Professional Paper SJ95-PP3

PREDICTING AREAS OF FUTURE PUBLIC WATER SUPPLY PROBLEMS: A GEOGRAPHIC INFORMATION SYSTEM APPROACH

by

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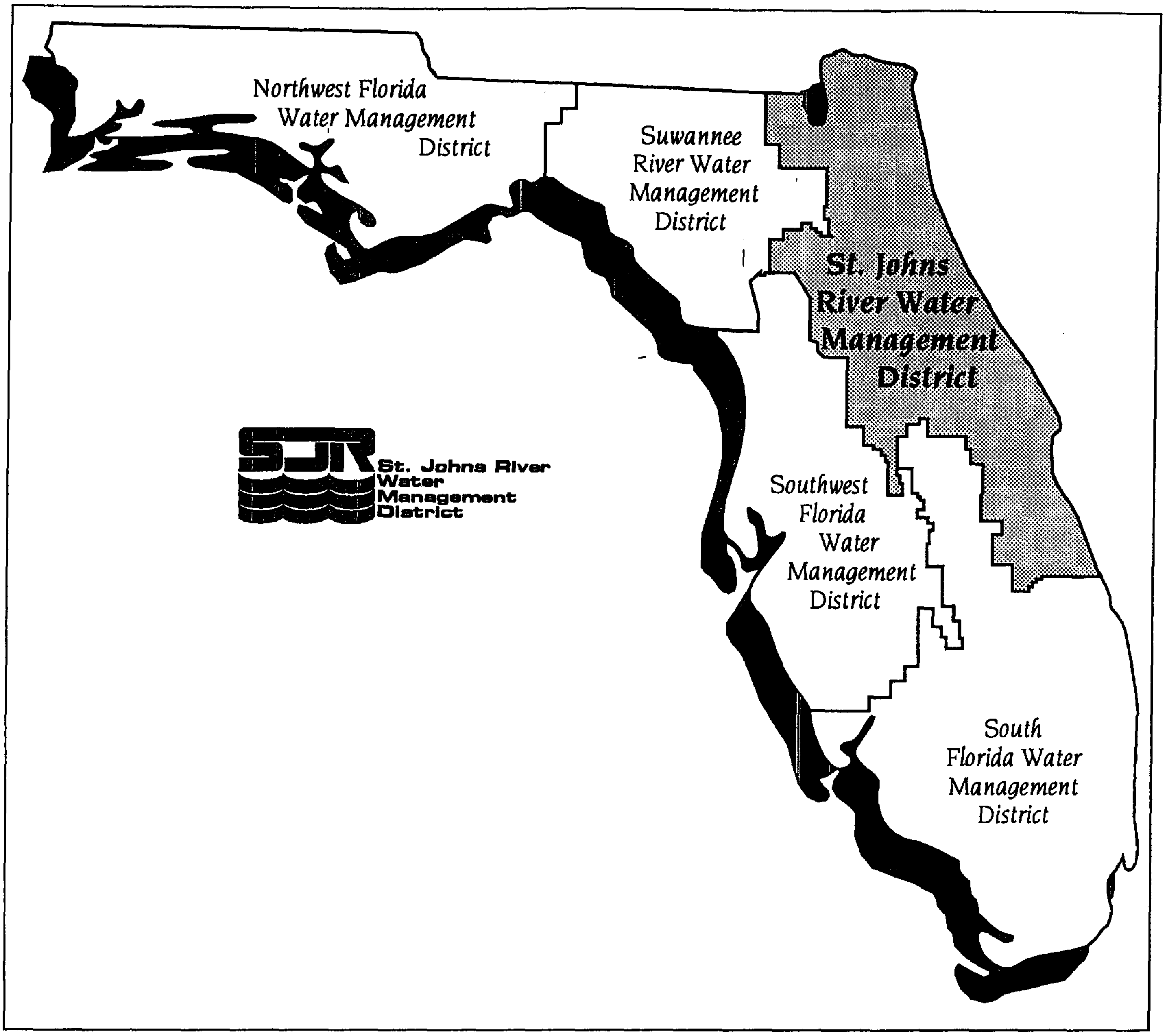
Palatka, Florida

1995



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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ABSTRACT: A geographic information system methodology was developed to ensure the adequate placement of the locations of current ground water flow models used by the St. Johns River Water Management District and to delineate areas where new analyses should be performed. This methodology uses an overlay procedure with gridded surfaces to identify areas that have a high potential for (1) impacts to wetland vegetation, (2) saltwater intrusion, and/or (3) an increase in public water supply demand. Eight thematic surfaces were created, each of which bears some relationship to the three potential hydrologic impacts considered. Based upon the distribution of the data and the hydrology, the data within each surface were weighted from 1 to 5, where 5 represented the greatest contribution to one of the three areas of evaluation. Each of the surfaces was weighted against the others based upon how each factor influenced the impacts being evaluated in the study. The designated weights were multiplied by each surface, then all of the surfaces were added together to produce a final surface of scores. The boundaries for the regional numerical ground water flow models and the large public and private water utility service areas were overlaid on the final surface. The results confirmed the locations of the ground water flow models, which covered areas most likely to be affected by increased ground water withdrawals to meet public water supply demand. This information can be used to identify areas where future analyses need to be performed.

The Florida legislature charged the St. Johns River Water Management District (SJRWMD), located in northeast Florida, and the other four water management districts to perform a needs and sources assessment of current and future water supply demands. Within the over 12,000 square miles of SJRWMD, ground water is the preferred source for public, agricultural, and industrial water supply (Florence 1995). Ground water is derived primarily from the Floridan aquifer system. The Floridan aquifer system is a semiconfined limestone aquifer system that extends from southeast South Carolina, southern Georgia, and southern Alabama through Florida. In 1990, ground water use for the 4,638,000 people in SJRWMD was 1,089 million gallons per day, and water use is projected to increase to 1,487 million gallons per day by the year 2010 (Vergara 1994).

Section 62-40.520, *Florida Administrative Code*, requires water management districts to identify "specific geographical areas that have water resource problems which have become critical or are anticipated to become critical within the next 20 years." SJRWMD is assessing water supply needs and sources using regional numerical ground water flow models and local analytical ground water flow models to identify areas expected to have inadequate water resources to meet the anticipated water supply demand in 2010.

This study, which was conducted parallel to the ground water flow modeling studies, is based on a geographic information system (GIS) technique which was used to identify areas having the potential for public water supply problems. By using this GIS technique, SJRWMD could ensure adequate placement of the locations of the regional and local ground water flow models and identify areas where future work may need to be performed. This paper details the GIS methodology used, and the results, in identifying areas having a high potential for (1) impacts to wetland vegetation, (2) saltwater intrusion, and/or (3) an increase in public water supply demand.

The study area covers the entire SJRWMD (Figure 1), which includes all or part of 19 counties, extending from the Florida/Georgia state line in the north to the Indian River/Brevard county line in the south. The eastern border of SJRWMD is the Atlantic Ocean, and the area of jurisdiction extends as far west as central Florida. Wetlands, lakes, and springs are important features of the landscape. Land surface elevations change from 0 feet (ft) above mean sea level to approximately 310 ft above mean sea level.

The hydrogeology and other related parameters, such as demography, that would affect public water supply problems vary significantly throughout SJRWMD. The hydrogeology typically consists of a surficial aquifer system, a semiconfining unit, and the Floridan aquifer system, which is the primary source of water supply. In some areas, the surficial aquifer system is used for public water supply, and in other areas the surficial aquifer system is nonexistent. The semiconfining unit ranges from nonexistent in some areas to many hundreds of feet thick in other areas. The top of the Floridan aquifer system ranges from near land surface to depths between 500 and 1,000 ft. Water quality in the Floridan aquifer system varies from poor (high chloride concentrations) to very good (low chloride concentrations). The decline in the elevation of the potentiometric surface of the Floridan aquifer system varies in SJRWMD based upon the hydrogeology and magnitude of withdrawals.

METHODOLOGY

The GIS platform used for this study consisted of a SUN Sparcstation 2 using SunOs 4.1.3 (UNIX) running ARC/INFO 6.1.1 (ESRI 1992). Much of the work completed on the project was done via an XWindow™ connection (using eXceed 4) between a local personal computer and a workstation.

The methodology was an overlay procedure in the GRID module of ARC/INFO. Boniol et al. (1993) determined that a 380-ft cell size provided a good calibration between the actual and simulated 1990 potentiometric surfaces; therefore, all of the surfaces were created with a grid cell size of 380 ft.

Eight surfaces were created, each relating in some way to (1) impacts on wetland vegetation, (2) saltwater intrusion, and/or (3) an increase in public water supply demand (Figure 2). Based upon the distribution of the data and the hydrology, the data within each surface were weighted from 1 to 5. A 1 represented a factor having the least effect on the impacts being evaluated, and a 5 represented a factor having the greatest effect on the impacts being evaluated. The surfaces also were weighted against each other on the same scaling system, from 1 to 5, based upon the interrelationships among the surfaces and how these interrelationships would influence the impacts being

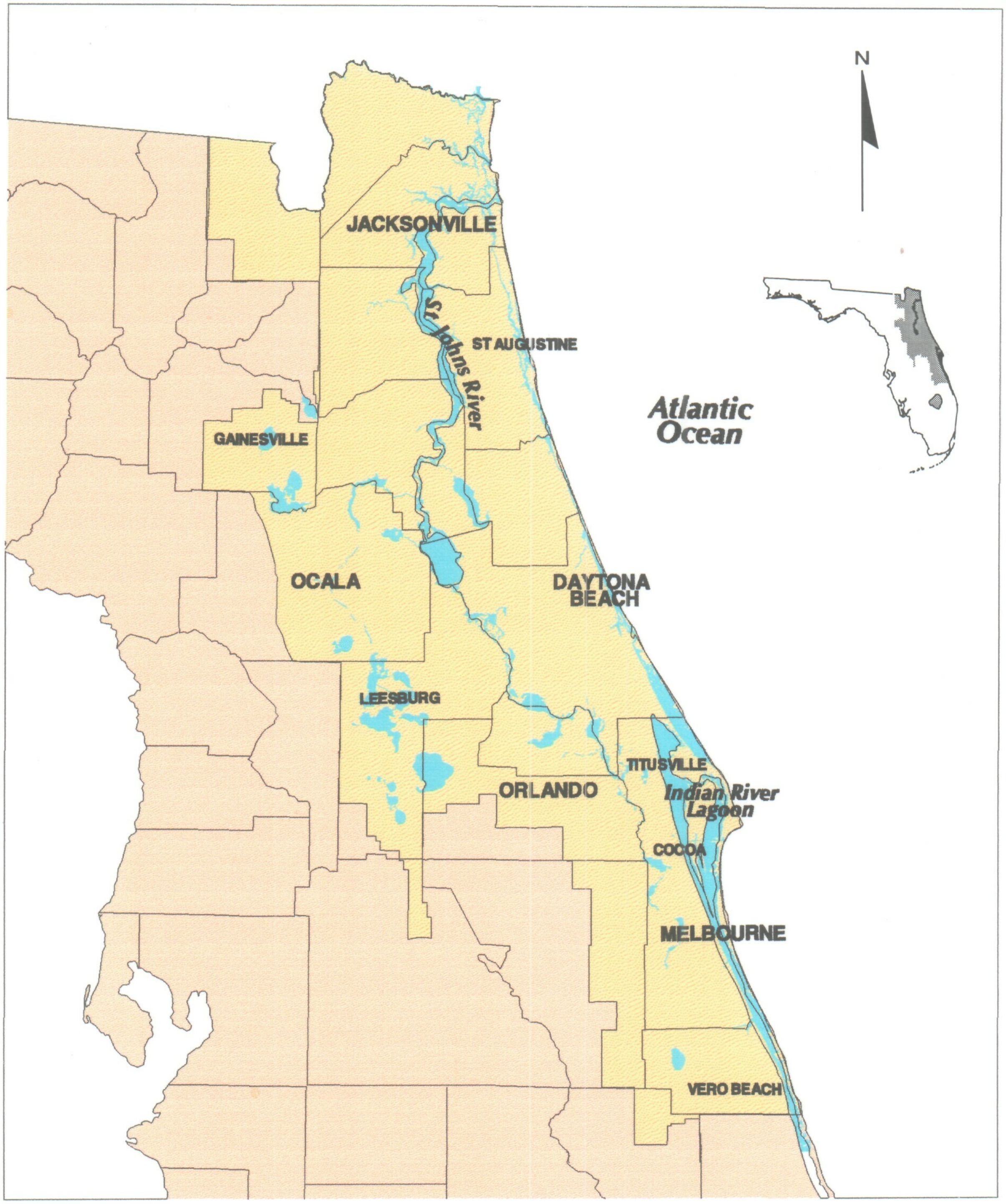

Figure 1.
St. Johns River Water Management District, Florida

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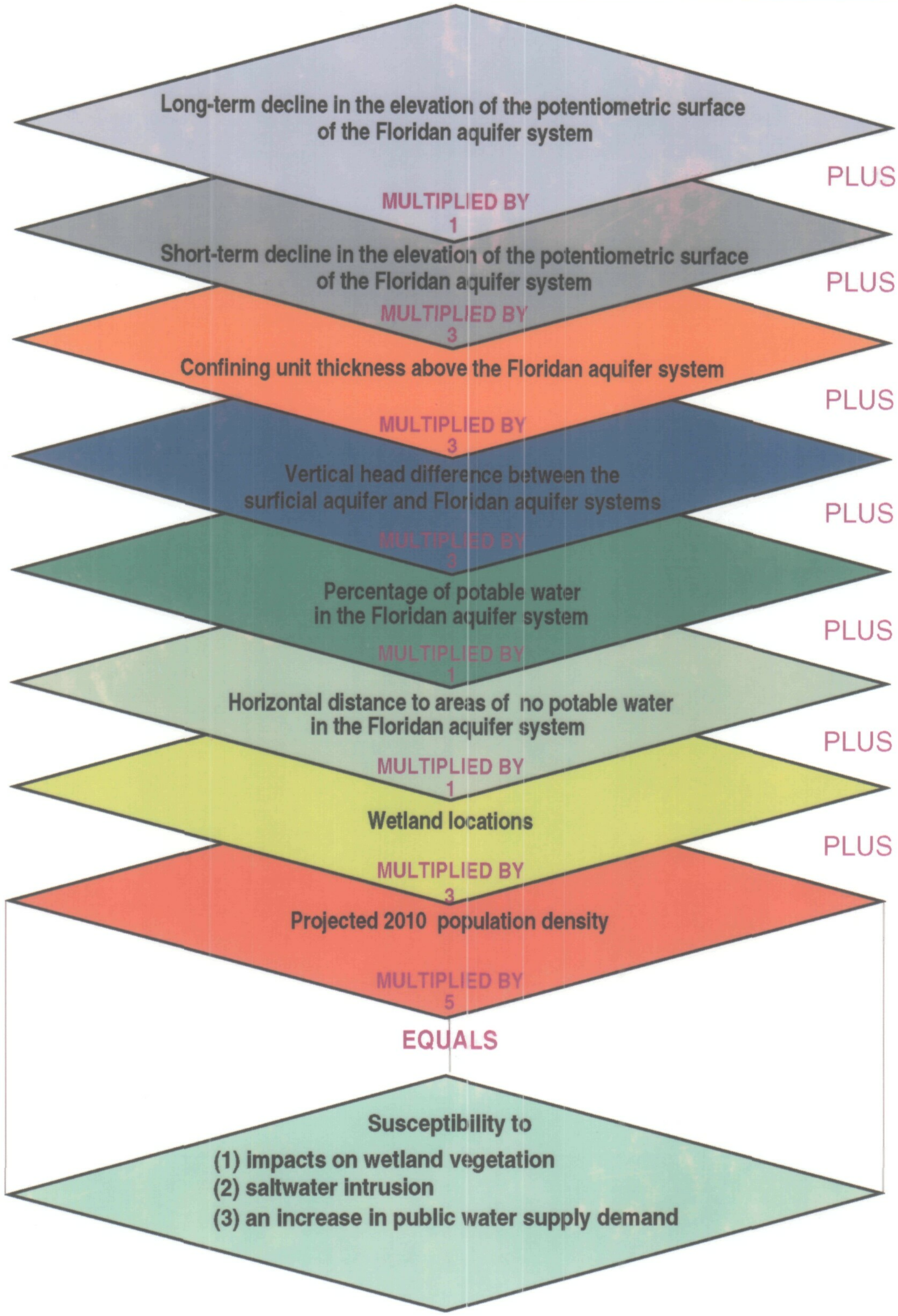

Figure 2.
Overlay methodology

evaluated in the study. Each surface was multiplied by the designated weight, then all of the surfaces were added together to produce a final surface of scores.

The surfaces used in the project consisted of (1) long-term decline in the elevation of the potentiometric surface of the Floridan aquifer system, (2) short-term decline in the elevation of the potentiometric surface of the Floridan aquifer system, (3) confining unit thickness above the Floridan aquifer system, (4) vertical head difference between the surficial aquifer and the Floridan aquifer systems, (5) percentage of potable water in the Floridan aquifer system, (6) horizontal distance to areas of no potable water in the Floridan aquifer system, (7) wetland locations, and (8) projected 2010 population density.

Surface 1, the long-term decline in the elevation of the potentiometric surface of the Floridan aquifer system, was created to represent the long-term (1936–90) change in water levels in the Floridan aquifer system. This surface represents the overall decline in the elevation of the potentiometric surface of the Floridan aquifer system due to long-term development in SJRWMD.

The predevelopment surface, created primarily from 1936 data, was a U.S. Geological Survey (USGS) contour map (Johnston et al. 1980) with contours representing the elevation of the potentiometric surface of the Floridan aquifer system in feet above mean sea level. This map was digitized into GIS. The coverage was processed through the triangulated irregular network (TIN) module of ARC/INFO, then through the GRID module to create the final surface representing the predevelopment potentiometric surface of the Floridan aquifer system.

Boniol et al. (1993) created the 1990 potentiometric surface of the Floridan aquifer system. This surface began originally as a point coverage of monitoring-well water levels from May 1990. The point coverage was processed through the TIN module, then through the GRID module to create a surface representing the elevation of the potentiometric surface of the Floridan aquifer system for 1990 (Boniol et al. 1993).

Finally, the long-term change in the elevation of the potentiometric surface of the Floridan aquifer system was calculated by subtracting the predevelopment potentiometric surface from the 1990 potentiometric surface. This procedure produced a surface showing the amount of long-term decline in the elevation of the potentiometric surface of the Floridan aquifer system (Figure 3).

Surface 2, the short-term decline in the elevation of the potentiometric surface of the Floridan aquifer system, was created to represent the short-term (1980–90) decline in the elevation of the potentiometric surface of the Floridan aquifer system caused by recent economic development and the associated increase in water supply demand in SJRWMD.

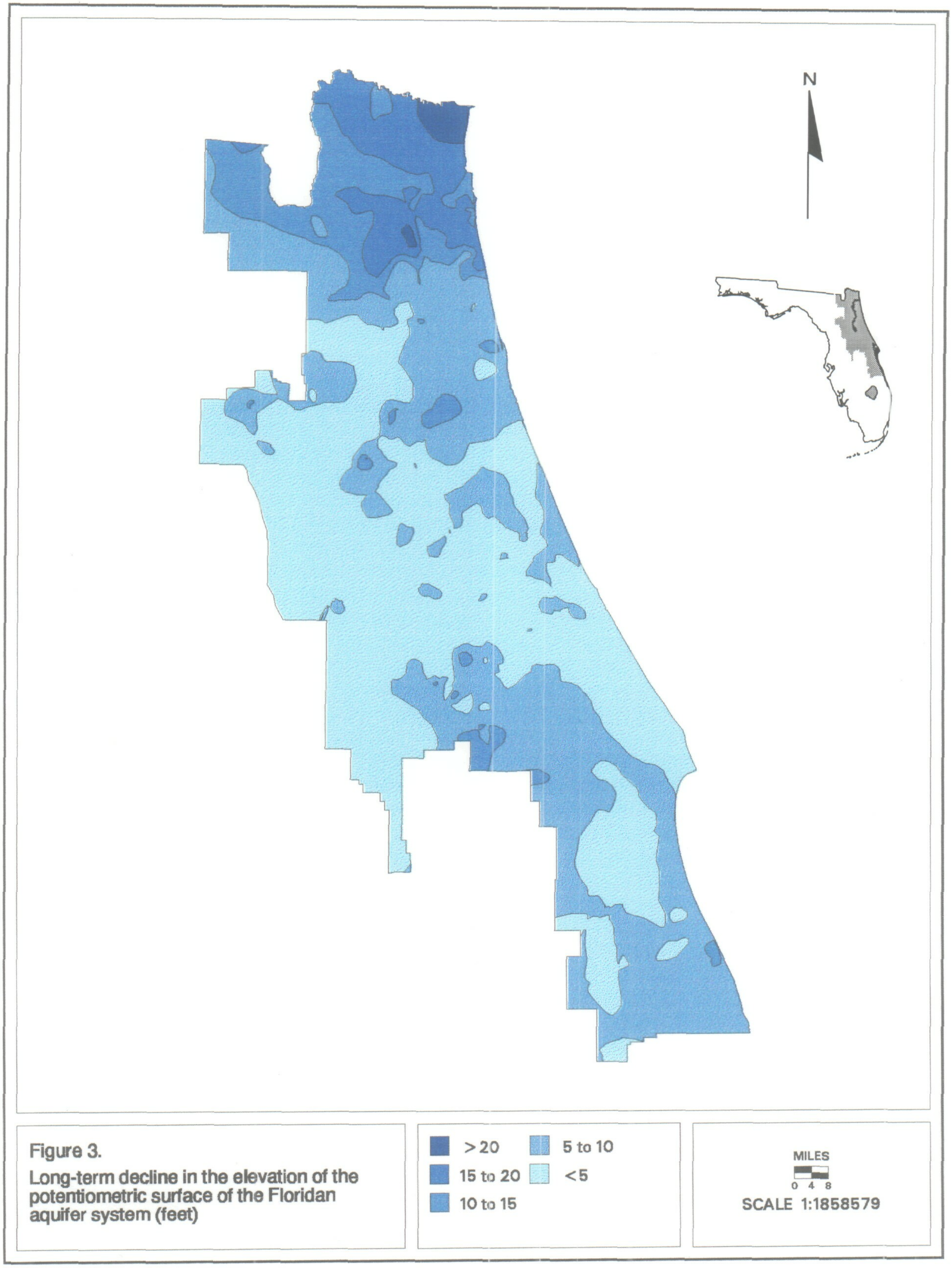

Figure 3.
Long-term decline in the elevation of the potentiometric surface of the Floridan aquifer system (feet)

The 1980 potentiometric surface was created using monitoring-well water levels from May of 1980 (SJRWMD 1994). The coordinates and water levels of the well points were used to create a point coverage. The point coverage was processed through the TIN module, then through the GRID module to create a surface representing the elevation of the potentiometric surface of the Floridan aquifer system for 1980. The 1990 potentiometric surface, described previously (p. 7), was used again in the analysis.

The short-term change in the elevation of the potentiometric surface of the Floridan aquifer system was calculated by subtracting the 1980 potentiometric surface from the 1990 potentiometric surface. This procedure produced a surface showing the amount of short-term decline in the elevation of the potentiometric surface of the Floridan aquifer system (Figure 4).

Surface 3, the confining unit thickness above the Floridan aquifer system, was created to represent the amount of confining material through which water moves that recharges the Floridan aquifer system or discharges from the Floridan aquifer system. This surface is important for determining impacts to wetland vegetation. The thicker the confining unit, the less the amount of induced drawdown that will occur in the surficial aquifer system due to pumping in the Floridan aquifer system. The less induced drawdown in the surficial aquifer system, the fewer expected impacts to wetland vegetation.

Boniol et al. (1993) created the thickness of the confining unit surface. The initial coverages were compiled by evaluating geophysical well logs taken from throughout SJRWMD to determine the top of the confining unit and the top of the Floridan aquifer system. Both of these coverages were processed through the TIN module, then through the GRID module. The elevation at the top of the confining unit was subtracted from the elevation of the top of the Floridan aquifer system (Boniol et al. 1993) to obtain the thickness of the confining unit above the Floridan aquifer system (Figure 5).

Surface 4, the vertical head difference between the surficial aquifer and the Floridan aquifer systems, was created to represent the head difference between these aquifer systems. This head difference is significant, as it is a factor controlling the amount of water being recharged to or discharging from the Floridan aquifer system, as well as the amount of upwelling of poor quality water in the Floridan aquifer system. Areas with a positive vertical head difference provide recharge to the aquifer. Areas with a negative vertical head difference are susceptible to saltwater intrusion, because they are discharge areas where water is upwelling from the lower, saltier portion of the Floridan aquifer system to the upper portions of better water quality. As withdrawals from the Floridan aquifer system increase and result in more drainage of water from the surficial aquifer system, the impact on wetland vegetation due to the change in vertical head difference can be significant.

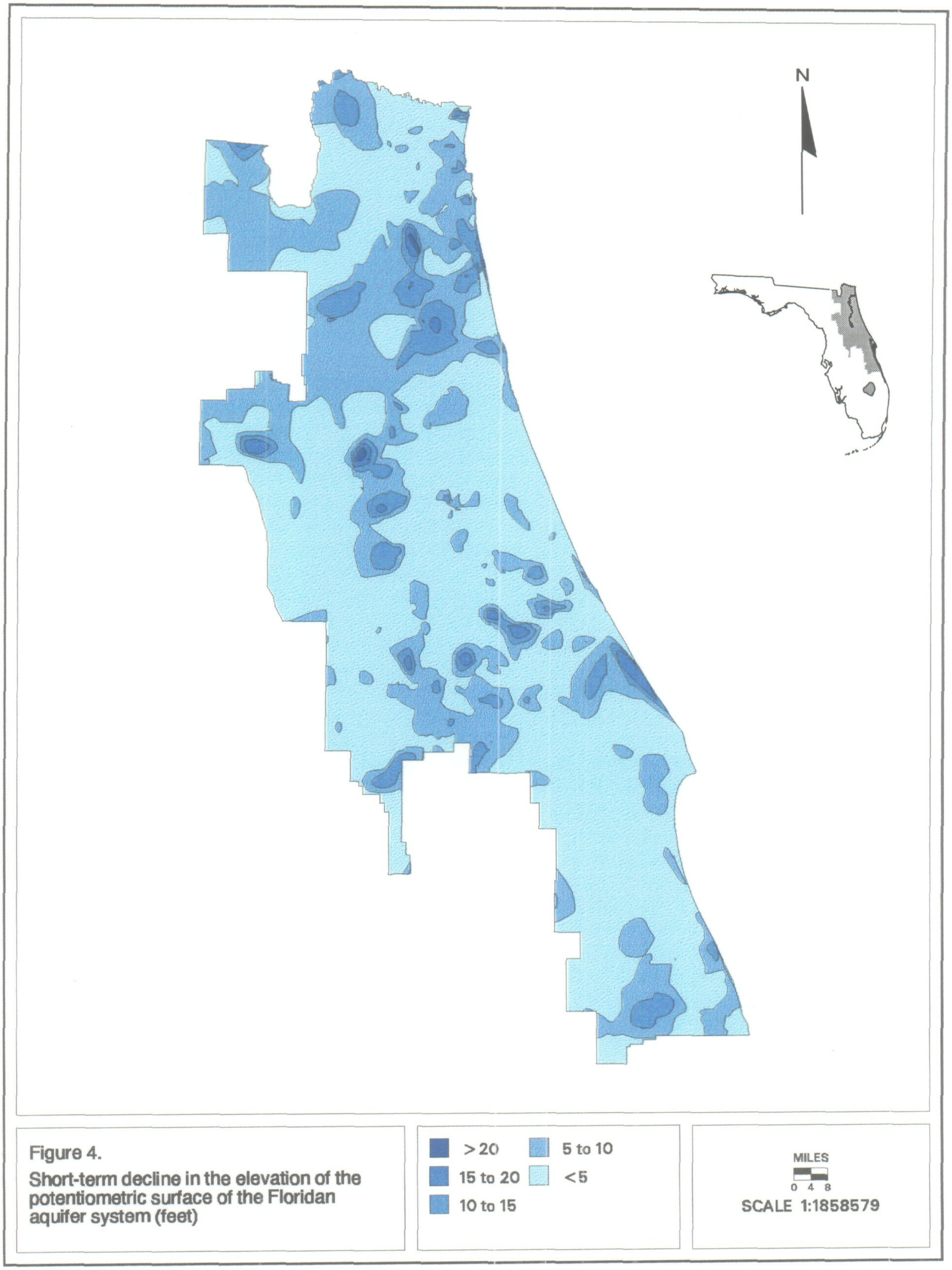

Figure 4.
Short-term decline in the elevation of the potentiometric surface of the Floridan aquifer system (feet)

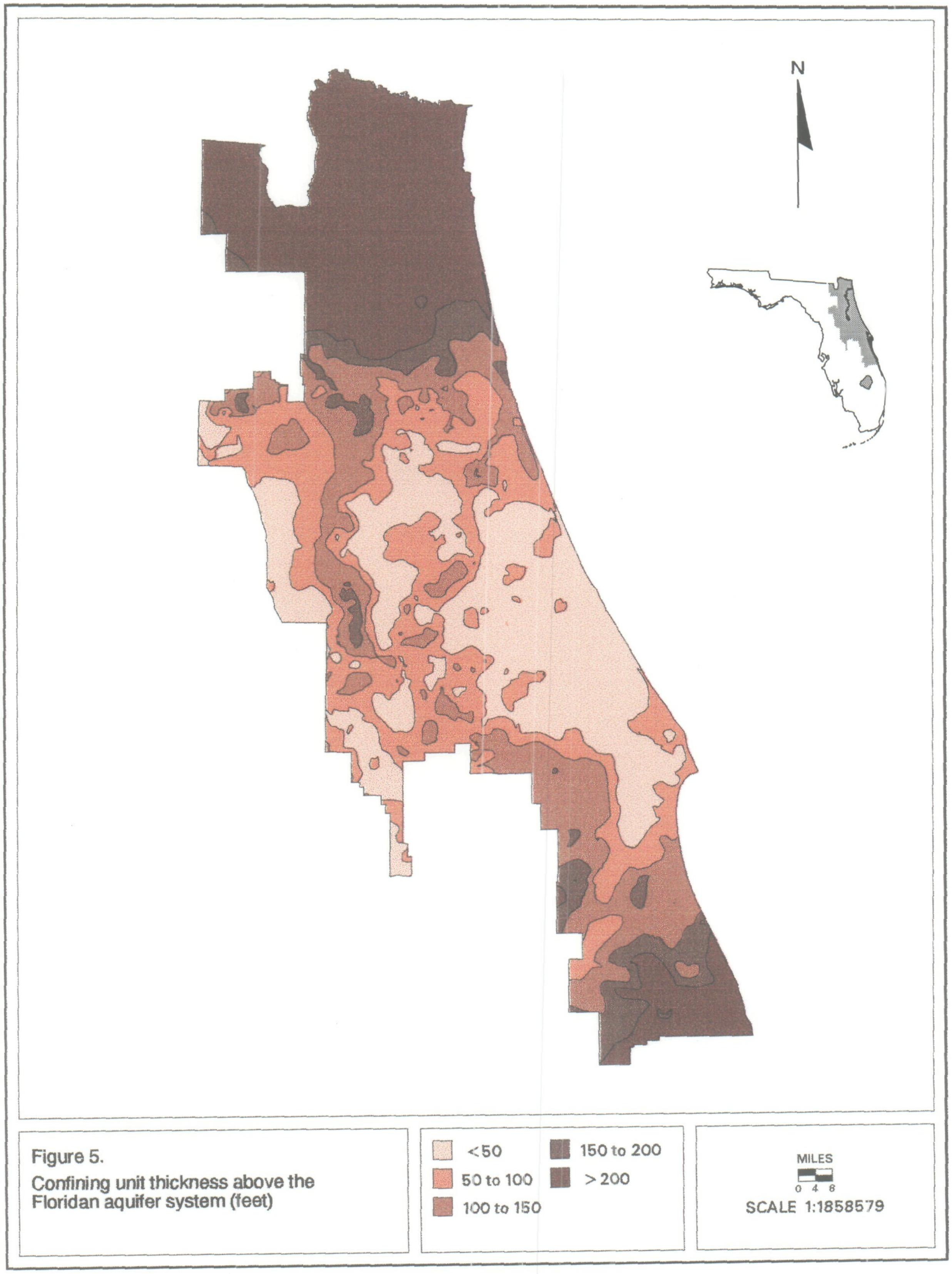

Figure 5.
Confining unit thickness above the Floridan aquifer system (feet)

Boniol et al. (1993) created the vertical head difference surface using two other surfaces: the 1990 potentiometric surface of the Floridan aquifer system, discussed previously (p. 7), and water levels in the surficial aquifer system. To create the water table of the surficial aquifer surface, Boniol used a regression equation ($Y = 0.901X - 1.61$) that gives the relationship between land surface elevation and the depth to the water table. A surface of hypsography was then processed through the regression equation to create a depth to the water table surface. The depth to the water table was subtracted from the hypsography to yield a surface representing the elevation of the water table of the surficial aquifer system. The elevation of the 1990 potentiometric surface of the Floridan aquifer system was subtracted from the elevation of the water table of the surficial aquifer system to produce the vertical head difference between the water table of the surficial aquifer system and the Floridan aquifer system (Figure 6).

Surface 5, the percentage of potable water in the Floridan aquifer system, was created to show the amount of potable water in the Floridan aquifer system relative to the total thickness of the aquifer. In some locations, the Floridan aquifer system is greater than 1,000 ft thick; however, not all of the water in the aquifer is potable. Potable water is defined as water containing chlorides or sulfates less than 250 milligrams per liter (mg/L), with a total dissolved solids concentration less than 500 mg/L (EPA 1993). The percent of potable water surface indicates how much of the water in the Floridan aquifer system is actually potable relative to the thickness of the aquifer system.

This surface was created using two other surfaces: the thickness of potable water and the thickness of the Floridan aquifer system. A coverage was produced showing the thickness of potable water in the Floridan aquifer system using Causey and Leve (1977), a water quality map. This USGS map was digitized into GIS, and the contours were edited based upon current information from ground water flow models, monitoring wells, and time-domain electromagnetic studies. The contours were processed through the TIN module, then the TIN was processed through the GRID module. This surface was evaluated to ensure that it matched the edited contour coverage.

Miller (1986) produced a map showing the total thickness of the Floridan aquifer system. This map was digitized into GIS. This contour coverage was then processed through the TIN module, then the GRID module, to produce a surface representing the total thickness of the Floridan aquifer system.

To calculate the percentage of potable water in the Floridan aquifer system, the following equation was used.

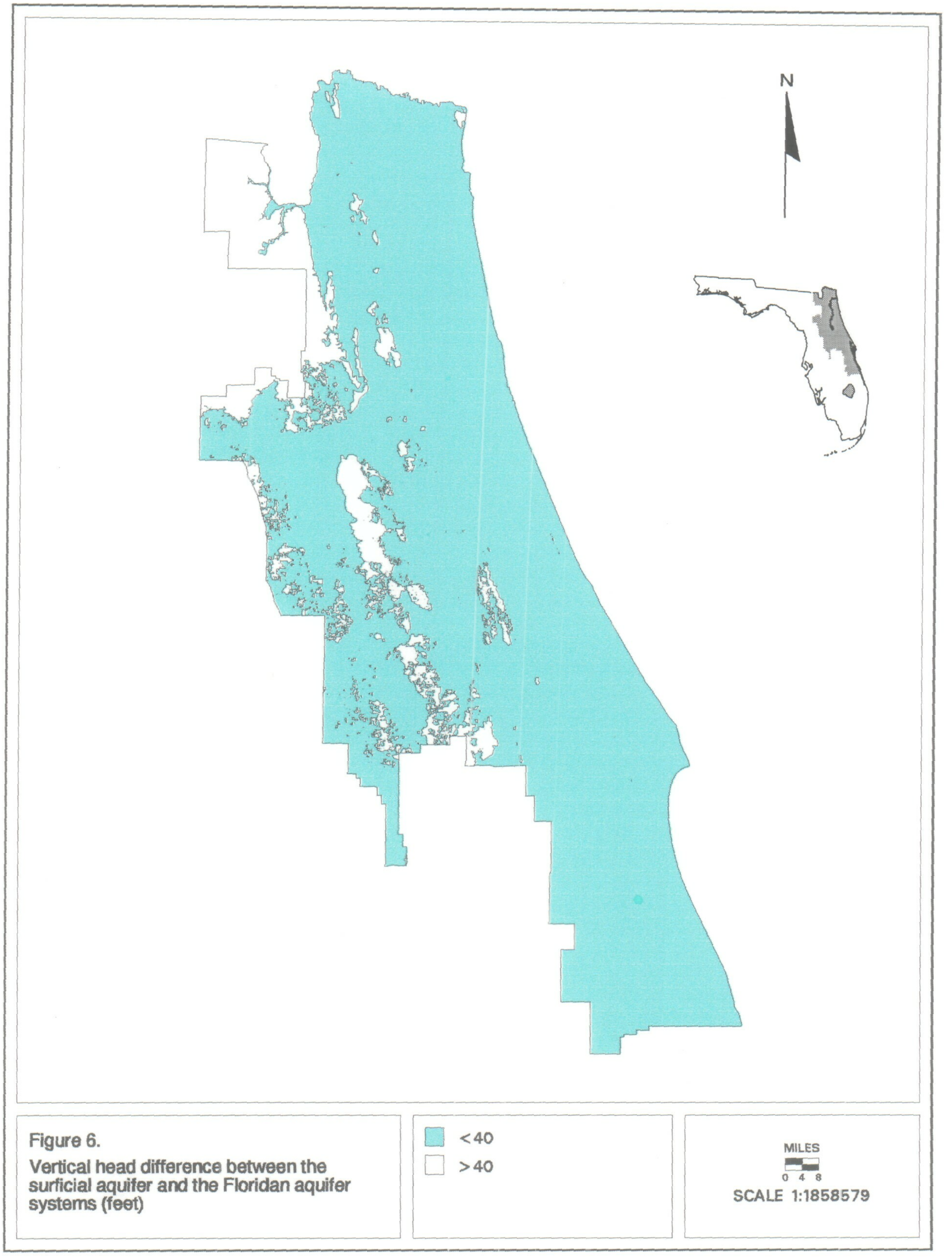

Figure 6.
Vertical head difference between the surficial aquifer and the Floridan aquifer systems (feet)

$$\frac{(\textit{thickness of potable water}) - (\textit{total thickness of the Floridan aquifer system})}{\textit{total thickness of the Floridan aquifer system}} * 100$$

Figure 7 represents the final output for surface 5, using the above equation.

Surface 6, the horizontal distance to areas of no potable water in the Floridan aquifer system, was developed as a surface to give additional weight in the scoring scheme to those areas far from areas with poor water quality. The farther a wellfield is located from areas of no potable water, the less susceptible the wellfield should be to saltwater intrusion.

Areas of no potable water, identified as areas where the chlorides were greater than 250 mg/L throughout the entire Floridan aquifer system, were selected from the thickness of potable water surface. The NEAR function in ARC/INFO, which calculates the distance from any point to the nearest point, node, or arc, was used to calculate the distance of any potential wellfield from the area of no potable water (Figure 8).

Surface 7 was created to show wetland locations. The wetland areas were of particular concern to this project because of the potential for impacts to vegetation caused by increased withdrawals from the Floridan aquifer system. Withdrawals from the Floridan aquifer system can induce drawdowns in the water level of the surficial aquifer system. These drawdowns could affect wetland vegetation.

The wetland surface was created from the hydrography layer in the USGS Digital Line Graph (DLG) coverage. The areas designated wetlands were reselected from the coverage and placed in a separate coverage. The layers reselected were hydrography, intermittent water bodies, deep water wetlands, marsh or wetlands, and mangroves. The polygon coverage of wetlands was processed through the GRID module to create a surface representing wetlands (Figure 9).

Surface 8, projected 2010 population density, was created to indirectly identify areas where future water withdrawals are expected to be large. This is the only surface that has the capability of incorporating future or anticipated elements into the study.

The projected 2010 population density surface was created using a coverage of 1990 census tract population data. The 1990 population data were projected to 2010 by multiplying the census tract data for each county by a percentage that represents the projected population change between 1990 and 2010 on a county level (Bureau of Economic and Business Research 1993). After calculating the projected 2010 population figures, the population value for each census tract was normalized to account for varying population figures over varying census tract sizes. To normalize the data, the tract population was divided by the area of the census tract to obtain the projected 2010

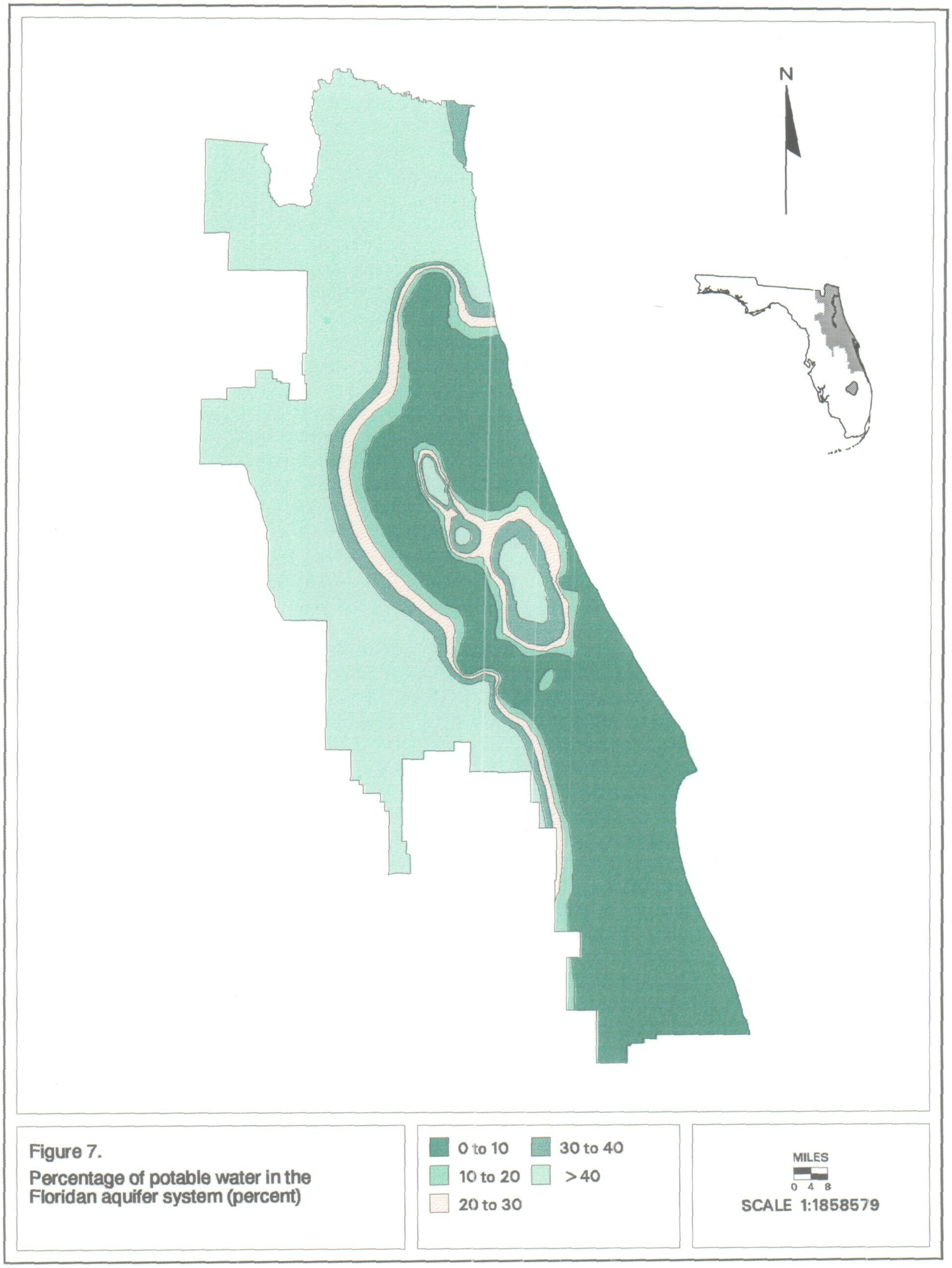

Figure 7.
Percentage of potable water in the Floridan aquifer system (percent)

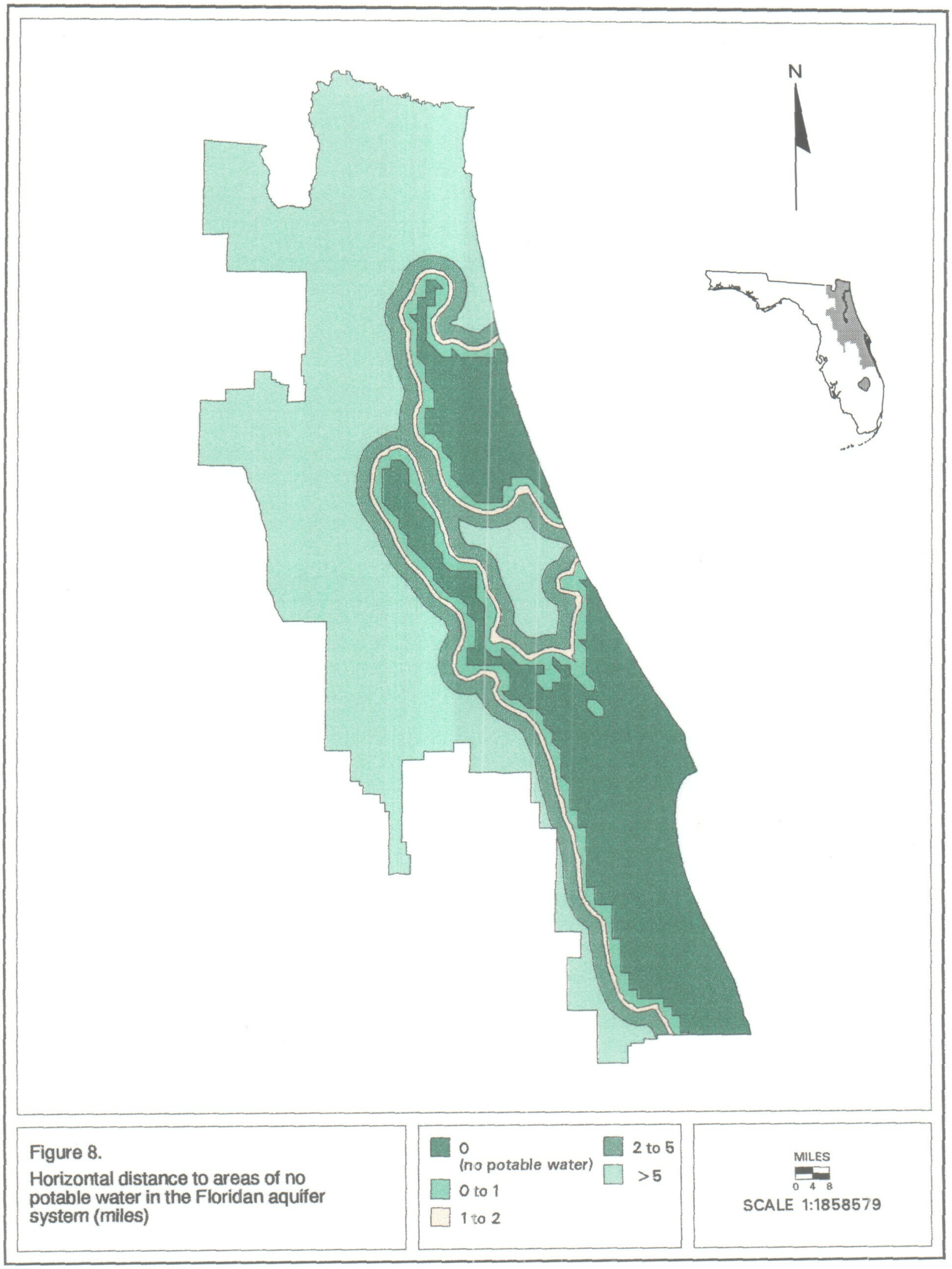

Figure 8.
Horizontal distance to areas of no potable water in the Floridan aquifer system (miles)

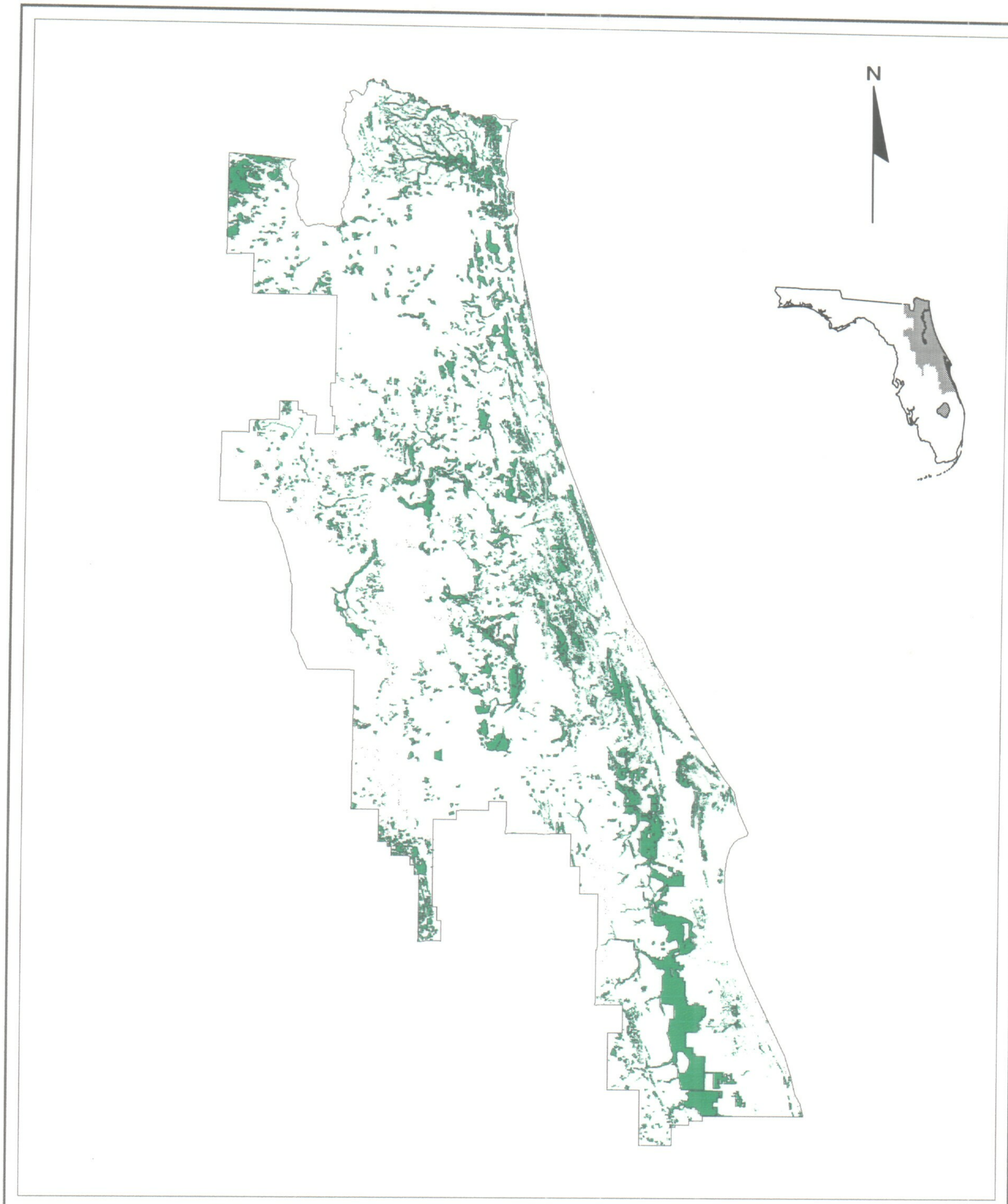

Figure 9.
Wetland locations

Wetlands
Non-wetlands

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population density in persons per square mile. The resultant surface is represented as Figure 10.

After these eight surfaces were created, the data from each surface were integrated using a weighting scheme. Data within each surface were weighted, then each surface was weighted against the others based upon the interrelationship of the surfaces and how the surfaces affected the impacts being evaluated (Figure 2).

The data in each surface were evaluated based upon the hydrogeology and/or histogram distribution of the data. The data in each surface were weighted from 1 to 5, using a separate lookup table for each surface. A value of 1 indicated a factor having the least significance in causing or contributing to one of the three areas of evaluation, and a value of 5 indicated a factor having the greatest significance in causing or contributing to one of the three areas of evaluation. The items for each surface were weighted as shown in Table 1.

Table 1. Item weights for each surface

Surface Number	Surface Description	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5
1	Long-term decline in the elevation of the potentiometric surface of the Floridan aquifer system	>-10 ft	-10 to -20 ft	-20 to -30 ft	-30 to -40 ft	<-40 ft
2	Short-term decline in the elevation of the potentiometric surface of the Floridan aquifer system	>-5 ft	-5 to -10 ft	-10 to -15 ft	-15 to -20 ft	<-20 ft
3	Confining unit thickness above the Floridan aquifer system	>200 ft	150 to 200 ft	100 to 150 ft	50 to 100 ft	<50 ft
4	Vertical head difference between the surficial aquifer and Floridan aquifer systems	>40 ft	NA	NA	NA	<40 ft
5	Percentage of potable water in the Floridan aquifer system	>40%	30 to 40%	20 to 30%	10 to 20%	0 to 10%
6	Horizontal distance to areas of no potable water in the Floridan aquifer system	>5 mi	2 to 5 mi	1 to 2 mi	0 to 1 mi	0 mi
7	Wetland locations	everything except marsh and wetland	NA	NA	NA	marsh and wetland
8	Projected 2010 population density	<100 persons/mi^2	100 to 200 persons/mi^2	200 to 400 persons/mi^2	400 to 600 persons/mi^2	>600 persons/mi^2

Note: ft = foot
NA = not applicable
mi = mile
mi^2 = square mile

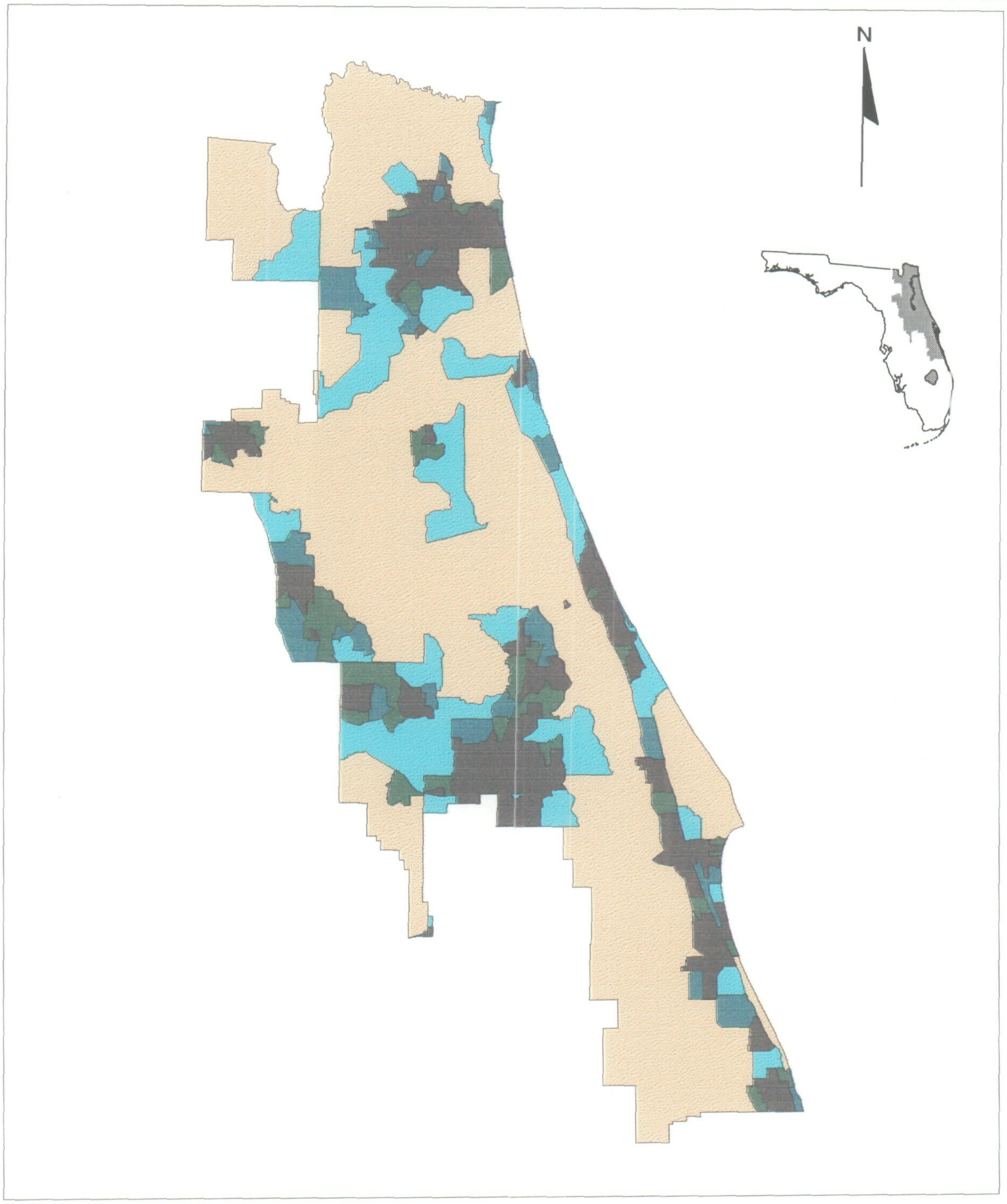

Figure 10.
Projected 2010 population density (persons per square mile)

In some cases, a histogram of the distribution of values led to the assigned weights, as was the case with surfaces 1 and 2. For the other surfaces, weights were determined based upon knowledge of hydrology and geology as to the relative influence of the factor or surface on (1) impacts to wetland vegetation, (2) saltwater intrusion, and/or (3) an increase in public water supply demand.

Several assumptions were made while categorizing the data into weights. Surface 4 was difficult to categorize into weights, because at one extreme of the values, impacts to wetland vegetation occur and at the other extreme of the values, saltwater intrusion impacts occur. Saltwater intrusion impacts were assumed to be accounted for more accurately; therefore, areas with low values, having the potential for saltwater intrusion, were weighted the highest. Specifically, in the wetlands surface, an assumption was made that there would be little or no effect in locations where there were no wetlands; consequently, wetlands were weighted the highest.

The weighted surfaces then were weighted against each other with a factor ranging from 1 to 5. The factor affecting the overall weight the most received a weight of 5. The factor affecting the overall weight the least received a weight of 1. Table 2 lists the weights given to each surface.

Table 2. Surface weights

Surface Number	Surface Description	Weight
1	Long-term decline in the elevation of the potentiometric surface of the Floridan aquifer system	1
2	Short-term decline in the elevation of the potentiometric surface of the Floridan aquifer system	3
3	Confining unit thickness above the Floridan aquifer system	3
4	Vertical head difference between the surficial aquifer and Floridan aquifer systems	3
5	Percentage of potable water in the Floridan aquifer system	1
6	Horizontal distance to areas of no potable water in the Floridan aquifer system	1
7	Wetland locations	3
8	Projected 2010 population density	5

The weighted surfaces were overlaid and weighted against each other before being added together to create a cumulative final score surface. Surface 5 and surface 6 were weighted using a value of 1 because they are conceptually and physically similar to each other. This weighting procedure causes the general distribution of the data to automatically appear twice in the overall scores. Surface 1 was weighted using a value of 1, and surface 2 was weighted using a value of 3 because the current and near-future changes were more important to this study. Surface 3 was weighted using a value of 3 because it is an important factor affecting vegetation. Surface 4 also was weighted using a value of 3 because it affects both impacts to vegetation and saltwater upconing. Surface 7 was weighted using a value of 3 because of the high sensitivity of wetlands to changes in the water table and a general emphasis in Florida to preserve and/or enhance wetland functionality. Surface 8 was weighted the highest, using a value of 5, because this is the only surface that accounts for future or anticipated changes.

RESULTS

The possible range of scores on the final surface was from 20 to 100. A value of 20 would indicate the least potential for impacts, and a value of 100 would indicate the greatest potential for impacts. The distribution fell into a classic bell-shaped histogram (Figure 11). The high, medium, and low potential categories were selected based upon the overall distribution of the data. The low potential category had scores less than 40; the medium potential category, where the peak on largest numbers of occurrences of the histogram occurred, had scores between 40 and 60; and the high potential category had scores greater than 60.

Figure 12 represents the composite surface, which indicates the potential for (1) impacts to wetland vegetation, (2) saltwater intrusion, and/or (3) an increase in public water supply demand.

DISCUSSION

Several distinct areas show a high potential for any of the three water resource problems (Figure 12). The Atlantic coastal areas (e.g., Daytona Beach, Melbourne, Vero Beach) show high scores, as do the Gainesville and Ocala areas (Figures 1 and 12). These areas appear with high scores due to several compounding factors. Along the coast, these factors include the presence of high chloride concentrations in the Floridan aquifer system, the distance to no potable water, changes in the elevation of the potentiometric surface of the Floridan aquifer system, and large population projections. High inland scores occurring at Gainesville and Ocala are due to large population projections, changes in the elevation of the potentiometric surface of the Floridan aquifer system, and a thin confining unit in the Ocala area. Other areas showing a high

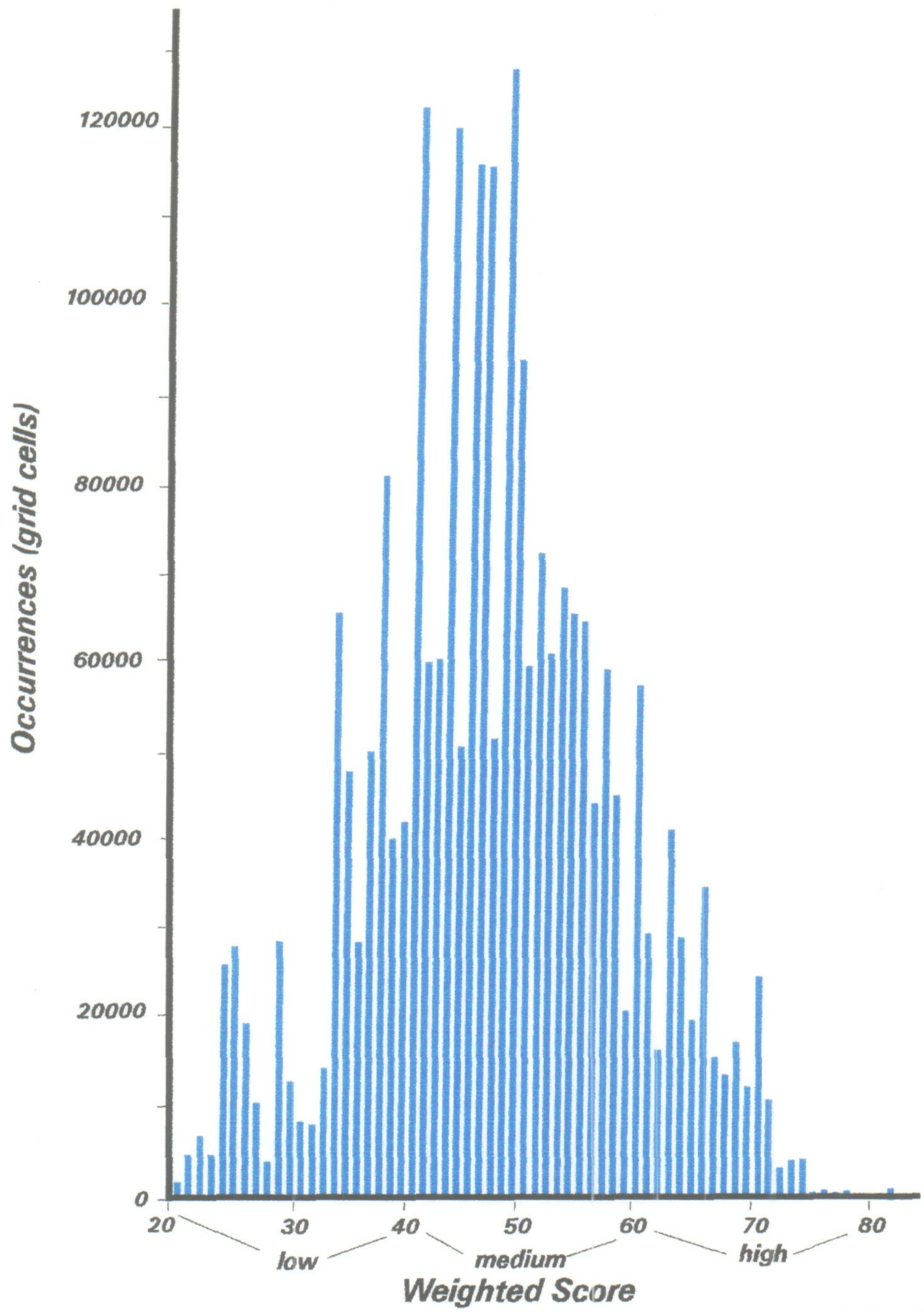

Figure 11.
Histogram distribution of data on final surface of scores

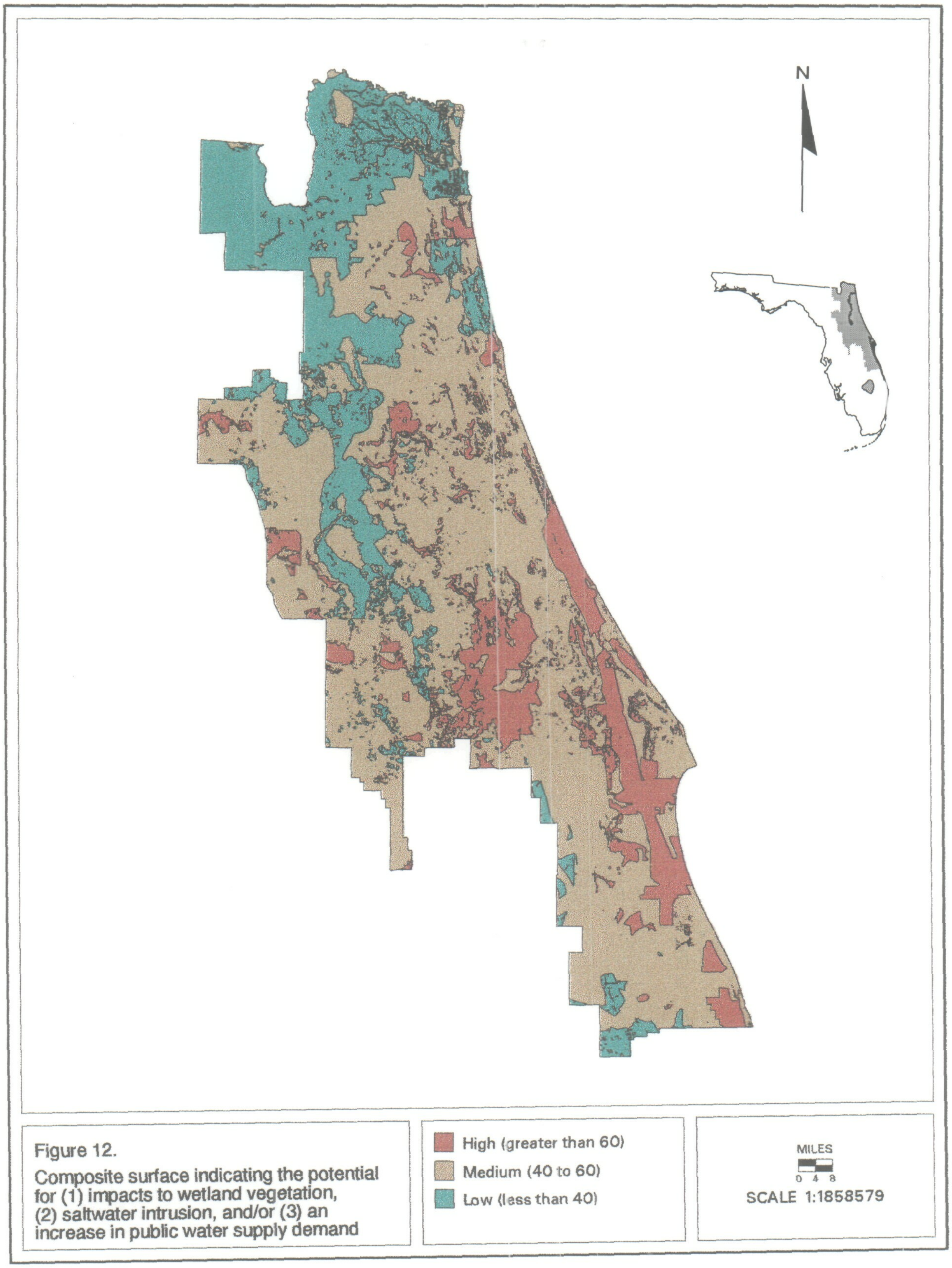

Figure 12.
Composite surface indicating the potential for (1) impacts to wetland vegetation, (2) saltwater intrusion, and/or (3) an increase in public water supply demand

potential are located north and northeast of Orlando (Figures 1 and 12). This area shows high scores due to the occurrence of poor quality water, wetlands, a negative vertical head difference, and a significant change in the elevation of the potentiometric surface of the Floridan aquifer system.

The public water supply service areas further defined those areas that need special attention, although some wellfields do occur outside of the water service areas. The cumulative effect of all of the wellfields in an area can cause a general decline in the elevation of the potentiometric surface of the Floridan aquifer system outside the public water supply service areas.

The locations of the regional numerical ground water flow models also were overlaid on the final scored surface (Figure 13 and Table 3). The distribution of the regional ground water flow models shows that virtually all of the areas that have high scores fall within the boundaries of the flow models. Several cities that fall outside any of the regional ground water flow models, including Ocala and Vero Beach, have been evaluated with local-scale analytical models.

CONCLUSIONS

Those areas identified as having a high potential for impacts to wetland vegetation, saltwater intrusion, and/or an increase in public water supply demand are apparent using this GIS methodology to overlay related surfaces. These results support the locations of the regional numerical ground water flow models and the local analytical ground water models. A high potential for any of the three water resource problems is evident in the coastal areas where the combined effects of saltwater intrusion, declines in the potentiometric surface of the Floridan aquifer system, and high population densities are the greatest. Several coastal cities, including Daytona Beach, have already developed wellfields further inland because of saltwater encroachment in the aquifer systems. Areas of large potential impacts are in the Upper St. Johns River Basin (the approximate area from Vero Beach to Melbourne) and the major municipalities (Figures 1 and 12). An extensive area north and east of Orlando currently is identified as a water resource caution area (Vergara 1994). More site-specific subregional ground water flow or transport models may need to be developed to fully understand the effects associated with future water supply development.

The methodology used in this study provides a tool that could be used to identify areas in need of water resource assessment, including the need to develop ground water models.

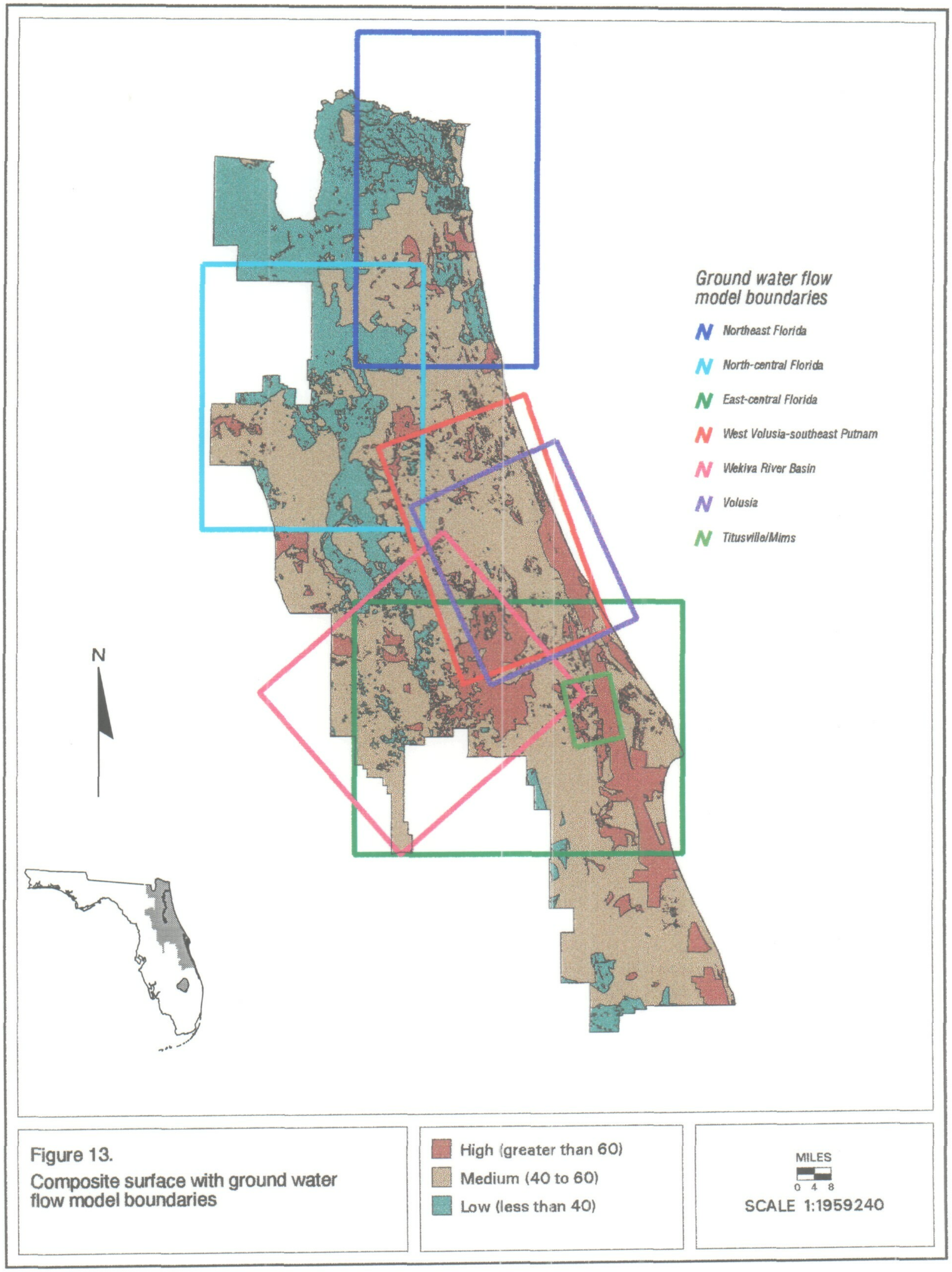

Figure 13.
Composite surface with ground water flow model boundaries

Table 3. Summary of regional numerical ground water flow models

Model Name	Publication Describing Model	Counties within Model Boundaries
Northeast Florida	*Finite-difference simulation of the Floridan aquifer system in northeast Florida and Camden County, Georgia* (Durden 1995, draft)	Parts of Duval, St. Johns, Nassau, and Clay counties and Camden County, Georgia
North-central Florida	*North-central Florida regional ground-water investigation and flow model* (Motz et al. 1995, draft)	Parts of Columbia, Baker, Duval, Union, Bradford, Clay, Alachua, Putnam, Marion, and Levy counties
Wekiva River Basin	*Wekiva River Basin ground water flow and solute transport modeling study: Phase I: Regional ground water flow model development* (GeoTrans 1992)	Parts of Lake, Seminole, Orange, Polk, Marion, and Volusia counties
Volusia	*Revision and recalibration of a regional flow model of the Volusia ground water basin* (Williams 1995a, draft)	Volusia County and parts of Flagler, Putnam, Lake, and Seminole counties
Titusville/Mims	*Regional ground water flow model of the surficial aquifer system in the Titusville/Mims area, Brevard County, Florida* (Williams 1995b)	Northern Brevard County
East-central Florida	*Regional ground-water flow modeling for east-central Florida with emphasis on Orange and Seminole counties* (Blandford and Birdie 1992)	All of Orange and Seminole counties and parts of Brevard, Osceola, Polk, Lake, and Volusia counties
West Volusia-southeast Putnam	*Regional simulation of projected ground water withdrawals from the Floridan aquifer system in western Volusia County and southeastern Putnam County, Florida* (McGurk 1995, draft)	All of Volusia and Flagler counties and parts of Putnam, Lake, and Seminole counties

Modified from Vergara 1994

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CONVERSION TABLE

Multiply	By	To Obtain
foot (ft)	0.3048	meter (m)
million gallons per day	3.785×10^3	cubic meters per day (m^3/day)