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DEVELOPMENT AND APPLICATION OF A MODIFIED KINSER-MINNO METHOD FOR ASSESSING THE LIKELIHOOD OF HARM TO NATIVE VEGETATION AND LAKES IN AREAS WITH AN UNCONFINED FLORIDAN AQUIFER

TECHNICAL MEMORANDUM

Development and Application of a Modified Kinser-Minno Method for Assessing the Likelihood of Harm to Native Vegetation and Lakes in Areas with an Unconfined Floridan Aquifer

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Introduction

This technical memorandum summarizes the development of a depth to water in the Upper Floridan Aquifer (UFA) ranking criteria for use as an additional step to the methods for estimating the likelihood of harm to native vegetation and lakes from ground water withdrawals. In order to determine the suitability of depth to water ranking criterion a pilot study was conducted. This effort consisted of developing and using modified versions of the GIS overlay analyses described in St. Johns River Water Management District (SJRWMD) Technical Publication SJ95-8, *Estimating the likelihood of harm to native vegetation from groundwater withdrawals*, SJRWMD Professional Paper SJ2003-PP3, *Modification of modeling criteria for application in the 2025 likelihood of harm assessment, and* Professional Paper SJ2006-PP1, *Estimating the likelihood of harm to lakes from groundwater withdrawals in the St. Johns River Water Management District for year 2025.* The methods described in these publications are hereinafter referred to by the name of the authors of the methods as the Kinser-Minno method(s). The purpose of this effort was to recategorize the potential for harm to wetland and lake systems based on the depth to the water in areas where the Upper Floridan aquifer is unconfined.

Application of the Kinser-Minno methods for estimating likelihood of harm to wetland and lake systems in association with SJRWMD's 2003 Water Supply Assessment identified wetland and lake systems in the western portion of SJRWMD's North-Central Florida Regional Groundwater Flow Model (Motz and Dogan 2004) domain, as likely to experience moderate to higher likelihood of harm as a result of projected 2025 groundwater withdrawals. Some of these wetland and lake systems are located in western Marion County where an unsaturated portion of the Floridan aquifer exists at or near the land surface downward to the potentiometric surface of the unconfined Upper Floridan aquifer (UFA). In this area water levels in wetland and lake systems are not likely to be affected by changes in the potentiometric surface of the Upper Floridan aquifer in the same way as is contemplated in the Kinser-Minno methods. SJRWMD and Southwest Florida Water Management District (SWFWMD) staffs agreed to work together to examine the appropriateness of the Kinser-Minno methods to address the likelihood of harm to wetlands and lakes in this unconfined area, which are in the vicinity of the boundary between SJRWMD and SWFWMD in north-central Florida. In addition, the staffs agreed to work together to identify appropriate changes in the Kinser-Minno methods that would better define the likelihood of harm in unconfined areas.

A team of scientists and hydrogeologists representing both SJRWMD and SWFWMD conducted a field trip to inspect the wetlands and aquatic systems of concern in the north-western portion of Marion County with an emphasis in the Fairfield Hills area. General Floridan aquifer potentiometric surface information for the area indicates that water levels in the unconfined Upper Floridan aquifer are approximately 50 ft NGVD and the land surface varies from about 50 to over 250 ft NGVD. In these areas several wetland systems were observed that did not appear to be well connected to near-surface Floridan aquifer water levels. This field trip confirmed the reality of the concern that modifications to the Kinser-Minno method are appropriate in areas where the Floridan aquifer is unconfined and significant depth to water exists.

Literature Review

The Kinser-Minno methods for assessing the likelihood of harm to native vegetation and lakes as a result of groundwater withdrawals are used by SJRWMD in its water supply planning process. The method addressing the likelihood of harm to native vegetation has been used for more than 10 years. It is a GIS based method used to identify areas with vegetative communities that are susceptible to adverse impacts due to reduced water levels in the surficial aquifer system (SAS) and the relative likelihood of harm to those communities in response to projected water level declines. Susceptibility is determined based on community type, soil drainage class, degree of water level drawdown in the SAS, and landscape position. The original method and application is described in detail in Kinser and Minno (1994).

The Kinser-Minno method was first modified (Kinser *et al.* 2003) to incorporate and reconcile updated vegetation constraints, which define the thresholds for the likelihood of unacceptable harm.

The Kinser-Minno method for assessing the likelihood of harm to lakes was first used in the development of SJRWMD's 2003 Water Supply Assessment. The method has not been previously modified. The additional modifications described in this document require the following two additional steps.

- Areas that lack a confining unit overlying the UFA need to be delineated.
- The assignment of the likelihood of harm to vegetative communities (lower, moderate, and higher) or lakes (low and high) must be recategorized to account for depth from land surface elevation to the water level in the unconfined Floridan aquifer. For this step the likelihood of harm is assumed to diminish with depth.

Based on a review of published geologic information the only areas in or adjacent to SJRWMD that lack a confining unit overlying the UFA, are within the domain of SJRWMD's North-Central Florida Regional Groundwater Flow Model (NCF model) (Motz and Dogan 2004). SJRWMD and SWFWMD staffs identified Miller's (1996) delineation of the areas within the NCF model that lack an upper confining unit overlying the UFA as an appropriate basis for the desired modifications.

The rationale for the adjustment of the likelihood of harm on the basis of depth from land surface elevation to the potentiometric surface of the UFA is that at some depth the vegetative community and the SAS are not hydraulically connected to the UFA, and therefore the SAS would not be under the influence of changes in the levels of the UFA potentiometric surface. This depth of hydraulic influence was expected to be a function of the depth and thickness of the SAS, landscape elevation, depth to the potentiometric surface of UFA, vegetation type and rooting depth, soil type, depth and thickness of the capillary rise and vadose zones. In the literature these are collectively used to define the evapotranspiration extinction depth (ETED).

The depth of the root zone in most plant communities typically range between one and three meters (m), however, depths of 10 m and deeper have been reported (Stone and Kalisz 1990, Lehmann 2003). Lugo *et al*. (1984) report measured rooting depth in forested wetlands in Florida as ranging between 0.4 and 2.0 m. The higher value came from a study of a pond cypress dome in Alachua County by Mitch and Ewel (1979). Because root zone studies are particularly difficult to do in wetland ecosystems it is anticipated that actual rooting depth in the cypress dome extended beyond the reported 2.0 m. Studies in the sandhill ecosystems of north-central Florida by Kalisz (1982) found roots of some woody plants extending beyond depths of 10 m. The root zones of riparian and transitional woody species in the southwest U.S. have been reported to extend to depths of 5 to 10 m.

Tibbals (1990) proposed a relationship between evapotranspiration (ET) to water table depth in east-central Florida. The graphical model (see Figure 7 in Tibbals 1990) gives average ET extinction with depth in which the average annual ET decreased non-linearly from 48 in/yr for conditions with the water table at or close to the land surface and decreasing to a minimum of 30 in/yr in areas where the water table was more than 15 ft (4.57 m) below land surface. Tibbals' ETED approach is widely referenced for the development of groundwater models in north and central Florida (Tibbals 1999, Merritt 2001, Patrick Burger/SJRWMD personal communication 2007).

Ross *et al*. 2005 developed a specific ET algorithm for use in an HSPF-MODFLOW integrated surface and groundwater model partitioning ET between surface storage, vadose zone storage, and saturated ground storage. This approach considers evaporative loss from surface sources, proximity of water table to land surface, relative moisture of the saturated zone, thickness of the capillary zone, thickness of the root zone, soil type and texture, and relative plant cover density. Using this conceptualization of ET extinction, Shah *et al*. 2007 conducted extensive field studies of ET extinction in west-central Florida. They developed extinction depth relationships for combinations of soil texture (course sand to clay) and land cover types (bare soil, grass, forested). In their summary of extinction depths (see Table 1 in Shah *et al.* 2007) the ETED increases as the soil texture becomes finer, and varies with cover type, being highest for forest and lowest for bare soil. The range in ETED by cover type is as follows:

- Bare soil--50 cm in sand, 265 in loam, 430 in silt, and 620 in clay
- Grass--145 cm in sand, 370 in loam, 530 in silt, and 715 in clay
- Forest--250 cm in sand, 470 in loam, 630 in silt, and 820 in clay

Shah *et al.* (2007) assume that rooting depth for forest cover is 2 m, thus this cover type seems to be the best choice as a model for estimating ETED for this modification of the Kinser-Minno harm assessment method. The estimated range in ETED for forest cover varies from 2.5 to 8.2 m as a function of soil texture with a mid point of 5.35 m.

Tibbals' (1990) value of 4.57 m falls into the lower half of the ETED range for forest cover developed by Shah *et al*. (2007) and can serve as a conservative estimate of ETED, noting however, the possibility that some vegetative communities may have deeper ETED values due to more deeply rooted plants, or presence of very fine textured soils, or both.

From this review it was determined that a depth increment of 4.57 m (15 ft) would be used to recategorize the potential for harm to wetland vegetation and lakes as follows:

- 0 to 4.75 m (0 to 15 ft)—wetland or lake system is hydraulically connected to the UFA
- >4.75 m to 9.14 m (15 to 30 ft)—wetland or lake system may be hydraulically connected to the UFA
- >9.14 m (30 ft)—wetland and lake systems are not hydraulically connected to the UFA

Method Modification for Unconfined Floridan Aquifer Conditions

SJRWMD modified the Kinser-Minno methods to address areas in the NCF model domain where the UFA is unconfined to semi confined. In the model Miller's line (Miller 1986, and 1997) defines the boundary of the confined zone while the model's actual unconfined zone occupies a smaller area (Figure 1). The area lying between the NCF model's and Miller's delineations of the unconfined UFA has moderate to high leakance, so in the model there is a gradual change across the area between the two delineations from an unconfined system to a confined system (Doug Munch/SJRWMD, personal communication, December 2007). The method modifications for an unconfined UFA consisted of re-categorizing the results of applications of the earlier versions of the methods using depth criteria that reflect the degree of hydraulic conductivity between the SAS and the water level in the UFA. These modified methods are hereinafter referred to as the unconfined Floridan modified methods. The modified methods were applied to the predicted water level declines in UFA (Figure 2) and SAS (Figure 3) for the year 2025 withdrawal scenario for the north-central Florida area used in the SJRWMD's 2003 Water Supply Assessment (WSA) (SJRWMD 2006). The 2003 WSA simulation for 2025 in the north-central Florida area was selected for the comparative evaluation of the current versus modified Kinser-Minno methods because this modeling simulation has been reviewed, published, and used as the basis for projecting wetland and lake harm for the 2003 WSA. The unconfined Floridan modified methods include the addition of a few new screening steps to the earlier version of the Kinser-Minno methods. The vegetative harm analysis was done using the District's 1995 land use and land cover mapping, this is the same mapping used in the 2003 WSA.

Because the current applications of the Kinser-Minno vegetative and lake harm assessment methods are already described in detail for vegetative communities (Kinser and Minno 1995, Kinser *et al*. 2003) and lakes (Kinser *et al*. 2006) only the modification to the GIS analysis is described below.

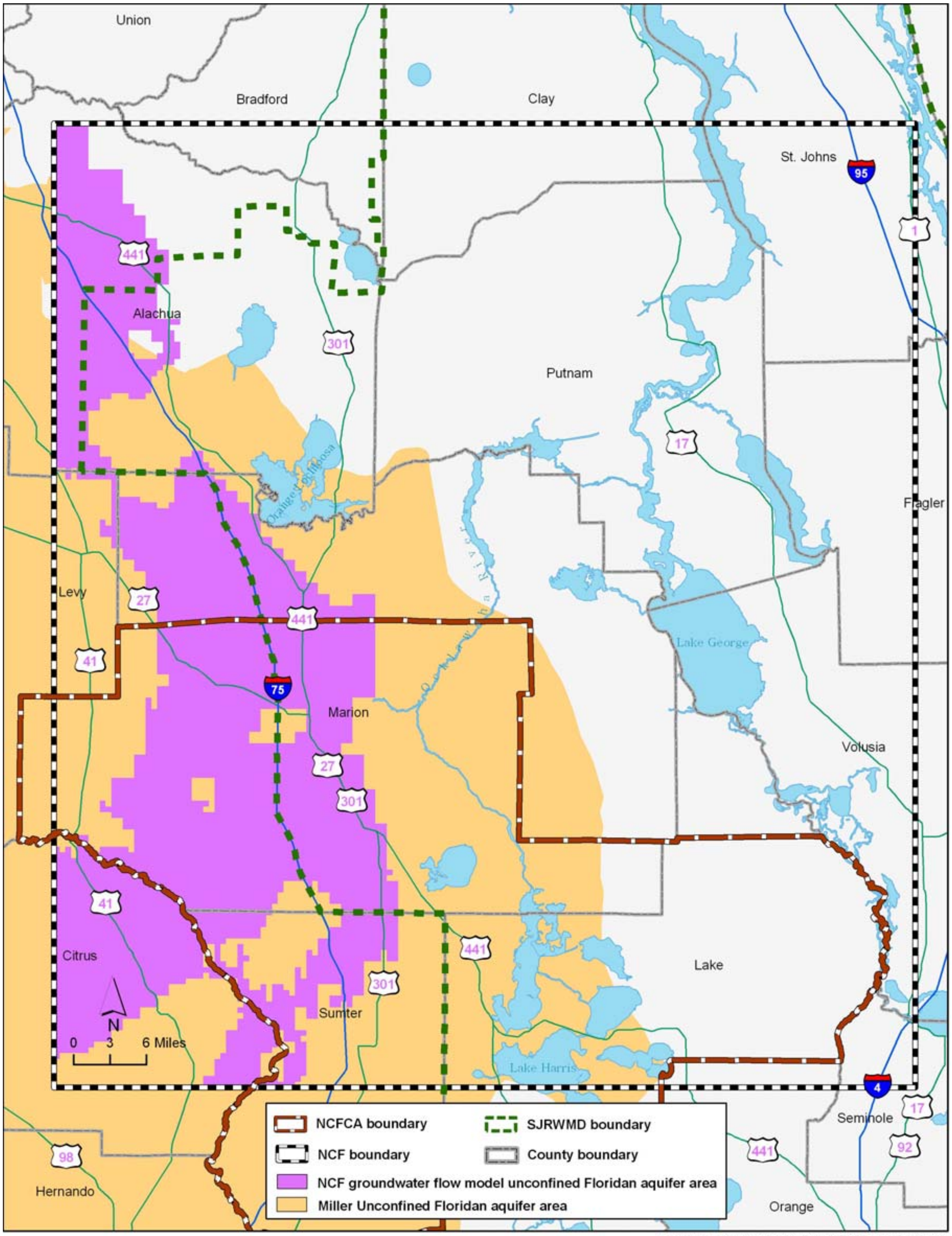

Figure 1. Areal extent of the unconfined Upper Florida Aquifer in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain

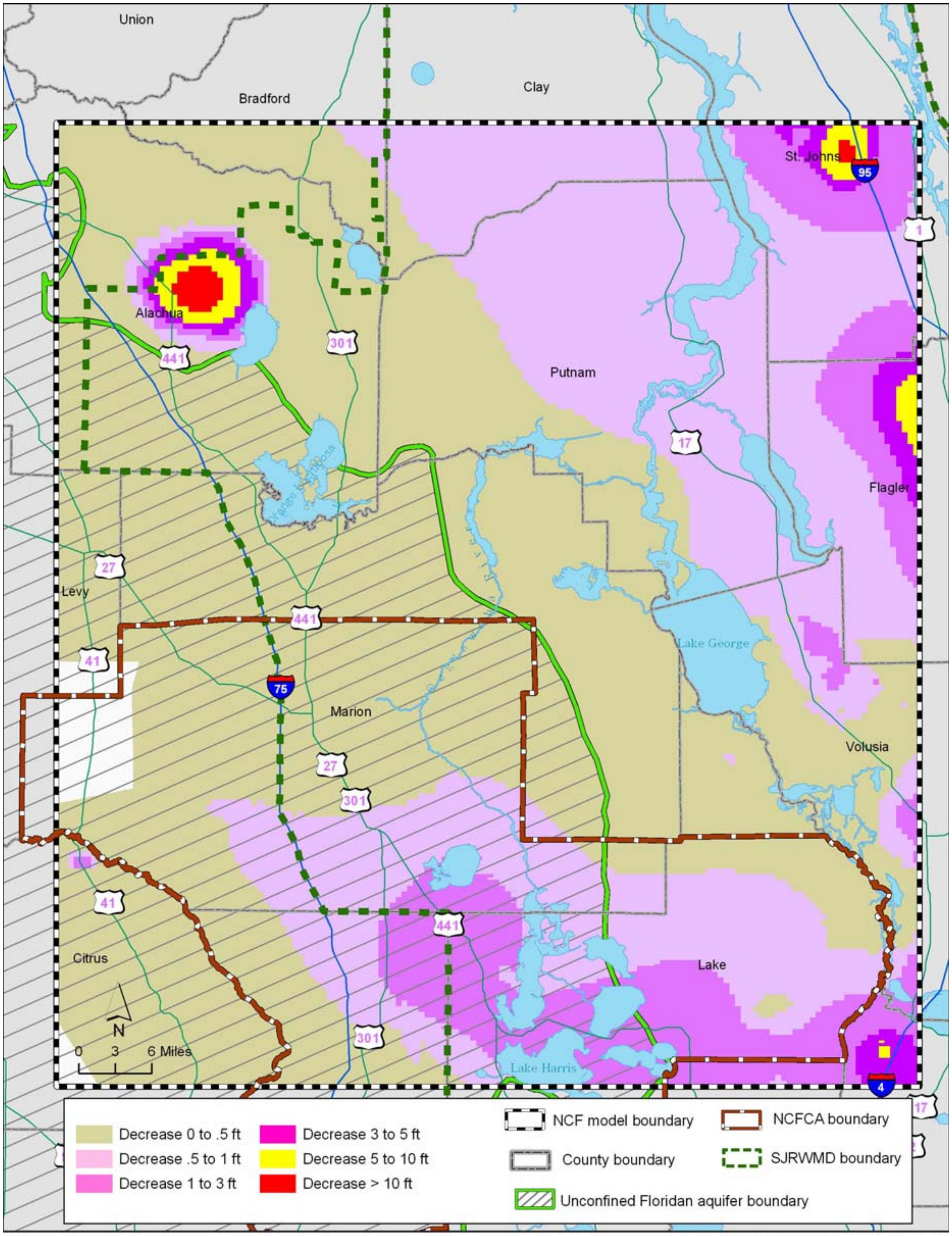

Figure 2. Estimated changes in the potentiometric surface of the Upper Florida aquifer in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain as a result of projected water use increases from 1995 to 2025 as described in the 2003 District Water Supply Assessment.

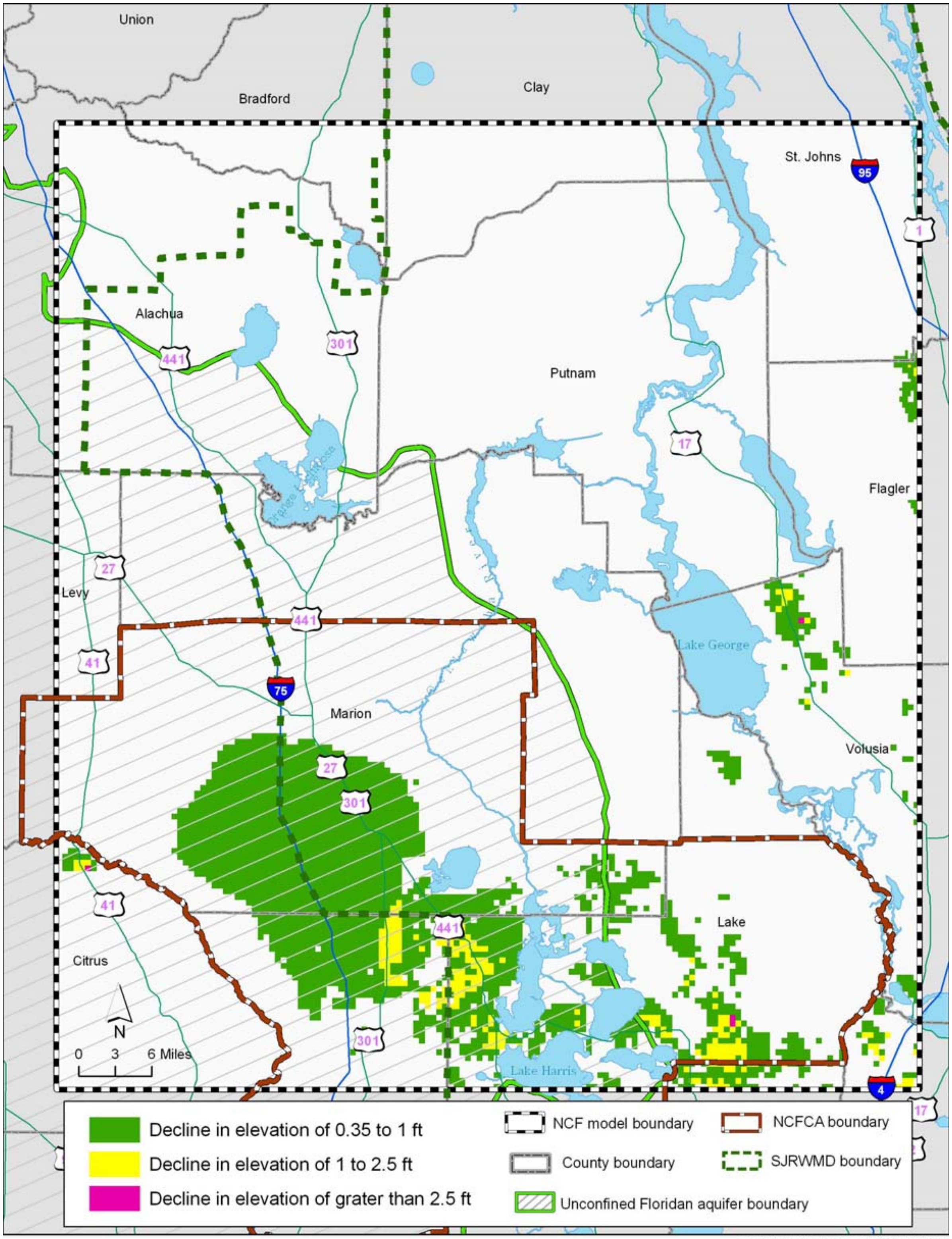

Figure 3. Projected changes in surficial aquifer system (SAS) water levels in the SJRWMD North-Central Florida Groundwater Flow Model domain as a result of projected water use increases from 1995 to 2025 as described in the 2003 District Water Supply Assessment

Unconfined Floridan Modified Method for Likelihood of Harm to Native Vegetation

Application of the unconfined Floridan modified method requires two additional screening steps to account for areas that lack an effective confining unit overlying the UFA (Figure 1), and to account for depth from land surface to the Floridan aquifer potentiometric surface. To accomplish this the following two new data layers were created.

- Unconfined Floridan Aquifer Boundary data layer (Figure 1) was used for extracting data in the area of interest
- Depth to the 2001 Floridan Aquifer potentiometric surface in which the depth from land surface or lake level to the 2001 potentiometric surface were classified into three 15 ft intervals (0 to 15, >15 to 30, and >30) (Table 1 and Figure 4). Area-weighted land and lake surface elevations were calculated using SJRWMD's GIS system's digital elevation model (DEM) at 10-meter resolution.

Table 1 provides a matrix for recategorization of the initial likelihood of harm value based on depth to water in the Floridan aquifer. For example, an initial designation of a higher likelihood for harm will remain unchanged for a wetland with a 0 to 15 ft depth interval, but will be downgraded to moderate and then lower likelihood for the depths of 15 to 30 ft, and greater than 30 ft, respectively. A GIS layer was created for categorizing the depth intervals to the Floridan aquifer potentiometric surface for areas where the UFA is unconfined (Figure 3).

Table 1. Matrix for modifying the values for likelihood for harm to native vegetation (lower harm score is 1, moderate harm score is 2, and higher harm score is 3) based on depth from land surface to the potentiometric surface of the unconfined Floridan aquifer

Depth Interval	Lower (1)	Moderate (2)	Higher (3)
> 30 ft (1)	1	1	1
15 - 30 ft (2)	1	1	2
0 - 15 ft (3)	1	2	3

Following is a description of the additional steps in the unconfined Floridan modified method for assessing the likelihood of harm to native vegetative.

- The likelihood of vegetative harm data layer produced using the standard Kinser-Minno method and depth to the potentiometric surface of the Floridan data layer were overlaid using a conditional statement to extract a new data layer for areas where the hydraulic connection between vegetative communities and the Floridan aquifer potentiometric surface are influenced by depth from land surface.
- Finally, in the extracted layer for the unconfined Floridan aquifer the likelihood of harm values (lower, moderate, and higher) were re-categorized based on depth intervals (Table 1) to yield the final likelihood of harm data layer.

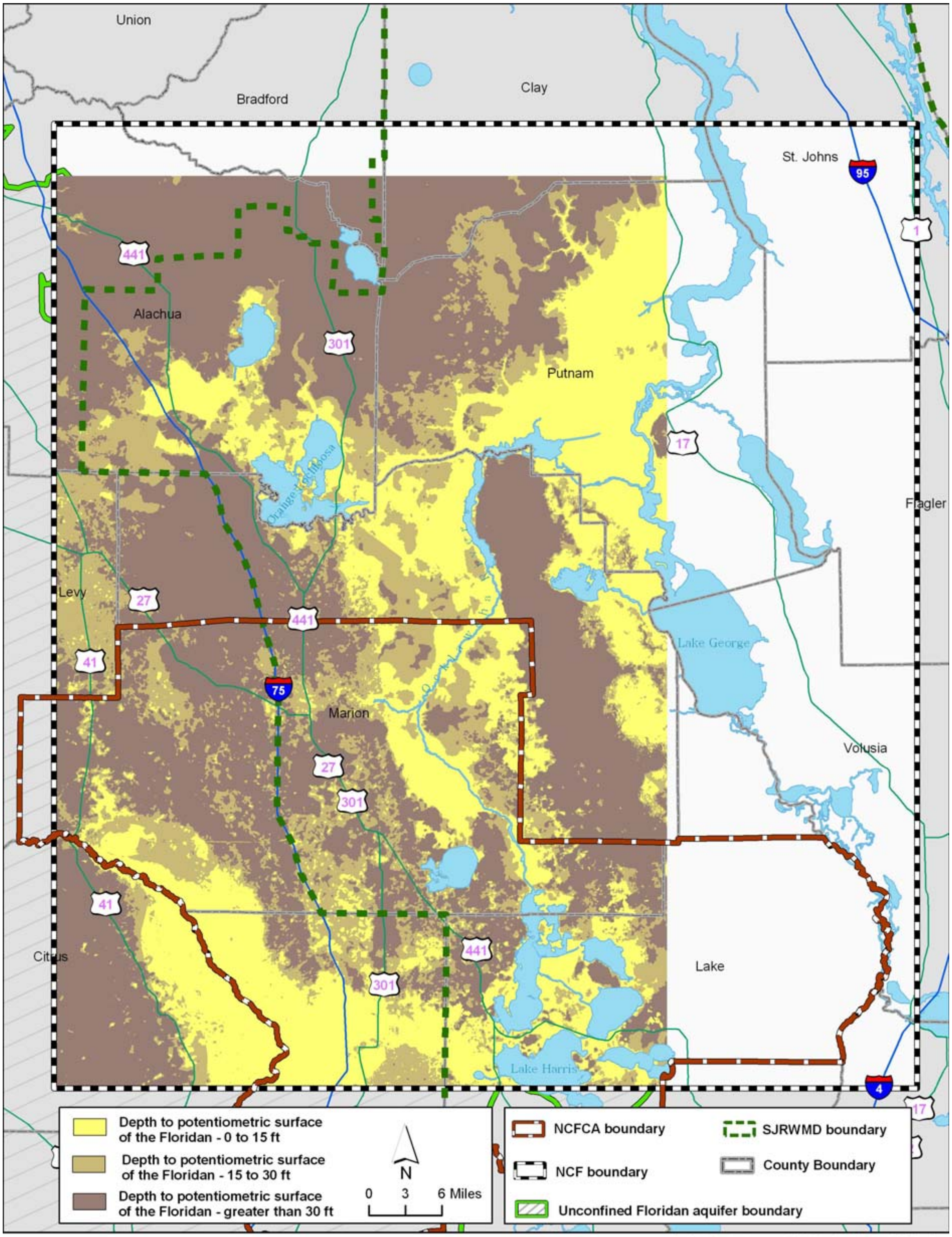

Figure 4. Depth from land surface to the 2001 potentiometric surface for areas with an unconfined UFA in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain.

Unconfined Floridan Modified Method for Likelihood of Harm to Lakes

The modification to the Kinser-Minno method for likelihood of harm to lakes is essentially the same as the unconfined Floridan method for likelihood of harm to native vegetation. A GIS model process was used that incorporates the data layers of the susceptibility of harm to lakes and the decline in water levels in the SAS. Like the modification to the likelihood of harm to native vegetation method an additional screening step was added to the likelihood for lake harm method to account for areas within the model's boundaries that lack an effective confining unit overlying the UFA. To accomplish this the same two new data layers that were created for the vegetation harm analysis were used.

- Unconfined Floridan Aquifer Boundary data layer (Figure 1), and
- Depth to the Floridan aquifer potentiometric surface (Figure 4) in which the depths from land surface to the potentiometric surface were classified into three 15 ft intervals (0 to 15, >15 to 30, and >30)

A matrix was developed for recategorization of the initial lake harm value based on the intervals for depth to the Floridan aquifer potentiometric surface (Table 2). For example, an initial designation as high likelihood for harm will remain unchanged for a lake with a less than 15 ft depth to water, but will be downgraded to a low likelihood for the depths greater than 15 ft.

Table 2. Matrix for modifying the values for likelihood for harm to lakes (low harm score is 1 and high harm score is 2) based on depth from land surface to the potentiometric surface of the unconfined Floridan aquifer.

Depth Interval	Low (1)	High (2)
> 30 ft (1)	1	1
15 - 30 ft (2)	1	1
0 - 15 ft (3)	1	2

Following is a description of the additional steps in the unconfined Floridan modified method for assessing the likelihood of harm to lakes:

- The likelihood of lake harm data layer produced using the standard Kinser-Minno method and depth to the potentiometric surface of the Floridan data layer were overlain using a conditional statement to extract a new data layer for areas where the hydraulic connection between wetland vegetative communities and the potentiometric surface of the Floridan aquifer are influenced by depth from land surface to the potentiometric surface of the Floridan aquifer.
- Finally, in the extracted layer for the unconfined Floridan aquifer the likelihood of lake harm values (low and high) were re-categorized based on depth intervals (Table 2) to yield the final likelihood of harm data layer.

Results and Discussion

Projection of Likelihood of Harm

As previously described, the Kinser-Minno methods for assessing harm to native vegetation and lakes were modified to account for areas within the boundaries of the NCF model that lack a confining unit overlying the UFA and have a significant depth below land surface to the potentiometric surface of the Floridan.

Using the unconfined Floridan modified methods the GIS analysis identified the wetland and lake areas within the NCF model's boundaries projected to experience unacceptable levels of harm to wetland communities (Figure 5) and lakes (Figures 6). In addition, Tables 3 and 4 provide the summary of the affected wetland and lake areas. Wetland areas projected to experience moderate to higher likelihood of harm that were screened out by the modified method are shown in Figure 7. Similarly lake systems that were screened out are shown in Figure 8. Tables 5 and 6 give a breakout of the areas screened out by the modified method, for wetlands and lakes, respectively.

Projected lake and wetland impacts were subdivided geographically (Tables 5 and 6) within the boundaries of the NCF model into the following categories:

- Within SJRWMD
- Within the Marion County portion of SJRWMD
- Within SWFWMD's portion, and
- Within Marion County's portion of SWFWMD

For the 2025 pumping scenario approximately 18,674 acres of wetlands are projected to experience moderate to higher likelihood of harm (Table 3) and 5,807 acres of lakes are projected to experience high likelihood of harm (Table 4) using the modified Kinser-Minno method. For wetland systems the majority of the moderate to higher likelihood of harm areas lie within the area where the Floridan aquifer is unconfined (Figure 4, Table 3).

The spatial patterns of areas projected to experience moderate to higher likelihood of harm to wetlands are similar to those projected to experience high likelihood of harm to lakes (Figures 5 and 6). The spatial pattern of projected likelihood for impacts to wetlands and lakes includes portions of each district and areas with and without confining layers above the UFA. The spatial distribution of projected lake and wetland impacts are clustered in several areas for 2025. For 2025 the projected lake and wetland impacts are located in the following areas.

- The Lake George-Crescent Lake-Middle Haw Creek basin from SR40 north to Welaka
- Northwest corner of Seminole County between I-4 and the Wekiva River
- Black Water Creek-Wekiva River Basin from Orange-Lake County line north to SR42
- Leesburg area in vicinity of Lakes Harris, Griffin, and Eustis; in particular the areas lying west of Lakes Harris and Griffin, extending across the SJRWMD/SWFWMD boundary toward Lake Panasoffkee

- Southwest and south-central Marion County from I-75 west to the Withlacoochee River.

Using the 2025 pumping scenario from the 2003 WSA, the modified methods screened out 294 acres of wetlands (Table 5) and 581 acres of lakes (Table 6) that otherwise would have been rated in the moderate to higher likelihood for harm to native vegetation and the high likelihood of harm to lakes categories, respectively. The wetland and lake systems that were screened out lie in the southwestern portion of the NCF model domain (Figures 6 and 7). There are two wetland area clusters that were screened, one in the area west of Lakes Harris and Griffin, and the other west of I-75 in southwest Marion County (Figure 7). There are also two area clusters for screened out lakes, one west of Lake Griffin and the other in south-central Marion County between US 441 and I-75 (Figure 8).

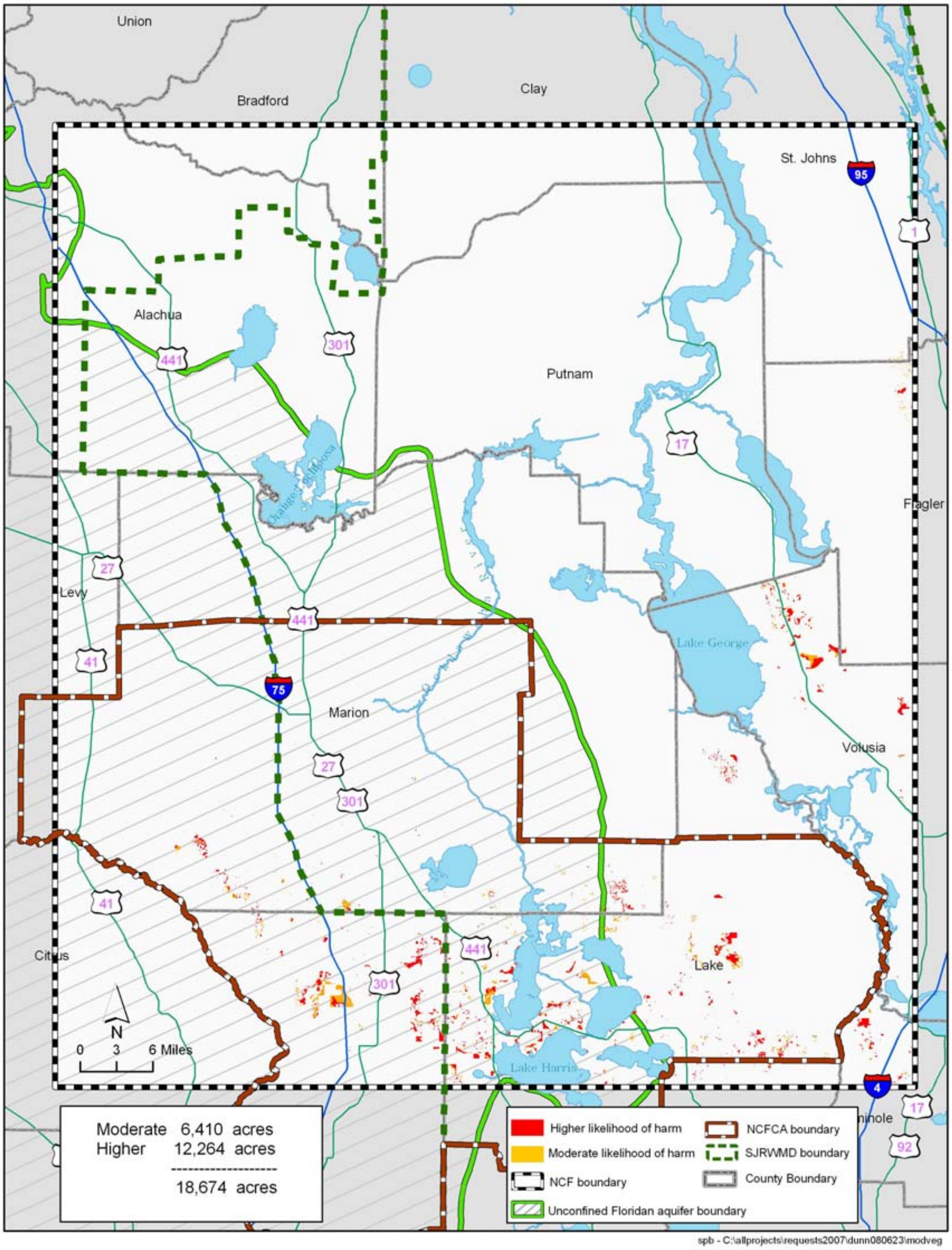

Figure 5. Areas in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain projected to experience moderate to higher likelihood of harm to native vegetation as a result of projected water use increases from 1995 to 2025 as described in the 2003 District Water Supply Assessment.

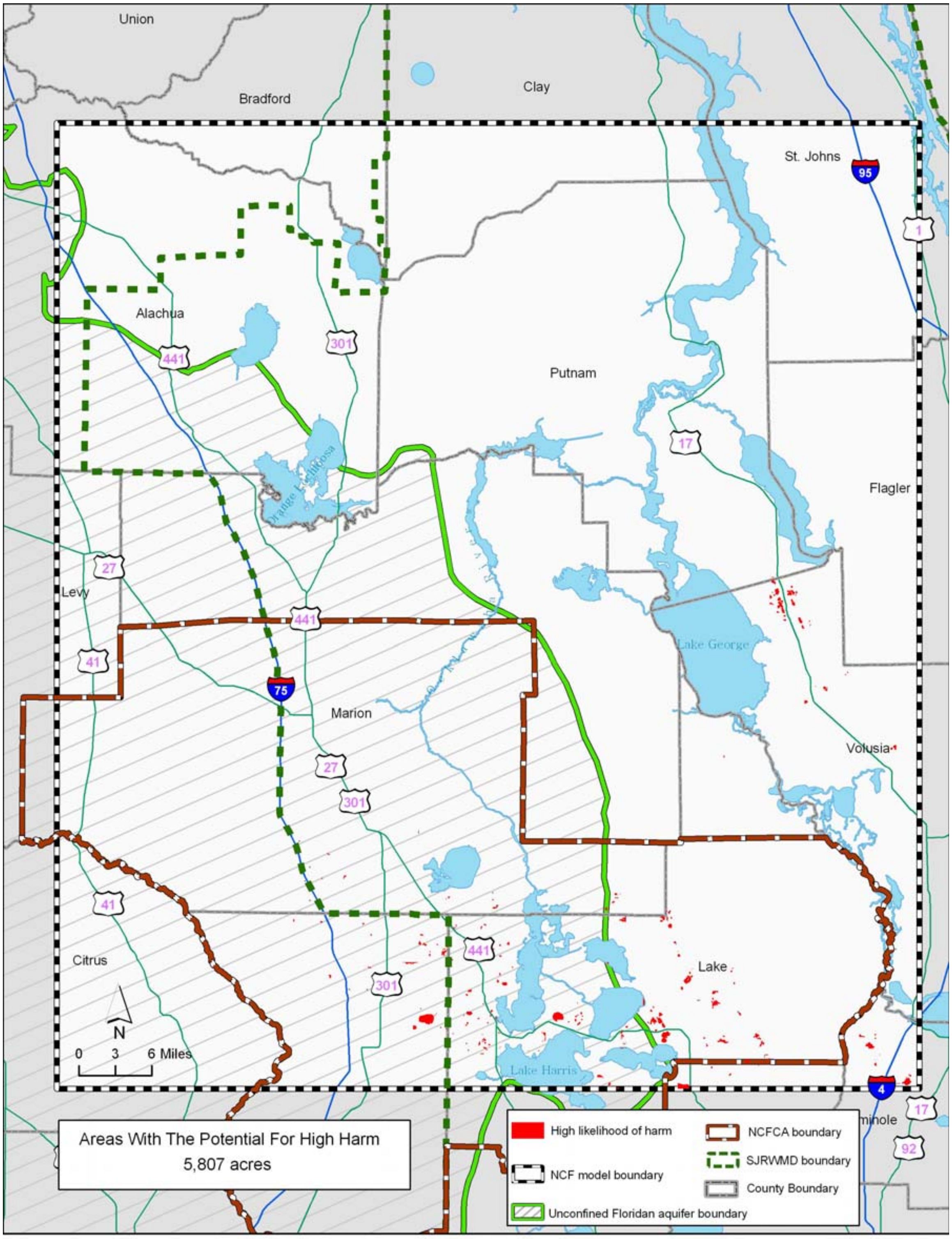

Figure 6. Areas in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain projected to experience high likelihood of harm to lakes as a result of projected water use increases from 1995 to 2025 as described in the 2003 District Water Supply Assessment.

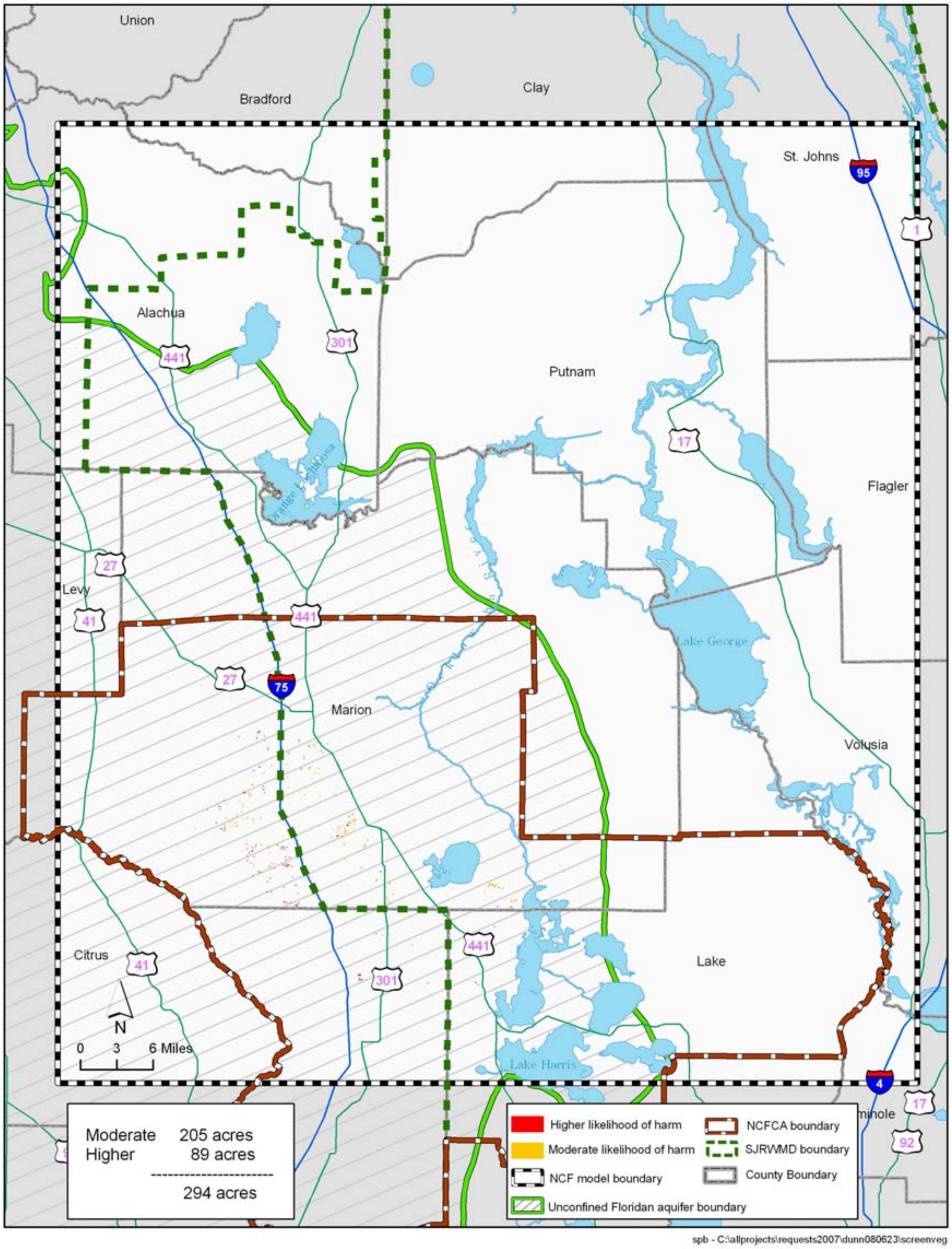

Figure 7. Areas in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain that were screened out of the moderate to higher likelihood of harm to native vegetation designation when the unconfined Floridan modified Kinser-Minno method was applied to predicted surficial aquifer water level changes due to projected water use increases from 1995 to 2025 as described in the 2003 District Water Supply Assessment.

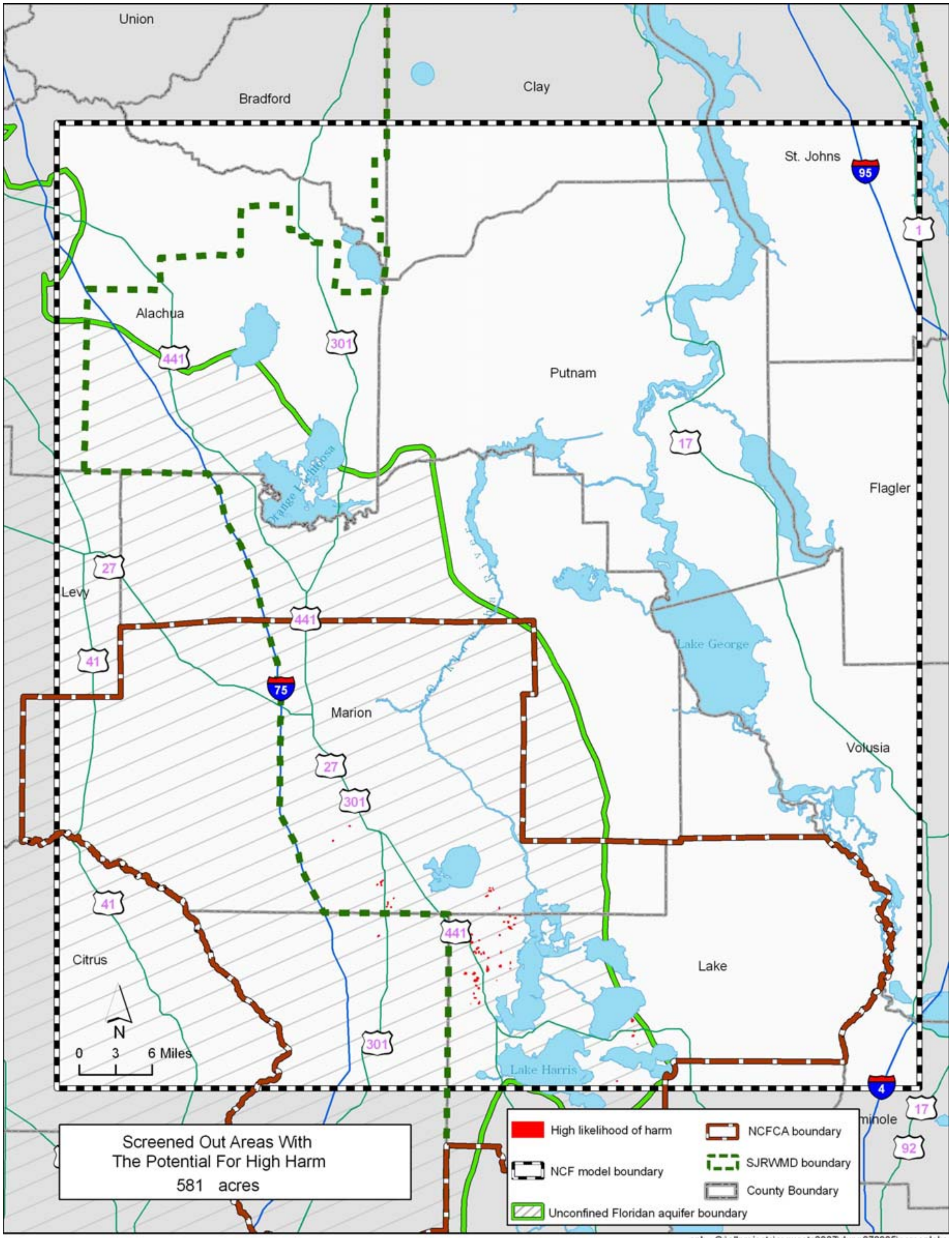

Figure 8. Areas in the SJRWMD North-Central Florida Regional Groundwater Flow Model domain that were screened out of the high likelihood of harm to lakes designation when the unconfined Floridan modified method was applied to predicted surficial aquifer water level changes due to projected water use increases from 1995 to 2025 as described in the 2003 District Water Supply Assessment

Table 3. Estimated number of acres of wetlands in the North-Central Florida Regional Groundwater Flow Model domain projected to experience moderate to higher likelihood of harm by 2025 based on application of the unconfined Floridan modified method under the 2003 Water Supply Assessment withdrawal scenario

Wetland Area	Moderate	Higher	Total
SJR Marion County	435	588	1023
SJR Total	4,256	9,053	13,309
SWF Marion County	363	574	937
SWF Total	2,154	3,210	5,364
NCF Total	6,410	12,264	18,674

Table 4. Estimated number of acres of lakes in the North-Central Florida Regional Groundwater Flow Model domain projected to experience high likelihood of harm by 2025 based on application of the unconfined Floridan modified method under the 2003 Water Supply Assessment withdrawal scenario

Lake Area	High
SJR Marion County	199
SJR Total	4,833
SWF Marion County	10
SWF Total	973
NCF Total	5,807

Table 5. Estimated number of acres of wetlands in the North-Central Florida Regional Groundwater Flow Model domain screened out of those projected to experience moderate to higher likelihood of harm by 2025 due to the application of the unconfined Floridan modified method

Wetland Area	Moderate	Higher	Total
SJR Marion County	155	18	173
SJR Total	150	16	166
SWF Marion County	44	60	104
SWF Total	49	71	120
NCF Total	205	89	294

Table 6. Estimated number of acres of lakes *in* the North-Central Florida Regional Groundwater Flow Model domain screened out of those projected to experience high likelihood of harm by 2025 due to application of the unconfined Floridan modified method

Lake Area	High
SJR Marion County	115
SJR Total	569
SWF Marion County	0
SWF Total	12
NCF Total	581

Summary

The north-central Florida area has an extensive system of lakes, wetlands and flowing waters that may potentially be impacted by the continuing development of groundwater resources. Potential impacts to wetland communities were estimated using SJRWMD's North-Central Florida Regional Groundwater Flow Model and the unconfined Floridan modified method for estimating the likelihood of harm to native vegetation and lakes as a result of projected groundwater withdrawals. The projected SAS water level declines were incorporated in the unconfined Floridan modified methods for identifying areas where wetlands and lakes are likely to be unacceptably impacted due to these projected declines, with consideration for the underlying soils and wetland types and their relative sensitivity to these declines. The modified methods described and applied in this document add a final screening step adjusting the final likelihood of harm designation based on depth from land surface to the potentiometric surface of the UFA for those areas lacking a confining unit overlying the UFA. The modification addresses the problem raised initially by screening out lake and wetland systems that lack an effective hydraulic connection to the UFA.

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