(s), Hawthorn aquifer, and water-bearing zones of the upper confining unit. Figure 1 correlates the Intermediate System to the stratigraphy within northwest Florida. Figure A-6 shows the areal extent and variability of stratigraphic units composing the Intermediate System.

Floridan Aquifer System

The Floridan Aquifer System consists of a persistent carbonate sequence that includes a variety of geologic formations ranging in age from middle Miocene to Paleocene (Figures 1 and A-7). Within northwest Florida, the formations display lateral and vertical variations in lithologic characteristics due to changes that occurred in the depositional environments. This variability results in wide permeability contrasts within the aquifer. In general, the Suwannee and Ocala limestones have the highest permeabilities, regardless of geographic area. As wells rarely tap the sediments underlying the Ocala Limestone, the permeability characteristics of these sediments are poorly understood. The younger portions of the system range from low to high permeability.

Near the middle portion of the panhandle, middle Eocene to Paleocene rocks change from relatively more clastic in the west to relatively more carbonate to the east. The significance of this change is that the sediments in the west function as a confining unit and are part of the Sub-Floridan System (Figure 1). To the east, contemporaneous deposits are carbonates and are hydraulically connected to the overlying younger carbonates. Thus, the thickness of the Floridan Aquifer System increases eastward across the panhandle (Figure 1).

In the westernmost portion of the panhandle, the Floridan Aquifer System is split vertically by a regional confining unit. The two parts are referred to as the upper limestone of the Floridan Aquifer System, which includes all or part of the Chickasawhay Formation, the Bruce Creek Limestone, and an undifferentiated Miocene limestone; and the lower limestone of the Floridan Aquifer System, which includes the Ocala Limestone (Figure 1). The confining unit separating the two portions is referred to as the Bucatunna Clay Confining Unit. Figure A-5 shows the extent of this unit. Where the unit pinches out to the east, the Floridan Aquifer System becomes one vertically undifferentiated unit. The Bucatunna Clay Confining Unit thickens to the southwest and thins to the north and east.

In the westernmost panhandle, the hydrostratigraphy is further complicated by the fact that the Bruce Creek Limestone and the undifferentiated Miocene limestone can contain moderate amounts of clay (e.g. Marsh, 1966). Where these clayey intervals are contiguous with the Pensacola Clay lithostratigraphic unit, they are most appropriately included in the Intermediate System.

Where the Floridan Aquifer System is overlain by the Intermediate System, confined conditions typically prevail. For example, in the easternmost part of the panhandle, the Floridan Aquifer System can be covered with as much as 150 feet of confining bed material, which contains Intermediate System aquifers. In this area the Floridan Aquifer System can have as much as 30 feet of unsaturated limestone. This is, in part, explained by extremely high transmissivity, which readily allows water to be moved downgradient within the aquifer, creating the unsaturated zone. If the Intermediate System is breached, as in karstic areas, the Floridan Aquifer System may be semi-confined to locally unconfined. In some karstic areas, the unsaturated zone can be filled to saturation during extended wet periods and actually create a condition whereby recharge is rejected and flow from the aquifer begins to pond, resulting in "ground water flooding." Where sediments composing the aquifer are near or at land surface, there is no overlying confinement and the aquifer contains water under unconfined conditions. In these areas, the Surficial Aquifer System and Intermediate System are usually absent.

The Floridan Aquifer System is present throughout northwest Florida. However, in the extreme western portion of the panhandle, the conditions are such that the aquifer is not used as a ground water source. In Santa Rosa and Escambia counties mineralization steadily increases in a southwesterly direction in both the upper and lower Floridan Aquifer System. In these areas, the Sand-and-Gravel Aquifer is the primary source for ground water. In most of southern Okaloosa and Walton counties, the lower Floridan is highly mineralized and is not potable. In these counties, the upper limestone of the Floridan Aquifer System is the primary source for ground water, and supplemental sources are derived from the Sand-and-Gravel Aquifer.

For much of northwest Florida, the Floridan Aquifer System is the deepest active flow system. In the north-central portion of the panhandle, freshwater aquifers also exist within the Sub-Floridan System. The base of the Floridan Aquifer System forms a gradational contact with fine-grained clastic sediments of much lower permeability. The term Floridan Aquifer System replaces terms such as principal artesian formations, principal aquifer, principal artesian aquifer, Floridan aquifer, and Tertiary limestone aquifer system.

Sub-Floridan System

The Sub-Floridan System consists of low-permeability sediments that form the base of the Floridan Aquifer System. The Sub-Floridan System primarily functions as a confining unit and any water-bearing zones contained within are usually highly mineralized. An exception occurs in the Dougherty Karst Region where the Claiborne and Clayton aquifers of the Sub-Floridan System yield freshwater supplies. These aquifers represent the downdip extent of more prolific aquifers that occur to the north-northeast in Alabama and Georgia. The top of the Sub-Floridan System is commonly difficult to define due to the transitional character of permeability within middle Eocene to Paleocene sediments. There is no defined base of this unit within northwest Florida. Figure 1 correlates the Sub-Floridan System to the stratigraphic units occurring within northwest Florida.

Ground Water Regions

Geologic conditions vary greatly across northwest Florida. Consequently, water-bearing characteristics from one area to another are quite diverse. Geographic areas with similar qualities are present primarily because of regional geologic structures. Four hydrogeologic settings are defined within the Florida panhandle. Within each setting, water quality, water availability, recharge-discharge mechanisms, hydrostratigraphy, and vulnerability to contamination exhibit similar characteristics due to the influence of similar hydrogeologic conditions. Thus, each of the four settings is distinct. The four settings are referred to as the Woodville Karst Region, the Apalachicola Embayment Region, the Dougherty Karst Region, and the Western Panhandle Region. Figure A-3 shows the extent of these ground water regions. All but the Dougherty Karst Region have a near-coastal sub-region in which the ground water is highly influenced by the position of the freshwater/saltwater interface.

Woodville Karst Region

The Woodville Karst Region includes most of Leon and Wakulla counties and that portion of Jefferson County within the NWFWMD (Figure B-1). The area is characterized by a fairly thin to absent Surficial Aquifer System that is of minor water-bearing significance. The Surficial Aquifer System is not present in much of the Coastal Lowlands portion of the region. Beneath the Surficial System is the Intermediate System, which is also relatively thin to absent or breached by sinkholes. Where present, the Intermediate System functions primarily as a confining bed. However, in the highland portion of the region, the basal carbonates form minor water-bearing zones sometimes utilized for domestic supplies. Due to the leaky nature of the confining unit, the vulnerability of the underlying Floridan Aquifer System to contamination is high.

The Floridan Aquifer System consists of a sequence of carbonates which attains a thickness of over 2,000 feet within the region. Although the aquifer is quite thick, only the upper several hundred feet are utilized, due to high availability in this upper portion. Productivity of the aquifer is believed to decline below the Ocala Limestone section. In addition, ground water becomes increasingly more mineralized in deeper portions of the aquifer. Within the Woodville Karst Region recharge to the Floridan Aquifer System is generally high. The regional ground water flow path is toward the major discharge points, including the St. Marks and Wakulla rivers, Wakulla Springs, the Spring Creek area, and the Gulf of Mexico. The Sub-Floridan System confines the base of the Floridan Aquifer System flow system and functions exclusively as a confining bed within the Woodville Karst Region. Hydrogeologic and Hydrochemical features of the Woodville Karst Region are found in Appendix B.

Apalachicola Embayment Region

West of the Woodville Karst Region lies the Apalachicola Embayment Region (Figure C-1). This region encompasses small portions of western Leon and Wakulla counties, most of Gadsden and Liberty counties, and all of Gulf County. Also included are portions of Franklin, Calhoun and Bay counties. This region is characterized by a deeply-buried Floridan Aquifer System and a thick Intermediate System.

The Surficial Aquifer System in this region is variable in thickness, ranging from less than 20 feet to as much as 75 feet. The aquifer is of minor importance as a ground water source. The Intermediate System is a highly complex sequence of clays, silts, sands, and low-permeability carbonates. The Intermediate System is highly effective as a confining unit within the region, limiting the amount of recharge to the Floridan Aquifer System. Carbonate beds within the system provide minor sources of ground water for domestic supplies. The Intermediate System ranges in thickness from about 150 to 500 feet and is thickest along the axis of the Apalachicola Embayment. The axis of the embayment trends northeast to southwest from the Quincy area through the Port St. Joe vicinity (Figure C-1). The Floridan Aquifer System lies more deeply buried along this axis, whereas, near the flanks, the limestone lies nearer the land surface.

Ground water recharge to the Floridan Aquifer System is low in the region due to the thickness of the Intermediate System. Therefore, extensive development of secondary porosity in the Floridan System does not occur. The flow system is relatively stagnant, which results in the presence of highly-mineralized water in the basal portion of the aquifer. This poor-quality water is not effectively flushed from the aquifer due to the low recharge volumes and long residence times.

The regional flow direction is southerly toward the Gulf of Mexico. In the northern and central portions of the region, the flow is toward the major rivers (the Apalachicola and Chipola rivers). Ground water availability is limited within the Apalachicola Embayment Region. Excessive water level declines can occur if the aquifer is overpumped. In addition, high discharge rates can cause mineralized water from below to invade the overlying freshwater zones. Although much of the water use is derived from ground water, the Apalachicola Embayment Region is the only region in which surface water is also used as a source of drinking water. The City of Quincy uses Quincy Creek as a water source, and Bay County withdraws from Deer Point Lake. St. Joe Paper Company uses water from a 23-mile-long canal which originates from the Chipola River. Historically, this region has had ground water withdrawal problems that have resulted in widespread cones of depression. Hydrogeologic and hydrochemical features of the Apalachicola Embayment Region are found in Appendix C.

Dougherty Karst Region

The Dougherty Karst Region lies north-northwest of the Apalachicola Embayment. The area included in this region are the northernmost portions of Calhoun and Bay counties, all of Jackson County, most of Holmes and Washington counties, and a small portion of northeastern Walton County (Figure D-1). This region is very similar to the Woodville Karst Region except that the Floridan Aquifer System is relatively thin. A regional structure referred to as the "Chattahoochee Arch" has influenced the deposition of sediments in this region (Figure A-8). The subsurface is further impacted by widespread karstic processes occurring within the area. The geology is such that the oldest unit crops out in the north, terminating against the structural high. Younger formations offlap and thicken to the south. The surface exposures of these offlapping sequences occur in a somewhat banded, crescent shape, and the erosional exposures have a highly irregular surface. A weathered residuum, which is the remains of younger formations, overlies most of the area. Paleosinks are especially abundant throughout the region. Wells penetrating these karst features sometimes encounter several hundred feet of unconsolidated clay and sand fill without penetrating limestone. In some cases, the sinks are plugged with clays or other low-permeability sediments which, instead of enhancing movement into the aquifer, actually inhibit flow.

The Floridan Aquifer System is the most important of the hydrogeologic systems and is the primary source of water in the Dougherty Karst Region. In the northern portions of the region, the aquifer is thin and only the Ocala Limestone is present. To the south, the aquifer thickens with the addition of the younger Marianna, Suwannee, and Chattahoochee formations to the sequence. The thickness of the aquifer ranges from less than 100 feet in the north to about 700 feet in the southern portion of the region. Due to the leaky nature of the confining unit caused by the karst features, much of the Floridan Aquifer System in the region exists under unconfined to semi-confined conditions. As in the Woodville Karst Region, the lack of an effective confining unit makes the Floridan Aquifer System highly vulnerable to contamination.

The Floridan Aquifer System exhibits both conduit and diffuse flow characteristics that result from fractures and a wide range of secondary porosity development. In some areas where the residuum is thin and the confining beds are either effectively breached or are absent, the upper portion of the carbonate sequence may be unsaturated. Flow within the Floridan Aquifer System moves toward the principal discharge areas which include: Chattahoochee/Apalachicola River, Chipola River, Holmes Creek, Choctawhatchee River, and Econfina Creek (Figure A-2).

The Sub-Floridan System underlies the Floridan Aquifer System in the region. In parts of the Dougherty Karst Region, water-bearing beds within the system form minor aquifers of local importance. Water-bearing characteristics vary from north to south. Generally to the south-southwest, the unit is primarily a confining unit; to the south-southeast, sediments grade from clastic to carbonate; and farther to the east, sediments actually become part of the Floridan Aquifer System. In the northern portion of the region and extending into Alabama and southwest Georgia, beds within this unit form a secondary aquifer. Overall, ground water availability is not as good as in the overlying Floridan Aquifer System. Hydrogeologic and hydrochemical features of the Dougherty Karst Region are found in Appendix D.

Western Panhandle Region

The Western Panhandle Region is similar to the Apalachicola Embayment Region in that a thick, effective confining unit exists over a majority of the area and the Floridan Aquifer System is deeply buried. This region encompasses the far western panhandle counties of Walton, Okaloosa, Santa Rosa, and Escambia (Figure E-1). Within this region, the Surficial Aquifer System is referred to as the Sand-and-Gravel Aquifer (Figure A-5). This unit increases in thickness to the west and in Escambia County attains a thickness greater than 400 feet. In most of Santa Rosa County and all of Escambia County, the Sand-and-Gravel Aquifer is the primary source for potable ground water supplies.

The Sand-and-Gravel Aquifer is composed of admixtures of sand (ranging in size from fine to coarse), clay, silt, and gravel. Locally, where the clay, silt, and fine sand dominate, low-permeability zones exist and partially confine the underlying sands. These "confining zones" are highly discontinuous and lithologically variable. The aquifer essentially exists under leaky, confined conditions because of the leaky nature of the low-permeability zones. Due to proximity to land surface and the lithologic characteristics, the aquifer is highly vulnerable to contamination. The lack of a regionally-extensive confining unit exposes the entire aquifer to the impact of land-surface activities.

The Sand-and-Gravel Aquifer has been informally subdivided into three zones in Escambia County. The differentiation of zones to the east is not as pronounced and may not correspond to the Escambia County zonation. The uppermost zone is composed of primarily fine sands and is referred to as the surficial zone (SZ). Underlying this zone is the low-permeability zone (LPZ) which locally, due to the clay and silt content, tends to provide confined to semi-confined conditions. The main-producing zone (MPZ) is the lowermost zone and is characterized by highly-permeable coarse sand and gravel beds interspersed in places with fine sand and clayey-sand beds. The majority of water withdrawn from the aquifer in Escambia County is derived from the main-producing zone.

The Sand-and-Gravel Aquifer is recharged locally by infiltrating rainfall. Due to highly-permeable soils and the lack of effective confinement, the entire occurrence area for the aquifer is a recharge area. Flow directions are generally patterned from higher to lower topography. These flow patterns are locally influenced by streams and rivers which dissect the aquifer and serve as discharge boundaries. In coastal areas, the aquifer discharges to the bays or the Gulf of Mexico.

In the Western Panhandle Region, the Intermediate System is a highly efficient confining unit limiting the exchange of waters between the Sand-and-Gravel Aquifer and Floridan Aquifer System. The Intermediate System is composed of thick beds of clays and other low-permeability sediments. Its thickness varies from 100 feet to over 1,000 feet. No significant water-bearing zones exist within the Intermediate System in the Western Panhandle Region (Figure A-5).

The Floridan Aquifer System within this western region is covered by a thick sequence of overburden. The aquifer's surface dips from 100 feet above sea level in the northeast to 1,400 feet below sea level in the southwestern portion of the region. Near the eastern extent of the Choctawhatchee Bay and continuing northwest and then northward through Okaloosa County, the Floridan Aquifer System is divided by a regionally-extensive confining bed known as the Bucatunna Clay Confining Unit (Figure A-5). In Escambia, Santa Rosa, Okaloosa, and southernmost Walton counties, this clay divides the aquifer into upper and lower limestone units (Figure 1). The upper limestones are made up of the Oligocene and Lower Miocene carbonates. The lower limestone portion is composed entirely of the Ocala Limestone. In much of the south-southwestern portion of the region, the lower limestone of the Floridan Aquifer System is highly mineralized. In southwestern Santa Rosa County and in southern Escambia County, the upper limestone part of the aquifer is also highly mineralized and not readily available as a drinking water source (Figure A-5). East of Santa Rosa County, the upper limestone of the Floridan Aquifer System is the primary source of ground water, and the Sand-and-Gravel Aquifer provides a supplemental source (Figure A-5).

Water availability from the Floridan Aquifer System in the Western Panhandle Region is moderate to low. Lowest-availability areas are adjacent to the coast. Availability increases to moderate inland. A regionally-extensive cone of depression is centered in the Ft. Walton Beach vicinity, due to over-development of the resource (Figure E-14). Water levels which were measured at 50 feet above land surface in the late 1940s have declined to nearly 120 feet below land surface near pumping centers. The regional flow direction of the Floridan has been impacted by this cone of depression and generally moves southerly toward the vicinity of Ft. Walton Beach. Hydrogeologic and hydrochemical features of the Western Panhandle Region are found in Appendix E.

CHAPTER III: GROUND WATER ISSUES

Water Availability

Ground water availability varies greatly throughout northwest Florida within each of the aquifers present in the panhandle. In addition, a given aquifer will vary both laterally and with depth in its ability to yield water. Site-specific factors combine to create aquifer yields that range from a few gallons per minute in a domestic well tapping the Surficial Aquifer System to the extremely high availability from the Floridan Aquifer System in Leon County.

Surficial Aquifer System

The availability of ground water from the Surficial Aquifer System across the panhandle generally increases from east to west, as a result of the presence of thicker beds of coarse-grained sediments in the west. The Surficial Aquifer System is relatively insignificant, in terms of water availability, within the Woodville and Dougherty Karst regions. This is true of much of the Apalachicola Embayment Region as well. However, in localized portions of the embayment region, the Surficial Aquifer System is sufficiently productive to be used as a source of supply. These areas are typically found along the coast, where as much as 100 feet of relatively coarse-grained sand and gravel may be present (e.g. coastal Bay County).

The Sand-and-Gravel Aquifer, which comprises the westernmost portion of the Surficial Aquifer System, exhibits the highest availability characteristics of this system. In the Western Panhandle Region, the Sand-and-Gravel Aquifer is a major water-bearing unit in Escambia and Santa Rosa counties. The availability and quality of ground water from the Sand-and-Gravel Aquifer within these two counties is much better than that of the underlying Floridan Aquifer System. Within Okaloosa and Walton counties, the Sand-and-Gravel Aquifer is considered a secondary source of ground water supplementing limited availability from the Floridan Aquifer System.

Floridan Aquifer System

Some sense of the varying availability of ground water from the Floridan Aquifer System can be obtained by examining spatial trends in aquifer transmissivity. Figure A-9 shows a generalized spatial distribution of Floridan Aquifer System transmissivity. Transmissivity is a measure of the ease with which water will move through porous media and is, thus, directly related to ground water availability. Low-transmissivity values (less than 5,000 feet squared per day (ft^2/d)), correspond to more limited availability. In general, the areas with the lowest transmissivities are the Apalachicola Embayment Region, the Western Panhandle Region, and the coastal fringe. The highest values are found in the Dougherty Karst Region and the Woodville Karst Region.

In the vertical sense, the most prolific zones within the Floridan Aquifer System generally coincide with the Suwannee and Ocala limestone sections. Typically, those carbonate units that overlie the Suwannee and Ocala units (Bruce Creek Limestone, Chattahoochee Formation, St. Marks Formation) have lower water-yielding properties. In some areas, these overlying units contain substantial clay fractions, limiting yield. Yield in the generally-prolific Suwannee and Ocala carbonates is limited in areas where they contain mineralized water (the coastal fringe of the Woodville Karst Region, for example) or where significant cones of depression exist.

Overpumping the Floridan Aquifer System in several areas of the panhandle serves to further limit water availability. The area most significantly affected by excessive drawdown is the coastal portion of the western panhandle. In this area (from Navarre in the west to south Walton County in the east, and north onto Eglin AFB) the Floridan Aquifer System is differentiated into upper and lower units by the Bucatunna Clay Confining Unit. Due to poor water quality, the lower unit is not currently used for potable supply. The upper unit (having acceptable water quality) is heavily pumped and its potentiometric surface is substantially depressed (Figure A-10). Since pumping began, water levels in the center of the cone of depression have declined more than 150 feet. Water levels were at or below sea level over an area of 1,400 square miles in 1995. In addition, the Panama City/Panama City Beach and Port St. Joe areas have cones of depression, albeit smaller than the one centered in coastal Okaloosa and Walton counties.

The Okaloosa/Walton depressurization is of concern because non-potable water is known to exist in the upper Floridan Aquifer System on the western and eastern flanks of this feature. Further, poor-quality water is present at depth beneath all three potentiometric surface depressions. As long as the potentiometric surface remains substantially depressed in these coastal areas, the potential exists for poor-quality water to affect potable supply wells.

Figure A-11 shows general ground water availability trends for the Floridan Aquifer System. The figure relates availability to the 250 mg/L isochlor, existing cones of depression, aquifer transmissivity trends, and recharge areas. Figure A-11 also identifies areas susceptible to pumping-induced upconing of highly-mineralized water. These areas include the Apalachicola Embayment Region, the Western Panhandle Region, and the coastal fringe of the entire panhandle. Due to remoteness from mineralized ground water, current low pumping rates, relatively high recharge, and high transmissivity, the Dougherty and Woodville Karst regions generally have the highest ground water availability. The Floridan Aquifer System in the extreme western portion has virtually no potable ground water availability (without substantial treatment), due to the highly-mineralized water it contains.

Other Aquifers

Other aquifers found within northwest Florida (i.e. intermediate aquifers, Claiborne Aquifer, Clayton Aquifer) are considered minor water-producing zones. Limited yields with excessive pumping levels normally characterize these minor aquifers. The intermediate aquifer is most prevalent in the Apalachicola Embayment Region. It is frequently used as a domestic supply source in Bay, Gulf, and Gadsden counties and in the southern portions of Calhoun and Liberty counties. It is also used for domestic supply in the extreme southeast portion of the Western Panhandle Region. In coastal Bay and Gulf counties the intermediate aquifer is sufficiently productive to be used for public and industrial supply. Intermediate aquifer wells in these areas can produce as much as 300 gallons per minute.

In the extreme northern reaches of the Dougherty Karst Region, the Claiborne Aquifer is used. Public supply wells in Esto, Campbellton, Noma, Graceville, and Malone tap this aquifer. Elsewhere it is used for domestic and agricultural supply. The Clayton Aquifer, lying below the Claiborne, is infrequently used for water supply in Florida.

Water Use Trends

Several factors, including permanent and transient population levels, household income, land use, and climatic variability influence levels of water use in northwest Florida. These factors are dynamic, and some are subject to both predictable and unpredictable changes. Where demand is incompatible with resource availability, problems occur and water use must be modified to cope with resource limitations.

In northwest Florida, thermoelectric power generation is the single largest user of water resources. Since nearly all the water for this use originates from surface water sources, ground water impacts are minimal. In 1990, approximately 300 million gallons per day (Mgal/d) of fresh water was used for this purpose (Marella, 1992). This volume represents slightly less than half of the total freshwater use in the panhandle. A comparable amount of saline water is also withdrawn for power generation. There has been a decrease of about 40 percent in the thermoelectric water use between 1975 and 1990 (NWFWMD, 1994). It is anticipated that the current demands represent a stabilization in use; significant increases are not expected. Future demands for this use will probably not exceed historic highs.

Public water supply (160 Mgal/d in 1990) represents the second largest demand on water resources; about 23 percent of total freshwater usage (Marella, 1992). Use increased by about 60 percent between 1975 and 1990 (NWFWMD, 1994). Growth of service areas and increases in water use to meet population demands are expected in the future. Urban centers and heavily-populated coastal regions are expected to have the greatest increases. Seventy-five percent of the water used for public water supplies is from ground water.

Currently, about half of the water used for industry is ground water. Industrial water usage declined significantly between 1975 and 1990. Much of the 40 percent decline can be attributed to conservation practices implemented by industrial users. This decrease in use follows trends seen elsewhere in the state. It is anticipated, however, that future declines will not be significant and use will align at current levels. These levels represent about 15 percent of total freshwater use in the NWFWMD (Marella, 1992).

Agricultural irrigation has experienced the most significant increase in the recent past; increasing about 450 percent between 1975 and 1990 (NWFWMD, 1994). Currently, this category accounts for about ten percent of freshwater use. Water for this use is mostly derived from ground water. Future increases in this classification of water use are anticipated.

Rural water use represents less than five percent of total freshwater use. Over the years, this category has been relatively static, and its proportion of total use is not anticipated to change significantly in the future.

Figure A-12 presents the total ground water use per county as of 1990. It is believed that current water use remains within the ranges specified in this figure. Leon and Escambia counties represent the largest ground water users within northwest Florida.

Susceptibility to Contamination

Given sufficient time, all aquifer systems in all portions of the panhandle are "susceptible" to anthropogenic contamination. Susceptibility to contamination is the outcome of processes that occur in both the unsaturated and saturated portions of a given geologic medium. What defines some aquifers (and portions of aquifers) as more susceptible is when the time required to move contaminants from land surface to a withdrawal well is relatively short. This time (referred to as the time-of-travel) is a function of the length of the flow path along which contaminants move and the average contaminant velocity along that path. Typically, it is the sum of times-of-travel associated with transport through both unsaturated and saturated media. "Relatively short" is somewhat subjective; it refers to time scales of importance to humans and is, typically, no longer than a decade or two.

Regardless of whether the medium is saturated or unsaturated, the time-of-travel is influenced by the hydraulic conductivity of the geologic medium along the relevant flow path and the flow path length. Low hydraulic conductivity materials provide increased resistance to water movement and, in turn, decrease the average contaminant velocity and increase the associated time-of-travel (for a given hydraulic gradient). Increased flow path lengths have correspondingly longer times-of travel (for a given contaminant velocity).

The Surficial Aquifer System is universally susceptible to contamination. This derives from two factors. First, the flow path length from land surface to the top of the aquifer (the water table) is short. Second, the system is frequently minimally confined. Through much of the panhandle, the depth to the water table is on the order of 20 to 40 feet. Rarely is this distance more than 60 feet; in many areas it is ten feet or less. Given such short distances, it is obvious that the Surficial Aquifer System is susceptible to contamination, in all but those instances where the geologic media in the unsaturated zone have extremely low hydraulic conductivity.

The vulnerability of the Sand-and-Gravel Aquifer in Escambia County is typical of the Surficial Aquifer System in general and of particular significance. A long history of urban, commercial and industrial land use in the southern half of the county has resulted in numerous instances of ground water contamination. Ground water has been affected by inorganic fertilizer manufacturing, wood preservation, landfilling, leaking underground storage tanks and uncontrolled solvent releases, particularly, drycleaning solvents. Throughout urbanized Pensacola, a large number of public supply wells have been adversely affected by various contaminants (principally solvents, hydrocarbon derivatives and pesticides). Costs associated with remediating this contamination have been significant. In terms of the number of people who have been affected, or who could potentially be affected, the contamination problems in southern Escambia County are the most significant in the panhandle.

For the Floridan Aquifer System, areas most susceptible to ground water contamination generally coincide with the Woodville and Dougherty Karst regions. These areas are susceptible because the Floridan Aquifer System is at or near land surface, and because karstic and alluvial erosional processes have removed some (or all) of the overlying confining unit. The net effect of these processes is that times-of-travel through the materials overlying the Floridan Aquifer System are shortened. An example of susceptibility within the Woodville Karst Region is the experience of the City of Tallahassee. Since 1988, seven wells operated by the City have been affected by drycleaning solvents to the point that remedial actions were required.

Elsewhere, the Floridan Aquifer System, being better confined, is relatively less susceptible. This derives primarily from the fact that times-of-travel through regional confining units are beyond time scales of immediate relevance to humans. Whereas the hydraulic gradient may be such that contaminants (if present) would eventually migrate through the confining unit, the time required is too long to have an impact on human perceptions of priorities.

Saltwater Encroachment

The Floridan Aquifer System throughout coastal portions of the panhandle is, to a greater or lesser extent, susceptible to saltwater intrusion. This results from the fact that the system is, to varying degrees, hydraulically connected to the Gulf of Mexico. Further, the Gulf is the ultimate discharge point for ground waters moving through the system. Over time, fresh water moving through the discharge area and the seaward-lying salt water have come into a state of quasi-equilibrium. The amount of energy contained in the freshwater portion of the flow system dictates the position of the saltwater interface at any given point. The present interface position probably represents a state of equilibrium that took millennia to reach. Recent human perturbations (in the form of pumping) threaten to disrupt this equilibrium, and to move the position of the freshwater/saltwater interface.

Regional water-level declines (due to pumpage) can develop and exist for many years without a significant change in water quality. In general, it takes decades for large-scale changes in water quality to occur. Typically, a well which taps a deeper portion of the aquifer will show signs of saltwater movement earlier than will a well open to shallower intervals. Once water quality has deteriorated, even if pumpage is discontinued or reduced, water quality problems persist. Water quality does not recover as quickly as do water levels. Should saltwater intrusion occur, it will take many years (in the absence of pumping) for the aquifer to return to pre-existing geochemical conditions.

If ground water resources in an area are overdeveloped, and if poor water quality occurs at depth, there is the potential for the freshwater portion of the aquifer to be adversely affected. In this instance, saline degradation occurs by the process of upconing. Upconing is the upward movement of poor quality, highly-mineralized water from lower portions of the aquifer in response to the reduction in hydraulic head associated with pumping. Initially, upconing is a local-scale problem, affecting a well or a group of wells. Continued pumpage may result in a significant reduction in the availability of fresh water.

Woodville Karst Region

In the Woodville Karst Region, the potential for saltwater encroachment is high because the outcrop area for the Floridan Aquifer System exists at the coastline. Additionally, the coastline and the near inland vicinity are a natural discharge area, where several first-magnitude springs discharge over 400 million gallons per day. This discharge, along with the exposure of the carbonate sequence beneath saline surface water bodies, is the reason why the saltwater front lies close to the coastline. If intensive ground water development occurs in the coastal section of the Woodville Karst Region, there is a high potential for saltwater encroachment. The problems associated with saltwater encroachment are expected to increase as population growth and coastal development create a greater demand for ground water in coastal Franklin, Wakulla and Jefferson counties.

Apalachicola Embayment Region

In the Apalachicola Embayment Region, highly-mineralized waters occur within the Floridan Aquifer System throughout the region. Typically, these waters lie in the deeper portions of the aquifer. Overly deep wells are susceptible to upconing. From a resource standpoint, these upconing episodes may not have a long-term impact on the freshwater resources of the aquifer. If the water quality is poor, it generally will not be suitable for its intended use. Either the well is not used or the pumpage is reduced to limit water-quality impacts.

Water demand in the Apalachicola Embayment Region is relatively low, and the need to exploit ground water resources to a point where upconing is a problem has not occurred (except on the basis of individual wells). Surface water supplies and low volume wells tapping the upper portion of the Floridan Aquifer System are sufficient to meet current demand. However, in recent years, irrigation water use has increased in an area with limited ground water availability (central Gadsden County). The result is higher demand on selected surface streams to provide irrigation water. As surface waters in this area are near (or at) their capacity to provide irrigation water, ground water is seen as a source of supplemental water. Given its limited availability, even relatively low to moderate ground water use in this area has the potential to significantly impact the resource.

Along the coastline, the saltwater front is located several miles offshore for most of the region. However, in the eastern Bay County, the front has a closer landward extent. Wells tapping the Floridan Aquifer System on the Tyndall AFB (Figure 2) encounter ground water with higher chloride concentrations than wells tapping the same zones to the east or west.

Dougherty Karst Region

The Dougherty Karst Region as a whole is not susceptible to saline intrusion processes since there are no coastal areas in the region. With the exception of the vicinity of the Choctawhatchee River, the entire Floridan Aquifer System contains fresh water. Along some reaches near the river, saline, connate water is present in the Floridan Aquifer System. In these areas, the potential for upconing exists and deeply-penetrating wells may yield unacceptable water quality.

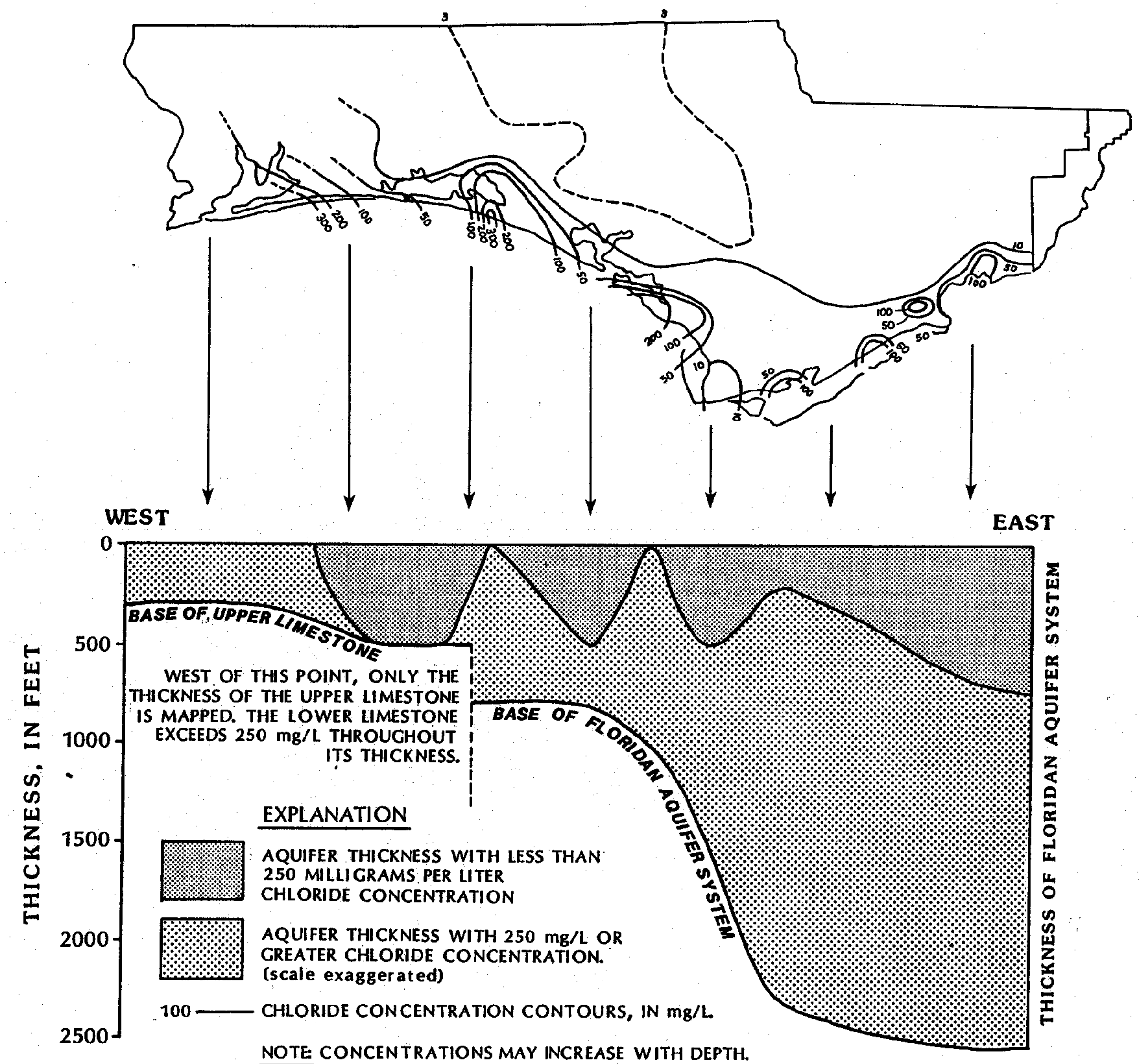


Figure 2. Profile of the Floridan Aquifer System and Ground Water Chloride Concentrations Along the Coast of Northwest Florida.

Western Panhandle Region

In the Western Panhandle Region, the coastal portion of Okaloosa and Walton counties has experienced water level declines approaching 150 feet. As water levels decline, the threat for migration of highly-mineralized water into the freshwater portion of the upper Floridan Aquifer System increases. To date, no significant encroachment is believed to have occurred, but it must be recognized that water levels decline much more rapidly than the interface can move. The re-establishment of chemical equilibrium in response to water level changes may take decades.

Near the eastern end of Choctawhatchee Bay, the upper portion of the undifferentiated Floridan Aquifer System contains water which exceeds the drinking water standard for chloride (Figure 2). Two aspects of the local hydrogeology likely account for this naturally-occurring phenomenon. First, the Bucatunna Clay Confining Unit becomes extremely thin; further east it is absent. Second, the Intermediate System thins and becomes more permeable in this region. Wells tapping the Floridan Aquifer System in this area have higher chloride concentrations than wells tapping the same depths to the east or west. Figure 3 shows the conceptual relationship of fresh water, the zone of dispersion, and the saltwater front within the Floridan Aquifer System in the Western Panhandle Region.

Interstate Ground Water Relationships

Contrary to popular folklore, the water contained in any part of the ground water systems underlying northwest Florida comes from rain that has fallen less than 75 miles away. The actual movement of water within the various aquifers, however, may take from a few days to many thousands of years. Thus, ground water within northwest Florida is influenced by localized conditions. Since a distance of 75 miles may place locations contributing recharge in Alabama and Georgia, interstate ground water relationships have relevance to the water resources of northwest Florida.

Surficial and Intermediate Aquifer Systems

The Surficial Aquifer System (including the Sand-and-Gravel Aquifer) displays highly localized recharge characteristics. For example, rain falling on a hilltop recharges the Surficial Aquifer System and the ground water flows downgradient to discharge into a stream at the foot of the hill. For the Surficial Aquifer System, the recharge and discharge areas are almost always in close proximity. The Surficial Aquifer System is so locally influenced that there is virtually no out-of-state contribution, except in the immediate vicinity of state lines. The same conditions hold for the intermediate aquifers(s), where present, and for associated contamination issues. What happens in Alabama and Georgia does not significantly impact waters within the Surficial Aquifer System and intermediate aquifer(s) in northwest Florida.

Floridan Aquifer System

Being a regional flow system, the Floridan Aquifer System is more susceptible to out-of-state impacts than either the Surficial Aquifer System or the Intermediate System. In the western panhandle (Jackson to Escambia counties), that portion of Alabama north of the state line to the updip limit of the aquifer is part of the recharge area. The updip limit, which lies at distances from 10 to 30 miles north of the state line, represents the northernmost occurrence of the Floridan Aquifer System in Alabama. Therefore, ground water impacts from interstate activities are limited to activities occurring within this area.

The updip limit of the Floridan Aquifer System extends east into Georgia as well. Here, the limit extends as far as 100 miles north of the state line. Lying along the Flint and Chattahoochee rivers in southwest Georgia is an area of karst topography known as the Dougherty Plain. The Marianna Lowlands are the southern

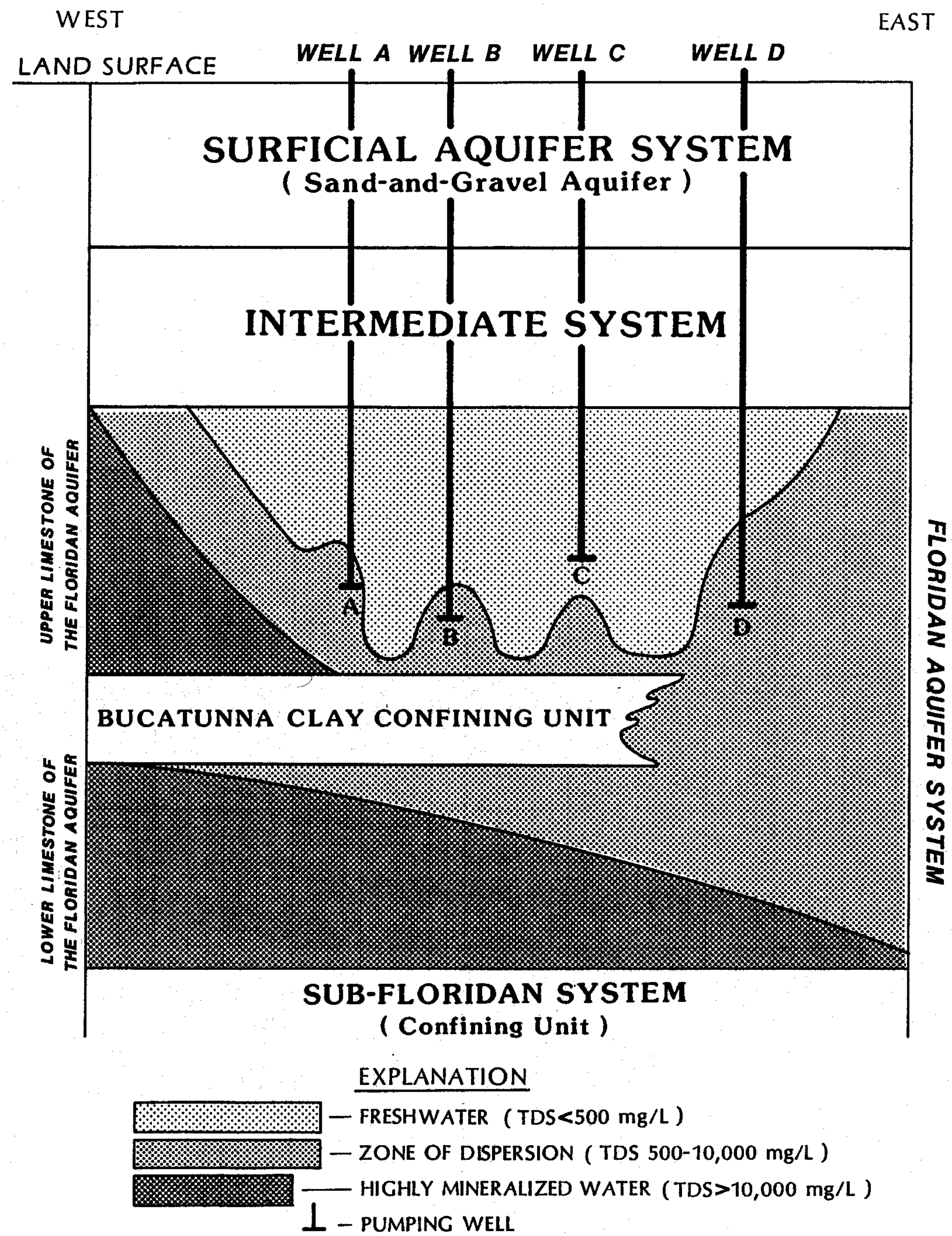


Figure 3. Conceptual Freshwater-Saltwater Relationships in the Coastal Portion of the Western Panhandle Region.

extent of this physiographic region. The Dougherty Plain has a similar hydrogeologic setting to that found in the Dougherty Karst Region in northwest Florida. The aquifer is exposed at land surface or is near land surface throughout much of southwest Georgia. Karstic and erosional processes have destroyed the competency of the regional confining unit. As a consequence, the confining unit ranges from being absent to very leaky and recharge rates are influenced accordingly. Given the topography, soil characteristics and ground water availability, agricultural activity is intense on the Dougherty Plain.

Throughout the Dougherty Plain, surface streams are well connected hydraulically to the Floridan Aquifer System. Floridan Aquifer System discharge comprises the baseflow of many streams, particularly the larger ones. This well-developed stream/aquifer hydraulic connection sets the stage for significant interstate water resource impacts. Numerical ground water model application (Torak and McDowell, 1996) demonstrated that as much as 60 percent of the ground water pumped in the Dougherty Plain is water that would have otherwise discharged to surface streams. Since these streams ultimately flow into Florida, reductions in streamflow in southwest Georgia reduce streamflow in northwest Florida. This, in turn, has some impact on Apalachicola Bay, a regionally-significant surface water resource reliant on freshwater inputs to maintain its biological productivity.

Abandoned Wells

The abandonment of wells is one of the most significant water-resource problems occurring in northwest Florida. There are so many abandoned wells within northwest Florida that they will never be fully accounted for. Unfortunately, there are a number of ways in which abandoned wells can contribute to ground water contamination. As water distribution systems expand and provide service to areas that previously utilized private wells, these private wells are generally left unused. These wells generally fall into a state of disrepair and often are covered and forgotten. As land uses change, these abandoned wells are usually destroyed in the land-clearing and preparation process.

If an old subdivision that had one well per lot is rezoned as an industrial park, as many as 100 abandoned wells could exist. If not plugged properly, these wells could act as conduits to funnel contamination into an underlying drinking water supply. It is not uncommon for old abandoned wells to be used as drains or dumping receptacles for motor oil, septage, and an array of other contaminants. There is an undoubtedly significant, but unknown, number of abandoned wells in northwest Florida. Most of which could potentially act as conduits for transporting pollutants into drinking water supplies. Many will never be accounted for or properly abandoned.

Deep Well Injection

Deep well injection is currently used for disposal of industrial waste at two sites in northwest Florida. The larger system is maintained by the Monsanto Chemical Company at a site in Escambia County adjacent to the Escambia River (approximately seven miles north of Escambia Bay). The other site is maintained by Cytec Industries Inc. and is located in Santa Rosa County on the northeast shore of Escambia Bay. The Monsanto injection facility has been in operation since 1963 and currently has three injection wells. The Cytec Industries facility has been operational since 1975 and has one injection well. Historically, the volume of waste injected at the Monsanto site has been three to four times greater than the volume at Cytec Industries. Both facilities are strictly monitored and operated under the Department of Environmental Protection, Underground Injection Control Permitting Program.

Both facilities inject industrial waste into the lower limestone of the Floridan Aquifer System. In the vicinity of the injection facilities, the natural quality of water in the injection zone is too saline for potable use. Chloride concentrations prior to injection ranged from 6,000 to 8,000 mg/L in the lower Floridan Aquifer System (Foster and Goolsby, 1972). The drinking water standard for chloride is 250 mg/L.

The injection zone is located about 75 miles south of the recharge area for the lower limestone unit and approximately 100 miles north of the presumed discharge area underlying the Gulf of Mexico. The injection zone is overlain by the Bucatunna Clay Confining Unit, which separates the upper and lower limestone units of the Floridan Aquifer System in this area. The confining unit is described as massive, dense waxy clay with admixed sand. The Bucatunna Clay prevents the vertical migration of the injected waste into the overlying unit. In the vicinity of the injection sites, the overlying upper limestone unit contains chloride concentrations in excess of 250 mg/L. Additionally, there is about 500 feet of confining unit material separating the Floridan System from the Sand-and-Gravel Aquifer; the primary source of drinking water. Thus, the injection zone is isolated from the potable ground water by two massive, regionally-extensive confining units and the entire thickness of the upper Floridan Aquifer System (greater than 200 feet). To date, after 33 years of operation, no leakage has been detected into the upper limestone unit. Impacts by the waste injection practices on potable water sources are considered unlikely, based on current operations and conditions.

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CHAPTER IV : APPENDICES

APPENDIX A

DISTRICT-WIDE FEATURES

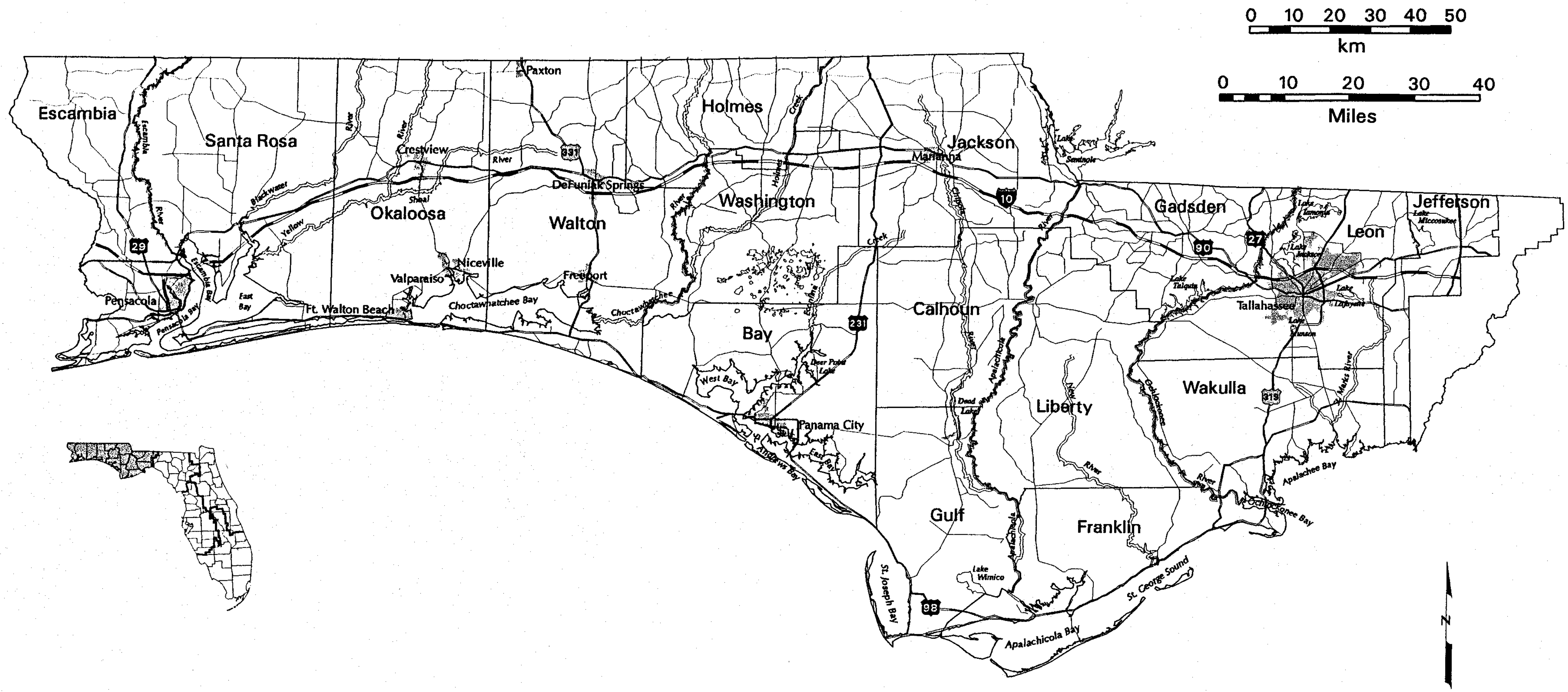
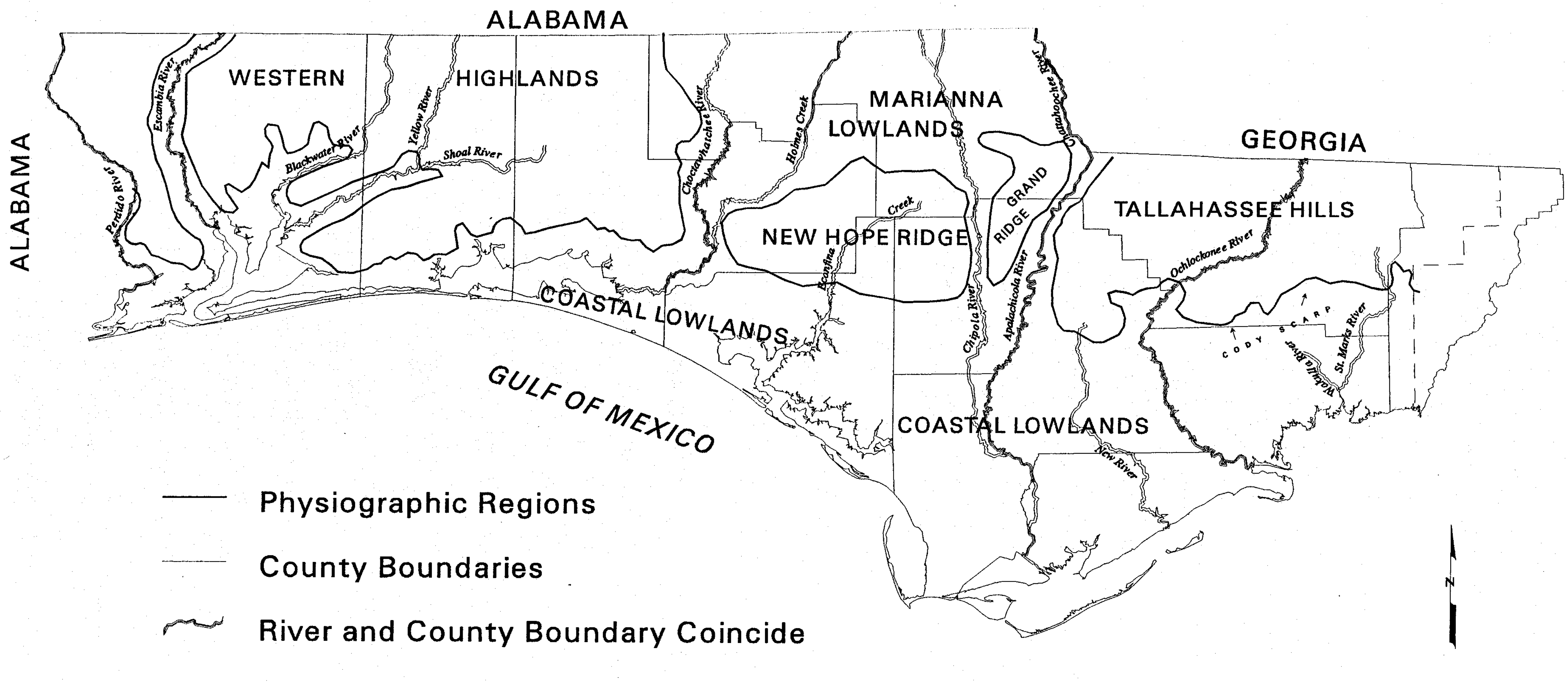


Figure A-1

Northwest Florida Water Management District



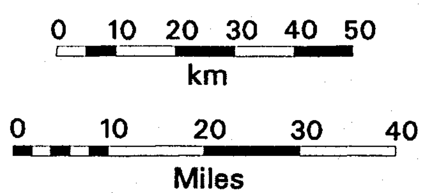


Figure A-2

Physiography and Rivers in the Northwest Florida Water Management District

MODIFIED FROM BROOKS, 1981

13-02-004

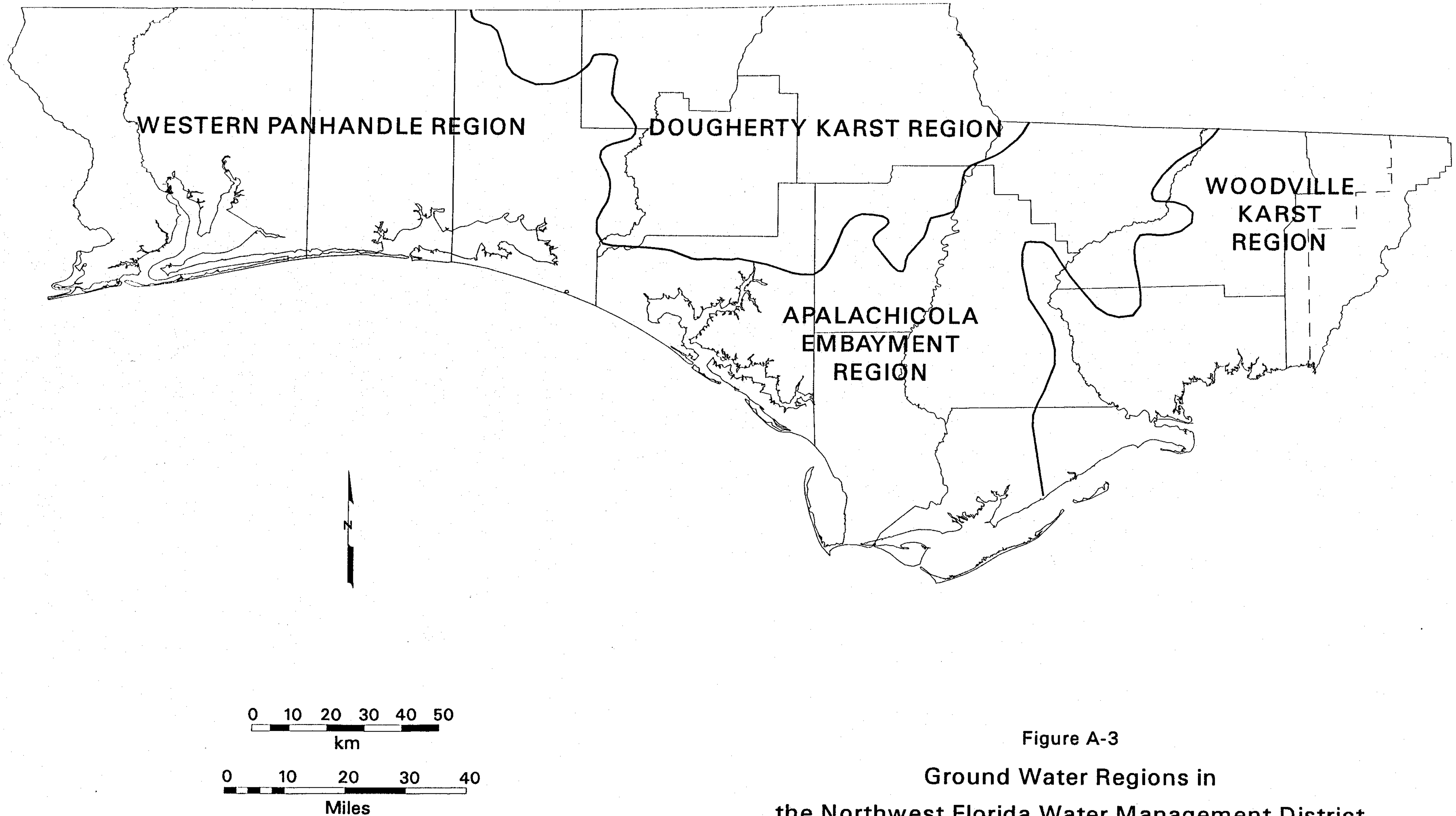


Figure A-3

Ground Water Regions in the Northwest Florida Water Management District

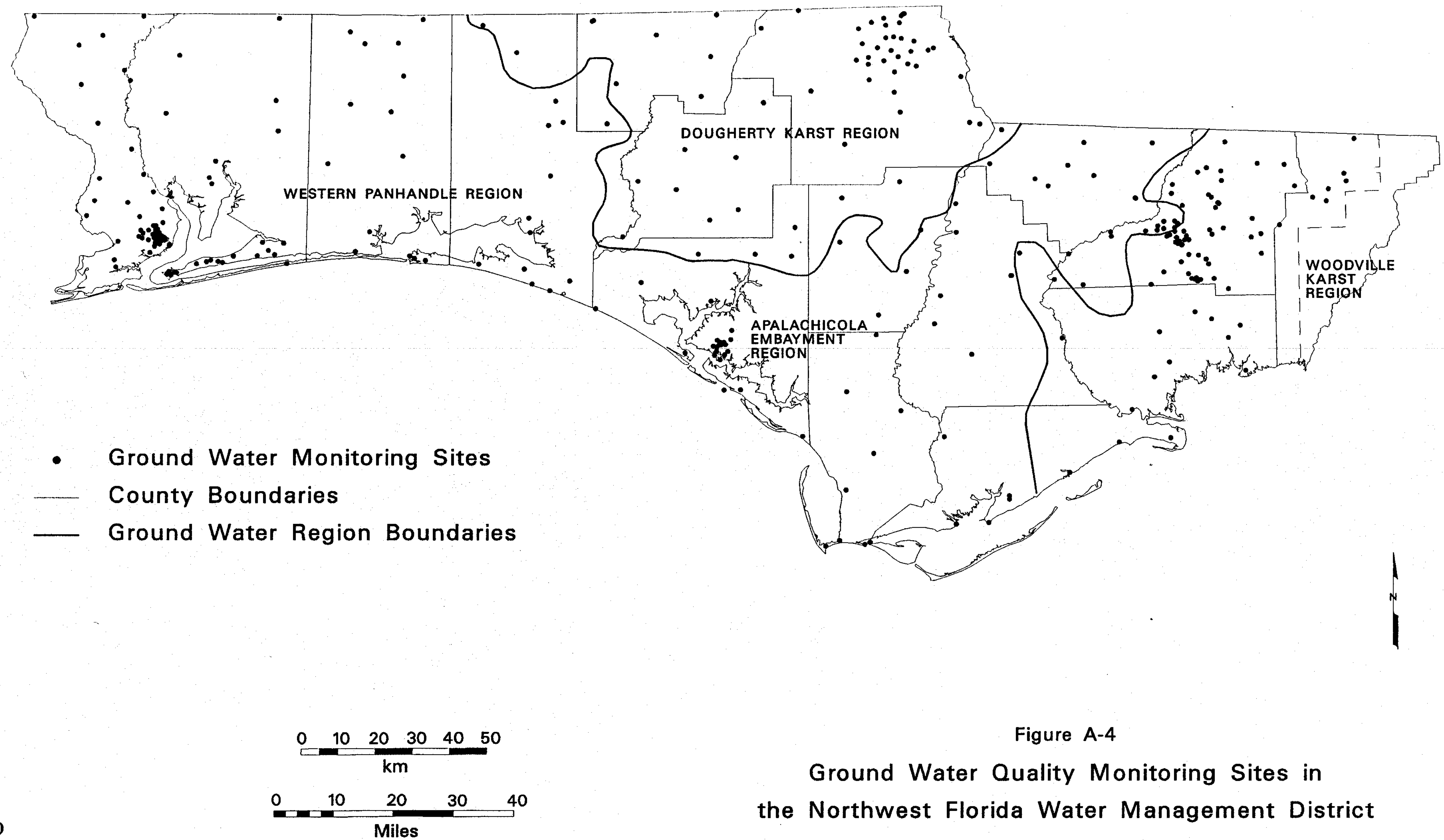


Figure A-4

Ground Water Quality Monitoring Sites in the Northwest Florida Water Management District

13-02-009

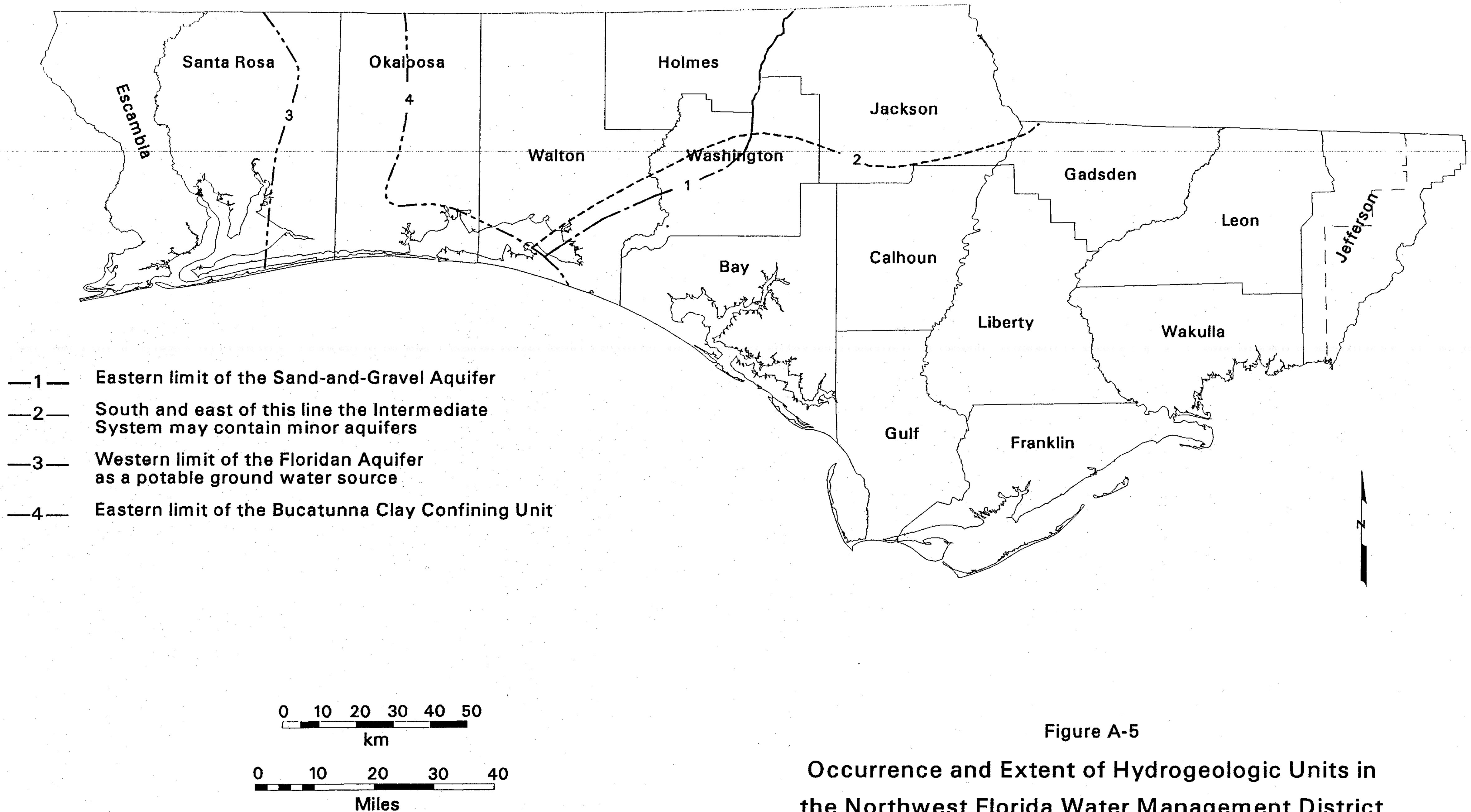
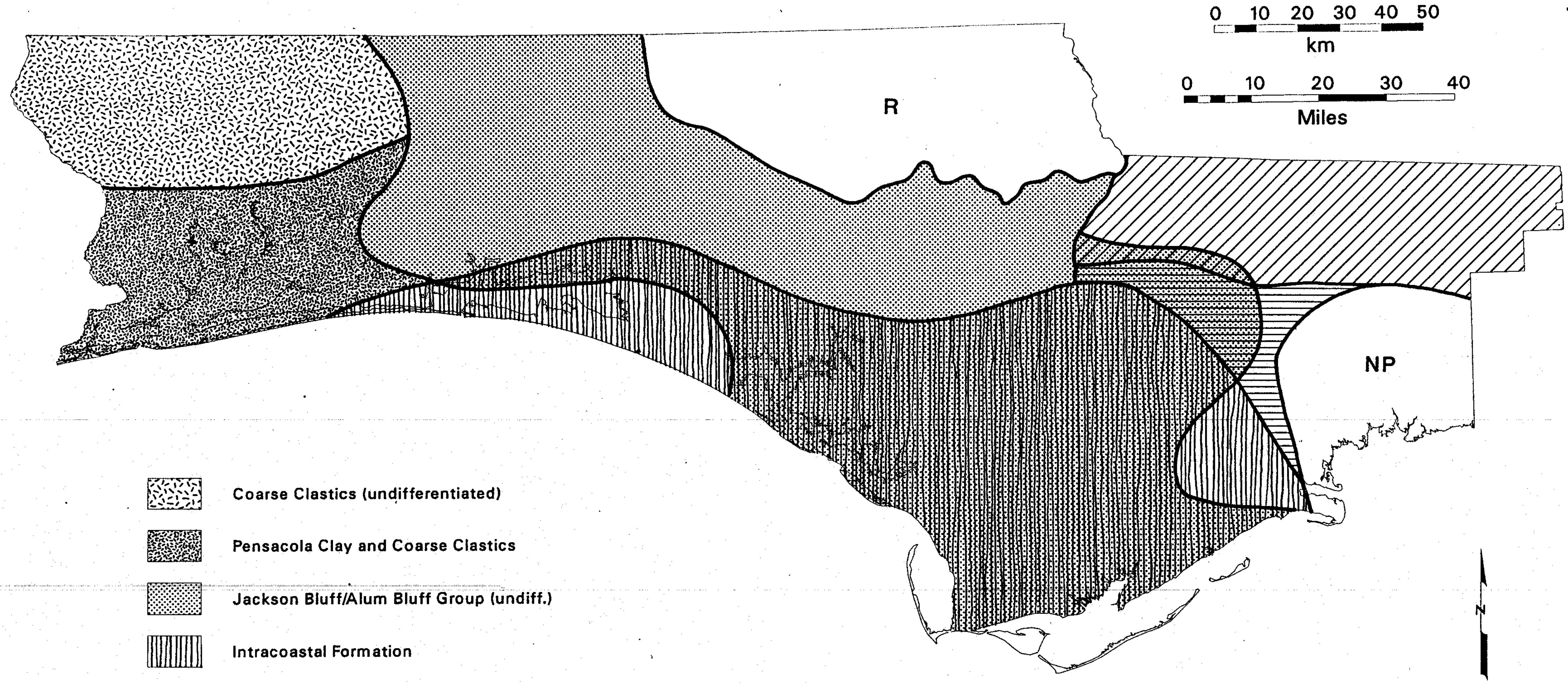


Figure A-5

Occurrence and Extent of Hydrogeologic Units in the Northwest Florida Water Management District



Coarse Clastics (undifferentiated)

Pensacola Clay and Coarse Clastics

Jackson Bluff/Alum Bluff Group (undiff.)

Intracoastal Formation

Miccosukee Formation and Hawthorn Group

Hawthorn Group

R Residuum

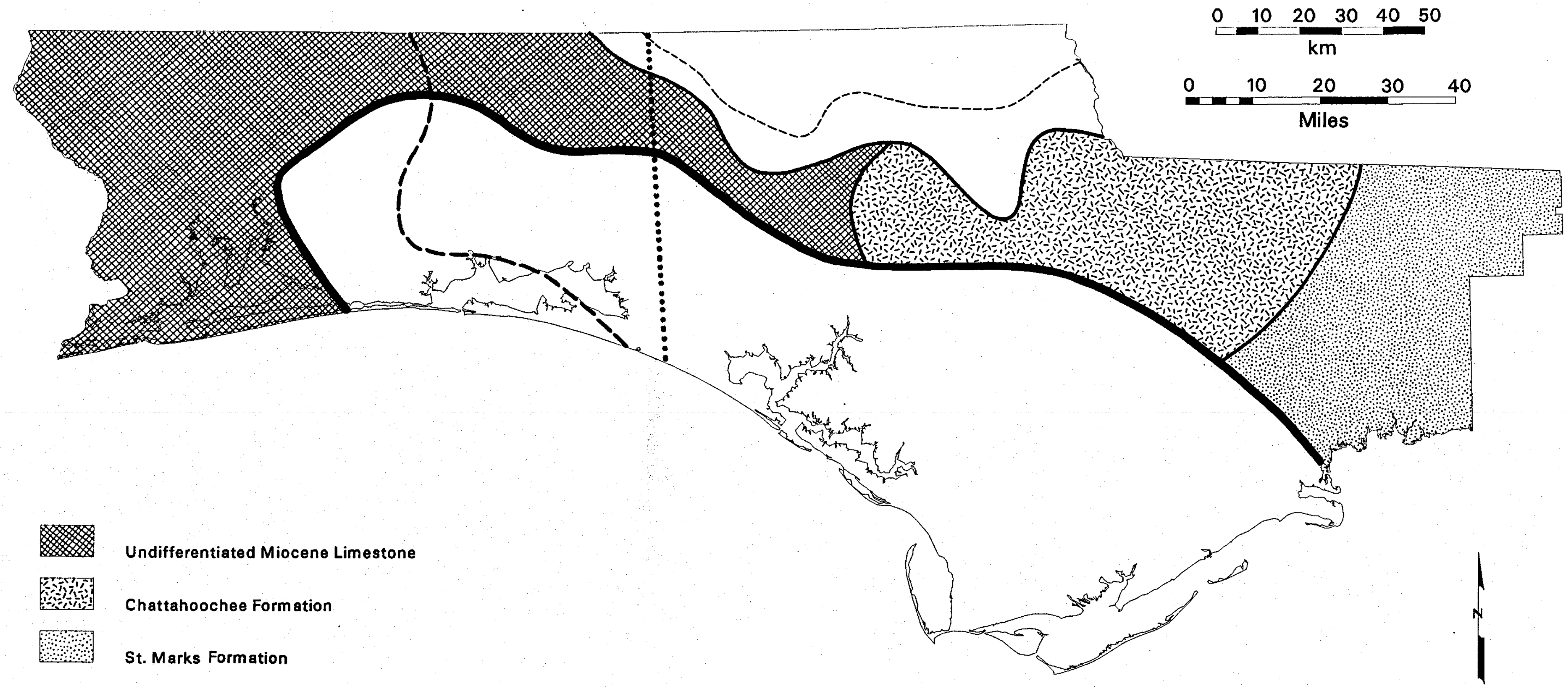
NP Intermediate System not present

Each areal extent of a stratigraphic unit is represented by unique symbol.
Due to the occurrence of two or more units in an area the symbols may overlap.

Figure A-6

Areal Extent of Stratigraphic Units Composing the Intermediate System

REFERENCES : MARSH, 1966 ; SCHMIDT, 1984 ; SCOTT, 1988



Undifferentiated Miocene Limestone

Chattahoochee Formation

St. Marks Formation

Bruce Creek Limestone (south of line)

Bucatunna Clay (west of line)

Suwannee Limestone (south of line, north of line only Ocala Group is present)

West of line Chickasawhay Formation is present, east of line Suwannee Limestone is present

Ocala Group underlies entire District

Figure A-7

Areal Extent of Stratigraphic Units Composing the Floridan Aquifer System

REFERENCES : SCHMIDT AND COE, 1978 ; SCHMIDT, 1984

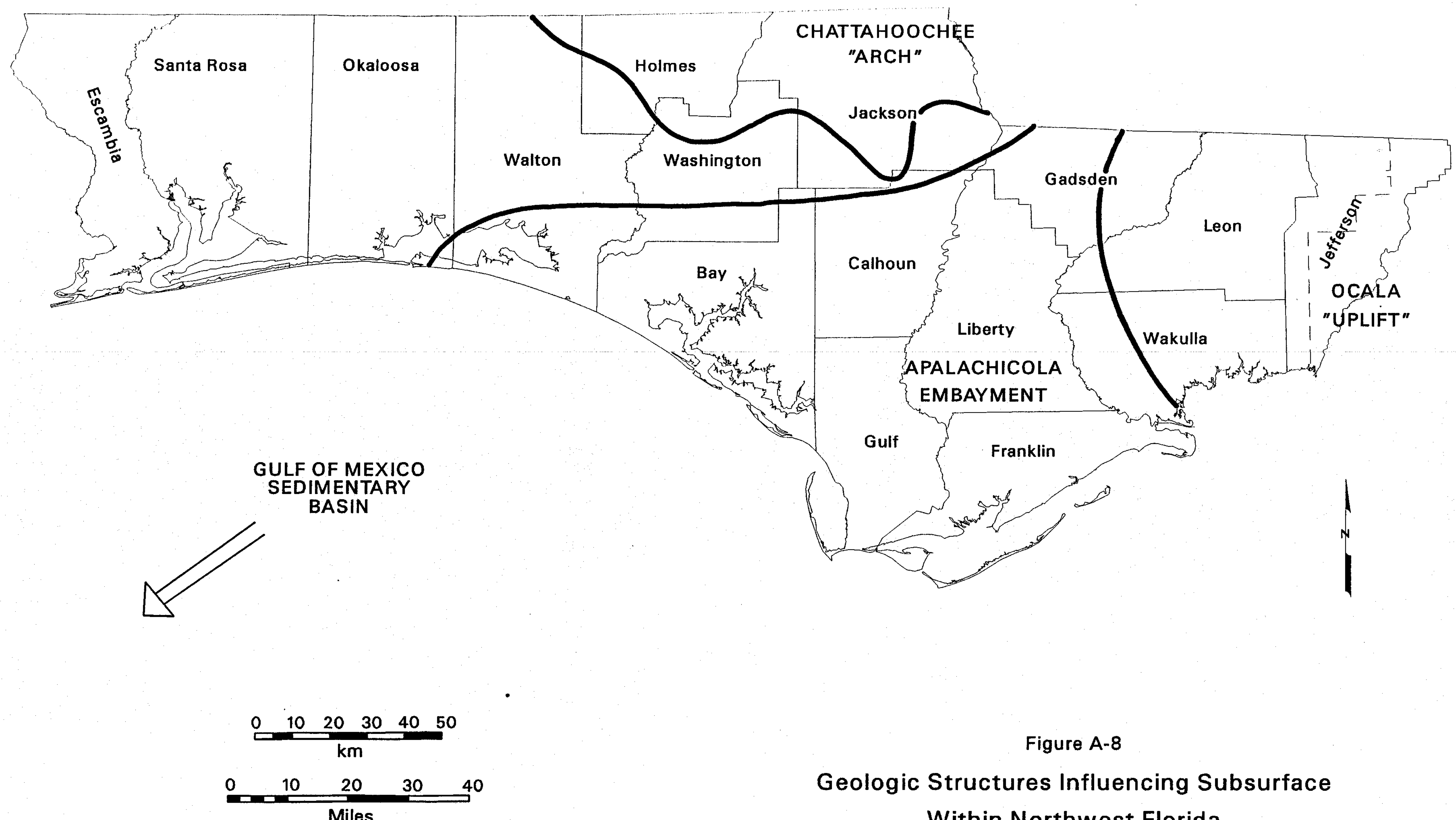


Figure A-8

Geologic Structures Influencing Subsurface Within Northwest Florida

MODIFIED FROM SCHMIDT, 1984

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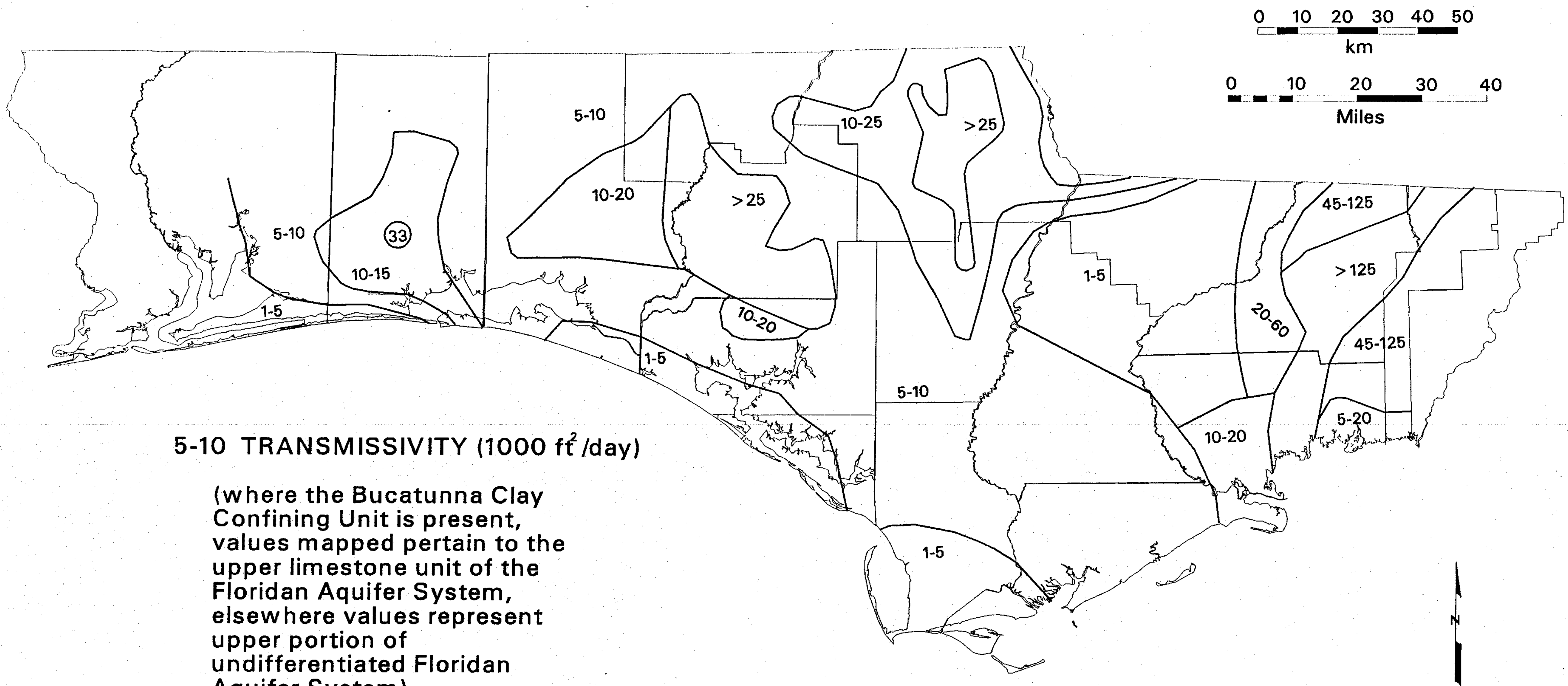


5-10 TRANSMISSIVITY (1000 ft^2/day)

(where the Bucatunna Clay Confining Unit is present, values mapped pertain to the upper limestone unit of the Floridan Aquifer System, elsewhere values represent upper portion of undifferentiated Floridan Aquifer System).

NOTE: Transmissivity is variable and dependent on aquifer interval tested.

Figure A-9

Estimated Transmissivity Distribution for the Floridan Aquifer System

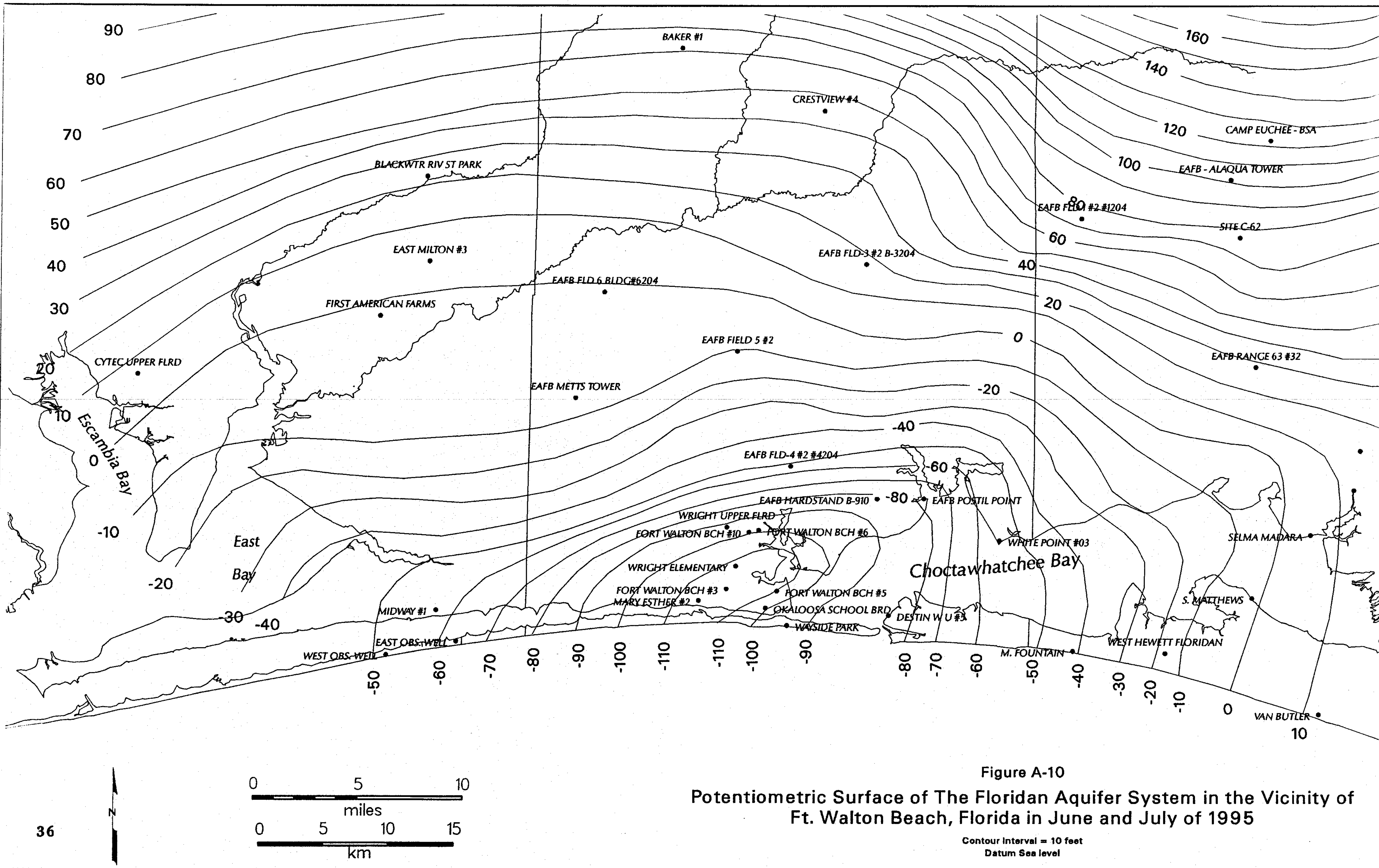
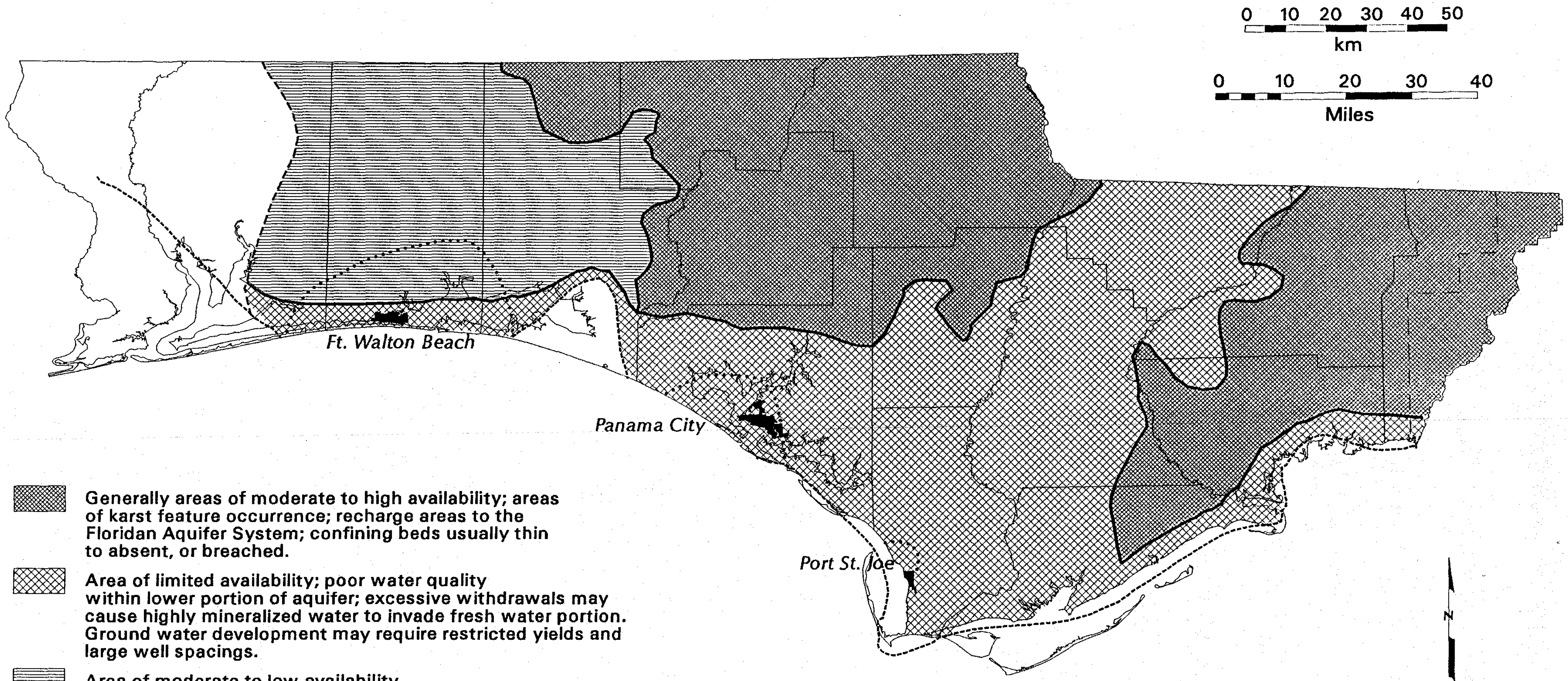


Figure A-10

Potentiometric Surface of The Floridan Aquifer System in the Vicinity of Ft. Walton Beach, Florida in June and July of 1995

Contour Interval = 10 feet
Datum Sea level



- Generally areas of moderate to high availability; areas of karst feature occurrence; recharge areas to the Floridan Aquifer System; confining beds usually thin to absent, or breached.
- Area of limited availability; poor water quality within lower portion of aquifer; excessive withdrawals may cause highly mineralized water to invade fresh water portion. Ground water development may require restricted yields and large well spacings.
- Area of moderate to low availability.
- Western extent for utilization of the Floridan Aquifer System as a drinking water source.
- Estimated position of the 250 milligram per liter isochlor.
- FT. WALTON BEACH VICINITY - cone of depression.

PANAMA CITY VICINITY - cone of depression with history of previous declines.

PORT ST. JOE VICINITY - history of previous water level declines.

Figure A-11

Generalized Ground Water Availability from the Floridan Aquifer System

13-02-003

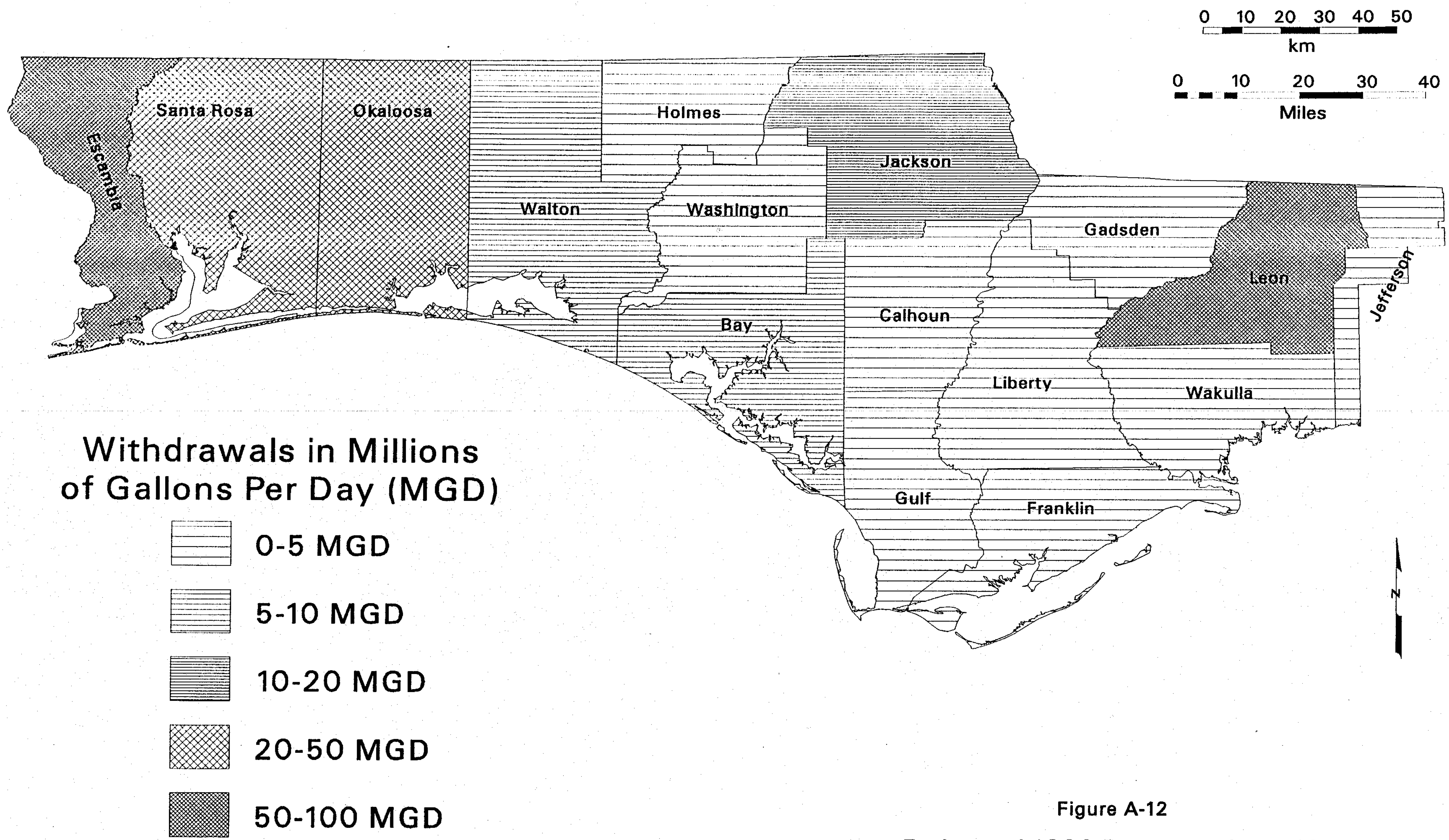


Figure A-12

Estimated 1990 Pumpage from All Ground Water Sources for All Uses

SOURCE : MARELLA, 1992

13-02-005

APPENDIX B

WOODVILLE KARST REGION

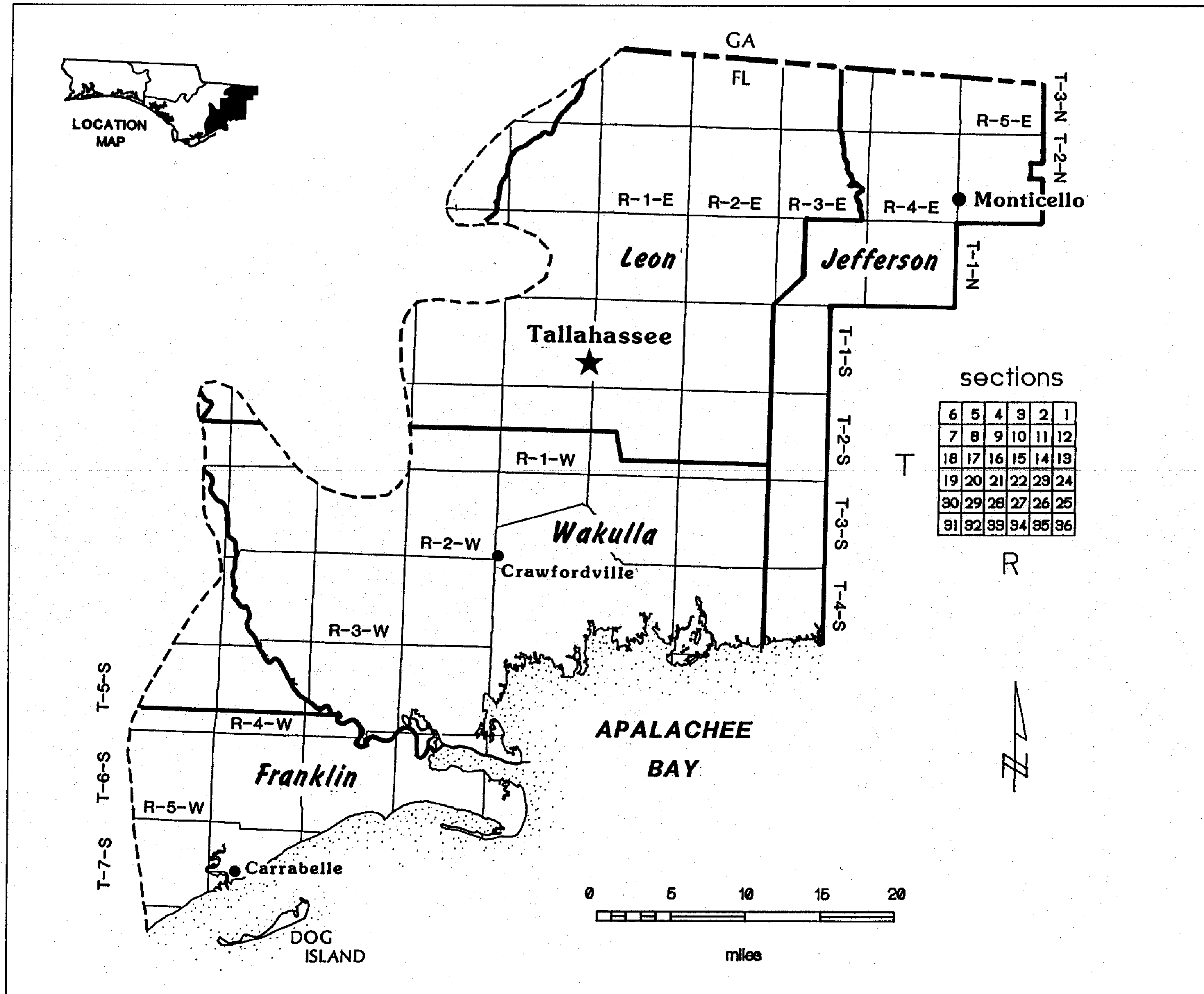


Figure B-1

Township and Range Regional Locational Reference for Woodville Karst Region

UTM Zone 17 Projection
Base Map Source: DOT County Maps

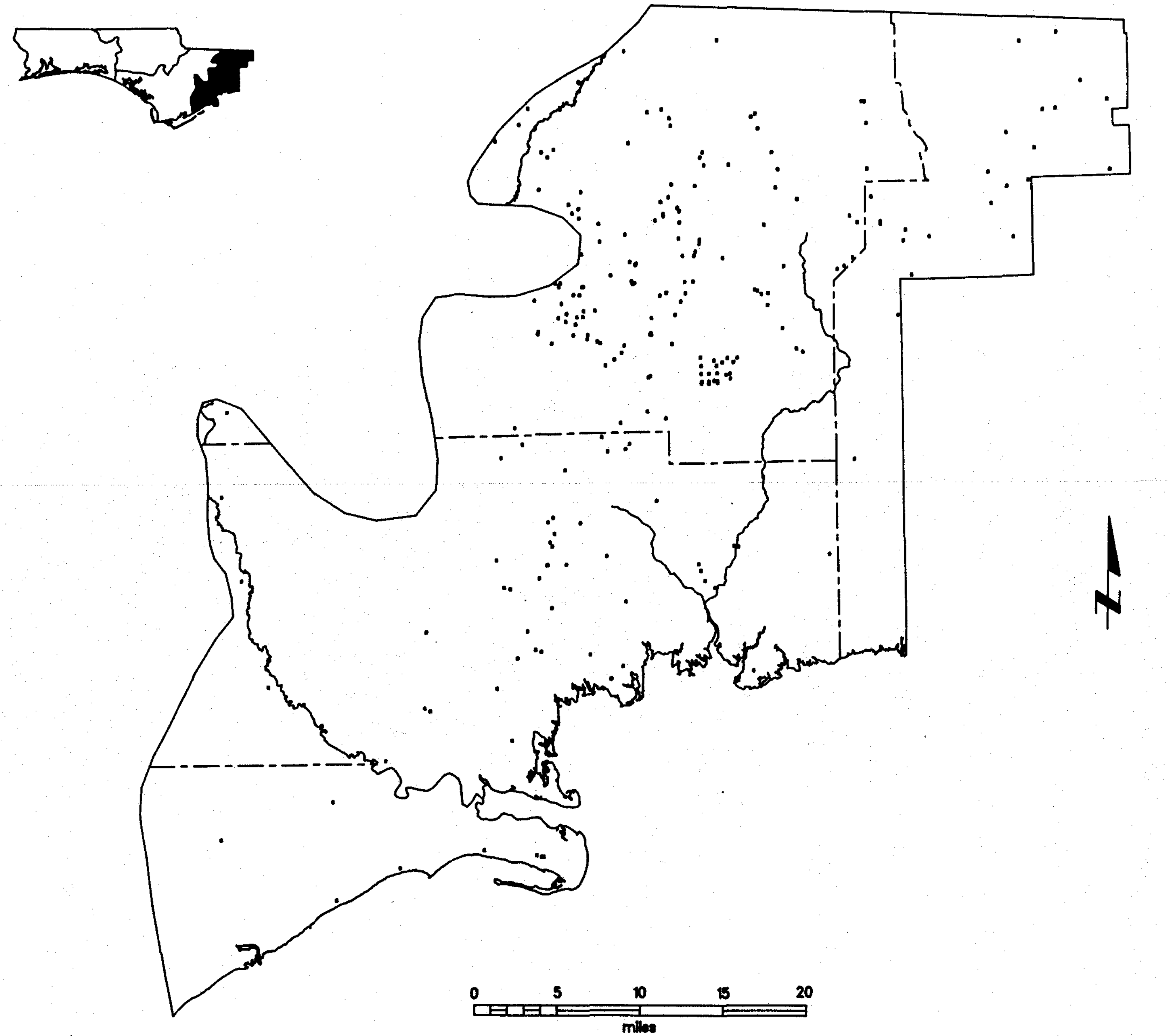


Figure B-2

Distribution of Hydrogeologic Data Control

Legend

• Control site with geophysical log data.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

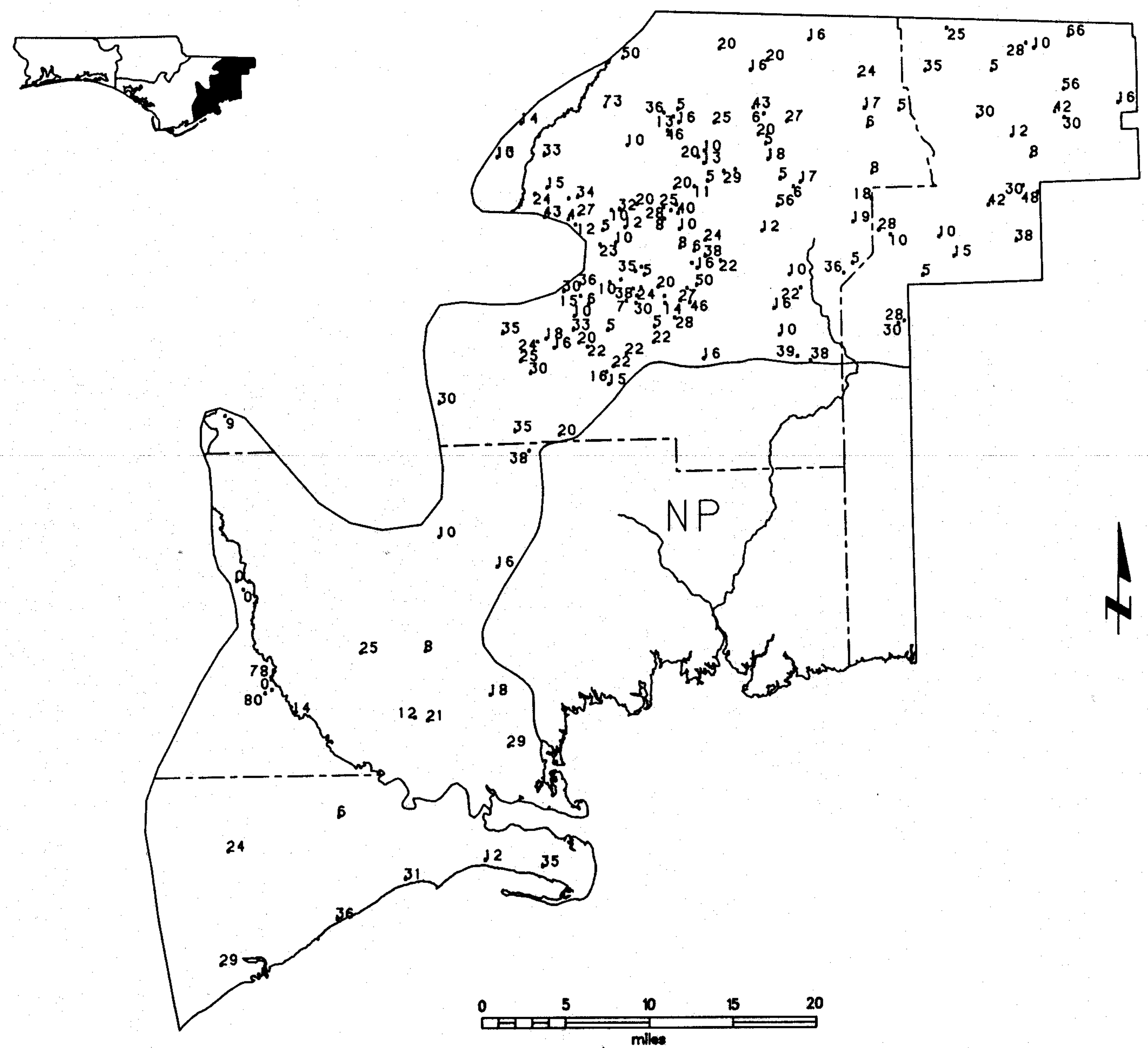


Figure B-3

Thickness Distribution for the Surficial Aquifer System

Legend

• 90	Thickness of aquifer at control point, in feet.
NP	Surficial Aquifer not present.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

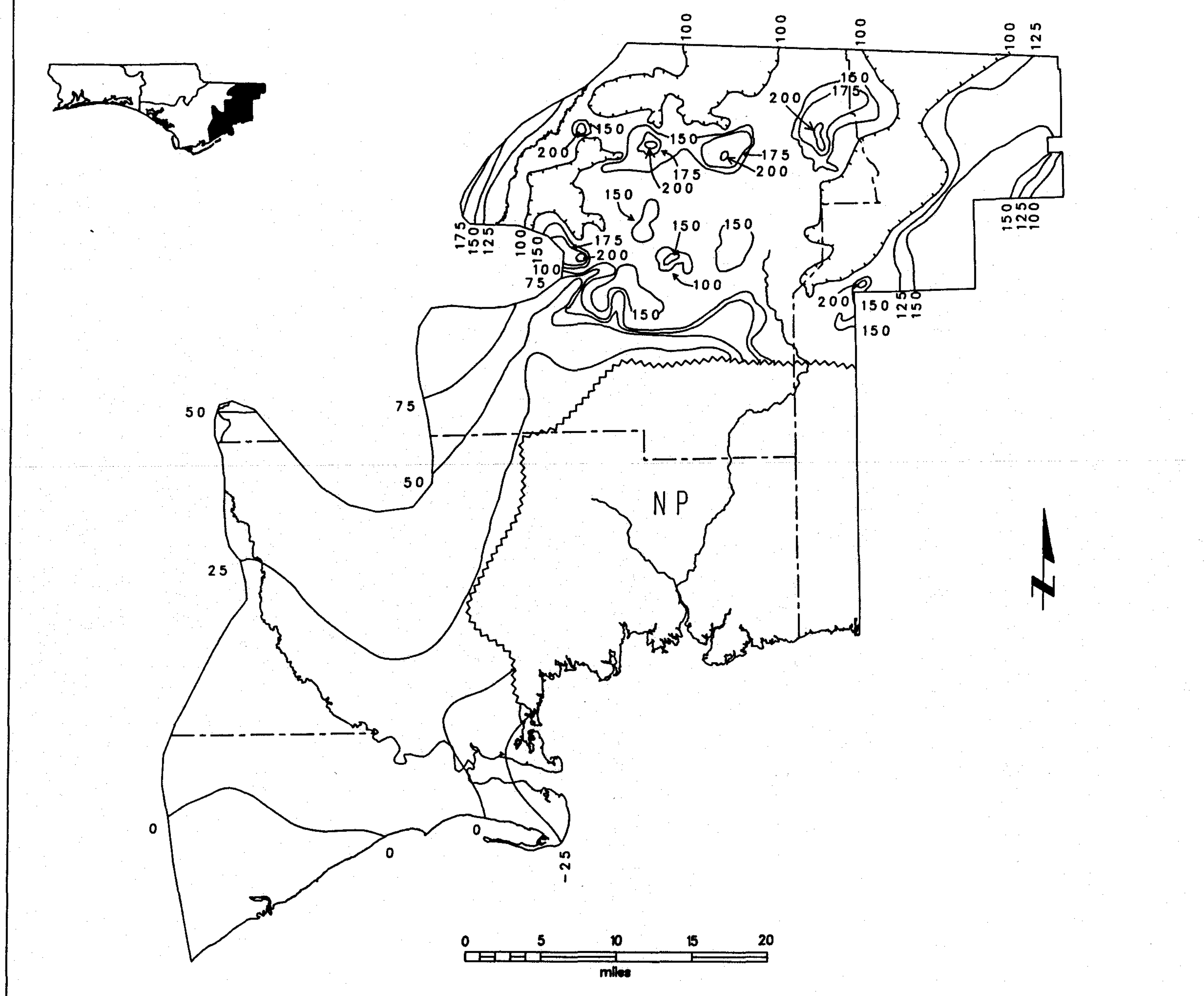


Figure B-4

Altitude of the Top of the Intermediate System

Legend

— 25 — Structural contour showing altitude of the top of the Intermediate System. Contour interval is 25 feet. Datum is sea level.

NP Intermediate System not present.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

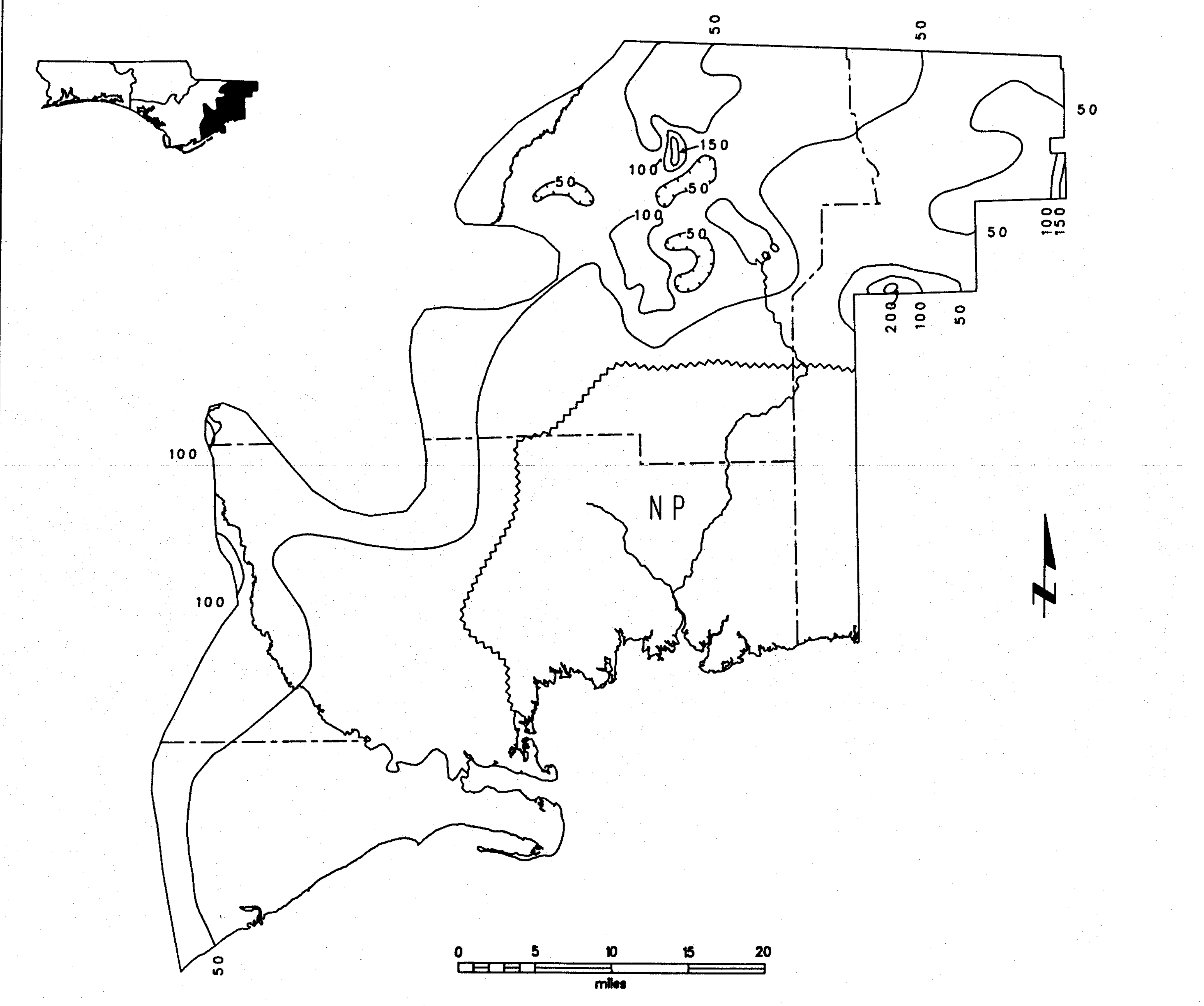


Figure B-5

Thickness of the Intermediate System

Legend

— 50 — Line of equal thickness of the Intermediate System. Contour interval is 50 feet.

NP Intermediate System not present.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

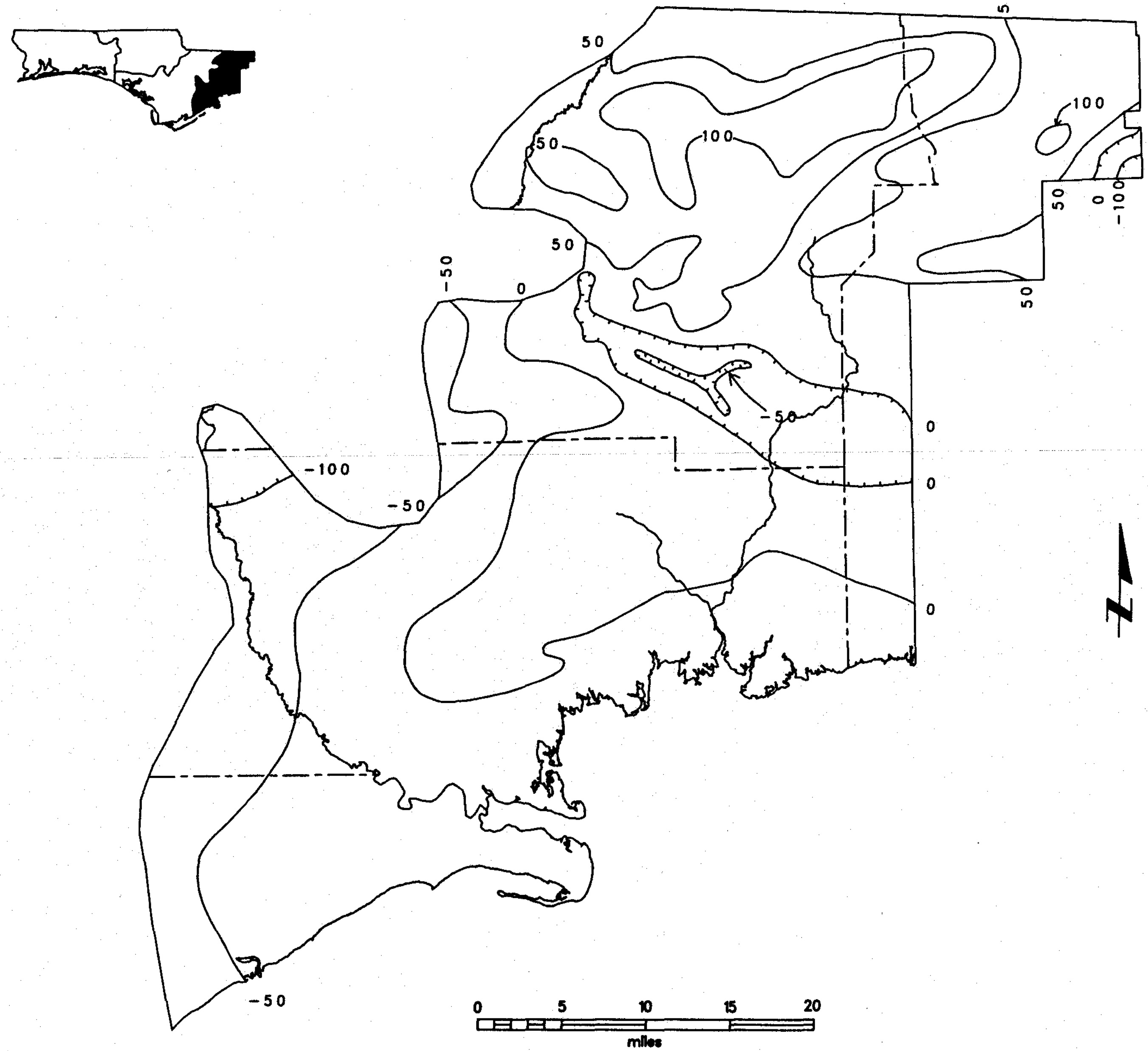


Figure B-6

Altitude of the Top of the Floridan Aquifer System

Legend

— 50 — Structural contour showing altitude of the top of the Floridan Aquifer System. Contour interval is 50 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

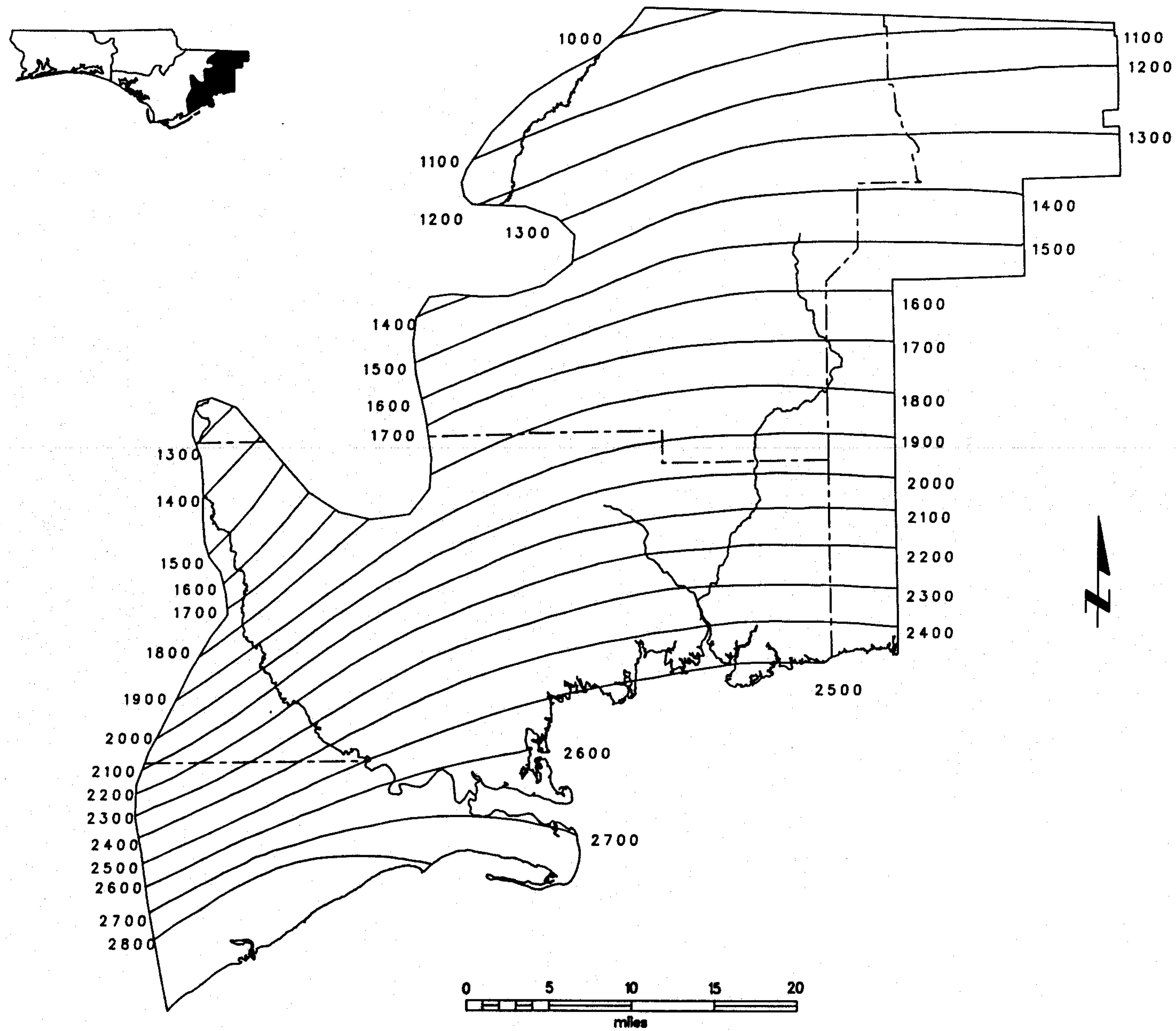


Figure B-7

Thickness of the Floridan Aquifer System (Undifferentiated)

Legend

— 1000 — Line of equal thickness of the Floridan Aquifer (undifferentiated). Contour interval is 100 feet.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

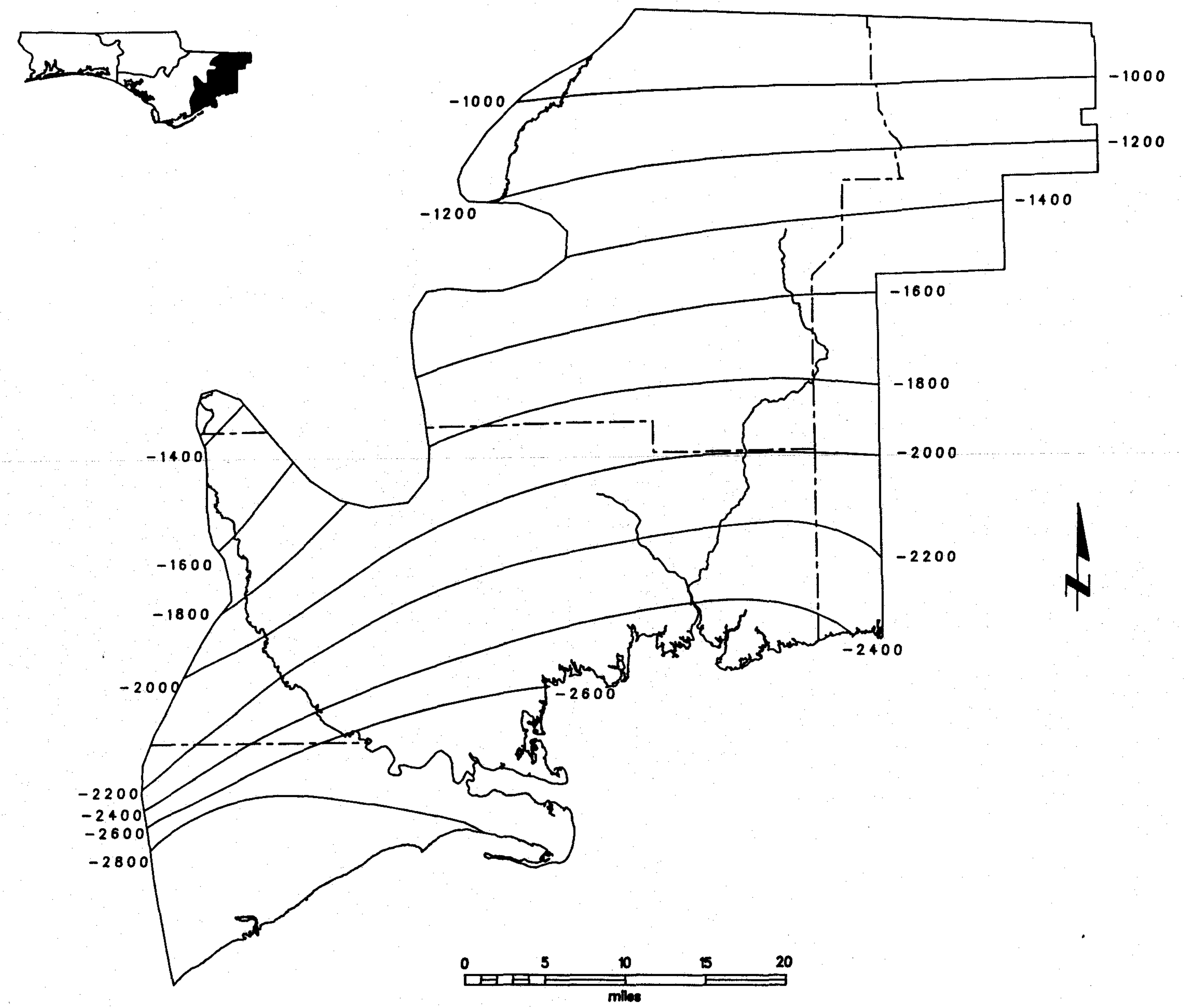


Figure B-8

Altitude of the Top of the Sub-Floridan System

Legend

— -1000 — Structural contour showing altitude of the top of the Sub-Floridan System. Contour interval is 200 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

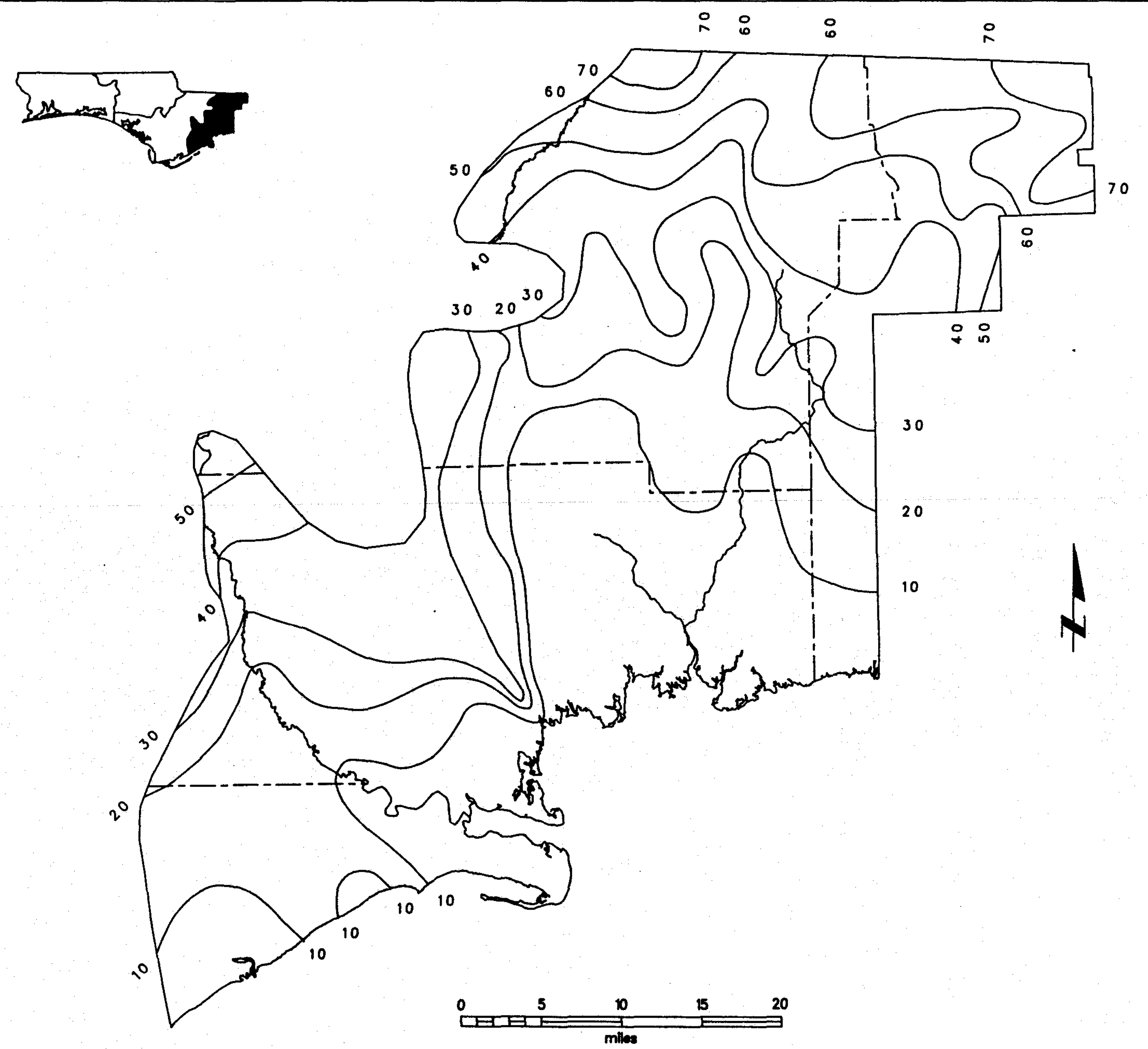


Figure B-9

Potentiometric Surface of the Floridan Aquifer System, May 1986

Legend

— 10 — Potentiometric contour showing altitude at which water level would have stood in tightly cased wells; dashed where approximate.
Contour interval is 10 feet.
Datum is sea level.

Modified from Wagner, 1989

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

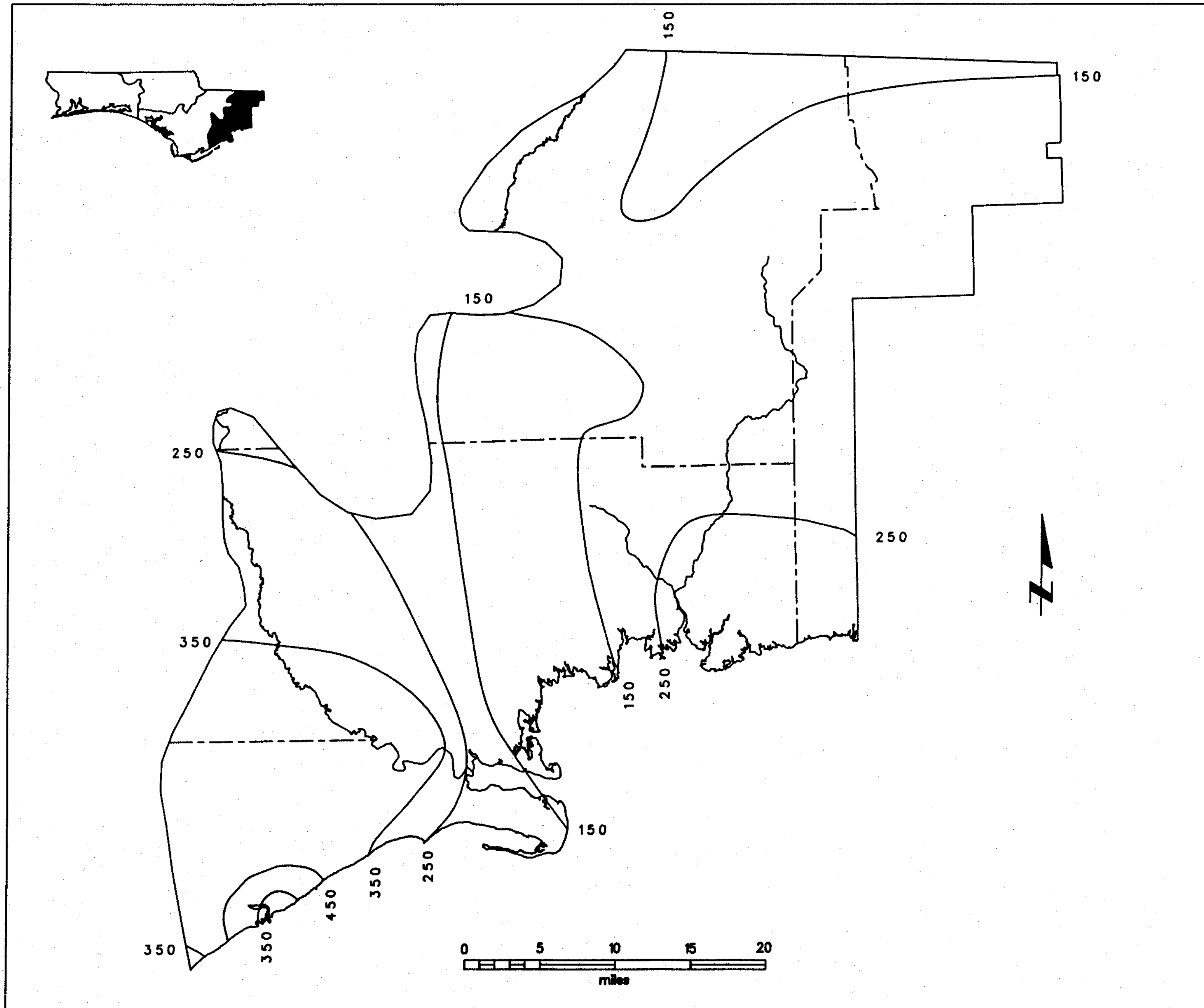


Figure B-10

Total Dissolved Solids Concentrations for Ground Water from the Floridan Aquifer System

Legend

— 150 — Line of equal total dissolved solids concentration in milligrams per liter (mg/L).
Contour interval is 100 mg/L.

Concentrations greater than 500 mg/L exceed recommended limits for drinking water. Wells tapping deeper portions of aquifer may yield water with concentrations that exceed 500 mg/L.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

TABLE B1.-- TYPICAL LITHOLOGY OF HYDROGEOLOGIC SYSTEMS WITHIN THE WOODVILLE KARST REGION

SURFICIAL AQUIFER SYSTEM

* Unit is a very thin veneer to absent in south-southeastern portion of region.
* Very fine to very coarse loose sand, graded and bedded, light colored, some carbonaceous zones, clay lenses present.

INTERMEDIATE SYSTEM

* Entire unit absent in south-southeastern portion of region; sporadically absent in north-northeast portion of region.
* Heterogeneous clastics, interbedded and cross-bedded clays, silts, sands and gravels of varying coarseness and admixtures, varicolored generally grayish-orange to grayish-red, mottled, sandstone lenses may be present; also ironstone pebbles; moderately to poorly sorted.
* Western Edge Only - Typically greenish-gray to brown, very macrofossiliferous, clayey sand and sandy clay; mollusk shells abundant throughout; sandy, light orange to cream, very light gray or off white marl in southwest.
* Southwestern Edge - Very sandy highly microfossilferous; poorly consolidated, olive gray limestone; generally argillaceous, micritic and phosphatic.
* Dominantly sandy clay to very sandy clayey sand; carbonate content increases to west; fine to medium grained sand; sand-sized phosphorite; silt, clay, and sandy phosphoritic limestone; limestone very pale orange, very finely crystalline, moderately sandy, slightly to moderately phosphoritic, dolomitized and partially recrystallized; to the east, pale olive, light greenish gray, yellowish gray, light gray to yellow; sandy, waxy clay; thin sandy limestone stringers; dolomite may be present.

FLORIDAN AQUIFER SYSTEM

* Southwestern Edge - White to light yellow gray, moderately indurated, cemented sand-size detrital calcite; sandy highly fossiliferous limestone.
* Elsewhere, predominantly fine to medium grained, partially recrystallized, silty to sandy limestone with secondary dolomitization; white to very pale orange to grayish orange, finely crystalline mass with overall slightly chalky to earthy appearance; microfossils present but not common; generally not phosphoritic; poor to moderate porosity; silicified to the east.
* Very pale orange, abundantly microfossiliferous, granular, partially recrystallized, cemented sand-sized detrital calcite with finely crystalline matrix; can be weakly cemented, moderate to good porosity, partially dolomitized throughout entire section; chert zones may be present.
* Very pale orange, microcoquinoid, moderate to very porous, soft to medium hard limestone conglomerate; sometimes partially recrystallized; grayish orange, recrystallized, very dense dolomite with molds and casts; dolomite is secondary and for the most part the dolomitization has destroyed the original lithology.
* Pale orange, moderately indurated, soft, granular, poorly porous, microfossiliferous, sand-sized detrital calcite in a silty to finely crystalline matrix; also some beds of chert.
* Cream and tan, crystalline limestone, somewhat argillaceous; chert and gypsum common.
* Pale orange recrystallized, microfossiliferous, very glauconitic, cemented sand-sized detrital calcite with noticeable intergranular porosity; dark yellow sucrosic crystalline, glauconitic dolomite; minor occurrence chert and gypsum.

SUB-FLORIDAN SYSTEM

* Pale orange, soft, argillaceous, slightly dolomitic, glauconitic, cemented silt to clay-sized detrital calcite; grayish green, calareous clay.

APPENDIX C

APALACHICOLA EMBAYMENT REGION

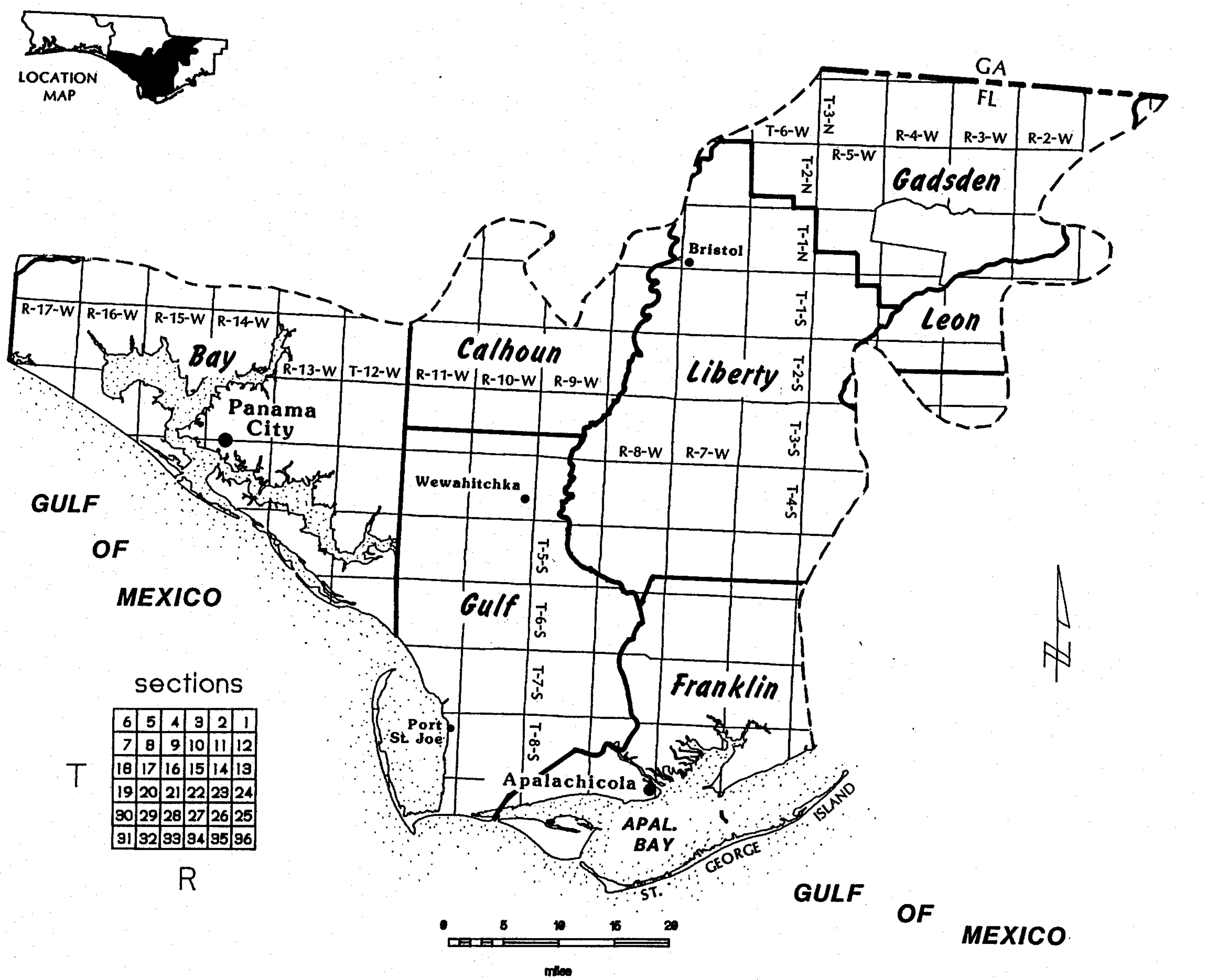


Figure C-1

Township and Range
Regional Locational Reference for the
Apalachicola Embayment Region

UTM Zone 17 Projection
Base Map Source: DOT County Maps

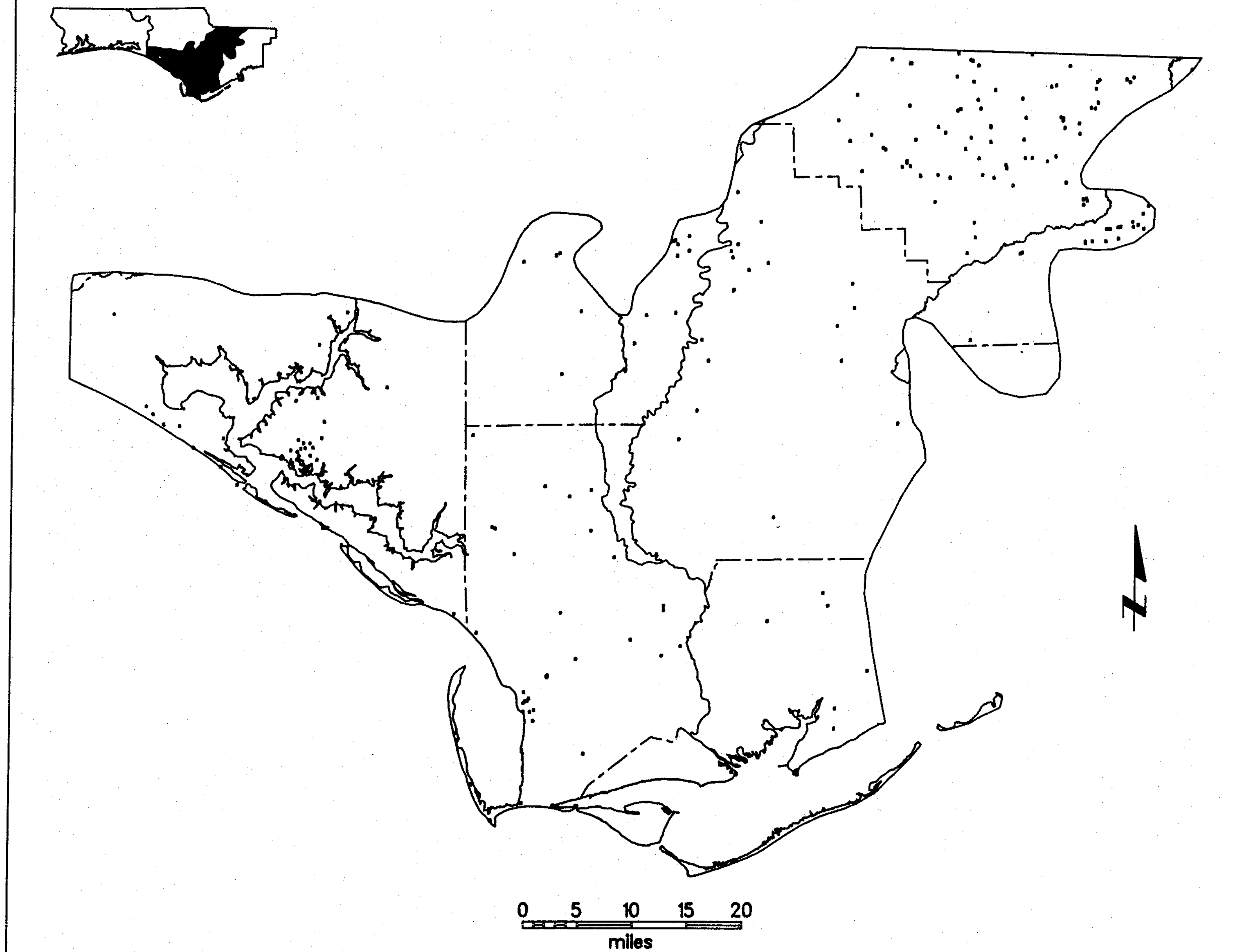


Figure C-2

Distribution of Hydrogeologic Data Control

Legend

• Control site with geophysical log data.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

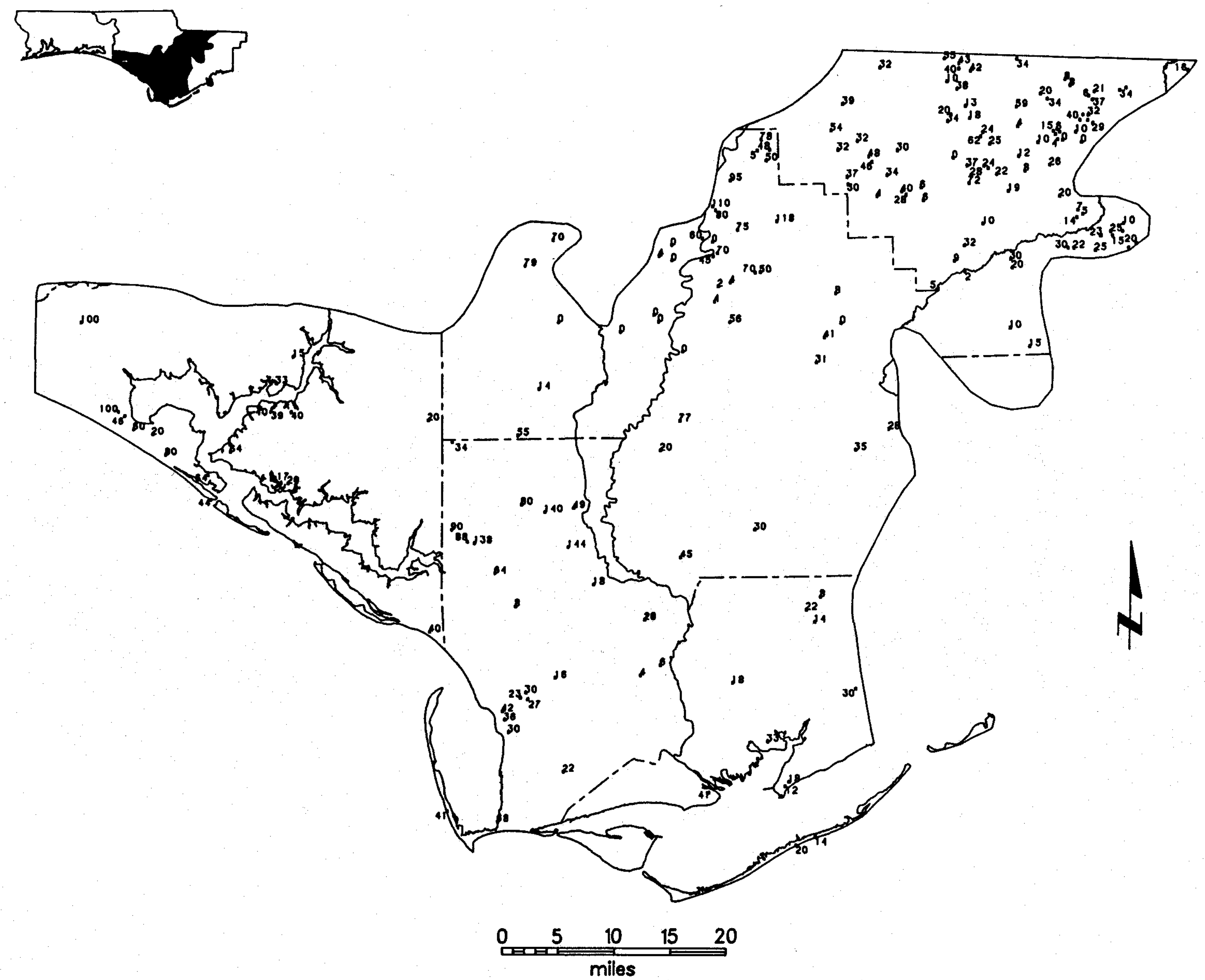


Figure C-3

Thickness Distribution for the Surficial Aquifer System

Legend

• 90 Thickness of aquifer at control point, in feet.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

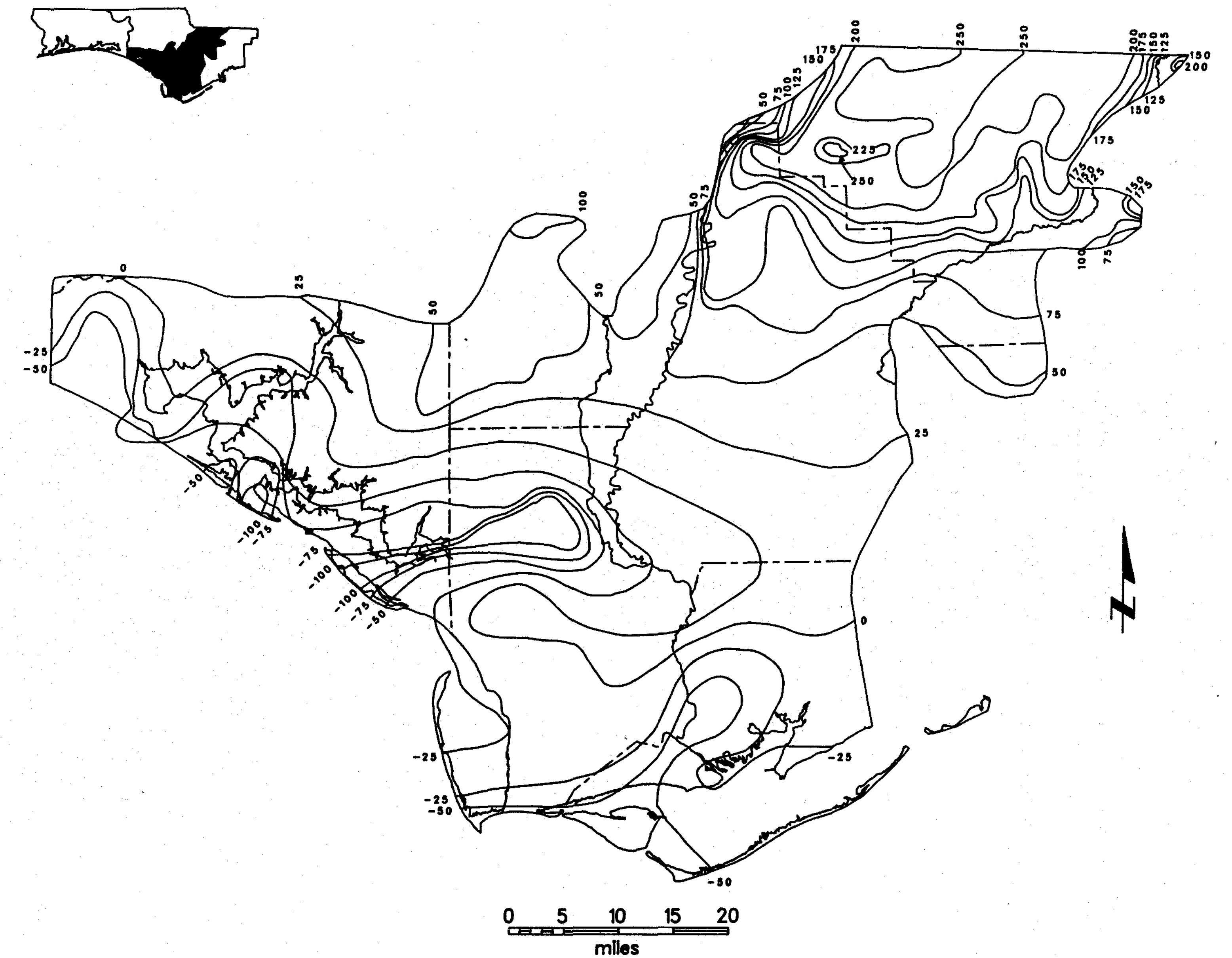


Figure C-4

Altitude of the Top of the Intermediate System

Legend

— 50 — Structural contour showing altitude of the top of the Intermediate System. Contour interval is 25 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

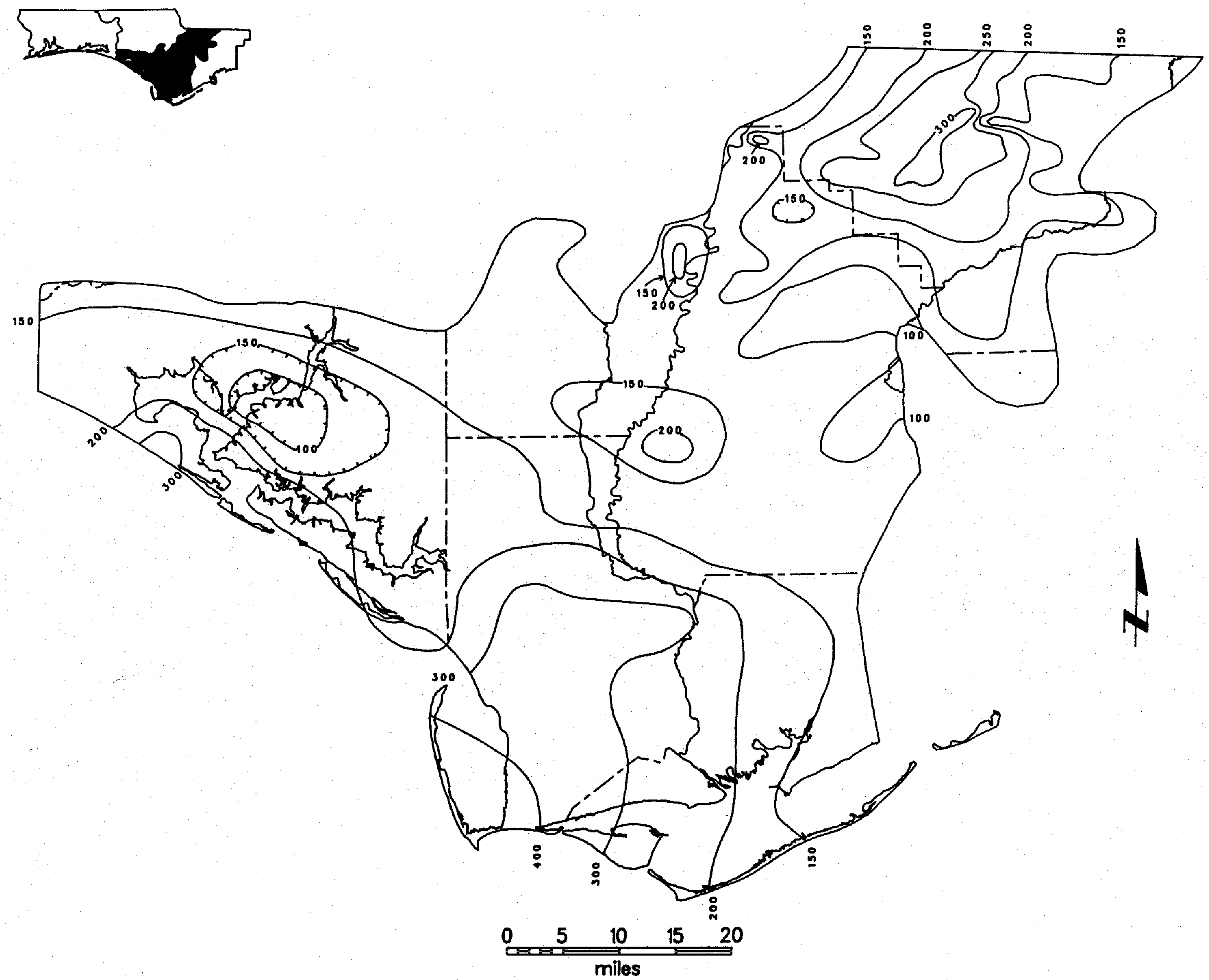


Figure C-5

Thickness of the Intermediate System

Legend

— 100 — Line of equal thickness of the Intermediate System. Contour interval is 50 feet.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

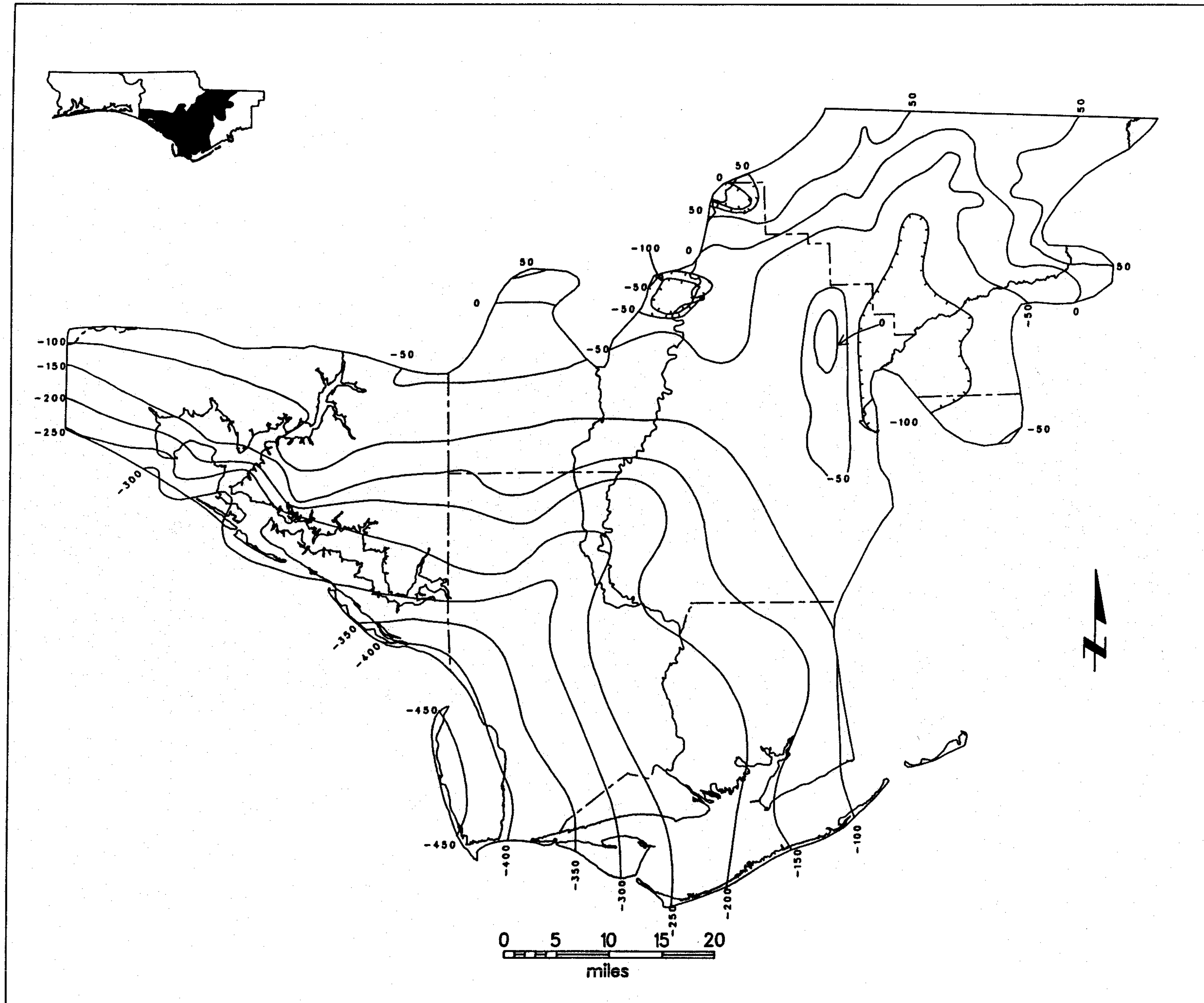


Figure C-6

Altitude of the Top of the Floridan Aquifer System

Legend

— 50 — Structural contour showing altitude of the top of the Floridan Aquifer System. Contour interval is 50 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

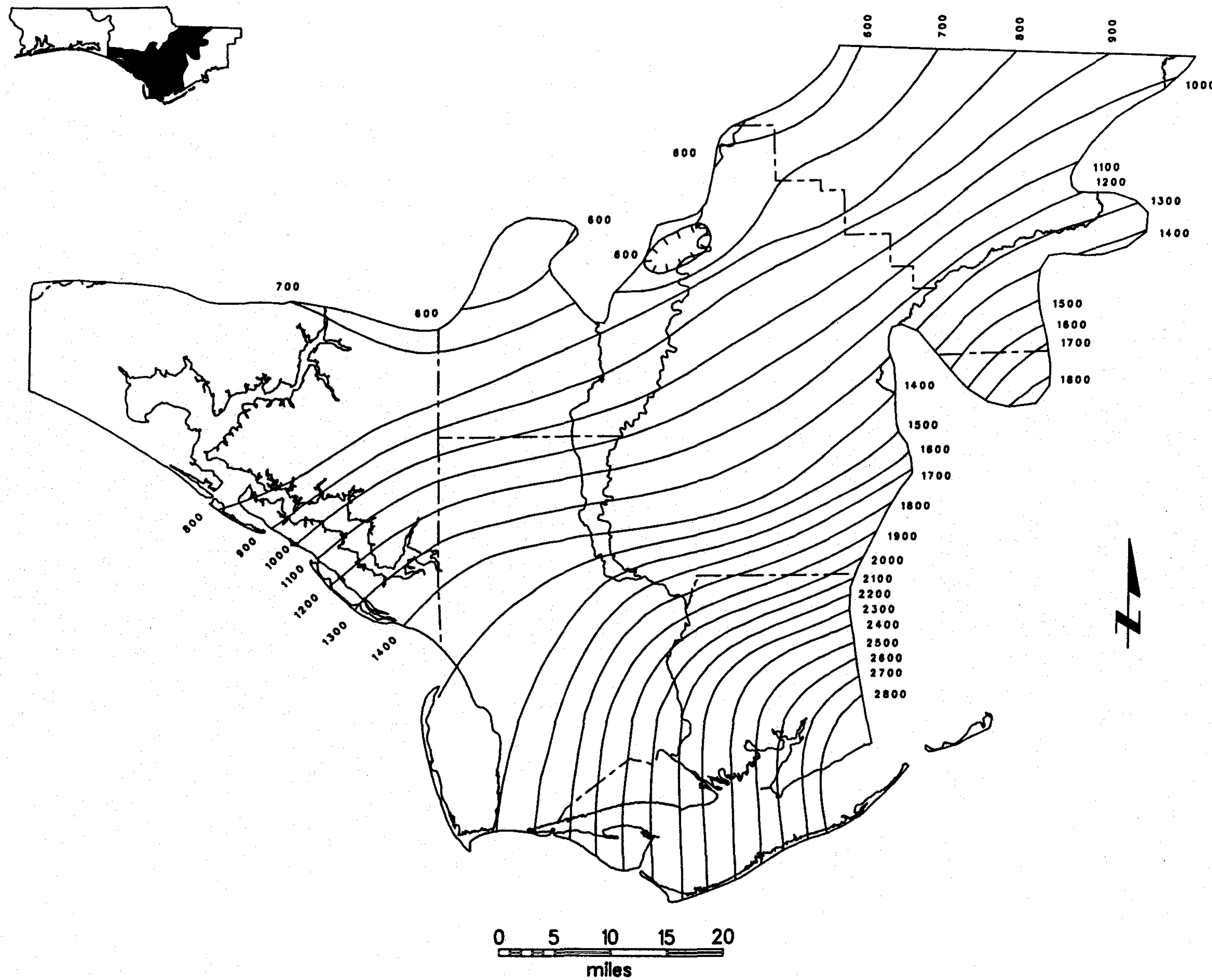


Figure C-7

Thickness of the Floridan Aquifer System (Undifferentiated)

Legend

— 600 — Line of equal thickness of the Floridan Aquifer (undifferentiated). Contour interval is 100 feet.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

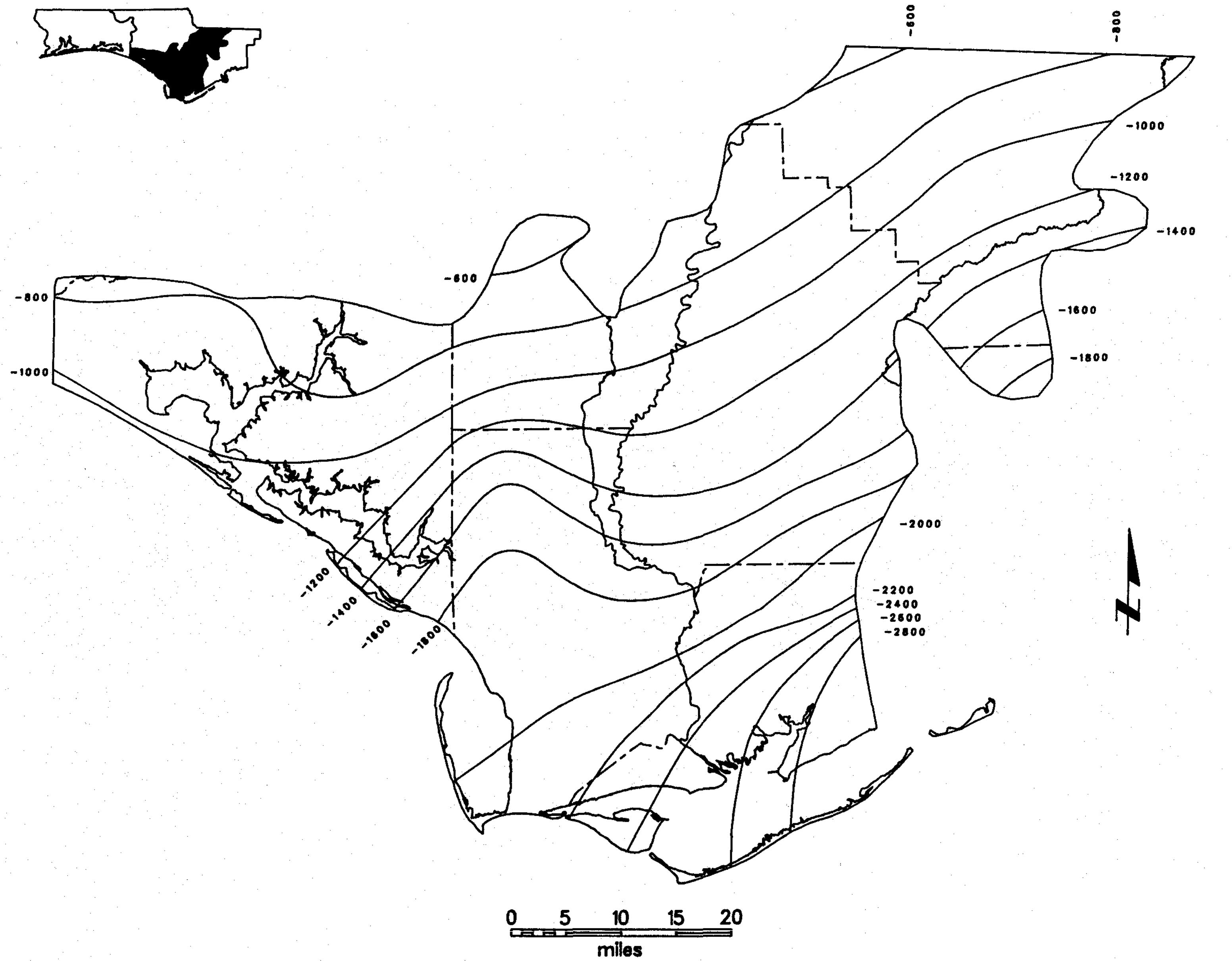


Figure C-8

Altitude of the Top of the Sub-Floridan System

Legend

— -600 — Structural contour showing altitude of the top of the Sub-Floridan System. Contour interval is 200 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

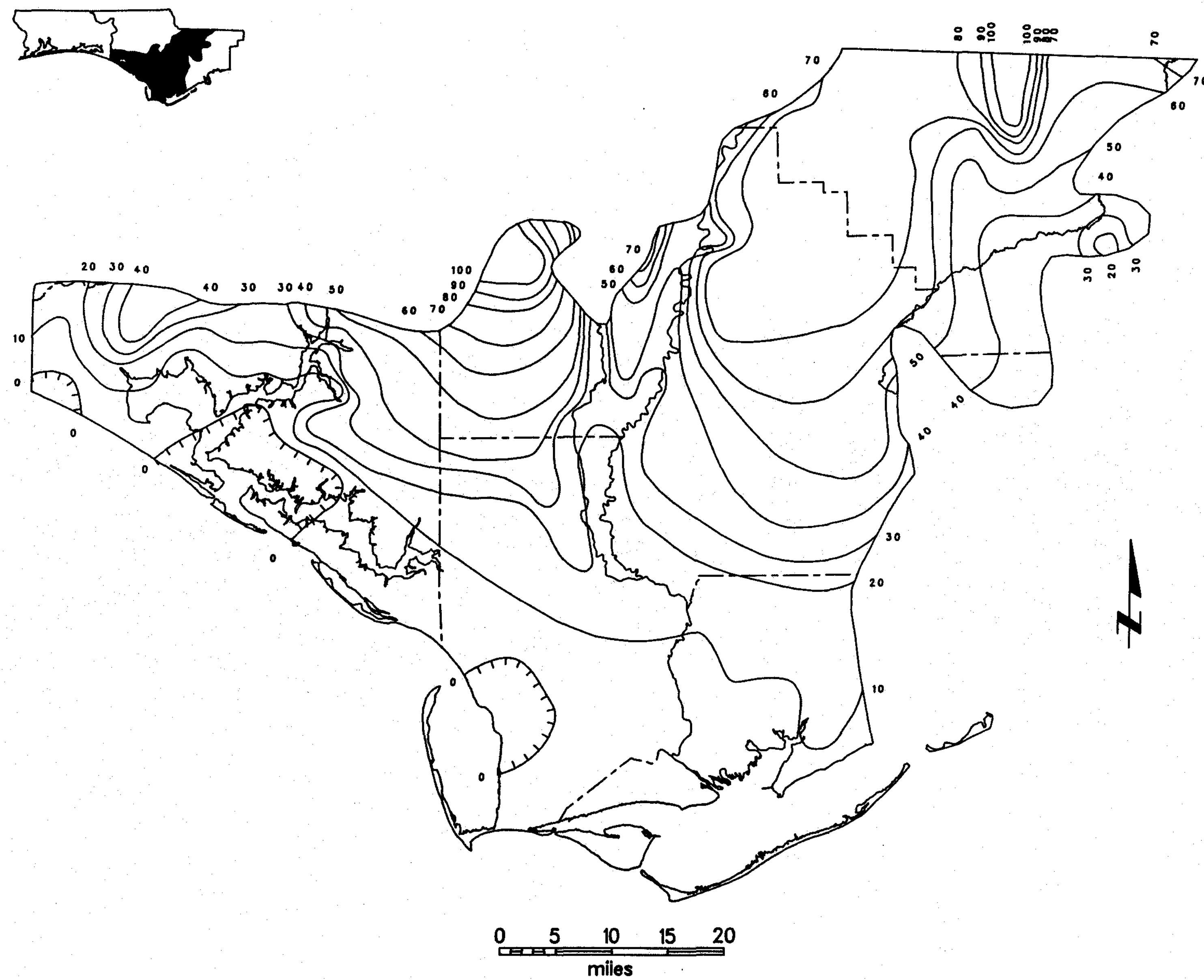


Figure C-9

Potentiometric Surface of the Floridan Aquifer System, May 1986

Legend

— 10 — Potentiometric contour showing altitude at which water level would have stood in tightly cased wells; dashed where approximate.
Contour interval is 10 feet.
Datum is sea level.

Modified from Wagner, 1989

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

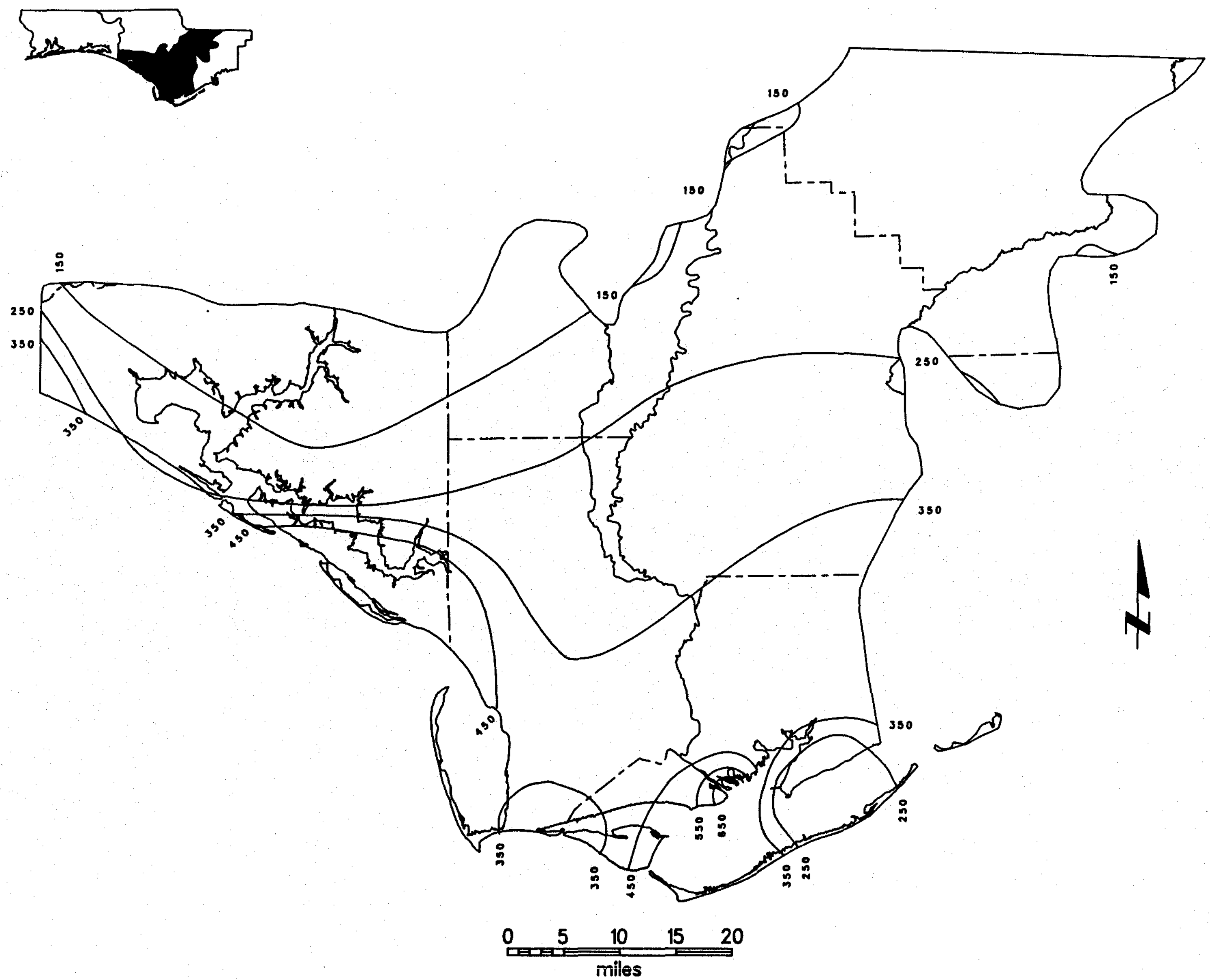


Figure C-10

Total Dissolved Solids Concentrations for Ground Water from the Floridan Aquifer System

Legend

— 150 — Line of equal total dissolved solids concentration in milligrams per liter (mg/L). Contour interval is 100 mg/L.

Concentrations greater than 500 mg/L exceed recommended limits for drinking water. Wells tapping deeper portions of aquifer may yield water with concentrations that exceed 500 mg/L.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

TABLE C1.-- TYPICAL LITHOLOGY OF HYDROGEOLOGIC SYSTEMS WITHIN APALACHICOLA EMBAYMENT REGION

SURFICIAL AQUIFER SYSTEM

* Sands and clays of various admixtures.
* White to light gray sand, also orange clayey sands; gravels toward north; very fine to gravel; eastern edge: reddish siliciclastics; orange to red clayey, medium to coarse sands; clay lenses; quartz pebbles; cross bedding.

INTERMEDIATE SYSTEM

* Fine to medium clayey sands; gravels present; poorly indurated; mottled clays, sandy clays, ironstone pebbles.
* In Central and Southern Portions: Tan to orange brown to gray green, shell beds, interbedded with sandy clays and clayey sands; calcareous; macrofossiliferous; mollusk shells abundant; argillaceous; occasional sandy limestone; also described as poorly consolidated marl.
* In Northern Portion: Siliciclastic, white to light olive gray, very fine to medium grained clayed sand to sandy, silty clay; variable amounts of sand, limestone, dolomite, phosphorite; carbonate content increases downward; also sandy, clayey limestone or dolomitic limestone; often fossiliferous, molds and casts of mollusks; induration varies from poor to moderate; clay rich facies contain fullers earth beds.
* In Southern Portion: Olive gray green, microfossils abundant, very sandy, poorly consolidated, argillaceous, cemented sand-sized detrital calcite limestone; more sand upward and to west; calcium carbonate increases downward, phosphoritic.
* West of Apalachicola River: Very light orange, sandy limestone with crystal, micrite and pellet grain types, fine to coarse grained, sparry and micritic cement; foraminifera, mollusks, coral, bryozoans; variable induration, porosity, sand content, and presence of argillaceous material; updip poorly to moderately indurated, sandy; downdip better induration and lesser sand content.

FLORIDAN AQUIFER SYSTEM

* Southern Half of Region Only: White to light yellow gray, moderately indurated, cemented granular to sand-sized detrital calcite limestone, micritic, sandy; minor amounts phosphorite, glauconite and pyrite; dolomite and sparry calcite may be present; less indurated to east.
* Eastern Fringe Only: Very light gray to pale to yellowish gray to white, argillaceous, moderately indurated, massive limestone with casts and molds of mollusks; micritic limestone; minor beds of interbedded clay and sand; more calcareous to east; also greenish clay blebs.
* More silty, clayey or dolomitic than above; siliciclastic and more dolomitic to west; sandy dolomite with occasional occurrences of limestone, generally unfossiliferous; also white, hard to chalky limestone interspersed and alternating with sandy limestone and lenses of sandy clay; minor amounts of phosphorite.
* Updip: White to cream to light olive gray, fossiliferous, micritic to crystalline limestone; frequently containing brown dolomite and minor sand.
* Downdip: Light gray to yellow gray limestone with micrite and biogenic grain types, moderately indurated and contains fossils (mollusks, foraminifera), may be dolomitized and sucrosic dolomitic lithology, highly altered and recrystallized; minor amounts of clay; occasionally chalky.
* West-Southwest: Primarily tan sucrosic dolomite, also dolomitic, fossiliferous limestone; sand interbedded.
* West-Southwest: Light gray, massive, chalky limestone; large foraminifera common; little glauconite; sand common; moderately to well indurated; biomicrite or wackestone.
* Updip: Cream colored, highly fossiliferous, crystalline, abundant foraminifera, varying amounts of sand, dolomite and clay.
* Downdip: Light orange to white limestone with high porosity, both micrite and sparry calcite cement, crystal and skeletal grain types, some glauconite and sand; abundant fossils; glauconite and chert occurrence increase with depth.
* Lower portion of unit becomes more clastic to the west and more calcareous to the east;
* This part of unit is more clayey to the west and is part of the Sub-Floridan Confining Unit; to the east is more calacareous, and is part of the Floridan Aquifer System.
* Argillaceous, glauconitic, arenaceous, fossiliferous limestone, some beds of calcareous shale; also glauconitic and calcareous sandstone.

SUB-FLORIDAN SYSTEM

* Argillaceous, dolomitic, glauconitic, cemented silt to clay-sized detrital calcite, interbedded calcareous clays and sandstones; calcareous shale sometimes laminated; minor beds of argillaceous, fossiliferous limestone.

APPENDIX D

DOUGHERTY KARST REGION

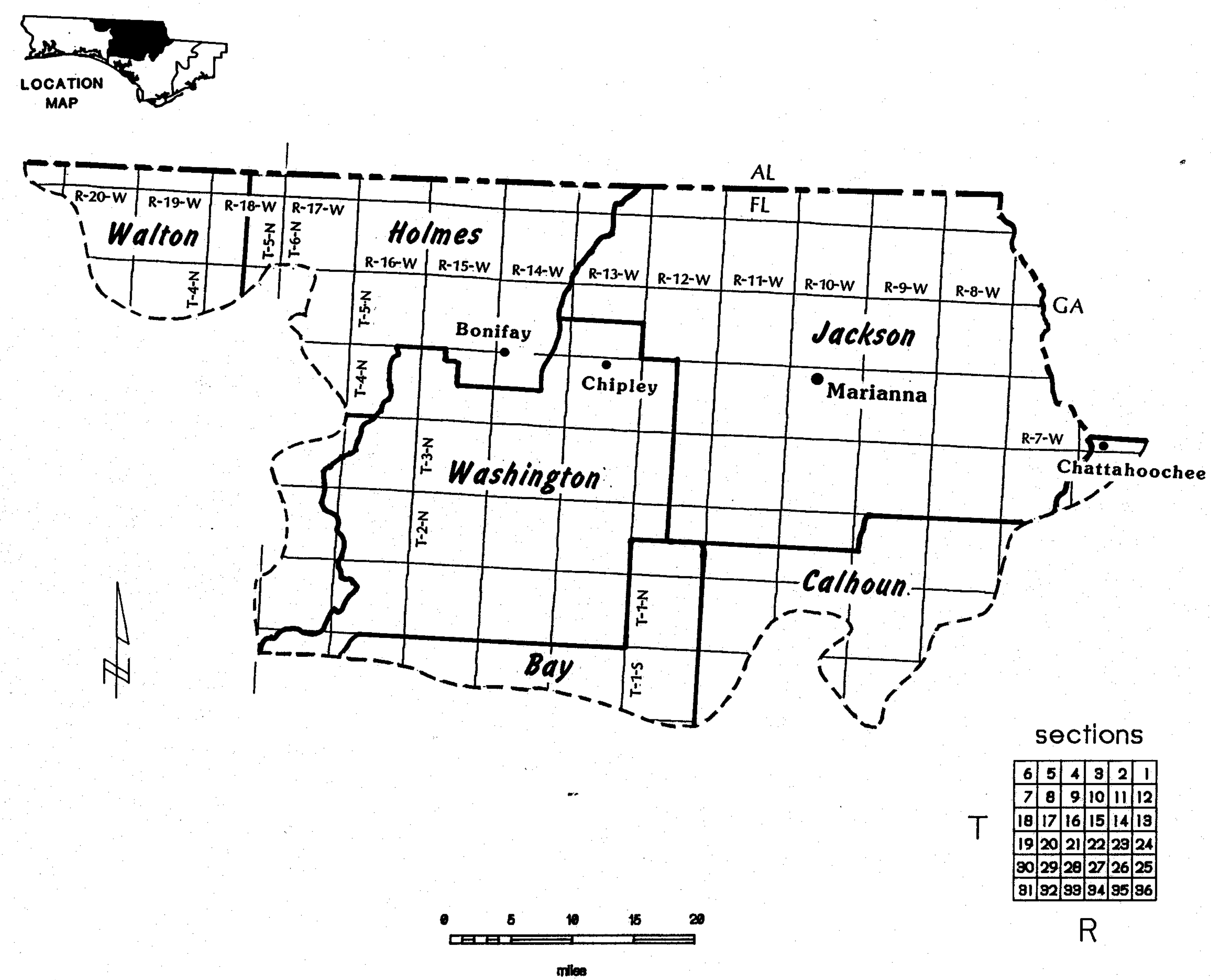


Figure D-1

Township and Range
Regional Locational Reference for the
Dougherty Karst Region

UTM Zone 17 Projection
Base Map Source: DOT County Maps

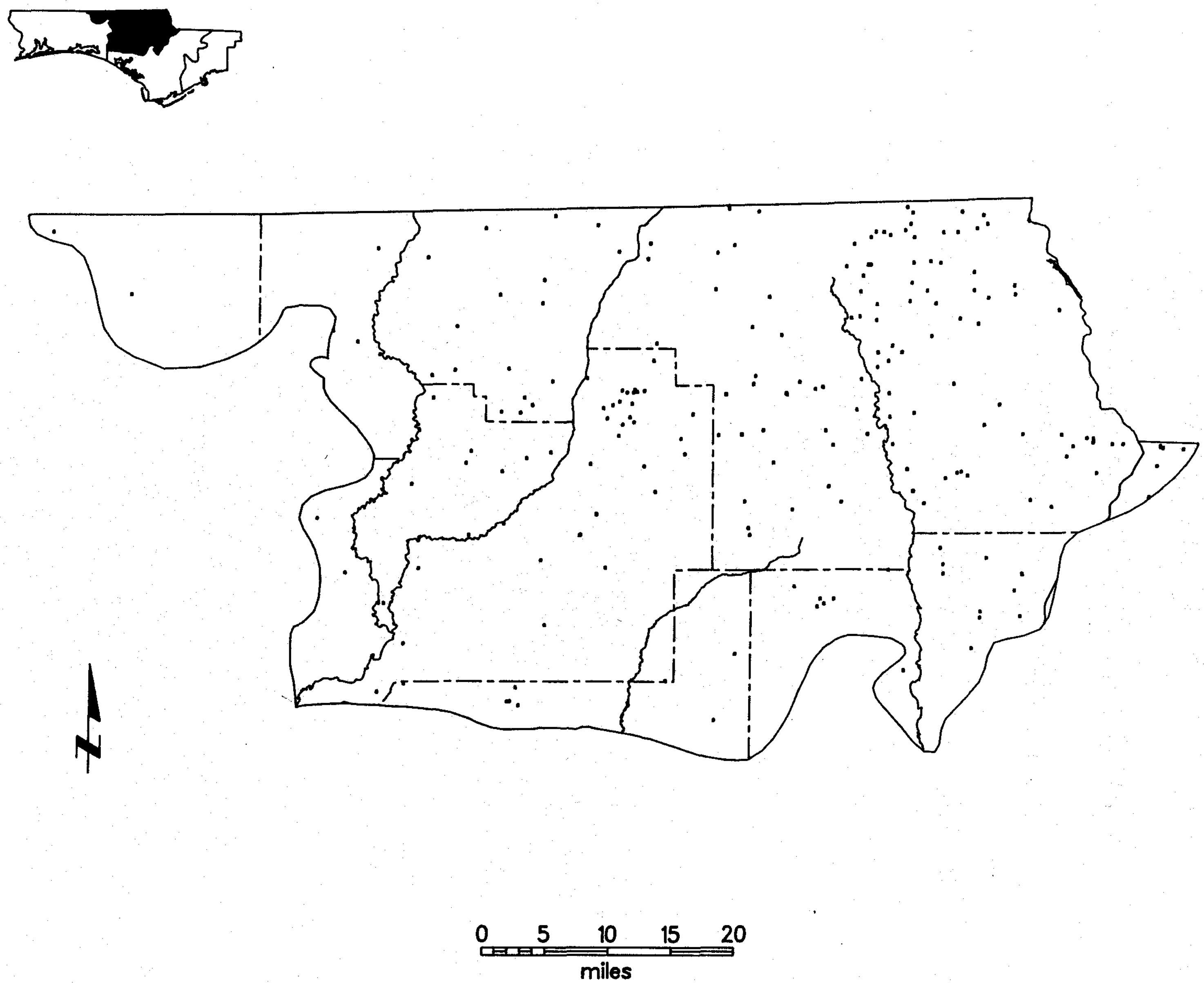


Figure D-2

Distribution of Hydrogeologic Data Control

Legend

• Control site with geophysical log data.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

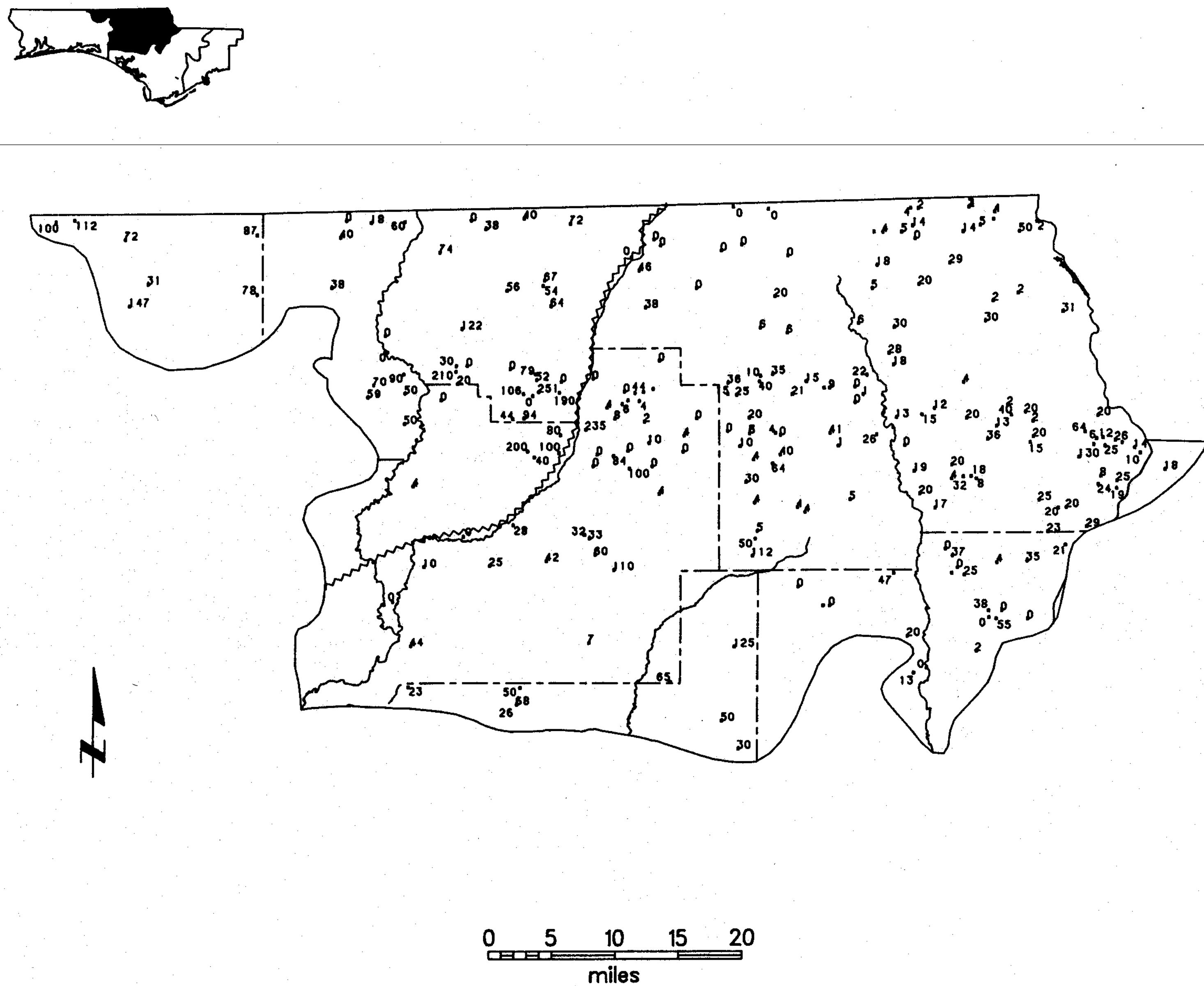


Figure D-3

Thickness Distribution for the Surficial Aquifer System

Legend

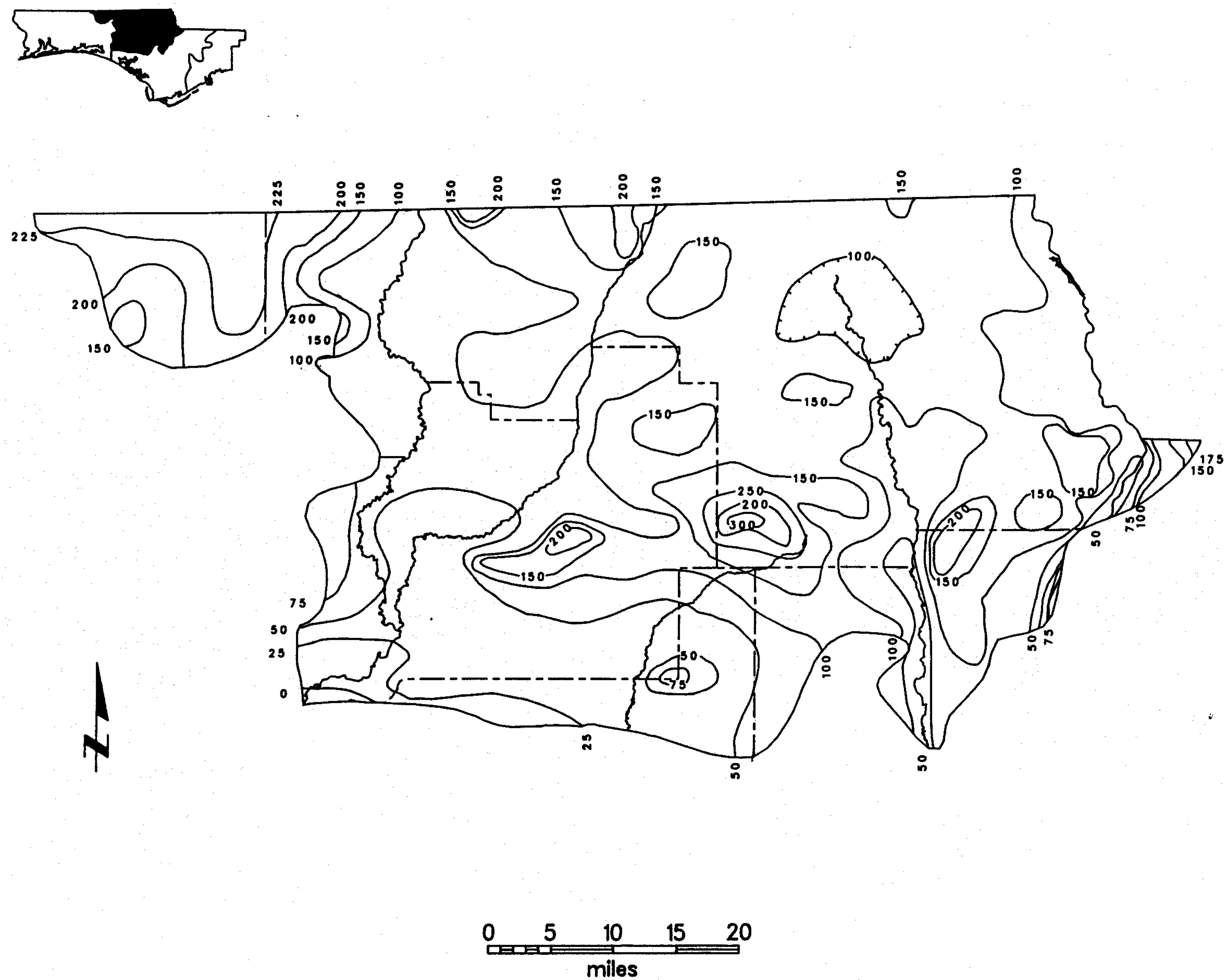
• 90 Thickness of aquifer at control point, in feet.

West of line Surficial Aquifer System is referred to as the Sand-And-Gravel Aquifer. East of line Surficial Aquifer System is undifferentiated.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

Figure D-4

Altitude of the Top of the Intermediate System



Legend

— 50 — Structural contour showing altitude of the top of the Intermediate System. Contour interval is 50 feet with supplementary contours at 25 foot intervals. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

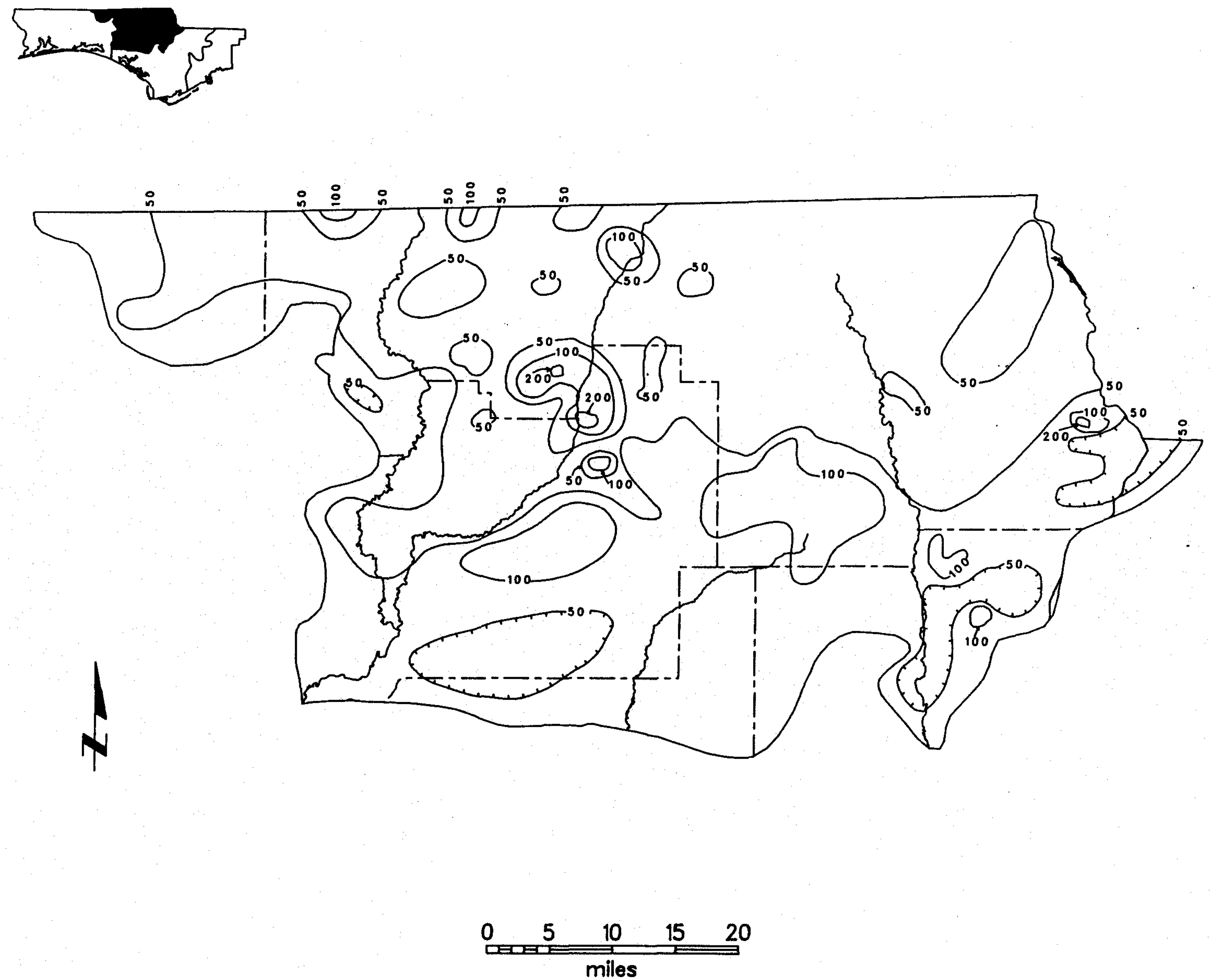


Figure D-5

Thickness of the Intermediate System

Legend

— 50 — Line of equal thickness of the Intermediate System. Contour interval is 50 feet.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

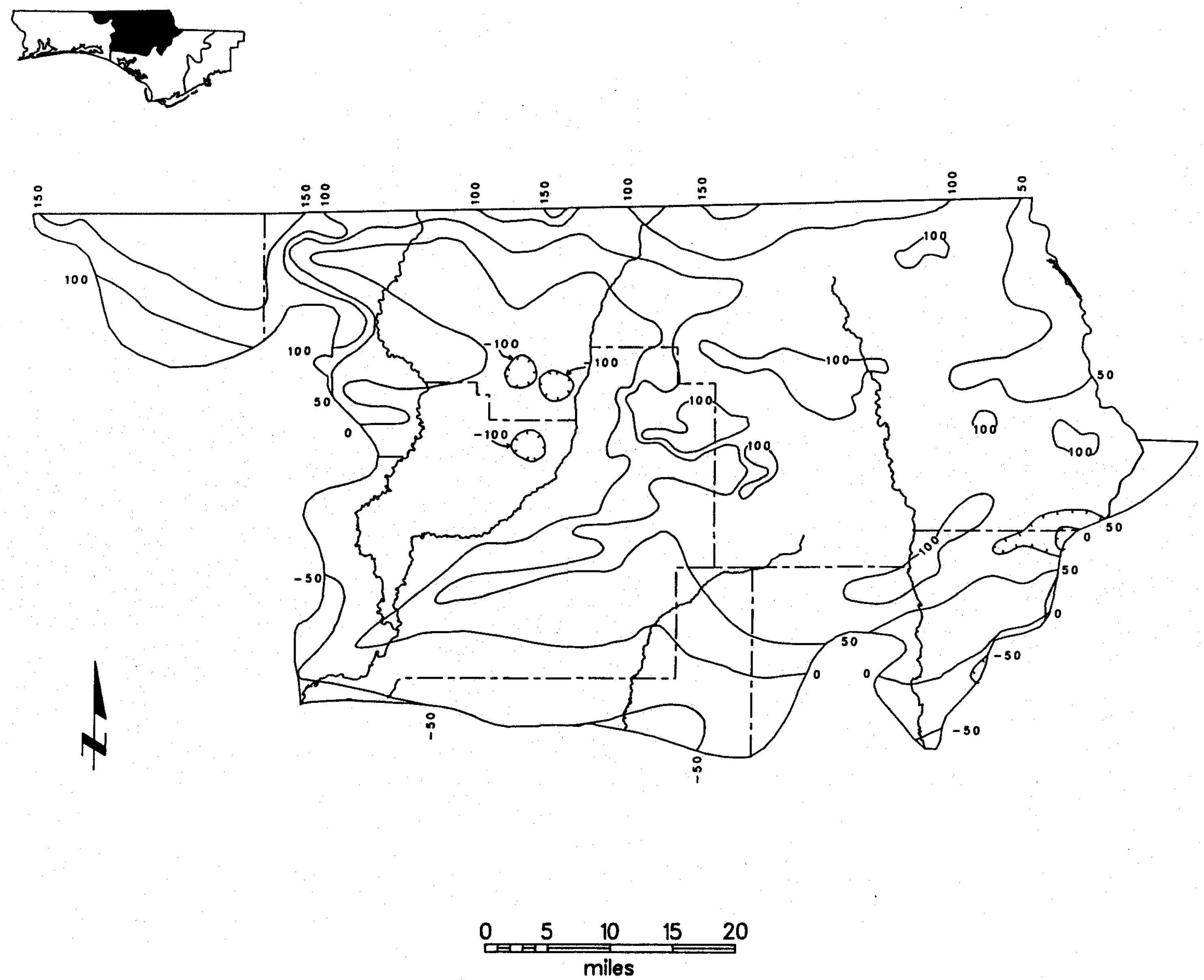


Figure D-6

Altitude of the Top of the Floridan Aquifer System

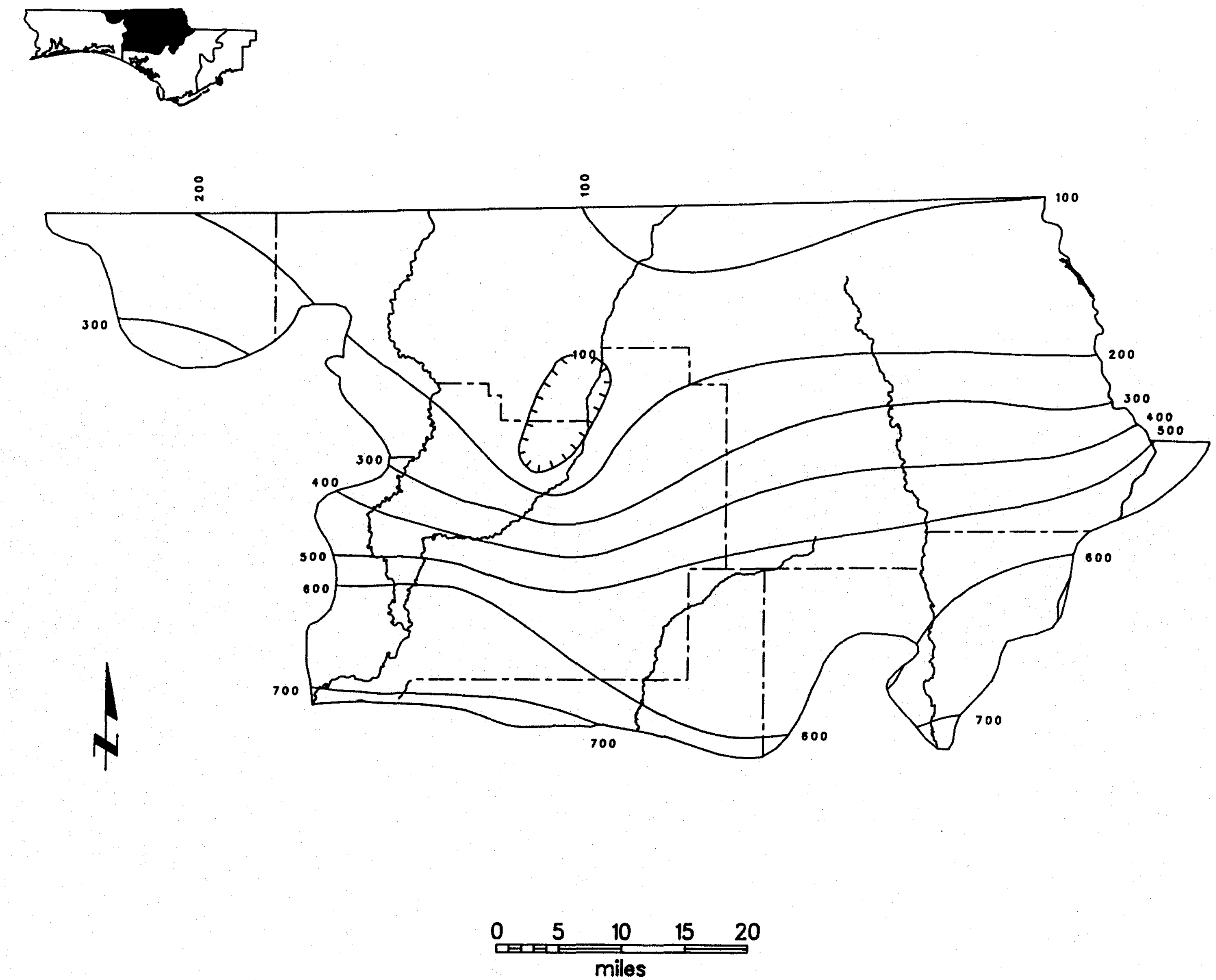
Legend

— 50 — Structural contour showing altitude of the top of the Floridan Aquifer System. Contour interval is 50 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

Figure D-7

Thickness of the Floridan Aquifer System (Undifferentiated)



Legend

— 100 — Line of equal thickness of the Floridan Aquifer (undifferentiated). Contour interval is 100 feet.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

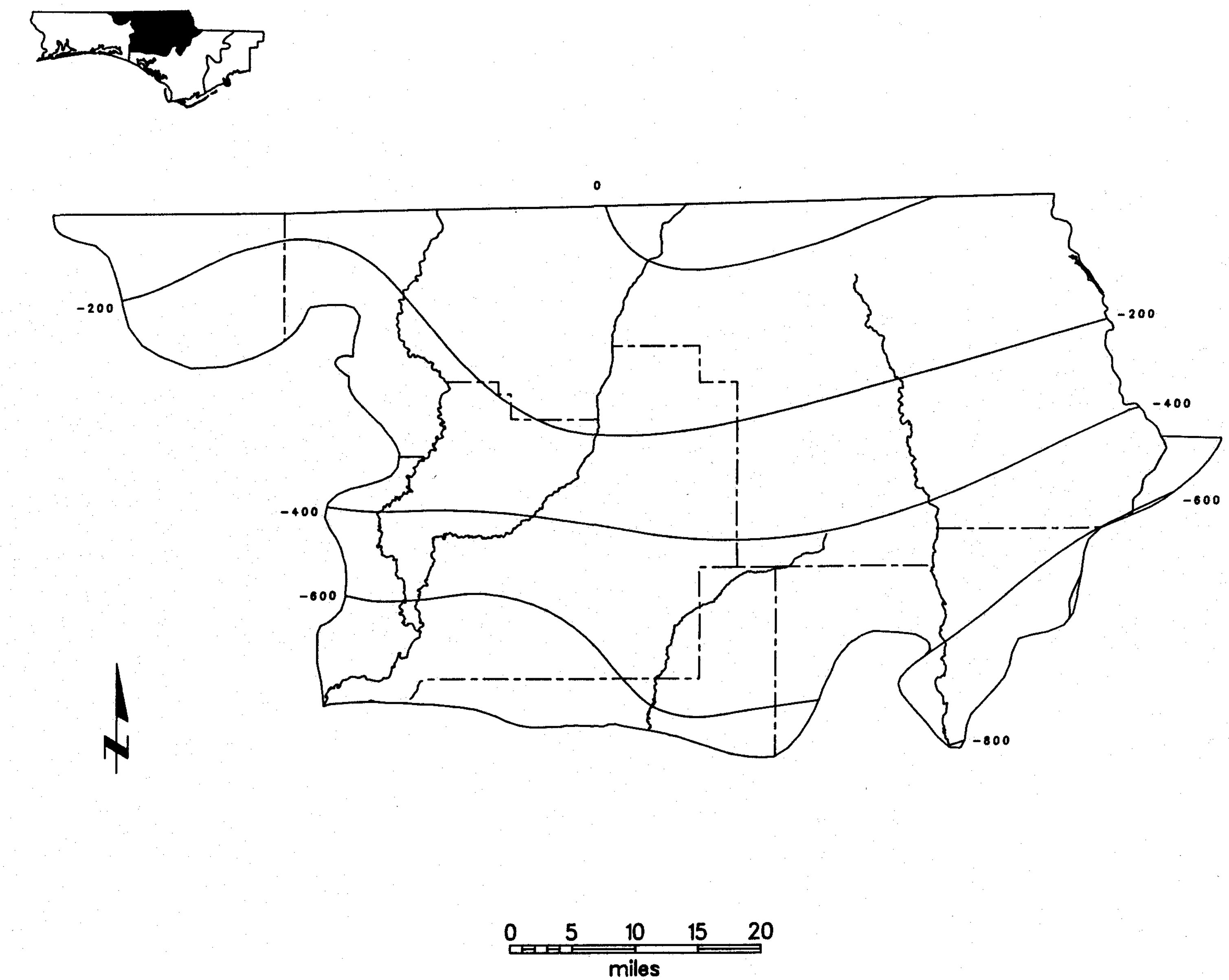


Figure D-8

Altitude of the Top of the Sub-Floridan System

Legend

— -200 — Structural contour showing altitude of the top of the Sub-Floridan System. Contour interval is 200 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

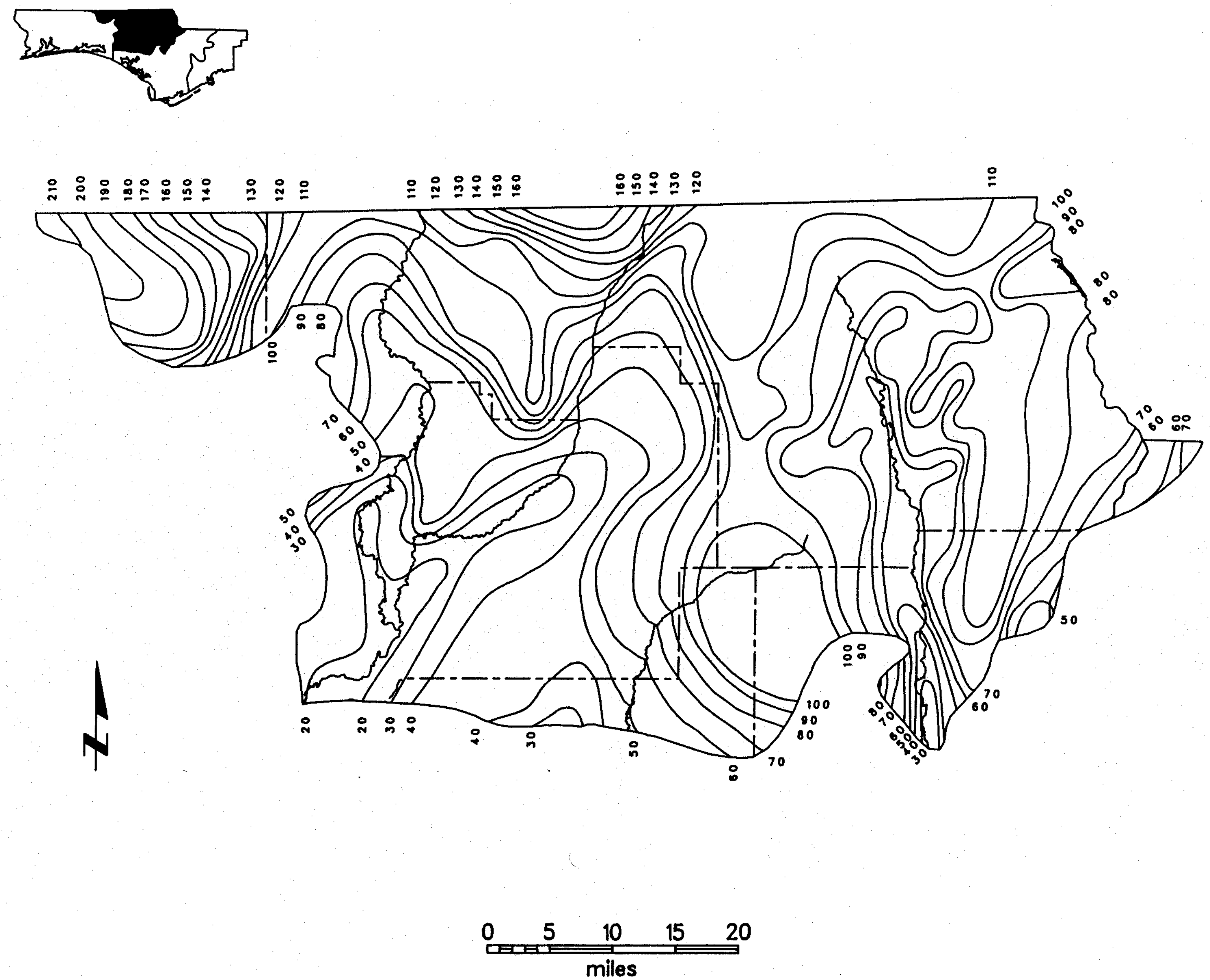


Figure D-9

Potentiometric Surface of the Floridan Aquifer System, May 1986

Legend

— 10 — Potentiometric contour showing altitude at which water level would have stood in tightly cased wells; dashed where approximate.
Contour interval is 10 feet.
Datum is sea level.

Modified from Wagner, 1989

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

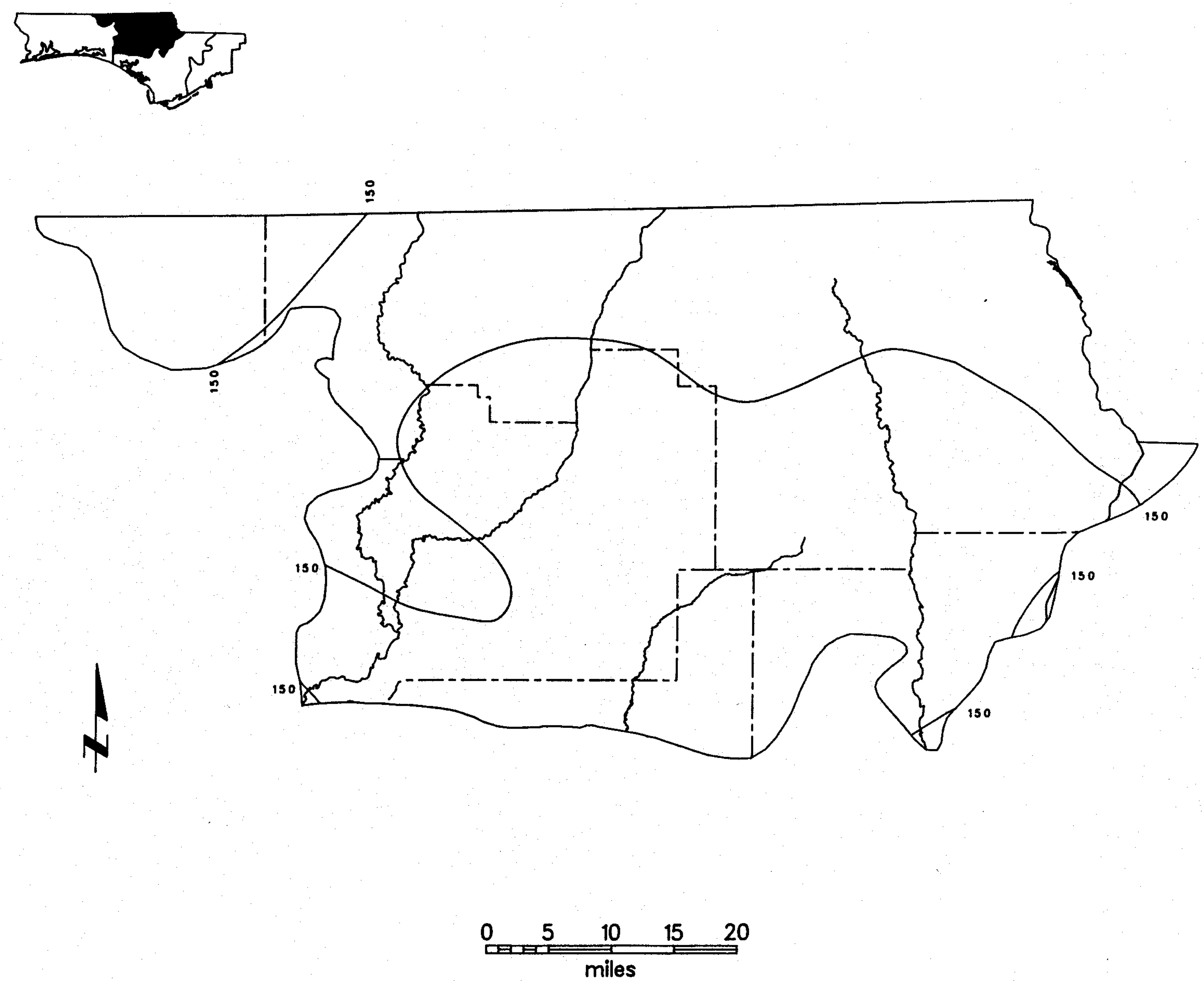


Figure D-10

Total Dissolved Solids Concentrations of Ground Water in the Floridan Aquifer System

Legend

— 150 — Line of equal total dissolved solids concentration in milligrams per liter (mg/L).

Concentrations greater than 500 mg/L exceed recommended limits for drinking water. Wells tapping deeper portions of aquifer may yield water with concentrations that exceed 500 mg/L.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

TABLE D1.-- TYPICAL LITHOLOGY OF HYDROGEOLOGIC SYSTEM WITHIN THE DOUGHERTY KARST REGION

SURFICIAL AQUIFER SYSTEM

* Unit may be absent in portions of region.
* Clayey sands, sands, clays, sandy clays; some gravel; lithology variable and discontinuous due to sedimentation and due to karst processes.

INTERMEDIATE SYSTEM

* Unit may be absent in various portions of region.
* Lithology variable and discontinuous due to karst processes.
* Clays, sandy clays and clayey sands, calcareous; mollusks shells may be abundant.

FLORIDAN AQUIFER SYSTEM

* Fine, quartz sand within an argillaceous limestone; gray and white sandy calcareous clays; sparsely fossiliferous; can be silty and very sandy; sand scattered throughout interval. This portion is absent in northern portion of region.
* Tan to buff limestone, dolomitic limestones and dolomitic to calcareous clays; porous and fossiliferous. This portion of unit is absent in northern portion of region.
* Generally light color ranging from white to cream to light gray, slightly glauconitic, homogeneous (massive) and generally impermeable, very soft; abundant fossil fauna. This portion of unit is absent in northern portion of region.
* White to cream to light yellow colored, soft, granular, permeable, highly fossiliferous, pure limestone; frequently composed of almost entirely foraminifera tests; frequently recrystallized to dense limestone. Becomes glauconitic and sandy and greenish gray in color near top of next unit; often large flat foraminifera; sometimes silicified in northwest part of region. This portion of unit may be sporadically absent in the west-northwest portion of region.

SUB-FLORIDAN SYSTEM

* Upper most beds calcareous clays, generally blue to blue gray; fine to coarse sand, interbedded sandy limestone; also calcareous sand, calcareous siltstone, and sandstone; unit increases in clay content downward and grades to dense clay.

APPENDIX E

WESTERN PANHANDLE REGION

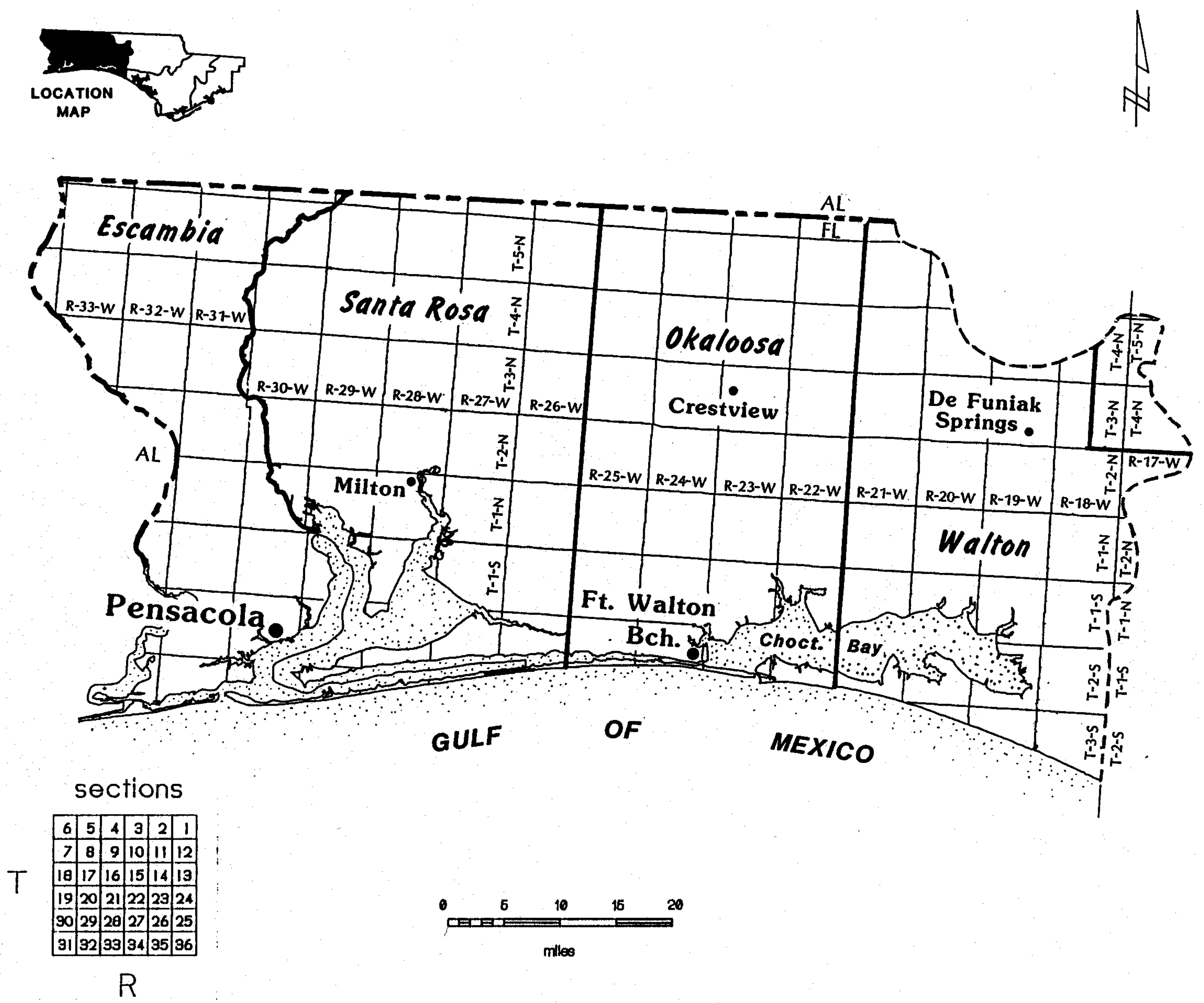


Figure E-1

Township and Range
Regional Locational Reference for the
Western Panhandle Region

UTM Zone 17 Projection
Base Map Source: DOT County Maps

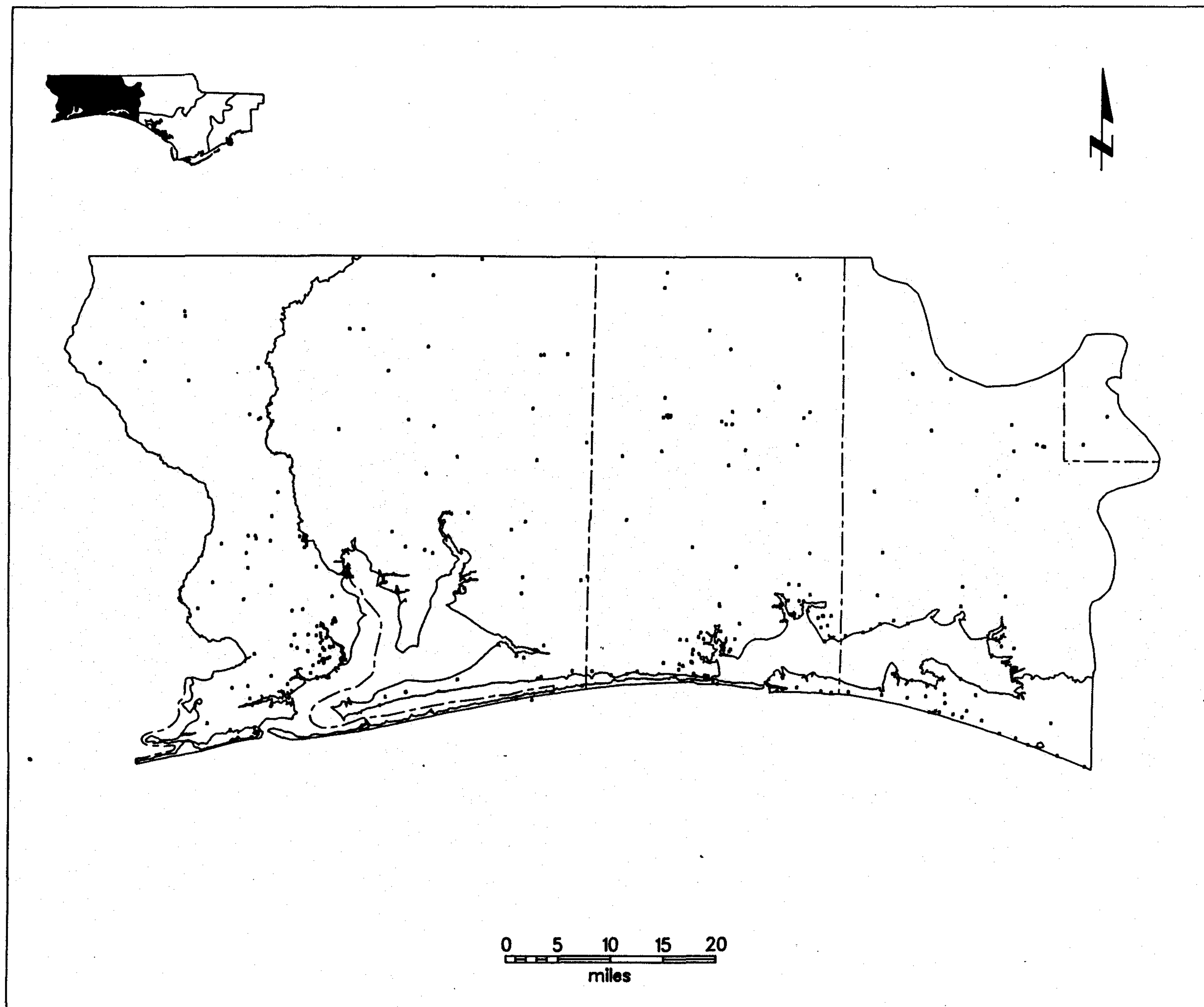


Figure E-2

Distribution of Hydrogeologic Data Control

Legend

• Control site with geophysical log data.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

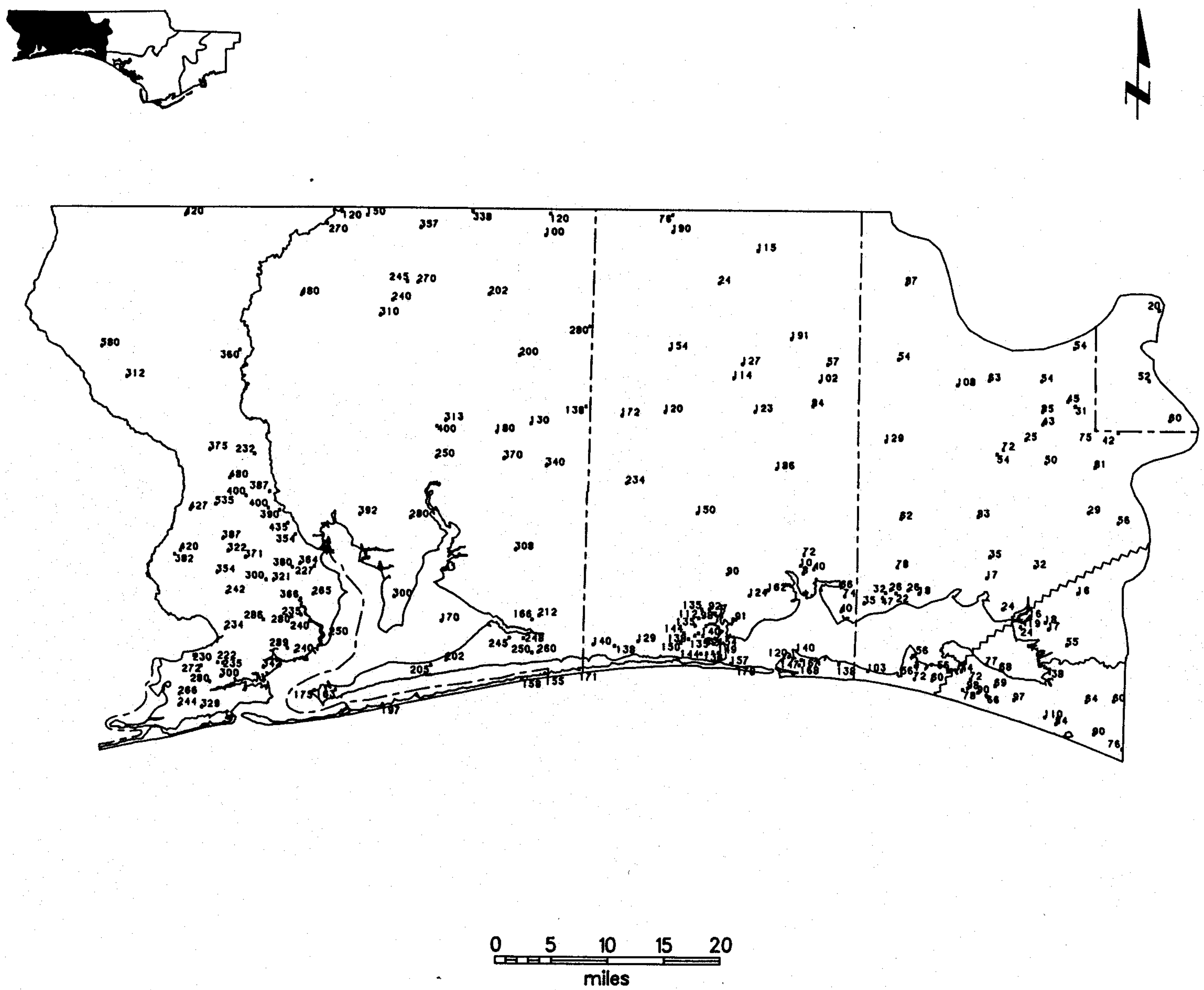


Figure E-3

Thickness Distribution for the Surficial Aquifer System

Legend

• 90 — Thickness of aquifer at control point, in feet.

∿∿∿∿∿ — West of line Surficial Aquifer System is referred to as the Sand-And-Gravel Aquifer. East of line Surficial Aquifer System is undifferentiated.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

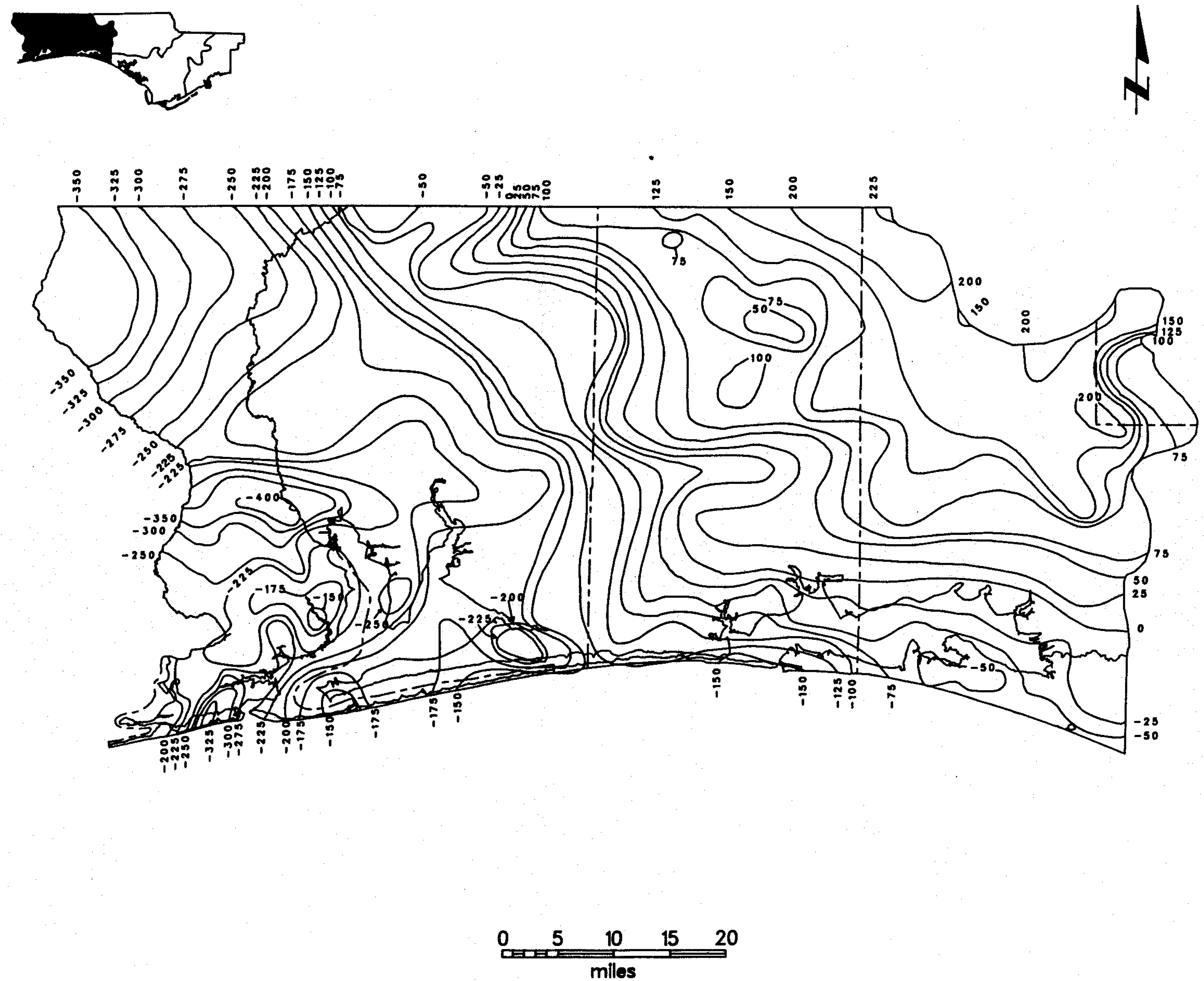


Figure E-4

Altitude of the Top of the Intermediate System

Legend

—50— Structural contour showing altitude of the top of the Intermediate System. Contour interval is 25 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

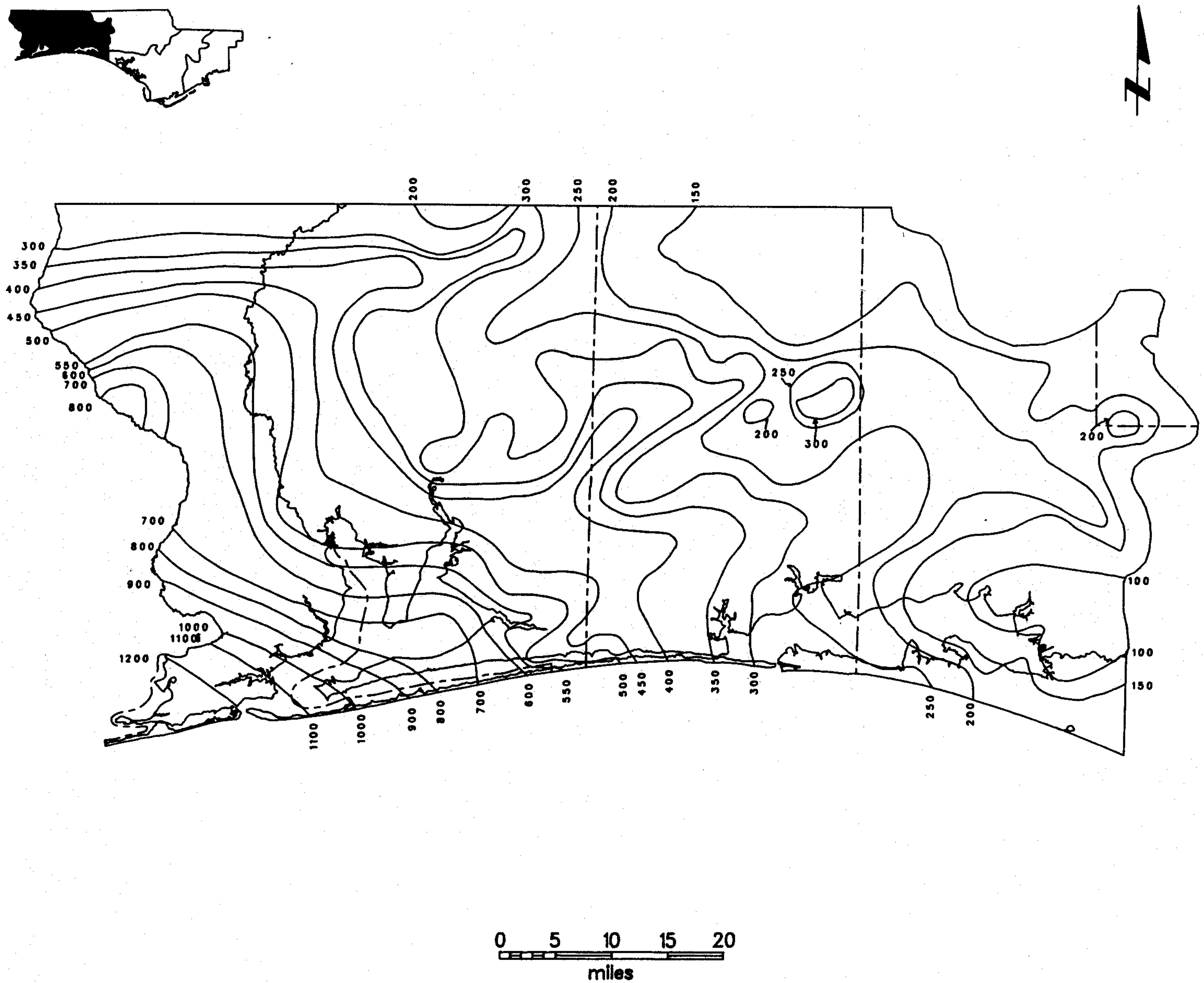


Figure E-5

Thickness of the Intermediate System

Legend

— 100 — Line of equal thickness of the Intermediate System.
Contour interval is 100 feet with supplementary contours at 50 foot intervals.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

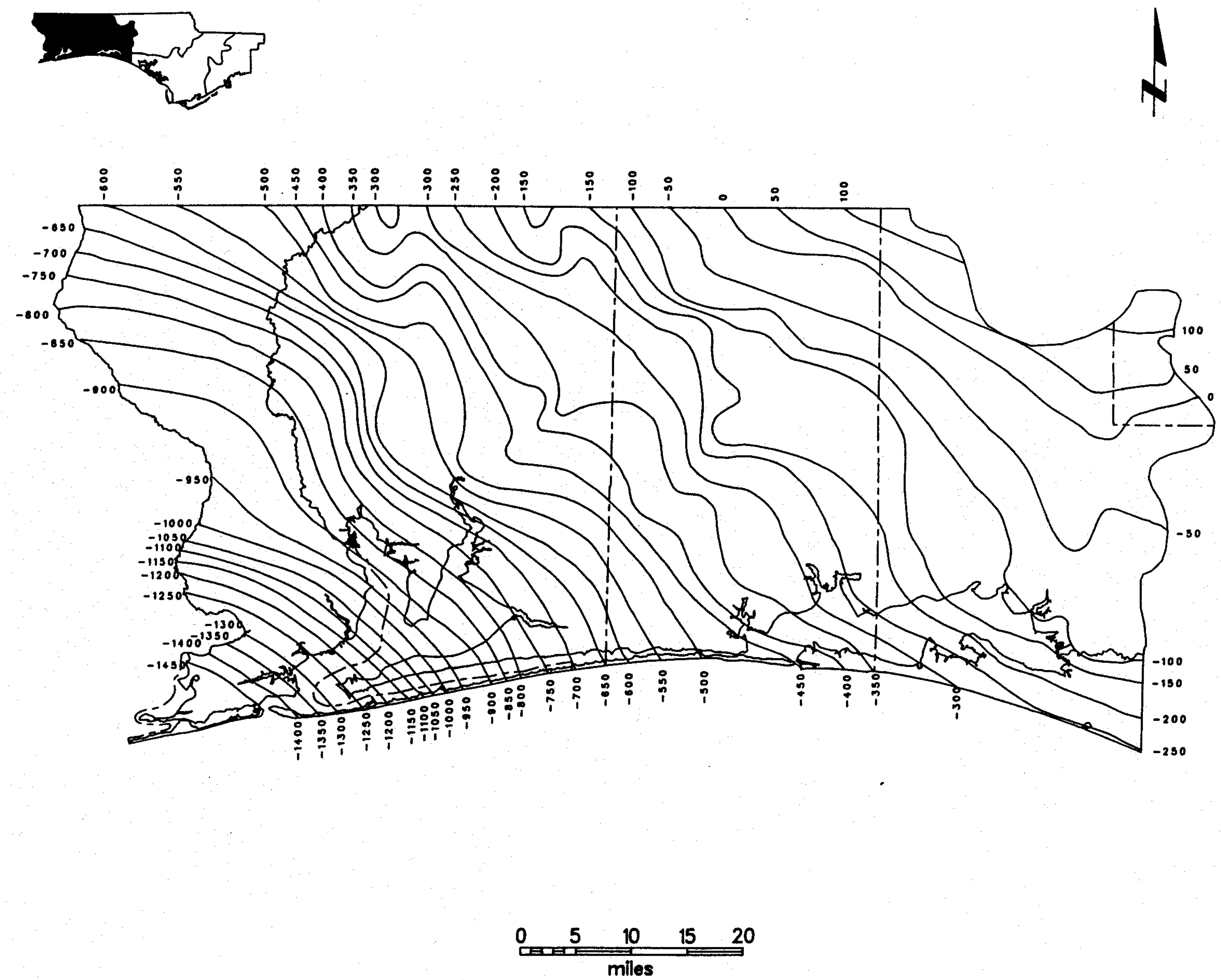


Figure E-6

Altitude of the Top of the Floridan Aquifer System

Legend

— 50 — Structural contour showing altitude of the top of the Floridan Aquifer System. Contour interval is 50 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

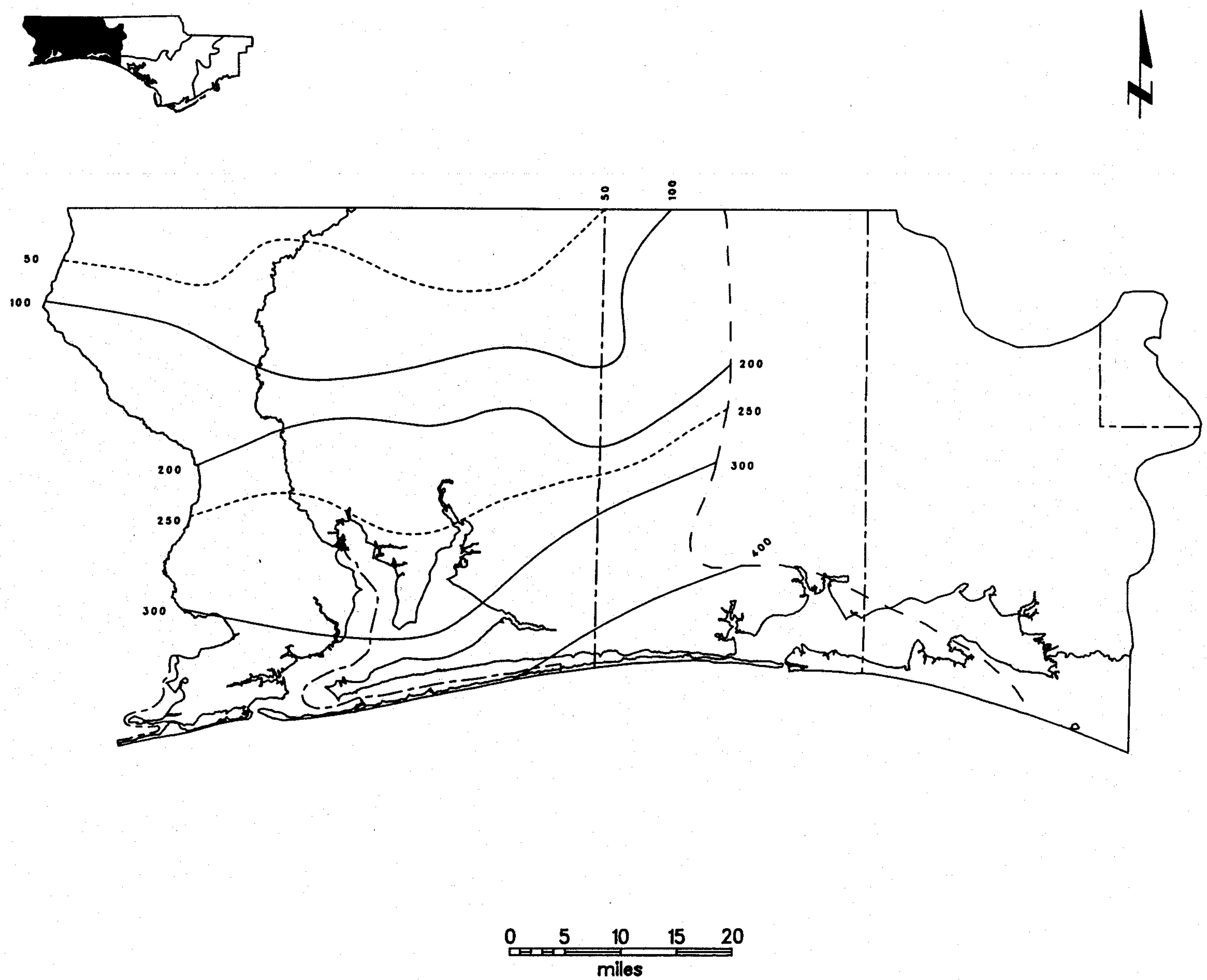


Figure E-7

Thickness of the Upper Limestone of the Floridan Aquifer System

Legend

— 100 — Line of equal thickness of the upper limestone unit. Contour interval is 100 feet with dashed supplementary contours at selected 50 foot intervals.

— — — Represents easterly extent of the Bucatunna Clay Confining Unit. The Floridan Aquifer becomes undifferentiated eastward of this line.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

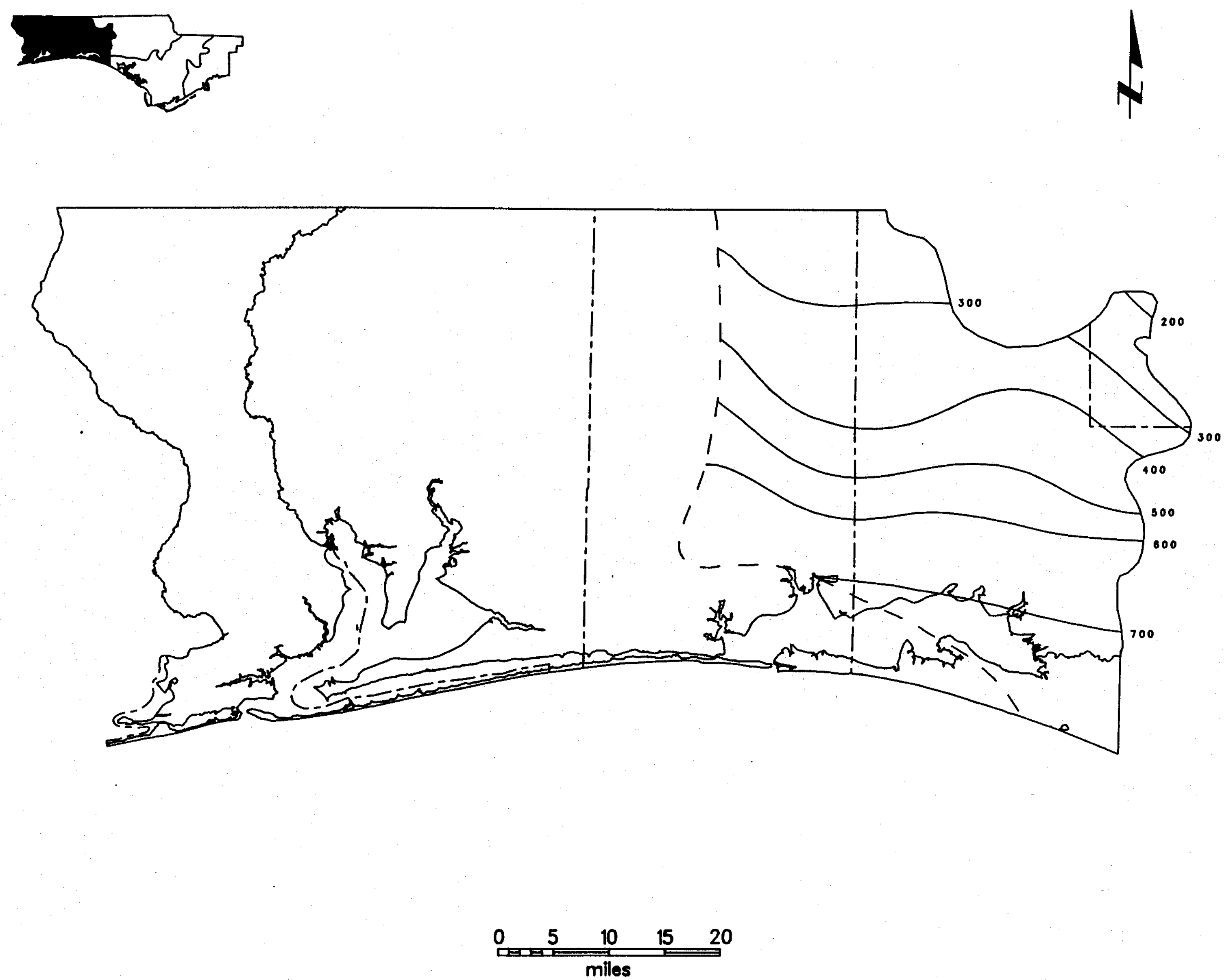


Figure E-8

Thickness of the Floridan Aquifer System (Undifferentiated)

Legend

—200— Line of equal thickness of the Floridan Aquifer (undifferentiated). Contour interval is 100 feet.

— — — Represents western extent of the Undifferentiated Floridan Aquifer. West of this line the Bucatunna Clay Confining Unit divides the aquifer into upper and lower portions.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

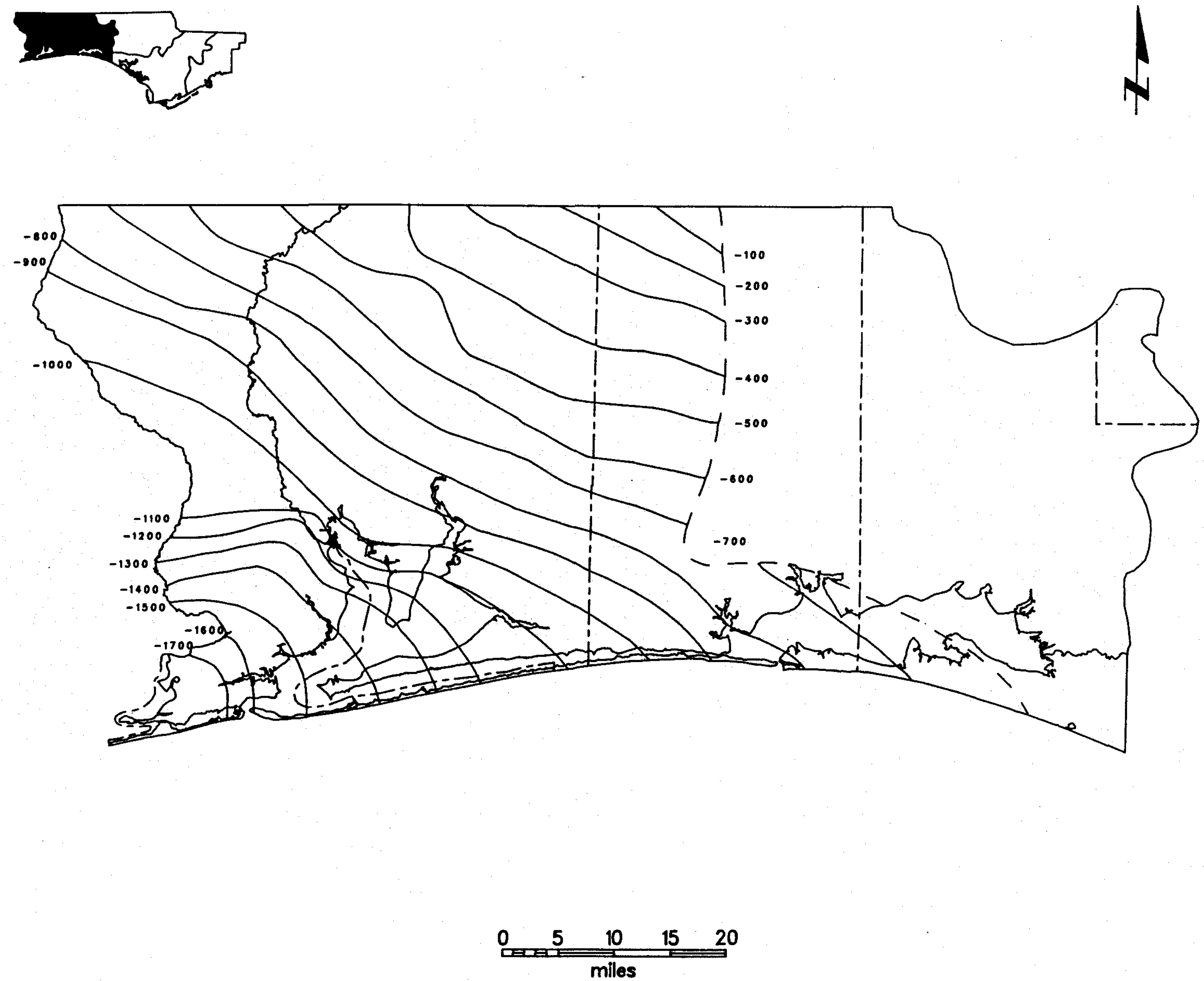


Figure E-9

Altitude of the Top of the Bucatunna Clay Confining Unit

Legend

— -100 — Structural contour showing altitude of the top of the confining unit. Contour interval is 100 feet. Datum is sea level.

— — — Represents easterly extent of the Bucatunna Clay Confining Unit.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

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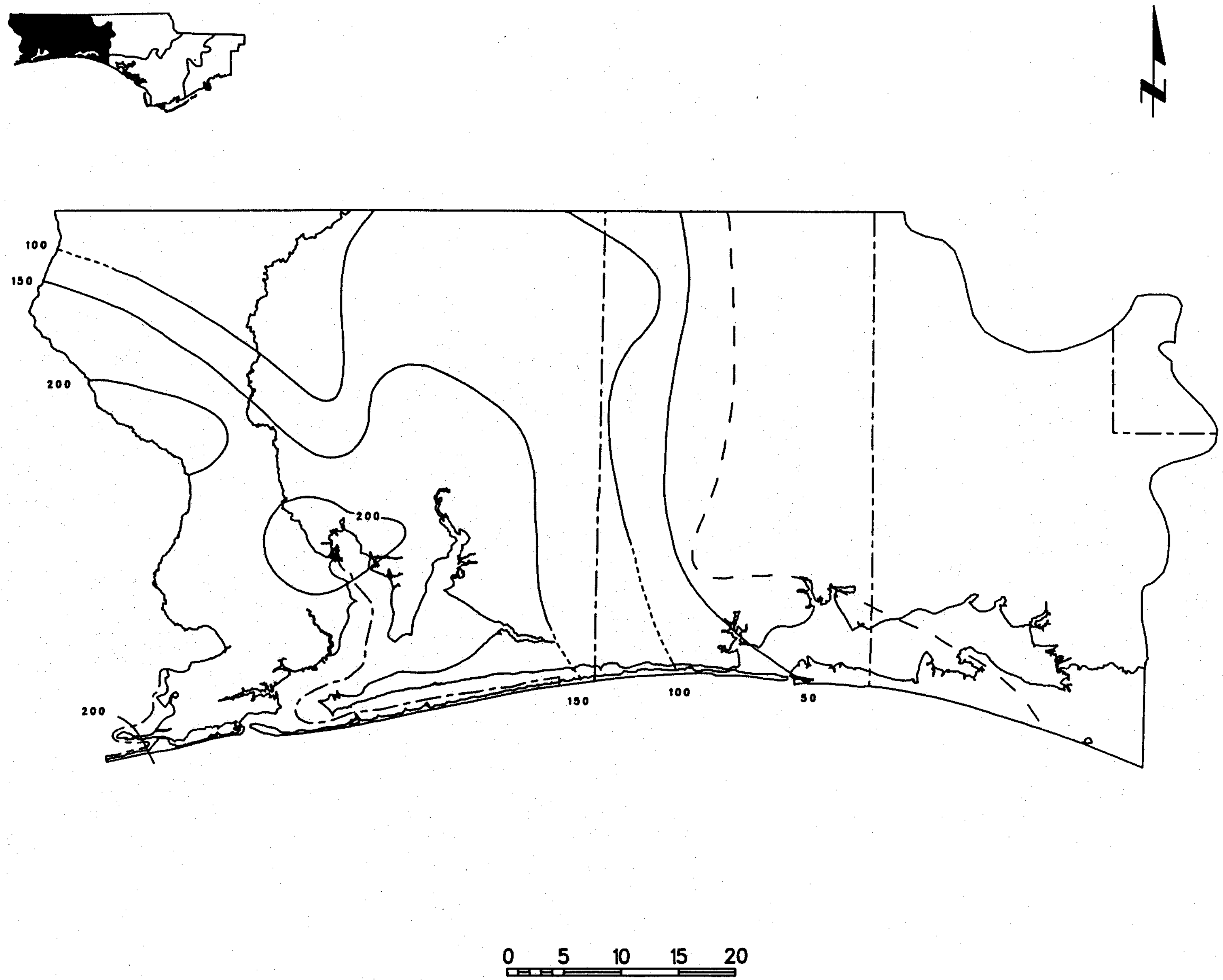

Figure E-10

Thickness of the Bucatunna Clay Confining Unit

Legend

— 50 — Line of equal thickness of the confining unit; dashed where approximate. Contour interval is 50 feet.

— — — Represents easterly extent of the Bucatunna Clay Confining Unit.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

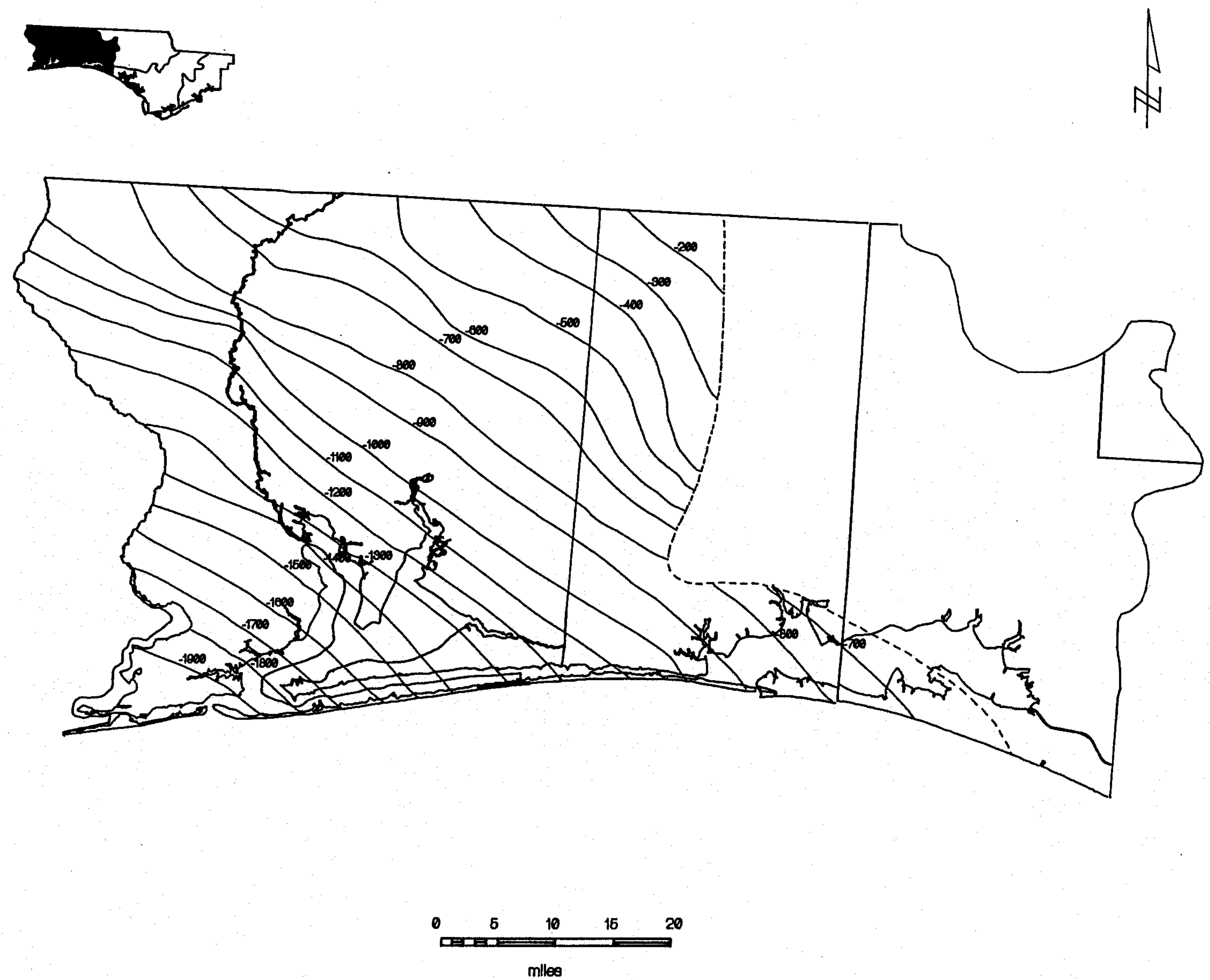

Figure E-11

Altitude of the Top of the Lower Limestone of the Floridan Aquifer System

Legend

— -200 — Structural contour showing altitude of the top of the lower limestone of the Floridan Aquifer System. Contour interval is 100 feet. Datum is sea level.

- - - - - - Represents easterly extent of the Bucatunna Clay Confining Unit. West of this boundary the Bucatunna separates the Floridan Aquifer into an upper and lower limestone. East of this boundary the Floridan Aquifer exists as one undifferentiated aquifer.

Base Map Source: DOT County Maps
UTM Zone 17 Projection

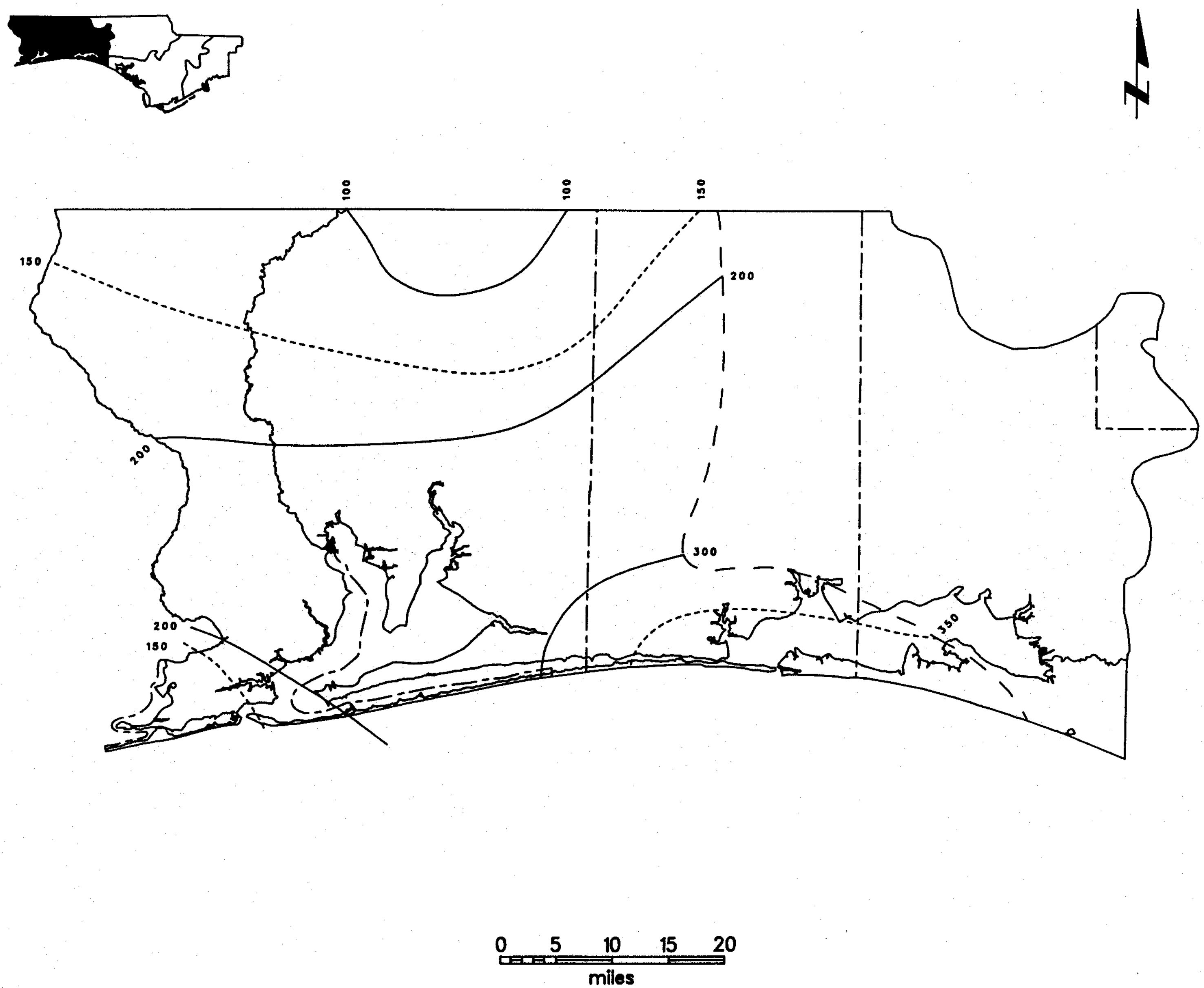

Figure E-12

Thickness of the Lower Limestone of the Floridan Aquifer System

Legend

— 100 — Line of equal thickness of the lower limestone unit. Contour interval is 100 feet with dashed supplementary contours at selected 50 foot intervals.

— — — Represents easterly extent of the Bucatunna Clay Confining Unit. The Floridan Aquifer becomes undifferentiated eastward of this line.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

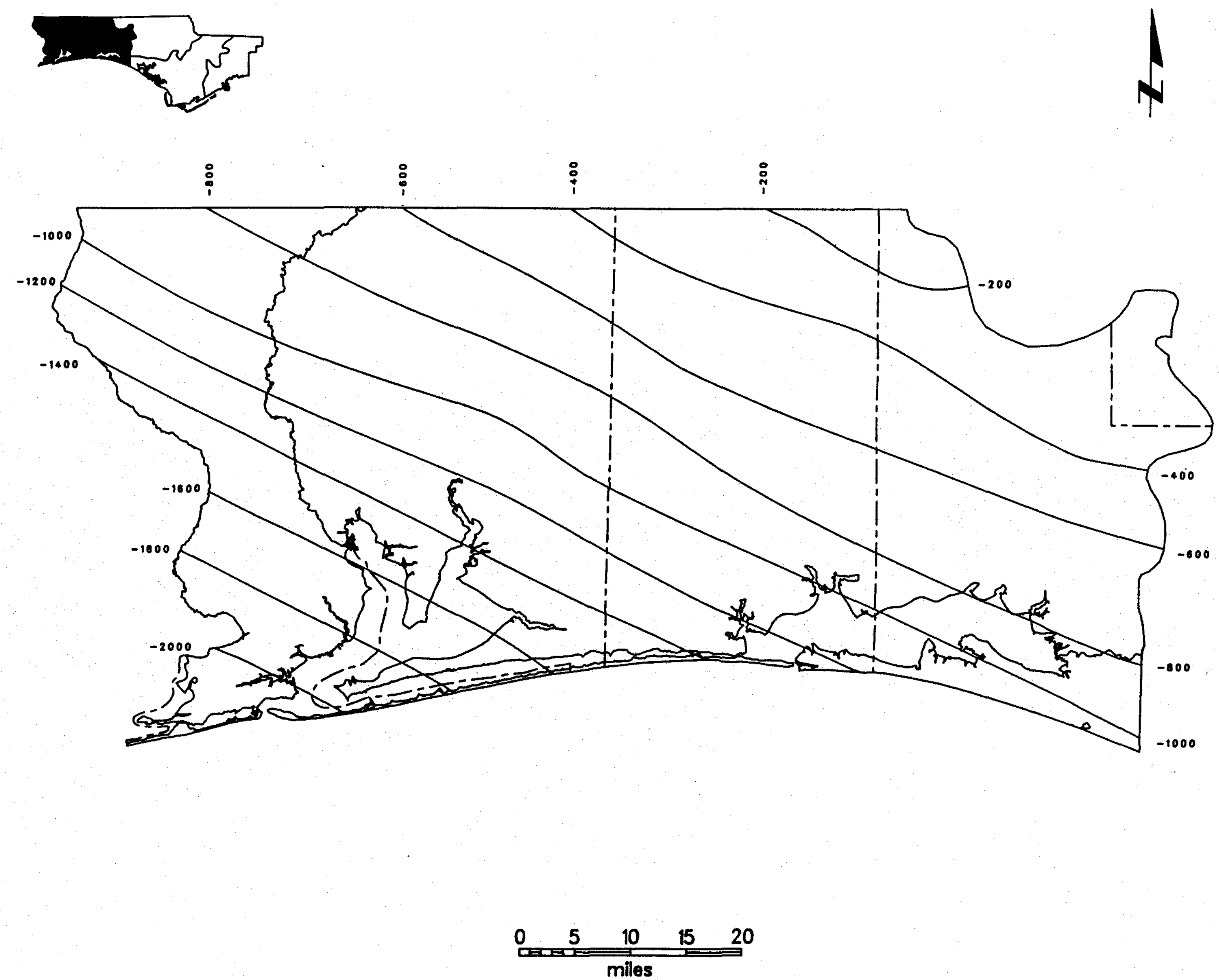

Figure E-13

Altitude of the Top of the Sub-Floridan System

Legend

— -200 — Structural contour showing altitude of the top of the Sub-Floridan System. Contour interval is 200 feet. Datum is sea level.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:250,000 Scale
UTM Projection

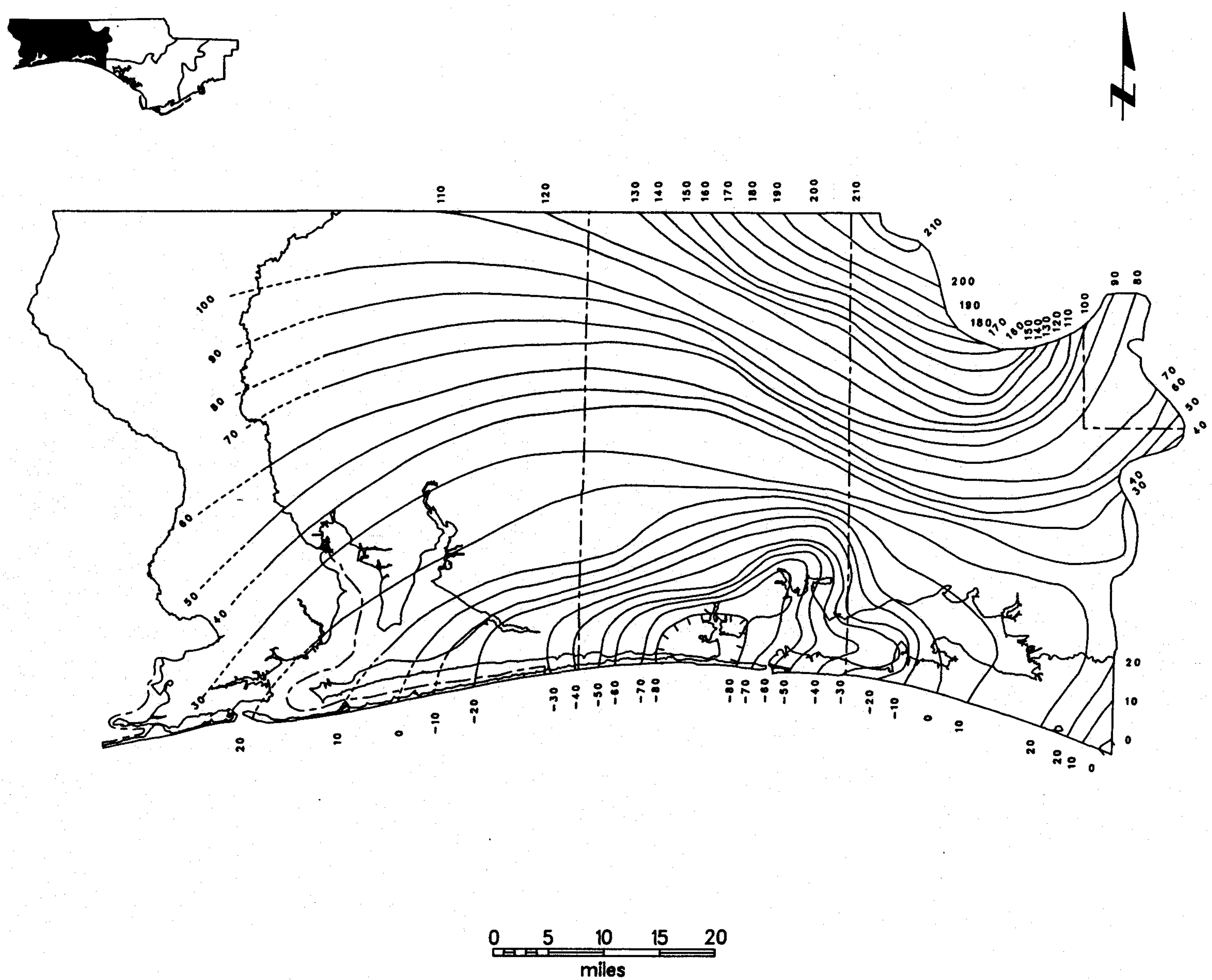

Figure E-14

Potentiometric Surface of the Floridan Aquifer System, May 1986

Legend

— 10 — Potentiometric contour showing altitude at which water level would have stood in tightly cased wells; dashed where approximate.
Contour interval is 10 feet.
Datum is sea level.

Modified from Wagner, 1989

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

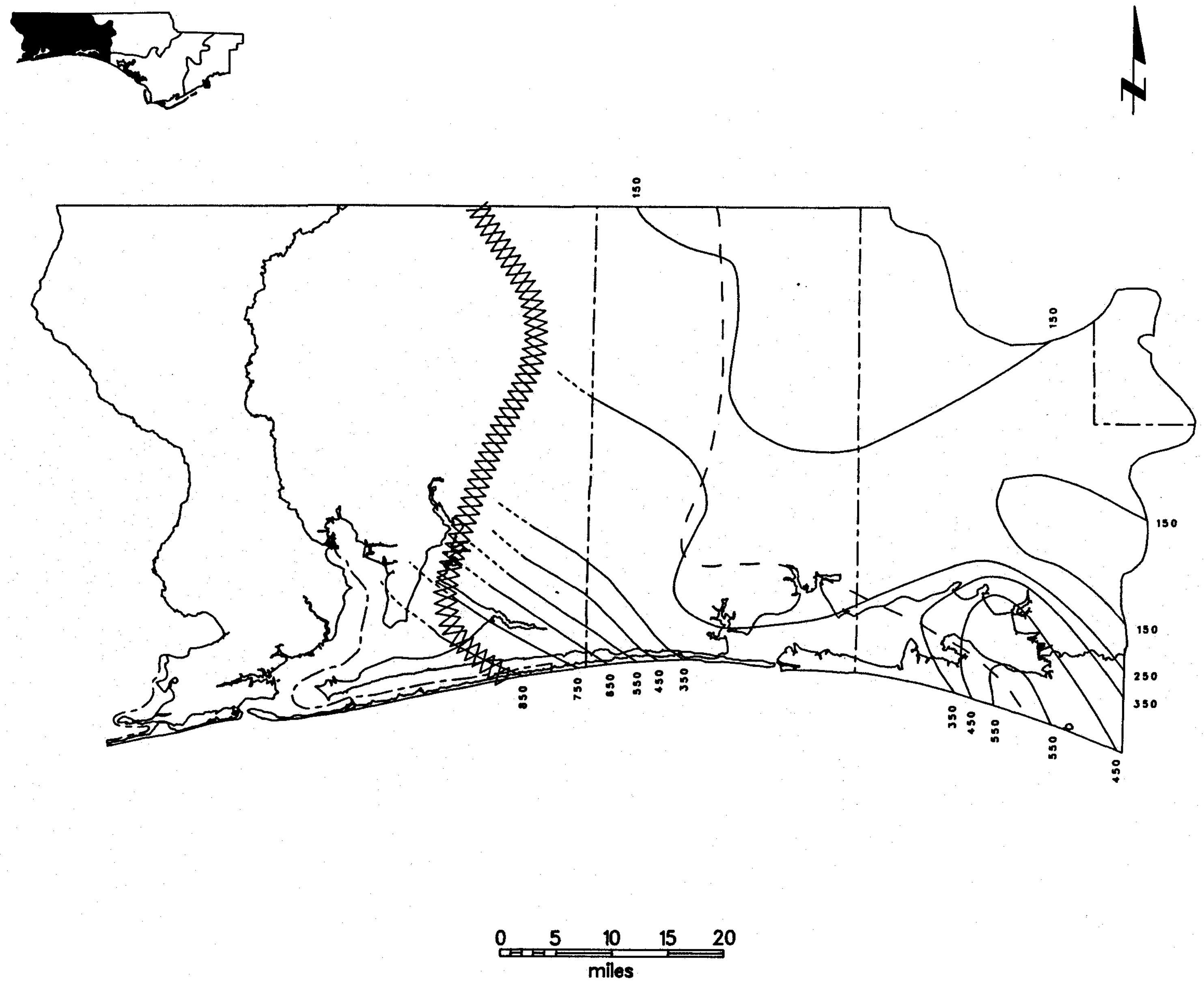

Figure E-15

Total Dissolved Solids Concentrations for Ground Water from the Floridan Aquifer System

Legend

— 150 — Line of equal total dissolved solids concentration in millligrams per liter (mg/L). Contour interval is 100 mg/L.

Concentrations greater than 500 mg/L exceed recommended limits for drinking water. Wells tapping deeper portions of aquifer may yield water with concentrations that exceed 500 mg/L.

— — — Represents easterly extent of the Bucatunna Clay Confining Unit. The Floridan Aquifer becomes undifferentiated eastward of this line.

XXXXX Westward extent for utilization of the Floridan Aquifer as a drinking water source. West of line aquifer becomes more mineralized.

Base Map Source: U.S. Geological Survey
1:24,000 Scale Topographic Quadrangles
Data Developed at 1:500,000 Scale
UTM Projection

TABLE E1.-- TYPICAL LITHOLOGY OF HYDROGEOLOGIC SYSTEM WITHIN THE WESTERN EMBAYMENT REGION

SURFICIAL AQUIFER SYSTEM (INCLUDES SAND-AND-GRAVEL AQUIFER)

* Unfossiliferous sand, clay, gravel; discontinuous layers; nonindurated to poorly indurated with clay, occasionally iron cement; limonite; accessories include heavy minerals, mica, phosphate, limestone, and carbonized wood; variable in color ranging from white to orange to yellow to pink/red hues; lithology changes abruptly over short distances; poorly sorted ranging from very fine to very coarse; few pebbles are silicified oolitic limestone; sands grade to siltstones and clays; clays occur in lenses; beds in underlying unit are much more clayey.

INTERMEDIATE SYSTEM

* Generally light brown to light gray to olive gray clayey, numerous shell beds, fossiliferous material; sand, gravel, and clay; clay acts as cementing agent for the unconsolidated, poorly consolidated clastics; minute mollusks abundant; accessories pyrite, glauconite, and mica, carbonized wood fragments, and lignite.

* North and East: Sandy clay or clayey sand to shell marl to pure sand or clay; accessories phosphate, glauconite, heavy mineral, pyrite and mica; thin limestone beds, micritic; poorly to moderately consolidated with clay or carbonate cement; fossils include bryozoans,mollusks, foraminifera, echinoids, and ostracods.

* West: Becomes more clayey, less sand; consists of tough, dark to light gray to green clay, also brownish gray; silty, variable amounts of very fine to very coarse sand; pieces of carbonized wood and plant remains; micaceous, calcareous; minor amounts pyrite; mollusk shells present and foraminifera abundant; also light gray to brownish gray fine to very coarse sand.

* Coastal South-Southeast: Poorly consolidated, sandy, clayey, microfossiliferous limestone becomes more clayey and phosphatic with depth and to the north. Grades to a clay unit west and a clay, sandy clay unit north with the loss of carbonate.

UPPER LIMESTONE OF THE FLORIDAN AQUIFER SYSTEM

* Light gray to grayish white, hard limestone; sand beds locally common in central and north; green and brown clay; bits of lignite; also gray to light gray, hard, highly, porous or vesicular limestone and dolomitic limestone; sucrosic dolomite; also cream to buff fossiliferous limestone; interbedded limestone and dolomite; includes glauconitic clay, pyrite, calcite sand; moderate to well indurated.

* South-Southeast: White to light gray moderately indurated, granular, fossiliferous, cemented sand-sized detrital calcite, micritic limestone; more dolomitic toward west; accessories pyrite, phosphate, mica, clay, calcite, glauconite and sand.

BUCATUNNA CLAY CONFINING UNIT

* Moderate brown to dusky yellow brown clay; accessories include sand, phosphate; sparsely fossiliferous.

* Western Portion: Sand disseminated throughout clay; thin limestone bed occurs within near bottom portion; also dark gray to olive green, soft dense, calcareous, silty to sandy clay; flecks of carbonized wood and small amount of pyrite.

* Unit pinches out toward the east-northeast in around Okaloosa County and Walton County.

LOWER LIMESTONE OF THE FLORIDAN AQUIFER SYSTEM

* Limestone varies from white to light gray, chalky, and extremely fossiliferous to tan, sucrosic dolomite; limestone and dolomite are interlayered; glauconite and calcite present in minor amounts; moderately indurated; micritic or dolomitic cement; foraminifera, mullusks, bryozoan.

SUB-FLORIDAN SYSTEM

* Cream, sandy, pryritic, glauconitic, argillaceous limestone, clay and sand, calcareous; also green gray to dark gray, glauconitic, arenaceous and calcareous shale; argillaceous sandstone.