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MAPPING RECHARGE TO THE FLORIDAN AQUIFER USING A GEOGRAPHIC INFORMATION SYSTEM

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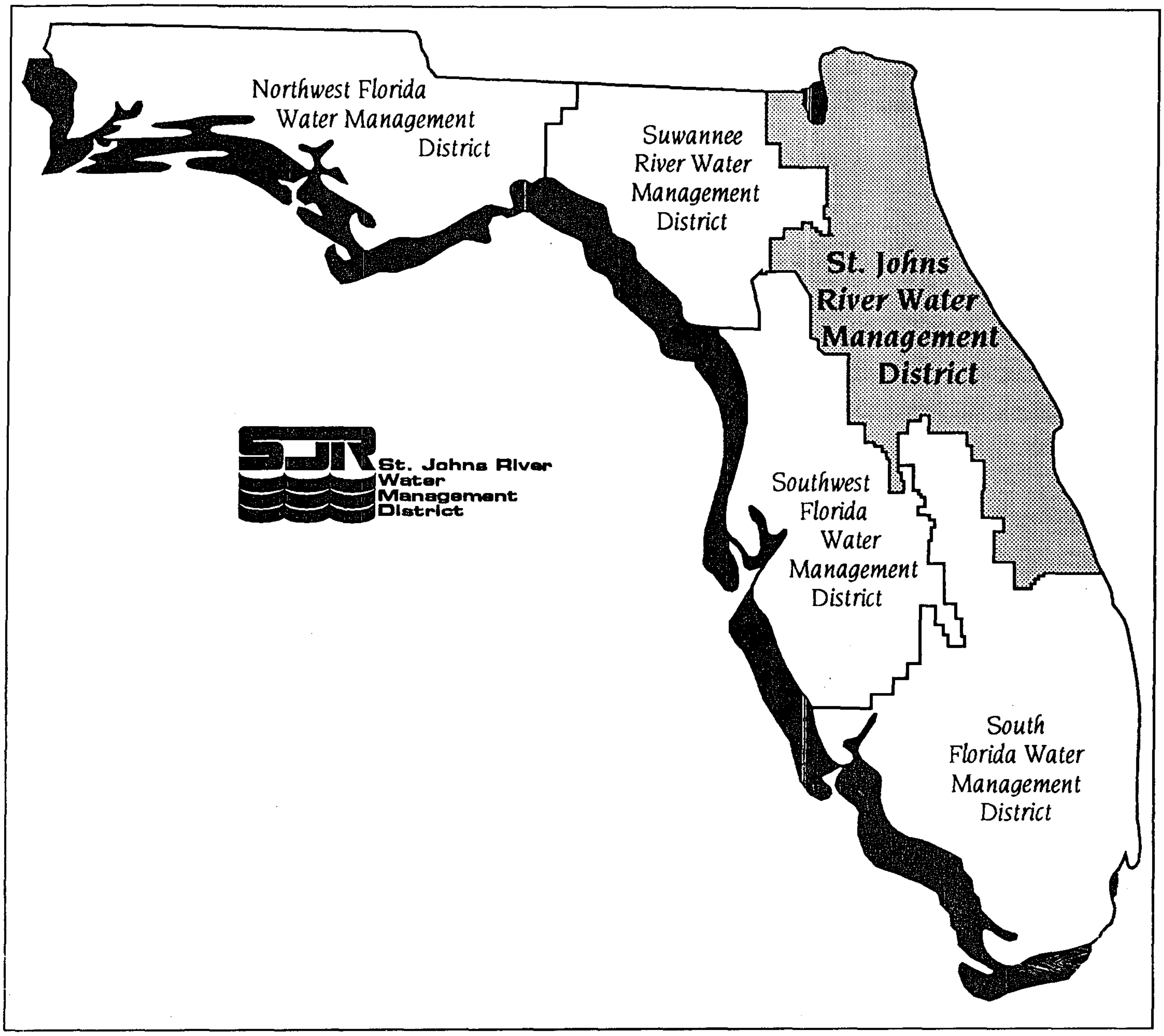

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

Maps of ground water recharge areas are useful planning tools for ground water resource management. Sections 373.0391, 373.0395, and 373.0397, *Florida Statutes*, require the water management districts to provide recharge area information to local governments and planning agencies. Recharge areas of the Floridan aquifer in the St. Johns River Water Management District (SJRWMD) were mapped using a geographic information system to analyze the geologic and hydrologic factors that affect recharge.

Ground water recharge to the Floridan aquifer, as presented in this report, is the addition of water to the Floridan aquifer from the overlying surficial aquifer. Recharge rates to the Floridan aquifer were based on hydraulic pressure differences between the water table of the surficial aquifer and the potentiometric surface of the Floridan aquifer (in May 1990) and on leakance of the upper confining unit separating the aquifers. Recharge rates were mapped at a 4-inch-per-year (in/yr) contour interval.

Recharge to the Floridan aquifer occurs in areas where the elevation of the water table of the surficial aquifer is higher than the elevation of the potentiometric surface of the Floridan aquifer. In these areas, water moves from the surficial aquifer in a downward direction through the upper confining unit to the Floridan aquifer. Recharge also occurs directly from infiltrating rainfall where the limestones of the Floridan aquifer are at or near land surface. In addition, significant local recharge may occur where sinkholes have breached the upper confining unit.

Discharge from the Floridan aquifer occurs in areas where the elevation of the Floridan aquifer potentiometric surface is higher than the elevation of the water table. In these areas, water moves from the Floridan aquifer in an upward direction through the upper confining unit to the surficial aquifer. Where the elevation of the Floridan aquifer potentiometric surface is higher than land surface, springs and free-flowing artesian wells occur.

Sixty percent of SJRWMD (4,711,229 million acres) contributes recharge to the Floridan aquifer. Discharge from the Floridan aquifer occurs in the remaining 40 percent (3,160,770 acres).

Recharge areas with rates greater than 12 in/yr encompass 14 percent of the total recharge area. Areas with recharge rates of 8 to 12 in/yr encompass 9 percent of the recharge area. Areas with recharge rates of 4 to 8 in/yr encompass 25 percent of the recharge area. Areas with recharge rates of 0 to 4 in/yr encompass 52 percent of the recharge area.

The recharge map included in this report—*Recharge Areas of the Floridan Aquifer in the St. Johns River Water Management District* (Plate 1)—provides a regional assessment of recharge to the Floridan aquifer. The map is intended to be used as a regional planning aid for ground water resource management; it is not intended for site-specific assessments.

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INTRODUCTION

Ground water recharge is vital for providing adequate ground water supplies for future uses and for preserving the quality of ground water resources. Maps of ground water recharge areas are important planning tools for the effective management of ground water resources. Ground water recharge to the Floridan aquifer, as presented in this report, is the addition of water to the Floridan aquifer from the overlying surficial aquifer or more directly from rainfall in areas where the surficial aquifer is thin or absent and the limestones of the Floridan aquifer are at or near land surface.

Florida Statutes (*FS*) requires the water management districts to inventory prime ground water recharge areas (Section 373.0395) and to map boundaries of prime recharge areas of the Floridan and Biscayne aquifers (Section 373.0397). The water management district governing boards must adopt these maps and provide them to local governments, along with information on prime ground water recharge areas. Section 373.0391, *FS*, requires the water management districts to provide technical assistance to local governments in the development and revision of their comprehensive plans. The information contained in this report is a necessary basic step in the process of satisfying the statutory requirements concerning delineation of recharge areas; it is not intended to completely satisfy these requirements.

The objectives of this study were to determine the hydrologic and geologic factors that affect recharge to the Floridan aquifer in the St. Johns River Water Management District (SJRWMD), to develop a geographic information system (GIS) methodology to analyze these factors, and to map rates of recharge to the Floridan aquifer.

The recharge map included in this report—*Recharge Areas of the Floridan Aquifer in the St. Johns River Water Management District* (Plate 1)—provides a regional assessment of recharge to the Floridan aquifer. The map is intended to be used as a regional

regional planning aid for ground water resource management; it is not intended for site-specific assessments.

PREVIOUS INVESTIGATIONS

Recharge areas of the Floridan aquifer have been mapped in previous investigations. The most notable of these are Tibbals (1975), Stewart (1980), Phelps (1984), Aucott (1988), Vecchioli et al. (1990), and Boniol et al. (1990).

Tibbals (1975) mapped Floridan aquifer recharge areas in Seminole County based on hydrogeology and spring discharge. The map delineated the most effective recharge areas (recharge rates of 10 to 21 inches per year [in/yr]), moderately effective recharge areas (3 to 10 in/yr), poor recharge areas (0 to 3 in/yr), and areas of very poor recharge.

Stewart (1980) qualitatively mapped statewide variations in recharge to the Floridan aquifer using topographic, soils, and hydrogeologic data. The generalized map depicted areas of high, low to moderate, very low, and no recharge.

Phelps (1984) mapped areas of high, low to moderate, and no recharge to the Floridan aquifer in SJRWMD based on the hydraulic gradient between the surficial and Floridan aquifers and on upper confining unit characteristics.

Aucott (1988) used hydrogeologic and numerical modeling information to produce a generalized, statewide map of areas having recharge rates of greater than 10 in/yr, 1 to 10 in/yr, and less than 1 in/yr.

Vecchioli et al. (1990) determined recharge rates to the Floridan aquifer in Okaloosa, Pasco, and Volusia counties through an analysis of topography, soils, hydrogeology, stream flow, spring flow, and pumpage. The maps delineated areas having recharge rates of 10 in/yr or more, 0 to 10 in/yr, and 0 in/yr.

Boniol et al. (1990) mapped recharge rates to the Floridan aquifer in the Crescent City Ridge of southeast Putnam County using GIS to analyze the hydraulic pressure differences between the surficial and Floridan aquifers and leakance of the upper confining unit separating the aquifers. The map delineated areas having recharge rates greater than 8 in/yr, 2 to 8 in/yr, and 0 to 2 in/yr and areas of no recharge.

GENERAL HYDROGEOLOGY

The hydrogeologic characteristics of the surficial aquifer system, the upper confining unit of the Floridan aquifer, and the Floridan aquifer system control rates of recharge to the Floridan aquifer in SJRWMD. The surficial aquifer system extends from the land surface downward to the top of the upper confining unit of the Floridan aquifer (Figure 1). The water table of the surficial aquifer is the upper surface of the zone of saturation.

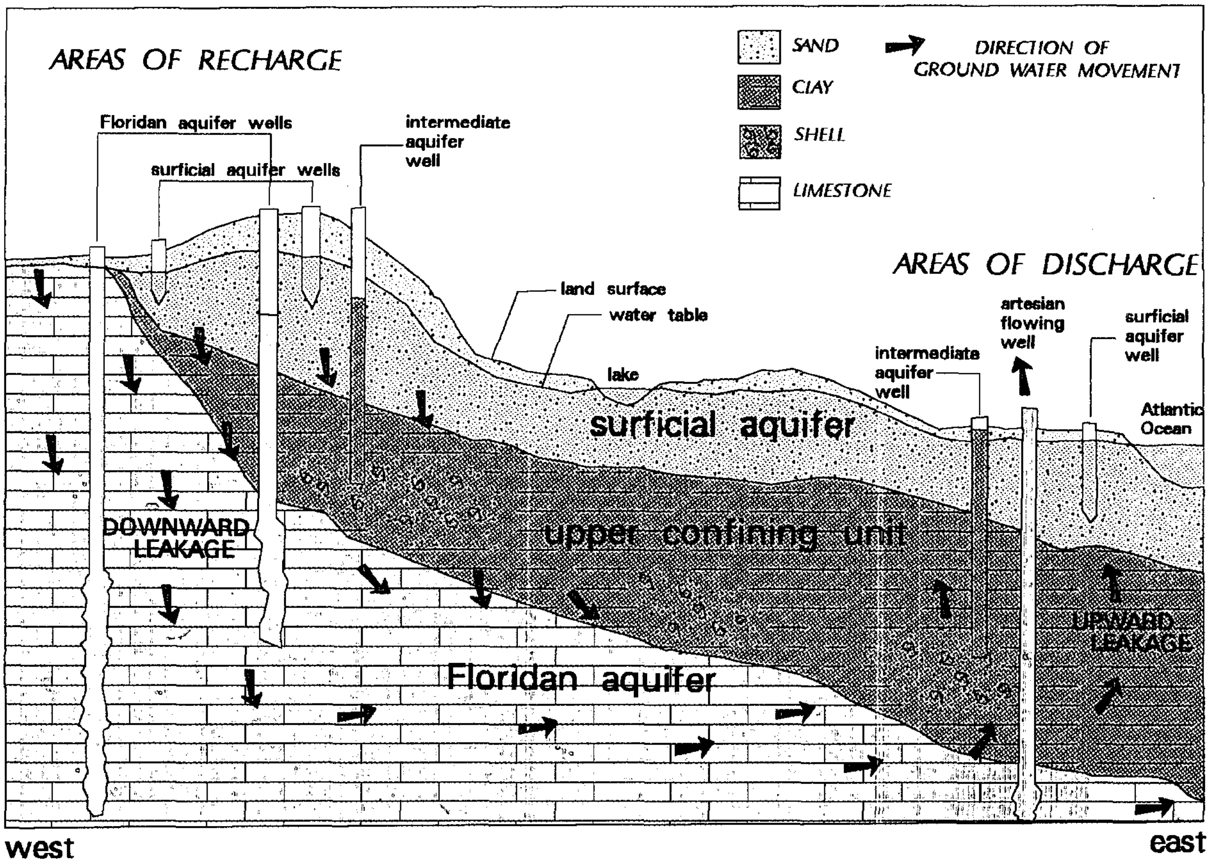
The upper confining unit of the Floridan aquifer, where present, retards the movement of water between the surficial and Floridan aquifers. Rates of leakage of water through the upper confining unit are dependent on the thickness and hydraulic conductivity of the upper confining unit.

The water level in a well that is tightly cased into the Floridan aquifer is called the potentiometric level of the Floridan aquifer. This water level can be higher, lower, or at the same elevation as the water table. In this report, reference to the potentiometric surface of the Floridan aquifer means the potentiometric surface of the Upper Floridan aquifer, as described by Tibbals (1990).

Recharge to the Floridan aquifer occurs in areas where the elevation of the water table of the surficial aquifer is higher than the elevation of the Floridan aquifer potentiometric surface. In these areas, water moves from the surficial aquifer in a downward direction through the upper confining unit to the Floridan aquifer. Recharge also occurs directly from infiltrating rainfall where the limestones of the Floridan aquifer are at or near land surface. In addition, significant local recharge may occur where sinkholes have breached the upper confining unit.

Discharge from the Floridan aquifer occurs in areas where the elevation of the Floridan aquifer potentiometric surface is higher than the elevation of the water table of the surficial aquifer. In these areas, water moves from the Floridan aquifer in an upward direction through the upper confining unit to the surficial aquifer.

Where the elevation of the Floridan aquifer potentiometric surface is higher than land surface, springs and free-flowing artesian wells occur (Figure 1).



not to scale

Figure 1. Generalized hydrogeologic cross section, St. Johns River Water Management District

GEOGRAPHIC INFORMATION SYSTEM METHODOLOGY

Recharge rates to the Floridan aquifer were calculated based on an analysis of the hydraulic pressure differences between the water table of the surficial aquifer and the potentiometric surface of the Floridan aquifer and on leakance of the upper confining unit of the Floridan aquifer. Calculation of recharge is based on the following formulas.

Recharge = Hydraulic Pressure Difference x Leakance

Hydraulic Pressure Difference = Water Table Elevation - Floridan Aquifer Potentiometric Surface Elevation

$$\text{Leakance} = \frac{\text{Vertical Hydraulic Conductivity of Upper Confining Unit}}{\text{Thickness of Upper Confining Unit}}$$

This hydrologic and geologic information was represented in a series of GIS maps called coverages. The methodology was evaluated and refined initially in a pilot study by Boniol et al. (1990). The hydrologic and geologic map coverages used are as follows.

- The elevation of the top of the upper confining unit of the Floridan aquifer
- The elevation of the top of the limestones of the Floridan aquifer
- The vertical hydraulic conductivity of the upper confining unit of the Floridan aquifer
- The elevation of the water table of the surficial aquifer
- The elevation of the potentiometric surface of the Floridan aquifer

The following mathematical operations were performed on the data represented by map coverages to determine upper confining unit leakance, hydraulic pressure differences between the surficial and Floridan aquifers, and recharge to the Floridan aquifer.

- Subtraction of the elevation of the top of the limestone comprising the Floridan aquifer from the elevation of the top of the upper confining unit to produce the thickness of the upper confining unit
- Division of the vertical hydraulic conductivity of the upper confining unit by its thickness to produce an estimate of leakance of the upper confining unit
- Subtraction of the elevation of the potentiometric surface of the Floridan aquifer from the elevation of the water table to produce the hydraulic pressure, or head, differences between the surficial and Floridan aquifers
- Multiplication of the hydraulic pressure differences by the leakances to produce recharge rates to the Floridan aquifer, which were mapped at a 4-in/yr contour interval

GIS was used to compile, analyze, and manipulate the geologic and hydrologic data needed to map recharge rates to the Floridan aquifer. Environmental Systems Research Institute's (ESRI) ARC/Info system was the GIS software used by SJRWMD. ARC/Info is used to automate the compilation of the map coverages, each coverage consisting of sets of map features.

Triangulated Irregular Network (TIN) is the ESRI software used by SJRWMD to create, store, and analyze 3-dimensional surfaces for use in ARC/Info. TIN has two data structures in which map data are analyzed: a triangulated irregular structure and a lattice. A triangulated structure is a network of adjacent triangles that connects the *z* data values located at (*x*,*y*) coordinates. The resulting 3-dimensional surface is used to interpolate elevations at points for which there are no observed data.

A lattice structure consists of (x,y) coordinates and interpolated z values derived from the original data points. All surface mathematical operations were done using lattices of the same size and location. The actual lattice used in this recharge mapping project consists of 1,820 columns by 3,249 rows, representing a spacing of 380 feet (ft) on the earth's surface. SJRWMD encompasses 12,300 square miles; however, the area covered by each lattice structure extended beyond SJRWMD boundaries and covered 30,628 square miles. Contours were generated from the lattice structure to represent the 3-dimensional surface of the data in two dimensions (Figure 2).

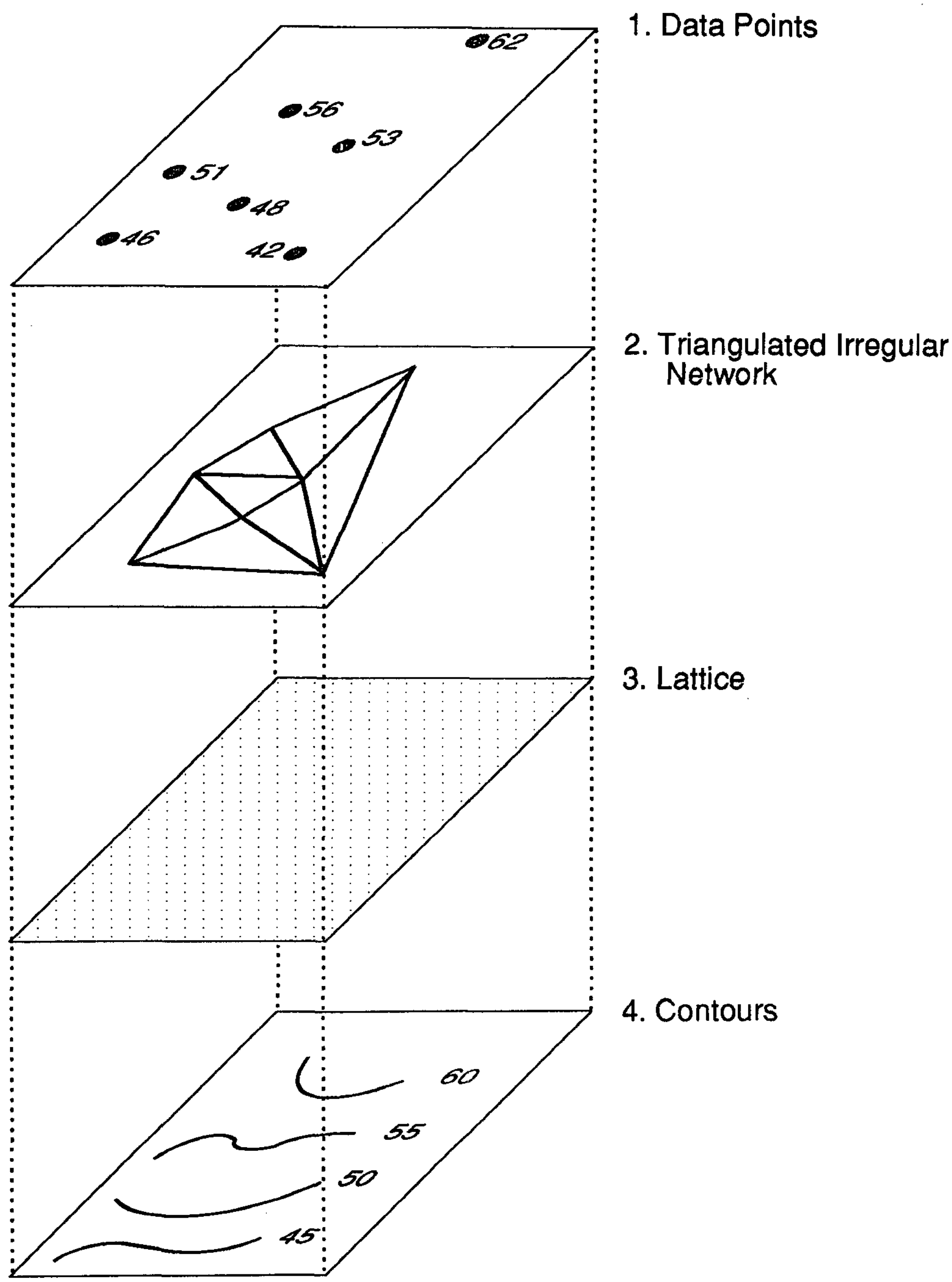


Figure 2. Geographic information system procedure used in making contour maps

ANALYSIS

LEAKANCE

The complex and highly variable lithology, thickness, and integrity of the upper confining unit of the Floridan aquifer influence the varying rates of water movement through the unit. The leakance of the upper confining unit can be calculated by dividing the vertical hydraulic conductivity of the upper confining unit by its thickness. The thickness of the upper confining unit is the difference in elevations of the top of the upper confining unit and the top of the Floridan aquifer.

Elevation of the Upper Confining Unit

The upper confining unit is composed of the sediments that lie between the surficial aquifer and the Floridan aquifer. These sediments slow the movement of water between the surficial and Floridan aquifers. The top of the upper confining unit coincides with the top of the laterally extensive and vertically persistent, fine-grained sediments of lower permeability, as compared to those sediments that comprise the surficial aquifer (Southeastern Geological Society 1986). In most areas of SJRWMD, this correlates to the top of the Miocene-age Hawthorn Group.

The elevations of the top of the upper confining unit range from 220 ft below mean sea level (msl) to 170 ft above msl (Figure 3). The TIN software was used to contour the 848 data points that were compiled from SJRWMD geophysical well logs and Florida Geological Survey (FGS) lithologic well logs.

Elevation of the Limestones of the Floridan Aquifer

The Floridan aquifer system is the principal ground water resource in SJRWMD. This system is composed of the Eocene age Ocala Limestone, the middle Eocene age Avon Park Formation, the early Eocene age Oldsmar Formation, and the Paleocene age Cedar Keys Formation (Miller 1986). The top of the Floridan aquifer system coincides with the top of the vertically persistent, permeable carbonates (Southeastern Geological Society 1986). The aquifer has been extensively altered by karst processes in many areas.

The elevations of the top of the limestones of the Floridan aquifer range from 650 ft below msl to 110 ft above msl (Figure 4). The TIN software was used to contour the 1,541 data points that were compiled from SJRWMD geophysical well logs and FGS lithologic well logs.

Thickness of the Upper Confining Unit

The thickness of the upper confining unit ranges from near 0 to 540 ft (Figure 5). The thickness was derived by subtracting the lattice representing the elevation of the top of the Floridan aquifer from the lattice representing the elevation of the top of the upper confining unit. The upper confining unit is less than 20 ft thick—or is missing—along the western SJRWMD boundary in Alachua and Marion counties.

The upper confining unit may be breached by karst features which permit a more direct hydraulic connection between the surficial and Floridan aquifers, particularly in the central and western parts of SJRWMD. It was not possible to map every sinkhole or sinkhole-related feature and to determine the hydrologic and geologic characteristics of these features in this regional assessment of recharge areas.

Vertical Hydraulic Conductivity of the Upper Confining Unit

Vertical hydraulic conductivity, as used for this study, is a measure of the ability of the upper confining unit to transmit water between the surficial and Floridan aquifers. Upper confining unit conductivity values may vary widely at the same location, depending upon depth, and from location to location due to the variable lithology of the sediments comprising the unit. As a result, attempts to contour conductivity data were impractical.

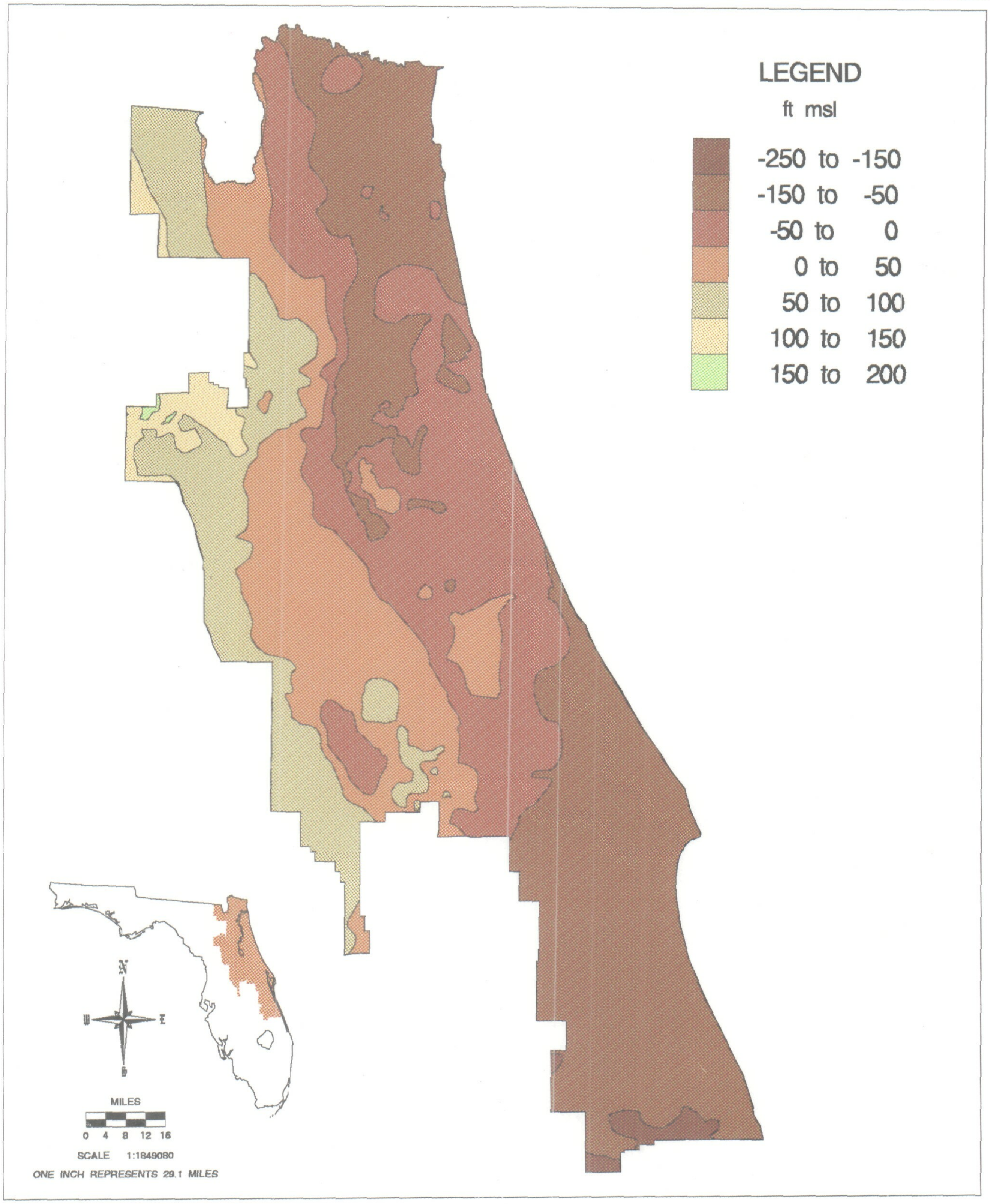


Figure 3. Elevation of the top of the upper confining unit of the Floridan aquifer

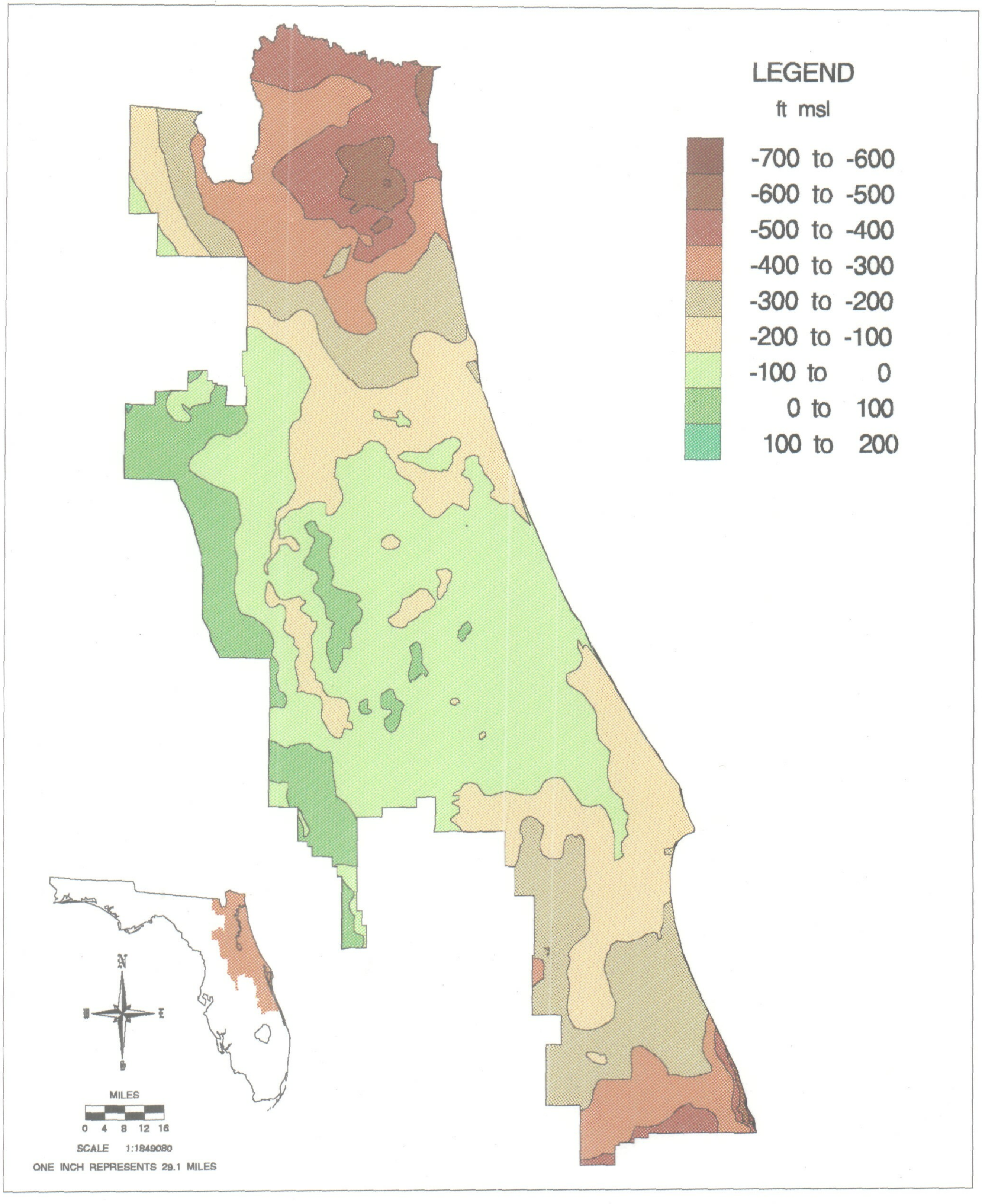


Figure 4. Elevation of the top of the limestones of the Floridan aquifer

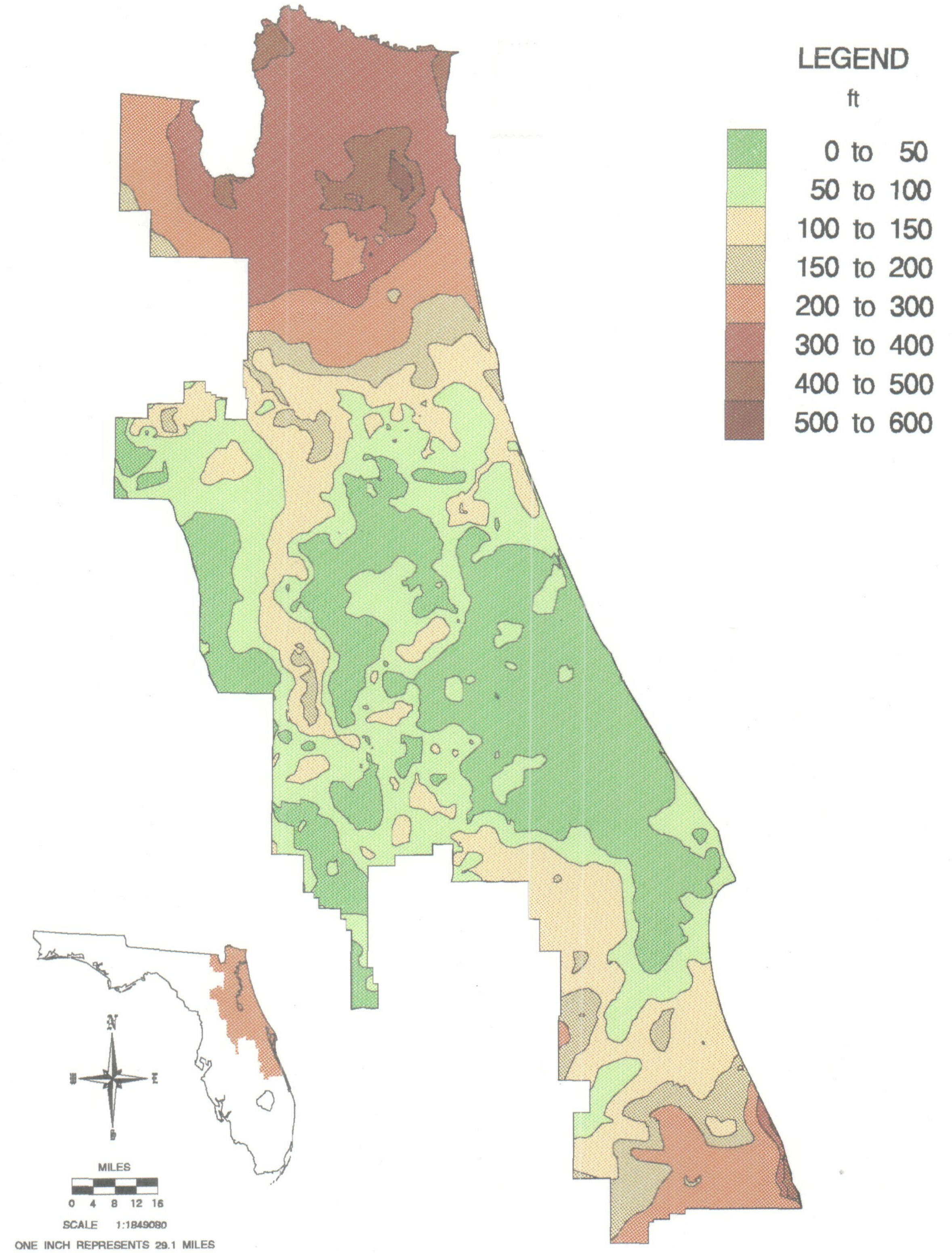


Figure 5. Thickness of the upper confining unit of the Floridan aquifer

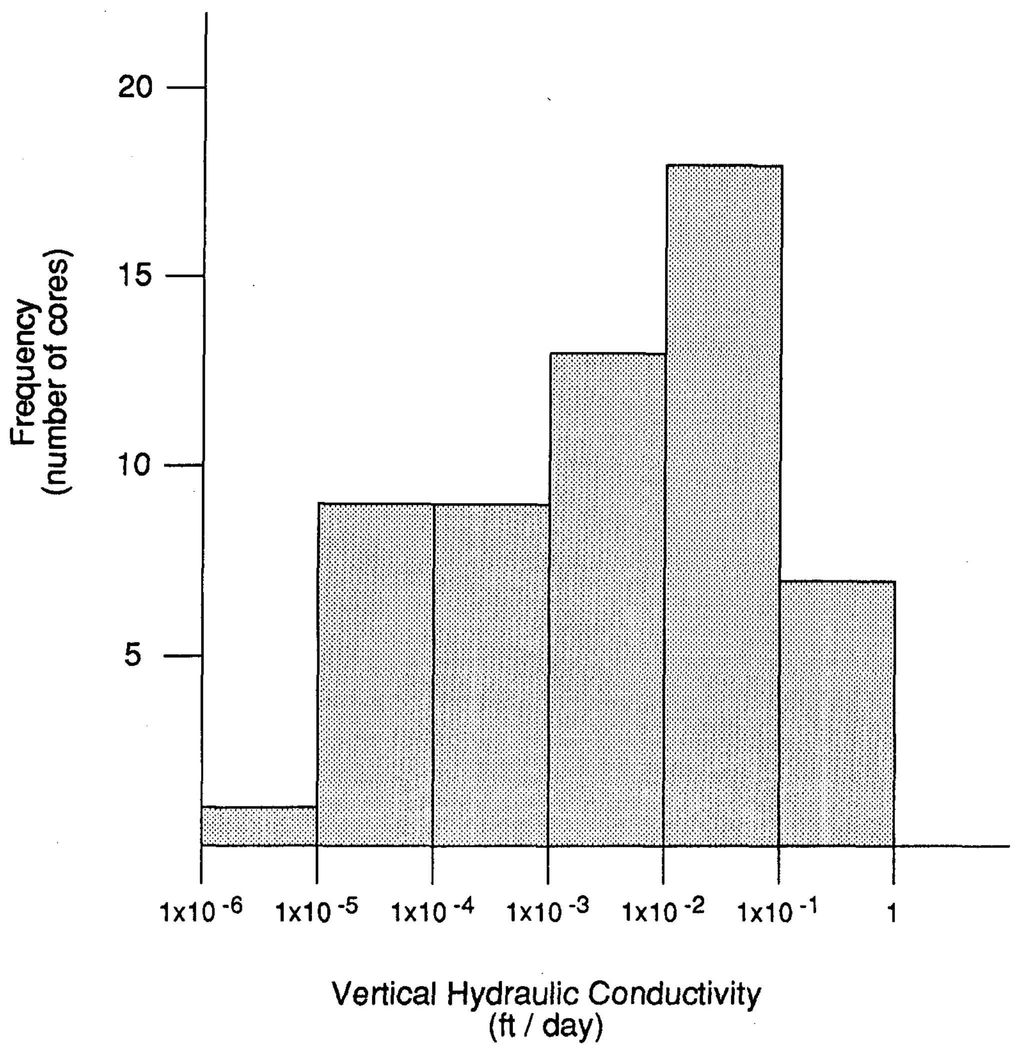
Vertical hydraulic conductivity data were obtained from laboratory analyses of cores collected for this study and from conductivity data from previous investigations by Phelps (1990), McGurk (1989), and Strom and Stewart (1985) (Table 1 and Figure 6). Conductivity data derived from ground water flow model leakance calibrations by McGurk (draft 1993) are also included in Table 1 for comparison.

Table 1. Vertical hydraulic conductivity data

Data Type	Data Source	Range (ft/day)	Mean (ft/day)	Median (ft/day)
11 core tests	This study	7.7×10^{-5} to 4.0×10^{-1}	4.1×10^{-2}	2.1×10^{-4}
11 core tests	Phelps (1990)	7.6×10^{-5} to 3.4×10^{-1}	6.1×10^{-2}	1.0×10^{-2}
12 core tests	McGurk (1989)	2.7×10^{-4} to 3.7×10^{-1}	9.8×10^{-2}	2.7×10^{-2}
23 core tests	Strom and Stewart (1985)	3.2×10^{-6} to 8.6×10^{-2}	1.7×10^{-3}	1.7×10^{-2}
Total of all 57 core tests	(sources listed above)	3.2×10^{-6} to 4.0×10^{-1}	4.6×10^{-2}	3.7×10^{-3}
Model-derived	McGurk (draft 1993)	5.0×10^{-4} to 5.0×10^{-2}	5.4×10^{-3}	4.9×10^{-3}

The mean of all 57 core permeability tests was 4.6×10^{-2} feet per day (ft/day), with a median of 3.7×10^{-3} ft/day. Because the high conductivity values weighted the mean conductivity toward the high values in the data set when compared to the majority of the data, the median conductivity value of 3.7×10^{-3} ft/day was deemed more representative of the data set.

This median vertical hydraulic conductivity of 3.7×10^{-3} ft/day was used as a starting value to perform sensitivity analyses of leakance. This conductivity value was decreased and increased to observe resulting changes in leakance, as discussed in the following section.



Mean = 4.6×10^{-2} ft / day

Median = 3.7×10^{-3} ft / day

Figure 6. Distribution of vertical hydraulic conductivity data of the upper confining unit of the Floridan aquifer

Leakance of the Upper Confining Unit

Leakance is the ratio of the upper confining unit's vertical hydraulic conductivity to its thickness and is a measure of the movement of water through the upper confining unit to or from the Floridan aquifer.

The median vertical hydraulic conductivity lattice of 3.7×10^{-3} ft/day was divided by the lattice representing the thickness of the upper confining unit to estimate leakance of water through the upper confining unit. The resultant leakance ranged from 6.9×10^{-6} to 1.2×10^{-4} per day (/day).

The median conductivity value was decreased and increased to observe the changes in leakance (Table 2). The five leakance ranges resulting from varying conductivity in the GIS model were then compared to the upper confining unit leakance ranges derived from ground water flow models by Bush and Johnston (1988), Tibbals (1990), Durden (draft 1993), and McGurk (draft 1993). A vertical hydraulic conductivity of 4.7×10^{-3} ft/day and the resultant leakance range of 8.7×10^{-6} to 1.6×10^{-4} /day best simulate the leakance of the upper confining unit when compared to the ground water flow models (Figure 7).

The sensitivity analysis illustrated that leakance is very sensitive to variations in vertical hydraulic conductivity. Although the varying conductivity and resultant leakance values directly changed the magnitude of recharge rates, the pattern of contour lines delineating the recharge rates and the relative areal distribution of recharge areas remained the same.

This leakance analysis is a regional assessment of leakance. In areas where the upper confining unit may be breached and filled in with more permeable material, leakance values may be greater than estimated. For example, Motz and Heaney (1992) reported that leakance (1.1×10^{-3} /day) under Brooklyn Lake in southwest Clay County was significantly greater than leakance for other lakes in the area, such as Sand Hill Lake (2.3×10^{-4} /day). It was not feasible to estimate leakance values for each sinkhole-related feature in SJRWMD as part of this regional study.

Table 2. Hydraulic conductivity sensitivity analysis and leakance data

Data Source	Conductivity (ft/day)	Leakance Range (/day)
Table 1, median	3.7×10^{-3}	6.9×10^{-6} to 1.2×10^{-4}
GIS sensitivity analysis	2.7×10^{-3}	5.0×10^{-6} to 9.0×10^{-5}
	3.2×10^{-3}	5.9×10^{-6} to 1.1×10^{-4}
	4.2×10^{-3}	7.8×10^{-6} to 1.4×10^{-4}
	4.7×10^{-3}	8.7×10^{-6} to 1.6×10^{-4}
Bush and Johnston (1988) (statewide)		2.3×10^{-6} to 2.3×10^{-4}
Tibbals (1990) (east-central Florida)		1.0×10^{-6} to 6.0×10^{-4}
McGurk (draft 1993) (western Volusia and southeastern Putnam counties)		1.0×10^{-5} to 7.5×10^{-4}
Durden (draft 1993) (northeast Florida)		1.0×10^{-7} to 1.0×10^{-5}

HYDRAULIC PRESSURE DIFFERENCES

The hydraulic pressure difference between the elevation of the water table of the surficial aquifer and the elevation of the potentiometric surface of the Floridan aquifer is the primary factor determining recharge to the Floridan aquifer. The hydraulic pressure, or hydraulic head, of an aquifer system is a function of the elevation of the top of the aquifer, the water available for input into the system, and the distribution of hydraulic conductivities in the system.

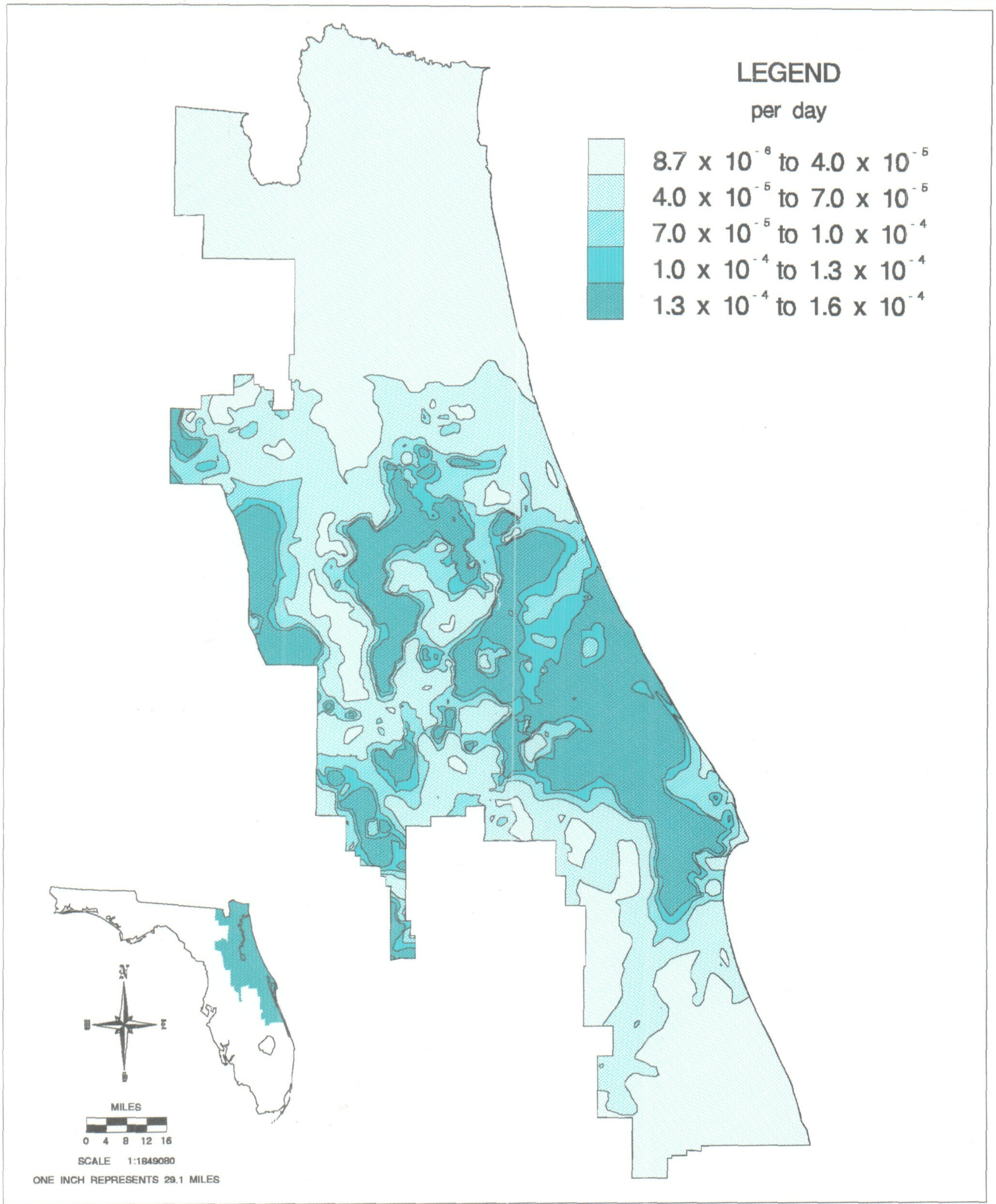


Figure 7. Leakance of the upper confining unit of the Floridan aquifer

Water Table Elevation

The water table of the unconfined surficial aquifer system is the upper surface of the zone of saturation. The water table has the same general shape as the topography, although water table relief is not as great as topographic relief. The water table is near land surface in topographically low areas, wetlands, or near a lake's shore, and at greater depths in the upland, sandy ridges where there are no surface water features.

The elevation of the water table is indicated by the level at which water stands in an unconfined well or borehole. Water levels from 538 monitoring wells and auger boreholes were measured in May 1990, as were the Floridan aquifer potentiometric levels. The 538 water table elevations were measured in physiographic regions ranging from low-lying areas to sandy ridges.

The water table elevation measurements with respect to mean sea level and the corresponding land surface elevations were statistically analyzed with a regression analysis using the Minitab statistical software (Arnold 1981). The relation of water table elevation to land surface elevation, showing a 90 percent linear correlation, is presented in Figure 8. The regression equation is as follows.

Water Table Elevation = -1.61 + (0.901 x Land Surface Elevation)

The water table elevations from the surficial aquifer wells and auger boreholes, the regression equation relating water table elevations to land surface elevations, and the elevations of lakes and streams were used in conjunction with digitized 1:24,000 topographic quadrangles of the study area to map the water table. The elevations of the water table range from less than 10 ft above msl in topographically low areas to 176 ft above msl in western Clay County (Figure 9).

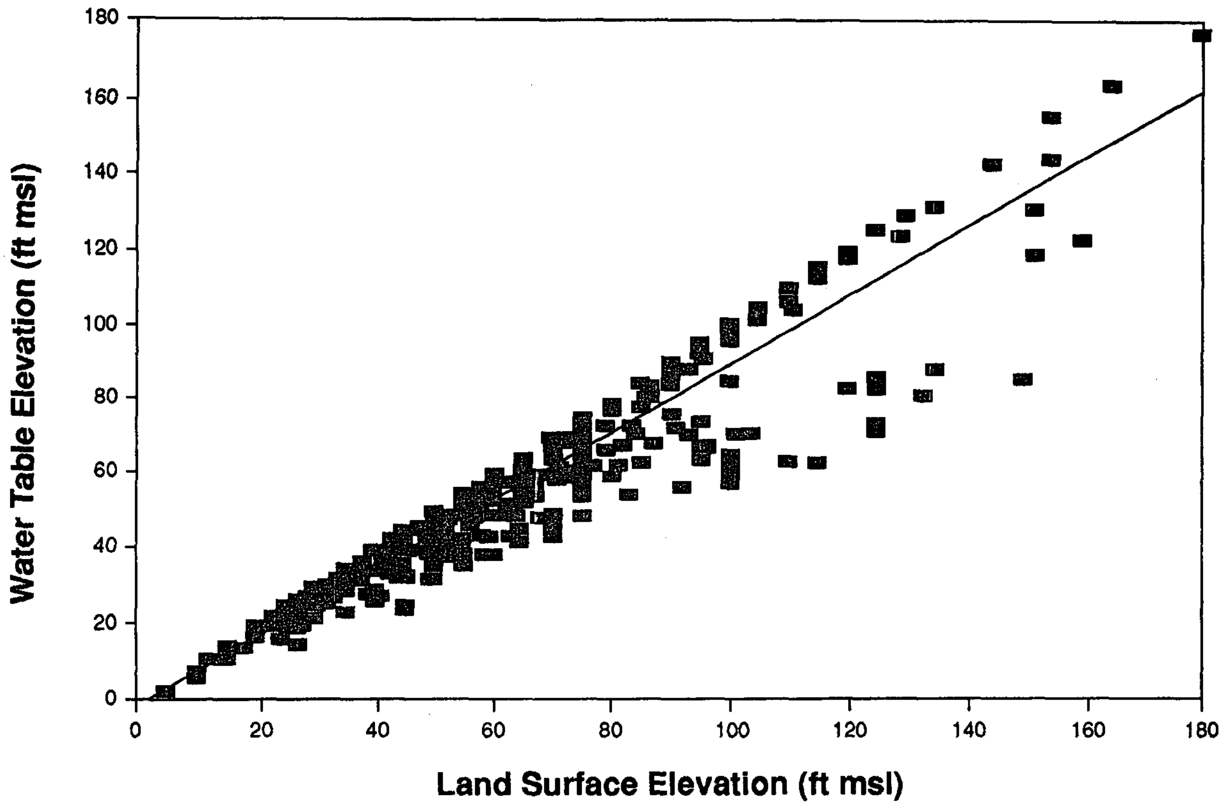


Figure 8. Relation of water table elevation to land surface elevation

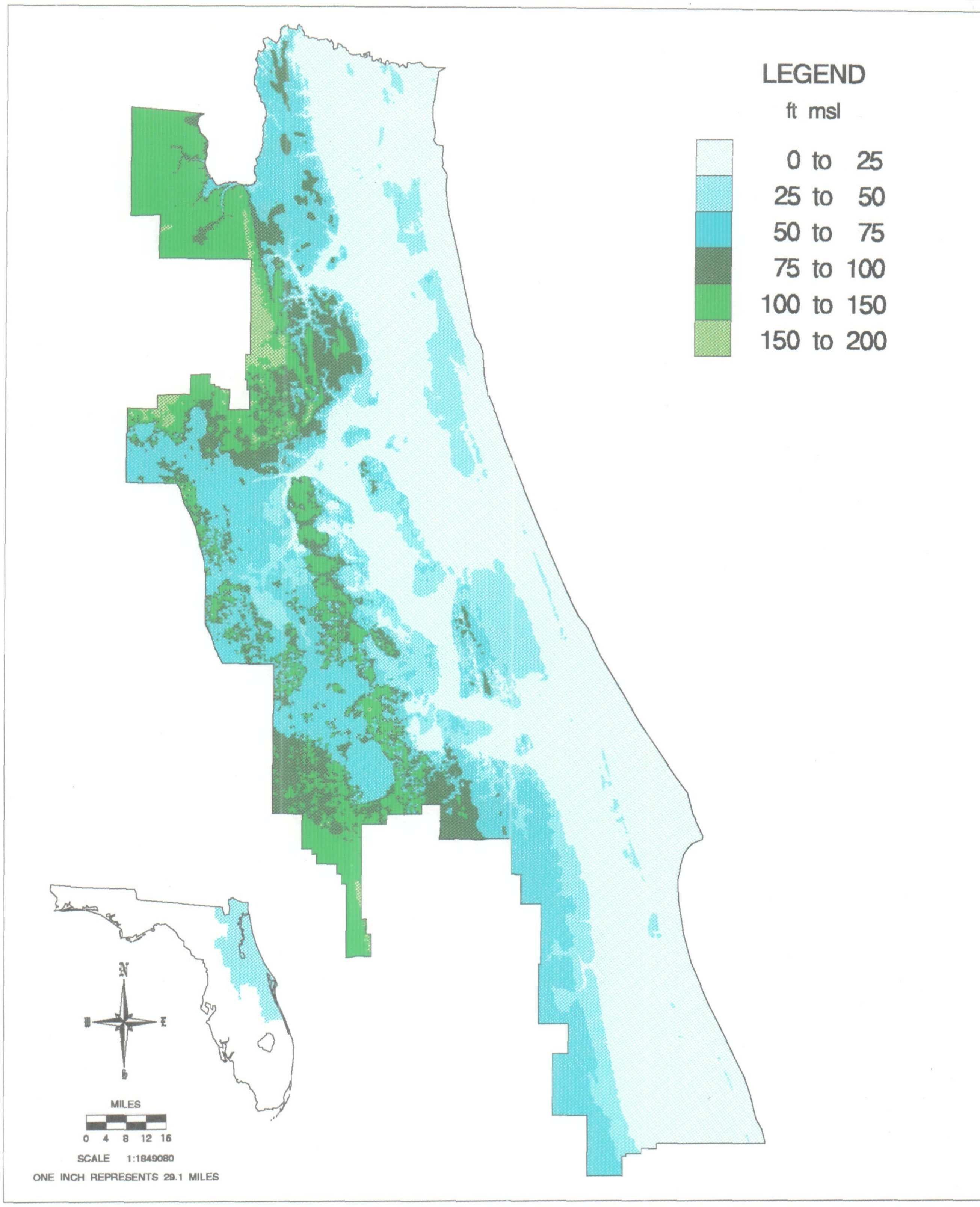


Figure 9. Elevation of the water table of the surficial aquifer, May 1990

Floridan Aquifer Potentiometric Levels

The potentiometric surface of an aquifer is the level to which water will rise in a well tightly cased into the aquifer. Where the Floridan aquifer is confined, the water level in a well drilled into the aquifer will stand above the top of the limestones comprising the aquifer.

The potentiometric surface of the Floridan aquifer was mapped using 1,057 water level measurements from SJRWMD and from U.S. Geological Survey Floridan aquifer semiannual monitoring well network. The elevations of the potentiometric surface for May 1990 ranged from 40 ft below msl to 125 ft above msl (Figure 10).

The general direction of water movement in the Floridan aquifer is from areas of higher potentiometric levels toward areas of lower potentiometric levels. Ground water flows downgradient and radially outward from potentiometric highs of approximately 125 ft above msl in Polk County and 80 ft above msl in the Keystone Heights area of Clay, Putnam, and Alachua counties.

Hydraulic Pressure Differences Between the Surficial and Floridan Aquifers

The hydraulic pressure (head) differences between the water table of the surficial aquifer and the potentiometric surface of the Floridan aquifer (Figure 11) were derived by subtracting the lattice representing the Floridan aquifer potentiometric surface from the water table lattice. Elevations of the water table of the surficial aquifer were up to 120 ft higher than elevations of the potentiometric surface of the Floridan aquifer in May 1990.

RECHARGE TO THE FLORIDAN AQUIFER

The amount of water available as recharge to the Floridan aquifer is that part of rainfall, after losses to runoff and evapotranspiration, that infiltrates to the water table and continues to move downward to the Floridan aquifer system. Soils having high infiltration potential with little or no runoff due to a lack of surface drainage features are most conducive to recharging ground water systems.

Recharge to the Floridan aquifer occurs in areas where the elevation of the water table of the surficial aquifer is higher than the elevation of the potentiometric surface of the Floridan aquifer. In these areas, water moves from the surficial aquifer in a downward direction through the upper confining unit to the Floridan aquifer. Recharge also occurs directly from infiltrating rainfall where limestones of the Floridan aquifer are at or near land surface. In addition, significant local recharge may occur where sinkholes have breached the upper confining unit.

Recharge rates to the Floridan aquifer were derived by multiplying the lattice representing the hydraulic pressure difference by the upper confining unit leakance lattice. The resultant lattice was contoured at 4-in/yr intervals to depict relative potential recharge to the Floridan aquifer (Figure 12 and Plate 1).

Recharge rates are highest in areas where the hydraulic pressure difference and leakance are greatest. Recharge rates are directly proportional to the hydraulic pressure difference and upper confining unit hydraulic conductivity and inversely proportional to upper confining unit thickness.

Sixty percent of SJRWMD (4,711,229 acres) contributes recharge to the Floridan aquifer. Discharge from the Floridan aquifer occurs in the remaining 40 percent (3,160,770 acres). Springs commonly occur in discharge areas near the recharge/discharge boundaries.

The recharge areas with rates greater than 12 in/yr encompass 649,989 acres, or 14 percent of the total recharge area. Areas with recharge rates of 8 to 12 in/yr encompass 423,580 acres, or 9 percent of the recharge area. Areas with recharge rates of 4 to 8 in/yr cover 1,184,723 acres, or 25 percent of the recharge area. Areas with recharge rates of 0 to 4 in/yr encompass 2,452,937 acres, or 52 percent of the total recharge area.

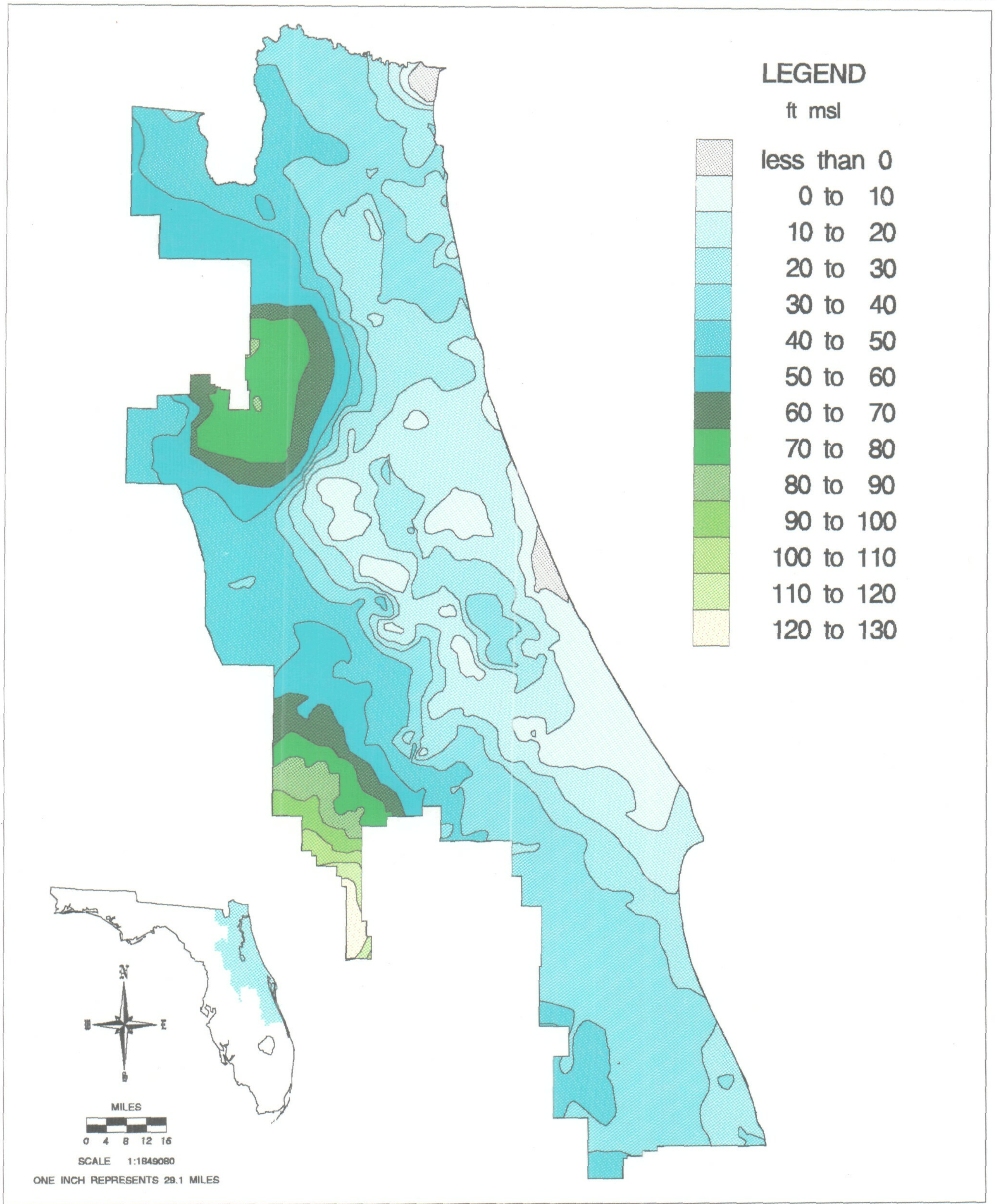


Figure 10. Elevation of the potentiometric surface of the Floridan aquifer, May 1990

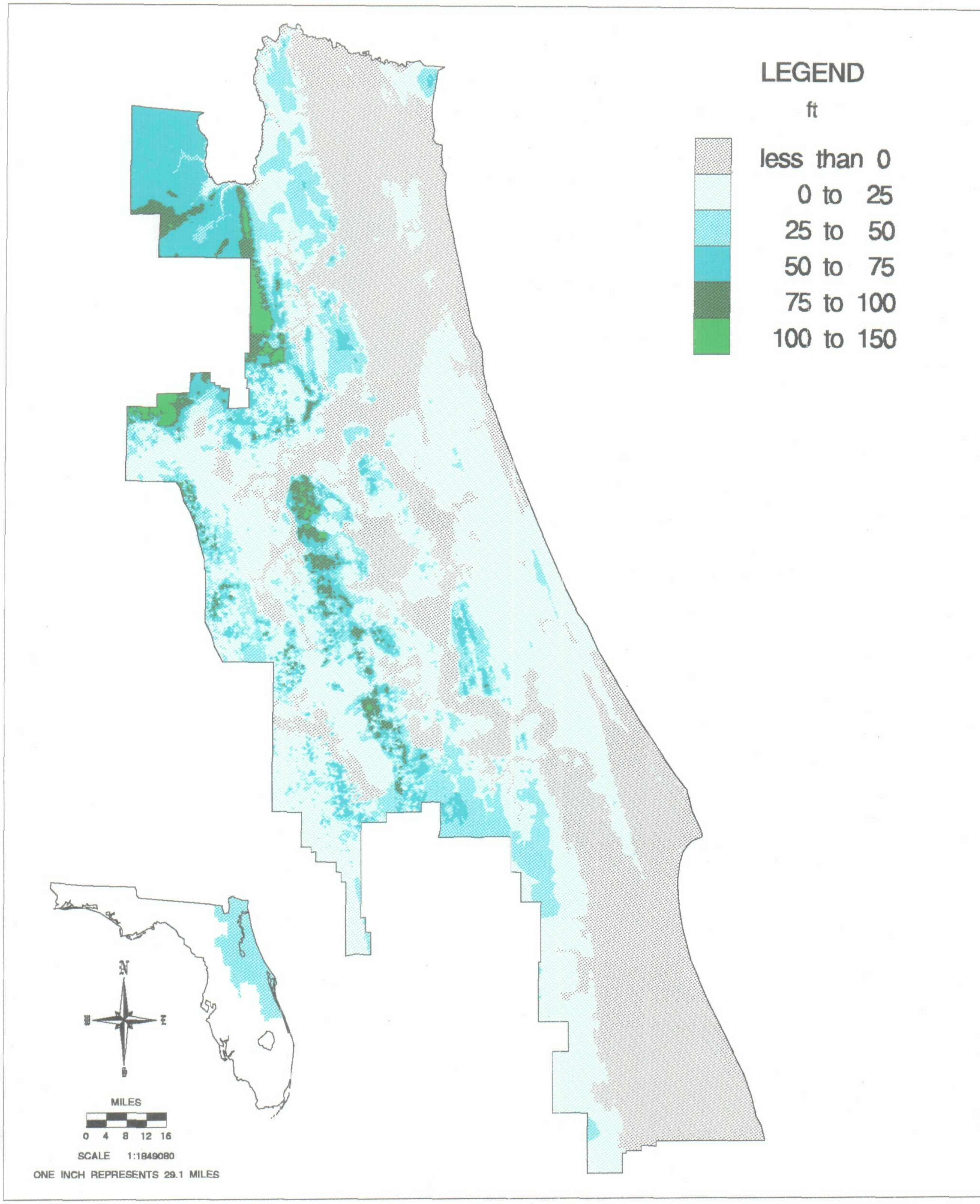


Figure 11. Hydraulic pressure differences between the water table of the surficial aquifer and the potentiometric surface of the Floridan aquifer, May 1990

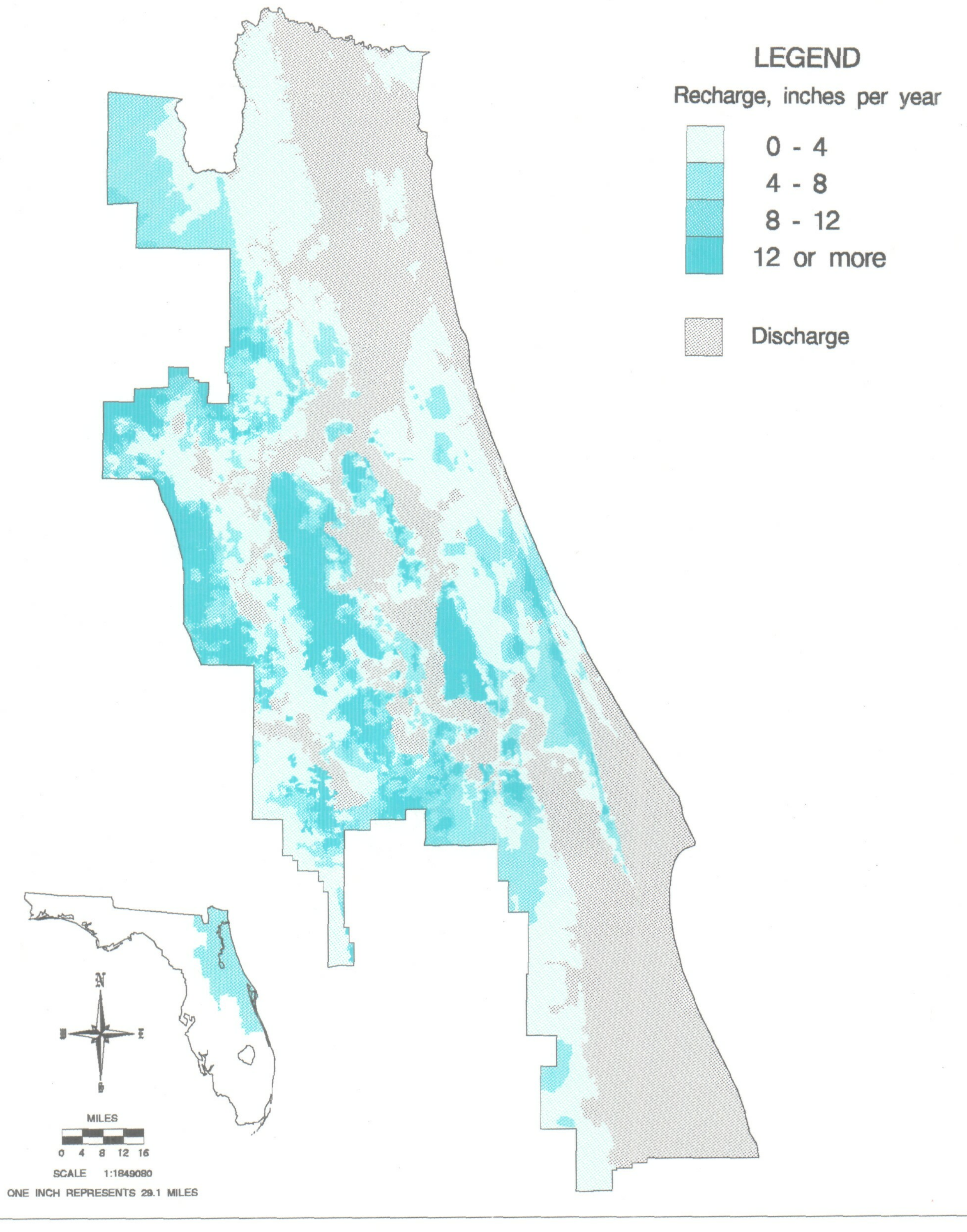


Figure 12. Recharge areas of the Floridan aquifer

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