MODELING OF GROUND WATER FLOW IN WALTON, OKALOOSA AND SANTA ROSA COUNTIES, FLORIDA

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MODELING OF GROUND WATER FLOW IN WALTON, OKALOOSA, SANTA ROSA, AND ESCAMBIA COUNTIES, FLORIDA

1.0 INTRODUCTION

1.1 BACKGROUND

The Northwest Florida Water Management District (NWFWMD), in the issuance of consumptive use permits and water supply planning, has the primary objective of protecting its water resources and the ecosystems sustained by it. Ground water use in the area has increased consistently since pre-development times, with only a few wells tapping the resources before 1941 (Trapp et al., 1977). An associated decline has been observed in the potentiometric surface of the Upper Floridan Aquifer, of as much as 160 feet (ft) in the last 50 years of development. Additional development of ground water in the region, therefore, needs to be carefully planned to minimize adverse impacts on the aquifer systems, and on all existing water withdrawals and uses. An analysis of the hydrogeologic system and water budgets of this sub-region using numerical simulations can determine the stress/response behavior required for managing the water resources. A simulation model is thus required, which reproduces major features and behavior of ground water flow in the region and will be a valuable tool in assessing the system's water availability.

1.2 PURPOSE AND SCOPE

The goal of this study is to provide a calibrated, numerical model of ground water flow, which may be used to manage the water resources of the system. A fully three-dimensional ground water flow model of the system is first developed and calibrated to quantify the water budgets and potentiometric levels in the region. The model is calibrated to steady state, 1990 average daily rate pumping conditions for the Floridan Aquifer system, and verified using estimates of pre-development conditions. Sensitivity analyses are then performed to identify the impacts of uncertainty in model parameters on the simulated behavior of the system. The model may be applied to investigate the impacts of various future pumping strategies on the hydrogeologic system and on adjacent users. Specific questions that the model is capable of answering include the ultimate impact of expanded withdrawals from the Floridan Aquifer on the water resource, on adjacent users, and potential impacts on the water table, wetlands, and streams. The calibrated model will also serve as a baseline for conducting more detailed investigations of water resources evaluation using transient analyses, for saltwater intrusion analyses in localized areas of interest, and for regional water supply planning.

1.3 LOCATION AND EXTENT OF STUDY AREA

The study area is located in northwestern Florida. Figure 1.1 shows the domain of study which encompasses Escambia, Santa Rosa, Okaloosa, and Walton counties and parts of Bay, Washington, and Holmes counties in Florida, and extends north into parts of Escambia, Covington, and Geneva counties in Alabama for about 18 miles from the Florida/Alabama border. The southern extent of the domain lies in the Gulf of Mexico, approximately 21 miles south of Destin, near the mouth of the Choctawhatchee Bay. The east-west extent of the domain stretches for approximately 121 miles, and the north-south extent, for approximately 82 miles encompassing an area of over 9,900 square miles.

The area of investigation lies mainly in two physiographic divisions (Puri and Vernon, 1964): the Gulf Coastal Lowlands and the Western Highlands. The Gulf Coastal Lowlands region contains sand dunes, beach ridges, and wave-cut bluffs along the coast, and swamps and flat woods a few miles inland. The Western Highlands region, which generally ranges in altitude from 50 to 200 ft above sea level (ASL), consists largely of sand hills cut by streams that have high base runoff and usually occupy deep, narrow ravines.

The Sand-and-Gravel Aquifer and the Floridan Aquifer system comprise the major water bearing units in the region. Ground water recharge occurs predominantly in the north via rainfall infiltration and flows in a dominantly southward direction to ultimately discharge into the Gulf of Mexico. Wells tapping the upper part of the Floridan Aquifer supply most of the water used in the study area. The Floridan Aquifer system is therefore of primary concern for this investigation. The Sand-and-Gravel Aquifer, although utilized as a primary source of water farther west in Escambia and Santa Rosa counties, is not a primary source of water in Okaloosa and Walton counties. However, the Sand-and-Gravel Aquifer has become important because of steadily increasing demands being placed on the Floridan Aquifer which have resulted in declining water levels, increasing pumping costs, interference between wells, and a potential for saline water intrusion. Further, streams and rivers in the area which supply critical water for the ecosystems in the bays are in close communication with the Sand-and-Gravel Aquifer, which is therefore included in the numerical investigation.

2.0 TECHNICAL APPROACH

2.1 OVERALL APPROACH

Following is the procedure used for obtaining a reliable numerical groundwater flow model of a sub-region of the NWFWMD, which is shown in Figure 1.1. All data available for the domain of interest and its adjoining areas are first compiled and reviewed to form a conceptual understanding of the hydrogeologic system. Reliable data are then extracted for simulation purposes. Arc/Info is used to compile all hydrogeologic, geologic, and hydrologic information of the modeling area to create a Ground Water Information System (GWIS) and express the conceptual flow system. A three-dimensional finite-difference grid is generated next over the model domain, and the conceptual flow system is expressed numerically for simulations using the ground water flow code, MODFLOW. The system is then calibrated by systematically adjusting material parameters and the conceptualization, until the numerical expression is representative of the physical flow system. Pre-development and post-development conditions are investigated to calibrate and verify the model. Finally, a sensitivity analysis on critical parameters is performed to identify the impacts of variations in model parameters on the simulated behavior of the system.

2.2 CODE SELECTION

The ground water flow code MODFLOW (McDonald and Harbaugh, 1988) is selected to develop the sub-regional flow model for the study area. MODFLOW is a well-accepted, public domain flow code developed by the USGS, and has been used in many previous studies to model regional ground water flow in various parts of Florida including within the NWFWMD jurisdiction. MODFLOW is capable of simulating steady state and transient three-dimensional flow in multi-aquifer, heterogeneous, anisotropic systems for confined and unconfined conditions. Several boundary conditions may be incorporated into a MODFLOW simulation, including Dirichlet conditions, recharge, wells, drains, rivers and streams. These capabilities are necessary and sufficient to simulate ground water flow conditions in the sub-region for purposes of quantifying water budgets and managing the water resources. Furthermore, MODFLOW is computationally efficient, relatively easy to use, and is interfaced with numerous accessory softwares for efficient pre- and post-processing capabilities.

Limitations to MODFLOW, as related to the current work include:

- MODFLOW is designed to simulate ground water flow in porous media. The code may not be used to explicitly model flow in individual fractures, faults or solution cavities.

- The effects of density and/or temperature on the ground water flow field are not considered. Therefore, in regions where dissolved solids in ground water affect the flow pattern, these density effects are neglected.

- The aquifer material within each grid cell is assumed to be homogeneous and the grid is assumed to be aligned with the principal directions of hydraulic conductivity if the aquifer material is anisotropic.

- Stresses applied to a grid cell (e.g., pumping) are assumed to be distributed uniformly over the entire cell volume.

3.0 PREVIOUS INVESTIGATIONS

Several field and modeling studies have been conducted in the domain of interest shown in Figure 1.1. As summarized by Barr (1983), the earliest available studies by Sellards and Gunter (1912) describe the water resources, physiography, drainage, wells, and soils of Walton County, which originally included what is now Okaloosa County, and indicate several locations adjacent to Choctawhatchee Bay where flowing artesian wells could be drilled. Matson and Sanford (1913) discuss the surface features, geology, and water supply of the Walton-Okaloosa County area. Barraclough and Marsh (1962) describe the system of aquifers and ground water quality along the gulf coast from the Choctawhatchee River to the Perdido River (the western boundary between Florida and Alabama, also the western boundary of the domain of interest for this study). Foster and Pascale (1971) provide data on the streamflow, water quality, and ground water levels in Okaloosa County and adjacent areas. Pascale (1974) describes in detail the climate, hydrogeologic characteristics, hydraulic properties, yield, water levels and budgets, and water quality of the upper part of the Floridan Aquifer and to a lesser extent, the Sand-and-Gravel Aquifer and surface water features in Walton County. Pascale (1976) provides details on construction and aquifer testing of two deep injection wells in the Lower Floridan Aquifer, with simulations of this aquifer conducted by Merritt (1984) to understand injection response behavior of the deeper zone.

CH2M Hill (1996) conducted similar simulations in the same area to examine the effects of a third proposed injection well at the site. The results of an extensive investigation of the water resources and quality of Okaloosa County and part of western Walton County were published in a report by Trapp et al. (1977). Wagner et al. (1980) give a comprehensive listing of basic hydrologic data for Okaloosa and Walton counties. Maslia and Hayes (1988) provide estimates of the regional pre-development potentiometric surface of the Floridan aquifer system. Barr et al. (1981) describe the ground and surface water resources of southern Okaloosa and Walton counties including the results of model simulations of various pumping schemes for both the Floridan and Sand-and-Gravel Aquifers. Hayes and Barr (1983) provide a detailed examination of the Sand-and-Gravel Aquifer in southern Okaloosa and Walton counties, as a result of its increased importance as a secondary source of water. Barr (1983) further details the hydrogeology and water quality in the vicinity of Choctawhatchee Bay in southern Walton and Okaloosa counties, and Barr et al. (1985) analyze the hydrogeology, water budgets, and water quality of the area, including the water-table, Upper Floridan and Lower Floridan Aquifer systems. Bush and Johnston (1988) provide a regional analysis of the entire Floridan Aquifer system including parts of Alabama. They present general trends in water level declines from pre-development conditions, as well as regional hydrogeologic analysis of the Floridan Aquifer.

An analysis of net ground water recharge in Okaloosa County is provided by Vecchioli et al. (1990) as a first attempt to quantify this parameter from estimates of rainfall and evapotranspiration. Previous studies typically focused only on recharge to the Upper Florida Aquifer. Ground water recharge estimates for Escambia and Santa Rosa counties are provided by Grubbs (1995). Pratt et al. (1996a) examine available data in the Choctawhatchee Bay area of Walton County, and develop a numerical model of the Floridan Aquifer system to examine local drawdowns under various pumping conditions, for a range of uniformly assigned hydrogeologic properties. Numerical modeling investigations of the current study area were also conducted by Richards (1993) for the

Floridan Aquifer system to comprehend sub-regional hydraulics, and investigate the effects of further development for various well spacings and discharges, under a range of aquifer conditions. A similar analysis was conducted by Richards (1997), covering the eastern portions of the current study area and beyond. Finally, Pratt et al. (1996b) provide Arc/Info coverages depicting structural elevations and potentiometric levels for the hydrogeologic units in the study area. These GIS layers represent a compilation and interpretation on a regional scale of all reliable data available within the domain, and provide an understanding of the hydrogeologic setting of the study area.

4.0 HYDROGEOLOGICAL SETTING

4.1 INTRODUCTION

An initial understanding of the behavior of the system is obtained by examining the hydrologic setting of the region. Calibration simulations then improve conceptualization of the flow of fluids within the domain and point out data gaps and misrepresentations of the system behavior. Specifically, data collected from core samples or local-scale investigations and laboratory tests may not accurately depict system behavior for regional simulations in the case of scale-dependent parameters or parameters with high local variations, not captured by the monitoring well network. Therefore, acquisition and compilation of hydrogeologic and hydrologic data throughout the region of interest in an appropriate manner are important processes reflected in the accuracy of the results.

Data compilation and interpretation, and development of the model are inter-linked processes. The level of detail of a modeling effort depends on the available data, and the necessity of data depends on the level of complexity of the model. This does not necessarily imply that the complexity of the model should increase with the availability of data. Rather, the scale of the modeling effort should be taken in perspective with the objectives of the simulation study, the availability of reliable data, the scale of heterogeneity of the site and the density of the data points. Sensitivity analyses then determine the degree of variation of the results due to inaccuracies in model input (within realizable limits for the site), thus suggesting future monitoring and data acquisition strategies.

The objective of this modeling effort is to understand and quantify the hydrological behavior of the Floridan Aquifer system within a sub-region of the NWFWMD. The Floridan Aquifer system is of interest since it is a primary source of water; however, the surficial aquifer system is becoming increasingly important as a possible secondary source of water due to limited resources and is therefore included as an aquifer unit in the model study. It is also of relevance as a source of recharge to the underlying Floridan Aquifer system. Significant surface water features (rivers and streams) are largely fed by ground water, and their flow rates have an impact on the ecology of the rivers, streams and bays in the region, and are also included in this study. The data assimilation effort therefore focuses on collecting appropriate information to enable modeling of these important hydrologic features. General data available for the site include:

1. ***Recharge/Discharge Information.*** Generalized information is available for rainfall and potential evapotranspiration of the region, providing rough estimates of recharge to the surficial aquifer system. Modeling analyses and examination of other pertinent data also provide recharge/discharge estimates for the aquifer systems in the region.

2. ***Stream Flows.*** Discharge estimates of the Floridan Aquifer to the Choctawhatchee River and Holmes Creek are available, where these surficial features are connected to the Floridan Aquifer. These discharges will be examined during model calibration.

3. ***Hydrostratigraphy and Aquifer Information.*** The aquifer systems underlying the area of investigation have been extensively studied since the early 1900s, with intensive efforts on

mapping stratigraphy and hydrogeologic properties during the 1970s and 1980s. The District is continually updating this understanding, as new data becomes available.

4. ***Topography.*** Topographic data for the region are available as DEMs (Digital Elevation Models) or DLGs (Digital Line Graphs) from the USGS. This information is useful in delineating land surface elevation and streambed elevation for the rivers and streams, and in identifying low lying areas covered by wetlands and marshes. The land surface elevation is significant in this steady-state simulation study for characterizing interactions at the surface such as seepage faces and overland runoff. It is further used in this study for estimating elevations for river beds, and in lower lying areas of reduced recharge or discharge into wetlands or marshes, via seepage.

5. ***Water Level Information.*** Potentiometric levels of the Floridan Aquifer are available for several years, at monitoring wells in the study area. This data has been interpreted to provide average potentiometric contours for the system. Potentiometric levels for 1990 are of particular interest in this study for the purpose of model calibration. Pre-development conditions have also been estimated and mapped for the system. Little data exists for the Lower Floridan Aquifer, and it is believed that hydraulic heads in the Lower Floridan were almost equal to Upper Floridan Aquifer heads during pre-development times. Currently, the Upper Floridan Aquifer heads are lower than Lower Floridan Aquifer heads due to pumping from the Upper Floridan Aquifer, and injection into the Lower Floridan Aquifer. Water levels of the Sand-and-Gravel Aquifer are available at monitoring locations. They have also been assimilated by the District and lie close to the land surface in much of the domain.

6. ***Pumping.*** The District, as monthly rates and yearly averages, has assimilated information regarding pumping stresses and locations within the study domain over the past several years. Most pumping in Okaloosa and Walton counties occurs in the Upper Floridan Aquifer, with only about five percent of the water supply coming from the surficial aquifer. In Escambia and Santa Rosa counties, most of the pumping occurs in the Sand-and-Gravel Aquifer. Deep injection wells in the Lower Floridan Aquifer also exist in Escambia and Santa Rosa counties. Pumping information for the Floridan Aquifer system for 1990 average daily withdrawal rates is of particular interest in this study for model calibration.

4.2 PHYSIOGRAPHY AND GEOLOGIC FRAMEWORK

4.2.1 Physiography

The area of investigation lies in the Gulf Coastal Lowlands and the Western Highlands topographic divisions in Florida, as summarized by Pascale (1974). The Coastal Lowlands contain white-sand beaches and sand dune ridges along the coast, with swamps and flatwoods 10 to 15 miles further inland. The Lowlands generally range in elevation from sea level to 100 ft. Numerous creeks connect with the gulf. The swamps and flatwoods are in an area adjacent to Choctawhatchee Bay and River and extend approximately 15 miles north from the coast. The swamps include the low, poorly drained areas south of Choctawhatchee Bay and in the flood plain of the Choctawhatchee

River, usually less than 30 ft ASL. The flatwoods forest area north of the bay is generally well drained by small streams, which discharge into the bay.

The Western Highlands extend northward from the Coastal Lowlands into Alabama. The southern part consists of gently rolling sandhills, which range in elevation from 100 to 250 ft ASL and are characterized by the steepness of the heads of many streams that drain the area. The northern part contains swampy bays in the north central and the hilly section along the Florida/Alabama state line where elevations are as much as 345 ft ASL. Trapp et al. (1977) further sub-divide these physiographic features in Okaloosa County to better understand the runoff and infiltration characteristics of the system.

4.2.2 Geology

Schmidt (1984) defines the Neogene and Paleogene formations down to the Upper Eocene Ocala Limestone within the study area. The middle Eocene to Recent series contains the major hydrogeologic units of interest for this study. The strata consist mainly of marine limestone, clay, and sand. Table 4.1 details the stratigraphic units and lithologic description, and correlates the formations to hydrogeologic units. The Recent to Pliocene formations constitute the uppermost hydrogeologic unit, the Sand-and-Gravel Aquifer. Upper to Middle Miocene units constitute the Intermediate System, which typically acts as a confiner to the Upper Floridan Aquifer beneath it. The Upper Floridan Aquifer is comprised of Lower Miocene and Upper Oligocene strata, while the Middle to Lower Oligocene members constitute the Bucatunna Clay confining unit, where it exists, up to coastal Walton and Okaloosa counties in the east. Finally, the Upper Eocene and Middle Eocene formations constitute the Lower Floridan Aquifer and the Sub-Floridan system (Claiborne Stage sediments) at the bottom. The Sub-Floridan system is predominantly impermeable and constitutes the base of the ground water flow system for this study.

4.3 LOCAL HYDROGEOLOGY AND STRATIGRAPHY

The hydrogeologic units of interest in the study area are contained in the Middle Eocene to Recent Series as presented in Table 4.1. The geologic units are further classified into hydrogeologic layers depending on transmissive and storage properties of the rocks. The principal hydrologic zonation from top to bottom consists of the Sand-and-Gravel Aquifer, which forms the surficial system, the Intermediate System regional confining unit, the Upper Floridan Aquifer, the Bucatunna Clay confining unit (where present) and the Lower Floridan Aquifer. Table 4.1 shows the ranges of thicknesses for these layers, and summarizes their hydrogeologic characteristics. Figure 4.1 shows a typical hydrogeologic section within the study area depicting the hydrostratigraphic sequences of interest for the study.

4.3.1 Sand-and-Gravel Aquifer

The Sand-and-Gravel Aquifer underlies the entire study area extending from land surface to the top of the Intermediate System. It comprises sediments ranging in age from late Miocene to Holocene, and consists of quartz sand and gravel mixed with clay, silt and shell. Differences in lithology and hydraulic properties cause the Sand-and-Gravel Aquifer to be divided into up to three hydraulic zones. In descending order, they are a surficial zone, a low-permeability zone, and a main-producing zone. The surficial zone consists of white to light gray to light-brown, fine to medium, moderately sorted sand and extends from land surface to a depth of 20 to 60 ft. Below the surficial zone are 10- to 65-feet thick beds of clay, sandy clay, and clayey sand. The permeability of this low-permeability zone varies widely, but is relatively low throughout most of the area. The main-producing zone is the most permeable part of the Sand-and-Gravel Aquifer, consisting of sand that is white to light orange to light brown in color, medium to coarse grained with some fine gravel, and is moderately to well sorted. This zone includes the bottom 10 to 85 ft of the aquifer. The main-producing zone usually functions as a leaky, semi-confined (artesian) aquifer in that it is hydraulically separated from the surficial zone by the low-permeability zone. Depending on local conditions, it is not always possible to differentiate the aquifer into the three hydraulic zones. One or more of these zones may be absent where the aquifer is thin.

The overall permeability of the surficial and main-producing zones varies in accordance with areal variations in the lithology of their sediments. In Escambia, Santa Rosa, and in coastal Okaloosa and Walton counties, these sediments consist largely of fine to medium sand with varying amounts of clay. The grain size of the sediments of the surficial and main-producing zones is believed to decrease to the north and east. As a result, the permeability of the aquifer is greatest in Escambia, Santa Rosa, and coastal Okaloosa and Walton counties. Hydraulic conductivity values for the Sand-and-Gravel Aquifer, however, have not been extensively published throughout the study area. The only available data seems to be reported by Hayes and Barr (1983), in the immediate vicinity of Fort Walton Beach. The five single well tests were analyzed using Jacobs' straight-line method in the main producing zone, consequently, the transmissivity values are considered as estimates that are conservative. A representative specific yield value of 0.2 is given by Barr et al. (1981) for the Sand-and-Gravel Aquifer.

The Sand-and-Gravel Aquifer will be considered as one hydrogeologic unit for this study. The land surface constitutes the top of this unit, and is expressed by the topographic map of Figure 4.2. Elevations are almost at sea level in the Coastal Lowlands, and rise up to 300 ft in the Western Highlands with deep narrow ravines cut by streams and rivers. The bottom elevation of the Sand-and-Gravel Aquifer has been interpreted by the District (Pratt et al., 1996b) on a regional scale and lies between 200 ft and -350 ft NGVD. This surface generally dips in a west-southwesterly direction causing the Sand-and-Gravel Aquifer to thicken to the west. In Santa Rosa and Escambia counties, the Sand-and-Gravel Aquifer is more than 400 ft thick (Merritt, 1984) and is the primary source of potable and industrial water, while elsewhere in the study area, it is generally thinner and less productive, being tapped by shallow domestic wells or for recreational purposes.

The modeling study of CDM (1997) that extends over a portion of the study domain, uses a uniform material value for the Sand-and-Gravel Aquifer with horizontal and vertical conductivities of 150 and 10 feet per day (ft/d), respectively, and a specific yield of 0.2. Other available modeling studies in the region do not consider the Sand-and-Gravel Aquifer, focusing only on the Floridan Aquifer system.

4.3.2 Intermediate System

The Intermediate System is defined by material of relatively low permeability between the Sand-and-Gravel Aquifer and the Floridan Aquifer. Geologically, the unit is comprised of the Pensacola Clay, the Alum Bluff Group, and the Intracoastal formation of Middle to Upper Miocene age. The Pensacola Clay is predominantly comprised of a gray to bluish-black to light brown calcareous clay; light gray to brown, very fine to coarse clayey sand; and shell fragments. It occurs chiefly in the southern half of Escambia and Santa Rosa counties and in coastal Okaloosa County. Beyond Escambia and Santa Rosa counties and the western portion of Okaloosa County, the Intermediate System also includes Miocene Coarse Clastics (Merritt, 1984). The undifferentiated Alum Bluff Group consists of clayey quartz sand with shells and shell beds, and occurs throughout most of northern and central Walton and Okaloosa counties. The Intracoastal Formation occurs in the southern coastal portions of Walton and Okaloosa counties and consists of low permeability, poor consolidated, clayey, sandy, microfossiliferous limestone.

The permeability of the Intermediate System varies across the study area due to changes in lithology discussed above. In the eastern portion of the study area, the clayey sand and clayey limestone lithologies cause the permeability of the Intermediate System to be relatively high compared to further west, where the Miocene Coarse Clastics and Pensacola Clay make up the Intermediate System. Regionally, the sediments become finer grained and exhibit lower permeabilities in the western and southwestern portion of the study area. A core sample from a test well near Milton, Santa Rosa County, indicated a vertical hydraulic conductivity value of 4.9×10^{-7} ft/d (Trapp et al. 1977). On the basis of geophysical and lithologic logs and aquifer test analysis, the average vertical hydraulic conductivity of the Intermediate System confining unit ranges from 10^{-2} to 10^{-6} ft/d (Barr et al., 1981, Barr et al. 1985). It averages 10^{-5} ft/d in Okaloosa County and 10^{-3} ft/d in Walton County.

The elevation of the top of the Intermediate System is distinctively marked by the presence of a thin, clayey bed of weathered shell material at the bottom of the Sand-and-Gravel Aquifer. The elevation of the bottom of the Intermediate System lies between 100 and -1,400 ft in the study area and the thickness of the Intermediate System ranges from 50 ft to 1,200 ft (Pratt et al., 1996b). The Intermediate System is noted to dip and thicken toward the southwest. A combination of this, and the lithology becoming finer grained to the west and southwest, results in the Intermediate System being a more effective confiner in the western and southwestern portion of the study area. The clays, if extensive under the Gulf of Mexico, probably outcrop tens of miles to the south of the shoreline.

Considering the previous modeling efforts in the region, CDM (1997) uses vertical hydraulic conductivity values for the Intermediate System ranging from 10^{-6} ft/d to 5×10^{-2} ft/d with large portions of the domain acquiring the lower end values. The model of Barr et al. (1981) uses leakance values within an order of magnitude of values used by Richards' (1993) model, with a somewhat similar zonation pattern. Barr et al. (1981) further express the opinion that these calibrated model values are within probable range of actual values. Richards' (1997) study in the easternmost region of the current study domain, uses vertical hydraulic conductivity values for the Intermediate System which are typically one to two orders of magnitude higher than those in the central regions of the study area.

4.3.3 Upper Floridan Aquifer

The upper limestone of the Floridan Aquifer constitutes the principal source of water in southern Okaloosa and Walton counties. It consists of sediments ranging from Upper Oligocene to Lower Miocene ages, and is comprised of the Bruce Creek Formation, the Tampa Stage Limestone, and the Chattahoochee-Chickasawhay formation geologic units. Although these carbonate rocks differ vertically and horizontally in texture, porosity and permeability, they can be treated as a single hydrologic unit in that their internal hydrologic dissimilarities are small compared to the dissimilarities with overlying and underlying units. Lithologically, the Bruce Creek Formation consists of white to gray, fine-grained, fossiliferous, moderately indurated limestone with traces of clay and sand. The basal portion of the Bruce Creek Formation may include lenses of loose, fine-grained to gravel sized quartz sand and blue-green clay. In coastal Walton County, the Bruce Creek typically consists of poorly to moderately indurated, fine-grained, chalky limestone. To the west, in Okaloosa County, the Bruce Creek consists of moderately to well indurated limestone. Poorly indurated intervals are less common. Throughout the study area, the thickness of the formation ranges between 110 and 150 ft. Owing to its distinctive, predominantly limestone lithology, the Bruce Creek Formation is readily distinguishable from the overlying and underlying geologic units. Underlying the Bruce Creek Formation are the Tampa Stage limestone and the Chickasawhay Formation. The Tampa Stage limestones present in the Choctawhatchee Bay area are part of the Chattahoochee Formation (Schmidt, 1984). These two formations are grouped into one undifferentiated unit due to the difficulty of distinguishing between them, since both units consist of white, moderately to well-indurated, fine-grained limestone, dolomitic limestone and well-indurated, tan, sucrosic dolomite.

Ground water storage and movement in the Upper Floridan Aquifer system occurs in a combination of pore-water flow, small solution fissures, and larger solution channels and cavities. The transmissivity of the Upper Floridan Aquifer is highly variable ranging from 4,000 gal/d/ft (535 ft^2/d) along the central and eastern gulf coast to 180,000 gal/d/ft (24,062 ft^2/d) in southeast Walton County (Pascale, 1974). The storage coefficient ranges from $1.6x10^{-4}$ to $5.6x10^{-4}$. Pratt et al. (1996a) estimate transmissivities from single well tests as well as from specific capacity data, using assumed aquifer storativities, in southern Walton County. Transmissivity estimates from specific capacity data range from 500 ft^2/d to 3,100 ft^2/d, and provide a lower end limit on the transmissivity value. Trapp et al. (1977) estimate Upper Floridan transmissivities to range from as low as 300 ft^2/d on Santa Rosa Island to 27,000 ft^2/d in south central Okaloosa County based on specific capacity tests. Barr et al. (1985), Trapp et al. (1977) and Barr et al. (1981) report transmissivity values ranging from 1,300 to 25,000 ft^2/d from seven test sites, with storage coefficients ranging from $1.6x10^{-4}$ to $5.6x10^{-4}$. Figure 4.3 shows the location of aquifer test sites for the Upper Floridan Aquifer used in this modeling study. Table 4.2 provides additional specific capacity information for the Floridan Aquifer.

The top elevation of the Upper Floridan Aquifer corresponds to the bottom of the Intermediate System. The bottom elevation of the Upper Floridan Aquifer corresponds to the top of the underlying Bucatunna Clay confining unit and ranges from -100 to -1,700 ft NGVD with a southwesterly dip. The formation extends well into the Gulf of Mexico, where it would outcrop at sufficient depth. Note that the Bucatunna Clay unit is absent in the eastern regions of the study area where the entire Floridan Aquifer system may be treated as undifferentiated. The thickness of the Upper Floridan Aquifer system in regions where it is not undifferentiated from the lower limestone ranges from 50 ft in northern portions of the domain to more than 400 ft near Choctawhatchee Bay (Pratt et al., 1996b).

An investigation of previous modeling efforts in and around the study area shows a large variation in hydraulic properties. Upper Floridan hydraulic conductivity values used by the CDM (1997) model study range from 5 to 30 ft/d in most of their study domain, with a zone of 100 ft/d occurring in east Santa Rosa and west Okaloosa County. Calibrated transmissivity values for the Upper Floridan Aquifer obtained by Richards (1993) are similar in trend and magnitude to values used by Barr et al. (1981), except in northwest Okaloosa County where Barr et al. (1981) indicate a much higher value of 35,000 ft^2/d. Barr et al. (1981) note that their modeled transmissivities are generally higher than values obtained from aquifer tests. Both modeling efforts consider the entire Floridan Aquifer in the analysis, in locations where the Bucatunna Clay does not exist. The hydraulic conductivity distribution for Richards' (1993) modeling effort, as calculated by the transmissivity divided by the Upper Floridan Aquifer thickness (or the entire Floridan Aquifer thickness where it is considered undifferentiated), ranges from 100 ft/d in Central Okaloosa County to less than 10 ft/d in coastal areas and in Santa Rosa County. Richards' (1997) study further to the east uses similar transmissivity values to Richards (1993) along the coast, but has much higher transmissivities inland.

4.3.4 Bucatunna Clay Confining Unit

The Bucatunna Clay confining unit underlies the limestone of the Upper Floridan Aquifer and where present, separates it hydrologically from the lower limestone of the Floridan Aquifer. Geologically, the unit is composed of the Bucatunna Clay member of the Byram Formation and of other clastic unconsolidated materials of low permeability of middle to lower Oligocene age, occurring between the two principal carbonate aquifers. The Bucatunna Clay confining unit underlies all of Escambia and Santa Rosa counties, part of Okaloosa County, and a small part of coastal Walton County. It is thickest in south central Escambia and Santa Rosa counties, where it reaches a maximum thickness of about 200 ft. The unit thins toward the east and pinches out in central Okaloosa County and in coastal Walton County. The unit is present up to 15 miles north of Fort Walton Beach in Okaloosa County and is generally present in coastal Walton County. In Destin, the Bucatunna Clay confining unit has a thickness of about 40 ft. Further east, in Walton County (Four-Mile Point), the Bucatunna Clay confining unit has a thickness of about 15 ft. Still further east, the Bucatunna Clay does not exist as a continuous confining unit. In the northwest regions of the domain, the Bucatunna Clay pinches out further north of the domain boundary for this study, in Monroe and Conecuh counties, Alabama.

On the basis of core samples from test wells in eastern Santa Rosa County, Pascale (1976) reported the Bucatunna Clay confining unit to consist of "waxy, dark to medium gray, very dense clay," with measured vertical hydraulic conductivities ranging from 2.9×10^{-6} to 2.6×10^{-7} ft/d and an effective porosity of 13 to 14 percent. Merritt (1984) shows the locations of the wells from which core samples were taken, to be in central Santa Rosa and southeast Santa Rosa County respectively. In southern Okaloosa County, Barr et al. (1981) describe the Bucatunna Clay confining unit as consisting of "silty to sandy calcareous clay, with occasional thin beds of blue to dark gray clay." They report the vertical hydraulic conductivity of the unit as being higher than in Santa Rosa County and estimate a value of approximately $1x10^{-5}$ ft/d in coastal Okaloosa County. In coastal Walton County, the Bucatunna Clay confining unit thins to the point where it is no longer an effective confining unit. Barr (1983) reports the vertical hydraulic conductivity of the Bucatunna Clay in Okaloosa County (where it exists) to be about 10^{-3} ft/d along the northern portions, and about 10^{-5} ft/d along the coast, estimated from driller's samples, geophysical logs, and data from seven aquifer tests. Discrete measurement values and locations are not provided. Merritt (1984) noted that some degree of confinement exists even in regions where the Bucatunna Clay pinches out in the east.

The top elevation of the Bucatunna Clay confining unit is coincident with the bottom elevation of the Upper Floridan Aquifer limestones. The bottom elevation of the Bucatunna Clay unit ranges from -200 ft to -1,900 ft NGVD. The unit generally dips south-southwest at about 25 feet per mile (ft/mi) and forms an effective confining unit, restricting the upward movement of possibly saline water from the Lower Floridan Aquifer. The Bucatunna Clay extends to the south beyond the domain boundary and, if it extends sufficiently far, it crops out in the Gulf of Mexico.

Of model simulations in and around the study region, only the CDM (1997) study includes the Bucatunna Clay or the Lower Floridan Aquifer. The vertical hydraulic conductivity of the Bucatunna Clay has been divided into two zones; a value of $1x10^{-4}$ ft/d is applied in south Walton and Santa Rosa counties, and a value of $5x10^{-5}$ ft/d is applied elsewhere where the Bucatunna Clay exists.

4.3.5 Lower Floridan Aquifer

Underlying the Bucatunna Clay confining unit in the western part of the study area and the undifferentiated Chattahoochee-Chickasawhay carbonate unit in the east, are the Ocala Limestone carbonates of Upper Eocene age that comprise the Lower Floridan Aquifer. In the western part of the study area, the Bucatunna Clay confining unit/Ocala Limestone contact is readily apparent due to the sharp contrast in lithology between the two units. To the east, the undifferentiated Chattahoochee/Chickasawhay and Ocala Limestone contact is ill defined. This is due to lithologic similarities between the two units and a lack of well control. On the whole, this portion of the freshwater flow system is poorly understood, since the lower portion of the Floridan Aquifer system is infrequently exploited as a source of water. What little is known is derived from oil test wells and the occasional deep ground water exploration well. According to Clark and Schmidt (1992), the Ocala Limestone in the study area varies from a "white to light gray, chalky, fossiliferous limestone to a tan, sucrosic dolomite." Traces of glauconite, clay, and sand may be present. They also describe the unit as being abundantly fossiliferous. The contact between the Ocala Limestone and the underlying carbonates is gradational and poorly defined.

Like the upper limestone aquifer, water in the Lower Floridan Aquifer occurs under confined conditions and moves through the aquifer via microscopic and macroscopic solution openings. Saline water containing chlorides in excess of 1,000 mg/L occurs within the entire thickness of the aquifer in southern Okaloosa County. Further to the north where the Bucatunna Clay pinches out, the aquifer contains fresh water. It is likely that moderate to high sustained yields could be obtained from properly constructed wells. At present, this aquifer is not used as a source of water in the study area, and therefore potentiometric levels, conductivity, and storage data are sparse. The aquifer is, however, used for deep well injection in Escambia and western Santa Rosa counties, and aquifer test data is available in these locations. The injection system at Solutia, Inc. has been in operation since 1963 and Vecchioli (1995) provides the average injection rate for this system for 1990 as 1,500 gal/min. The injection system near Milton, operated by Cytec, Inc., has an average injection rate of 680 gal/min for 1990 (Vecchioli, 1994). Transmissivity estimates for the Lower Floridan Aquifer range from 267 ft^2/d at Regional Monitor Well 2 to about 5,000 ft^2/d at Regional Monitor Well 1 (Merritt, 1984). Effective porosity ranges from 11 to 28 percent, and the storage coefficient varies from 0.001 to 0.0001 (Barraclough, 1966).

The top elevation of the Lower Floridan Aquifer in the western regions of the domain coincides with the bottom of the Bucatunna Clay confining unit. The bottom of the Lower Floridan Aquifer is not entirely conformable due to lithologic similarity between the Ocala Limestone and the upper carbonate unit of the Claiborne group beneath it. The elevation of the bottom of the Lower Floridan Aquifer has been estimated by the District (Pratt et al., 1996b) and dips in a south westerly fashion from -200 ft to -2,000 ft NGVD. The thickness of the Lower Floridan Aquifer ranges from 100 ft in the north to more than 300 ft in the south of the domain. The lower limestone of the Floridan Aquifer is underlain by the Claiborne confining unit of middle Eocene age which is comprised of impermeable or low permeability beds of dense sand, shale, clay, and limestone of the Lisbon-Tallahatta Formation. The unit inhibits upward movement of water from underlying units and also delineates the base of the subsurface flow regime for this study. The southern outcrop of the Lower Floridan system in the Gulf of Mexico occurs between 50 to 80 miles south of the coastline if the unit continues with the same degree of dip (Merritt, 1984).

Of model simulations in and around the study region, only the CDM (1997) study includes the Lower Floridan Aquifer as a separate unit. They use a uniform horizontal hydraulic conductivity value of 75 ft/d for the Lower Floridan Aquifer model layer.

4.3.6 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 is middle Eocene in age and includes the Lisbon and Tallahatta formations. It functions primarily as a confining unit and hydraulically separates the Floridan Aquifer system from the underlying sediments. The elevation of the top of the unit ranges from -200 ft NGVD in the northeast part of the study area to -2,400 ft NGVD in the southwest.

4.4 POTENTIOMETRIC DATA

Potentiometric data has been collected and compiled for the various layers in the system, to varying degrees. Most data is available for the Upper Floridan Aquifer, followed by the Sand-and-Gravel Aquifer, with little information available for the Lower Floridan Aquifer. Of interest to this study are the average potentiometric levels for pre-development and May 1990 conditions, for steady state simulation of the Floridan flow system.

4.4.1 Potentiometric Data on Sand-and-Gravel Aquifer

Hayes and Barr (1983) indicate that historical data on the water table in the surficial zone of the Sand-and-Gravel Aquifer is sparse, but is generally a subdued replica of the topography, being a few feet below land surface in most of the Coastal Lowlands, and 25 to 50 ft below land surface in much of the Western Highlands. These water levels are generally higher than those of the main producing zone of the Sand-and-Gravel Aquifer and are believed to be fairly consistent through pre-development times, except for possibly in central Escambia County, where this aquifer is used as a source of water.

4.4.2 Potentiometric Data on Upper Floridan Aquifer

The potentiometric surface of the Upper Floridan Aquifer within the study area has been declining steadily due to increased water supply from this aquifer. Before 1941, only a few wells tapped the Floridan Aquifer in the area of investigation. Figure 4.4 shows the estimated pre-development potentiometric surface of the Upper Floridan Aquifer (Maslia and Hayes, 1988), the earliest year for which sufficient control existed to produce a potentiometric map. This potentiometric surface configuration may be taken as pre-development conditions. Figure 4.5 shows the approximate configuration of the potentiometric surface of the Upper Floridan Aquifer for May 1990 conditions. The potentiometric surface is noted to have declined by as much as 160 ft on an average, in 50 years of pumping with an additional 20 to 30 ft decline during periods of peak demand (Barr et al., 1985).

4.4.3 Potentiometric Data on Lower Floridan Aquifer

Information on the Lower Floridan Aquifer in the study area is relatively sparse. Barr et al. (1985) report on four test wells in Southern Okaloosa and Walton counties, and note that at Fort Walton Beach (Beal Cemetary), the Lower Floridan Aquifer potentiometric level is approximately five ft ASL, while water levels of the Upper Floridan Aquifer are approximately 44-67 ft below sea level. At other test sites, water levels were only one to five ft above those of the Upper Floridan Aquifer.

4.5 RECHARGE AND DISCHARGE

Rainfall precipitation is the primary source of recharge to the area. Average rainfall in the study area is approximately 60 inches per year (in/yr), with 15 to 18 in/yr recharging the Sand-and-Gravel Aquifer and the rest being lost to evapotranspiration and surface runoff. Pascale (1974) reports an average rainfall for Walton County of 65 in/yr. Hayes and Barr (1983) report a mean average rainfall of 62 in/yr for southern Okaloosa and Walton counties with highest precipitation occurring during late spring or early summer. Trapp et al. (1977) report an average of 64 in/yr for Okaloosa County and adjacent areas, and note that it may vary substantially from year to year and from station to station. Barr et al. (1985) present a range of 31 in/yr in 1954 to 95 in/yr in 1975. Grubbs (1995) presents investigations on ground water recharge in Escambia and Santa Rosa counties. Precipitation averages 60 to 64 in/yr and potential evapotranspiration ranges from 42 to 46 in/yr. Recharge to the Sand-and-Gravel Aquifer approximates 15 to 18 in/yr and is highest in southern Santa Rosa County near or on Eglin Air Force Base. Barr et al. (1981) use 35 in/yr of evapotranspiration as a reasonable number in their study, giving an average of 18 in/yr recharge to the subsurface for their modeling study. Bush and Johnston also show evapotranspiration in the area to be about 35 in/yr.

Average runoff is between one to seven in/yr in the Coastal Lowlands, and varies from 20 to 35 in/yr in the Western Highlands region (Bush and Johnston, 1988). Rainfall is also areally variable in the region and, therefore, a net recharge to the system is difficult to estimate at different locations within the study area. Vecchioli et al. (1990) performed a study determining net ground water recharge using baseflow analysis, which indicated that average recharge to the Sand-and-Gravel Aquifer was over 10 in/yr throughout Okaloosa County, except for stream-valley floors, swamps and coastal wetland areas, which are discharge locations. Recharge to the Upper Floridan Aquifer occurs from the Sand-and-Gravel Aquifer in Florida, across the Intermediate System confining unit. This recharge is less than five in/yr everywhere in Okaloosa County (Vecchioli et al., 1990). The Upper Floridan Aquifer was discharging in the southern coastal regions during pre-development conditions, while it is a recharging system for 1990 conditions due to extensive lowering of its potentiometric levels as a result of development. North of the border in Alabama, the Floridan Aquifer crops to the surface where it is directly recharged by rainfall. The northern boundary of the study area defines the limit of the Floridan Aquifer, where water levels are noted to be fairly stable. No water enters the Floridan Aquifer system laterally, from sediments further north of this boundary.

Water that recharges the aquifers in the northern portion of the study area generally moves south, discharging to streams and rivers, and into the Gulf of Mexico. Trapp et al. (1977) report that about 2,500 million gallons per day (Mgal/d) of water discharges into the bays and the Gulf of Mexico via streams and rivers in and around Okaloosa County. This amount does not fluctuate extensively during drought periods or even seasonally, indicating that only a small portion of it is surface runoff. They estimated that 75 to 96 percent of total streamflow is base runoff, mainly from the Sand-and-Gravel Aquifer. Vecchioli et al. (1990) determine base flows for streams and rivers in Okaloosa County to range from 14.3 in/yr to 50.7 in/yr. Trapp et al. (1977), Barr et al. (1985), Vecchioli et al. (1990), and Barr et al. (1981) report streamflows for several streams and rivers in the study area. Most streams and rivers in the study area are in close communication hydraulically, with the Sand-and-Gravel Aquifer. Portions of the Choctawhatchee River and Holmes Creek are also in close hydraulic communication with the Floridan Aquifer. Floridan Aquifer discharge to the Choctawhatchee River ranges from about 150 cubic feet per second (cfs) to 250 cfs.

Ground water is the principal source of water in the study area. In 1941, only a few wells tapped these water resources. Since then, the demand for potable water has been continually increasing. Barr et al. (1985) estimated 10.9 Mgal/d withdrawals in January and 19 Mgal/d in June, for Okaloosa and Walton counties for the year 1978. Vecchioli et al. (1990) estimate average Upper Floridan Aquifer withdrawals of 26.14 Mgal/d, and Sand-and-Gravel Aquifer withdrawals of 1.53 Mgal/d in

1985 for Okaloosa County. Barr et al. (1981) report that 95 percent of ground water withdrawals in south Okaloosa County occur via nine separate water supply systems. Pumping estimates increase from 1.51 Mgal/d in 1940, to 11.8 Mgal/d in 1968, to 15.1 Mgal/d in 1978. Richards (1993) has assimilated most of the pumping data in the study area for 1990 average daily rate withdrawals. These data have been augmented (NWFWMD, 1999) to cover the current study area and are presented in Table 4.3. Figure 4.6 shows the locations of these pumping wells.

5.0 GROUND WATER FLOW MODEL CALIBRATION

5.1 CONCEPTUAL MODELING FRAMEWORK

The relevant information presented in Chapter 4 is used to develop an initial understanding of the flow behavior of the system under study. The objectives of the study and the scale of the problem are considered while compiling and interpreting data. Conceptualization of the system proceeds accordingly.

The system under study is a multi-layered aquifer system. The domain of interest includes the Sand-and-Gravel Aquifer, the Intermediate System, the Upper Floridan Aquifer, the Bucatunna Clay, and the Lower Floridan Aquifer. The stratigraphy of these systems has been interpreted by Pratt et al. (1996b) on a sub-regional scale. A fully three-dimensional conceptualization is considered for each of the aquifer units, including the confining units (i.e., the Intermediate System and the Bucatunna Clay). The Sand-and-Gravel Aquifer is an unconfined system, while the remaining units are considered to be fully confined since the Intermediate System does not de-saturate and cannot allow air to enter the underlying aquifers. The base of the Lower Floridan Aquifer is considered as the bottom boundary of the domain and is conceptualized as a no-flow condition across it, due to the impermeable nature of the underlying Claiborne sediments.

Hydrogeologic properties for these units have been assimilated from various aquifer tests. Sand-and-Gravel Aquifer properties are discussed in Section 4.3.1. A uniform value of its hydraulic properties will be used in the model for calibration purposes, since this unit has only sparse characterization and its pumping is less well defined and not used in the model. Hence, the Sand-and-Gravel Aquifer is treated as a mechanism for transmitting recharge water to the underlying units, its presence in the model providing a reasonableness check on recharge fluxes to the system. Section 4.3.2 discusses leakance information for the Intermediate System, with vertical hydraulic conductivity of the Intermediate System decreasing from east to west. Hydraulic properties for the Upper Floridan Aquifer are discussed in Section 4.3.3 and are highly variable throughout the domain of study. Aquifer tests in southern Okaloosa and Walton counties, and in Santa Rosa County provide vertical hydraulic conductivity information for the Bucatunna Clay confining unit discussed in Section 4.3.4. The Bucatunna Clay confining unit exists in the western regions of the study area, but is absent in the eastern portions of the domain, where the Floridan Aquifer may be considered as undifferentiated. Finally, hydrogeologic information available for the Lower Floridan Aquifer is discussed in Section 4.3.5.

Fresh water recharges the Sand-and-Gravel Aquifer and the Floridan Aquifer system in the northern regions of the domain and generally flows southward within the Floridan Aquifer system as depicted by the potentiometric contours in Figures 4.4 and 4.5. Floridan Aquifer recharge is highest near, and north of the Florida-Alabama state line, where the Floridan Aquifer crops up to the surface. Recharge to the Floridan Aquifer occurs in regions further to the south for 1990 conditions than for pre-development conditions, induced by pumping the Upper Floridan system. The Sand-and-Gravel Aquifer accepts recharge in most of the upland regions of the domain, averaging 18 in/yr. Spatial variation of this recharge is not known, however, the Sand-and-Gravel Aquifer water levels are known to be within a few feet of land surface. This information can be used to reject additional recharge when water levels in the Sand-and-Gravel Aquifer exceed land surface. Discharge to the surface occurs in streams, rivers, bays, and the Gulf of Mexico. The surface boundary condition in these discharge areas, therefore, is conceptualized as a constant head boundary, with a head value of zero in the bays and the Gulf of Mexico. The Sand-and-Gravel Aquifer discharges to rivers and streams under prescribed river stage conditions, via leakage across the river bed sediments. A portion of the Choctawhatchee River and Holmes Creek are in direct communication with the Floridan Aquifer. These regions within the Floridan Aquifer are also connected to the river with Floridan Aquifer discharge occurring across the river bed sediments under prescribed river stage conditions.

Lateral boundaries of the domain are selected to accommodate the objectives of this study. The northern boundary lies along the updip limit of the Floridan Aquifer in Alabama, to form a natural no-flow boundary where the Floridan Aquifer system pinches out. In western portions of the domain, however, the Lower Floridan Aquifer is still confined along the northern boundary, but extends only a little further outside the model domain before it too outcrops and pinches out. The east and west boundaries are located sufficiently beyond the anticipated radius of influence of the major pumping centers, since natural boundaries do not exist in the vicinity. These boundaries are further treated as head-dependent flux boundary conditions for all aquifers under study, to additionally reduce boundary influences on pumping in the vicinity. However, the Perdido River acts as a natural boundary for the Sand-and-Gravel Aquifer's western model boundary, therefore the region further west of the Perdido River in the Sand-and-Gravel Aquifer is of no consequence to the analysis. The southern boundary of the domain lies approximately 21 miles into the Gulf of Mexico from the mouth of Choctawhatchee Bay, to provide the ability to examine saltwater intrusion in future modeling efforts. Since a natural boundary does not exist nearby, the southern lateral boundary is also treated as a head-dependent flux boundary condition for the Floridan Aquifer system to reduce boundary influences on pumping in the Fort Walton Beach area and other coastal areas. Southern boundary heads in the lower hydrogeologic units increase with depth to reflect the additional weight due to the higher density of seawater as compared to fresh water. Appropriate pumping rates and locations are also included in the boundary conditions for 1990 pumping conditions. Figure 4.6 shows the well locations and Table 4.3 shows the associated pumping rates from within the Floridan Aquifer system.

This initial conceptualization of the system is incorporated into a numerical model. Model calibration is then performed by systematically adjusting parameter values within reasonable bounds to minimize errors between measured and model predicted head values within the domain. The model is calibrated in steady state to 1990 conditions to provide a realization of hydraulic conductivity distribution for all hydrogeologic units. Seasonal fluctuations and their associated transients are therefore neglected in the calibration process. The model is then verified by simulating pre-development conditions. The calibrated, verified model is then considered to represent field conditions and a sensitivity analysis is used to determine effects of model parameters on simulated results. This model may then be used for further investigations of the effects of different water demand conditions, as well as a baseline for localized, more detailed investigations.

5.2 NUMERICAL MODELING ASSUMPTIONS

The conceptual model discussed in Section 5.1 is implemented into a numerical framework for analysis. The numerical model is discretized into five layers, each layer representing one hydrogeologic unit. The first layer represents the Sand-and-Gravel Aquifer, which is unconfined. Therefore, the top and bottom elevations along with hydraulic conductivities will be required for this model layer to express its unconfined condition. The second layer represents the Intermediate System, the third layer represents the Upper Floridan Aquifer, the fourth layer represents the Bucatunna Clay where it exists, and the fifth layer represents the Lower Floridan Aquifer. Layers 2 through 5 are treated as confined units, therefore, only transmissivity values of these units are required for their numerical expression. Since each unit is not further sub-divided into model layers, it is assumed that vertical flow within a unit occurs instantaneously, with no capability of discriminating vertical head gradients within a unit. Horizontal flow occurs within each aquifer unit between horizontally discretized grid points, and vertical flow occurs between the aquifer units.

The numerical model further assumes that Darcy's Law can express flow within the sub-surface. Thermal or concentration influences are neglected. Furthermore, a steady-state analysis is performed for pre- and post-development conditions; therefore, storage effects are also neglected along with their associated transient fluctuations. Also, basic physical processes (e.g., rainfall, evapotranspiration, topography and land use) and aquifer parameters that control flow in the subsurface (e.g., transmissivities, leakance and Sand-and-Gravel Aquifer conductivities) are assumed to be time invariant. Hence, the difference between pre- and post-development conditions is only in the applied pumping stresses. The pumping stress applied to a grid cell is assumed to withdraw water over the entire thickness of the cell, and all pumping wells within a grid cell extract water uniformly from the whole cell volume. Finally, for a well pumping from multiple layers, the total extraction rate is divided among model layers according to the ratio of their transmissivities.

5.3 FLOW MODEL CODE

The ground water flow code MODFLOW (McDonald and Harbaugh, 1988) is selected to develop the sub-regional flow model for the study area. MODFLOW solves for the steady state or transient flow of water in the subsurface subject to various boundary conditions, and satisfies all the basic requirements for this study including:

- MODFLOW can simulate fully three-dimensional conditions as conceptualized for the system under study.
- MODFLOW is capable of simulating confined and unconfined multi-layer systems with different units being either confined or unconfined.
- MODFLOW incorporates sinks for pumping conditions needed for post-development analysis.
- MODFLOW incorporates areal recharge boundaries necessary for applying a net recharge to the modeled system.

- MODFLOW incorporates river boundary conditions needed for implementing the various surface water features of the system. The river boundary conditions of MODFLOW are flexible in allowing river connections to multiple aquifer units, as needed to express the connection of Choctawhatchee River and Holmes Creek to the Floridan Aquifer system.

- MODFLOW incorporates general head boundary conditions (head-dependent flux conditions) to allow for expression of boundaries distant from pumping centers or other features of interest, which may otherwise be affected by nearby boundary conditions.

- MODFLOW incorporates drain boundary conditions needed for expressing the reduced recharge that would occur when water levels in the Sand-and-Gravel Aquifer reach the land surface.

5.4 MODEL DOMAIN AND FINITE-DIFFERENCE GRID DESIGN

Figure 5.1 shows the domain of simulation and the areal grid used for this study. The domain encompasses Escambia, Santa Rosa, Okaloosa, and Walton counties and parts of Bay, Washington, and Holmes counties in Florida, and extends north into parts of Escambia, Covington, and Geneva counties in Alabama up to the updip limit of the Floridan Aquifer. The grid is rectangular in plan section with each layer containing 175 columns and 114 rows of grid blocks, totaling 19,950 nodes per layer, with a maximum grid block size of 13,123 ft and a minimum grid block size of 2,297 ft in regions of interest in the center of the study area.

One model layer is used to represent each of the five hydrostratigraphic units. The finite-difference grid blocks are distorted in the vertical dimension to conform to the stratigraphy of the system. The elevation of the top of model layer 1 representing land surface is shown in Figure 5.2. The thickness of model layer 1, representing the Sand-and-Gravel Aquifer is shown in Figure 5.3. The elevation of the bottom of model layer 1 is shown in Figure 5.4. This surface also represents the top of model layer 2. The thickness of model layer 2, representing the Intermediate System is shown in Figure 5.5. The elevation of the bottom of model layer 2 is shown in Figure 5.6. This surface also represents the top of model layer 3. The thickness of model layer 3, representing the Upper Floridan Aquifer and the upper portion of the undifferentiated Floridan Aquifer system to the east, is shown in Figure 5.7. The elevation of the bottom of model layer 3 is shown in Figure 5.8. This surface also represents the top of model layer 4. The thickness of model layer 4, representing the Bucatunna Clay confining unit where it exists, and the middle portion of the undifferentiated Floridan Aquifer system further to the east, is shown in Figure 5.9. The elevation of the bottom of model layer 4 is shown in Figure 5.10. This surface also represents the top of model layer 5. The thickness of model layer 5, representing the Lower Floridan Aquifer and the lower portion of the undifferentiated Floridan Aquifer system, is shown in Figure 5.11. The elevation of the bottom of model layer 5 is shown in Figure 5.12. This surface also represents the top of the Sub-Floridan System.

The three-dimensional finite-difference grid generated for this simulation study requires input for only the elevations of the top and bottom of model layer 1, which is unconfined. The other model layers are treated as confined and their tops, bottoms and thicknesses are not required for the simulation, which directly uses transmissivity values for these layers. The five model layers, with 19,950 grid blocks per layer, totals 99,750 grid blocks in the finite-difference grid.

5.5 BOUNDARY CONDITIONS

Boundary conditions on the top model layer include recharge on shoreward regions of the domain, constant head conditions in the bays and the Gulf of Mexico, river conditions along primary rivers and streams including the Perdido River along the western boundary, and general head boundary conditions along the eastern model domain boundary. Figure 5.13 shows regions of recharge and of prescribed head boundary conditions along the top model layer. A constant value of 20 in/yr (NWFWMD, 1999) is used for recharge to the system, and prescribed head conditions in the bays and the Gulf of Mexico receive a head value of zero representing mean sea level. Drain boundary conditions are also applied on nodes with prescribed recharge, with drain elevations being equal to the land surface elevation to shed the excess recharge which would otherwise allow for water levels in the Sand-and-Gravel Aquifer to exceed land surface. This method is used to determine the spatial variation of recharge to the ground water system. Grid blocks that contain major streams of interest in the study area, which are in communication with the Sand-and-Gravel Aquifer (model layer 1) are identified on Figure 5.14. The Perdido River forms the western boundary of the domain of interest, and this river behaves as a hydraulic divide for the Sand-and-Gravel Aquifer. Therefore, only the lateral eastern model boundary is provided with a general-head (head-dependent-flux) boundary (GHB) condition for the Sand-and-Gravel Aquifer in model layer 1.

Model Layer 2 represents the Intermediate Confining Unit, and is provided a no-flow condition along its lateral boundaries since its contribution is negligible compared to lateral inflow from the aquifer units above and below. No special treatment is required for no-flow conditions in MODFLOW.

Model Layers 3, 4, and 5 are provided GHB conditions along the east and west lateral boundaries and along the south. No flow conditions prevail in the north at the updip limit of the Floridan Aquifer system for model layers 3, 4 and 5. Head values for the GHB condition along the southern boundary are increased with depth to reflect the density of seawater since it is assumed that saline water exists in all aquifers far out into the Gulf of Mexico. Further, model layer 3 is in communication with portions of the Choctawhatchee River and Holmes Creek, and a river boundary condition is applied along these nodes which are shown in Figure 5.15.

The bottom boundary of the modeled system is a no-flow condition representing the extremely low conductivities of the Sub-Floridan System.

Withdrawals from, and injection into the Floridan Aquifer system for the calibration simulation of 1990 conditions are applied using MODFLOW's well boundary conditions which treat the wells as point sources or sinks which are uniformly applied over the entire volume of the node. Well locations are as depicted in Figure 4.6, with pumping values of Table 4.3. This boundary package is not needed for the unstressed pre-development conditions. All other boundary conditions remain the same for pre- and post-development conditions.

5.6 MATERIAL PROPERTIES

Material properties required for the MODFLOW simulation depend on the aquifer conditions. Model layer 1, representing the Sand-and-Gravel Aquifer is an unconfined system and requires input for its horizontal hydraulic conductivity and its top and bottom elevations. The horizontal hydraulic conductivity of model layer 1 is treated as homogeneous, with one average value representing the whole aquifer, as determined by the calibration. MODFLOW's horizontal conductivity averaging option 33 is used to calculate interblock flow between rows and columns of grid blocks. Thus, the unconfined transmissivity between grid blocks uses a logarithmic average of the horizontal hydraulic conductivity times the arithmetic average saturated thickness of the grid blocks. The vertical hydraulic conductivity of the Sand-and-Gravel Aquifer is also treated as homogeneous, with a horizontal to vertical anisotropy ratio of 10:1. The vertical leakance of model layer 1 as required by MODFLOW, is calculated as the weighted harmonic average vertical hydraulic conductivity between the Sand-and-Gravel Aquifer, and the Intermediate System, divided by half the sum of their thicknesses.

Model layer 2 represents the Intermediate System, which is treated as a confined system. Its hydraulic conductivity value is therefore multiplied by the thickness to provide a transmissivity, which is required by MODFLOW. The horizontal hydraulic conductivity is treated as variable within the Intermediate System. MODFLOW's transmissivity averaging option 20 is used to calculate interblock flow between rows and columns of grid blocks. Thus, the confined transmissivity between grid blocks uses a logarithmic average of the transmissivities of the individual grid blocks. The vertical hydraulic conductivity of the Intermediate System is also treated as heterogeneous and follows the trends of the horizontal hydraulic conductivity, with a constant anisotropy ratio of 35:1. This vertical hydraulic conductivity is required for the vertical leakance calculation of model layer 1 as discussed above, as well as for the vertical leakance calculation of model layer 2 representing flow between the Intermediate System and the upper layer of the Floridan Aquifer. The vertical leakance of model layer 2 as required by MODFLOW, is calculated as the weighted harmonic average vertical hydraulic conductivity between the Intermediate System and the Upper Floridan Aquifer, divided by half the sum of the thicknesses between model layer 2 and model layer 3.

Model layer 3 represents the Upper Floridan Aquifer and the upper portion of the undifferentiated Floridan Aquifer system and is treated as confined. Its hydraulic conductivity value is therefore multiplied by the thickness to provide a transmissivity value, which is required by MODFLOW. The horizontal hydraulic conductivity is treated as variable within model layer 3. MODFLOW's transmissivity averaging option 20 is used to calculate interblock flow between rows and columns of grid blocks for this layer. Thus, the confined transmissivity between grid blocks uses a logarithmic average of the transmissivities of the individual grid blocks. The vertical hydraulic conductivity of the Upper Floridan Aquifer system is also treated as heterogeneous and follows the trends of the horizontal hydraulic conductivity, with a constant anisotropy ratio of 35:1. This vertical hydraulic conductivity is required for the vertical leakance calculation of model layer 2 as discussed above, as well as for the vertical leakance calculation of model layer 3 representing flow between the Upper Floridan Aquifer and the Bucatunna Clay. This applies in regions where the Bucatunna

Clay is present, and between the upper portion of the undifferentiated Floridan Aquifer system and the middle portion of the undifferentiated Floridan Aquifer system in eastern regions of the domain. The vertical leakance of model layer 3 is calculated as the weighted harmonic average vertical hydraulic conductivity between the Upper Floridan Aquifer and the Bucatunna Clay (or between the upper portion of the undifferentiated Floridan Aquifer and the middle portion of the undifferentiated Floridan Aquifer in regions where the Bucatunna Clay is absent), divided by half the sum of the thicknesses between model layer 3 and model layer 4.

Model layer 4 represents the Bucatunna Clay confining unit and the middle portion of the undifferentiated Floridan Aquifer system in eastern regions of the domain where the Bucatunna Clay is absent, and is treated as confined. Its hydraulic conductivity value is therefore multiplied by the thickness to provide a transmissivity value, which is required by MODFLOW. The horizontal hydraulic conductivity is treated as variable within model layer 4. MODFLOW's transmissivity averaging option 20 is used to calculate interblock flow between rows and columns of grid blocks for this layer. Thus, the confined transmissivity between grid blocks uses a logarithmic average of the transmissivities of the individual grid blocks. The vertical hydraulic conductivity of the Bucatunna Clay and the middle portion of the undifferentiated Floridan Aquifer system is also treated as heterogeneous and follows the trends of the horizontal hydraulic conductivity, with a constant anisotropy ratio of 35:1. This vertical hydraulic conductivity is required for the vertical leakance calculation of model layer 3 as discussed above, as well as for the vertical leakance calculation of model layer 4 representing flow between the Bucatunna Clay and the Lower Floridan Aquifer in regions where the Bucatunna Clay is present, and between the middle and lower portions of the undifferentiated Floridan Aquifer system in eastern regions of the domain. The vertical leakance of model layer 4 as required by MODFLOW, is calculated as the weighted harmonic average vertical hydraulic conductivity between the Upper Floridan Aquifer and the Bucatunna Clay (or between the upper portion of the undifferentiated Floridan Aquifer and the middle portion of the undifferentiated Floridan Aquifer in regions where the Bucatunna Clay is absent), divided by half the sum of the thicknesses between model layer 4 and model layer 5.

Model layer 5 represents the Lower Floridan Aquifer and the lower portion of the undifferentiated Floridan Aquifer system in eastern regions of the domain, and is treated as confined. Its hydraulic conductivity value is therefore multiplied by the thickness to provide a transmissivity value, which is required by MODFLOW. The horizontal hydraulic conductivity is treated as heterogeneous within model layer 5. MODFLOW's transmissivity averaging option 20 is used to calculate interblock flow between rows and columns of grid blocks for this layer. Thus, the confined transmissivity between grid blocks uses a logarithmic average of the transmissivities of the individual grid blocks. Model layer 5 is the bottommost layer in the simulation, and does not require input for leakance during a MODFLOW simulation. Its vertical hydraulic conductivity is however used to calculate leakance of model layer 4. A constant anisotropy ratio of 35:1 is applied to the lower portions of the Floridan Aquifer for computation of this leakance.

Estimates of these parameter values are used in early model simulations, which are then systematically revised during calibration, to provide a calibrated model of the system, which represents field conditions. The physical parameter values obtained through model calibration are "effective" or "average" parameters over a grid block. The degree of local variation that may be accounted for is necessarily restricted by the grid block size. Furthermore, model calibrated parameter values may not be unique, with different combinations of values providing similar potentiometric surface distributions and fluxes at locations where these values are known. The goal of this modeling study was to obtain realistic calibration parameters that conform to the overall hydrogeologic framework, and that lie within a reasonable range that could be verified using field observations.

5.7 CALIBRATION PROCEDURE

The conceptual model is converted to a numerical representation of the system for simulation using the ground water flow code MODFLOW. Calibration simulations are then performed by systematically varying material parameters within reasonable ranges and investigating the effects of these changes on the results. Calibration simulations also indicate misrepresentations in the conceptualization, which are also adjusted during the calibration process. The water level distributions in all aquifers are checked for consistency with known or estimated field values and trends. Errors between measured and simulated heads are also checked to minimize the residuals to within the prescribed calibration targets. Finally, each calibration simulation is checked for biases in the results that may be present, even though the residuals are small.

5.8 CALIBRATION TARGETS

Calibration targets for 1990 conditions are the potentiometric surface of the Upper Floridan Aquifer depicted in Figure 4.5. Further, water levels in test wells in the Upper Floridan Aquifer, the Lower Floridan Aquifer, and the undifferentiated Floridan Aquifer system are used to calculate residuals between measured and simulated values which determine the goodness of fit of the simulation to known data points. The objective for the calibration, then, is to minimize the errors between measured and calculated water levels at observation locations and also minimize the spatial bias in the errors. Model parameters will be varied within the range of field values during the calibration procedure to produce the calibrated model, which will then be verified by comparing simulation results for pre-development water levels, with the estimated pre-development conditions shown in Figure 4.4. May 1990 potentiometric surface conditions were used for calibration purposes since they are the most complete set of potentiometric data available and are considered consistent with the pumping rates in Table 4.3 (NWFWMD, 1999).

5.9 CALIBRATION RESULTS

The calibration procedure discussed in Section 5.7 was used to provide a calibrated model for the flow system underlying the domain of study. The calibrated horizontal hydraulic conductivity value for the Sand-and-Gravel Aquifer is a uniform 35 ft/d. The underlying Intermediate System acts as a confining unit to the Floridan Aquifer system beneath it, with calibrated vertical hydraulic conductivity values as shown in Figure 5.16. The calibrated transmissivity values of model layer 3 representing the Upper Floridan Aquifer and the upper portion of the undifferentiated Floridan Aquifer system are shown in Figure 5.17. Model layer 4 represents the Bucatunna Clay confining unit, which acts as a confining unit for the Lower Floridan Aquifer, as well as the middle portion of the undifferentiated Floridan Aquifer system. Figure 5.18 shows the vertical hydraulic conductivity distribution of the Bucatunna Clay confining unit, and Figure 5.19 shows the transmissivity of the middle portion of the undifferentiated Floridan Aquifer system where the Bucatunna Clay is absent in model layer 4. Finally, Figure 5.20 shows the calibrated transmissivity values of model layer 5 representing the Lower Floridan Aquifer and the lower portion of the undifferentiated Floridan Aquifer system. Further, Figure 5.21 shows the combined calibrated transmissivities of model layers 3, 4 and 5, to represent the transmissivity of the entire Floridan Aquifer system. East of where the Bucatunna Clay pinches out, this transmissivity represents the transmissivity of the undifferentiated system. All parameter values are noted to be within the range of field observed values for each aquifer unit within the system.

The average potentiometric surface simulated by the calibrated flow model for 1990 pumping conditions is shown in Figure 5.22 for model layer 1, Figure 5.23 for model layer 3, and Figure 5.24 for model layer 5. Figure 5.22 shows the Sand-and-Gravel Aquifer water levels to generally follow the topographic surface as has been observed within the domain. Rivers and streams also have a control on the Sand-and-Gravel Aquifer heads, with heads dropping and seepage faces developing in their vicinity. Upon comparison of Figure 5.23 with the observed 1990 Floridan Aquifer potentiometric surface of Figure 4.5, it is again noted that the simulation represents the field conditions fairly well. Water levels in the Upper Floridan Aquifer model layer are as low as -97 ft NGVD in the center of depression of the high pumping regions around Choctawhatchee Bay and are as high as 280 ft in the upland regions near the northern edge of the domain. Figure 5.24 shows that there is considerable mounding of water levels in the Lower Floridan Aquifer near the injection wells of Solutia and Cytec (253 ft of water level elevation at its peak), which dissipates away from this region. Table 5.1 shows the observed versus simulated ground water elevations for 1990 pumping conditions along with the residuals and relevant statistics of calibration. The mean residual (simulated minus measured water levels) is 2.46 ft showing a negligible bias in calibration, with a root-mean-squared (RMS) residual of 12.56 ft, and a worst error of 57.4 ft. These errors, though considerably large, are acceptable for the simulation since it is noted that water levels in nearby observation wells can vary by large amounts and the model cannot capture this feature. Figures 5.25 and 5.26 show the water level residuals at measurement points for model layers 3 and 5 respectively, for 1990 conditions. The residuals are unbiased spatially, with random occurrence of positive and negative residuals, except for in central and northern Okaloosa and Walton counties, where a slight positive bias is noted. The highest residual of about 57 ft is noted to occur near West Bay, in Bay County. This location is close to the southern and eastern model boundary, which may influence the value even with the general head boundary conditions provided in the model. Figure 5.27 shows a scatter plot of simulated versus measured heads, which shows that the points lie close to the regression line with a small scatter, for the whole range of measured head values, again indicating that the calibration was unbiased. Figure 5.28 shows the frequency distribution of ground water residuals. It is noted that there is an even distribution of residuals about the zero value again indicating an unbiased calibration.

The water budgets for the calibrated model, of 1990 pumping conditions, is shown in Table 5.2. The recharge of 20 in/yr, applied to a model area of 7,635.3 square miles provides the major input of water to the system totaling 7,270.8 Mgal/d. A significant portion of this water is rejected recharge via the drain boundary condition of MODFLOW, which is applied along every top-layer node that is not a river node. This rejected recharge prevents water levels in the Sand-and-Gravel

Aquifer from exceeding land surface, and totals 2,343.5 Mgal/d. Other sources of water to the system include the injection wells totaling 3 Mgal/d, lateral general head boundaries totaling 23.6 Mgal/d, and water induced from the constant head boundaries in the bays and the Gulf of Mexico totaling 5.4 Mgal/d. The rivers in model layer 1 reject recharge as well as drain the Sand-and-Gravel Aquifer, which removes 4,208.8 Mgal/d from the system. The Floridan Aquifer drains directly into the Choctawhatchee River and Holmes Creek in the amount of 331.6 Mgal/d for this simulation, as calculated from river fluxes in model layer 3. Other outflux of water occurs along the constant head boundaries within bays and the Gulf of Mexico totaling 288.2 Mgal/d, via wells totaling 42.3 Mgal/d, and via lateral general head boundaries totaling 88.4 Mgal/d. A negligible mass balance error was noted for the simulation.

5.10 PRE-DEVELOPMENT VERIFICATION RESULTS

The calibrated model of the domain was verified by examining its performance for pre-development conditions. A steady state simulation was therefore performed using the calibrated model, without any pumping in the domain. Material parameter values and other boundary conditions were kept the same as for the calibrated model (NWFWMD, 1999). Figures 5.29, 5.30 and 5.31 show the simulated pre-development water levels in model layers 1, 3 and 5 respectively. The pre-development water levels in the Floridan Aquifer, as shown in Figure 4.4 are in close comparison to water levels representing the Upper Floridan Aquifer shown in Figure 5.30. Further, the simulated hydraulic heads in the Lower Floridan Aquifer are almost the same as those of the Upper Floridan Aquifer in and east of Okaloosa County, as is believed for pre-development conditions. The model is therefore noted to represent field conditions during stressed and unstressed periods. The differences in water levels between pre- and post-development conditions represent the drawdowns in the system from pre-development times. The simulated drawdowns from pre-development times are shown in Figures 5.32, 5.33 and 5.34 for model layers 1, 3 and 5 respectively. Drawdowns in model layer 1 due to pumping are negligible, and induced recharge makes up for the water deficiency which was otherwise shed from the system as runoff via the drain boundary conditions. Model layer 3 is noted to have pumping related drawdowns as high as 140 ft around the pumping centers off Choctawhatchee Bay which dissipates rapidly eastward, but extends northward and westward to the model boundary with almost 10 ft of drawdown at these extents. Drawdowns in model layer 5 are up to 120 ft around the pumping centers off Choctawhatchee Bay, with mounding of up to 160 ft near the injection regions in the Lower Floridan Aquifer.

The water budget for pre-development conditions is shown in Table 5.3. The recharge of 20 in/yr again translates to a total inflow of 7,270.8 Mgal/d. Rejected recharge prevents water levels in the Sand-and-Gravel Aquifer from exceeding land surface via drain boundary conditions, and totals 2,355.1 Mgal/d. This is about 11.6 Mgal/d more than for the 1990 pumping simulation case, which induces the extra recharge due to pumping. Other sources of water to the system includes lateral general head boundaries totaling 20.1 Mgal/d, which is 3.5 Mgal/d less than the 1990 pumping simulation case. The rivers in model layer 1 reject recharge as well as drain the Sand-and-Gravel Aquifer, and remove 4,216.2 Mgal/d from the system. The Floridan Aquifer drains directly into the Choctawhatchee River and Holmes Creek in the amount of 333.5 Mgal/d for this simulation, as calculated from river fluxes in model layer 3. Other outflux of water occurs along the constant head boundaries within bays and the Gulf of Mexico totaling 296.4 Mgal/d and via lateral general head boundaries totaling 89.7 Mgal/d. A negligible mass balance error was noted for the simulation.

5.11 MODEL SENSITIVITY ANALYSES

A series of sensitivity runs were performed to determine sensitivity of 1990 simulated water levels to variations in calibrated model parameters. Significant parameters that affect the Floridan Aquifer system include recharge, leakance of the Intermediate System, and transmissivity of the Floridan Aquifer system. These parameters were individually investigated in the sensitivity analyses with all other parameters kept at the calibrated (base case) values. Each sensitivity analysis is subject to four additional realizations, with a range of variability equal to that expected at the site, with two realizations being on the higher side, and two on the lower side of base case values.

5.11.1 Sensitivity to Recharge

For this sensitivity analysis, the recharge value of 20 in/yr was increased uniformly to 23 in/yr and 26 in/yr, and decreased uniformly to 17 in/yr and 14 in/yr to test its effect on the calibrated system. Figure 5.35 shows a plot of the RMS residual versus the recharge rate, depicting that the residuals do not change significantly with recharge rate. The RMS error increases slightly for both the higher and the lower recharge rates. In both instances the increase is very modest. Figures 5.36, 5.37 and 5.38 show the effects of changing the recharge to 26 in/yr, on water levels in model layers 1, 3 and 5 respectively. The plots depict the difference in water level values from the calibrated base case conditions for each unit (i.e., base case head value minus sensitivity simulation head value). The higher recharge value increases water levels in model layer 1 by as much as 15 ft, mostly in the western half of the domain, with little change in the eastern half where excess recharge is being shed by the drain boundary conditions. In model layers 3 and 5, heads are higher by up to 3 ft for recharge of 26 in/yr, than for the base case, with the largest differences occurring in the northern portions of Okaloosa County and in Bay and Washington counties where the Intermediate System is thin. Since recharge variation causes insignificant changes in calibration residuals or model conclusions, the model has a Type I sensitivity to recharge (ASTM D5611-94), which is of little concern to the system.

5.11.2 Sensitivity to Floridan Aquifer Transmissivity

For this sensitivity analysis, the transmissivity values of model layers 3, 4 and 5 (representing the Floridan Aquifer system) were multiplied by scaling factors of 0.6, 0.8, 1.2 and 1.4 throughout the domain to test its effect on the calibrated system. Figure 5.39 shows a plot of the RMS residual versus the scaling factor on transmissivity. The RMS error increases considerably for both lower and higher transmissivity values from the base case, being larger than thirty-five ft when the base case transmissivity is multiplied by a factor of 0.6. Figures 5.40, 5.41 and 5.42 show the effects of a scaling factor of 1.4, on water levels in model layers 1, 3 and 5 respectively. The plots depict the difference in water level values from the calibrated base case conditions (i.e., base case head value minus sensitivity simulation head value). Increasing the Floridan Aquifer transmissivity does not affect the Sand-and-Gravel Aquifer heads significantly. In model layer 3, however, the larger transmissivities provide higher heads (by about 35 ft) near the pumping centers around

Choctawhatchee Bay, than for the base case. Thus, the drawdowns are not as pronounced due to larger fluxes reaching the pumping centers. A similar situation occurs in model layer 5 around the cone of depression, with heads higher than the base case by about 30 ft. Further, the injection in Escambia and Santa Rosa counties does not provide as pronounced a mound with water levels being lower by about 60 ft at the injection locations than for the base case, due to the more rapid dissipation allowed by the higher transmissivity values. Since transmissivity variation causes significant changes to both calibration residuals and model conclusions, the model has a Type III sensitivity to transmissivity of the Floridan Aquifer system (ASTM D5611-94) which is of little concern since even though model conclusions change as a result of variation of the input, the variation of the parameters causes the model to become uncalibrated and the calibration procedure eliminates those values from being considered as realistic.

5.11.3 Sensitivity to Vertical Conductivity of the Intermediate System

For this sensitivity analysis, the vertical hydraulic conductivity values of the Intermediate System were multiplied by a scaling factors of 0.5, 0.75, 2.5 and 5 throughout the domain to test its effect on the calibrated system. MODFLOW accepts the vertical leakance as input for each model layer, which is equal to the thickness-weighted harmonic mean of the vertical conductivities of the layer and the one beneath it, divided by the vertical nodal distance. Hence, the leakance of model layer 1 represents the mean vertical conductivity of the Sand-and-Gravel Aquifer and the Intermediate System. The leakance of model layer 2 represents the mean vertical conductivity of the Intermediate System and of the upper limestones of the Floridan Aquifer. Since the harmonic mean biases the mean value towards the lower one, these vertical leakances practically represent the vertical conductivity of the Intermediate System, which is orders of magnitude smaller than of its adjacent units, the Sand-and-Gravel Aquifer, and the Upper Floridan Aquifer unit. Hence, these scaling factors can be directly applied to the vertical leakance values for model layer 1 and model layer 2. Figure 5.43 shows a plot of the RMS residual versus the scaling factor on the vertical conductivity of the Intermediate System. A scaling factor of 0.75 on the vertical hydraulic conductivity of the Intermediate System provides little change to the RMS error, which then increases to about 18 for a lower scaling factor of 0.5. For higher scaling factors of 2.5 and 5, the RMS error is noted to increase considerably, up to almost 30 ft. Figures 5.44, 5.45 and 5.46 show the effects of a scaling factor of 5, on water levels in model layers 1, 3 and 5 respectively. The plots depict the difference in water level values from calibrated base case conditions (i.e., base case head value minus sensitivity simulation head value). Water levels in model layer 1 decrease by as much as 10 ft in eastern regions of the domain for increased vertical hydraulic conductivity of the Intermediate System, as more water flows through to the lower layers. In the western portions of the study area, water levels are not affected significantly, since the Intermediate System is very thick in these regions and provides sufficient confinement even with higher conductivities. Water levels in model layers 3 and 5 are noted to increase by as much as 40 ft from the base case, with model layer 5 being a muted replica of model layer 3. Little change is noted between this sensitivity case and the base case, in regions where the Floridan Aquifer communicates directly with the Choctawhatchee River and Holmes Creek since this feature is the controlling feature for leakance. Since varying the vertical conductivity values of the Intermediate System causes significant changes to both calibration residuals and model conclusions, the model has a Type III sensitivity to this parameter (ASTM D5611-94). Type III sensitivities are of little concern since even though model conclusions change as a result of variation of the input, the variation of parameters causes the model to become uncalibrated, and the calibration procedure eliminates those values from being considered as realistic.

6.0 SUMMARY AND CONCLUSIONS

A ground water flow model has been calibrated for a portion of the Floridan Aquifer system within the Northwest Florida Water Management District, shown in Figure 1.1. Available hydrologic data in the region and previous modeling studies were first examined to develop a conceptual model of the system. A numerical representation was then developed, for simulation using the ground water flow code, MODFLOW. The model was calibrated using May 1990 potentiometric surface and average daily rate pumping conditions and validated against estimated pre-development conditions for the system. Calibration errors were within 2.46 ft for mean average heads and within 12.56 ft for RMS residuals of heads in the Floridan Aquifer system. The calibrated model is unbiased with respect to head values as well as their spatial distribution.

Sensitivity analyses were also conducted on significant parameters of the system. Recharge, transmissivity of the Floridan Aquifer system, and vertical hydraulic conductivity of the Intermediate System were identified as critical parameters for the study. The Floridan Aquifer system is noted to be insensitive to recharge boundary conditions applied to the model, indicating a Type I sensitivity. Type III sensitivities are noted for transmissivities of the Floridan Aquifer system and for vertical hydraulic conductivities of the Intermediate System. Thus, model results as well as the calibration statistics are affected by these parameters.

The model may be applied for investigations of the impacts of various long-term future pumping strategies from the Floridan Aquifer system and on Floridan Aquifer water levels. The model may also be used as a baseline for conducting more detailed investigations of water resource evaluation using transient analyses, for saltwater intrusion analyses and for further investigations concerning the Sand-and-Gravel Aquifer. Once additional data from different years becomes available, the model should be further tested to verify its range of predictive capability.

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TABLES

Table 4.1 Geologic Units in Southern Okaloosa and Walton Counties and Their Hydrogeologic Equivalents (modified from Barr, 1983)

Epoch	Stage	Formation	Thickness	Lithologic Description	Hydrogeologic Unit	Hydrogeologic Characteristics
Recent to Pliocene		Pliocene to Recent Sands	50-250	Unconsolidated, white to light gray fine to medium quartz sand. Accessories include heavy minerals and phosphate.	Sand-and-Gravel Aquifer	Water mainly unconfined. In Fort Walton Beach, includes surficial unconfined unit and lower leaky artesian unit. Yields range from less than 20 gal/min in coastal lowlands of Walton County to 1,000 gal/min in uplands of western Okaloosa County. Tapped by shallow wells for domestic supply and a few larger capacity wells for irrigation. Currently not used by municipal systems for public consumption.
		Citronelle Formation	50-250	Predominantly non-marine quartz sands with thin stringers of clay or gravel discontinuous over short distances.		
		Coarse Clastics	50-200	Found only along the western portion of Okaloosa County, the Coarse Clastics are comprised of poorly consolidated sand, gravel, clay, and shell beds.		
Pliocene to Middle Miocene		Intracoastal	0-360	Lithologically, the Intracoastal is made up of poorly consolidated, sandy, clayey, microfossiliferous limestone.	Intermediate System	Restricts vertical movement of water because of thickness and comparatively low permeability. In the area of investigations grades laterally from dense clay and sandy clay in western part to clayey, silty sand in the eastern part. Not a source of water.
Upper to Middle Miocene		Alum Bluff Group	0-300	The Alum Bluff occurs as a mixture of sands, clays, and shell beds in relatively well-sorted thin beds. The matrix material is commonly clay or carbonate cement.		
Upper to Middle Miocene		Pensacola Clay	0-190	In the western half of the study area, the Pensacola Clay interfingers with the Intracoastal Formation and Alum Bluff Group. The Pensacola Clay is predominantly a bluish gray to olive gray, dense, silty clay.		

Table 4.1 Geologic Units in Southern Okaloosa and Walton Counties and Their Hydrogeologic Equivalents (modified from Barr, 1983)

Epoch	Stage	Formation	Thickness	Lithologic Description	Hydrogeologic Unit	Hydrogeologic Characteristics
Middle to Lower Miocene		Bruce Creek Limestone	20-220	Light gray to white in appearance, the Bruce Creek is moderately indurated, granular, and occurs as a clastic limestone. Accessories include a sand fraction that increases north and east.	Upper Limestone of the Floridan Aquifer System	Principal source of water in area of investigation. Yields large quantities of fresh water under confined conditions. Yields range from 250 gal/min to over 1,000 gal/min. Sustained yields are generally lowest immediately adjacent to the coast in Okaloosa County. Individual zones vary greatly in permeability and vertical hydraulic connection. Contains over 250 ppm chlorides in parts of south-eastern Walton and southwestern Okaloosa counties.
Lower Miocene		Chattahoochee Formation	30-140	Lithologically, similar to Chickasawhay Limestones but slightly less dolomitic. Silt and clay content increase towards the top of the formation.		
Upper Oligocene		Chickasawhay Limestone	30-260	Primarily a tan sucrosic dolomite but may also occur as a cream to buff fossiliferous limestone.		
Middle to Lower Oligocene		Bucatunna Clay-Member of Byram Formation	0-130	The Bucatunna is a medium brown to dusky, yellowish-brown calcareous clay. Accessories include up to 10 percent quartz sand and up to one percent phosphate. The top contact of the Bucatunna Clay is sharp and well defined from the overlying limestone.	Bucatunna Clay Confining Unit	Where present, restricts vertical movement of water between overlying and underlying hydrogeologic units. Generally present in coastal Walton and Okaloosa counties but absent in northern parts of area.
Upper Eocene	Jackson	Ocala Limestone	165-600	A white to light gray, chalky, fossiliferous relatively pure calcium carbonate limestone. Occasionally the limestone is inter-layered with thin streaks of light brown to tan dolomite layers.	Lower Limestone of the Floridan Aquifer System	Comprises a separate hydrogeologic unit in coastal Walton and Okaloosa counties. In other parts, cannot be hydrologically distinguished from upper limestone aquifer.
Middle Eocene	Claiborne	Lisbon/ Tallahatta Formations	345-500 170-300	Massive shaly to chalky limestones often dark gray to brownish gray to cream in color. Thin shaly beds predominate in the more calcareous portions.	Sub-Floridan System	Predominantly impermeable strata. Comprises the base of the groundwater flow system.

Table 4.2 Specific Capacities for Floridan Aquifer Wells

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
ARGONAUT STREET 01	5	678	CBBS028T03SR16W	306	590	6	28.52	2.2	A
ARIZONA CHEMICAL #1	5	437	ABBS014T04SR14W	210	293	10	10	50.15	A
ARIZONA CHEMICAL #2	5	415	DAAS014T04SR14W	210	324	10	10	20.48	A
BAY PINES MOBILE HOM	5	481	DCAS007T04SR13W	312	600	6	32	13.6	A
BLEACH PLANT, WELL#7	5	427	BCAS014T04SR14W	336	540	6	10	5.06	A
BROWN MIDDLE SCHOOL	5	777	DCBS008T03SR13W	147	350	6	55	12.5	A
CT MARTIAL FARMS #3	5	2072	BACS012T01SR15W	144	365	10	82	73	A
EWELL INDUSTRIES	5	594	ACCS034T03SR14W	195	450	6	35	11.82	A
HARDERS PARK #1	5	783	BDBS011T03SR13W	217	355	8	36	8.48	A
INT PAPER CO #20	5	479	AADS011T04SR14W	201	503	18	27.06	18.8	A
INT PAPER CO #25	5	485	DCCS012T04SR14W	199	501	18	19.59	33.3	A
INT PAPER CO #26	5	484	DCBS012T04SR14W	206	470	18	28.11	27.6	A
INT PAPER CO #31	5	476	ABCS007T04SR13W	202	510	18	28.33	90.9	A
INT PAPER CO #35	5	471	ABDS007T04SR13W	205	512	18	32.17	41.8	A
INT PAPER CO #36	5	464	AACS008T04SR13W	203	515	18	28.2	82	A
INT PAPER CO #37	5	473	CCBS008T04SR13W	201	570	18	26.8	66.3	A
INT PAPER CO #38	5	487	DCAS008T04SR13W	205	575	18	32.81	41	A
INT PAPER CO #39	5	470	DDBS008T04SR13W	180	577	18	13.87	36.1	A
INT PAPER TEST WELL1	5	424	ADAS014T04SR14W	200	350	15	19.35	17.5	A
JOHN PITTS ROAD PARK	5	785	CBBS011T03SR13W	215	460	8	30	5.36	A
LANSING SMITH #2	5	842	ABDS036T02SR15W	316	405	14	9.63	20.19	A
LANSING SMITH #3	5	834	DBCS030T02SR15W	150	400	14	12	26.8	A
LYNN HAVEN #5	5	718	CCAS016T03SR14W	371	671	24	12	7.5	A
LYNN HAVEN WELL #1	5	773	CCBS009T03SR14W	314	497	12	14	14.5	A
MCCALL SOD FARM #1	5	975	DADS015T02SR14W	262	600	12	32	72.3	A
MCCALL SOD FARM #2	5	942	DAAS023T02SR14W	280	614	12	25	40	A
MEXICO BEACH #1	5	205	BADS023T06SR12W	424	497	18	12	13.9	A
MEXICO BEACH #2	5	207	ABCS023T06SR12W	451	617	18	13	6.49	A
MEXICO BEACH TEST #2	5	204	ABDS023T06SR12W	200	600	6	10	32.9	A
MIDWEST PIPE #1	5	599	CBDS034T03SR15W	225	500	6	7	10	A
MINE DEFENSE LAB #3	5	575	ABAS004T04SR15W	260	483	12	10	3.1	A
NAVAL COASTAL HOUSES	5	637	CAAS033T03SR15W	294	515	6	13	7.4	A
PANAMA CITY BCH #1	5	739	DDAS018T03SR16W	342	762	16	36	17	A
PANAMA CITY BCH #10	5	768	CADS012T03SR17W	422	709	18	30	23	A
PANAMA CITY BCH #11	5	681	DDDS023T03SR16W	298	556	18	15	2	A

Table 4.2 Specific Capacities for Floridan Aquifer Wells (continued)

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
PANAMA CITY BCH #12	5	794	DABS011T03SR17W	440	793	18	32	3.2	A
PANAMA CITY BCH #13	5	765	ABDS007T03SR16W	400	780	18	21	2.3	A
PANAMA CITY BCH #2	5	747	BBAS018T03SR16W	345	807	16	31	5.8	A
PANAMA CITY BCH #3	5	756	DDCS007T03SR16W	341	776	16	28	16	A
PANAMA CITY BCH #4	5	745	DAAS018T03SR16W	346	800	16	35	6.4	A
PANAMA CITY BCH #5	5	684	BABS027T03SR16W	358	816	18	17	2.1	A
PANAMA CITY BCH #6	5	685	BAAS027T03SR16W	347	717	18	30	33	A
PANAMA CITY BCH #7	5	600	ACCS036T03SR16W	292	434	10	7.89	2.4	A
PANAMA CITY BCH #8	5	593	DDCS036T03SR16W	286	450	10	10.89	1.8	A
PANAMA CITY BCH #9	5	743	CAAS017T03SR16W	406	770	18	40	8.2	A
POINT ROYAL DEV	5	498	DCBS009T04SR15W	294	535	6	10	2.1	A
ST ANDREWS PLANT #1	5	616	DDAS036T03SR15W	220	330	10	13.56	16.8	A
ST ANDREWS PLANT #2	5	632	BDAS036T03SR15W	213	438	10	10	5.6	A
ST ANDREWS PLANT #3	5	614	DCAS036T03SR15W	212	444	10	10	4.7	A
ST ANDREWS PLANT #4	5	643	BBAS036T03SR15W	426	640	10	13.55	5.7	A
ST ANDREWS PLANT #5	5	646	BAAS036T03SR15W	423	603	10	15.3	6.4	A
ST ANDREWS PLANT #6	5	647	AAAS036T03SR15W	423	604	10	13.02	3.6	A
ST ANDREWS PLANT #7	5	633	CBAS036T03SR15W	418	610	12	10	8.1	A
STATE ROAD DEPT	5	704	BCAS020T03SR16W	275	436	6	10	1.1	A
TAFB STRANGE POINT#1	5	248	ACDS025T05SR13W	395	526	12	12	11.2	A
TYNDALL #10 BACKUP#1	5	289	DDAS007T05SR13W	345	645	16	27.85	6.8	A
TYNDALL #12-7001	5	309	BCCS004T05SR13W	280	350	6	3.28	40	A
TYNDALL #2 BAY 43	5	301	CAAS007T05SR13W	339	435	12	26.21	12	A
TYNDALL #3 BAY 44	5	297	CBBS012T05SR14W	356	661	12	24.25	6.6	A
TYNDALL #4-3029	5	304	BBAS012T05SR14W	356	435	12	24.21	11.3	A
TYNDALL #8 DESTROYED	5	310	BCDS001T05SR14W	338	437	12	30.94	7	A
TYNDALL #9 BACKUP #2	5	320	CAAS001T05SR14W	351	644	16	31.17	11.7	A
TYNDALL FIELD	5	259	BDDS021T05SR13W	350	610	6	21.24	5.2	A
TYNDALL GC #1-3010	5	358	ADAS029T04SR14W	324	502	8	13	4.6	A
TYNDALL WELL #3	5	296	CBBS012T05SR14W	356	437	12	24.25	5.1	A
US NAVY COASTAL #1	5	627	DCAS033T03SR15W	300	550	6	11	4.5	A
WASTE ENERGY #1	5	835	DAS035T02SR13W	195	292	12	60	13.26	A
WEST P. C. BEACH	5	740	ADAS018T03SR16W	342	762	16	37.57	27.8	A
MONSANTO #1/SHAL MON	33	3998	S000T01NR30W	972	1140	8	37.56	4.9	B
MONSANTO #3/SHAL MON	33	7187	S014T01NR30W	968	1172	6	45.07	2.5	B

Table 4.2 Specific Capacities for Floridan Aquifer Wells (continued)

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
MONSANTO CLEAR CREEK	33	3783	S000T01NR30W	1430	1596	8	15.22	3.1	C
MONSANTO/INJECTION A	33	3994	S000T01NR30W	1390	1808	12	32.19	3	C
MONSANTO/N MONITOR	33	4173	S000T01NR30W	1340	1523	8	7.83	2.33	C
BONIFAY #1	59	5030	DAAS006T04NR14W	113	166	18	120	9.1	A
BONIFAY #2	59	5033	DBBS001T04NR15W	124	193	18	125	18.7	A
PONCE DE LEON #1	59	6009	S028T04NR17W	128	221	12	61	13.89	A
AUBURN #2	91	5236	DBDS027T04NR23W	350	500	12	254.13	27.3	A
AUBURN #3	91	5118	CBDS027T04NR23W	330	580	12	211.91	23.5	A
AUBURN #4	91	5081	BACS027T04NR23W	542	797	18	272.52	10.04	A
AUBURN #5	91	5013	BDCS034T03NR23W	410	673	16	231.68	15.4	A
BLUEWATER #1 (AUX)	91	3063	ABAS023T01SR22W	295	397	12	50	7	B
BLUEWATER #2	91	2891	BCBS026T01SR22W	310	489	18	23	53.57	B
BLUEWATER #3	91	3091	BDDS015T01SR22W	350	550	24	27	23.3	B
BLUEWATER #4	91	2814	DADS023T01SR22W	415	615	24	14	24	B
CRESTVIEW #1	91	4882	BDAS017T03NR23W	430	604	10	254.3	24	A
CRESTVIEW #4	91	4855	DBCS017T03NR23W	423	643	16	218	56.52	A
CRESTVIEW #5	91	5012	BDDS006T03NR23W	460	638	18	288.59	37	A
CRESTVIEW #6	91	7171	BAAS031T03NR23W	430	618	24	150	28.57	A
CRYSTAL BEACH TEST	91	1482	S000T02SR22W	395	725	6	15	20.01	B
DWU #1	91	1687	S000T02SR23W	440	657	10	25	7.39	B
DWU #2	91	1601	S000T02SR22W	460	662	16	28	74	B
DWU #3	91	1654	S000T02SR22W	465	746	16	15	376	B
DWU #4	91	1838	DDCS008T02SR22W	457	746	16	15	18	B
DWU #5	91	1796	LGTS000T02SR22W	503	747	16	12	12	B
DWU #5 LOWER FLRD	91	7181	LGTS000T02SR22W	503	1123	16	12	13	B, C
DWU #7	91	1586	S000T02SR22W	425	606	20	26	188	B
DWU #8	91	1611	LGTS023T02SR22W	510	677	12	18	131	B
DWU #9	91	1661	CABS022T02SR22W	505	670	12	13	61.5	B
EAFB A-10 BLDG 9203	91	1765	CDBS024T02SR25W	592	834	8	12	3.8	B
EAFB A-11 BLDG 9277	91	1720	LGTS000T02SR25W	654	752	6	13.3	6.2	B
EAFB A-3 BLDG 8351	91	1627	CDCS021T02SR23W	520	750	6	15	1.7	B
EAFB A-3 BLDG 8351	91	1628	CDCS021T02SR23W	460	630	6	15	2.6	B
EAFB A-7 BLDG 9281	91	1719	ABDS021T02SR24W	550	750	6	12	1.7	B
EAFB AUX FLD 6 #6204	91	4262	CBCS034T02NR25W	527	690	10	135.07	62.5	B
EAFB AUX FLD-6 #3	91	4245	DCDS034T02NR25W	629	775	10	18.54	31.8	B

Table 4.2 Specific Capacities for Floridan Aquifer Wells (continued)

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
EAFB FIELD 5 #2	91	3923	ABDS015T01NR24W	524	710	10	178.03	125	A
EAFB FLD#3 BLDG#3102	91	4376	CBBS027T02NR23W	510	795	6	221.5	3.13	A
EAFB FLD#3 BLDG#3204	91	4368	BCBS027T02NR23W	456	609	10	196.72	12.5	A
EAFB FLD-4 #2 #4204	91	3209	BBAS018T01SR23W	442	591	10	89.33	10	B
EAFB FLD2 BDG #2204	91	3841	DDDS016T01NR22W	409	652	10	155.61	8.93	A
EAFB FLD2 BLDG #2102	91	3815	ABBS021T01NR22W	436	585	10	154	10.42	A
EAFB FLD6#2 BLG 6102	91	4246	DDCS034T02NR25W	524	693	10	136	50	A
EAFB HOUS #11 #10634	91	2786	DBAS034T01SR23W	382	896	12	51	32	B
EAFB HOUS #12 #2829	91	2750	CDBS033T01SR23W	444	606	16	52	38	B
EAFB HOUS #15 #1320	91	3004	ABDS021T01SR23W	482	736	10	1.15	20.45	B
EAFB HOUS #16 #2755	91	2762	DDBS033T01SR23W	449	624	12	43	56.3	B
EAFB HURL #7 #91136	91	2168	ADCS018T02SR25W	719	865	16	38	37.91	B
EAFB JACKSON #1507	91	3381	CACS006T01SR22W	370	524	6	59	5.29	A
EAFB MAIN #2 #82	91	3033	BDAS024T01SR23W	362	607	12	51.6	18.87	A
EAFB MAIN #2A BLDG82	91	6006	S024T01SR23W	396	765	16	50	28.57	B
EAFB MAIN #3 #31	91	3012	DCAS024T01SR23W	364	652	12	61	21.74	B
EAFB MAIN #4 #303	91	2985	DCBS026T01SR23W	357	557	12	47	24.9	B
EAFB PINCHOT #1565	91	2887	AACS030T01SR23W	430	582	6	25	50	A
EAFB RANGE C64A	91	4495	DDDS014T02NR22W	378	540	6	320	15	A
EAFB SADS X A-21	91	2124	BBAS017T02SR25W	752	872	6	31	5.34	B
EAFB WELL #1 #4102	91	3186	DBAS018T01SR23W	524	640	8	87	13.88	A
EAFB WELL #1 #5102	91	3935	DCBS015T01NR24W	528	680	10	212	3.13	A
EAFB WELL #65 #1216	91	3083	ABAS023T01SR23W	413	582	6	63	18.75	B
EAFB WHITE POINT #3	91	2696	DDAS035T01NR22W	360	550	6	9	7.8	B
FWB #11	91	2146	ADDS009T02SR24W	580	976	18	30	40.6	B
FWB #3	91	2099	DDCS010T02SR24W	548	735	16	38.19	9.7	B
FWB #5	91	2085	BBBS013T02SR24W	510	803	24	8	4.3	B
FWB #6	91	2807	DBBS035T01SR24W	500	750	24	35.64	38.9	B
FWB #7	91	2758	DDBS035T01SR24W	451	631	16	37	34.3	B
HOLT #1	91	4692	BBAS033T03NR25W	540	645	8	190	14.57	B
HOLT #2	91	4704	ADDS004T02NR25W	663	673	8	202	12.6	B
ISL-3 (AMUSEMENT PK)	91	1710	BBCS019T02SR23W	500	854	12	12	1.2	B
ISL-4 (TREAT PLANT)	91	1714	ABDS24T2SR24W	555	746	10	8	2.7	B
ISL-6 (EL MATADOR)	91	1742	CCAS023T02SR24W	535	874	12	10	1.15	B
ISL-7 (JOHN BEASLEY)	91	1688	ABDS019T02SR23W	518	864	24	6	1.79	B

Table 4.2 Specific Capacities for Floridan Aquifer Wells (continued)

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
LAUREL HILL #1	91	5647	BABS005T05NR22W	428	484	6	285	2.7	A
LAUREL HILL #1A	91	5648	BABS005T05NR22W	410	730	12	285	2.06	A
LAUREL HILL #3	91	5667	BDCS032T06NR22W	300	500	8	305	2.83	A
LAUREL HILL #4	91	5658	CCCS033T06NR22W	262	485	12	270	3.64	A
LONGWOOD #1	91	2872	CADS030T01SR23W		680	6	43	35.3	B
MARY ESTHER #1	91	2023	CACS016T02SR24W	615	787	10	45	5.8	B
MARY ESTHER #2	91	2035	BACS016T02SR24W	595	764	12	20	18.5	B
MARY ESTHER #3	91	1940	AACS017T02SR24W	665	902	16	56	4.74	B
MARY ESTHER #4	91	2031	DADS017T02SR24W	521	850	20	25	8.44	B
MARY ESTHER #4-TEST	91	2030	DBDS016T02SR24W	521	750	20	25	6.08	B
MC #2 (LIVE OAK)	91	4709	BCAS032T03NR23W	536	664	18	140	19.25	B
MC#3(CREST IND PARK)	91	4997	CCCS003T03NR23W	392	603	16	195.42	20.73	A
MILLIGAN #2	91	4845	DDDS017T03NR24W	500	591	12	212	9.44	B
NICEVILLE #1	91	3350	ABAS006T01SR22W	340	465	10	15.7	21.9	A
NICEVILLE #10	91	3432	BBBS005T01SR22W	350	600	18	0	9.45	A
NICEVILLE #3	91	3367	BCBS008T01SR22W	375	523	16	48	9.7	A
NICEVILLE #4	91	3482	CCAS031T01NR22W	373	635	10	85	3	A
NICEVILLE #5	91	3457	BBBS005T01SR22W	382	499	16	3.73	14.3	A
NICEVILLE #6	91	3326	CCAS009T01SR22W	310	495	16	30	3.3	A
NICEVILLE #8	91	3231	DBDS010T01SR22W	586	800	16	30	15.46	A
OC-1 (OFFICE)	91	2404	AABS012T02SR24W	495	644	16	12	120	B
OC-10 (LOWERY)	91	2463	CADS004T02SR24W	590	834	24	36	71.5	B
OC-11 (FOREST)	91	7209	S025T01SR24W	495	745	24	35	40.17	B
OC-2 (LONGWOOD)	91	2874	CADS030T01SR23W	433	680	16	57	35.3	B
OC-3 (NEWCASTLE)	91	2506	CCAS002T02SR24W	500	652	12	13	57.1	B
OC-4 (GREEN STREET)	91	2508	CAAS002T02SR24W	500	652	24	18.51	142.9	B
OC-5 (SHALIMAR)	91	2581	AADS005T02SR23W	546	734	12	19	42.9	B
OC-6 (HAWKINS ROAD)	91	2554	DDAS003T02SR24W	515	650	24	42	45.5	B
OC-7(SHALIMAR ANNEX)	91	2584	BBBS006T02SR23W	560	770	24	17	18.9	B
OCWS/SEASHORE VIL #3	91	2048	AACS016T02SR25W	695	952	12	18	19.5	B
OCWS/SEASHORE VIL #4	91	5942	DBDS014T02SR25W	610	902	24	26	4.04	B
OKALOOSA CORR INST#1	91	4632	DDBS003T02NR23W	454	705	16	98	10	A
OKALOOSA CORR INST#2	91	4623	ACCS002T02NR23W	422	712	16	101	10.6	A
ROYAL OAKS #3	91	3068	BBAS022T01SR22W	285	440	6	13	10	B
SHALIMAR & PLEW ST	91	2524	ADBS006T02SR23W	380	536	6	7	11.8	B

Table 4.2 Specific Capacities for Floridan Aquifer Wells (continued)

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
SWU #6	91	1481	LGTS030T02SR21W	495	713	16	15	17.1	B
SWU #7	91	7306	NO LAND NET	480	700	20	7.5	375	B
VALPARAISO #1	91	3258	BCBS018T01SR23W		425	6	15	23.3	B
VALPARAISO #2	91	3240	ACDS012T01SR23W		600	10	60	16.6	B
VALPARAISO #4	91	3126	ABDS013T01SR23W	408	532	18	67	30.76	B
WRIGHT UPPER FLRD	91	2822	BBAS034T01SR24W	503	858	10	57.67	57.5	B
WRP LOWER FLRD	91	7174	S018T02SR22W	920	1083	8	15	31.25	C
DEEP TEST MONITOR	113	3755	S000T01NR29W	1464	1546	6	103	3.5	C
EAFB A-15 BLDG 12512	113	1645	DBBS25T2SR26W	708	1088	6	11	1.2	A
EAST MILTON #3	113	4393	ACCS029T02NR26W	660	800	18	148	2.8	B
EAST MILTON #3-TEST1	113	4391	ACCS029T02NR26W	660	800	18	148	11.4	B
EAST MILTON #3-TEST2	113	4392	ACCS029T02NR26W	660	785	18	148	2	B
HOLLEY-NAVARRE #2	113	2627	BDBS005T02SR26W	765	966	18	52	22.85	B
HOLLEY-NAVARRE #3	113	2053	BCDS014T02SR26W	886	1053	18	47	25	B
HOLLEY-NAVARRE #4	113	1841	BADS023T02SR27W	926	1104	16	33	38.9	B
HOLLEY-NAVARRE 4 TST	113	1840	BADS023T02SR27W	928	1103	8	33	24.7	B
JOHN CASEY #1	113	5556	BBDS018T05NR28W	90	130	6	225	10	A
MIDWAY #1	113	1887	ADBS024T02SR28W	744	1092	20	20	50	B
MIDWAY #2	113	2318	AACS007T02SR26W	933	1104	20	29	244	B
NAVARRE BEACH #2	113	1483	CCCS028T02SR26W	782	1051	10	6	34	B
NAVARRE BEACH #3	113	1369	ADBS031T02SR26W	925	1030	16	6	46.6	B
STATE HATCHERY #3	113	4788	CCAS025T03NR26W	510	587	16	95	13.5	B
YELLOW R. LOWER FLRD	113	3555	ADDS036T01NR27W	1220	1500	6	125.36	11.9	C
ARGYLE #2	131	4720	AS030T03NR18W	240	520	12	255	19.83	A
CITY OF PAXTON	131	5680	DACS036T06NR21W	281	420	8	332	13.5	A
DEFUNIAK SPRGS #3	131	4713	S035T03NR19W	304	621	12	257.79	80	A
DEFUNIAK SPRGS #5	131	5987	BBCS023T03NR19W	300	592	24	195	5.45	A
EAFB (HAGSTROM)	131	3393	DDAS002T01SR21W	275	325	6	80	1.25	A
EAFB D-51 EOD #116	131	3160	DAAS017T01NR21W	292	445	6	72	18.75	A
EAFB FLD-1 #2 #1204	131	4553	DCCS009T02NR21W	323	630	10	230.17	25	A
EAFB R52N ROAD #200	131	3280	ADDS015T01NR21W	341	390	6	170	7.5	A
EAFB RANGE 63 #32	131	3820	AABS014T01NR20W	278	440	10	142	42	A
EAFB RANGE D51 RD218	131	3061	ADCS017T01SR21W	185	230	6	60	1.87	A
EAFB ROCK HILL TRUCK	131	4055	BS016T01NR19W	260	360	6	80	8.57	A
EAFB ROCK HILL TWR#2	131	4011	CABS011T01NR19W	310	450	8	211	2.5	A

Table 4.2 Specific Capacities for Floridan Aquifer Wells (continued)

WELL NAME	COUNTY	NWF_ID	LAND_NET	CSG DEPTH (ft)	TD (ft)	DIA (in)	ELEVATION (ft above sea level)	SPCAP (gal/min/ft)	AQUIFER
EAFB WELL #1 #1102	131	4565	ADCS009T02NR21W	327	625	10	238	3	A
FCSC #11	131	2365	ACDS002T03SR20W	260	490	8	26	1.16	A
FCSC #12	131	1136	AABS012T03SR20W	260	490	8	20	1.16	A
FCSC #4	131	1044	CDAS015T03SR19W	270	480	12	15	1.43	A
FCSC #5A	131	922	AABS028T03SR18W	270	405	6	25	1.11	A
FREEPORT #3	131	3315	BADS010T01SR19W	252	440	16	63	47	A
INLET BEACH #2	131	863	DAAS036T03SR18W	263	610	12	23	1.06	A
MOSSY HEAD #2	131	5197	AADS019T04NR20W	397	517	12	285	3.89	A
PAXTON #2	131	5709	AAAS036T06NR21W	203	401	10	305	17.64	A
PERDUE H-3	131	4746	DBDS030T03NR18W	220	330	6	221.44	17.5	A
PERDUE P-1	131	4719	CDCS029T03NR18W	252	441	8	237.39	29.4	A
PERDUE P-4	131	4728	BCDS029T03NR18W	217	560	12	235.39	15.79	A
QUAIL RUN ESTATES	131	2390	ABDS002T02SR19W	115	200	6	15	5	A
REDBAY GOLF #1	131	3304	DDS003T01NR17W	165	370	6	80	21.43	A
RU ROCKHILL #1	131	7250	ADS002T01NR19W	284	710	16	163	17.5	A
RU ROCKHILL #1 TEST	131	7175	ADS002T02NR19W	284	550	16	163	15.77	A
SWU #2	131	1453	DACS027T02SR21W	400	600	18	5	22.2	B
SWU #3	131	1476	DBDS030T02SR21W	426	572	16	16.4	181.8	B
SWU #4	131	1431	CCCS026T02SR21W	555	655	16	37	19.8	B
SWU #5	131	1445	DACS025T02SR21W	435	730	16	10	2.89	B
WRP #2	131	7176	S007T01NR18W	220	512	24	150	50	A
CHIPLEY #1	133	5834	CDDS010T04NR13W	155	275	24	160	2000	A
CHIPLEY #2	133	5002	ADBS004T04NR13W	102	129	10	101	526	A
CHIPLEY #3	133	5833	BADS004T04NR13W	120	174	16	106.92	2800	A
DYSON #2	133	4014	ADAS007T02NR15W	196	524	16	40	35.7	A
GUETTLER WELL #1	133	4552	DCCS007T03NR13W	155	206	8	70	425	A
WAUSAU #2	133	4292	BDAS025T03NR14W	170	200	8	85.89	108.5	A
WCI #1	133	3313	CCBS005T01NR14W	245	440	24	155	21.7	A
WCI #2	133	3312	ABDS005T01NR14W	261	442	24	163.26	750	A

Note: Bay County = 5; Escambia County = 33; Okaloosa County = 91; Santa Rosa County = 113; Walton County = 131; Washington County = 133
Aquifer Code A = Undifferentiated Floridan Aquifer; B = Upper Floridan Aquifer; C = Lower Floridan Aquifer

Table 4.3 Well Pumpage Data as Used in the Model (yearly average pumping rate)

NWF_ID	WELL NAME	LAT	LONG	WELL DEPTH (ft)	CASING DEPTH (ft)	TOTAL PUMPAGE (gal/d)	LAYER 3 (gal/d)	LAYER 4 (gal/d)	LAYER 5 (gal/d)
4757	ARGYLE #1	304335	860317	372	248	-34500	-34500	0	0
4720	ARGYLE #2	304347	860449	520	240	-34500	-25699	-2464	-6337
5080	AUBURN #1	304804	863306	515	400	-440736	-440736	0	0
5236	AUBURN #2	305035	863133	500	350	-220001	-220001	0	0
5118	AUBURN #3	304844	862936	580	330	-210113	-175388	-16812	-17913
5081	AUBURN #4	304805	863520	797	542	-112491	-38934	-8825	-64732
5068	BAKER #2	304750	864043	708	520	-154873	-103592	-40543	-10738
2891	BLUEWATER #2	302809	862459	489	310	-129314	-129314	0	0
3091	BLUEWATER #3	302930	862529	550	350	-748493	-748493	0	0
5030	BONIFAY #1	304712	854050	166	113	-420000	-420000	0	0
5033	BONIFAY #2	304709	854107	193	124	-420000	-420000	0	0
4945	CARYVILLE #2	304705	854808	185	75	-50000	-50000	0	0
5178	CARYVILLE #3	304629	854819	340	222	-50000	0	-10824	-39176
4882	CRESTVIEW #1	304538	863406	604	430	-407502	-407502	0	0
4827	CRESTVIEW #3	304504	863428	710	463	-407502	-336306	-33037	-38159
4855	CRESTVIEW #4	304519	863339	643	423	-407502	-407502	0	0
5012	CRESTVIEW #5	304657	863434	638	460	-407502	-407502	0	0
3770	CYTEC PRIMARY INJECT	303413	870638	1526	1338	816592	0	0	816592
4714	DEFUNIAK SPRGS #1	304312	860706	650	521	-224998	0	-32080	-192918
4721	DEFUNIAK SPRGS #2	304315	860718	705	372	-224998	-66979	-13520	-144499
4713	DEFUNIAK SPRGS #3	304311	860705	621	304	-224998	-126831	-14199	-83968
4793	DEFUNIAK SPRGS #4	304411	860810	650	305	-224998	-104886	-13044	-107068
1687	DWU #1	302342	862944	657	440	-428334	-428334	0	0
1601	DWU #2	302320	862753	662	460	-428334	-428334	0	0
1654	DWU #3	302332	862847	746	465	-428334	-428334	0	0
1838	DWU #4	302410	862909	746	457	-428334	-428334	0	0
1796	DWU #5	302402	863032	747	503	-428334	-428334	0	0
1586	DWU #7	302308	862516	606	425	-428334	-428334	0	0
1697	EAFB A-11 BLDG 9262	302342	864248	802	440	-2498	-2498	0	0
1664	EAFB A-13 BLDG 9296	302334	864446	850	669	-2498	-2498	0	0
1736	EAFB A-6 BLDG 8552	302357	863829	880	731	-2498	-2498	0	0
4262	EAFB AUX FLD 6 #6204	303742	864414	690	527	-81098	-81098	0	0
4376	EAFB AUX FLD#3 #3102	303835	863147	795	510	-106298	-106298	0	0
2815	EAFB HOUS #10 #10941	302744	863301	896	400	-390328	-390328	0	0

Table 4.3 Well Pumpage Data as Used in the Model (yearly average pumping rate)

NWF_ID	WELL NAME	LAT	LONG	WELL DEPTH (ft)	CASING DEPTH (ft)	TOTAL PUMPAGE (gal/d)	LAYER 3 (gal/d)	LAYER 4 (gal/d)	LAYER 5 (gal/d)
2787	EAFB HOUS #11 #10634	302749	863236	750	441	-390328	-390328	0	0
2750	EAFB HOUS #12 #2829	302733	863313	606	444	-390328	-390328	0	0
3004	EAFB HOUS #15 #1320	302843	863318	736	482	-390328	-390328	0	0
2884	EAFB HOUS #7 #2590	302809	863238	627	424	-390328	-390328	0	0
2825	EAFB HOUS #8 #2594	302748	863250	603	425	-390328	-390328	0	0
2860	EAFB HOUS #9 #10000	302801	863206	695	450	-390328	-390328	0	0
2073	EAFB HURL #1 #90308	302458	864206	805	550	-160341	-160341	0	0
2134	EAFB HURL #2 #90601	302521	864152	807	596	-160341	-160341	0	0
2113	EAFB HURL #5 #90355	302515	864217	876	714	-160341	-160341	0	0
2168	EAFB HURL #7 #91136	302528	864035	865	719	-160341	-160341	0	0
3071	EAFB MAIN #1 #859	302918	862953	575	374	-390328	-390328	0	0
3033	EAFB MAIN #2 #82	302910	863015	607	362	-390328	-390328	0	0
3012	EAFB MAIN #3 #31	302903	863032	652	364	-390328	-390328	0	0
2985	EAFB MAIN #4 #303	302849	863014	557	357	-390328	-390328	0	0
2984	EAFB MAIN #5 #616	302853	862950	642	360	-390328	-390328	0	0
3015	EAFB MAIN #6 #62	302903	863020	590	365	-390328	-390328	0	0
1043	FCSC #10	301920	860828	460	290	-30000	-30000	0	0
5837	FCSC #2A	301902	860731	500	275	-30000	-30000	0	0
1000	FCSC #3	301857	860654	470	260	-30000	-30000	0	0
1044	FCSC #4	301920	860828	480	270	-189999	-189999	0	0
922	FCSC #5A	301745	860311	405	270	-58000	-58000	0	0
3095	FREEPORT #2	302931	860814	504	168	-149996	-114591	-8928	-26477
2792	FWB #10	302735	863716	800	487	-412522	-412522	0	0
2146	FWB #11	302524	864001	976	580	-576274	-576274	0	0
2093	FWB #2	302510	863642	839	494	-40272	-40272	0	0
2099	FWB #3	302511	863821	735	548	-72683	-72683	0	0
2085	FWB #5	302505	863555	803	510	-73094	-73094	0	0
2807	FWB #6	302738	863647	750	500	-645696	-645696	0	0
2758	FWB #7	302723	863647	631	451	-1071345	-1071345	0	0
2108	FWB #8	302512	863844	850	520	-52000	-52000	0	0
2139	FWB #9	302522	864001	938	567	-909208	-909208	0	0
2320	HOLLEY-NAVARRE #1	302555	865146	980	750	-186139	-186139	0	0
2627	HOLLEY-NAVARRE #2	302652	865202	966	765	-88847	-88847	0	0
2053	HOLLEY-NAVARRE #3	302445	864913	1053	886	-706381	-706381	0	0

Table 4.3 Well Pumpage Data as Used in the Model (yearly average pumping rate)

NWF_ID	WELL NAME	LAT	LONG	WELL DEPTH (ft)	CASING DEPTH (ft)	TOTAL (gal/d)	LAYER 3 (gal/d)	LAYER 4 (gal/d)	LAYER 5 (gal/d)
4692	HOLT #1	304257	864436	645	540	-30136	-30136	0	0
4704	HOLT #2	304246	864504	673	663	-30136	-30136	0	0
863	INLET BEACH #2	301647	860030	610	263	-25000	-25000	0	0
1710	ISL-3 (AMUSEMENT PK)	302356	863540	854	500	-93148	-93148	0	0
1742	ISL-6 (EL MATADOR)	302358	863753	874	535	-119313	-119313	0	0
1688	ISL-7 (JOHN BEASLEY)	302342	863500	864	518	-16792	-16792	0	0
843	LANSING SMITH #1	301615	854153	370	148	-381367	-381367	0	0
842	LANSING SMITH #2	301615	854139	405	316	-381367	-381367	0	0
834	LANSING SMITH #3	301608	854153	400	150	-381367	-381367	0	0
5585	LAUREL HILL #2	305702	862832	517	362	-44745	-9925	-5778	-29042
5667	LAUREL HILL #3	305801	862718	500	300	-83342	-41269	-8347	-33726
4732	LOUISIANA-PACIFIC #1	304321	864050	575	486	-30002	-30002	0	0
6043	LYNN HAVEN #3	301438	853851	604	330	-382500	-382500	0	0
718	LYNN HAVEN #5	301334	852925	671	371	-382500	-287464	-25530	-69506
773	LYNN HAVEN WELL #1	301429	853854	497	314	-382500	-382500	0	0
760	LYNN HAVEN WELL #4	301414	853853	566	375	-382500	-382500	0	0
2023	MARY ESTHER #1	302439	863947	787	615	-233331	-233331	0	0
2035	MARY ESTHER #2	302442	863941	764	595	-233331	-233331	0	0
1940	MARY ESTHER #3	302449	864047	902	665	-233331	-233331	0	0
4791	MC #1 (ANTIOCH ROAD)	304409	863714	740	401	-102737	-48624	-8060	-46054
4709	MC #2 (LIVE OAK)	304254	863714	664	536	-236988	-180780	-47006	-9203
4997	MC #3 (CREST IND PARK)	304653	863132	603	392	-8489	-6971	-805	-713
1887	MIDWAY #1	302418	865214	1092	744	-610495	-610495	0	0
2318	MIDWAY #2	302556	865403	1104	933	-754821	-754821	0	0
4873	MILLIGAN #1	304524	863905	503	351	-89999	-89999	0	0
3994	MONSANTO/INJECT A	303537	871456	1808	1390	719950	0	0	719950
3974	MONSANTO/INJECT B	303528	871506	1654	1415	719950	0	0	719950
4005	MONSANTO/INJECT C	303541	871444	1664	1386	719950	0	0	719950
2651	MOODY KELLY #1	302701	863717	670	540	-35006	-35006	0	0
4888	MOSSY HEAD #1	304556	861827	470	360	-40003	-40003	0	0
5197	MOSSY HEAD #2	304951	861650	517	397	-40003	-40003	0	0
1444	NAVARRE BEACH #1	302242	865247	950	810	-8325	-8325	0	0
1483	NAVARRE BEACH #2	302255	865157	1051	782	-106328	-106328	0	0
1369	NAVARRE BEACH #3	302242	865306	1030	925	-229202	-229202	0	0

Table 4.3 Well Pumpage Data as Used in the Model (yearly average pumping rate)

NWF_ID	WELL NAME	LAT	LONG	WELL DEPTH (ft)	CASING DEPTH (ft)	TOTAL PUMPAGE (gal/d)	LAYER 3 (gal/d)	LAYER 4 (gal/d)	LAYER 5 (gal/d)
3350	NICEVILLE #1	303114	862916	465	340	-374366	-374366	0	0
3432	NICEVILLE #10	303203	862750	600	350	-333615	-333615	0	0
3256	NICEVILLE #2	303041	862841	471	318	-360304	-360304	0	0
3367	NICEVILLE #3	303052	862756	523	375	-377014	-377014	0	0
3482	NICEVILLE #4	303212	862929	635	373	-42516	-42516	0	0
3457	NICEVILLE #5	303203	862837	499	382	-640190	-640190	0	0
3326	NICEVILLE #6	303109	862654	495	310	-211205	-211205	0	0
3231	NICEVILLE #8	303043	862618	800	586	-171097	-80258	-15991	-74849
2404	OC-1 (OFFICE)	302612	863611	644	495	-765563	-765563	0	0
2874	OC-2 (LONGWOOD)	302804	863510	680	433	-452928	-452928	0	0
2506	OC-3 (NEWCASTLE)	302630	863648	652	500	-210629	-210629	0	0
2508	OC-4 (GREEN STREET)	302632	863748	652	500	-663176	-663176	0	0
2581	OC-5 (SHALIMAR)	302624	863417	734	546	-482467	-482467	0	0
2554	OC-6 (HAWKINS ROAD)	302644	863830	650	515	-597809	-597809	0	0
2584	OC-7(SHALIMAR ANNEX)	302643	863454	770	560	-640302	-640302	0	0
2759	OC-8 (GREEN ACRES)	302721	863648	864	518	-661860	-661860	0	0
2236	OC-9 (NORTHGATE)	302533	863851	910	518	-270790	-270790	0	0
2046	OCWS/SEASHORE VIL #1	302445	864409	882	651	-94248	-94248	0	0
2040	OCWS/SEASHORE VIL #2	302457	864713	1061	686	-140003	-140003	0	0
2048	OCWS/SEASHORE VIL #3	302455	864552	952	695	-336001	-336001	0	0
4632	OKALOOSA CORR INST#1	304146	863133	705	454	-65001	-37663	-5182	-22156
4623	OKALOOSA CORR INST#2	304141	863124	712	422	-65001	-40674	-4487	-19840
3026	OLD GOLF COURSE #1	302904	862547	381	312	-142120	-142120	0	0
739	PANAMA CITY BCH #1	301346	855325	762	342	-393077	-320480	-18719	-53878
768	PANAMA CITY BCH #10	301423	855427	709	422	-393077	-344642	-27437	-20998
681	PANAMA CITY BCH #11	301220	854941	556	298	-393077	-393077	0	0
794	PANAMA CITY BCH #12	301450	855502	793	440	-393077	-258134	-22293	-112650
765	PANAMA CITY BCH #13	301430	855251	780	400	-393077	-264437	-20702	-107939
747	PANAMA CITY BCH #2	301358	855321	807	345	-393077	-281516	-17025	-94537
756	PANAMA CITY BCH #3	301408	855315	776	341	-393077	-297287	-18088	-77702
745	PANAMA CITY BCH #4	301357	855335	800	346	-393077	-290284	-17324	-85470
684	PANAMA CITY BCH #5	301221	855041	816	358	-393077	-272460	-17165	-103452
685	PANAMA CITY BCH #6	301245	855114	717	347	-393077	-358589	-21261	-13227
600	PANAMA CITY BCH #7	301046	854834	434	292	-393077	-393077	0	0

Table 4.3 Well Pumpage Data as Used in the Model (yearly average pumping rate)

NWF_ID	WELL NAME	LAT	LONG	WELL DEPTH (ft)	CASING DEPTH (ft)	TOTAL PUMPAGE (gal/d)	LAYER 3 (gal/d)	LAYER 4 (gal/d)	LAYER 5 (gal/d)
593	PANAMA CITY BCH #8	301041	854815	450	286	-393077	-393077	0	0
743	PANAMA CITY BCH #9	301353	855240	770	406	-393077	-299022	-21605	-72451
5690	PAXTON #1	305825	861806	375	260	-94996	-94996	0	0
5709	PAXTON #2	305858	861841	401	203	-94996	-94996	0	0
4728	PERDUE P-4	304331	860411	560	217	-840004	-517538	-48980	-273487
2390	QUAIL RUN ESTATES	302609	860652	200	115	-14249	-14249	0	0
891	SANDCLIFFS	301714	860217	660	390	-45000	-45000	0	0
2971	SEMINOLE #1	302842	862438	450		-35470	-35470	0	0
3049	SEMINOLE #2	302902	862435	450		-35470	-35470	0	0
2972	SEMINOLE #6	302845	862434	450		-35470	-35470	0	0
2909	SOUTH GOLF COURSE	302817	862537	610	314	-142120	-142120	0	0
1430	SWU #1	302243	862134	683	479	-307996	-307996	0	0
1453	SWU #2	302248	862033	600	400	-307996	-307996	0	0
1476	SWU #3	302259	862254	572	426	-307996	-307996	0	0
1431	SWU #4	302241	861943	655	555	-307996	-307996	0	0
1445	SWU #5	302246	861835	730	435	-307996	-307996	0	0
1604	US COAST GUARD #1	302327	863136	680	430	-10000	-10000	0	0
3258	VALPARAISO #1	303019	862925	425		-152502	-152502	0	0
3240	VALPARAISO #2	303034	863005	600		-152502	-152502	0	0
3295	VALPARAISO #3	303054	862956	537	405	-152502	-152502	0	0
3126	VALPARAISO #4	302954	862952	532	408	-152502	-152502	0	0
5998	VERNON #1	303732	854242	171	136	-50000	-50000	0	0
4244	VERNON #2	303732	854242	174	136	-50000	-50000	0	0
6023	VILLA TASSO #1	302738	862311	480	250	-28000	-28000	0	0
6024	VILLA TASSO #2	302740	862329	485	250	-28000	-28000	0	0

Negative pumping rate indicates withdrawal well
Positive pumping rate indicates injection well

Table 5.1 Observed and Simulated Ground Water Elevations for 1990 Pumping Conditions and Residual Calibration

Well Designation		Well Construction Details			Hydraulic Head (ft relative to sea level)			
Name	NWF_ID	Elevation (ft above sea level)	Well Depth (ft)	Casing Depth (ft)	Observed (ft)	Simulated (ft)	Model Layer	Sim – Obs (ft)
CYTEC UPPER FLRD	3771	109	1108	1096	15	18.3	(3)	3.3
DWU #1	1687	25	657	440	-61.88	-55.33	(3)	6.55
MARY ESTHER #2	2035	20	764	595	-104.78	-94.01	(3)	10.77
FWB #6	2807	35.64	750	500	-106.29	-87.14	(3)	19.15
EAFB WELL #61 HDSTD	2995	66	702	404	-73.7	-65.89	(3)	7.81
FAF #72	3485	123	506	218	29.17	30.78	(3)	1.61
EAFB RANGE 63 #32	3820	142	440	278	33.14	39.4	(3)	6.26
FAF #2 MONITOR	3807	153.46	440	191	39.36	43.08	(3)	3.72
EAFB AUX FLD 6 #6204	4262	135.07	690	527	9.92	5.13	(3)	-4.79
CAMP EUCHEE - BSA	4784	274	509	323	121.23	116.74	(3)	-4.49
CRESTVIEW #4	4855	218	643	423	58	52.54	(3)	-5.46
BAKER #2	5068	245	708	520	62.45	64.72	(3)	2.27
POINT WASHINGTON	1371	2.3	365	65	13.36	11.74	(3)	-1.62
USGS LAKE FIVE-O 1.5	5964	87.56	140	100	43.14	45	(3)	1.86
PAXTON WELCOME CTR	5656	324	350	230	218.02	226.81	(3)	8.79
ST THOMAS SQUARE	563	10	560	294	-76.91	-19.48	(3)	57.43
ARGONAUT STREET 02	679	26	369	267	-65.54	-39.93	(3)	25.61
FANNIN AIRPORT	697	4.03	345	326	-5.18	3.52	(3)	8.7
VAN BUTLER	1074	7.46	466	424	11.68	5.9	(3)	-5.78
ERIC ALLEN	1186	6	340	100	0.57	2.87	(3)	2.3

Table 5.1 Observed and Simulated Ground Water Elevations for 1990 Pumping Conditions and Residual Calibration

Well Designation		Well Construction Details			Hydraulic Head (ft relative to sea level)			
Name	NWF_ID	Elevation (ft above sea level)	Well Depth (ft)	Casing Depth (ft)	Observed (ft)	Simulated (ft)	Model Layer	Sim – Obs (ft)
J. HOLLEY	1404	12	545	265	9.23	-0.12	(3)	-9.35
M. FOUNTAIN	1408	23	420	350	-35.7	-27.37	(3)	8.33
NAVARRE BEACH MO#1	1472	5	940	730	-43.59	-37	(3)	6.59
WAYSIDE PARK	1675	12	690	477	-92.5	-64.57	(3)	27.93
BRIDGETENDER	1763	5	337	0	9.09	8.86	(3)	-0.23
NAVARRE CEMENT PLANT	1839	20	940	900	-34.79	-37.44	(3)	-2.65
OKALOOSA SCHOOL BRD	1894	16.44	672	504	-98.23	-75.66	(3)	22.57
TYE-PARRISH POINT	1917	5	808	652	-63.92	-47.81	(3)	16.11
S. L. MATTHEWS	2034	5	330	165	2.54	5.75	(3)	3.21
WRIGHT ELEMENTARY	2394	21	635	535	-95.64	-86.78	(3)	8.86
OLD COWFORD	2534	16	196	60	23.6	22.95	(3)	-0.65
EAFB WHITE POINT #02	2695	10	425	0	-40.5	-39.02	(3)	1.48
SELMA MADARA	2738	4	250	100	12	14.84	(3)	2.84
RAY WRIGHT	2820	19	440	220	-17.02	-30.22	(3)	-13.2
WRIGHT UPPER FLRD	2822	57.67	858	503	-84.26	-73.64	(3)	10.62
THOMAS MILLER	2961	40	200	0	15.8	26.35	(3)	10.55
R.E. LALONDE	2962	2	316	132	-4.98	-9.21	(3)	-4.23
EAFB POSTIL POINT	2994	7.54	510	300	-66.54	-58.11	(3)	8.43
CITY OF FREEPORT	3101	2.7	187	0	16.2	23.11	(3)	6.91
EAFB FLD-4 #2 #4204	3209	89.33	591	442	-43.67	-48.04	(3)	-4.37

Table 5.1 Observed and Simulated Ground Water Elevations for 1990 Pumping Conditions and Residual Calibration

Well Designation		Well Construction Details			Hydraulic Head (ft relative to sea level)			
Name	NWF_ID	Elevation (ft above sea level)	Well Depth (ft)	Casing Depth (ft)	Observed (ft)	Simulated (ft)	Model Layer	Sim – Obs (ft)
THOMPSON	3293	59.79	207	62	17.72	30.55	(3)	12.83
EAFB METTS TOWER	3642	192	796	600	4.36	-17.65	(3)	-22.01
REDBAY TOWER	3877	176	0	0	27.99	28.22	(3)	0.23
EAFB FIELD 5 #2	3923	178.03	710	524	-6.55	-8.85	(3)	-2.3
EAFB ROCK HILL TWR	4010	205	440	248	48.48	48.63	(3)	0.15
EAFB SITE C-62	4490	214.88	620	354	79.28	77.48	(3)	-1.8
EAFB FLD-1 #2 #1204	4553	230.17	630	323	75.89	71.44	(3)	-4.45
DAN HUGHES	4733	62	187	0	64.47	56.91	(3)	-7.56
ARGYLE TOWER	4754	261	236	226	85.15	82.16	(3)	-2.99
KINGDOM HALL	4940	111	220	181	88.43	81.96	(3)	-6.47
PETER	5240	279	320	180	186.73	168.53	(3)	-18.2
PROSPERITY TOWER	5271	285.68	233	200	77.37	80.55	(3)	3.18
GEOGHAGAN	5261	261	415	285	174.22	173.74	(3)	-0.48
HUTCH PAGETT	5346	304.77	341	0	116.6	145.72	(3)	29.12
JACKSON STILL FLORD	5417	270	240	167	204.3	191.78	(3)	-12.52
W.D. FLOURNOY	5499	178.43	500	400	156.78	139.04	(3)	-17.74
LAUREL HILL TOWER	5543	290	425	415	175.03	175.71	(3)	0.68
MONSANTO #2/SHAL MON	4006	12	1133	1088	43	41.13	(3)	-1.87
HOLIDAY CAMPGROUND	7367	24	520	0	-27.35	-24.86	(3)	2.49
EAFB FLD 4 LOW FLRD	3210	89	1371	938	-43.22	-47.78	(5)	-4.56

Table 5.1 Observed and Simulated Ground Water Elevations for 1990 Pumping Conditions and Residual Calibration

Well Designation		Well Construction Details			Hydraulic Head (ft relative to sea level)			
Name	NWF_ID	Elevation (ft above sea level)	Well Depth (ft)	Casing Depth (ft)	Observed (ft)	Simulated (ft)	Model Layer	Sim – Obs (ft)
YELLOW R. LOWER FLRD	3555	125.36	1500	1220	51.56	48.98	(5)	-2.58
WHITING LOWER FLRD	4700	125.05	1290	985	118.98	101.06	(5)	-17.92
CAMP HENDERSON	5746	280	815	702	109.07	130.03	(5)	20.96
BEAL CEM. LOWER FLRD	2173	35	1156	1016	-18.59	-25.96	(5)	-7.37
STD-BY INJECT WELL	3738	68	1508	1320	177	179.87	(5)	2.87
MONSANTO CLEAR CREEK	3783	15.22	1596	1430	248	240.36	(5)	-7.64
NORTH MONITOR WELL	3926	122	1492	1276	157	148.75	(5)	-8.25
MONSANTO/N MONITOR	4173	7.83	1523	1340	236	233.45	(5)	-2.55

MEAN ERROR	2.46 ft
MEAN ABSOLUTE ERROR	8.52 ft
RMS ERROR	12.56 ft
NO. OF POINTS	68
MAX. DIFFERENCE	57.43 ft

Table 5.2 Calibrated Model Water Budgets for 1990 Pumping Conditions

Water Budget Component	Flow (Mgal/d)
Inflow	
Overland Recharge	7270.8
General Head Boundaries	23.6
Injection Wells	3.0
Constant Head Boundaries in bays and Gulf of Mexico	5.4
Total Inflow:	**7302.8**
Outflow	
Rejected Recharge (Upland Drain Boundaries)	2343.5
River Boundaries in Layer 1	4208.8
River Boundaries in Layer 3	331.6
General Head Boundaries	88.4
Pumping Wells	42.3
Constant Head Boundaries in bays and Gulf of Mexico	288.2
Total Outflow:	**7302.8**

Table 5.3 Calibrated Model Water Budgets for Pre-development Conditions

Water Budget Component	Flow (Mgal/d)
Inflow	
Overland Recharge	7270.8
General Head Boundaries	20.1
Constant Head Boundaries in bays and Gulf of Mexico	0.0
Total Inflow:	**7290.9**
Outflow	
Rejected Recharge (Upland Drain Boundaries)	2355.1
River Boundaries in Layer 1	4216.2
River Boundaries in Layer 3	333.5
General Head Boundaries	89.7
Constant Head Boundaries in bays and Gulf of Mexico	296.4
Total Outflow:	**7290.9**

FIGURES

Location of Study Area

Legend

Hydrology
Counties
State / Coast Line

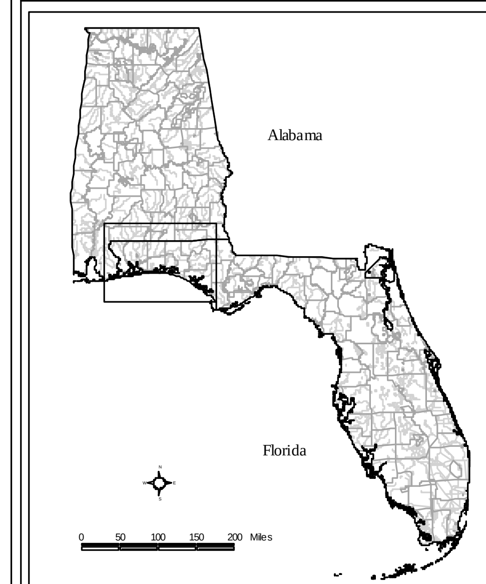

Figure 1.1

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Revised: 04/16/00 DD

HYDRO GeoLogic INC.

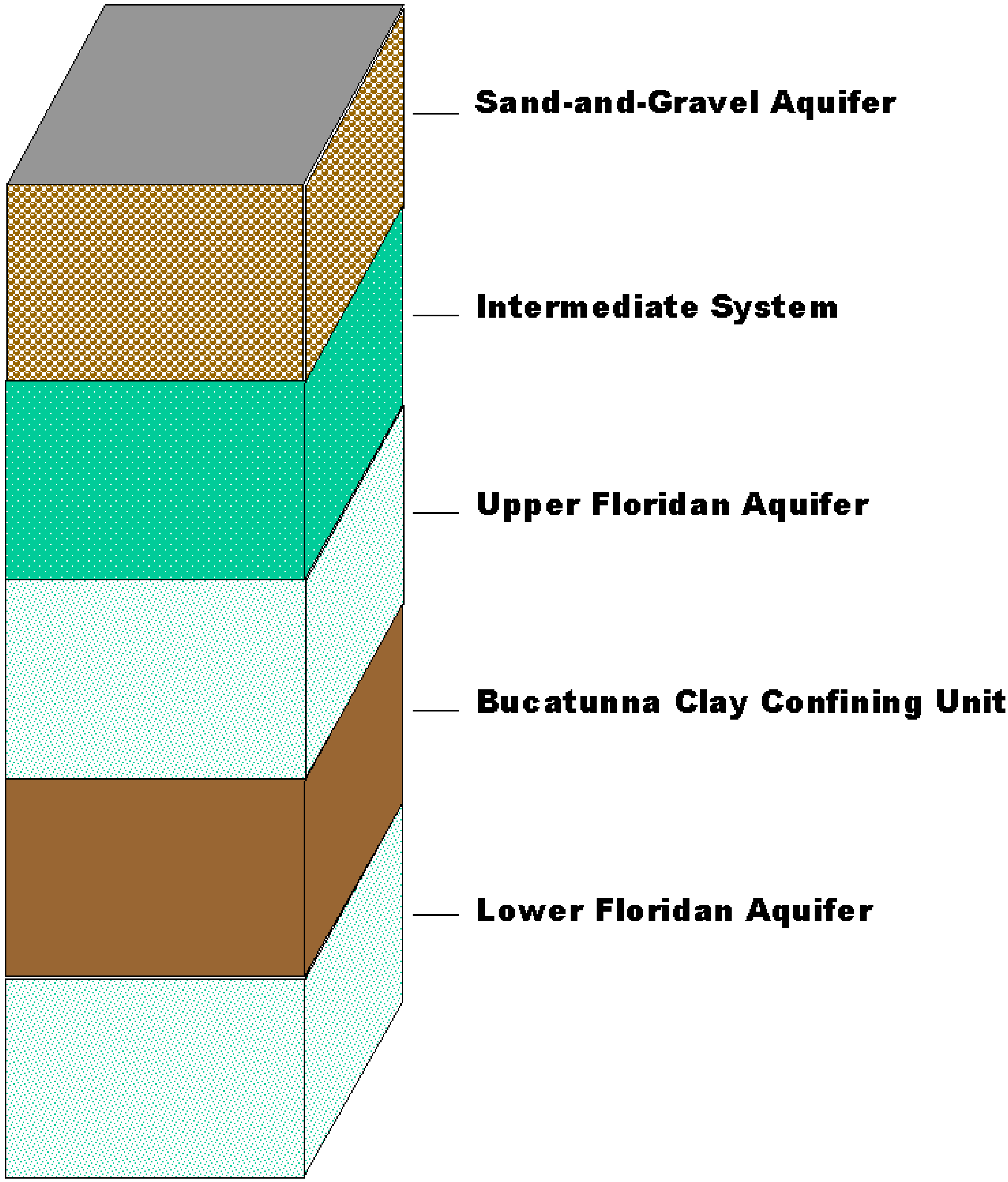

Figure 4.1 Hydrogeologic Structure of the Study Area

Land Surface Elevation for Modeled Region

Legend

- Topography (m msl.) Contour Interval: 20 m
- Hydrology
- Counties
- State / Coast Line
- Depressions

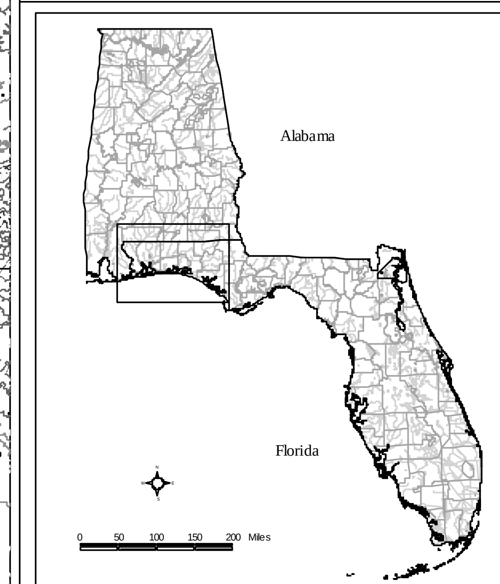

Figure 4.2

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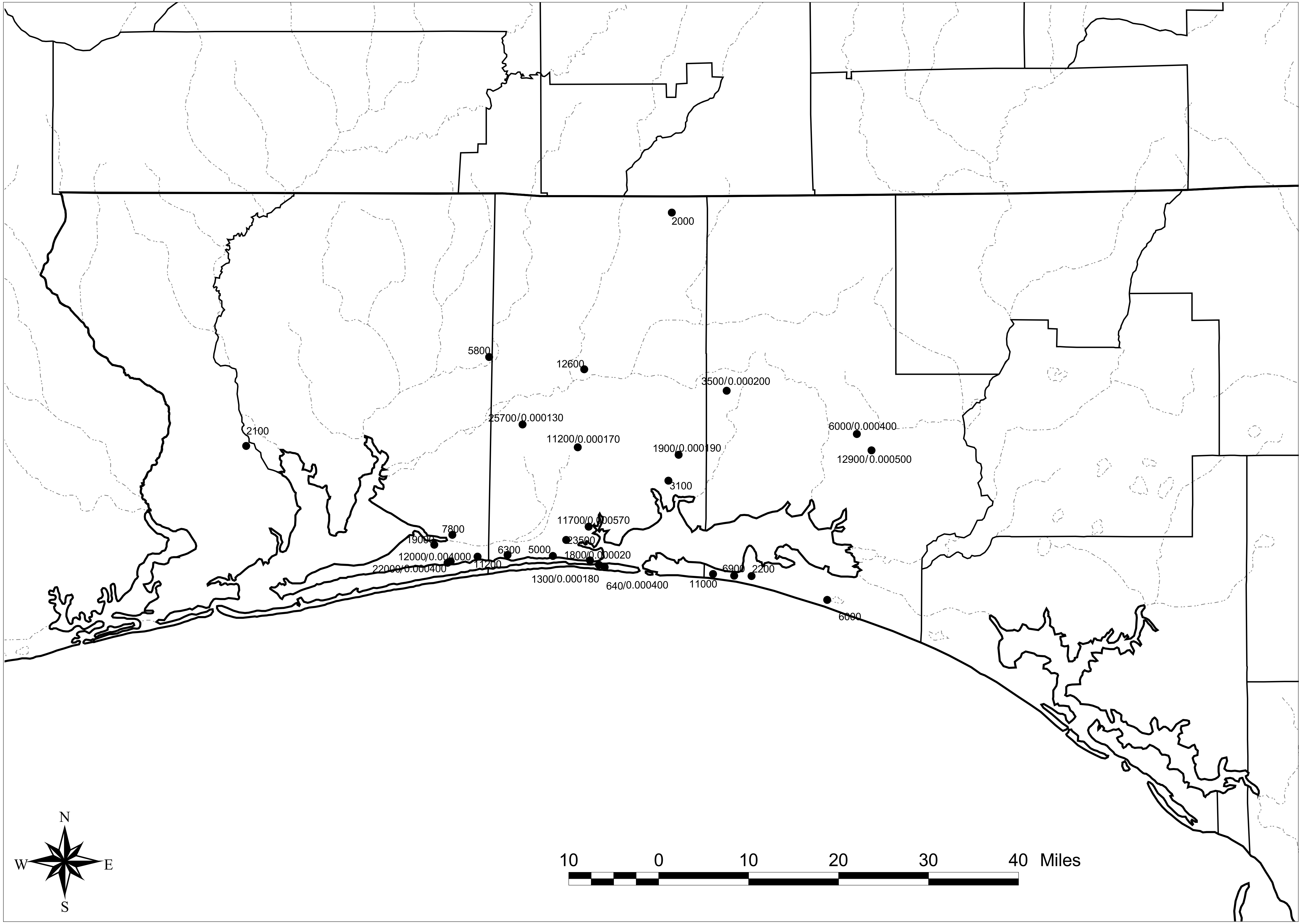

Measured Floridan Aquifer Transmissivity Values

Legend

1900/ Transmissivity (ft2/d)
/0.00019 Storativity
● Pumping Well
Hydrology
Counties
State / Coast Line

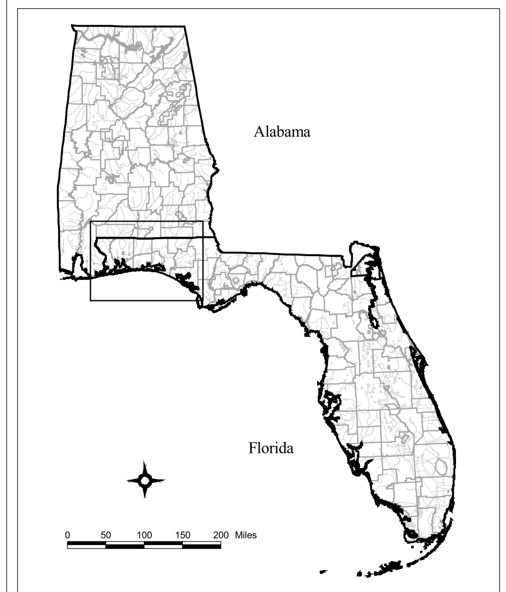

Figure 4.3

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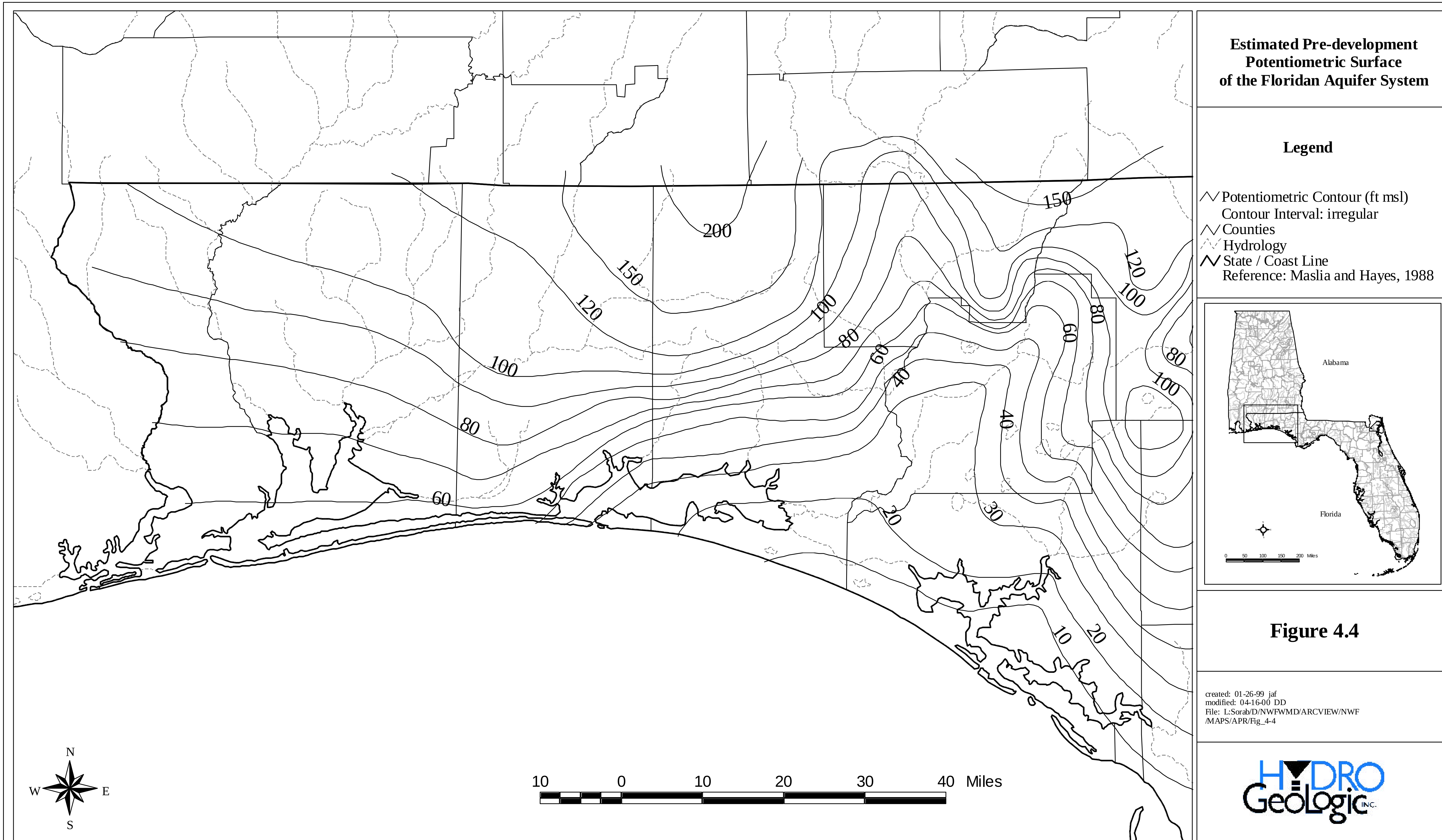
Revised: 04/16/00 DD

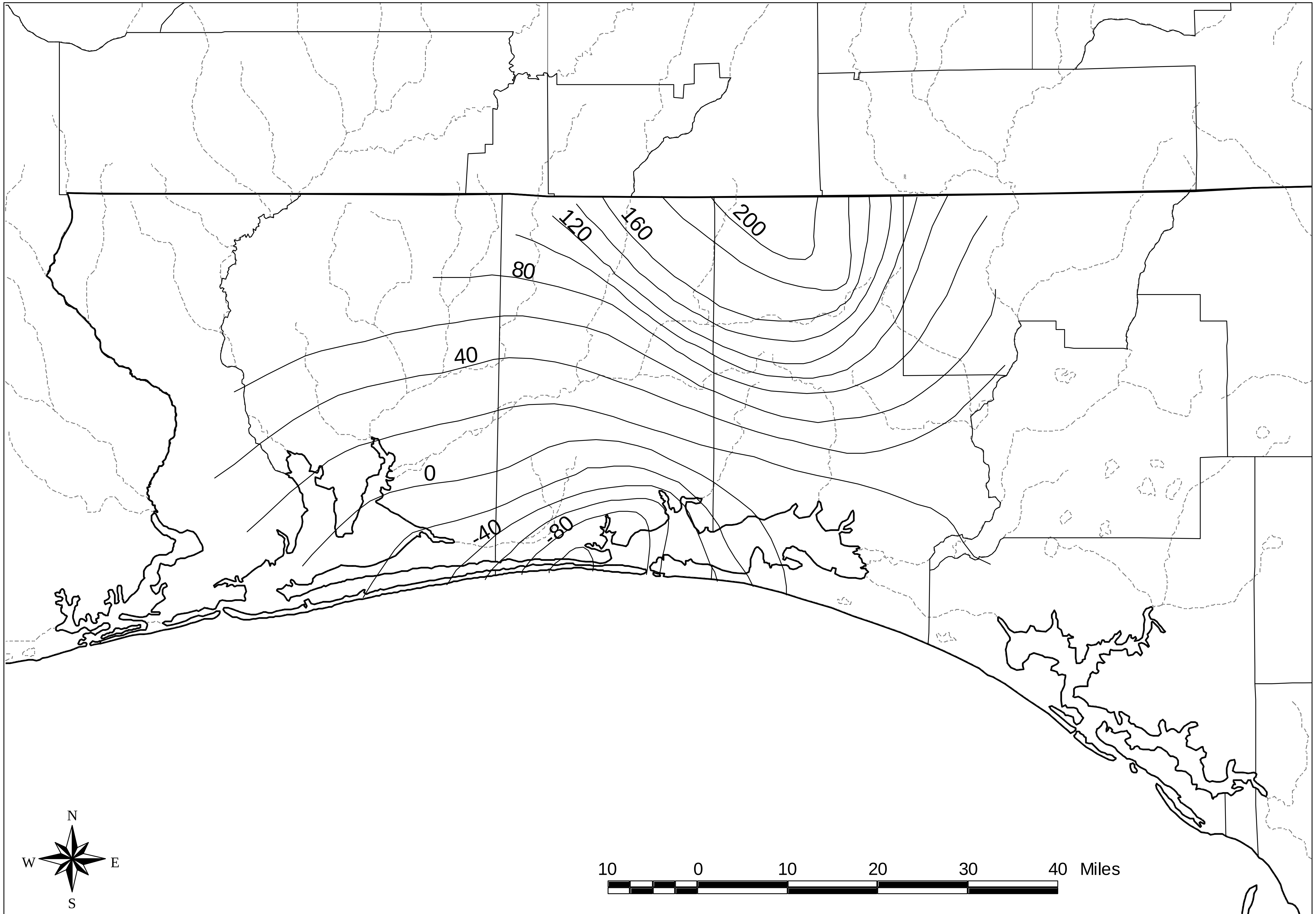
HYDRO GeoLogic INC.



Estimated Pre-development Potentiometric Surface of the Floridan Aquifer System

Figure 4.4

Observed Potentiometric Surface of the Upper Floridan Aquifer System, May 1990



Legend

Potentiometric Contour (ft msl)
Contour Interval: 20 ft
Counties
Hydrology
State / Coast Line
Reference: Richards, 1993

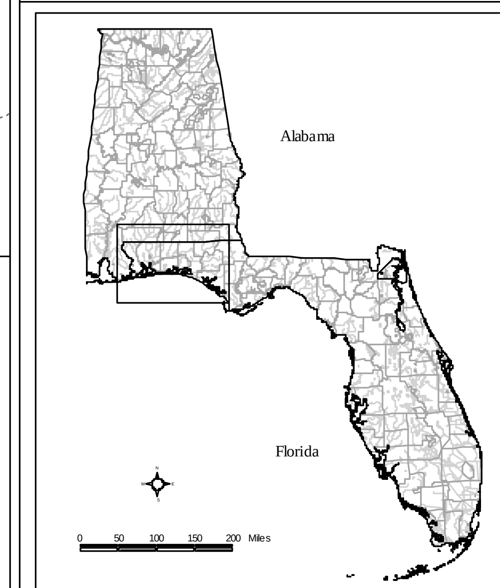


Figure 4.5

created: 02-19-99 jaf
modified: 04-16-22 DD
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Location of Wells Simulated in the Model

Legend

Pumping Well
Injection Well
Hydrology
Counties
State / Coast Line

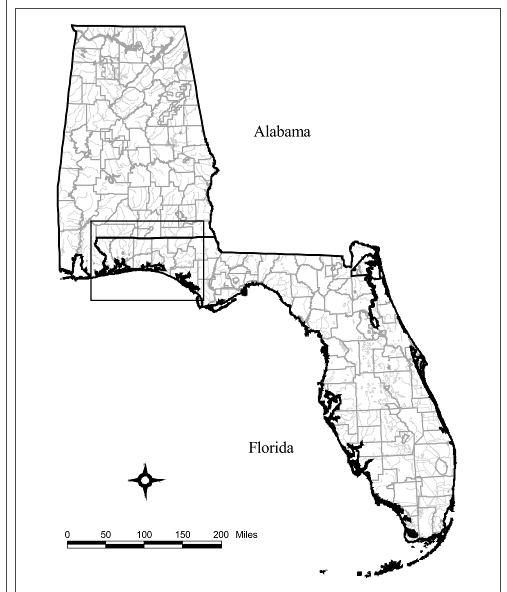

Figure 4.6

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Created: 02/09/00 TH
Revised: 04/16/00 DD

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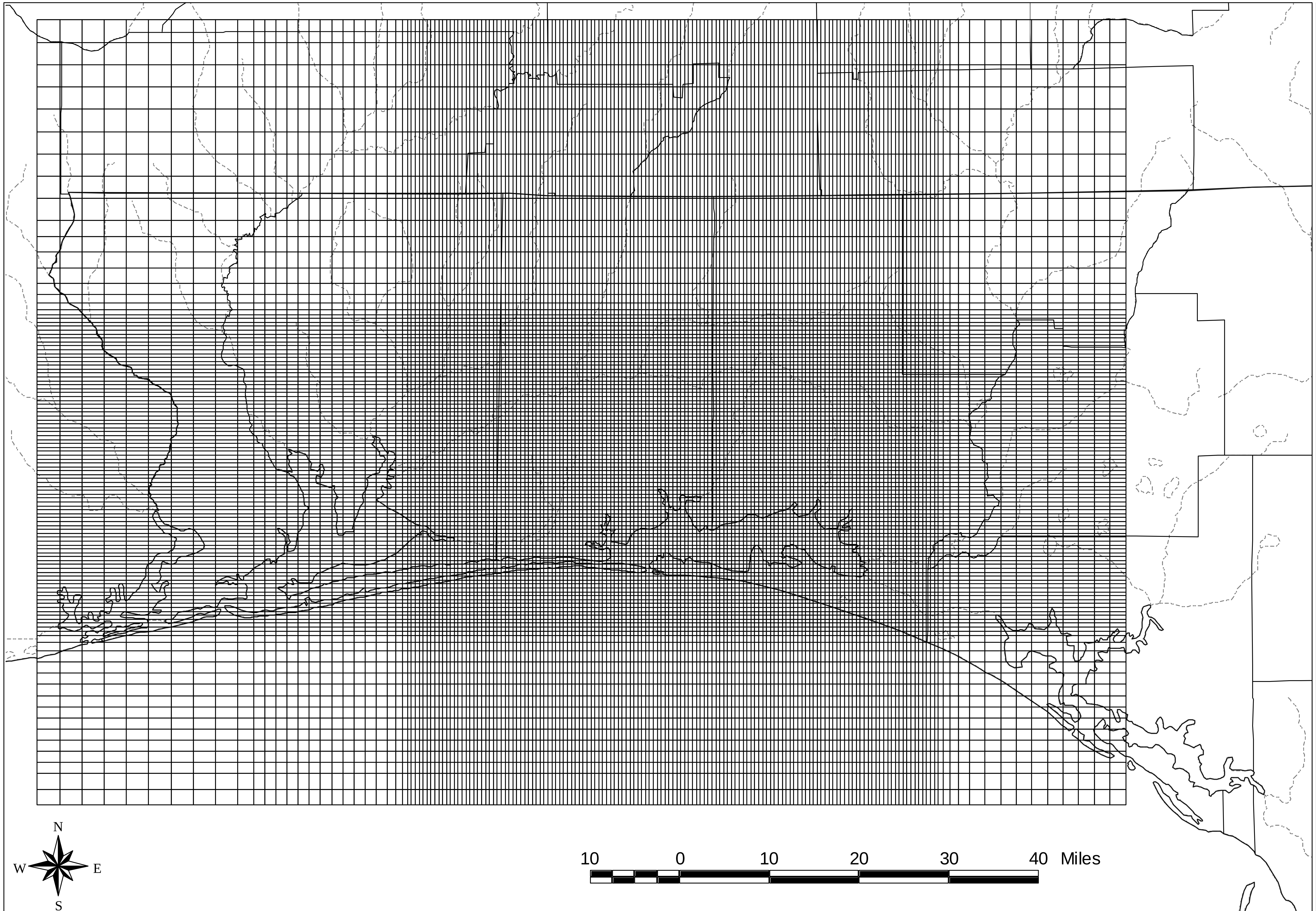

Plan View of Discretized Region

Legend

Hydrology
Counties
State / Coast Line

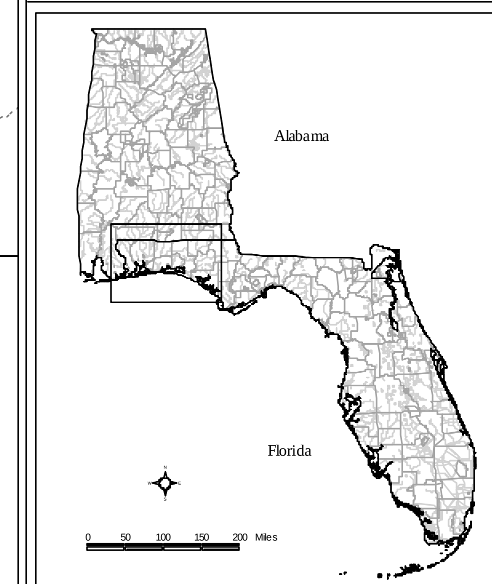

Figure 5.1

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Created: 02/09/00 TH
Revised: 04/17/00 DD

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Elevation of Top of Model Layer 1 Representing Land Surface

Legend

Elevation (ft), Contour Interval: 50 ft
Hydrology
Counties
State / Coast Line

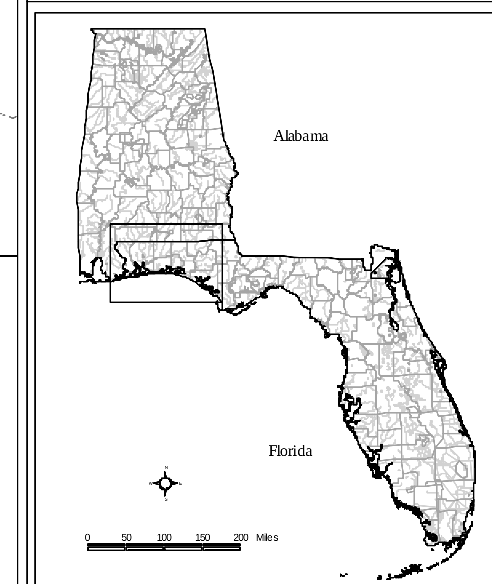

Figure 5.2

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
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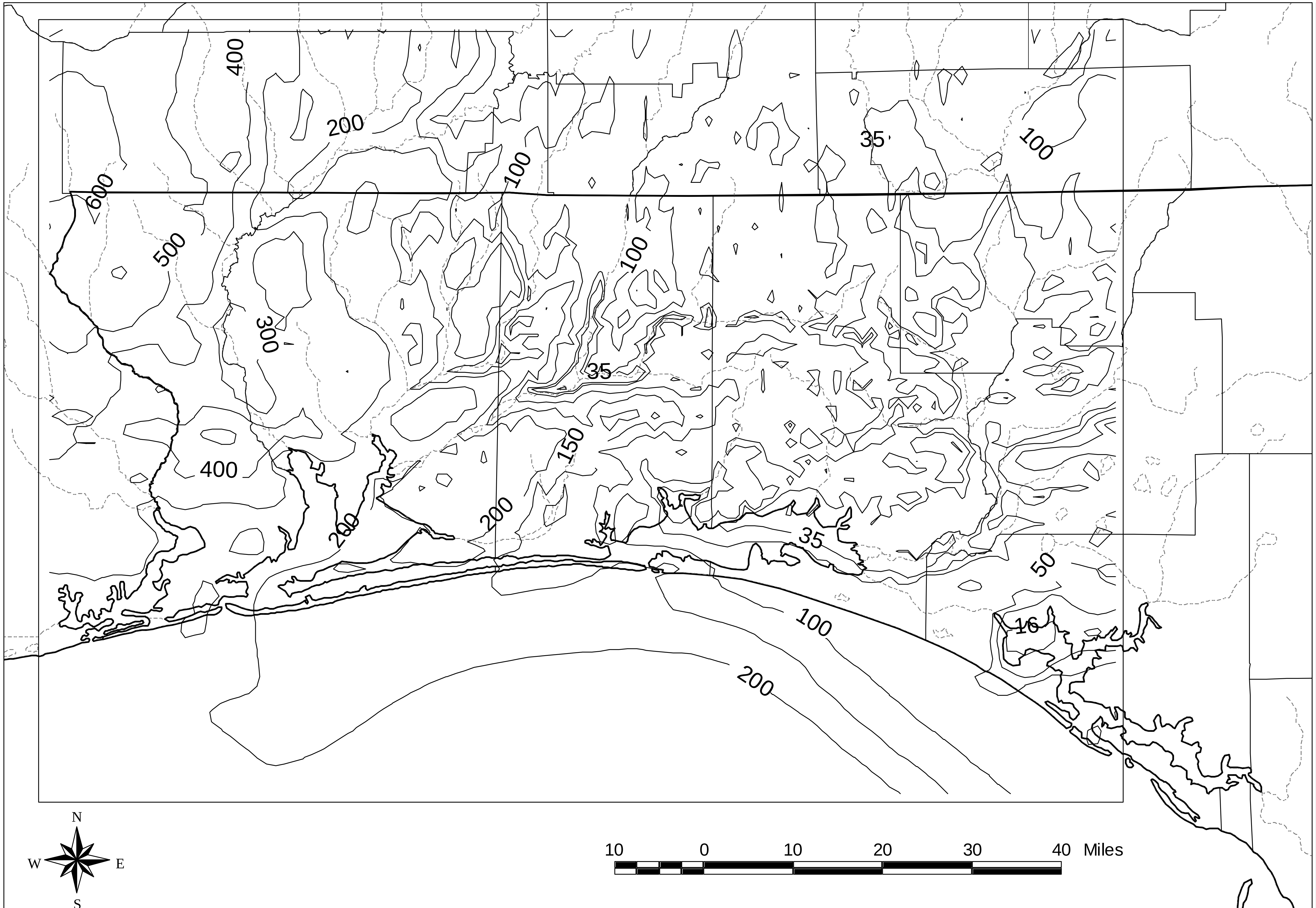
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/16/00 DD

HYDRO GeoLogic INC.

Thickness of Model Layer 1 Representing the Sand-and-Gravel Aquifer



Legend

Thickness (ft)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

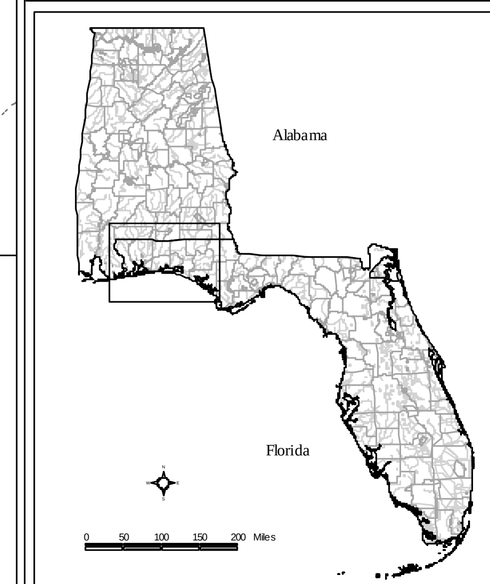


Figure 5.3

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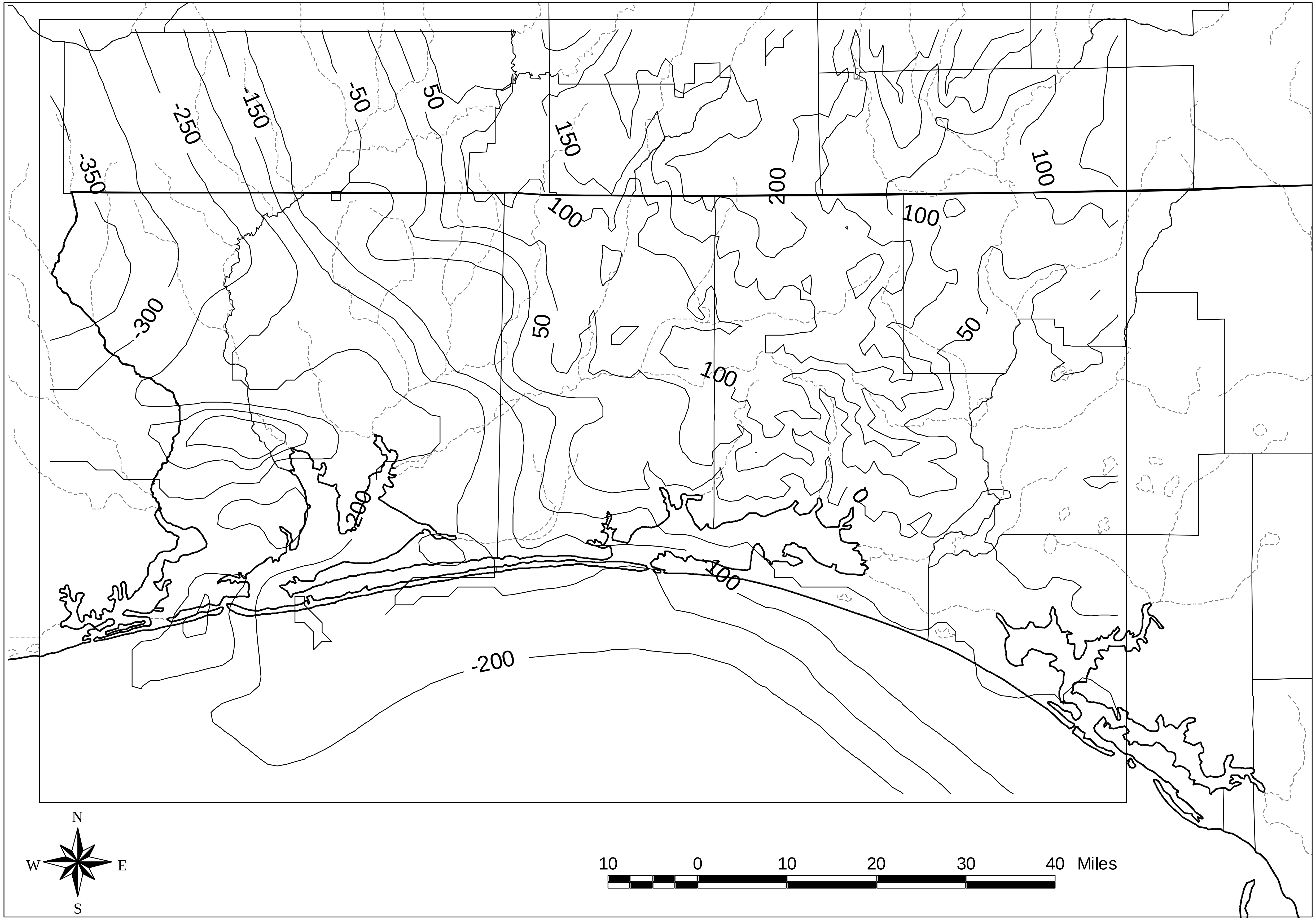
Revised: 02/10/00 cf

HYDRO GeoLogic INC.



Elevation of Top of Model Layer 2 Representing the Top of the Intermediate System

Legend

Elevation (ft)
Contour Interval: 50 ft
Hydrology
Counties
State / Coast Line

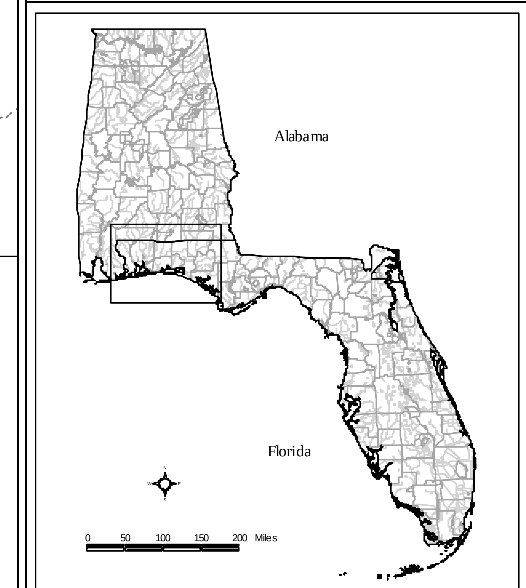


Figure 5.4

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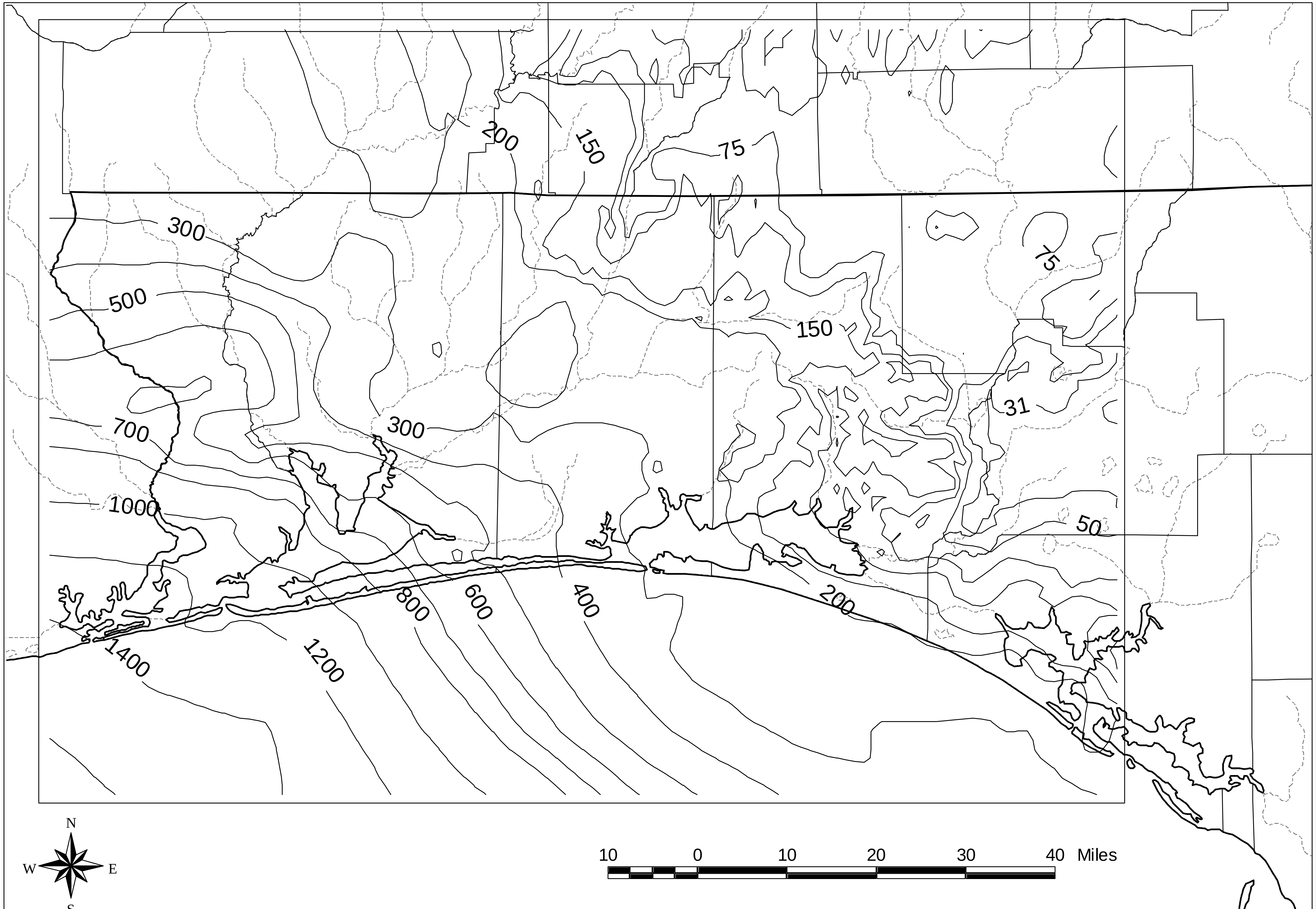
HYDRO GeoLogic INC.



Thickness of Model Layer 2 Representing the Intermediate System

Legend

Thickness (ft)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

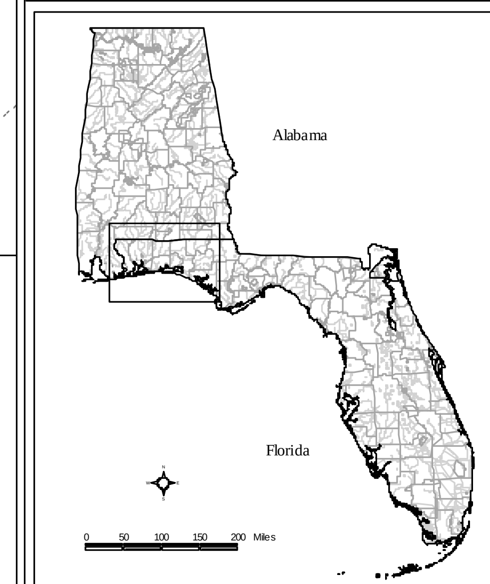


Figure 5.5

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Created: 02/09/00 TH
Revised: 04/17/00 DD

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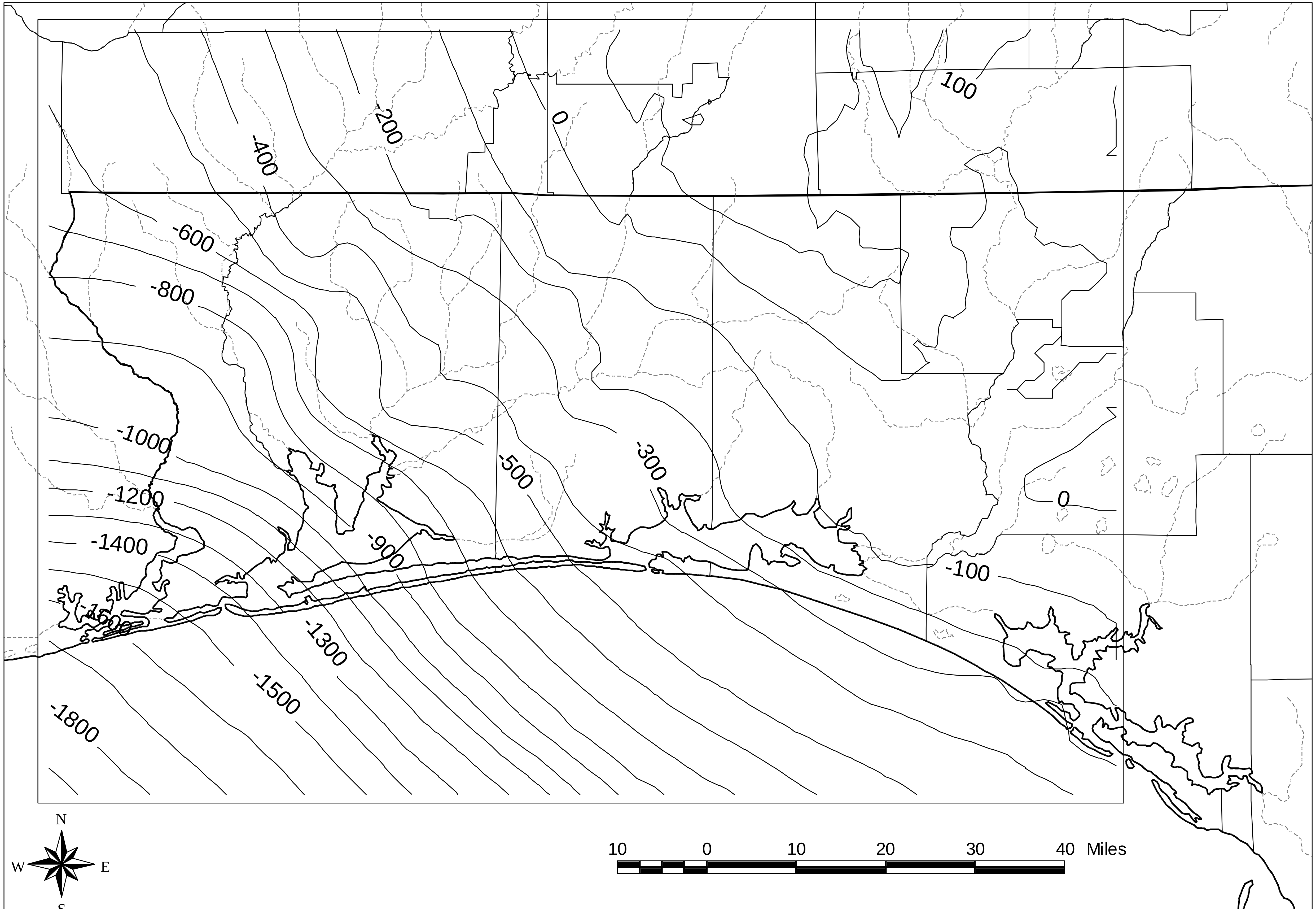
Elevation of Top of Model Layer 3 Representing the Top of the Floridan Aquifer System



Legend

Elevation (ft)
Contour Interval: 100 ft
Hydrology
Counties
State / Coast Line

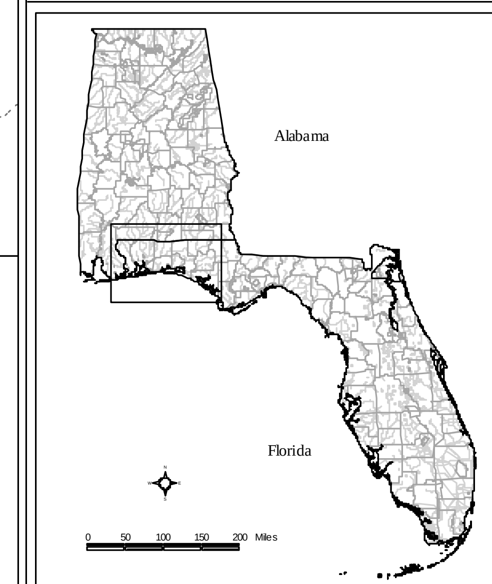


Figure 5.6

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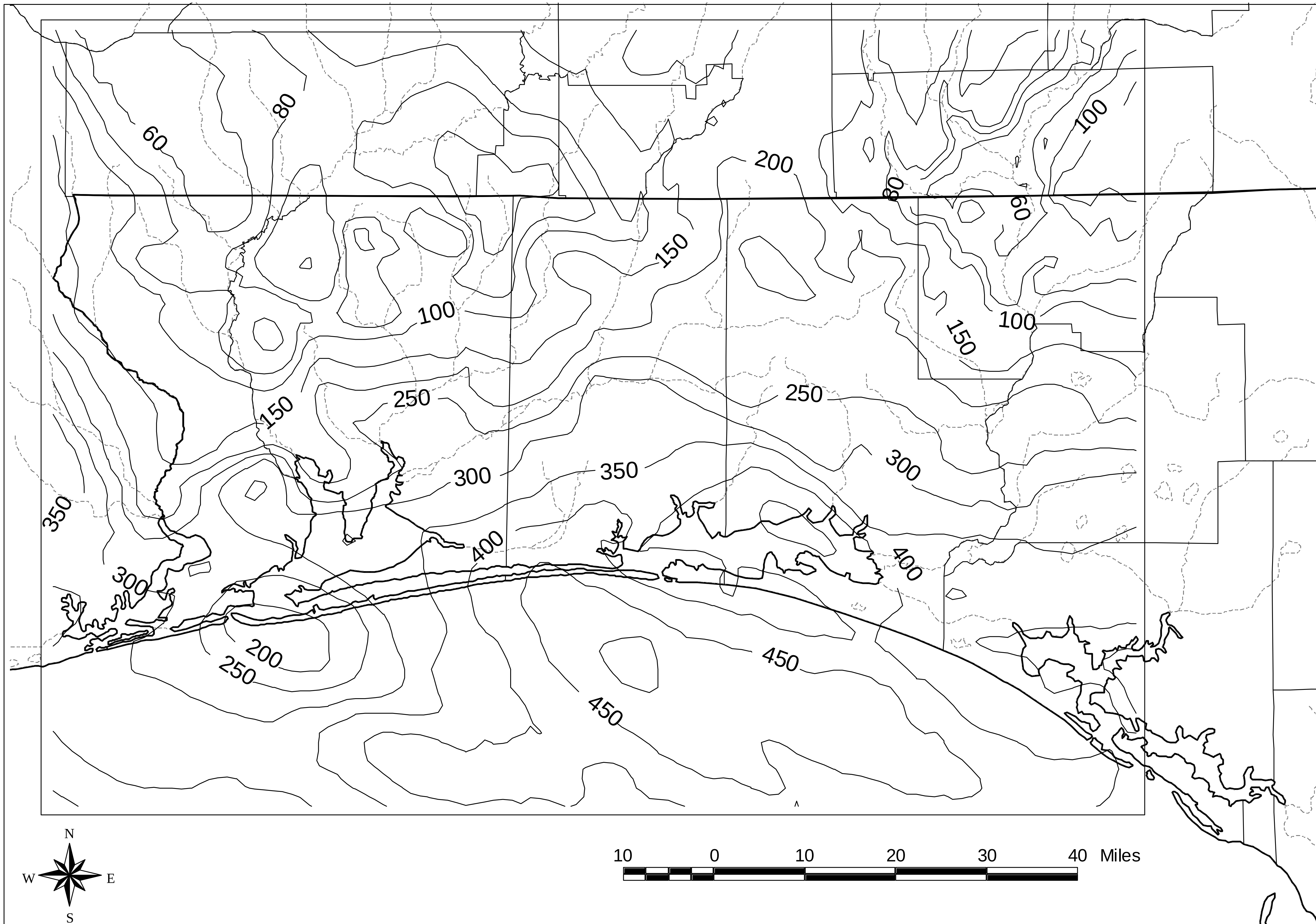
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Thickness of Model Layer 3 Representing the Upper Floridan Aquifer and the Upper Portion of the Undifferentiated Floridan Aquifer System

Legend

Thickness (ft)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

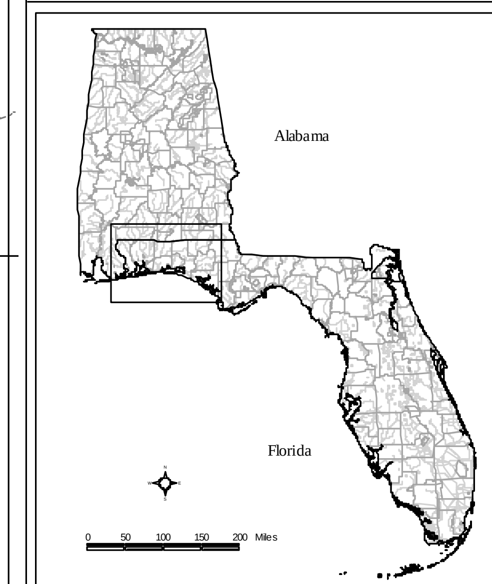


Figure 5.7

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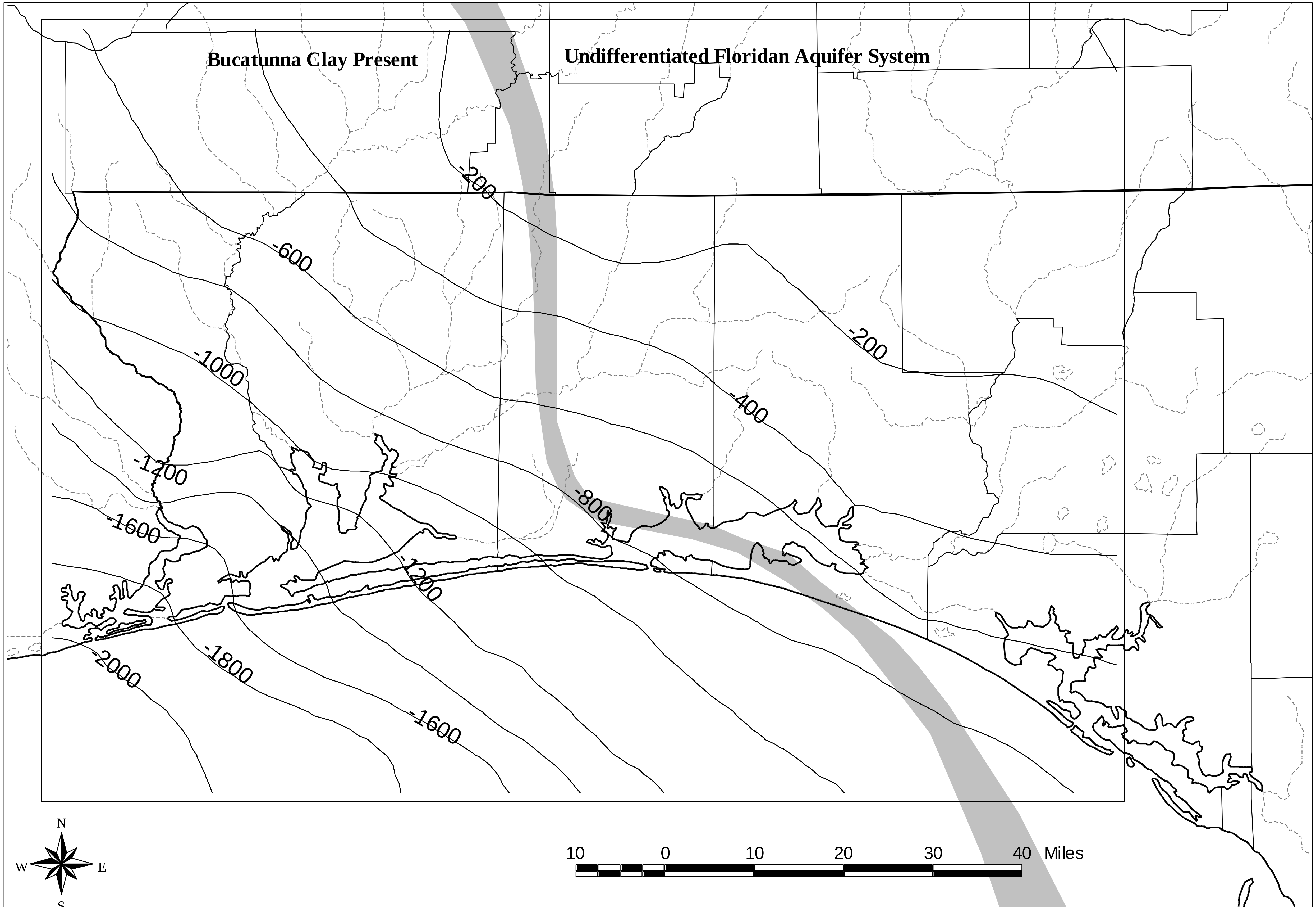
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Elevation of Top of Model Layer 4 Representing the Top of the Bucatunna Clay Confining Unit and the Middle Portion of the Undifferentiated Floridan Aquifer System

Legend

Denotes transition area over which Bucatunna Clay pinches out

Elevation (ft)
Contour Interval: 200 ft

Hydrology

Counties

State / Coast Line

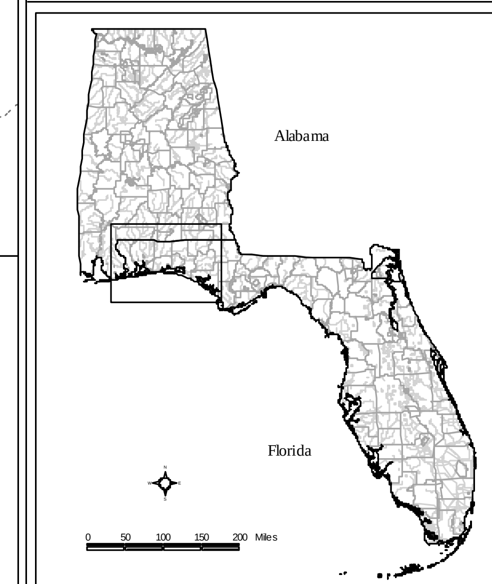


Figure 5.8

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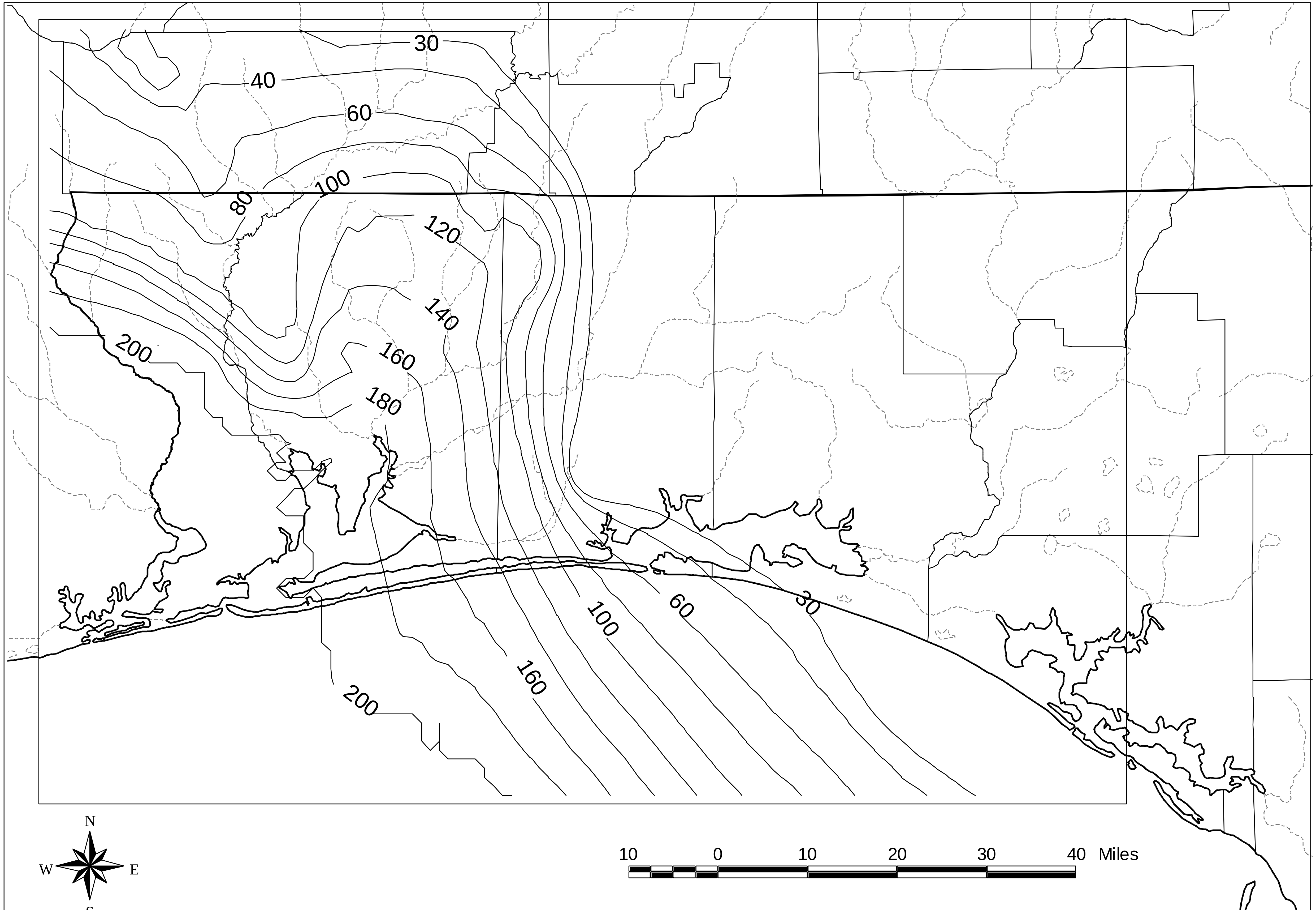
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Thickness of Model Layer 4 Representing the Bucatunna Clay Confining Unit and the Middle Portion of the Undifferentiated Floridan Aquifer System

Legend

Thickness (ft)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

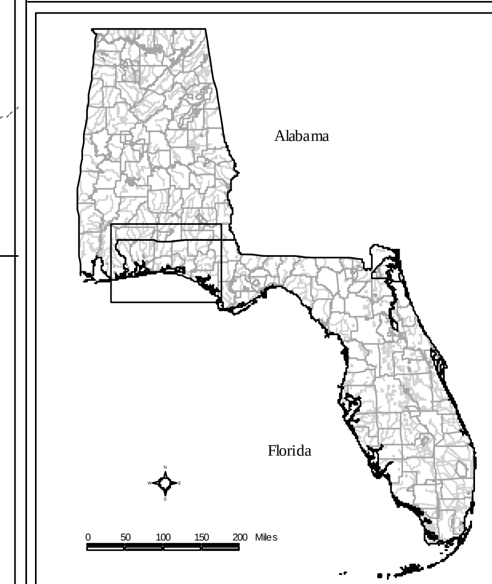
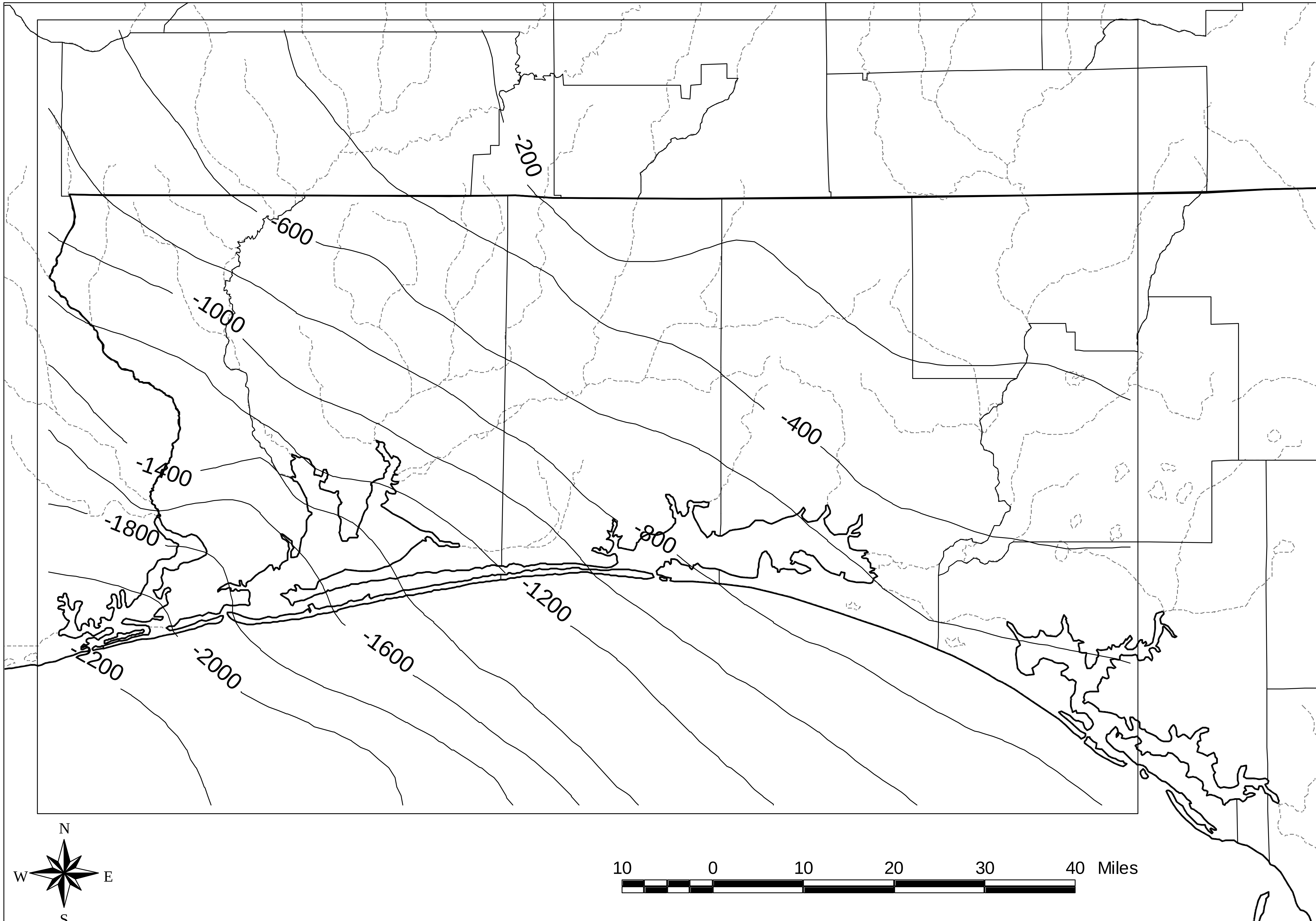


Figure 5.9

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Elevation of Top of Model Layer 5 Representing the Top of the Lower Floridan Aquifer and the Lower Portion of the Undifferentiated Floridan Aquifer System



Legend

- Elevation (ft)
  Contour Interval: 200 ft
- Hydrology
- Counties
- State / Coast Line

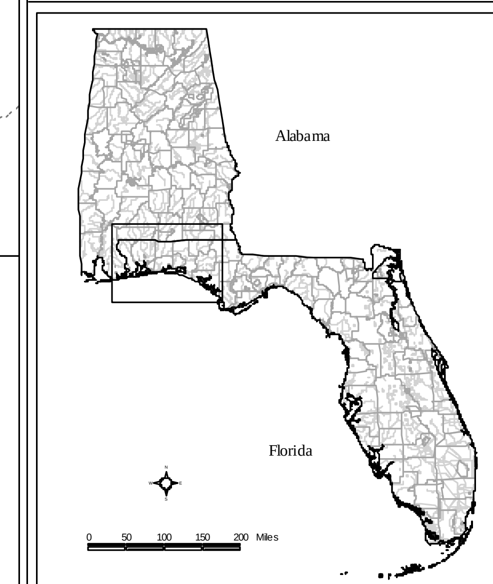
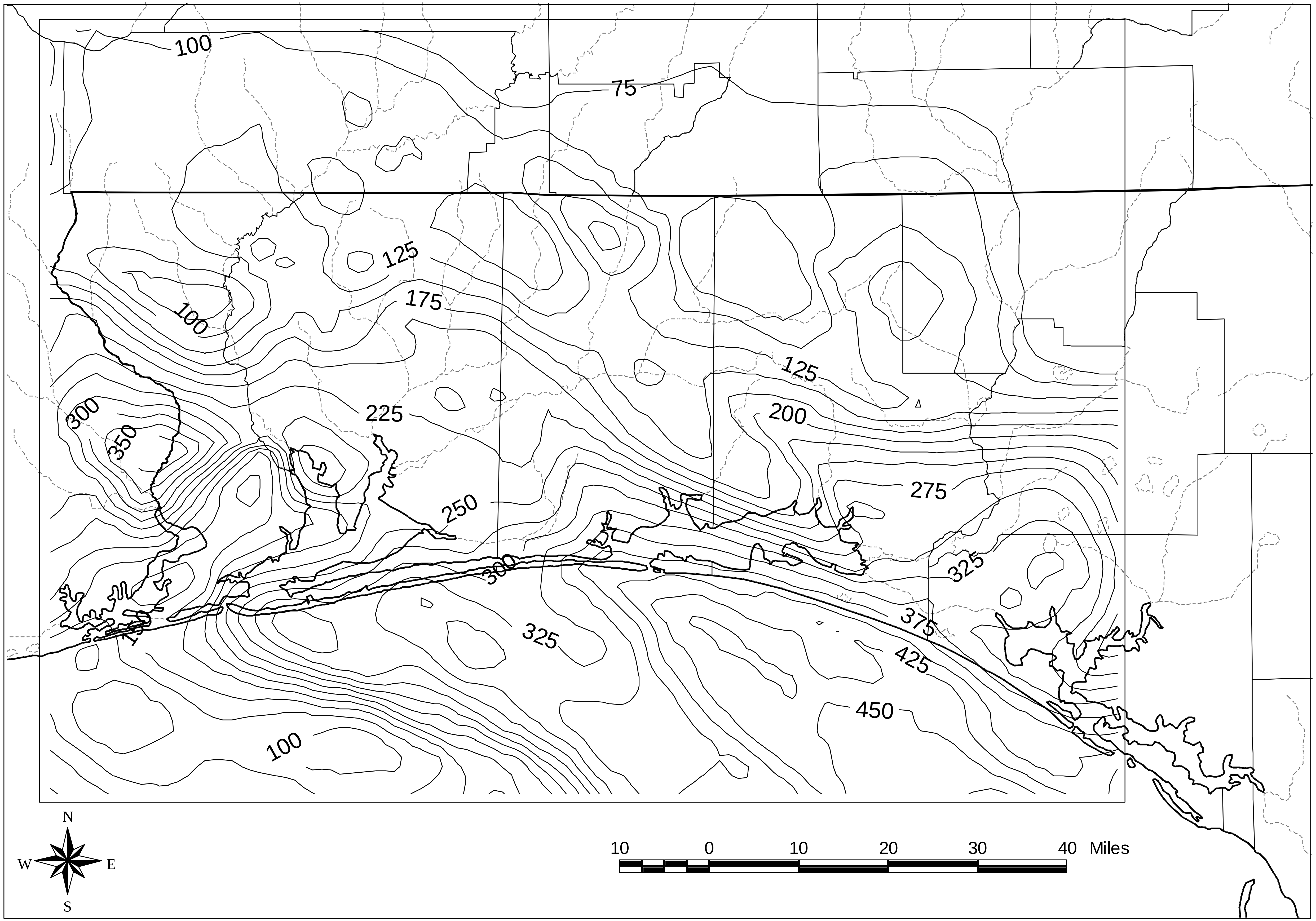


Figure 5.10

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Thickness of Model Layer 5 Representing the Lower Floridan Aquifer and the Lower Portion of the Undifferentiated Floridan Aquifer System

Legend

Thickness (ft)
Contour Interval: 25 ft
Hydrology
Counties
State / Coast Line

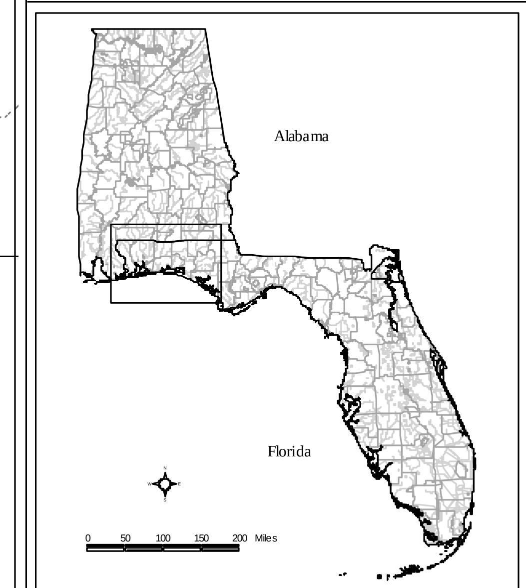
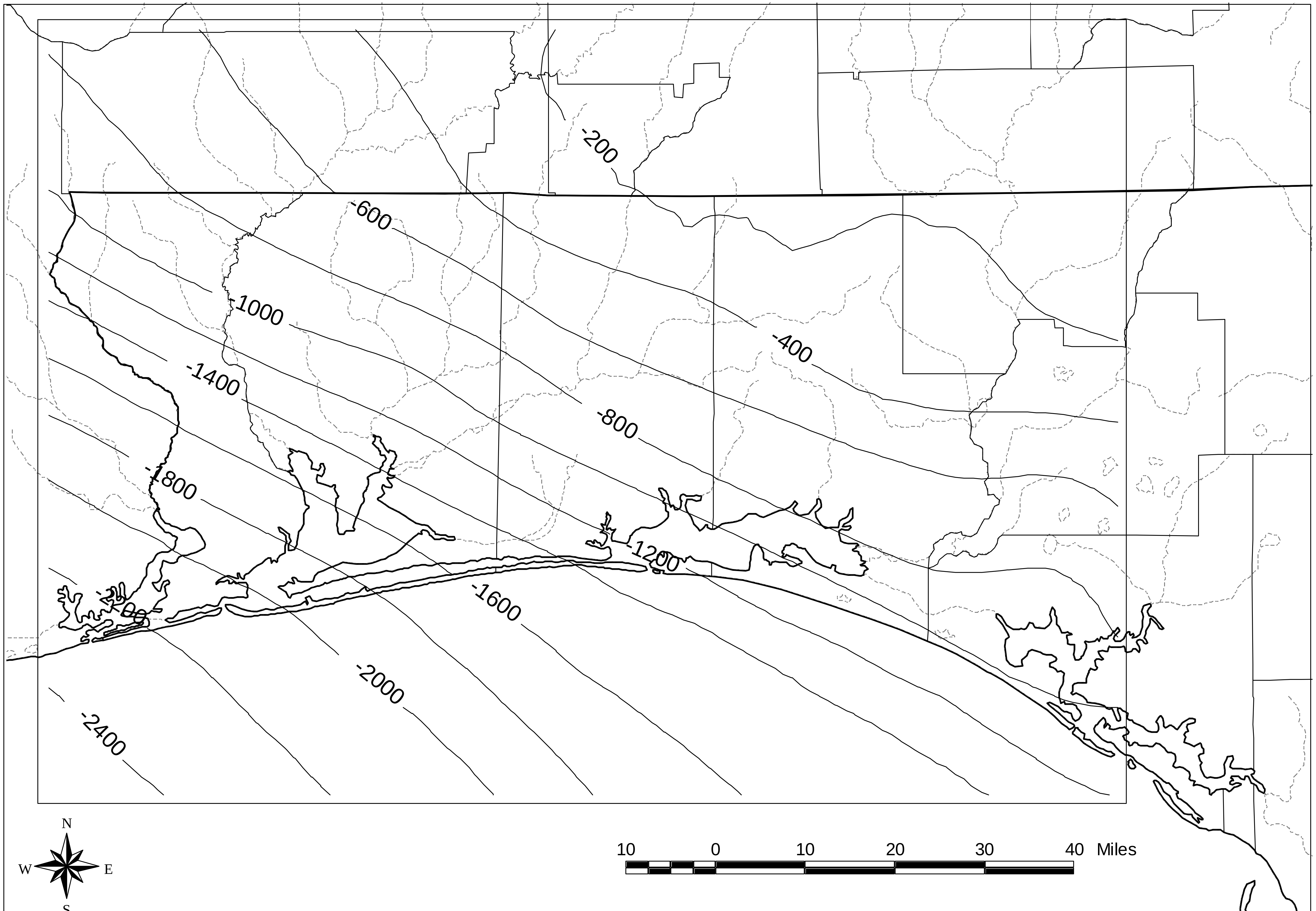


Figure 5.11

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Elevation of Bottom of Model Layer 5 Representing the Top of the Sub-Floridan Aquifer System

Legend

Elevation (ft)
Contour Interval: 200 ft
Hydrology
Counties
State / Coast Line

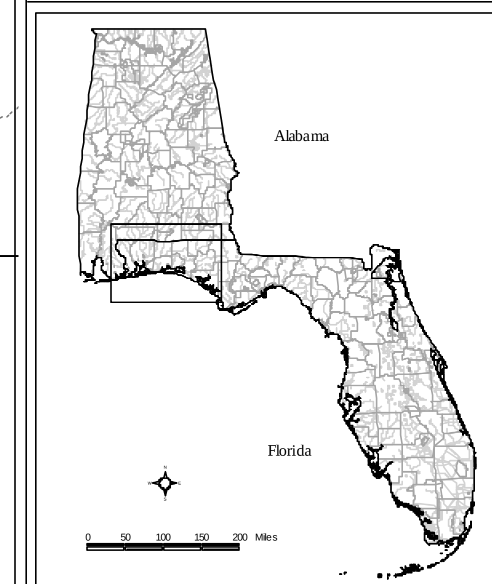
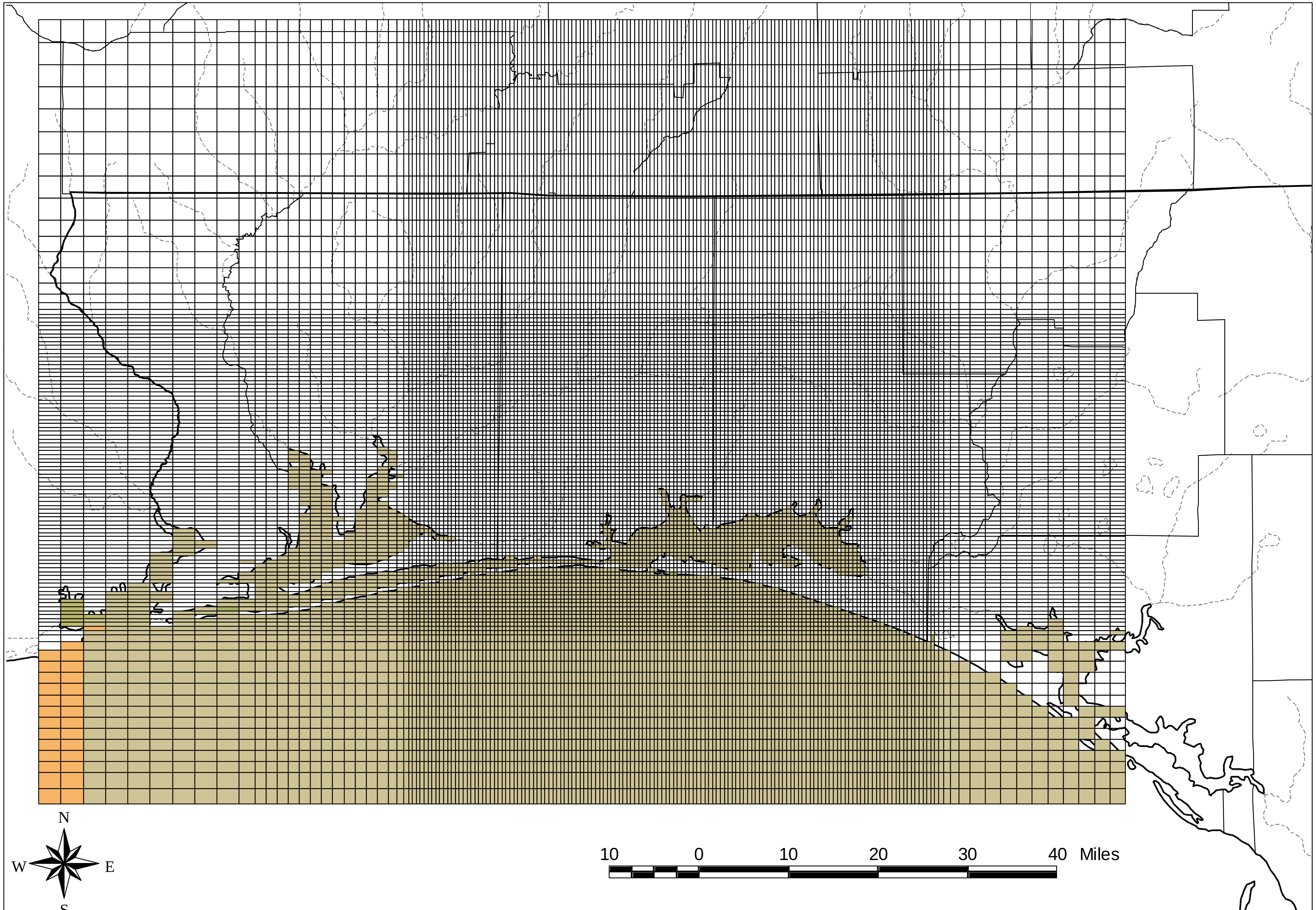


Figure 5.12

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Distribution of Recharge and Prescribed Head Boundary Conditions for Model Layer 1

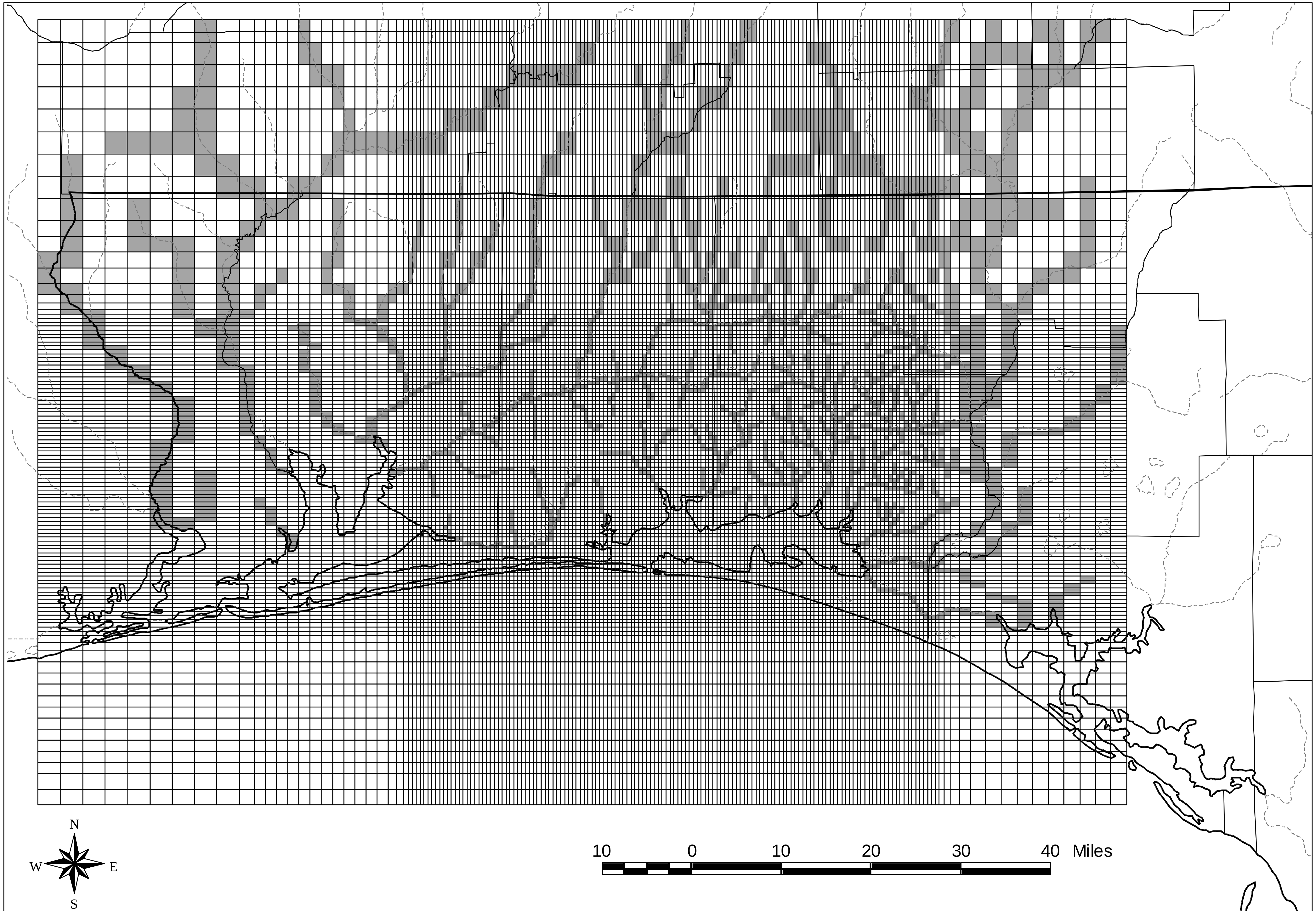
Legend

Recharge Applied
Prescribed Head Boundary
Hydrology
Counties
State / Coast Line

Figure 5.13

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Distribution of River Boundary Cells for Model Layer 1

Legend

River Boundary Cells
Hydrology
Counties
State / Coast Line

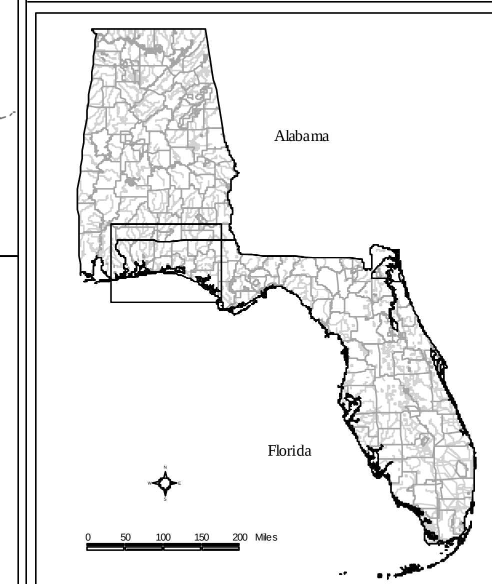
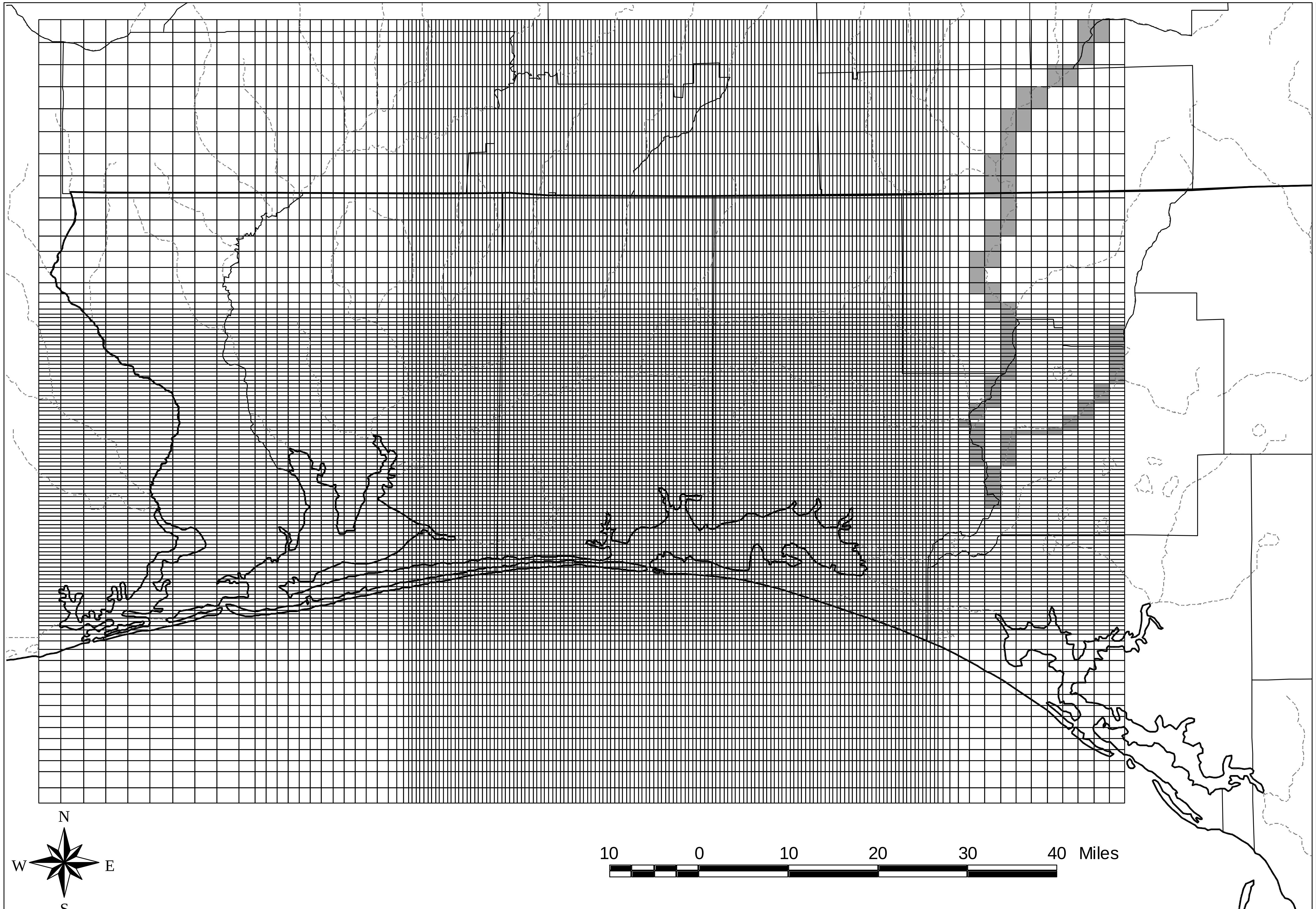


Figure 5.14

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Distribution of River Boundary Cells for Model Layer 3

Legend

River Boundary Cells
Hydrology
Counties
State / Coast Line

Figure 5.15

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Calibrated Vertical Hydraulic Conductivity of Model Layer 2

Legend

- Hydraulic Conductivity (ft/day) Contour Interval: irregular
- Hydrology
- Counties
- State / Coast Line

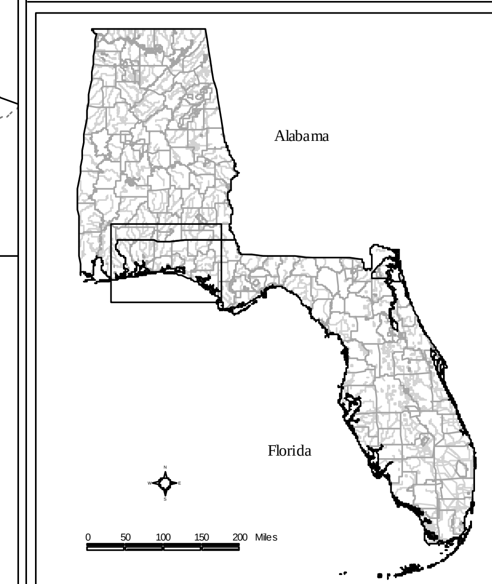
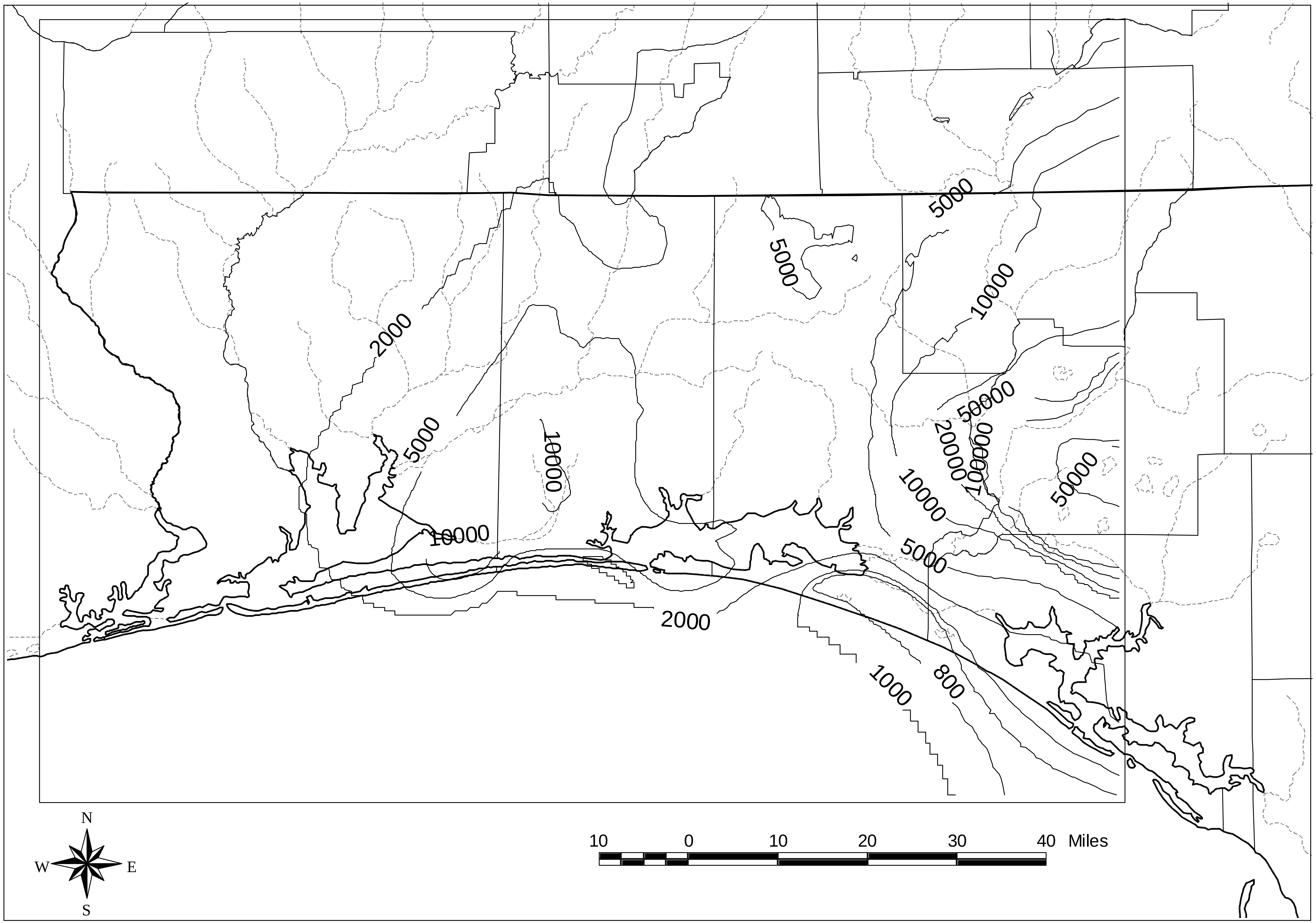


Figure 5.16

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDROGEOLOGIC INC.

Calibrated Transmissivity of Model Layer 3



Legend

Transmissivity (ft2/d)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

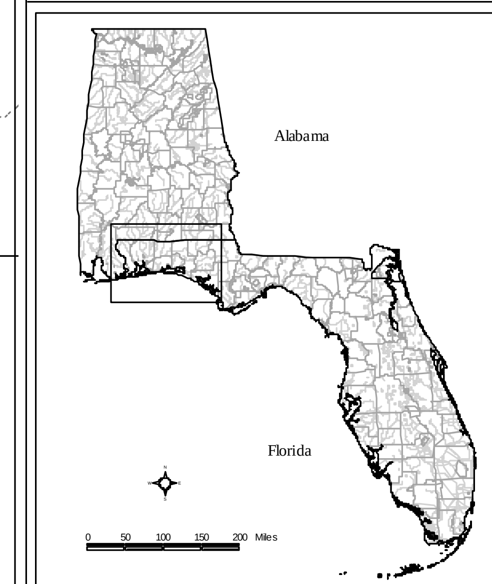
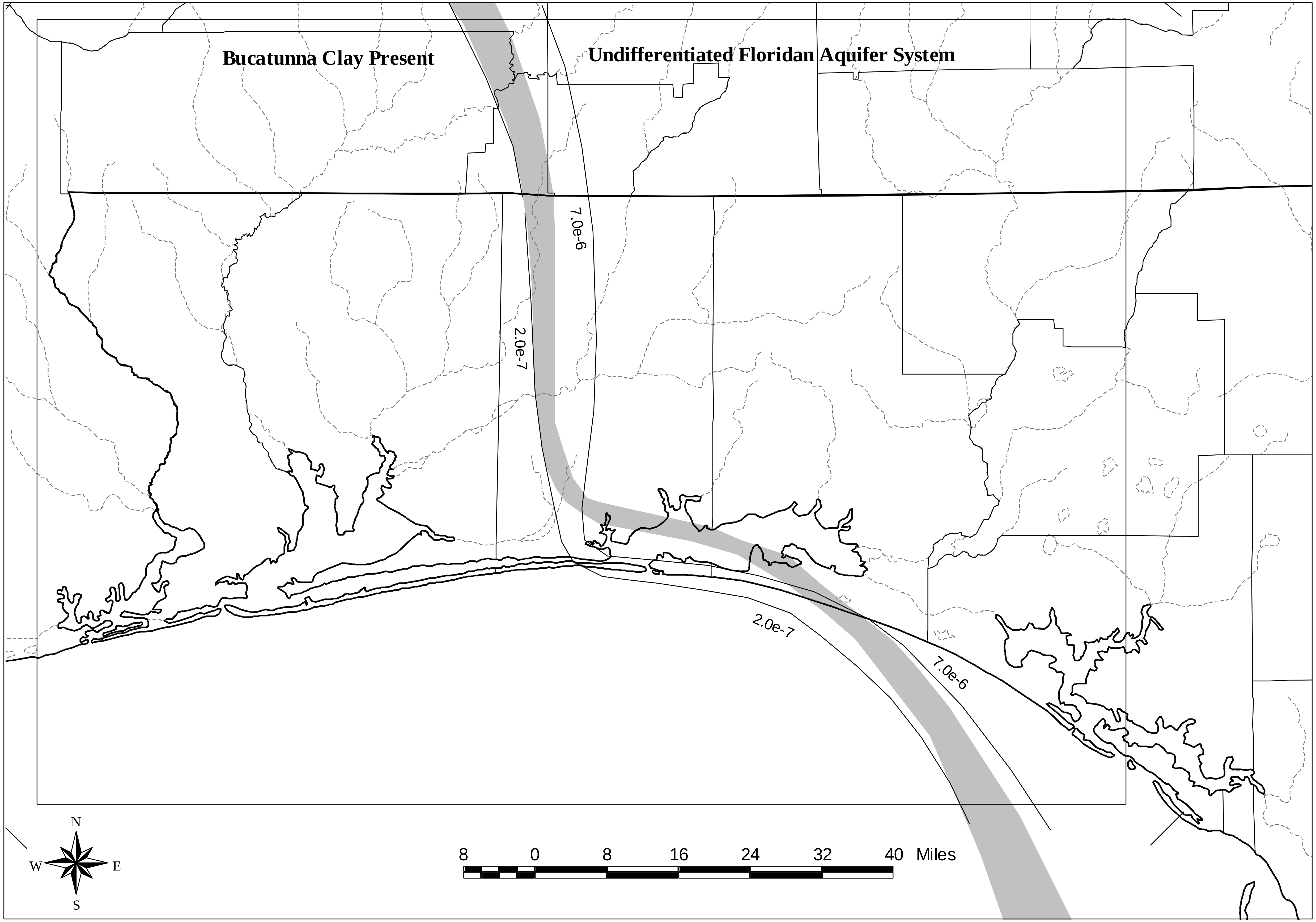


Figure 5.17

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

Calibrated Vertical Hydraulic Conductivity of the Bucatunna Clay Confining Unit



Legend

- Denotes transition area over which Bucatunna Clay pinches out
- Hydraulic Conductivity (ft/day) Contour Interval: irregular
- Hydrology
- Counties
- State / Coast Line

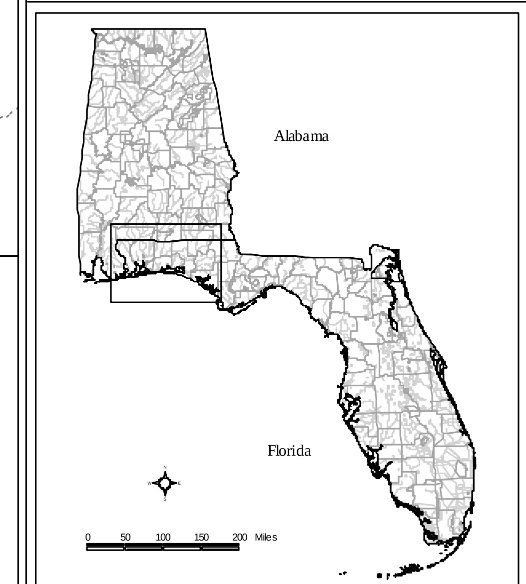
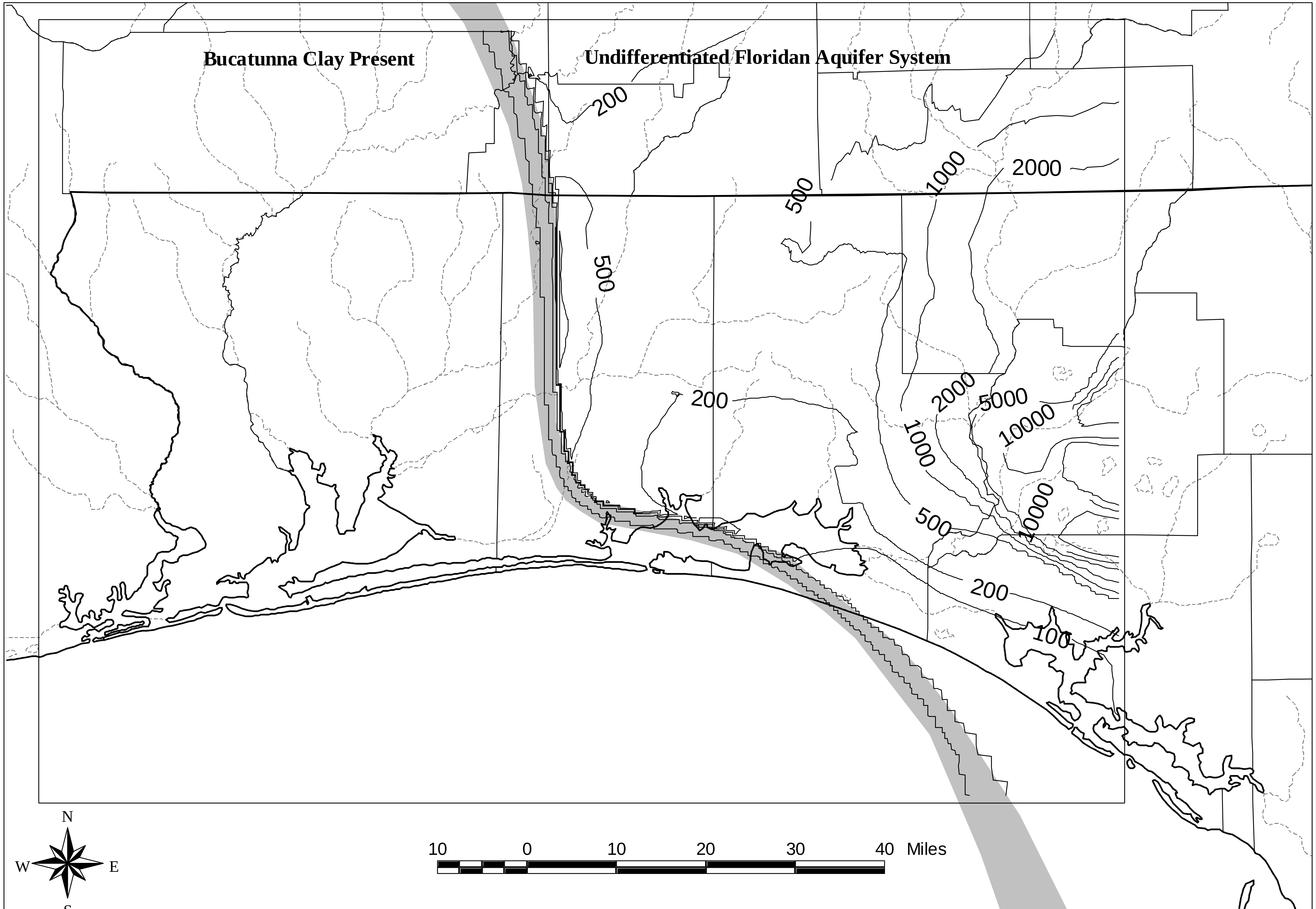


Figure 5.18

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDROGEOLOGIC INC.

Calibrated Transmissivity of the Middle Portion of the Undifferentiated Floridan Aquifer System



Legend

- Denotes transition area over which Bucatunna Clay pinches out
- Transmissivity (ft2/d) Contour Interval: irregular
- Hydrology
- Counties
- State / Coast Line

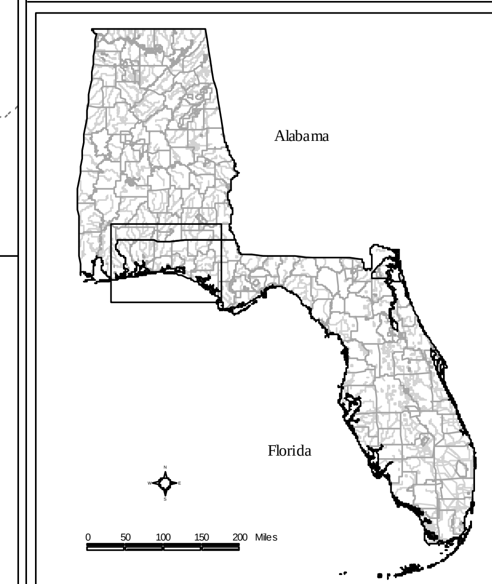
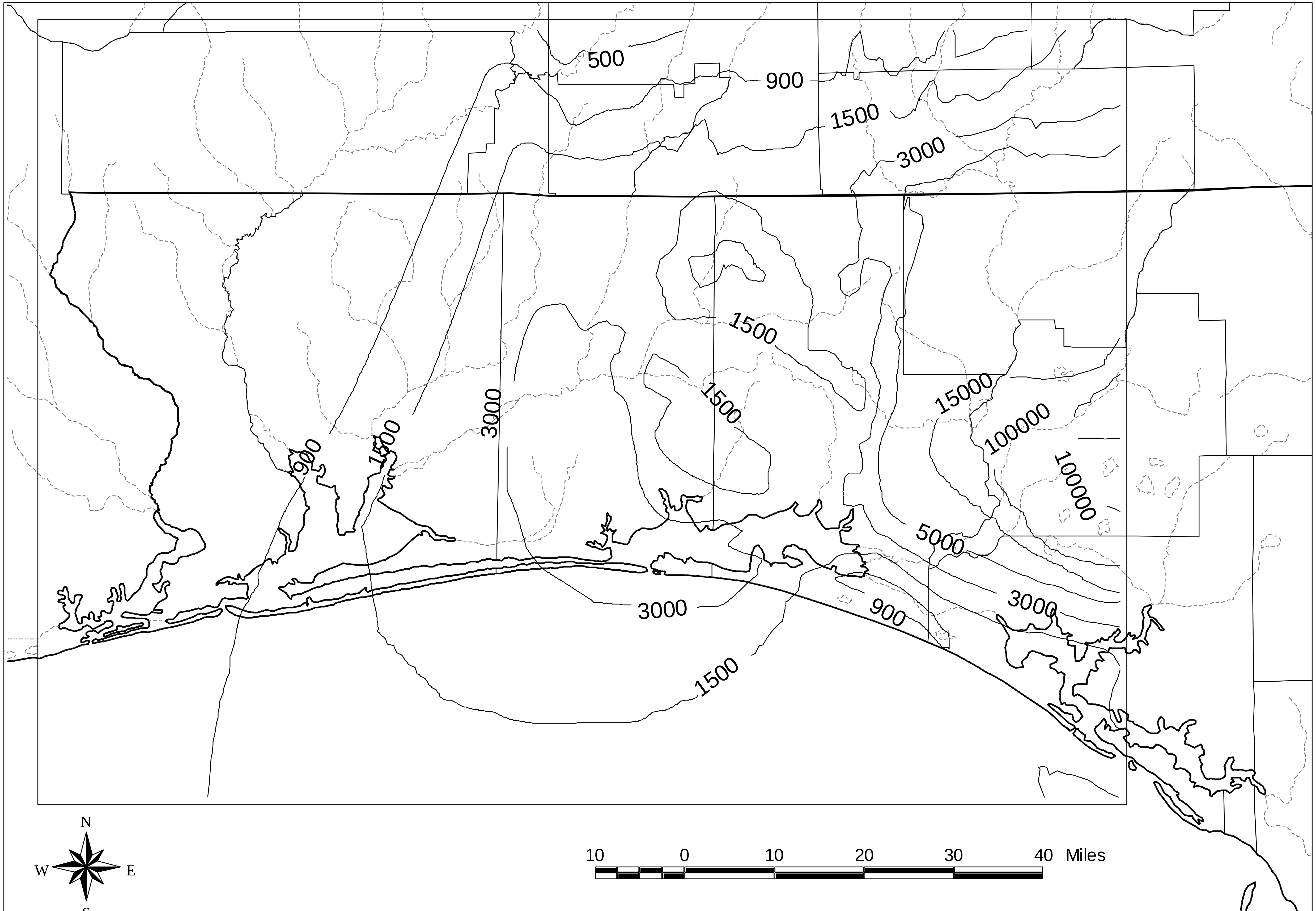


Figure 5.19

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Calibrated Transmissivity of Model Layer 5

Legend

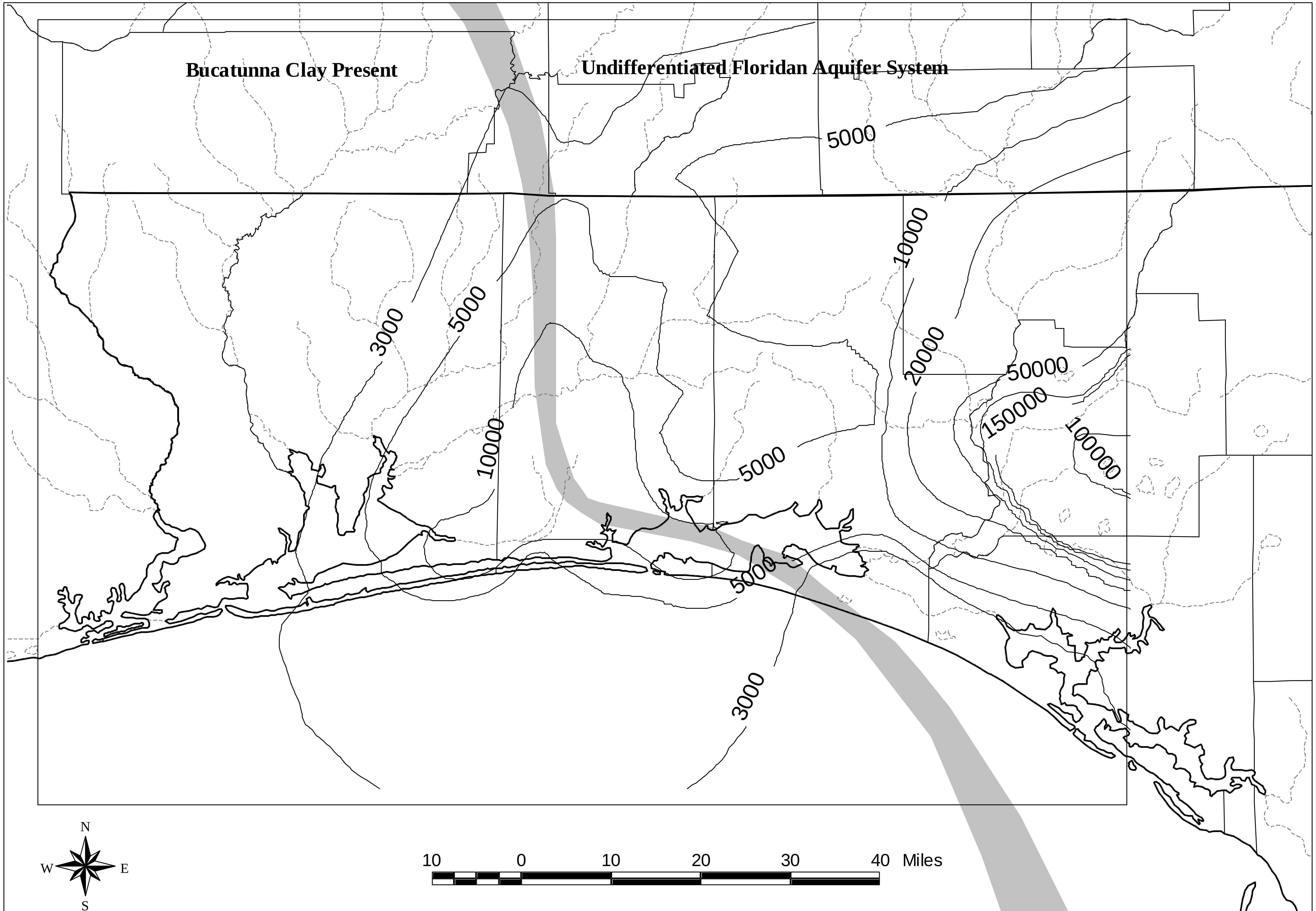
Transmissivity (ft2/d)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

Figure 5.20

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Calibrated Transmissivity of the Entire Thickness of the Floridan Aquifer System



Legend

- Denotes transition area over which Bucatunna Clay pinches out
- Transmissivity (ft2/d) Contour Interval: irregular
- Hydrology
- Counties
- State / Coast Line

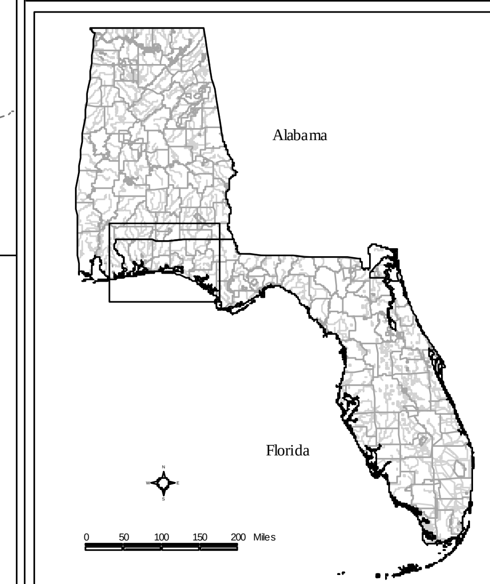
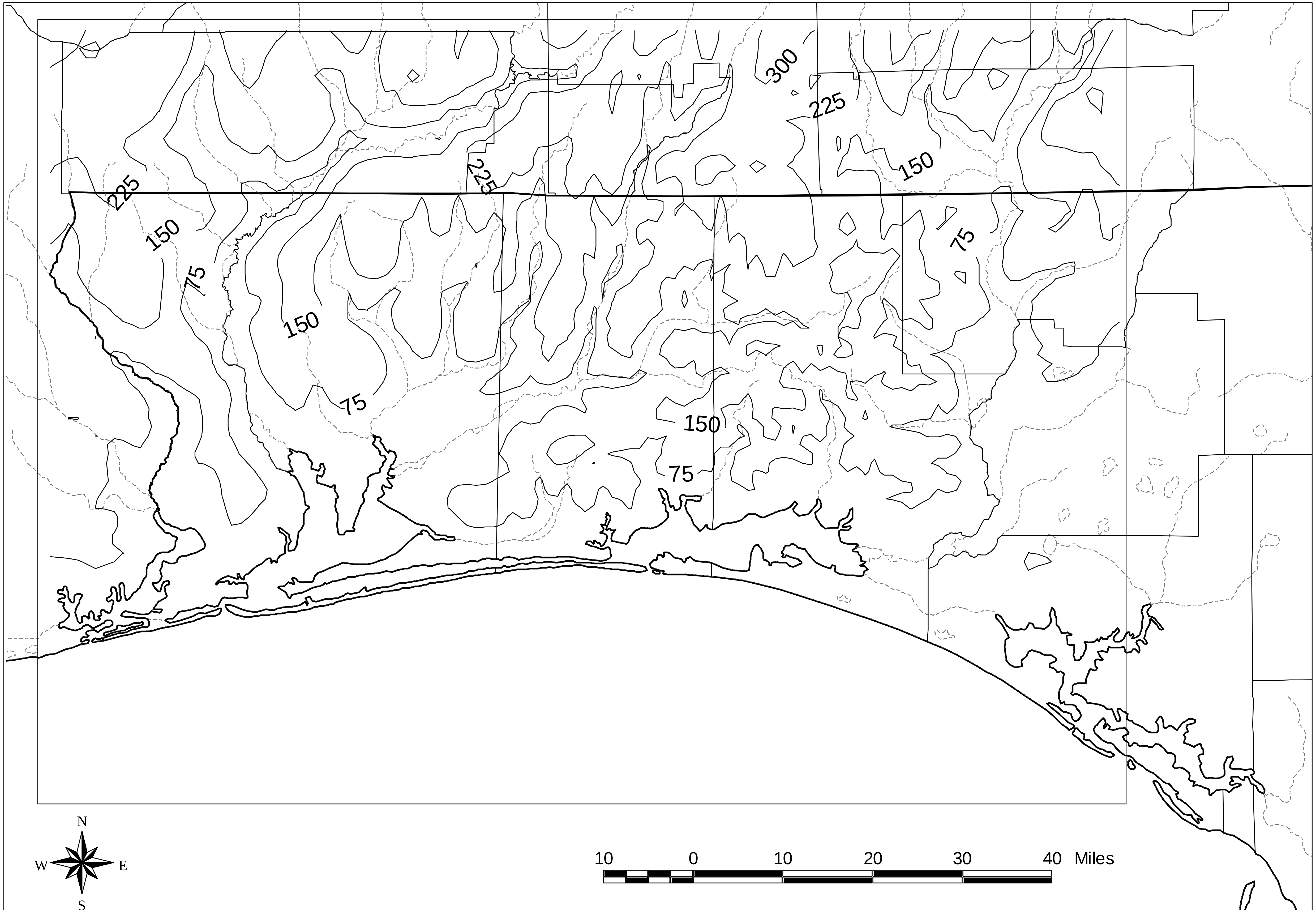


Figure 5.21

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Simulated Water Level Distribution for Model Layer 1 for the Calibration Simulation of 1990 Pumping Conditions



Legend

Water Level (ft)
Contour Interval: 75 ft
Hydrology
Counties
State / Coast Line

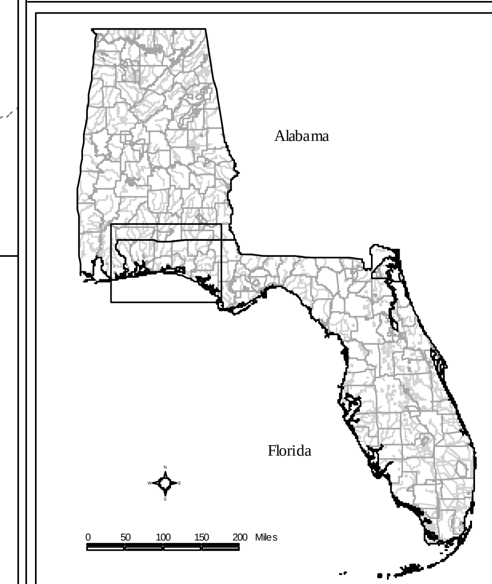
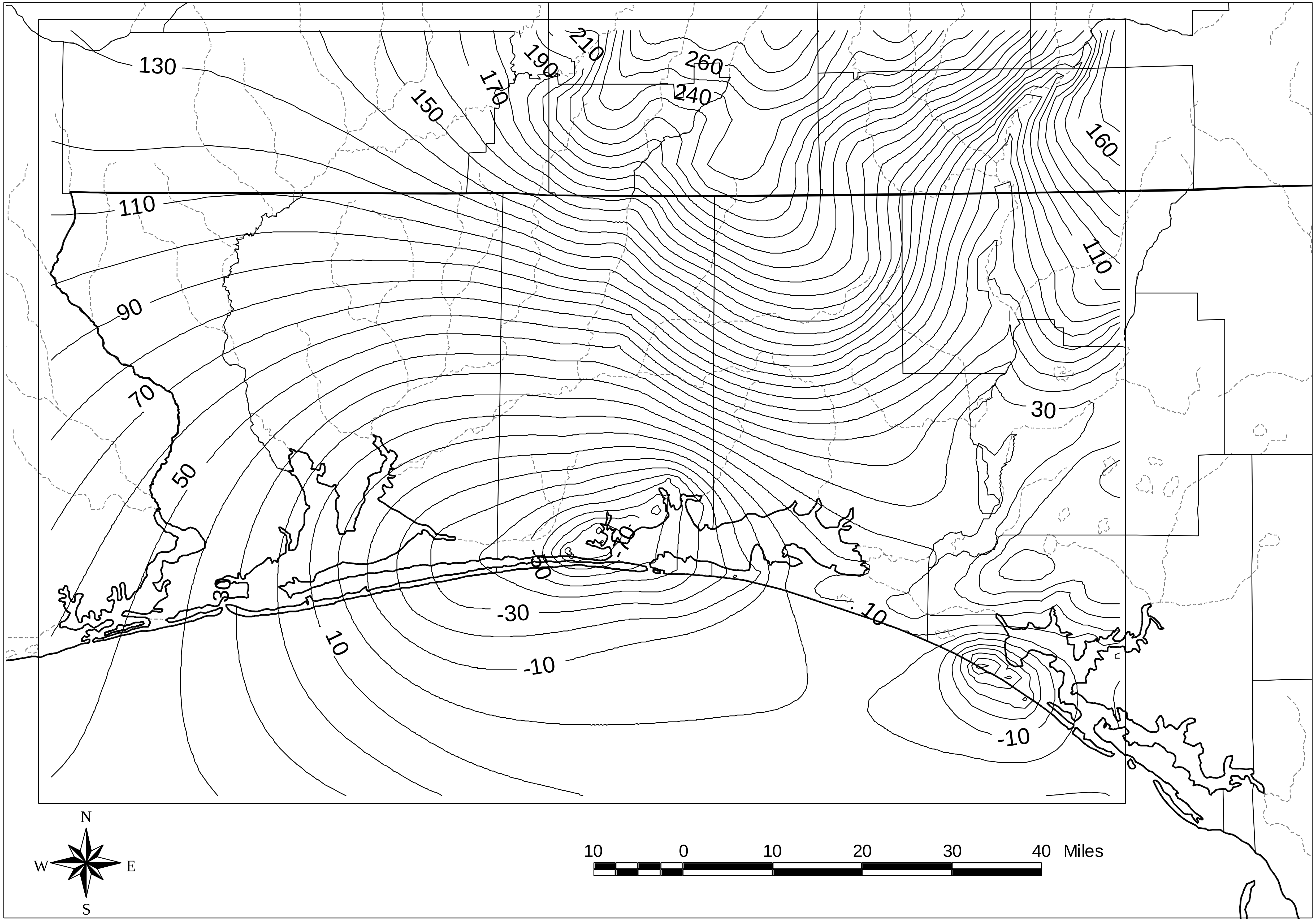


Figure 5.22

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/fig_5-22
Project: NFW002-0003
Created: 04/17/00 DD
Revised:

HYDRO GeoLogic INC.



Simulated Water Level Distribution for Model Layer 3 for the Calibration Simulation of 1990 Pumping Conditions

Legend

Water Level (ft)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

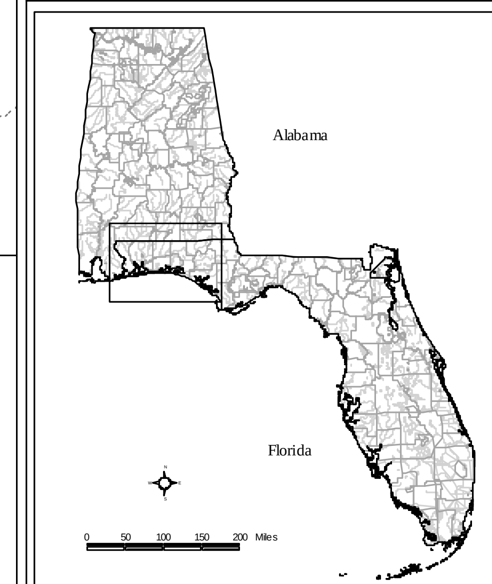
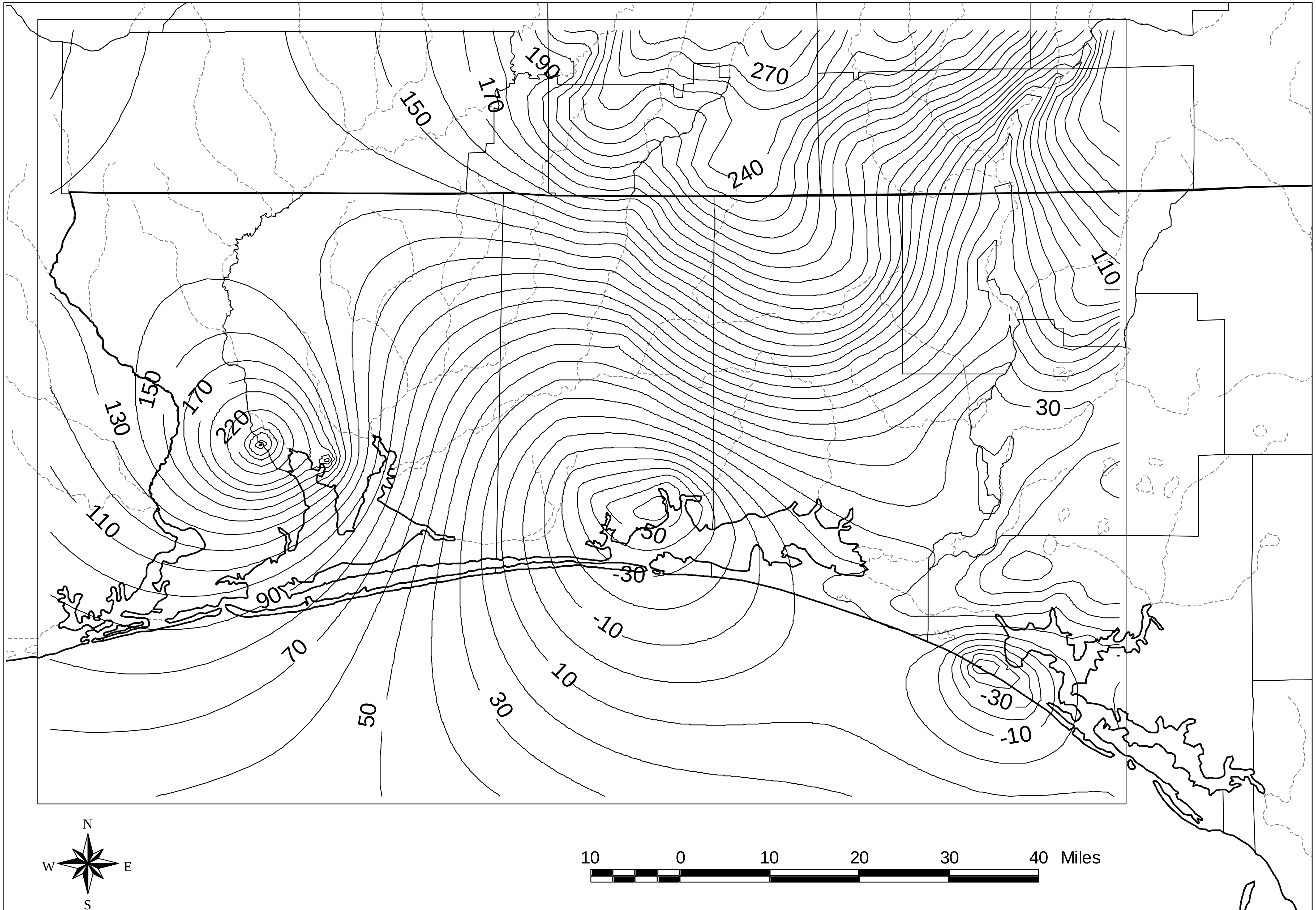


Figure 5.23

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Simulated Water Level Distribution for Model Layer 5 for the Calibration Simulation of 1990 Pumping Conditions



Legend

Water Level (ft)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

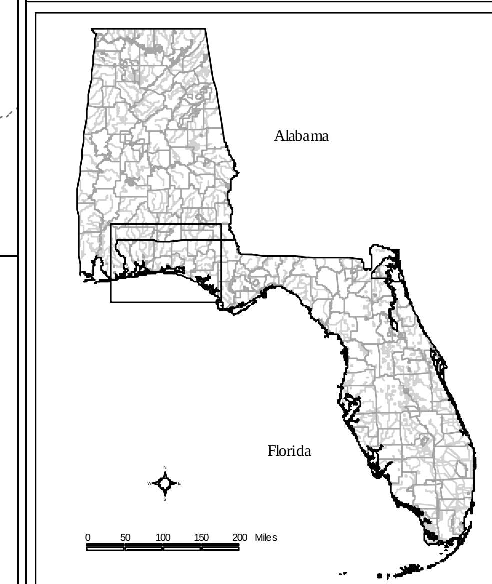
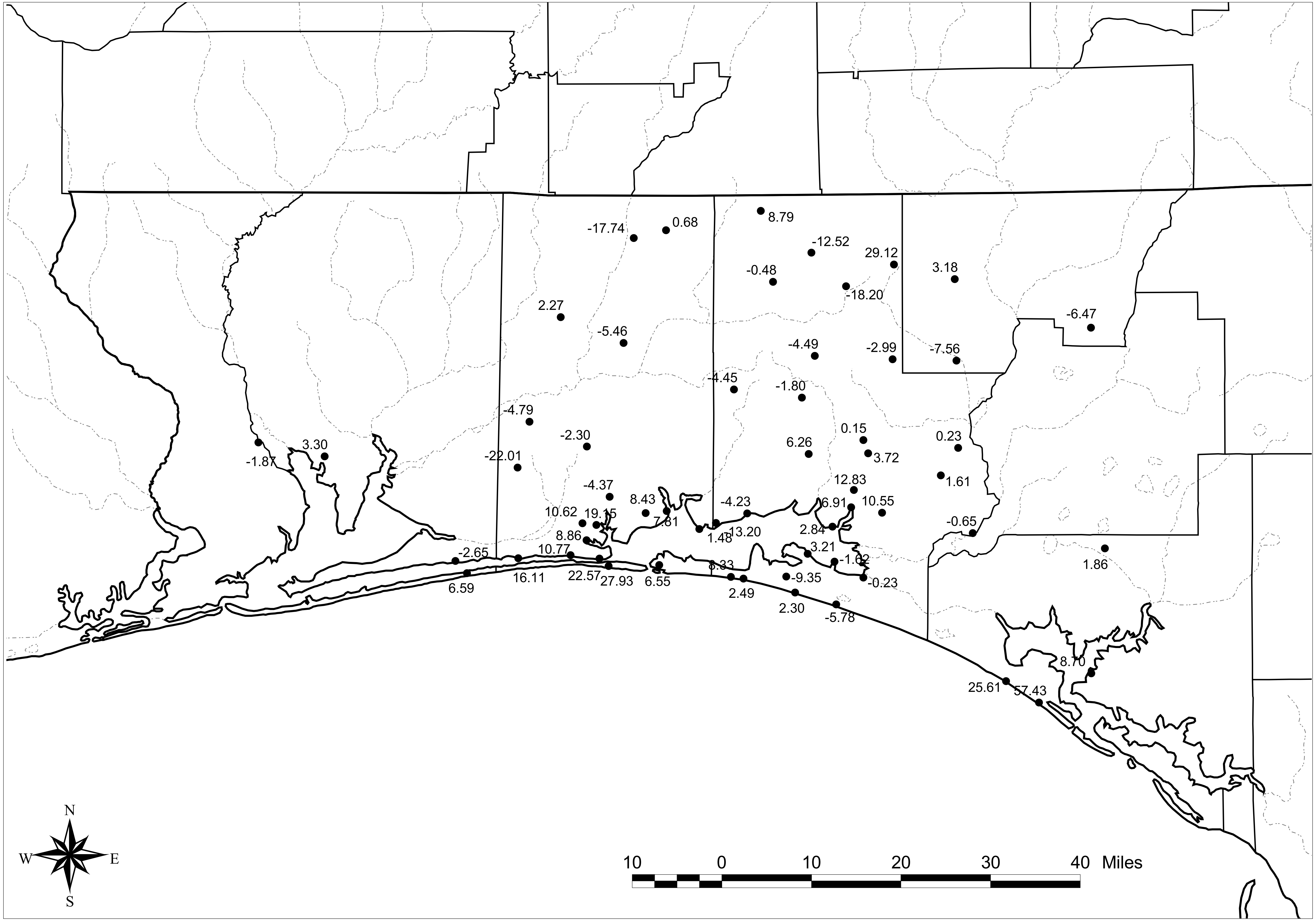


Figure 5.24

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Water Level Residuals for Model Layer 3 for the Calibration Simulation of 1990 Pumping Conditions

Legend

3.18 Difference (ft) (Sim-Obs)
Observation Well
Hydrology
Counties
State / Coast Line

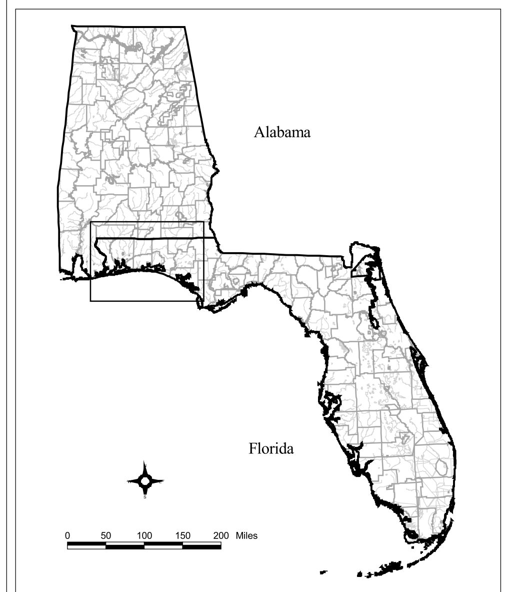
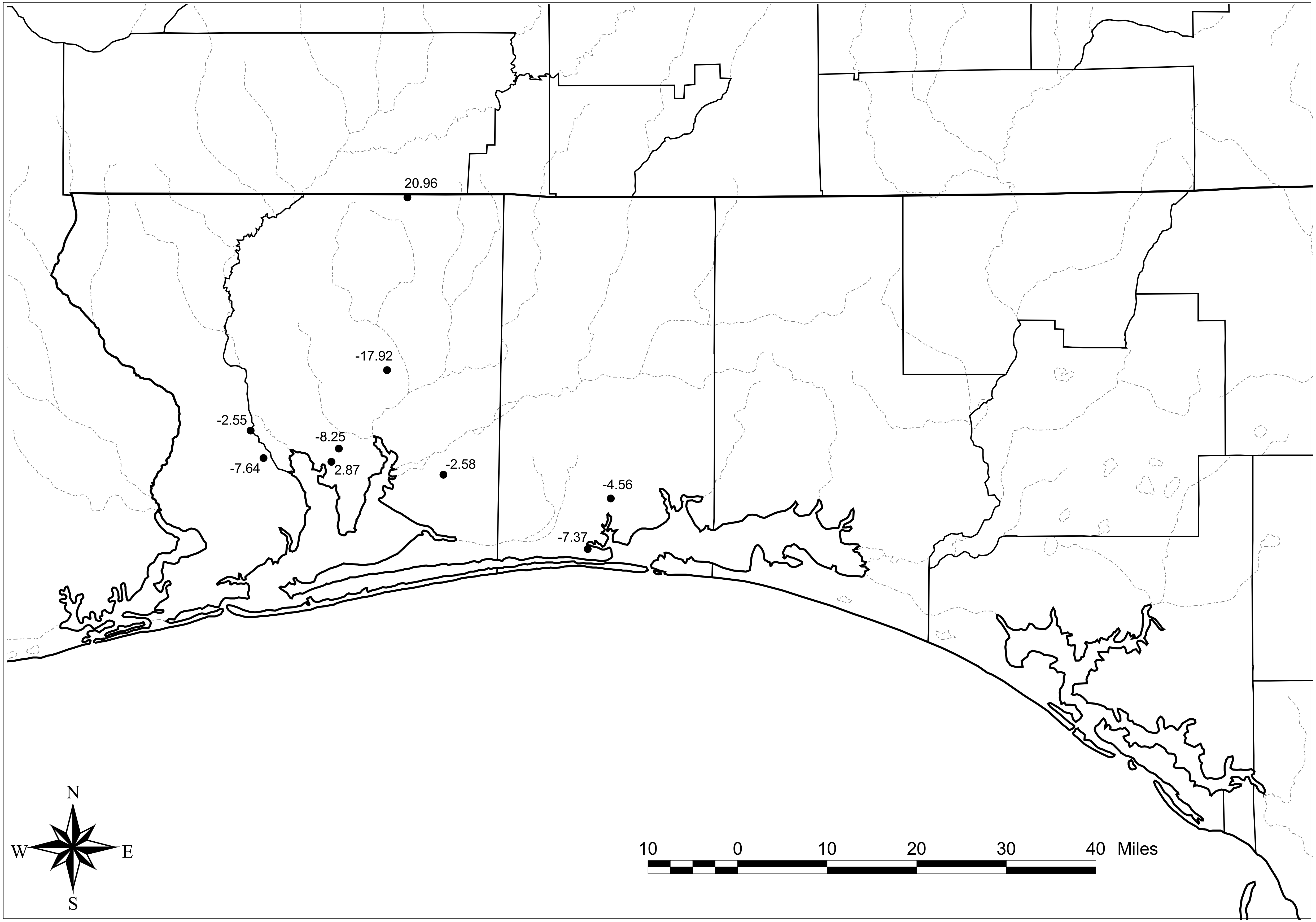


Figure 5.25

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/Fig_5-25
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Water Level Residuals for Model Layer 5 for the Calibration Simulation of 1990 Pumping Conditions

Legend

3.18 Difference (ft) (Sim - Obs)
● Observation Well
Hydrology
Counties
State / Coast Line

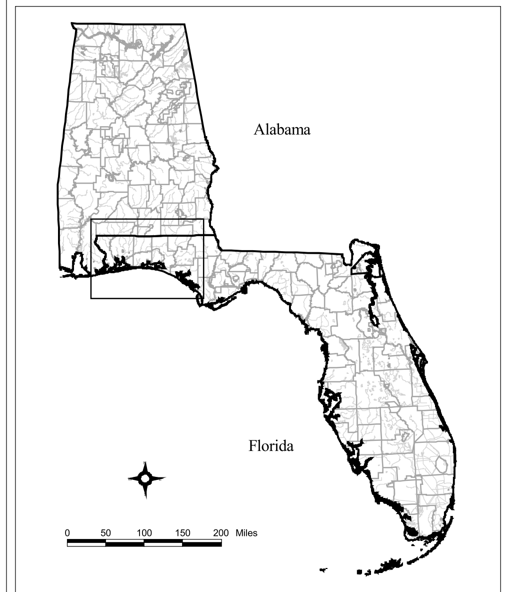


Figure 5.26

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/Fig_5-26
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Figure 5.27 Scatter Plot of Simulated Versus Measured Heads for the Calibrated Simulation of 1990 Pumping Conditions

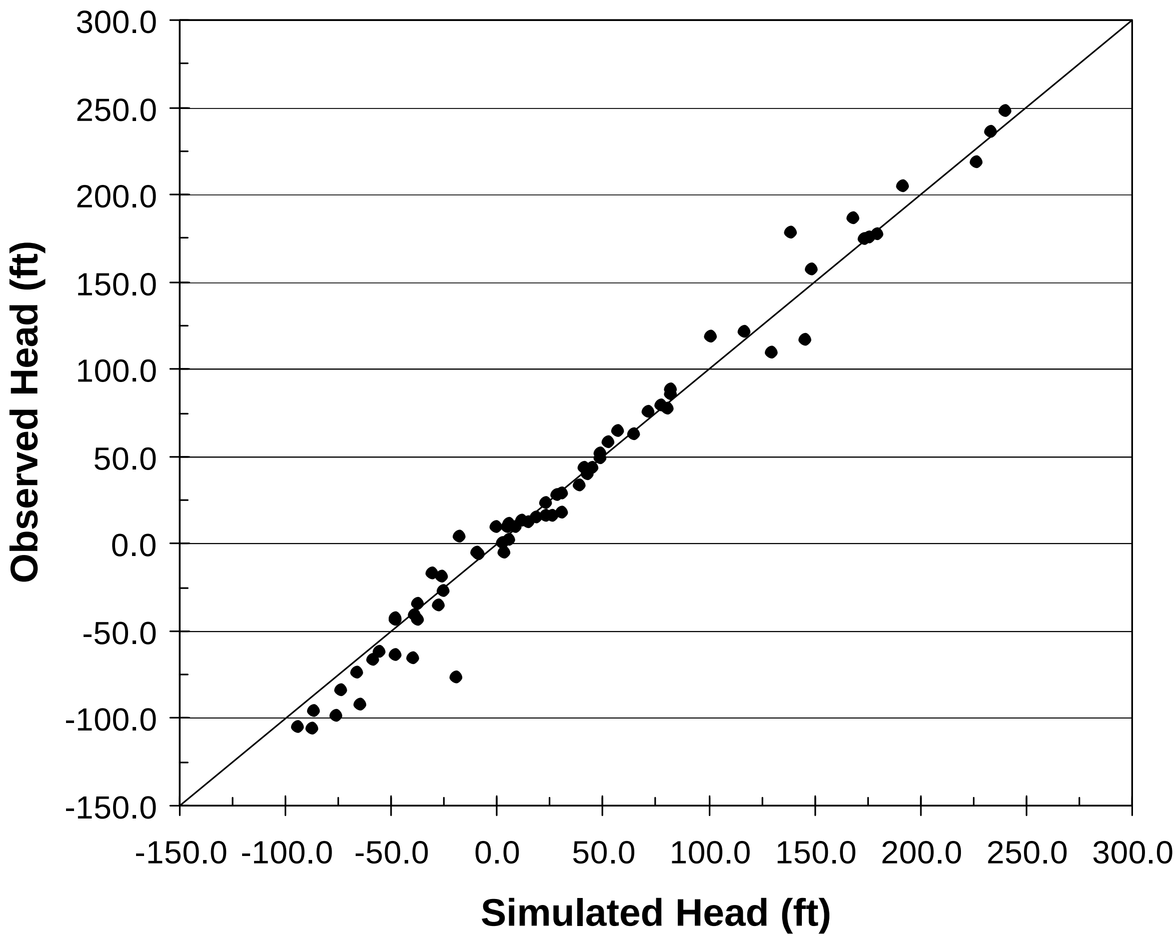
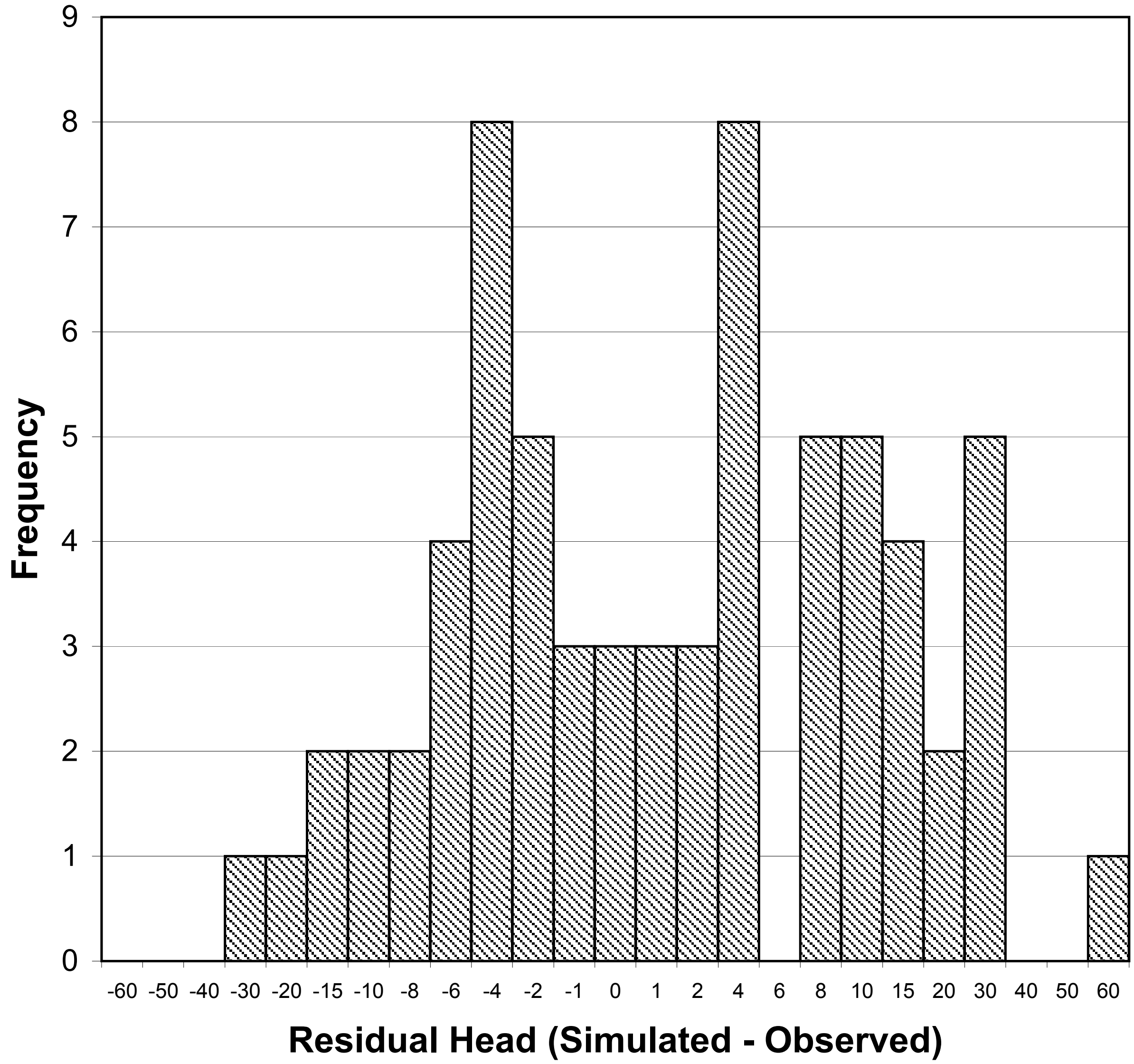
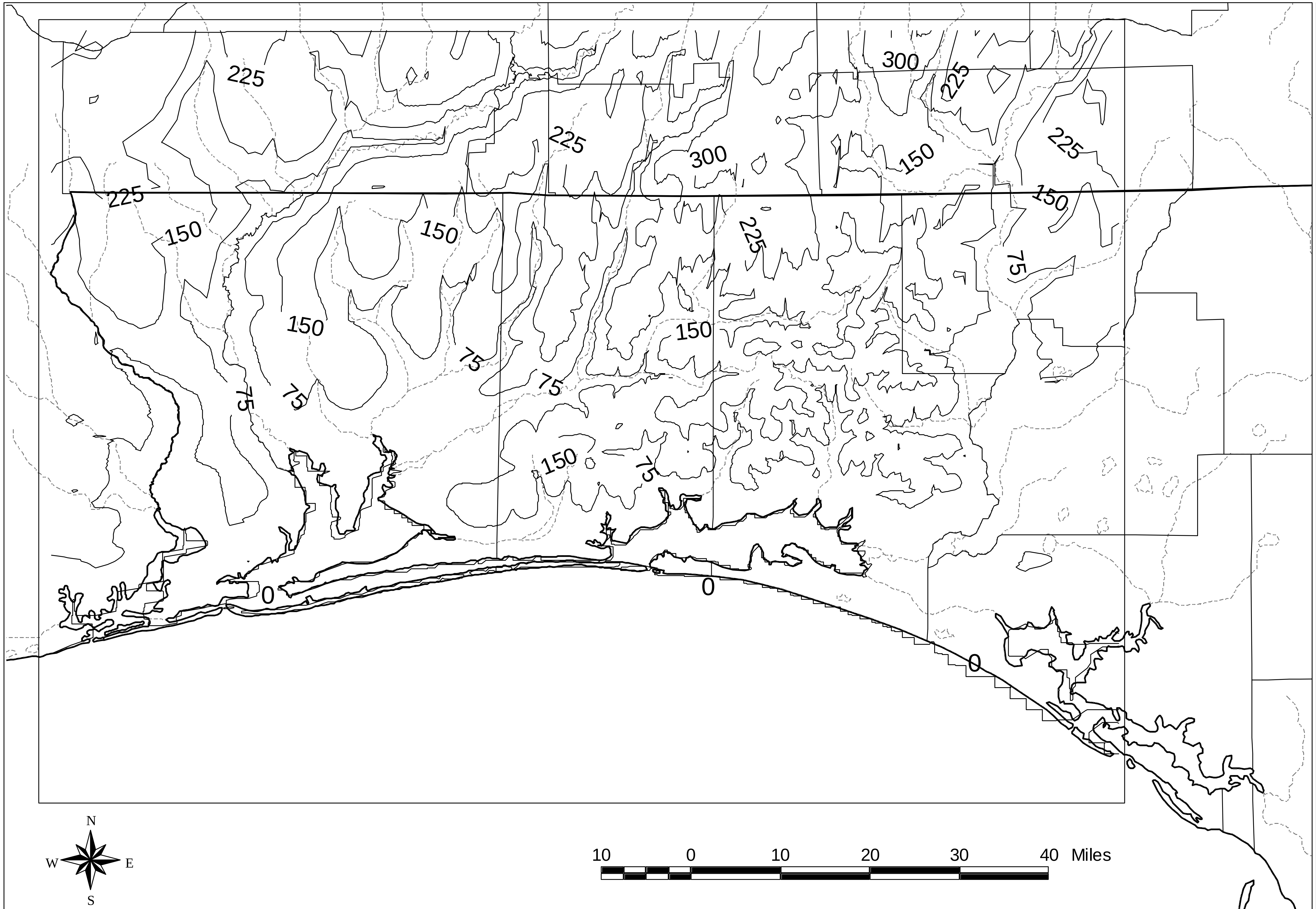


Figure 5.28 Frequency Distribution of Ground Water Residuals for the Calibration Simulation of 1990 Pumping Conditions





Simulated Water Level Distribution for Model Layer 1 for Pre-development Conditions

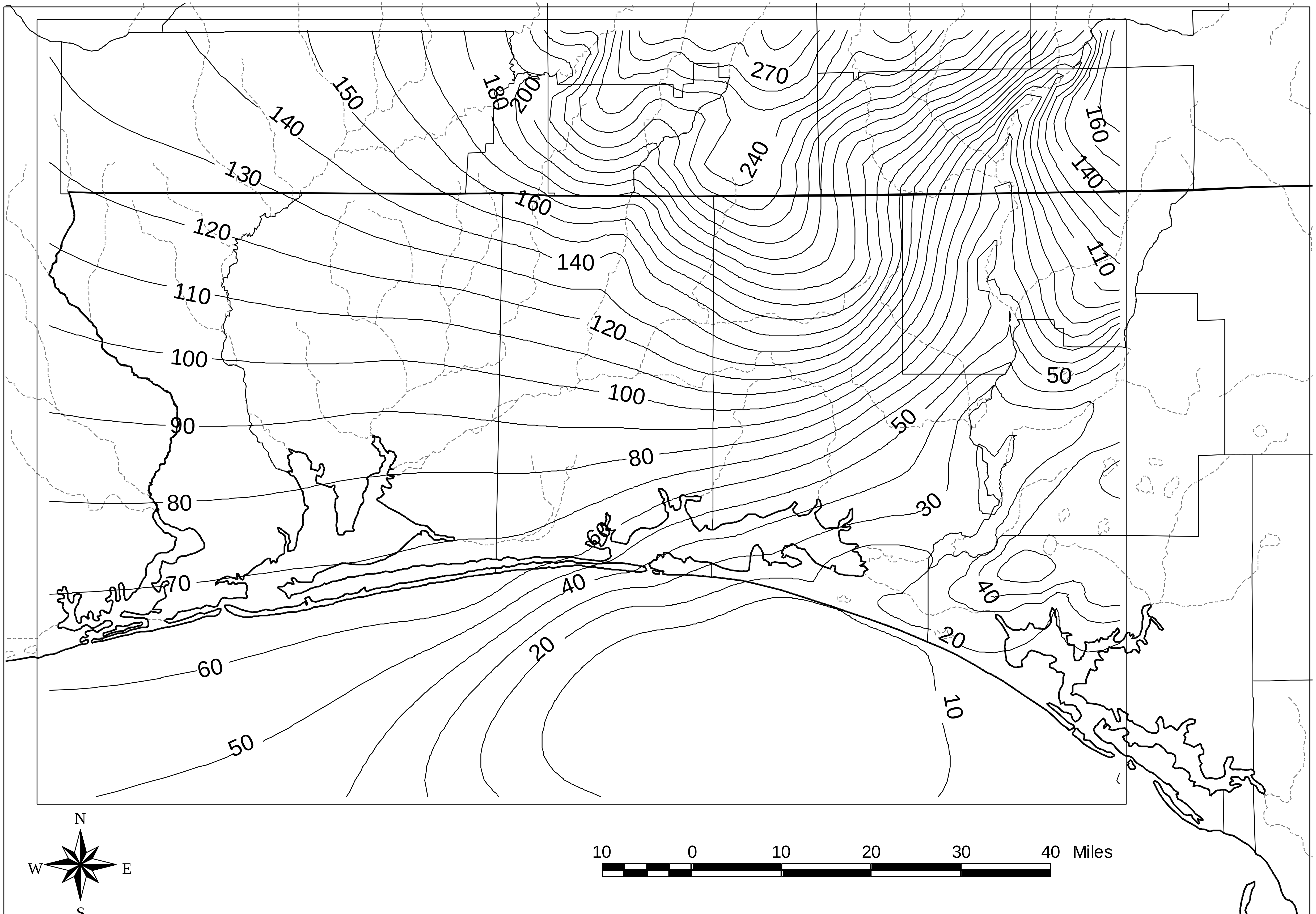
Legend

Water Level (ft)
Contour Interval: 75 ft
Hydrology
Counties
State / Coast Line

Figure 5.29

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Simulated Water Level Distribution for Model Layer 3 for Pre-development Conditions

Legend

Water Level (ft)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

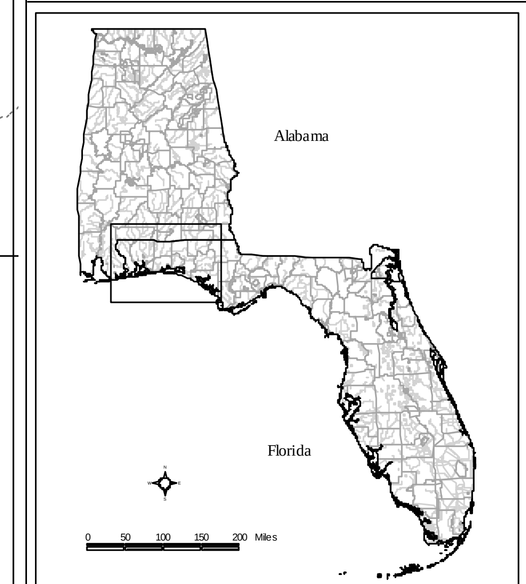
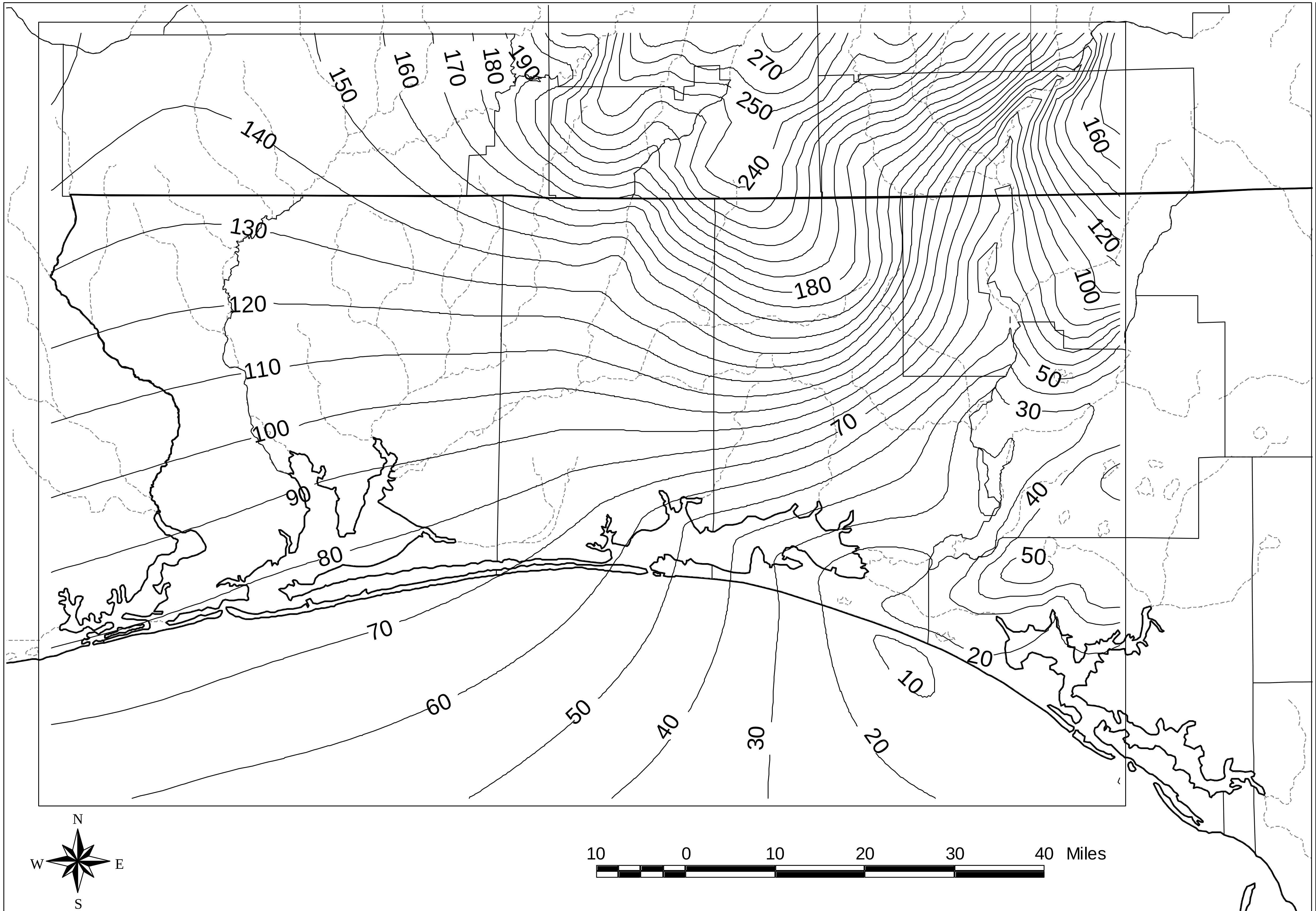


Figure 5.30

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Simulated Water Level Distribution for Model Layer 5 for Pre-development Conditions



Legend

Water Level (ft)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

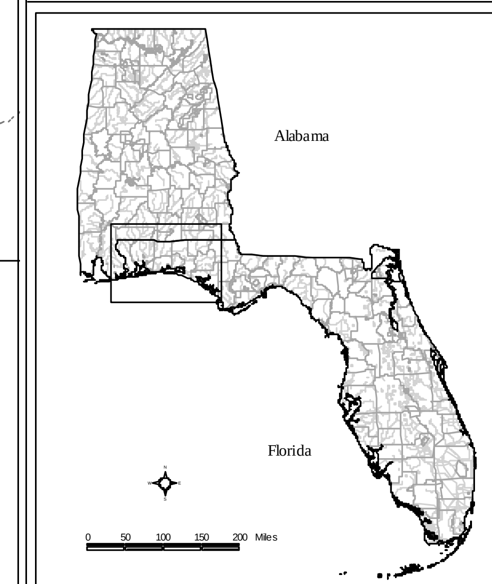
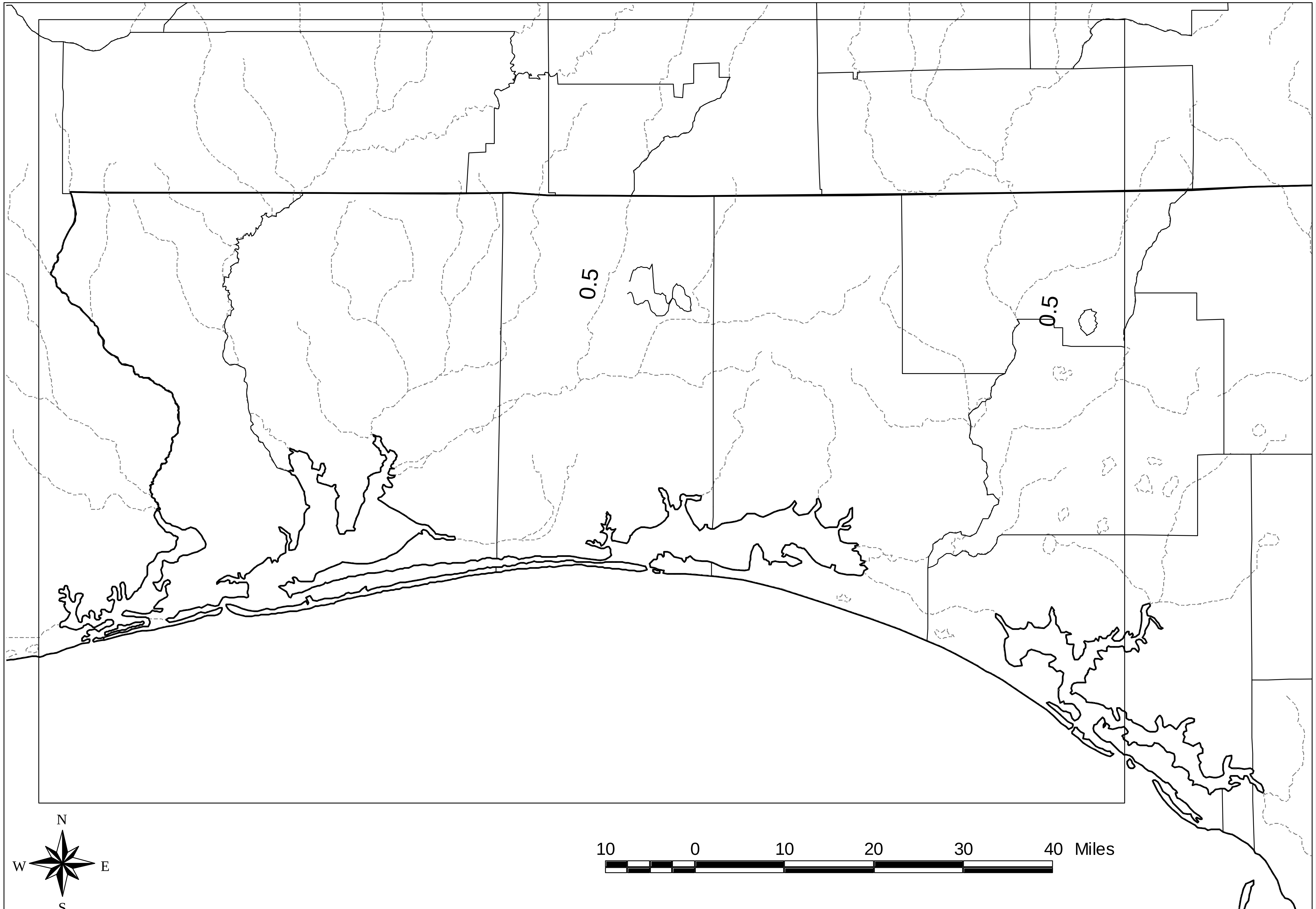


Figure 5.31

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD



Simulated Water Level Difference Between Pre-development and 1990 Pumping Conditions for Model Layer 1

Legend

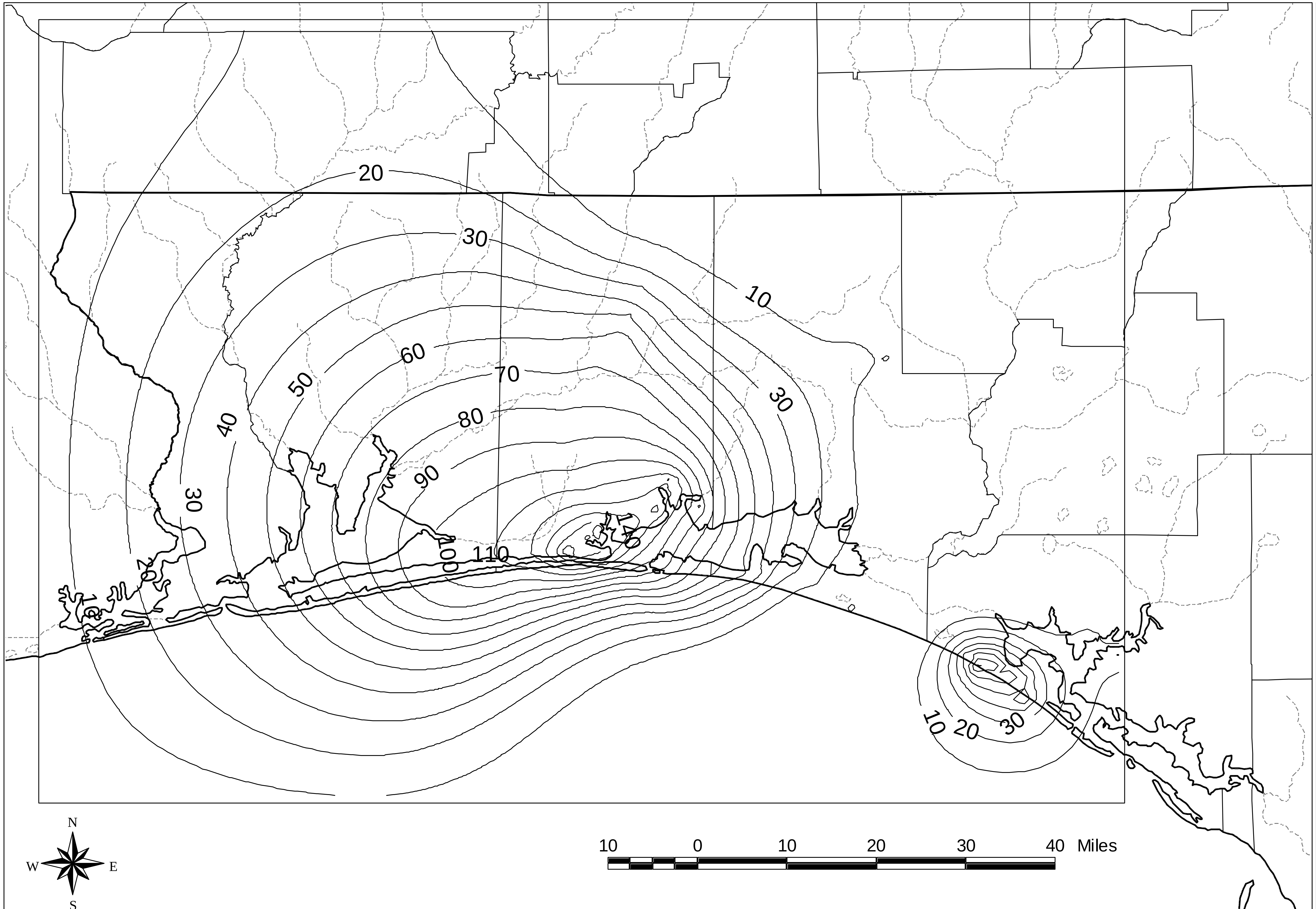
Water Level Difference (ft) (Pre-dev. - 1990 Conditions) Contour Interval: 0.5 ft
Hydrology
Counties
State / Coast Line

Figure 5.32

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Simulated Water Level Difference Between Pre-development and 1990 Pumping Conditions for Model Layer 3



Legend

Water Level Difference (ft)
(Pre-dev. - 1990 Conditions)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

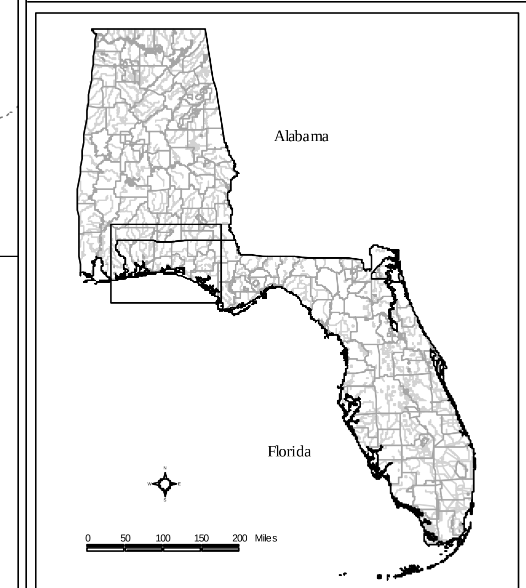
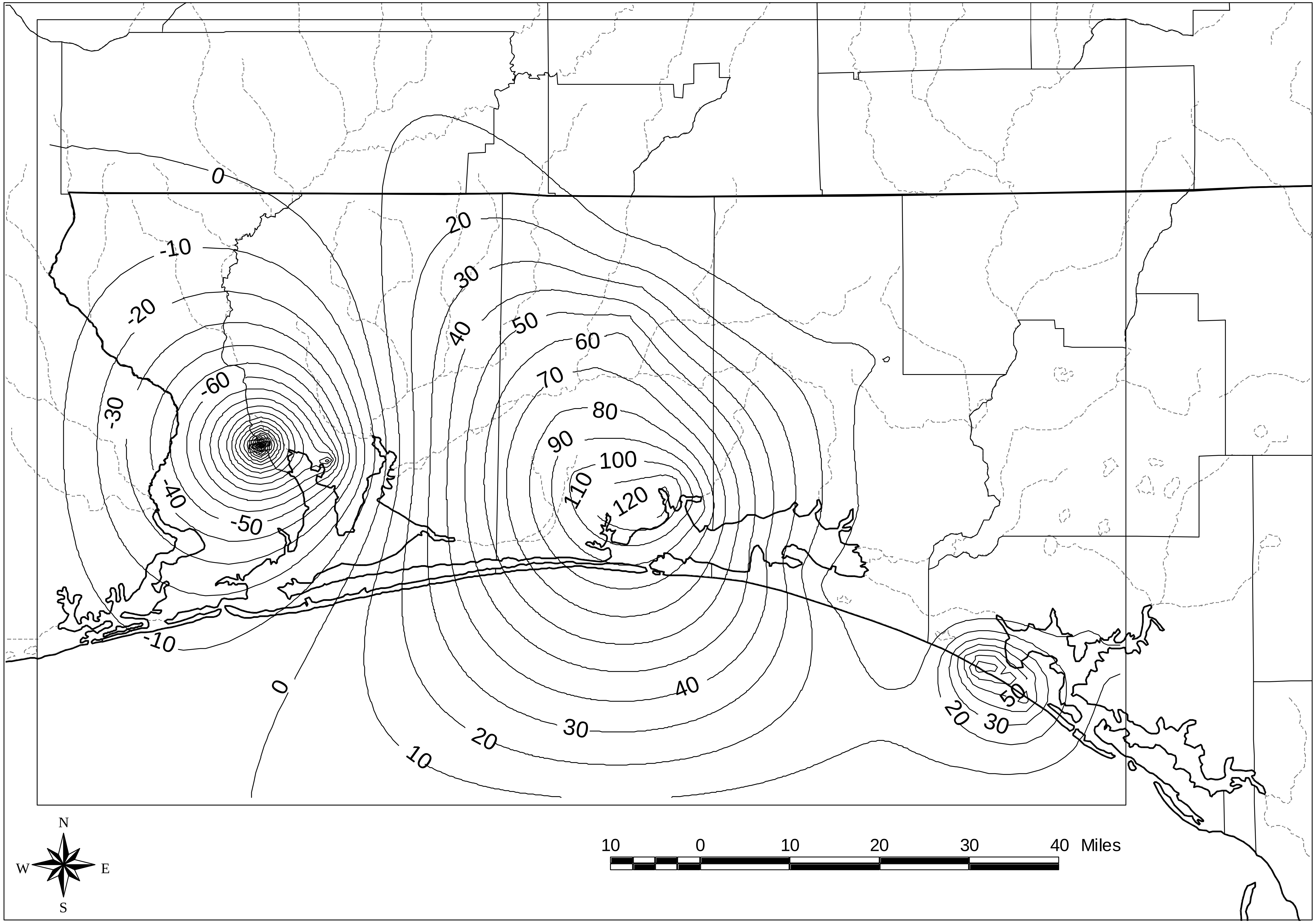


Figure 5.33

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Simulated Water Level Difference Between Pre-development and 1990 Pumping Conditions for Model Layer 5



Legend

Water Level Difference (ft)
(Pre-dev. - 1990 Conditions)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

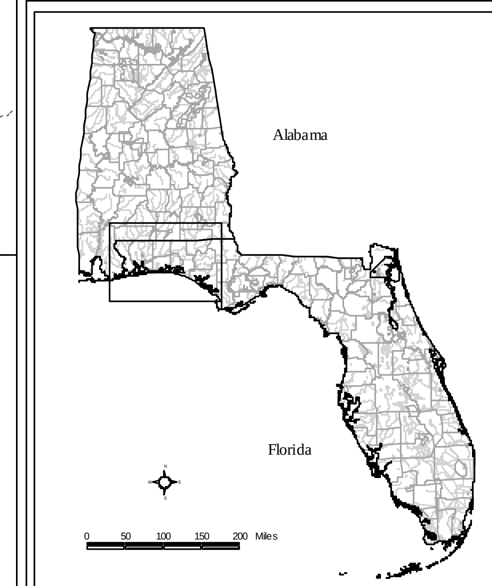
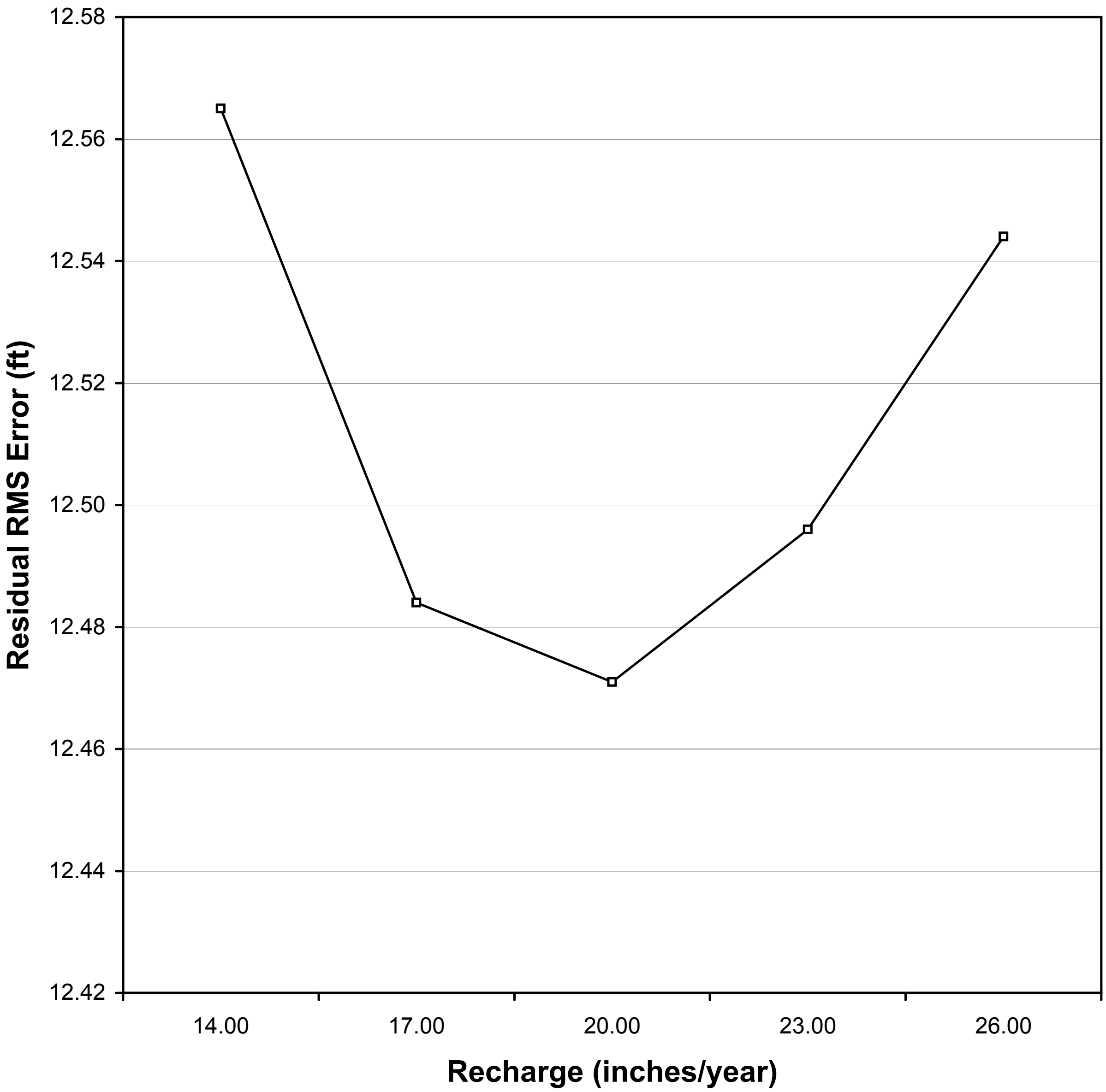


Figure 5.34

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.

Figure 5.35 RMS Error Sensitivity to Recharge



Water Level Difference Between Base Case and Sensitivity Simulation to Recharge of 26 in/yr for Model Layer 1

Legend

- Water Level Difference (ft) (Base Case - Sensitivity Sim.) Contour Interval: 5 ft
- Hydrology
- Counties
- State / Coast Line

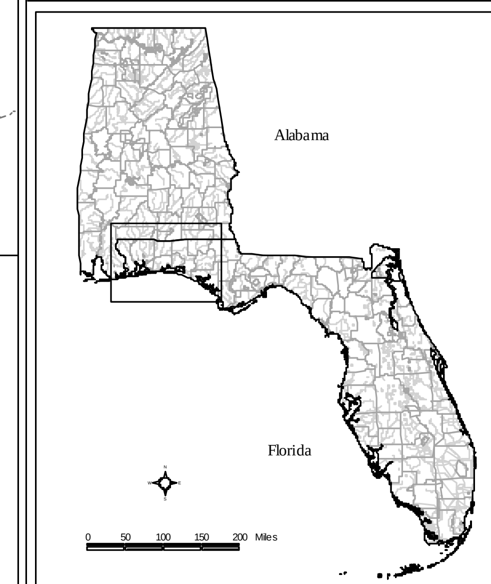


Figure 5.36

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

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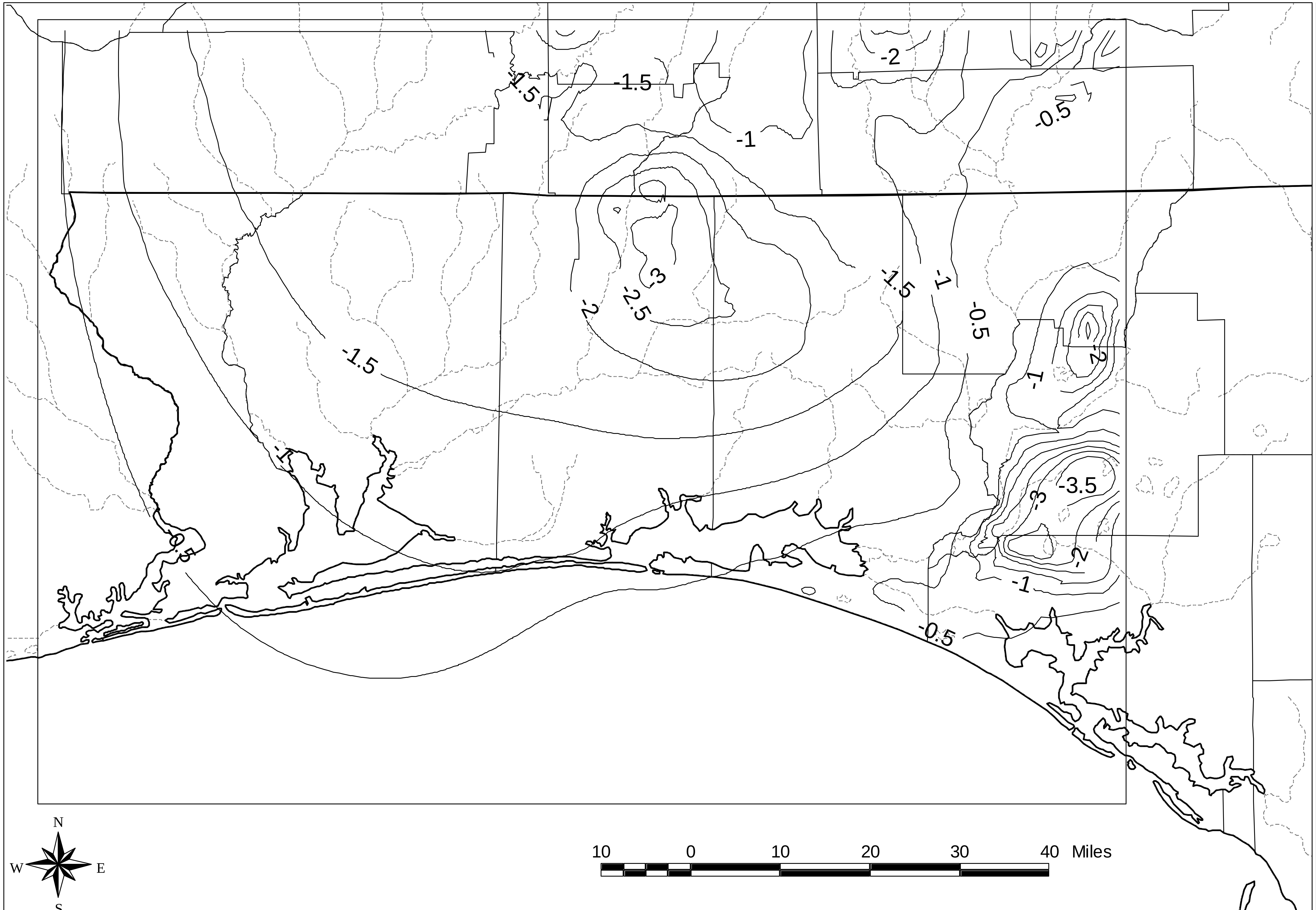


Water Level Difference Between Base Case and Sensitivity Simulation to Recharge of 26 in/yr for Model Layer 3

Legend

Water Level Difference (ft) (Base Case - Sensitivity Sim.) Contour Interval: 0.5 ft
Hydrology
Counties
State / Coast Line

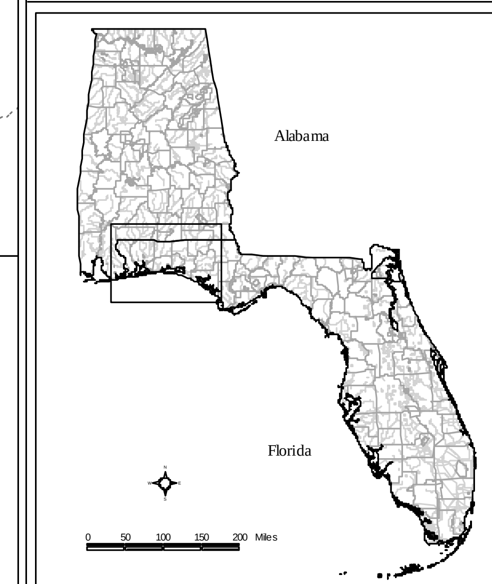
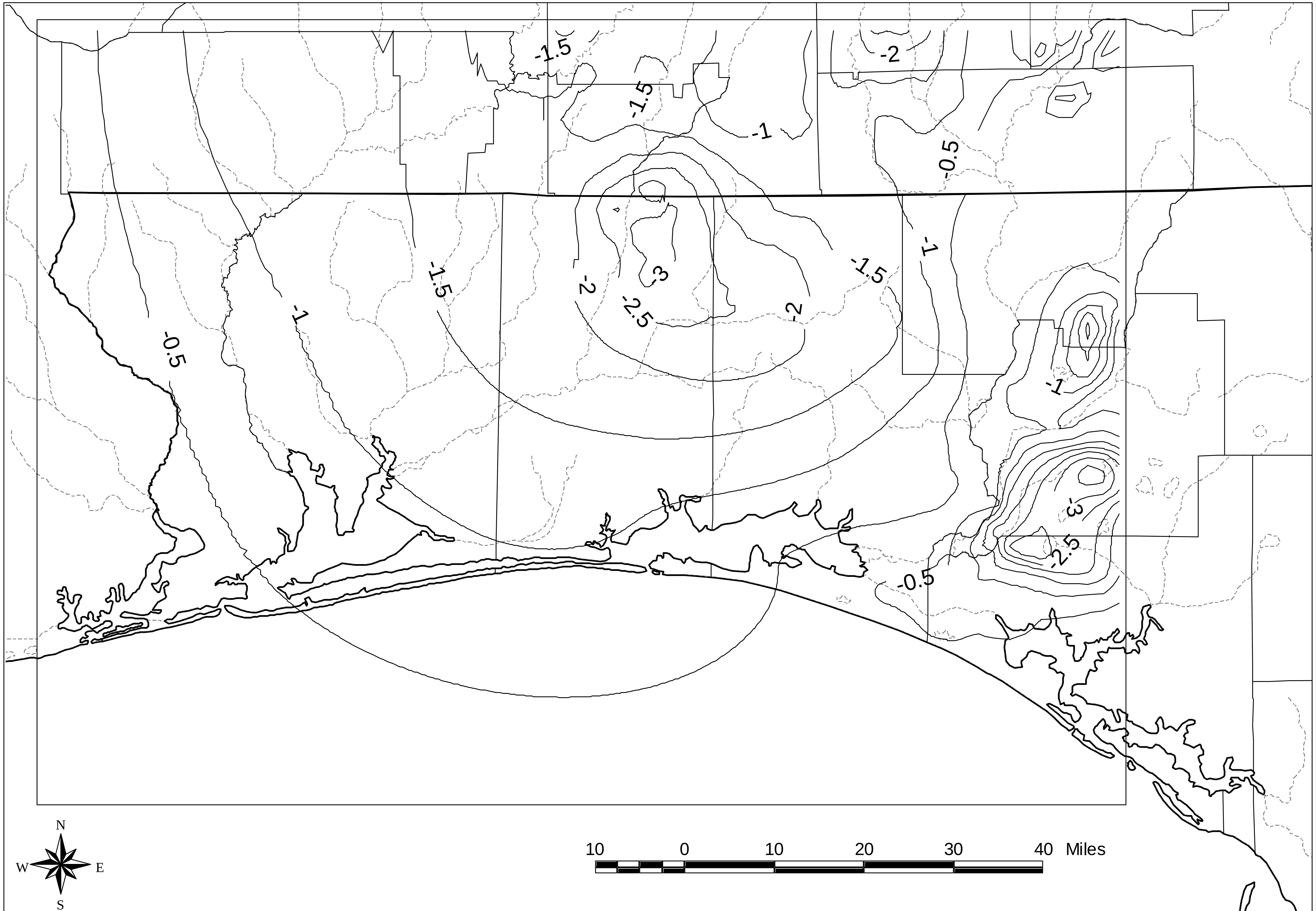


Figure 5.37

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD



Water Level Difference Between Base Case and Sensitivity Simulation to Recharge of 26 in/yr for Model Layer 5

Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: 0.5 ft
Hydrology
Counties
State / Coast Line

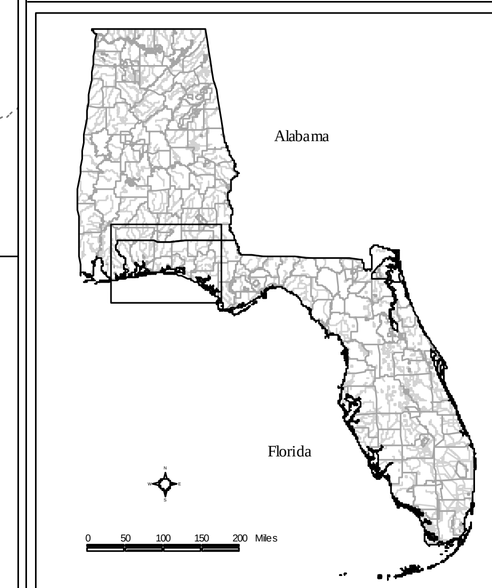
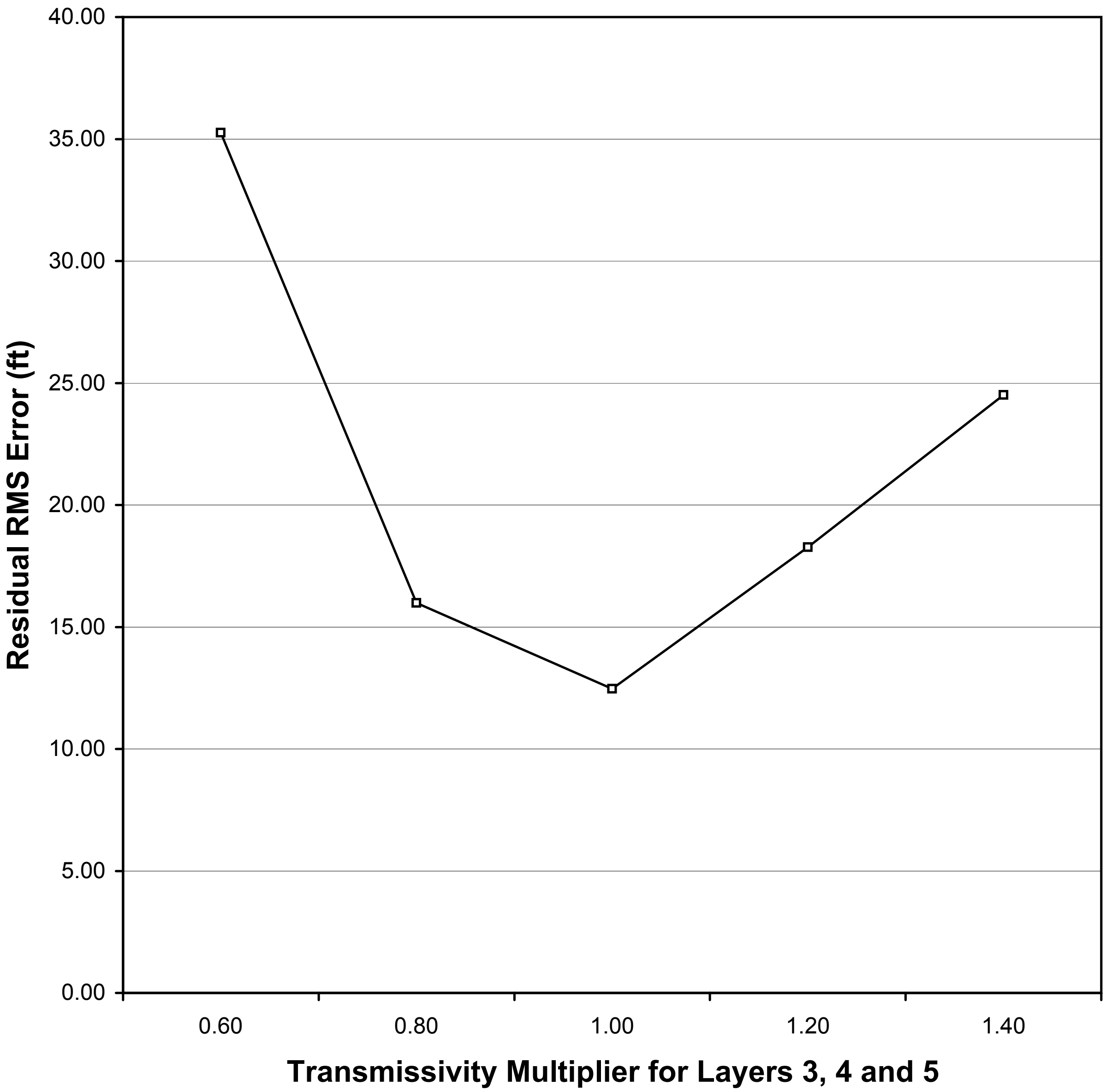


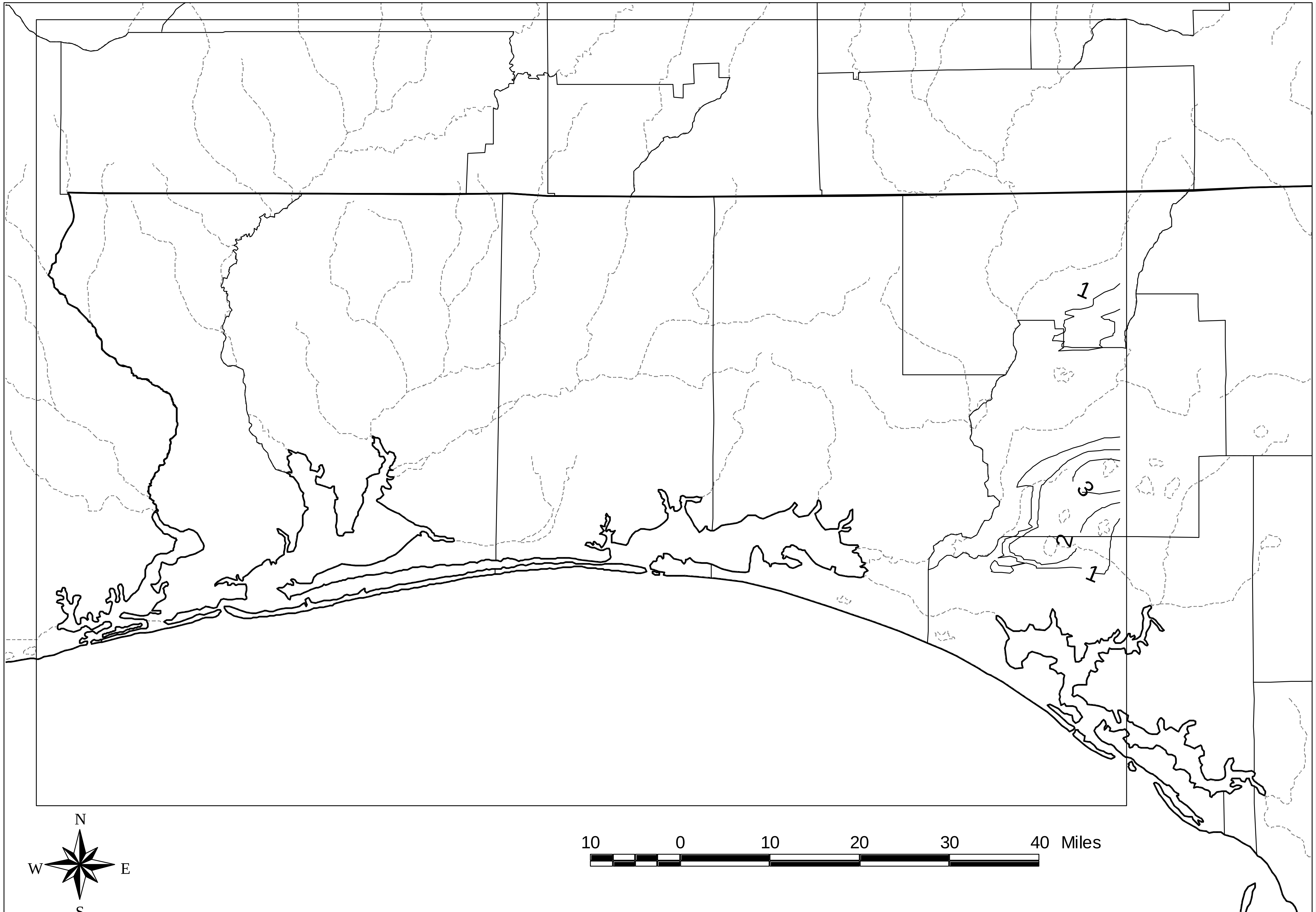
Figure 5.38

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

Figure 5.39 RMS Error Sensitivity to Floridan Aquifer Transmissivity



Water Level Difference Between Base Case and Sensitivity Simulation to Transmissivity (with a scaling factor of 1.4) for Model Layer 1



Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: 1 ft
Hydrology
Counties
State / Coast Line

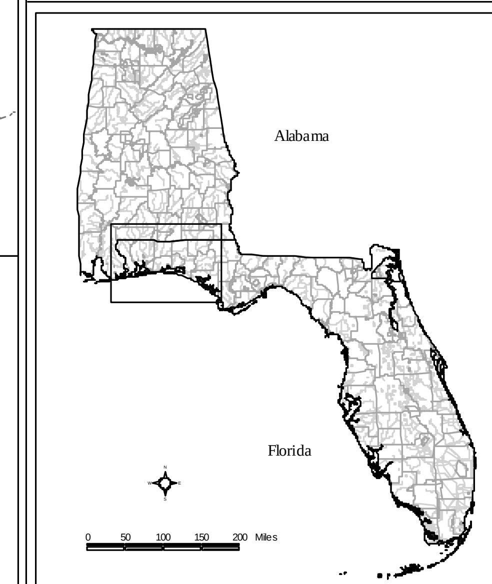


Figure 5.40

Filename: L: SORAB/D/NWFWMD/ARCVIEW/NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

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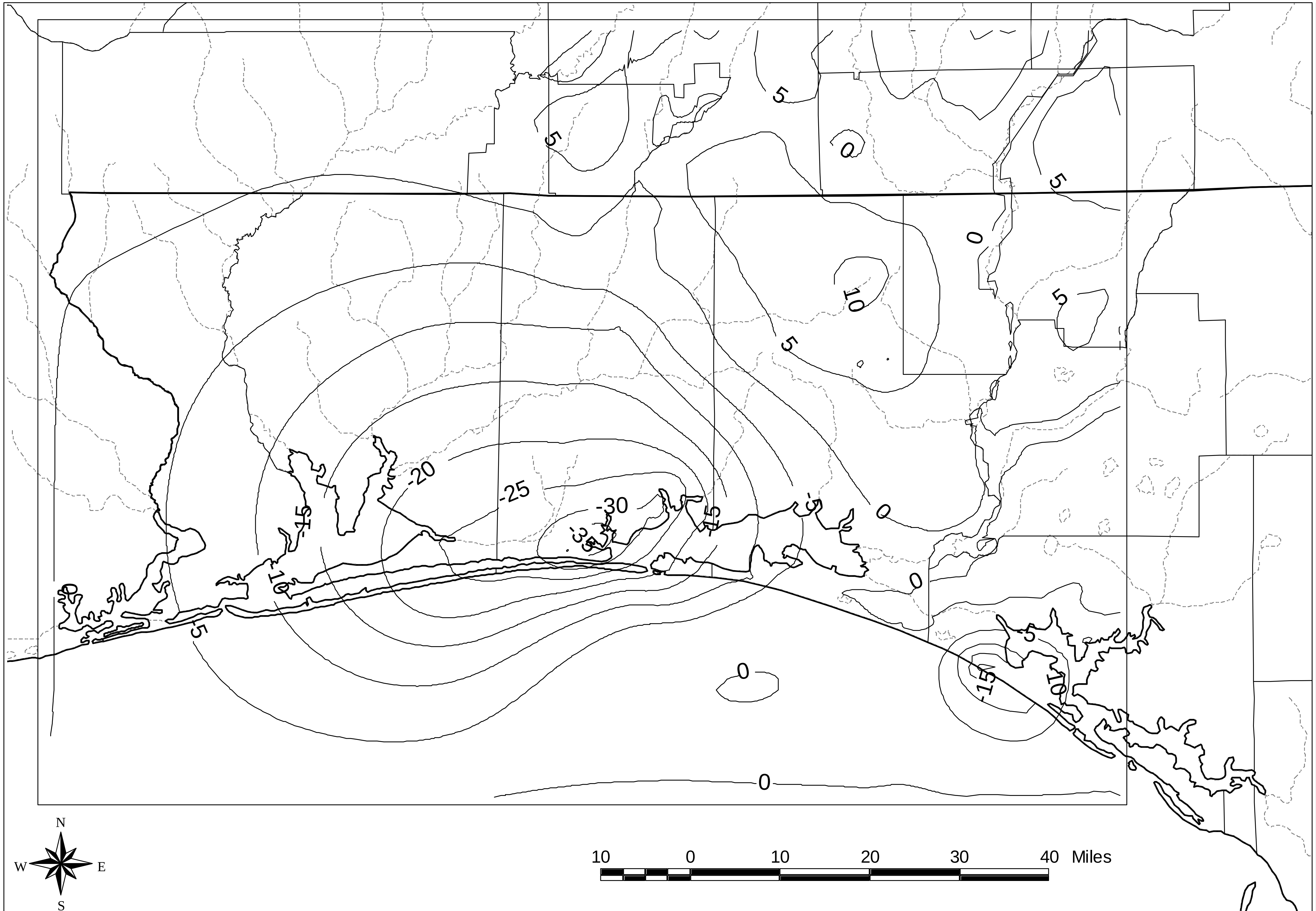


Water Level Difference Between Base Case and Sensitivity Simulation to Transmissivity (with a scaling factor of 1.4) for Model Layer 3

Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: 5 ft
Hydrology
Counties
State / Coast Line

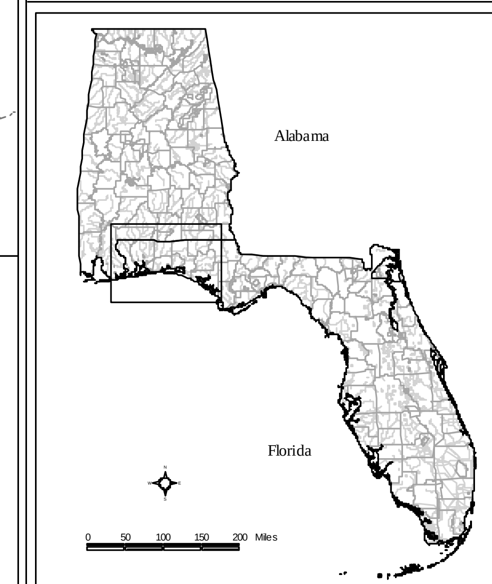
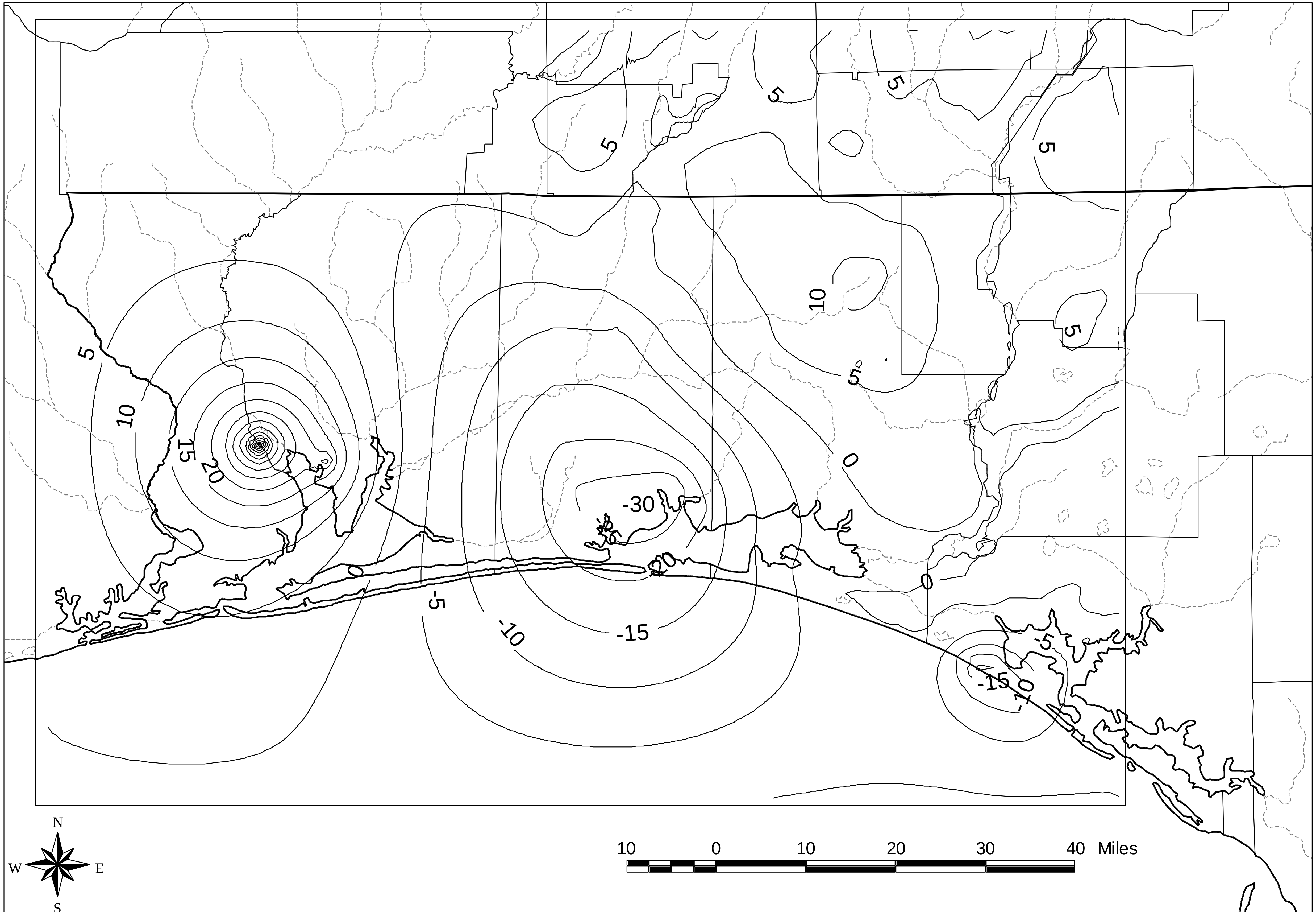


Figure 5.41

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

HYDRO GeoLogic INC.



Water Level Difference Between Base Case and Sensitivity Simulation to Transmissivity (with a scaling factor of 1.4) for Model Layer 5

Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: 5 ft
Hydrology
Counties
State / Coast Line

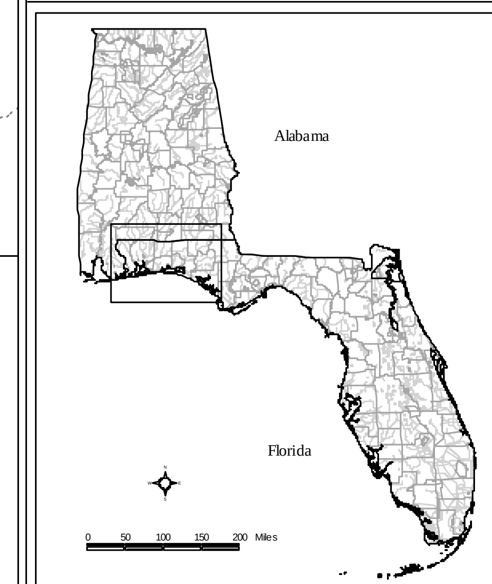
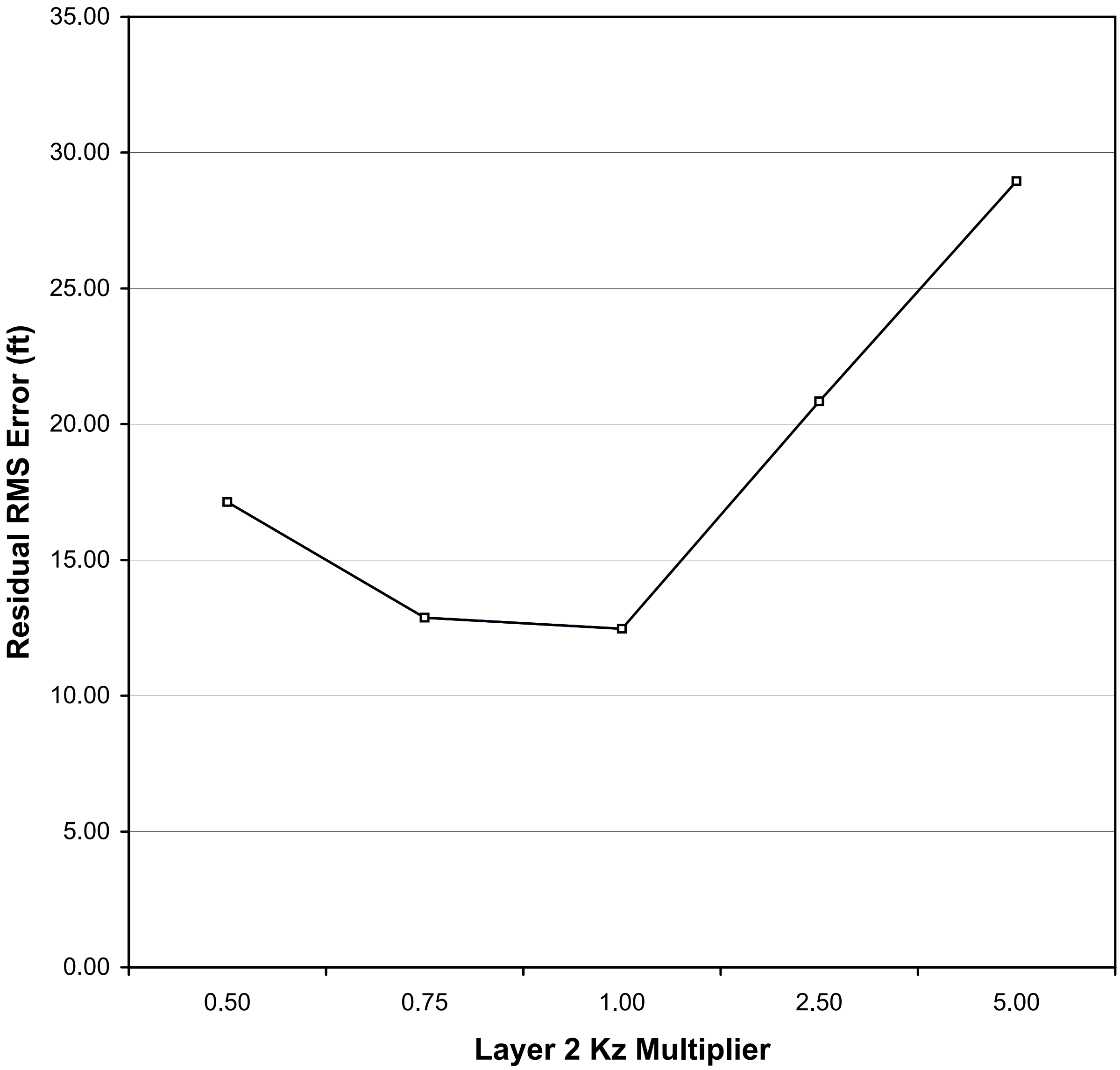
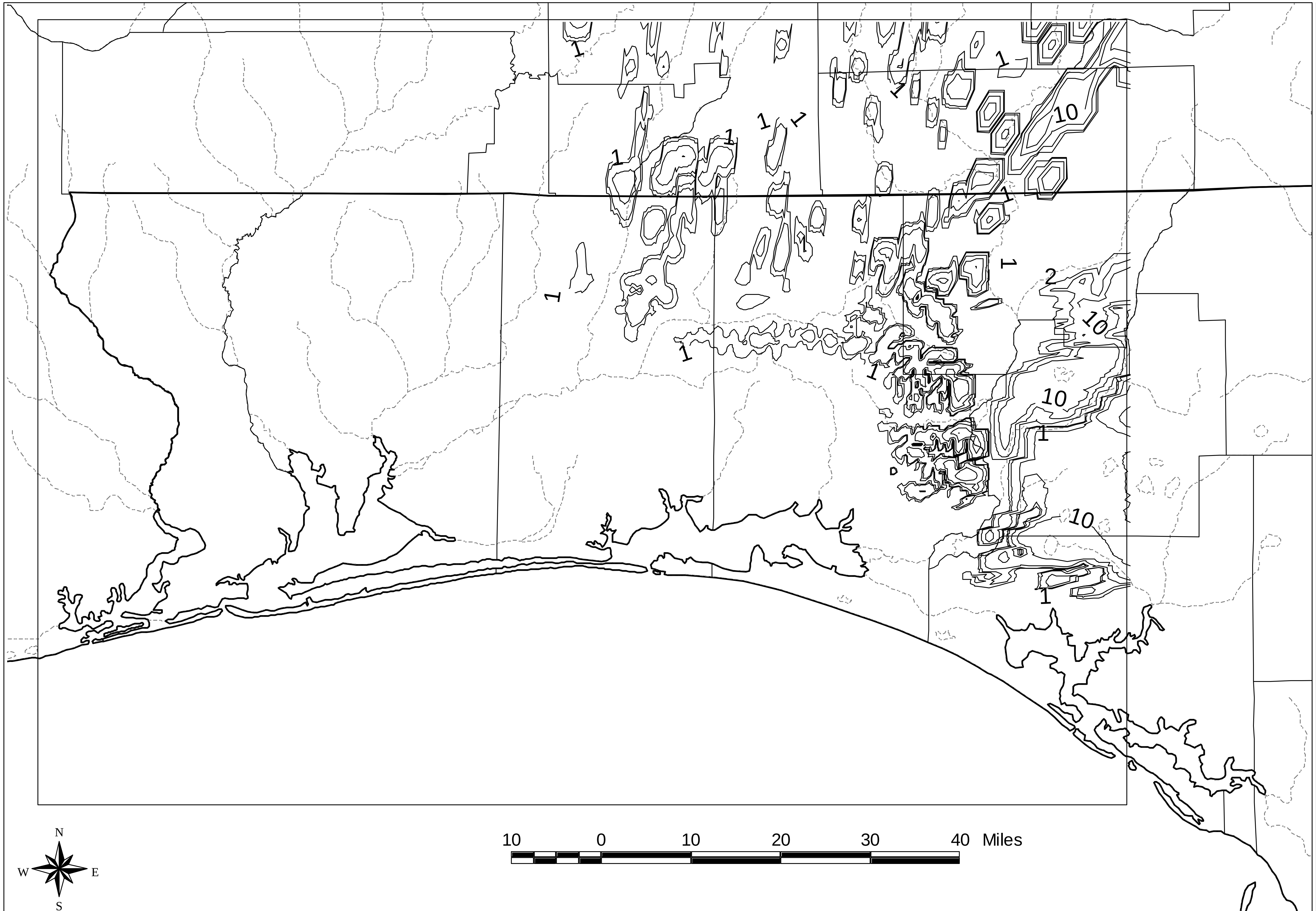


Figure 5.42

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

Figure 5.43 RMS Error Sensitivity to Vertical Hydraulic Conductivity of the Intermediate System





Water Level Difference Between Base Case and Sensitivity Simulation to Vertical Hydraulic Conductivity of the Intermediate System (with a scaling factor of 5) for Model Layer 1

Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: irregular
Hydrology
Counties
State / Coast Line

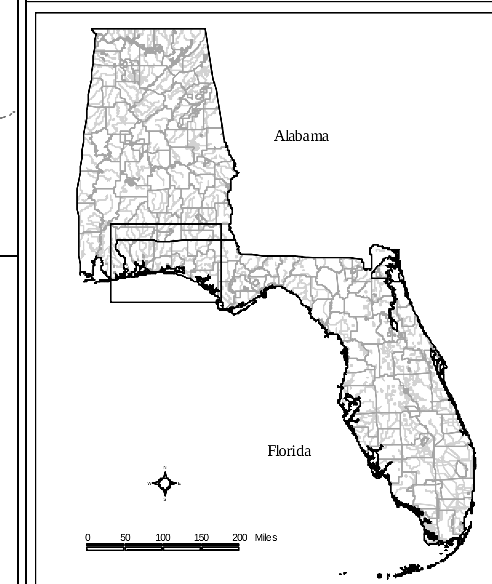
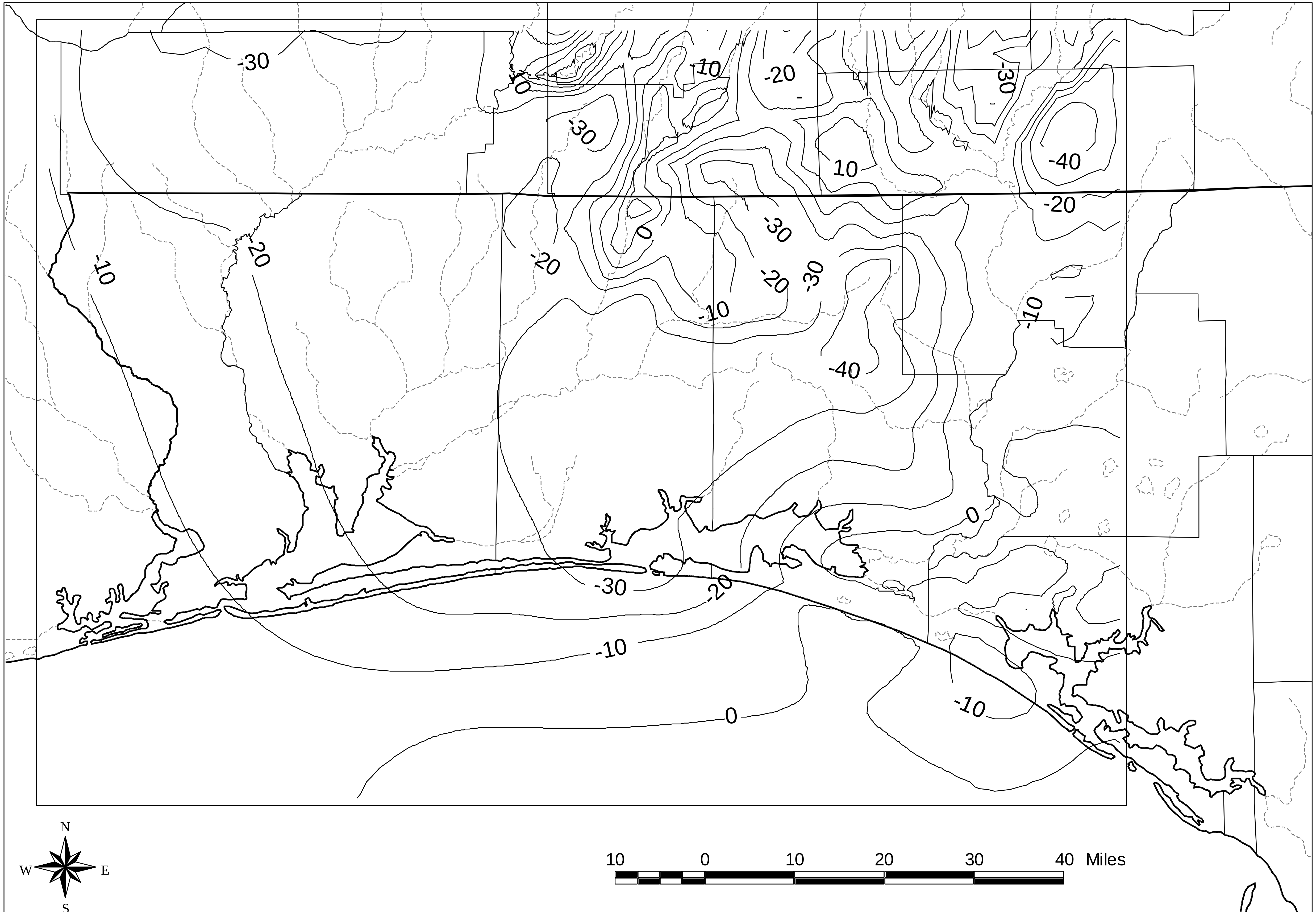


Figure 5.44

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD



Water Level Difference Between Base Case and Sensitivity Simulation to Vertical Hydraulic Conductivity of the Intermediate System (with a scaling factor of 5) for Model Layer 3

Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

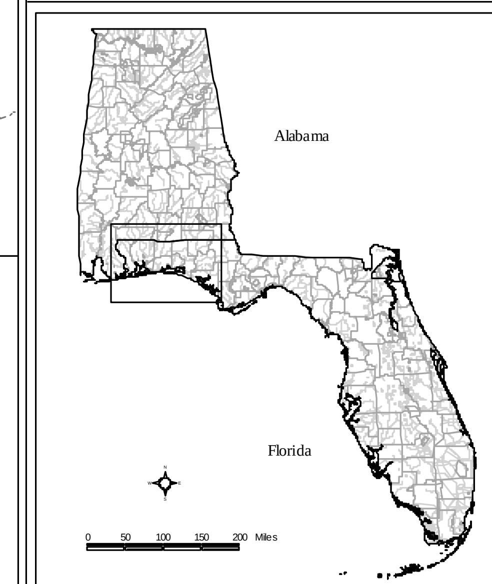


Figure 5.45

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

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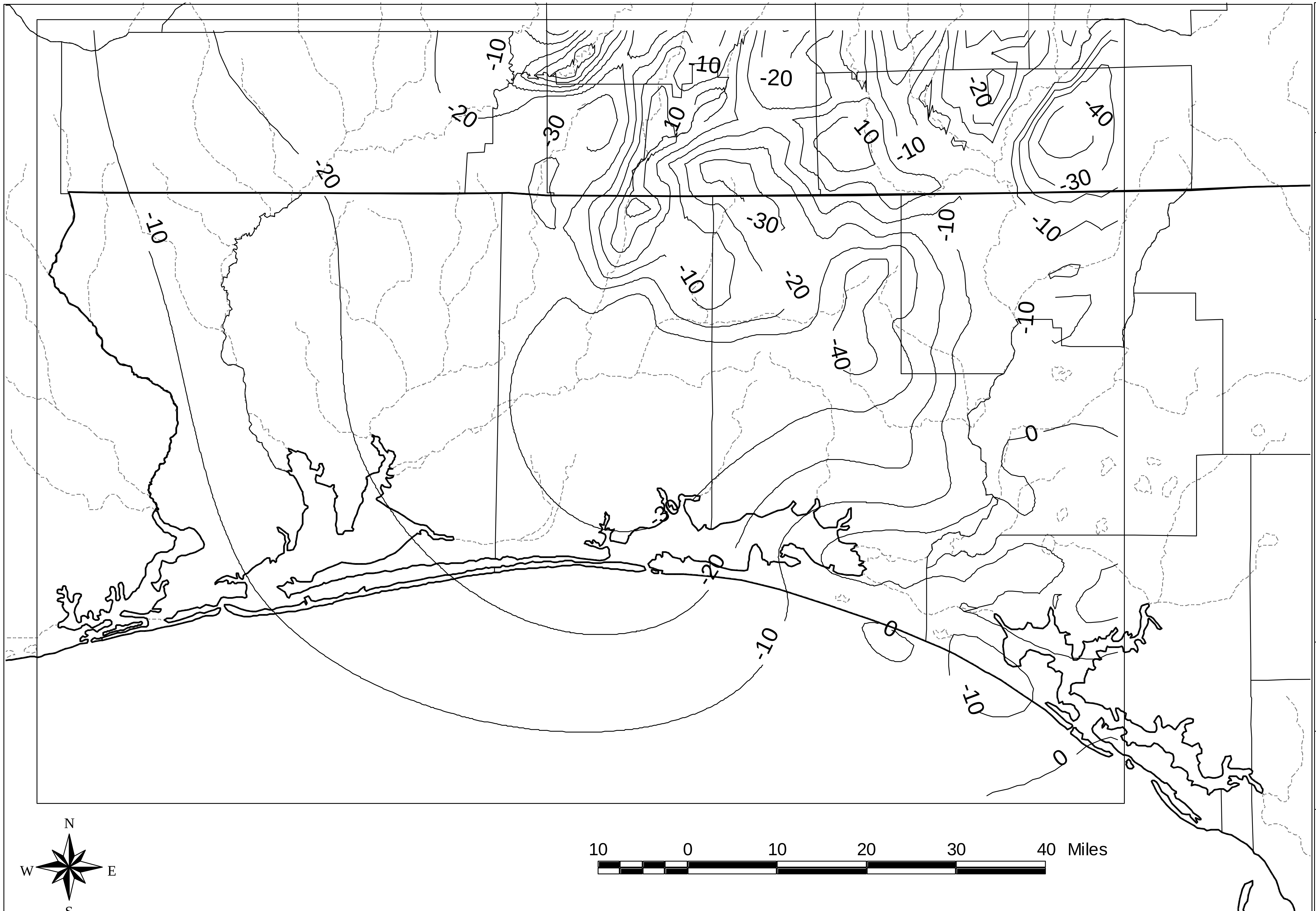

Water Level Difference Between Base Case and Sensitivity Simulation to Vertical Hydraulic Conductivity of the Intermediate System (with a scaling factor of 5) for Model Layer 5

Legend

Water Level Difference (ft)
(Base Case - Sensitivity Sim.)
Contour Interval: 10 ft
Hydrology
Counties
State / Coast Line

Figure 5.46

Filename: L: SORAB/D/NWFWMD/ARCVIEW/
NFW/MAPS/APR/template
Project: NFW002-0003
Created: 02/09/00 TH
Revised: 04/17/00 DD

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