Technical Publication SJ2000-4

ESTIMATES OF REGIONAL DRAWDOWNS IN THE POTENTIOMETRIC SURFACE OF THE UPPER FLORIDAN AQUIFER OF NORTHEAST FLORIDA USING A NUMERICAL DRAWDOWN MODEL

by

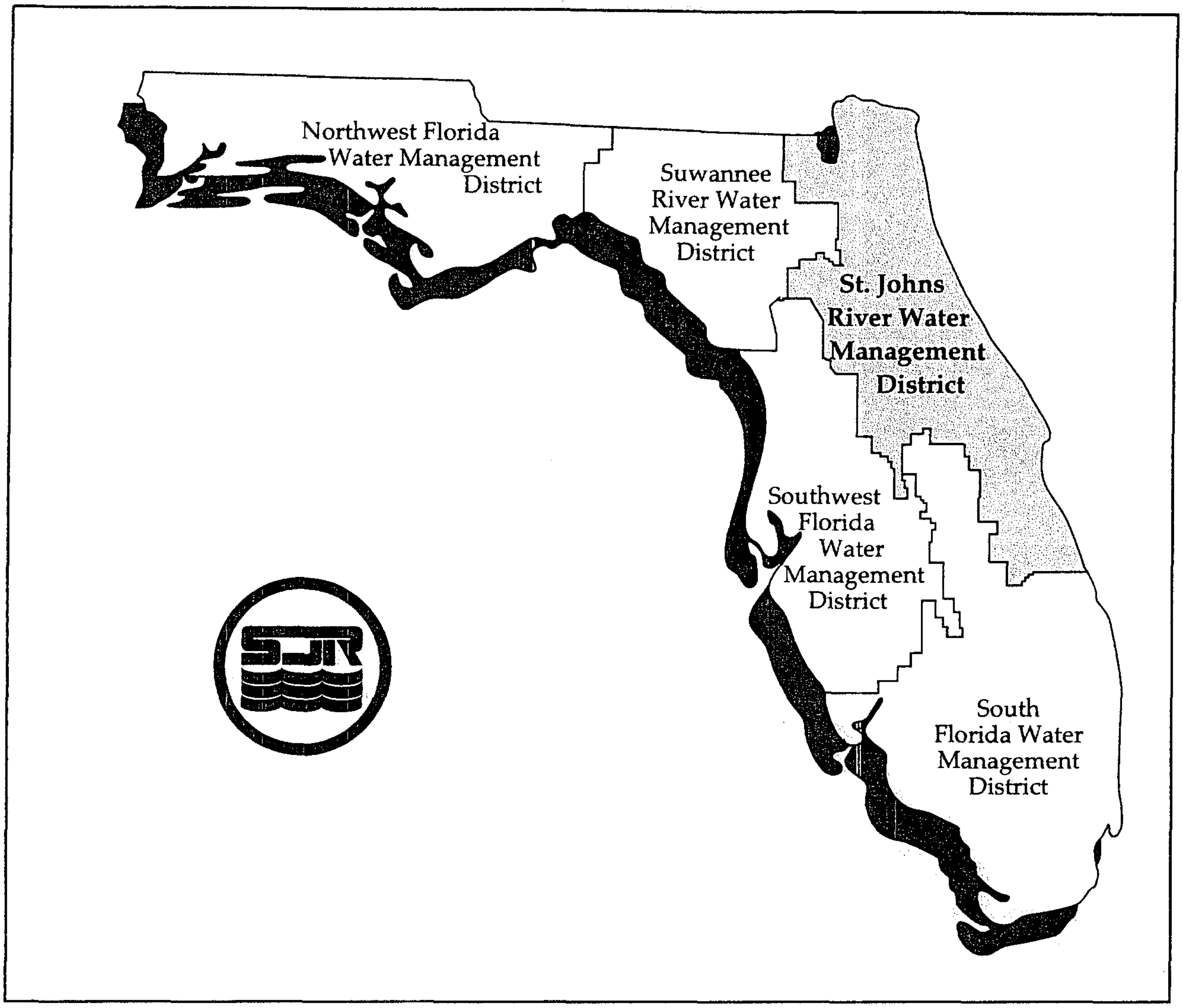
Douglas W. Durden, P.E.

Professional Engineer
License No. 0049483
October 13, 2000

SEAL

St. Johns River Water Management District
Palatka, Florida

2000



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.

This document is published to disseminate information collected by SJRWMD in pursuit of its mission. Copies of this document can be obtained from:

Library
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178-1429

Phone: (904) 329 4132

EXECUTIVE SUMMARY

A primary objective of the 1998 Water Supply Assessment of the St. Johns River Water Management District (SJRWMD) was to estimate regional drawdowns in the potentiometric surface of the Upper Floridan aquifer in response to projected changes in withdrawals of water from wells in the period of 1995 through 2020 (Vergara 1998). To this end, the Floridan aquifer system of northeast Florida was simulated using a regional, numerical drawdown model. The term "drawdown model," as used herein, refers to a type of groundwater model in which *changes* in water levels, as opposed to absolute water levels, are determined in response to *changes* in well-withdrawal rates. The term "flow model," as used herein, refers to a type of groundwater model in which absolute water levels resulting from various features of the groundwater system are determined.

The drawdown model of the present study is based on a regional groundwater flow model of the Floridan aquifer system in northeast Florida. The regional groundwater flow model on which the drawdown model is based is a revision of the regional groundwater flow model of Durden (1997). Thus, the present study involved the use of three different groundwater models: (1) the original model of Durden (1997), referred to as the original groundwater flow model; (2) a groundwater flow model resulting from revisions to the original groundwater flow model, referred to as the revised groundwater flow model; and (3) the regional drawdown model, referred to simply as the drawdown model. All three of the models of the present study are applications of the U.S. Geological Survey groundwater modeling code MODFLOW (McDonald and Harbaugh 1988).

The revised groundwater flow model differs from the original groundwater flow model primarily with respect to its lateral boundary conditions. In the revised groundwater flow model, the lateral boundary conditions consist almost entirely of general-head boundary (GHB) conditions, the MODFLOW implementation of the head-dependent flux boundary. In the original groundwater flow model, however, the lateral boundary conditions consist of a combination of GHB conditions and no-flow boundary conditions. The other difference between the two models lies in the estimates of VCONT used to represent the vertical permeability of the intermediate semiconfining unit (which separates the Upper

Floridan aquifer and the overlying surficial aquifer system). In the revised groundwater flow model, the VCONT estimates in the areas of the Atlantic Coastal Ridge in central St. Johns County and Center Park Ridge in east-central Duval County were reduced somewhat.

Four different simulations were performed as part of the study. In each of these simulations, the objective was to assess changes in the elevations of the potentiometric surface of the Upper Floridan aquifer and the water table of the surficial aquifer system in response to projected changes in rates and/or locations of well withdrawals. The time period of interest was 1995 through 2020. The four simulations are described as follows:

1. A simulation of the effects of projected changes in all significant municipal, commercial/industrial, and thermoelectric use withdrawals. In the present context, a "significant" withdrawal is, generally, a withdrawal of at least 100,000 gallons per day.

2. A simulation of the effects of projected changes in withdrawals of JEA only.

3. A simulation of the effects of projected changes in JEA withdrawals only but with all JEA wells that extend into the upper zone of the Lower Floridan aquifer in the JEA southgrid area "backplugged" to the Upper Floridan aquifer.

4. A simulation of the effects of projected changes in coastal area withdrawals only, excluding the effects of changes in JEA withdrawals. The coastal area of concern in this case is the Atlantic coast between St. Augustine and Mayport. This area extends about 10 miles inland in St. Johns County and about 2 miles inland in Duval County.

The most significant advantage of using the drawdown model in lieu of the revised groundwater flow model lies in the representation of well withdrawals as differences in rates rather than as absolute rates of withdrawals. Because of this method of representation, withdrawals that are not expected to change are not included in a drawdown model, regardless of their absolute magnitudes. Thus, representation of withdrawals that fall within the categories of agricultural irrigation, golf course irrigation, and domestic self-supply were not represented in the drawdown model because rates of withdrawals within these categories of water use are not expected to change significantly between 1995 and 2020.

The drawdown model consists of five model layers in all. Model layers 2 through 5 are variable-head model layers and represent, in descending order, the surficial aquifer system, the intermediate semiconfining unit, the Upper Floridan aquifer, the middle semiconfining unit, the upper zone of the Lower Floridan aquifer, the lower semiconfining unit, and the Fernandina permeable zone of the Lower Floridan aquifer. Model layer 1 of the drawdown model is a so-called constant-head, source-sink layer in which heads are specified as constant values of 0 feet (ft). The specified heads of model layer 1 are used in concert with the VCONT array of model layer 1 to effect the reduction in the rate of evapotranspiration (ET) that occurs in response to the simulated drawdown in the surficial aquifer system.

The lateral boundary conditions of the drawdown model consist almost entirely of GHB conditions, the MODFLOW implementation of the head-dependent-flux boundary. A GHB condition is prescribed at every grid cell along the outermost rows and columns of model layers 2 through 5. The source heads of the GHB conditions are specified as 0 ft in all cases, because 0 ft of drawdown is assumed to occur at the locations at which the source heads are specified. No-flow grid cells are present in model layer 5. These cells represent portions of the Fernandina permeable zone that are occupied entirely by saline water. Areas of saltwater flow are not part of the domain of the drawdown model because MODFLOW is not equipped to handle variable-density flow. Heads of 0 ft were specified in grid cells that border on the regions of no-flow grid cells in model layer 5. These grid cells represent the line of the interface tip in the Fernandina permeable zone.

The total of the average annual rates of withdrawal from the Floridan aquifer system of the study area in the municipal, commercial/industrial, and thermoelectric use categories in 1995 was approximately 228 million gallons per day. The total of the average annual rates of withdrawal in these categories in the year 2020 is projected to be approximately 368 million gallons per day. Thus, the total of the average annual rates of withdrawal in these categories is projected to increase from 1995 to 2020 by approximately 61%.

Changes in rates of withdrawal from the Floridan aquifer system for golf course irrigation, agricultural irrigation, and domestic self-supply are expected to be relatively small. Consequently, these categories of water use were not represented in the drawdown model of the present study.

The estimates of leakance and transmissivity assigned to model layers 3 through 5 were taken directly from the revised groundwater flow model. These model layers represent, respectively, the intermediate semiconfining unit, the Upper Floridan aquifer, the middle semiconfining unit, the upper zone of the Lower Floridan aquifer, the lower semiconfining unit, and the Fernandina permeable zone of the Lower Floridan aquifer. With the exception of the VCONT array used to represent the leakance distribution of the intermediate semiconfining unit, these estimates were derived entirely from the calibration of the original groundwater flow model. The permeability of the surficial aquifer system is represented by a single value of transmissivity (1,000 square feet per day) assigned to model layer 2. The value of the ET reduction coefficient of the surficial aquifer system (2.66×10^{-4}/day) is represented by a single value of VCONT assigned to model layer 1. The parameter VCONT is used normally to represent vertical permeability in MODFLOW, but it can also be used to represent the ET reduction coefficient of the surficial aquifer system.

The simulation of all significant well withdrawals (simulation 1 in the above list) resulted in cumulative drawdowns in the potentiometric surface of the Upper Floridan aquifer of approximately 0 to 23 ft. The maximum drawdowns resulting from this simulation occurred at the JEA Ridenour water treatment plant (WTP) in the JEA south grid and the Rayonier wellfield near Fernandina Beach. Generally, simulated drawdowns in most of the study area range from 2 to 10 ft. The areas of largest simulated drawdown include north- and south-central Duval County, the coastal areas between St. Augustine and Mayport, and the area of Fernandina Beach. In the surficial aquifer system, simulated drawdowns in the elevation of the water table ranged from approximately 0 to 2.2 ft. The maximum drawdown occurs in the vicinity of Green Cove Springs in eastern Clay County. Notably large drawdowns also occur near the location of the JEA Community Hall WTP, where the maximum simulated drawdown is approximately 0.9 ft. The maximum simulated drawdown in the area of northeast St. Johns County is approximately 0.3 ft.

The simulation of impacts due to JEA withdrawals only (simulation 2 in the above list) resulted in cumulative drawdowns in the potentiometric surface of the Upper Floridan aquifer of 0 to 20 ft. Throughout most of the study area, the drawdowns range between 0 and 6 ft. In the surficial aquifer system, simulated drawdowns in the elevation of the water table range between approximately 0 and 0.1 ft throughout most of the study area. Near the JEA Community Hall WTP, the drawdowns range up to approximately 0.3 ft. The most extensive areas of simulated drawdown, however, occur in east-central Clay County, where drawdowns range up to approximately 0.4 ft.

The simulation of impacts due to JEA withdrawals with backplugging of multi-aquifer wells in the JEA south grid (simulation 3 in the above list) resulted in only a slight increase in drawdown relative to the results of simulation 2. The reason for the relatively small increase in drawdown is that relatively few of the JEA wells were affected by backplugging. Consistent with CH2M HILL (1999a), all wells at the JEA Brierwood, Deerwood, and Community Hall WTPs were assumed to be open only to the Upper Floridan aquifer in simulation 2.

The simulation of impacts due to coastal area withdrawals (simulation 4 in the above list) resulted in drawdowns in the potentiometric surface of the Upper Floridan aquifer ranging approximately from 1 to 3 ft in most of the coastal area. The largest simulated drawdowns due to coastal area withdrawals occur in northeast St. Johns and southeast Duval counties. The drawdowns in that area range approximately from 3 to 6 ft. Drawdowns in the elevation of the water table of the surficial aquifer system due to coastal area withdrawals occur primarily in St. Johns and Clay counties. In St. Johns County, the simulated drawdowns range up to about 0.15 ft. In Clay County, the simulated drawdowns range up to about 0.25 ft.

CONTENTS

FIGURES

TABLES

INTRODUCTION

A primary objective of the 1998 Water Supply Assessment of the St. Johns River Water Management District (SJRWMD) was to estimate regional drawdowns in the potentiometric surface of the Upper Floridan aquifer in response to projected changes in withdrawals of water from wells in the period of 1995 through 2020 (Vergara 1998). To this end, a regional numerical drawdown model was used to simulate the Floridan aquifer system of northeast Florida (Figure 1).

The term "drawdown model," as used herein, refers to a type of groundwater model in which *changes* in water levels, as opposed to absolute water levels, are determined in response to *changes* in well-withdrawal rates. An alternate term for "drawdown model" is "superposition model." The term "flow model," as used herein, refers to a type of groundwater model in which absolute water levels resulting from the effects of various features of the groundwater system are determined. These features include absolute rates of well withdrawals.

The drawdown model of the present study is based on a regional groundwater flow model of the Floridan aquifer system in northeast Florida. The regional groundwater flow model on which the drawdown model is based is a revision of the regional groundwater flow model of Durden (1997). Thus, the present study involved the use of three different groundwater models: (1) the original model of Durden (1997), referred to hereafter as the original groundwater flow model; (2) a groundwater flow model resulting from revisions to the original groundwater flow model, referred to hereafter as the revised groundwater flow model; and (3) the regional drawdown model, referred to hereafter simply as the drawdown model. All three of the groundwater models of the study are applications of the U.S. Geological Survey groundwater modeling code MODFLOW (McDonald and Harbaugh 1988).

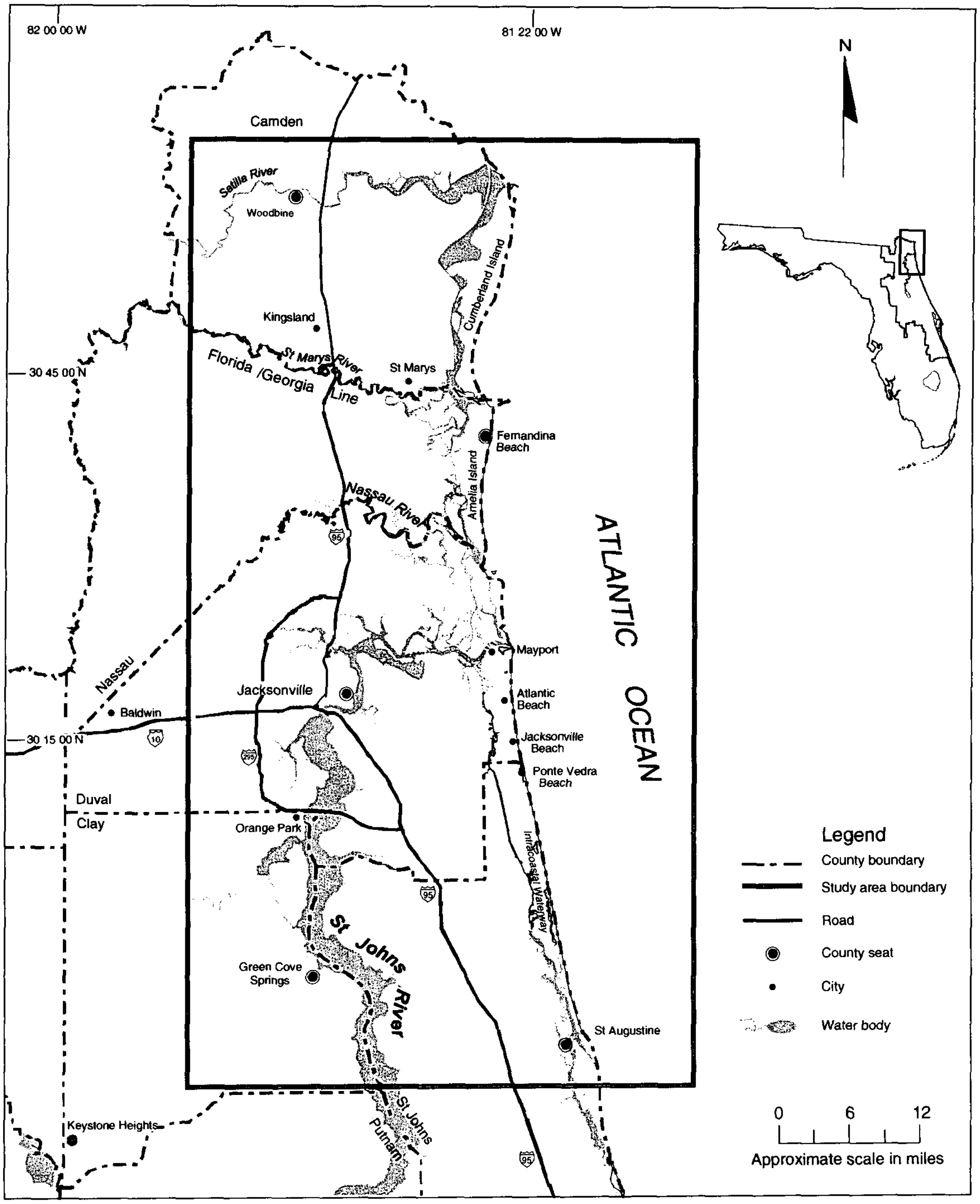


Figure 1. Location of study area

STUDY OBJECTIVES

Four different simulations were performed as part of the study. In each of these simulations, the objective was to assess changes in the elevations of the potentiometric surface of the Upper Floridan aquifer and the water table of the surficial aquifer system in response to projected changes in rates and/or locations of well withdrawals. The time period of interest was 1995 through 2020. The changes in withdrawals represented in the simulations include significant increases in rates of withdrawals as well as a major redistribution of the points of withdrawal of the largest single user in the study area, JEA. JEA meets most of the municipal water supply needs of the city of Jacksonville.

The four simulations are described as follows:

1. A simulation of the effects of projected changes in all significant municipal, commercial/industrial, and thermoelectric use withdrawals. In the present context, a "significant" withdrawal is, generally, a withdrawal of at least 100,000 gallons per day (Appendix A).

2. A simulation of the effects of projected changes in JEA withdrawals only.

3. A simulation of the effects of projected changes in JEA withdrawals only but with all JEA wells that extend into the upper zone of the Lower Floridan aquifer in the JEA southgrid area (Figure 2) "backplugged" to the Upper Floridan aquifer.

4. A simulation of the effects of projected changes in coastal area withdrawals only, excluding the effects of changes in JEA withdrawals. The coastal area of concern in this case is the Atlantic coast between St. Augustine and Mayport (Figure 1). This area extends about 10 miles inland in St. Johns County and about 2 miles inland in Duval County.

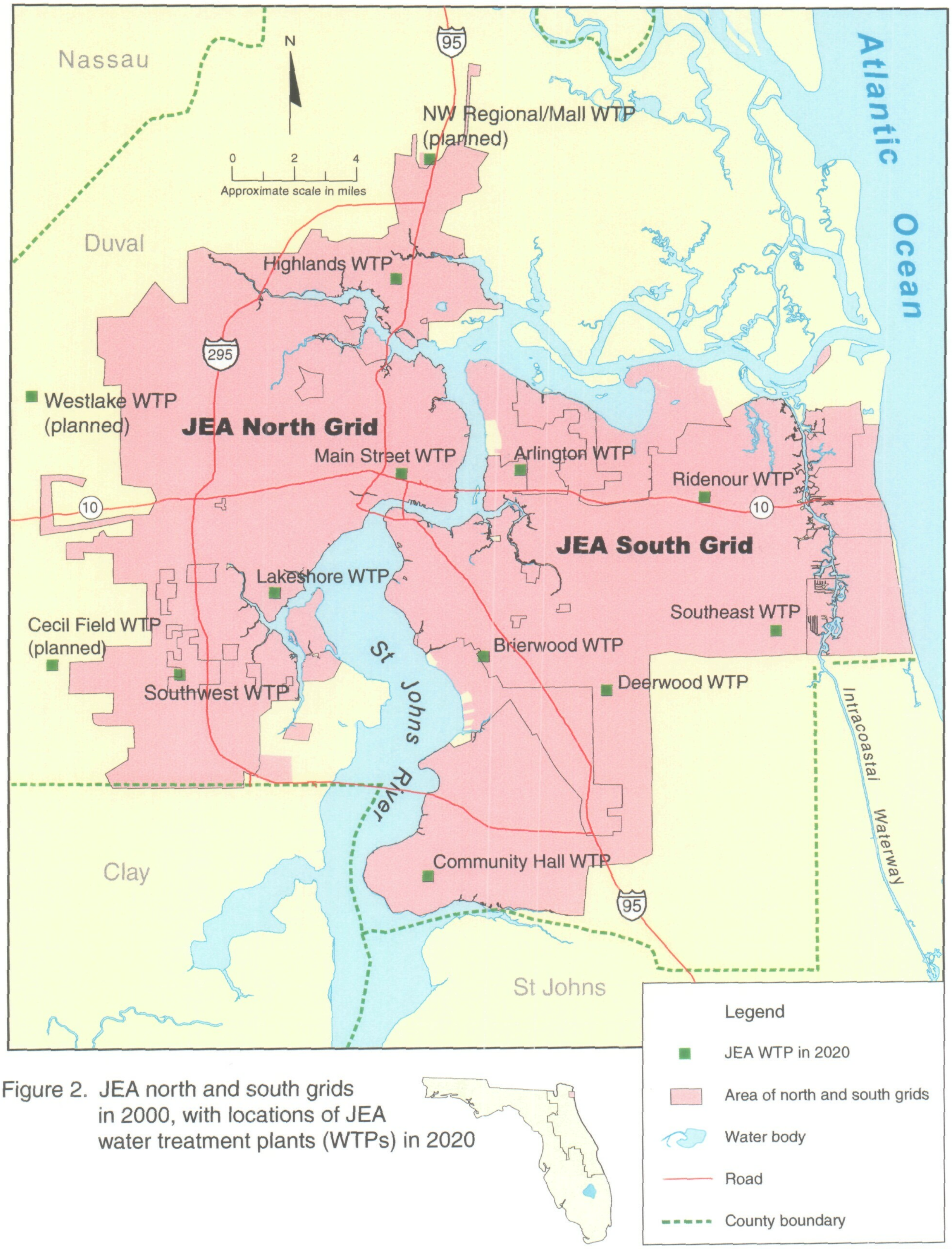


Figure 2. JEA north and south grids in 2000, with locations of JEA water treatment plants (WTPs) in 2020

STUDY METHOD

The primary study method was the application of the drawdown model. The first step toward development of the drawdown model was the revision of the original groundwater flow model to obtain the revised groundwater flow model. The process of revising the original groundwater flow model included (1) alteration of the model lateral boundary conditions and (2) alteration of the array of leakance estimates used to represent the vertical permeability of the intermediate semiconfining unit. Upon completion of these revisions, the revised groundwater flow model was converted to the drawdown model.

The process of converting the revised groundwater flow model included (1) alteration of the model starting heads; (2) alteration of the model lateral boundary conditions; (3) placement of specified-head boundary conditions along the tip of the freshwater/saltwater interface; (4) alteration of the representation of well withdrawals; (5) activation of the model layer that represents the surficial aquifer system; and (6) addition of a model layer for use in computing the reduction in the rate of evapotranspiration (ET) that occurs as a result of drawdowns in the surficial aquifer system.

REVISION OF THE ORIGINAL GROUNDWATER FLOW MODEL FOR ATTAINMENT OF THE REVISED GROUNDWATER FLOW MODEL

Revision of Lateral Boundary Conditions

Prior to development of the drawdown model, the original groundwater flow model was modified with respect to its lateral boundary conditions. In the original groundwater flow model, the lateral boundary conditions of the model layers that represent the Upper Floridan aquifer, the upper zone of the Lower Floridan aquifer, and the Fernandina permeable zone are represented with a combination of no-flow and general-head boundary (GHB) conditions. In the revised groundwater flow model, only GHB conditions are prescribed as lateral boundary conditions in the model layers that represent the Upper Floridan aquifer and the upper zone of the Lower Floridan aquifer. The change in the lateral boundary conditions was necessary because in most cases, the no-flow lateral boundary conditions in the original groundwater flow model had the unintended effect of constraining simulated flow via the model lateral boundaries (Faye and Tibbals, pers. com. 1998). This modification in the lateral boundary conditions and other minor modifications were documented in a response by Durden (letter dated October 15, 1998) to the commentary by Faye and Tibbals.

In the model layer that represents the Fernandina permeable zone, grid cells in two areas of the model domain are specified as no-flow because they correspond to areas that are likely to be occupied entirely by saline water (Durden 1997). Such areas are not included in the active portion of the model domain because MODFLOW is not capable of simulating variable-density flow. The variable-head grid cells that border on these no-flow areas were prescribed with no-flow boundary conditions because flow between the saltwater and freshwater regions of the Floridan aquifer system is idealized as nonexistent in the revised groundwater flow model. Otherwise, grid cells located at the edge of the variable-head region of model layer 5 are prescribed with GHB conditions, in accordance with the representation of lateral boundary conditions in the other three active model layers of the revised groundwater flow model.

Revision of VCONT Array

The VCONT array that represents the leakance distribution of the intermediate semiconfining unit was modified also. In this modification, leakance values were lowered in areas of the model domain corresponding to the Center Park Ridge in south-central Duval County and the Atlantic Coastal Ridge in central St. Johns County (White 1970) (Figures 3 and 4). These leakance values were probably overestimated in the calibration of the original groundwater flow model, in an attempt to simulate what was felt to be the maximum potential amount of recharge to the Upper Floridan aquifer in these areas. In the calibration of the original groundwater flow model, simulated hydraulic heads in parts of the model domain corresponding to the two aforementioned areas were initially lower than corresponding estimated values. Therefore, leakance values representing the intermediate semiconfining unit were increased to enable the simulation of greater amounts of recharge to the Upper Floridan aquifer from the overlying surficial aquifer system (Durden 1997). The leakance values assigned to these recharge areas, which are areas of induced recharge, were raised to values that are generally higher than values assigned to the grid cells corresponding to surrounding, nearby discharge areas. In retrospect, the representation of the leakance values as being peculiarly high in the recharge areas was deemed to be

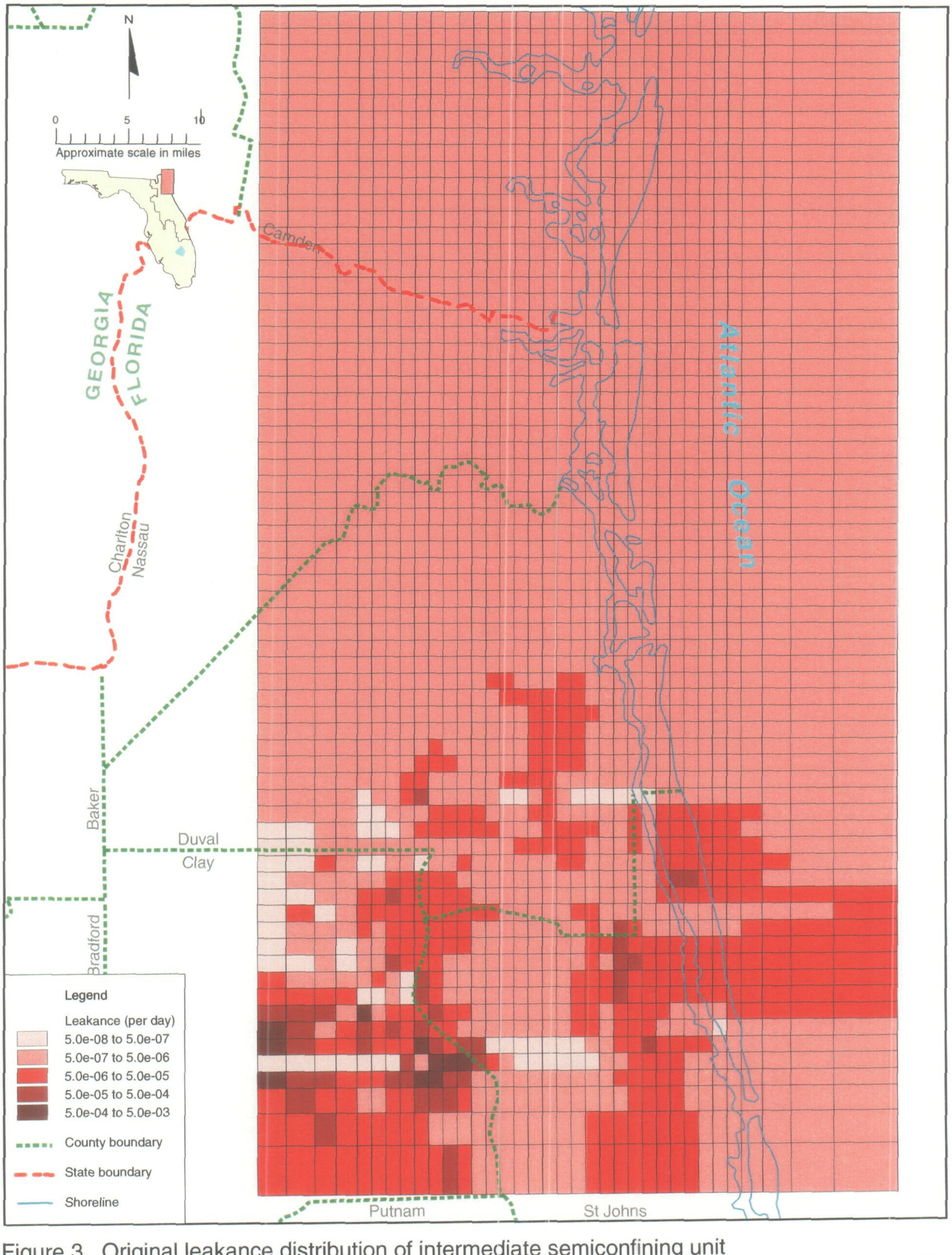


Figure 3. Original leakance distribution of intermediate semiconfining unit

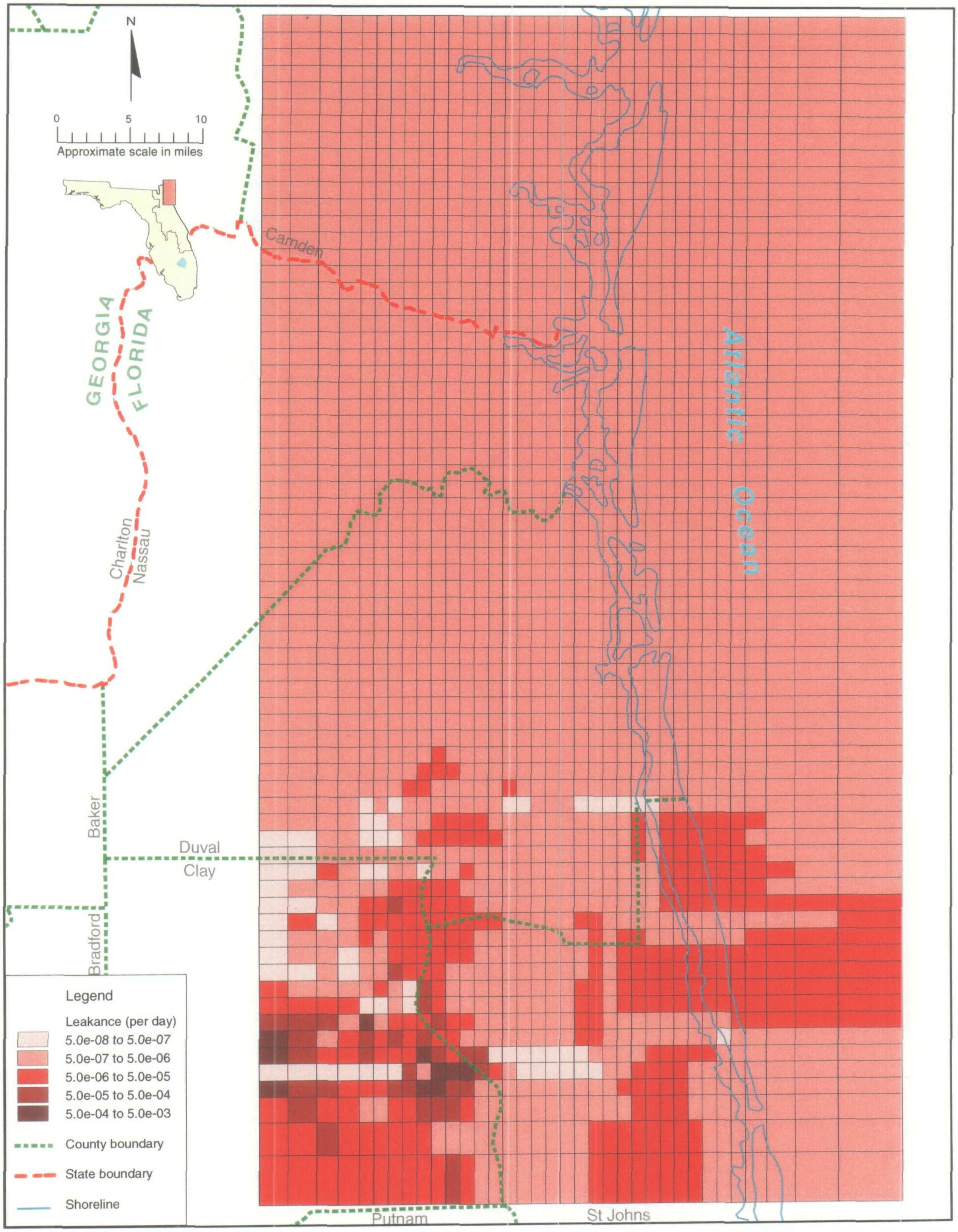


Figure 4. Revised leakance distribution of intermediate semiconfining unit

unjustifiable from a hydrogeological standpoint. In the creation of the revised groundwater flow model, the leakance values in these areas were lowered typically by an order of magnitude. They are now on par generally with values assigned to the nearby discharge areas (Figures 3 and 4).

Comparison of Mass-Balance Data and Residual Statistics

To help gauge the effects of the changes made in the original groundwater flow model, differences in mass-balance data as determined by MODFLOW were noted. The differences in the two sets of flow data range from moderate to, in the case of flows out via GHB conditions, somewhat large. These changes show that simulated circulation within the revised groundwater flow model is improved relative to that within the original groundwater flow model and that the lateral boundary conditions of both the original and revised groundwater flow models are relatively influential.

- Flow in via GHB conditions, original groundwater flow model = 0.471 X 10^8 cubic feet per day [ft^3/d]
- Flow in via GHB conditions, revised groundwater flow model = 0.517 X 10^8 ft^3/d

- Flow in via constant heads, original groundwater flow model = 0.348 X 10^7 ft^3/d
- Flow in via constant heads, revised groundwater flow model = 0.321 X 10^7 ft^3/d

- Flow out via GHB conditions, original groundwater flow model = 0.135 X 10^8 ft^3/d
- Flow out via GHB conditions, revised groundwater flow model = 0.181 X 10^8 ft^3/d

- Flow out via constant heads, original groundwater flow model = 0.641 X 10^7 ft^3/d
- Flow out via constant heads, revised groundwater flow model = 0.621 X 10^7 ft^3/d

Another gauge of the effects of the changes is the differences in the residual distributions between the original and revised groundwater flow models. Residuals are differences in estimated and simulated values of hydraulic head. As part of the calibration procedure of the original groundwater flow model, a number of different statistics based on the residual distribution of the model layer that represents the Upper Floridan aquifer were determined. In the present study, the same statistics were determined based on the residual distribution of the revised groundwater flow model. The residuals used in the analysis were based on differences in values of hydraulic head interpolated from a map of the September 1985 potentiometric surface of the Upper Floridan aquifer (Schiner and Hayes 1985) and values of hydraulic head that were simulated by the model. The effects on the simulated values of hydraulic head were fairly miniscule, as shown below. The results indicate that the revised groundwater flow model is still calibrated acceptably.

- Mean of residuals, original groundwater flow model = 0.06 ft
- Mean of residuals, revised groundwater flow model = -0.58 ft

- Standard deviation of residuals, original groundwater flow model = 3.61 ft
- Standard deviation of residuals, revised groundwater flow model = 3.53 ft

- Percentage of residuals less than 5 ft, original groundwater flow model = 92.1
- Percentage of residuals less than 5 ft, revised groundwater flow model = 92.2

- Percentage of residuals less than 10 ft, original groundwater flow model = 99.0
- Percentage of residuals less than 10 ft, revised groundwater flow model = 99.0

- Mean of absolute values of residuals, original groundwater flow model = 2.42 ft
- Mean of absolute values of residuals, revised groundwater flow model = 2.32 ft

- Maximum of absolute values of residuals, original groundwater flow model = 48.8 ft

- Maximum of absolute values of residuals, revised groundwater flow model = 49.9 ft

DIFFERENCES BETWEEN THE DRAWDOWN MODEL AND THE REVISED GROUNDWATER FLOW MODEL

The drawdown model is based directly on the revised groundwater flow model. In the conversion of the revised groundwater flow model to the drawdown model, changes were made only as necessary. Therefore, in many respects, the two models are identical. The conversion did, however, result in the following important differences:

1. Starting heads are specified as 0 ft in the drawdown model. Because the drawdown model, like the original and revised groundwater flow models, is a steady-state model, the specified starting heads do not influence the values of the simulated, final heads. The specification of the starting heads as 0 ft merely makes the interpretation of the model output more straightforward because MODFLOW calculates drawdown values as differences between starting heads and corresponding simulated heads. Thus, the calculated drawdown is positive in response to an increase in discharge and negative in response to an increase in recharge, in conformance with the usual sign convention for drawdown. The "heads" of a drawdown model represent changes in hydraulic head, not absolute hydraulic head. Thus, in the case of a drawdown model in which starting heads are specified as 0 ft, a given simulated head value is of the same absolute value but of the opposite sign as the corresponding drawdown value.

2. The source heads of the GHB conditions, which are employed as lateral boundary conditions in the drawdown model, are specified as 0 ft also. The assumption of 0 ft implies that no changes in water levels are anticipated between 1995 and 2020 at the locations of the GHB-condition source heads. In effect, then, points of well withdrawals are idealized as being removed far enough away as to have negligible effects on water levels at these locations. In actuality, some amount of drawdown is likely at most of these locations. Of course, if the actual change in water level between 1995 and 2020 were known at a particular source-head location, then specification of that value would represent an improvement over the specification of 0 ft. In the present case, however, the ultimate change in water level is not known at any

of these locations, so a change of 0 ft is assumed instead. In most cases, the source heads are, in fact, located far away from centers of well withdrawals; therefore, in most cases at least, 0 ft is probably a good approximation.

3. The GHB-condition source heads prescribed to column 1, rows 31 through 57 of all four variable-head model layers were relocated farther to the west in the drawdown model. In the original and revised groundwater flow models, the source heads of GHB conditions prescribed to grid cells along the western boundary were located at approximately 4.4 miles from the western edge of the model grid. In the drawdown model, these source heads are located approximately 10 miles from the western edge of the model grid. The relocation of these source heads was implemented to increase the distance between the source heads and two proposed JEA water treatment plants (WTPs) (Cecil Field WTP and Westlake WTP) that are to be located within areas corresponding to grid cells of column 1. As in all other cases, the values of these source heads are specified as 0 ft, in accordance with the assumption of no change in water levels between 1995 and 2020 at source-head locations. This alteration in the lateral boundary conditions of the drawdown model was implemented in response to commentary made by Faye and Tibbals (pers. com. 1999).

4. Heads in grid cells that correspond to the line of the freshwater/saltwater interface tip (i.e., the line of pinchout of freshwater) in the model layer that represents the Fernandina permeable zone are specified as 0 ft in the drawdown model. The heads in these grid cells were specified to enable them to function as sources of freshwater to surrounding grid cells in response to the simulated drawdowns in those grid cells. The freshwater produced by the specified-head cells is intended to approximate the volume of freshwater that is being removed from aquifer storage as the interface moves landwardly in response to well withdrawals within the study area. MODFLOW is unable to simulate the process of interface movement directly. Use of specified-head lateral boundary conditions is intended only as a rough approximation of this complex process. The value of 0 ft was specified in accordance with the assumption of no change in water levels between 1995 and 2020 at locations corresponding to model lateral boundaries. Initially, lateral boundary conditions along the tip of the interface in the Fernandina permeable zone were prescribed as no-flow, which is consistent with the

approach implemented in the original and revised groundwater flow models. The switch to specified-head lateral boundary conditions was implemented in accordance with commentary made by Faye and Tibbals (pers. com. 1999).

5. As with hydraulic heads, *differences* in rates of well withdrawals rather than absolute rates are specified in the drawdown model. The differences in withdrawal rates so specified are differences between the 1995 estimated rates and corresponding 2020 projected rates. The year 2020 is the year to which the 1995 withdrawal rates were projected in the 1998 Water Supply Assessment (Vergara 1998). An increase in withdrawal rate in the model is represented as a negative difference, which the MODFLOW code interprets as well discharge. A decrease in withdrawal rate is represented as a positive difference, which the MODFLOW code interprets as well recharge. Such points of recharge result in simulated head recoveries (i.e., negative drawdowns), which are to be expected whenever a withdrawal rate is reduced.

6. Variable heads are used in the representation of the surficial aquifer system in the drawdown model. Thus, the drawdown model is capable of determining changes in water levels in the surficial aquifer system, albeit with limitations, as discussed in a later section. In the original and revised groundwater flow models, the water levels of the surficial aquifer system are represented using specified heads and so are unable to change in response to changes in stresses.

7. An additional model layer is used to effect the reduction in the rate of ET that occurs in response to drawdowns in the water table of the surficial aquifer system in the drawdown model. Heads in this model layer are specified uniformly as 0 ft. The VCONT array is set uniformly to a single estimate of the ET reduction coefficient. The rationale for this approach is detailed in a later section of this report.

ADVANTAGES OF THE DRAWDOWN APPROACH

The conversion of the revised groundwater flow model to a drawdown model was advantageous in several respects, given the time constraints faced by SJRWMD with respect to the present modeling project. The most significant advantage lay in the representation of well withdrawals as differences in rates rather than as absolute rates of withdrawals. Because of this method of representation, withdrawals that are not expected to change are not included in a drawdown model, regardless of their absolute magnitudes.

Thus, representation of withdrawals that fall within the categories of agricultural irrigation, golf course irrigation, and domestic self-supply were not represented in the drawdown model because rates of withdrawals within these categories of water use are not expected to change significantly between 1995 and 2020 (Vergara 1998). This factor was important in the present project because, at the time of the required simulations, 1995 and projected 2020 water use data had been compiled only with respect to the municipal, commercial/industrial, and thermoelectric use categories.

Another significant advantage to use of the drawdown model is that the hydraulic parameters used in the representation of the surficial aquifer system can be assigned rather than derived through calibration. The resulting simulated drawdowns are acceptable because the simulation objective was merely to identify areas of *potential* adverse impact to the surficial aquifer system rather than to estimate drawdowns precisely. In the present drawdown model, the transmissivity and ET reduction coefficient of the surficial aquifer are assigned values.

Finally, another advantage to use of the drawdown model is that the source heads of the GHB conditions are specified uniformly as 0 ft rather than as estimates of absolute water levels. Thus, the need to determine estimates of water table elevations for use in the prescription of lateral boundary conditions was eliminated for the model layer that represents the surficial aquifer system.

DRAWDOWN MODEL CONFIGURATION

MODEL LAYERING

The drawdown model consists of five model layers in all (Figure 5). Model layers 2 through 5 are variable-head model layers and represent in descending order the surficial aquifer system, the Upper Floridan aquifer, the upper zone of the Lower Floridan aquifer, and the Fernandina permeable zone of the Lower Floridan aquifer (Table 1). These layers are all specified as confined.

Model layer 1 of the drawdown model is a so-called constant-head, source-sink layer. The term "constant-head, source-sink layer," as used herein, refers to a model layer in which heads are specified as constant values. The specified heads of model layer 1 are used in concert with the VCONT array of model layer 1 to effect the reduction in the rate of ET that occurs in response to the simulated drawdown in the surficial aquifer system.

Heads in model layer 1 are specified uniformly as 0 ft. The heads of model layer 1 were specified as 0 ft to make differences between corresponding heads in model layers 2 and 1 equivalent to changes in head in model layer 2. Thus, in the drawdown model, the change in the head of a given grid cell of model layer 2 in response to a simulated change in the withdrawal rate is equivalent to the difference in the head of that grid cell and the head of the grid cell above it in model layer 1. The difference in the heads results in a change in the flow rate between the grid cell of model layer 2 and that of model layer 1. As dictated by the Darcy equation, the change in flow rate is linearly proportional to the head difference between the grid cells. The coefficient of proportionality in this relationship is the negative of the product of the area and VCONT value assigned to the grid cell of model layer 1. In the drawdown model, the ET reduction coefficient is specified uniformly as the VCONT value of model layer 1.

Assuming that the simulated change in the withdrawal rate is an increase, then the head of the grid cell of model layer 2 will decrease in response. In the surficial aquifer system, a decline in water level results in a reduction in the rate of ET out of the surficial aquifer system, assuming the water level does not drop below the extinction depth of the surficial aquifer

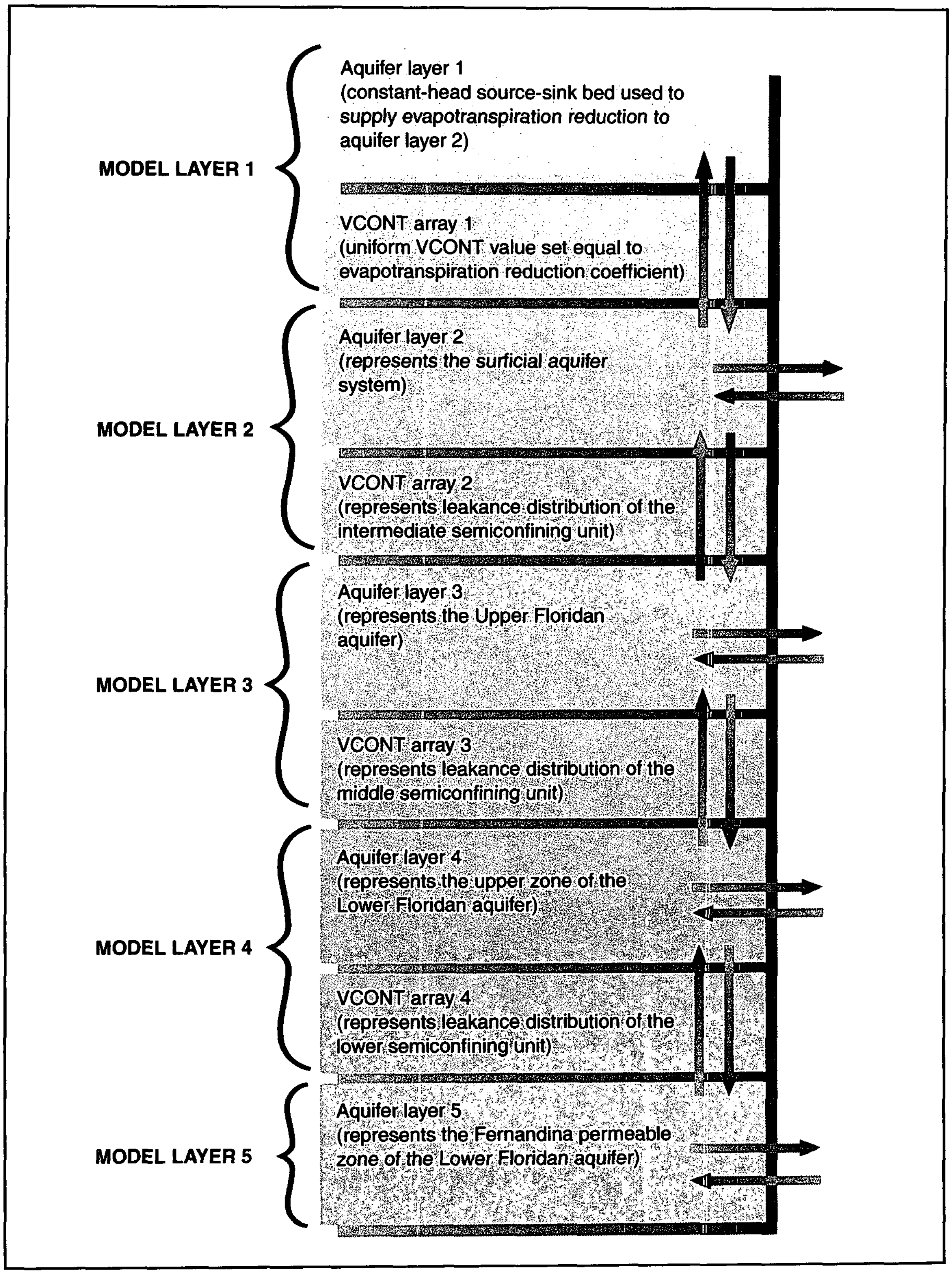


Figure 5. General configuration of drawdown model

Table 1. Summary of groundwater systems within the study area

Geologic Epoch	Geologic Unit	Hydrologic Unit		Description
Pleistocene and Recent	Pleistocene and Recent deposits	Surficial aquifer system		Consists of sand, clayey sand, shell, and thin limestone beds, and is divided into an upper, *water table zone* and a lower, *shallow-rock zone,* which are separated by a semiconfining unit. Thickness of the surficial aquifer system ranges approximately from 20 to 150 feet
Pliocene	Pliocene deposits			
Middle Miocene	Hawthorn Group	Upper confining unit, including the intermediate aquifer system		Upper confining unit consists of clay, marl, and discontinuous beds of sand, shell, dolomite, and limestone (aquifers of intermediate aquifer system). Confines intermediate aquifer system and underlying Floridan aquifer system. Thickness ranges approximately from 150 to 450 feet. Aquifers of intermediate aquifer system are up to 40 feet thick
Late Eocene	Ocala Limestone	Upper Floridan aquifer	FLORIDAN AQUIFER SYSTEM	Consists primarily of limestone. Thickness ranges approximately from 300 to 700 feet
Middle Eocene	Avon Park Formation	Middle semi-confining unit		Consists primarily of limestone and dolomite. Thickness ranges approximately from 50 to 300 feet
		Lower Floridan aquifer		Consists primarily of limestone and dolomite. Thickness ranges approximately from 400 to 1,000 feet
Early Eocene	Oldsmar Formation	Lower semi-confining unit		Consists primarily of limestone and dolomite. Thickness ranges approximately from 100 to 200 feet
		Fernandina permeable zone		Consists primarily of limestone and dolomite. Thickness ranges approximately from 170 to 1,000 feet
Paleocene	Cedar Keys Formation	Lower confining unit		Consists of low-permeability anhydrite beds. Thickness is unknown

Source: Bermes et al. 1963; Clark et al. 1964; Leve 1966; Fairchild 1972; Scott 1983; Miller 1986; Clarke et al. 1990 system. In the drawdown model, a decline in the head of model layer 2 results in an increase in the rate of flow from model layer 1 to model layer 2. Hydraulically, an increase in the inflow rate to a given grid cell is equivalent to a reduction of the same magnitude in the outflow rate. Thus, the model is equipped to handle the reduction in the ET rate as a linear response to simulated changes in hydraulic head in model layer 2. This approach to handling the rate of ET reduction is patterned after that of Motz (1978), who developed an analytical model of a coupled aquifer system with reduction in rates of ET (Appendix B).

Two important assumptions concerning the magnitudes of simulated drawdowns in model layer 2 of the drawdown model should be stated explicitly. One of the assumptions is that simulated drawdowns will not constitute a significant percentage of the saturated thickness of the surficial aquifer system. Treatment of model layer 2 (Figure 5) as confined is acceptable as long as simulated drawdowns are not a significant proportion of the total saturated thickness of the surficial aquifer system. Failure to meet this condition would result in the violation of the assumption of linearity in the groundwater flow equation used to represent the surficial aquifer system in the drawdown model. The other assumption is that simulated drawdowns will not be large enough to correspond to the points at which the water table drops below the extinction depths of the surficial aquifer system. ET losses from the surficial aquifer system cease when the water table drops below the extinction depth. Therefore, additional reductions in the ET rate cannot be realized under this condition. In its present configuration, the drawdown model would not be capable of shutting down its ET-reduction mechanism. The reduction in the ET rate would remain a linear function of the drawdown in model layer 2 regardless of the magnitude of the drawdown. Consequently, the amount of reduction in the ET rate might be overestimated significantly if relatively large drawdowns were simulated in model layer 2. Both of these assumptions are believed to have been satisfied in the present study.

Lateral Boundary Conditions

GHB Conditions

The lateral boundary conditions of the drawdown model consist almost entirely of GHB conditions, the MODFLOW implementation of the head-dependent-flux boundary. A GHB condition is prescribed at every grid cell along the outermost rows and columns of model layers 2 through 5 (Figure 5), with the exceptions of grid cells that are specified as no-flow in model layer 5. The source heads of the GHB conditions are specified as 0 ft in all cases, because 0 ft of drawdown is assumed to occur at the locations at which the source heads are specified. Along the southern, eastern, and northern boundary segments (i.e., sides) of the model grid, the distance from the edge of the model grid to the locations at which the source heads are specified differs from one segment to the next but is uniform within any one segment. Furthermore, the same distances are specified along corresponding segments of all four variable-head model layers. These distances are as follows: 3.5 miles along the southern boundary segment, 2.0 miles along the eastern boundary segment, and 3.5 miles along the northern boundary segment. These distances are consistent with those applied to the corresponding boundary segments of the original and revised groundwater flow models.

Along the western boundary segment, the distance from the edge of the model grid to the locations at which the source heads are specified is either 4.4 or 10 miles. As stated previously, the GHB-condition source heads prescribed to column 1, rows 31 through 57, of model layers 2 through 5 were relocated farther to the west in the drawdown model. In the original and revised groundwater flow models, source heads of GHB conditions prescribed to grid cells of column 1 were located at approximately 4.4 miles from the western edge of the model grid. In the drawdown model, these source heads are located at approximately 10 miles from the western edge of the model grid. The relocation of these source heads was implemented to increase the distance between the source heads and the proposed JEA Cecil Field and Westlake WTPs, the simulated withdrawals of which are assigned to grid cells at column 1, rows 48 and 40, respectively, of model layers 3 and 4. The GHB-condition source heads prescribed to column 1, rows 31 through 57, of model layer 2, which represents the surficial aquifer system, were located 10 miles from the western edge of the model grid also. The source heads of GHB conditions prescribed to grid cells along column 1 in the rows above row 31 and below row 57 of all four variable-head model layers of the drawdown model are specified at 4.4 miles from the western edge of the model grid.

The conductances of the GHB conditions were determined according to the following equation:

$$C = \frac{TW}{L}$$

where

C = conductance

T = transmissivity, which equals the product of hydraulic conductivity and the saturated thickness of the aquifer

W = the width of the cross-sectional area normal to the direction of flow

L = the length of the flow path

In the drawdown model, as in the original and revised groundwater flow models, the above transmissivity is that assigned to the grid cell to which the GHB condition is prescribed. The width of the cross-sectional area is the width of the grid cell to which the GHB condition is prescribed. The length of the flow path is the distance between the point at which the GHB-condition source head is specified and the center of the grid cell to which the GHB condition is prescribed.

Specified Heads

The no-flow grid cells of model layer 5 represent portions of the Fernandina permeable zone that are occupied entirely with saline water. Areas of saltwater flow are not part of the domain of the drawdown model because MODFLOW is not equipped to handle variable-density flow. As stated previously, however, heads of 0 ft were specified in grid cells that border on the regions of no-flow grid cells in model layer 5. These grid cells represent the line of the interface tip in the Fernandina permeable zone. Heads were specified for these grid cells to enable the grid cells to function as sources of freshwater to surrounding grid cells. The freshwater produced by these grid cells is intended to approximate the volume of freshwater that is being removed from aquifer storage as the interface moves landwardly in response to well withdrawals within the study area. Direct simulation of freshwater-storage removal as resulting from the process of landward interface movement is not possible with MODFLOW because MODFLOW is not a saltwater-intrusion model. The specification of freshwater heads as in the present study results in an approximation of this process. This approach was implemented at the direction of Faye and Tibbals (pers. com. 1999). The areas of saline water in the Fernandina permeable zone were delineated by Durden (1997).

ESTIMATED 1995 AND PROJECTED 2020 RATES OF WELL WITHDRAWALS

Municipal, Commercial/Industrial, and Thermoelectric Use

The total of the average annual rates of withdrawal from the Floridan aquifer system of the study area in the municipal, commercial/industrial, and thermoelectric use categories in 1995 was approximately 228 million gallons per day (mgd) (Florence 1997; Fanning 1997). The total of the average annual rates of withdrawal in these categories in the year 2020 is projected to be approximately 368 mgd (Vergara 1998; CH2M HILL, pers. com. 1998). Thus, the total of the average annual rates of withdrawal in these categories is projected to increase from 1995 to 2020 by approximately 61%.

Golf Course Irrigation

The total of the average rates of withdrawal from the Floridan aquifer system for golf course irrigation in Duval, Clay, Nassau, and St. Johns counties was approximately 23.8 mgd in 1995 (Vergara 1998). The rate of golf course irrigation in these four counties (data were not available for Camden County, Georgia) is projected to increase to approximately 37.7 mgd by 2020 (Vergara 1998). However, the great majority of this additional use will likely be supplied by reclaimed water. Furthermore, any additional withdrawals from the Floridan aquifer system that are implemented will likely be balanced by conversion of some existing withdrawals to use of reclaimed water. Thus, the total of the average annual rates of withdrawal from the Floridan aquifer system for golf course irrigation is expected to remain more or less unchanged, despite the projected increase in the rate of golf course irrigation (C. Moore, SJRWMD, pers. com. 1998). Therefore, the change in the rate of golf course irrigation was not represented in the drawdown model of the present study.

Agricultural Irrigation

The total of the average rates of withdrawal from the Floridan aquifer system for agricultural irrigation in Duval, Clay, Nassau, and St. Johns counties was approximately 33.3 mgd in 1995 (Vergara 1998). The total is projected to increase to approximately 36.6 mgd by 2020 (Vergara 1998), an increase of approximately 10%. However, the increase is only about 2% of the projected increase in the municipal, commercial/industrial, and thermoelectric use categories as stated above. Furthermore, most agricultural irrigation occurs in southern St. Johns County outside of the present study area. Therefore, the change in rates of withdrawal for agricultural irrigation was neglected in the present study.

Domestic Self-Supply

The total of the average rates of withdrawal from groundwater sources for domestic self-supply in Duval, Clay, Nassau, and St. Johns counties was approximately 17.9 mgd in 1995 (Vergara 1998). The Floridan, intermediate, and surficial aquifer systems are the sources of this water. The total of the average rates of withdrawal is projected to decrease between 1995 and 2020 by approximately 4.2 mgd in the four Florida counties of the study area (Vergara 1998). This amount is small compared to the projected increase in the municipal, commercial/industrial, and thermoelectric use categories. Furthermore, information needed to determine the aquifer system from which and the location at which individual withdrawals are made (i.e., well depth and location) is not readily available. Therefore, the change in rates of withdrawal for domestic self-supply was neglected in the present study.

SOURCES OF HYDRAULIC PARAMETERS

FLORIDAN AQUIFER SYSTEM

The estimates of leakance and transmissivity assigned to model layers 3 through 5 of the drawdown model were taken directly from the revised groundwater flow model. These model layers represent, respectively, the intermediate semiconfining unit, the Upper Floridan aquifer, the middle semiconfining unit, the upper zone of the Lower Floridan aquifer, the lower semiconfining unit, and the Fernandina permeable zone of the Lower Floridan aquifer (Figure 5). With the exception of the VCONT array used to represent the leakance distribution of the intermediate semiconfining unit, these estimates were derived entirely from the calibration of the original groundwater flow model. As noted previously, the VCONT array used in the revised groundwater flow model to represent the leakance distribution of the intermediate semiconfining unit (the VCONT array of model layer 1 in that model) was modified somewhat with respect to that of the original groundwater flow model.

SURFICIAL AQUIFER SYSTEM

The permeability of the surficial aquifer system is represented by a single value of transmissivity (1,000 square feet per day) assigned to model layer 2. This estimate of transmissivity is considered to be a generalized, average value. It was inferred from permeability and transmissivity estimates cited in previous groundwater publications (e.g., Brown 1984; Causey and Phelps 1978; Franks 1980).

The value of the ET reduction coefficient assigned to model layer 1 (2.66×10^{-4}/day) was based on information in Tibbals (1990). The same estimate was used in the previous needs and sources assessment conducted by SJRWMD (Vergara 1994). Estimates of the ET reduction coefficient are not widely available. Therefore, it too must be considered a generalized, average value.

The assigned ET reduction coefficient is generally more influential in model layer 2 than the assigned value of transmissivity, based on prior experimentation with a semi-analytical technique called SURFDOWN (Huang and Williams 1996), which combines the Motz (1978) analytical model (Appendix B) with MODFLOW (McDonald and Harbaugh 1988).

Experience with SURFDOWN also indicates that the leakance distribution used to represent the intermediate semiconfining unit is at least as influential as the ET reduction coefficient.

LIMITATIONS AND BENEFITS OF THE VARIABLE-HEAD REPRESENTATION OF THE SURFICIAL AQUIFER SYSTEM

The drawdowns in the surficial aquifer system as simulated by the model are limited to those induced by the drawdowns in the underlying Floridan aquifer system. Drawdowns due to direct withdrawals from the surficial aquifer system are not simulated; as such, withdrawals were not represented in the drawdown model. Projected increases in rates of withdrawal from the surficial aquifer system for municipal use in St. Johns County were evaluated separately by D. Toth (SJRWMD, pers. com. 1998).

The transmissivity estimate of model layer 2 and the ET reduction coefficient of model layer 1 (i.e., the uniform VCONT value) are assigned values in the present model. Therefore, they were not derived through the calibration process. The VCONT array of model layer 2, which represents the leakance distribution of the intermediate semiconfining unit, however, is primarily the product of calibration (Figure 4). Thus, as stated previously, model layer 2 is calibrated partly. Because model layer 2 is not calibrated fully, the drawdown distribution simulated for it should be used primarily as a general guide for delineating areas of *potential* adverse impacts. Despite the limitations, the benefits of activating model layer 2 are compelling and may be summarized as follows:

1. The ability to address the *potential* for significant drawdowns in the surficial aquifer system is made possible.

2. The simulated interaction between the surficial aquifer system and the Floridan aquifer system is made somewhat more realistic.

SUMMARY OF SIMULATION RESULTS

As stated previously, four different simulations were performed as part of the study, each with the objective of assessing changes (either decreases or increases) in the elevations of the potentiometric surface of the Upper Floridan aquifer and the water table of the surficial aquifer system in response to projected changes in rates and/or locations of well withdrawals. Specifically, these four simulations are described as follows:

1. A simulation of the effects of projected changes in all significant municipal, commercial/industrial, and thermoelectric use withdrawals. In the present context, a "significant" withdrawal is, generally, a withdrawal of at least 100,000 gallons per day (Appendix A)

2. A simulation of the effects of projected changes in JEA withdrawals only

3. A simulation of the effects of projected changes in JEA withdrawals only, but with all JEA wells that extend into the upper zone of the Lower Floridan aquifer in the JEA southgrid area (Figure 2) "backplugged" to the Upper Floridan aquifer

4. A simulation of the effects of projected changes in coastal area withdrawals only, excluding the effects of changes in JEA withdrawals. The coastal area of concern in this case is the Atlantic coast between St. Augustine and Mayport (Figure 1). It extends about 10 miles inland in St. Johns County and about 2 miles inland in Duval County

These simulations were based on the best information available at the time with respect to well locations, depths, and distributions of discharge. However, in some cases, particularly in the cases of the proposed JEA Cecil Field, Westlake, and Mall WTPs, the exact future locations and/or depths of the wells were unknown (Appendix A). In the cases of these three WTPs, the projected changes in withdrawal rates were represented as single points of discharge. Concurrent with CH2M HILL 1999a, 25% of the projected changes in rates of withdrawal was assigned to the Upper Floridan aquifer in each of these cases, while the remaining 75% was assigned to the upper zone of the Lower Floridan aquifer. In some other cases, the locations of wells were known, but not the total depths. In such cases, the bottom elevation of the well was assumed to be the same as the bottom elevation of the Upper Floridan aquifer, as determined by Miller (1986).

In the cases of the JEA Brierwood, Deerwood, and Community Hall WTPs, the depths of all wells were known, but the elevations of the bottom of the Upper Floridan aquifer and the top of the upper zone of the Lower Floridan aquifer at the three wellfields as specified by Miller (1986) was brought into question by CH2M HILL (1999a). Based on the elevation estimates of Miller (1986), several of the wells at each of these WTPs extend into the upper zone of the Lower Floridan aquifer. However, according to CH2M HILL (1999a), the wells at these three WTPs are all open only to the Upper Floridan aquifer. Concurrent with CH2M HILL 1999a, the projected changes in withdrawal rates at these three wellfields were represented in the drawdown model as being derived entirely from the Upper Floridan aquifer. This approach was taken for two reasons:

1. Aquifer performance tests performed by CH2M HILL using production wells at the subject WTPs resulted in transmissivity and leakance estimates that agree reasonably well with corresponding estimates of transmissivity and leakance used to represent the permeability of the Upper Floridan aquifer and its two bounding semiconfining units in the drawdown model (CH2M HILL 1999b, 1999c, 1999d). However, the transmissivity estimates resulting from the tests are much lower than the corresponding estimates of transmissivity used in the drawdown model to represent the permeability of the upper zone of the Lower Floridan aquifer. Hence, regardless of whether the wells in question actually penetrate into the Lower Floridan aquifer, the representation of the wells as being open only to the Upper Floridan aquifer in the drawdown model results in drawdown estimates that are more consistent with the hydraulic properties of the Floridan aquifer system as determined by the aquifer performance tests.

2. Because the transmissivity of model layer 3 (which represents the Upper Floridan aquifer) is less than that of model layer 4 (which represents the upper zone of the Lower Floridan aquifer) at the subject locations, assignment of changes in well withdrawal rates solely to model layer 3 results in simulated drawdowns that are greater than what would result if the changes in withdrawal rates were divided

between model layers 3 and 4. Therefore, the drawdown estimates are more likely to be conservative.

The effect of lumping the change in withdrawal rate of an entire wellfield into a single discharge point is generally to overestimate the maximum drawdown of the resulting cone of depression, assuming that the ultimate change in withdrawal rate is eventually distributed between several wells and that the estimate of the change is accurate. The lateral extent of the simulated cone of depression in such a case will not necessarily be overestimated to a significant extent, however. Of course, inaccurate distribution between the Upper Floridan aquifer and the upper zone of the Lower Floridan aquifer can lead to errors both in the maximum value and in the lateral extent of the drawdown.

The aforementioned simulations are discussed in greater detail below.

Impacts Due to Changes in All Significant Withdrawals—Simulation 1

Upper Floridan Aquifer

The cumulative drawdowns in the potentiometric surface of the Upper Floridan aquifer due to projected changes in the rates of all significant withdrawals range approximately from 0 to 23 ft (Figure 6 and Appendix A). The maximum drawdowns occur at the JEA Ridenour WTP and the Rayonier wellfield near Fernandina Beach.

Generally, drawdowns in most of the study area will range approximately from 2 to 10 ft. The largest cones of depression tend to be in areas of most intense aquifer development at present. These areas include the areas of north- and south-central Duval County, the coastal areas between St. Augustine and Mayport, and the area of Fernandina Beach (Figures 1 and 6).

Emphasis should be placed on the fact that the simulated drawdowns represent drawdown *in addition to* the drawdowns already represented by the potentiometric surface of the Upper Floridan aquifer in 1995. The total drawdown, the sum of the pre- and post-1995 drawdown (i.e., the drawdown relative to water levels in the predevelopment Upper Floridan aquifer), is the value that should be used in evaluating the likelihood of

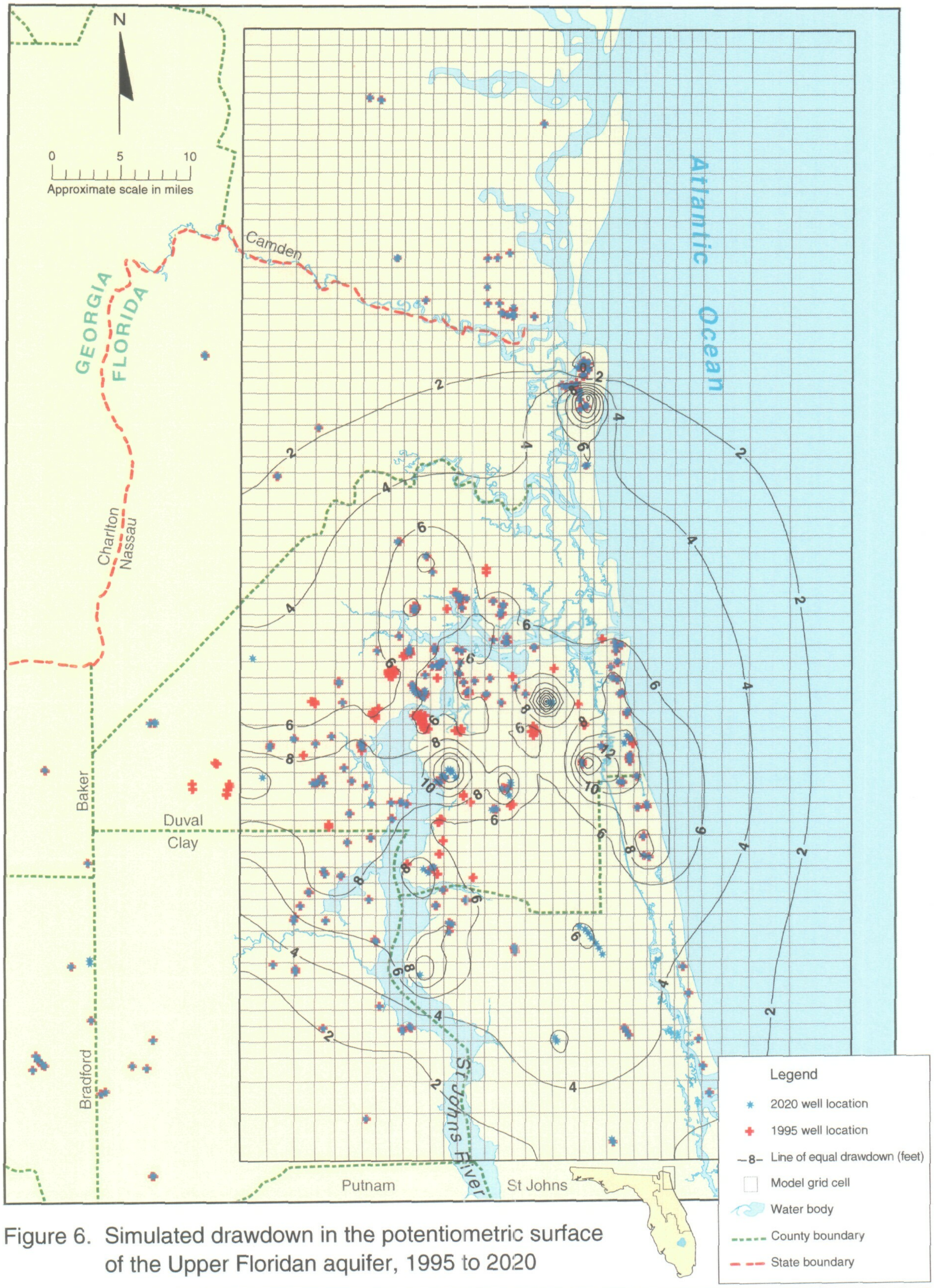


Figure 6. Simulated drawdown in the potentiometric surface of the Upper Floridan aquifer, 1995 to 2020

saltwater degradation in the withdrawal wells of any particular subregion within the study area.

To help in the evaluation of the potential effects of the projected drawdowns, the drawdowns were subtracted from an estimate of the May 1995 potentiometric surface of the Upper Floridan aquifer to produce a hypothetical potentiometric surface of the upper Floridan aquifer for 2020 (W. Osburn, SJRWMD, pers. com. 1999) (Figure 7). Other factors in addition to the rates and locations of well withdrawals will combine to produce the actual potentiometric surface of the Upper Floridan aquifer in May 2020. The other factors are largely climatic, and the present study does not attempt to account for variations in climate. In addition, the projected changes in withdrawal rates are subject to error, and many of the projected changes may never actually be realized, at least not entirely. Meanwhile, a number of currently unforeseen changes undoubtedly will be realized. Hence, the resulting simulated potentiometric surface is a representation of the 2020 potentiometric surface, based on the best available information; the actual surface in 2020 may differ from this representation. Nevertheless, the subtraction of the projected drawdowns from the May 1995 potentiometric surface of the Upper Floridan aquifer offers valuable insight into the potential effects of the projected changes in withdrawal rates.

The results show levels of hydraulic head in the range of the high teens to high twenties of feet in much of Duval County and northern St. Johns County. Areas of particular concern are the coastal area of southeastern Duval and northern St. Johns counties and the general area of the JEA south grid. These are areas where saltwater degradation in a number of wells has been observed already (Spechler 1994; Phelps and Spechler 1997) and where significant additional drawdowns are projected in the model simulation.

Of secondary concern are the areas around the proposed Cecil Field, Westlake, and N.W. Regional/Mall WTPs and the existing Main Street, Lakeshore, Southwest, and Highlands WTPs in the JEA north grid (Figures 2, 6, and 7). These areas are of secondary concern because (1) the freshwater/saltwater interface is generally at greater depth in areas west of the St. Johns River, (2) well withdrawals from the Upper Floridan aquifer are generally less intense in areas west and north of the St. Johns River, and (3) major water quality problems have not arisen to date in areas west and north of the St. Johns River (Spechler 1994). Despite these

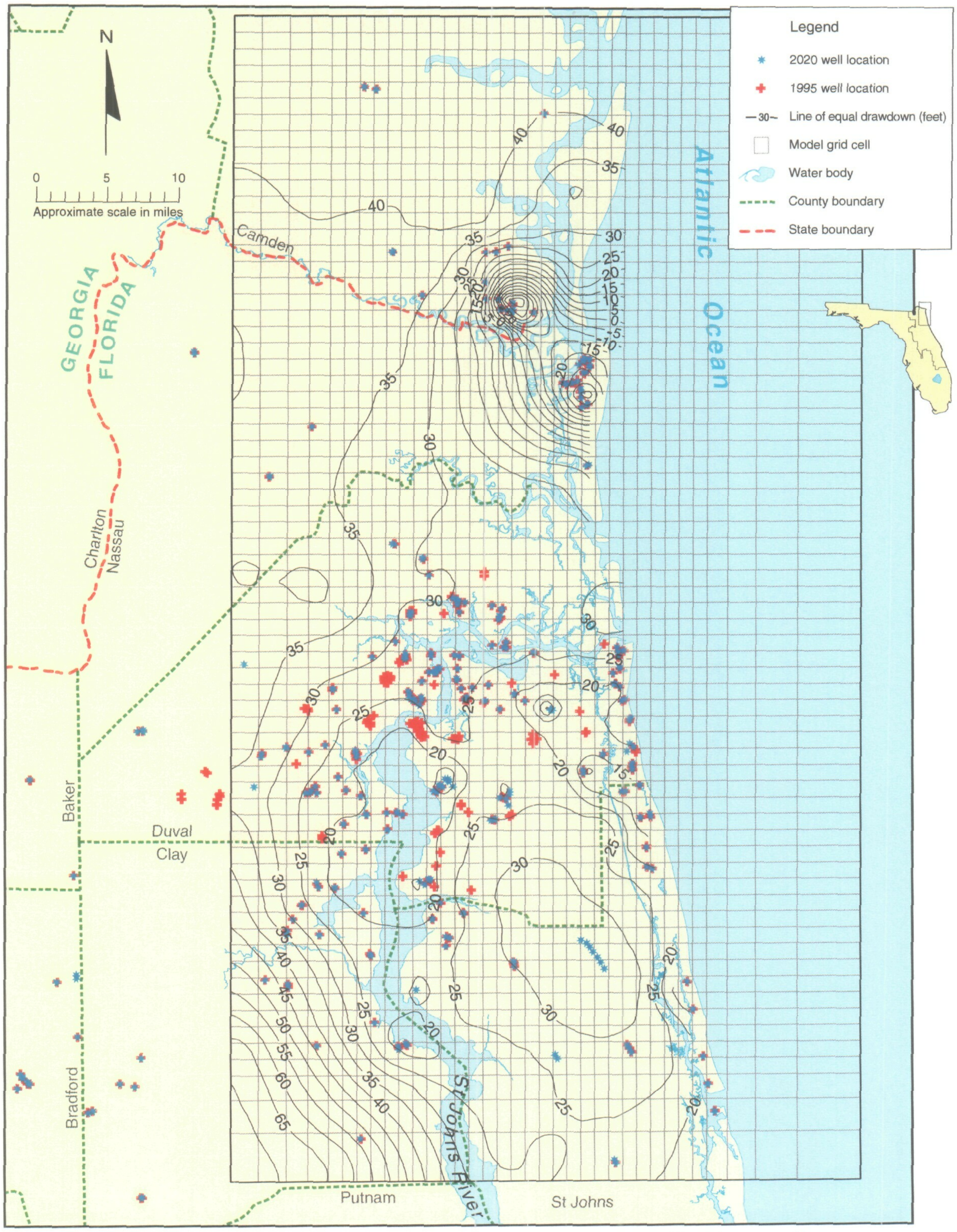


Figure 7. Hypothetical 2020 potentiometric surface of the Upper Floridan aquifer

considerations, a potential for saltwater degradation of wells in areas west and north of the St. Johns River does exist, and this potential will increase as more aquifer development takes place in these areas.

To date, wells in the Fernandina Beach area that are restricted to the Upper Floridan aquifer have been spared significant saltwater degradation, except in cases of well interference by deeper wells that tap or did tap the Lower Floridan aquifer (Brown 1984). Nevertheless, given the history of water quality problems in wells that withdrew water from both the Upper and Lower Floridan aquifers and the extremely large cone of depression in the Upper Floridan aquifer that is centered on this area, the area of Fernandina Beach should be of concern too. The simulation shows a further decline in this area of up to approximately 23 ft between 1995 and 2020 (Figure 6).

Surficial Aquifer System

The cumulative drawdowns in the elevation of the water table of the surficial aquifer system due to projected increases in the rates of all significant withdrawals from the Floridan aquifer system range from approximately 0 to 2.2 ft (Figure 8 and Appendix B). The area of greatest simulated drawdown is the eastern half of Clay County, particularly the vicinity of Green Cove Springs. Other areas of notable amounts of simulated drawdown are in southern Duval County near the location of the JEA Community Hall WTP and in the area of northeast St. Johns County. The maximum simulated drawdown at the Community Hall WTP is approximately 0.9 ft. The maximum simulated drawdown in the area of northeast St. Johns County is approximately 0.3 ft.

The areas of greatest drawdowns in the elevation of the water table of the surficial aquifer system (Figure 8) do not necessarily coincide with the areas of greatest drawdowns in the potentiometric surface of the Upper Floridan aquifer (Figure 6). Instead, the areas of greatest drawdown in the surficial aquifer system generally correspond to areas of higher leakance in the intermediate semiconfining unit (Figures 3 and 4). Thus, the relative importance of the leakance of the intermediate semiconfining unit in determining the drawdown distribution in the surficial aquifer system is apparent. The intermediate semiconfining unit is relatively thick in Duval and Nassau counties and moderately thick in the parts of Clay and St. Johns counties within the study area (Miller 1986). Leakance estimates of the intermediate semiconfining unit are, accordingly, lower in the

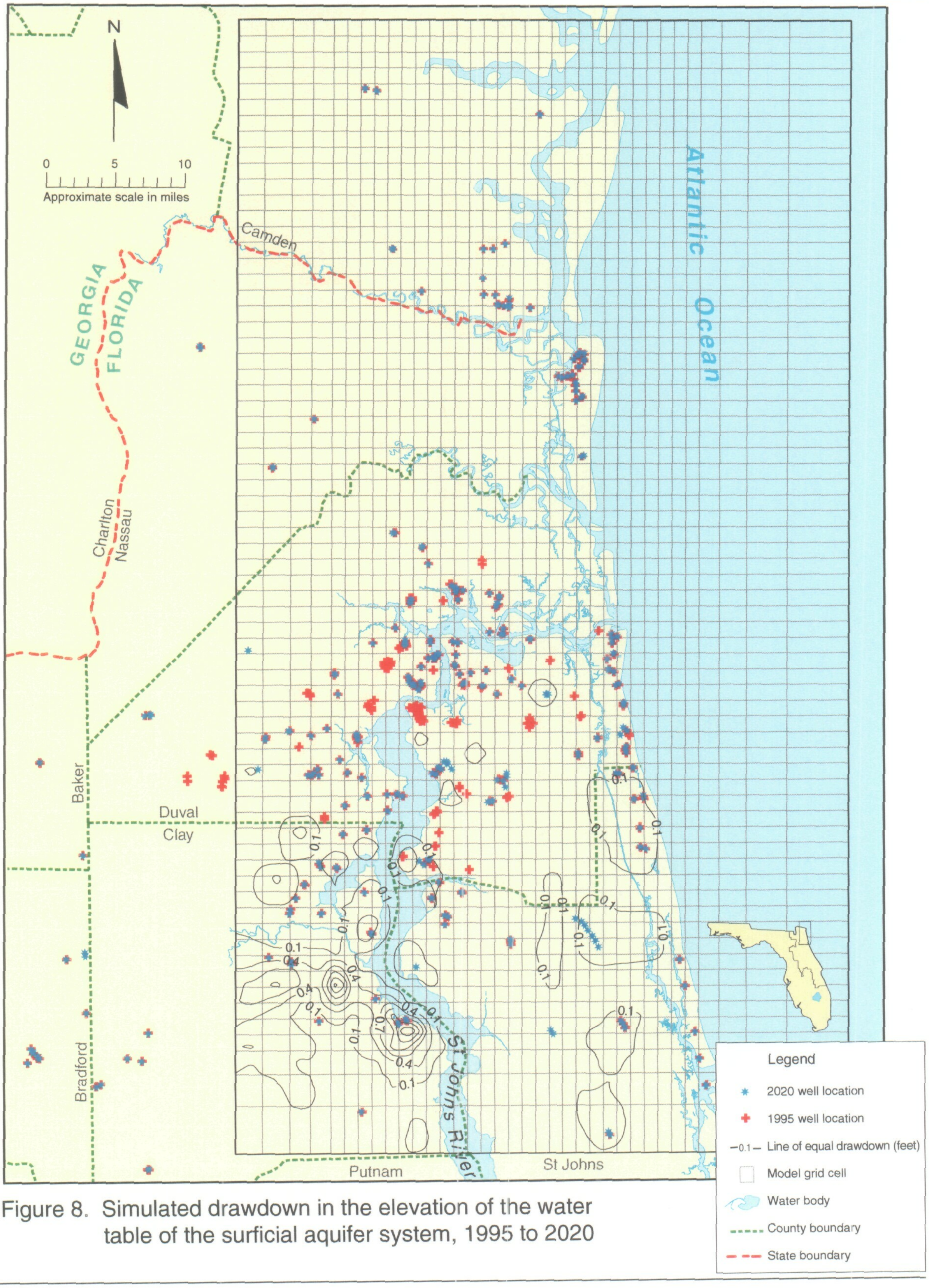


Figure 8. Simulated drawdown in the elevation of the water table of the surficial aquifer system, 1995 to 2020

northern half of the study area and higher in the southern half (Figures 3 and 4).

IMPACTS DUE TO CHANGES IN JEA WITHDRAWALS ONLY— SIMULATION 2

Upper Floridan Aquifer

A simulation was performed to estimate the impacts attributable to JEA only. In the north- and south-central areas of Duval County, the simulated drawdown in the potentiometric surface of the Upper Floridan aquifer due to JEA is somewhat less than the simulated drawdown due to all significant users (Figures 6 and 9 and Appendix A). In the area of northeast St. Johns County, a relatively small cone of depression extends into the coastal areas. This is the drawdown due to the projected increase in withdrawal at the JEA Southeast WTP (Figures 2 and 9 and Appendix B). The drawdown at Jacksonville Beach and Ponte Vedra Beach due to the JEA portion of the projected increase in withdrawal between 1995 and 2020 is approximately 4 ft (Figures 1 and 9).

Surficial Aquifer System

The locations of the drawdowns in the elevation of the water table of the surficial aquifer system in Duval and Clay counties due to changes in JEA withdrawals alone are generally the same as those resulting from the effects of projected changes in all significant users (Figure 10 and Appendix A). The magnitudes of the drawdowns, however, are considerably less.

IMPACTS DUE TO CHANGES IN JEA WITHDRAWALS ONLY, WITH BACKPLUGGING IN THE SOUTHGRID AREA— SIMULATION 3

A simulation was performed to estimate the effect of backplugging JEA wells that are open to both the Upper and Lower Floridan aquifers in the JEA southgrid area. All wells at the JEA Brierwood, Deerwood, and Community Hall WTPs are assumed to terminate in the Upper Floridan aquifer, in accordance with CH2M HILL (1999a). Therefore, the wells of these WTPs did not require backplugging in the present simulation. Comparisons of total well depths to estimates of the bottom elevations of the Upper Floridan aquifer and the top elevations of the Lower Floridan aquifer based on Miller (1986) indicate that the only other JEA WTP in the

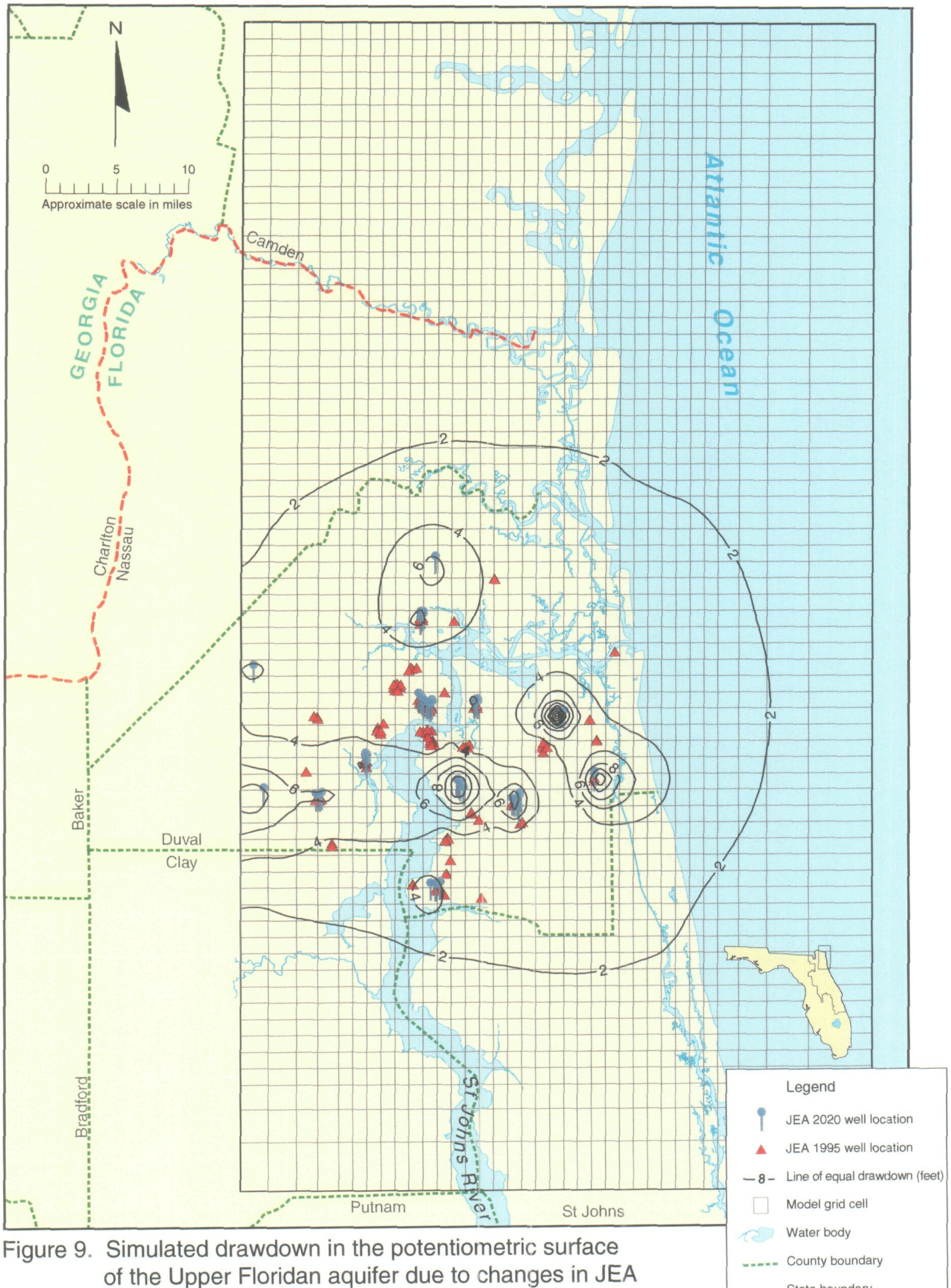


Figure 9. Simulated drawdown in the potentiometric surface of the Upper Floridan aquifer due to changes in JEA withdrawals only, 1995 to 2020

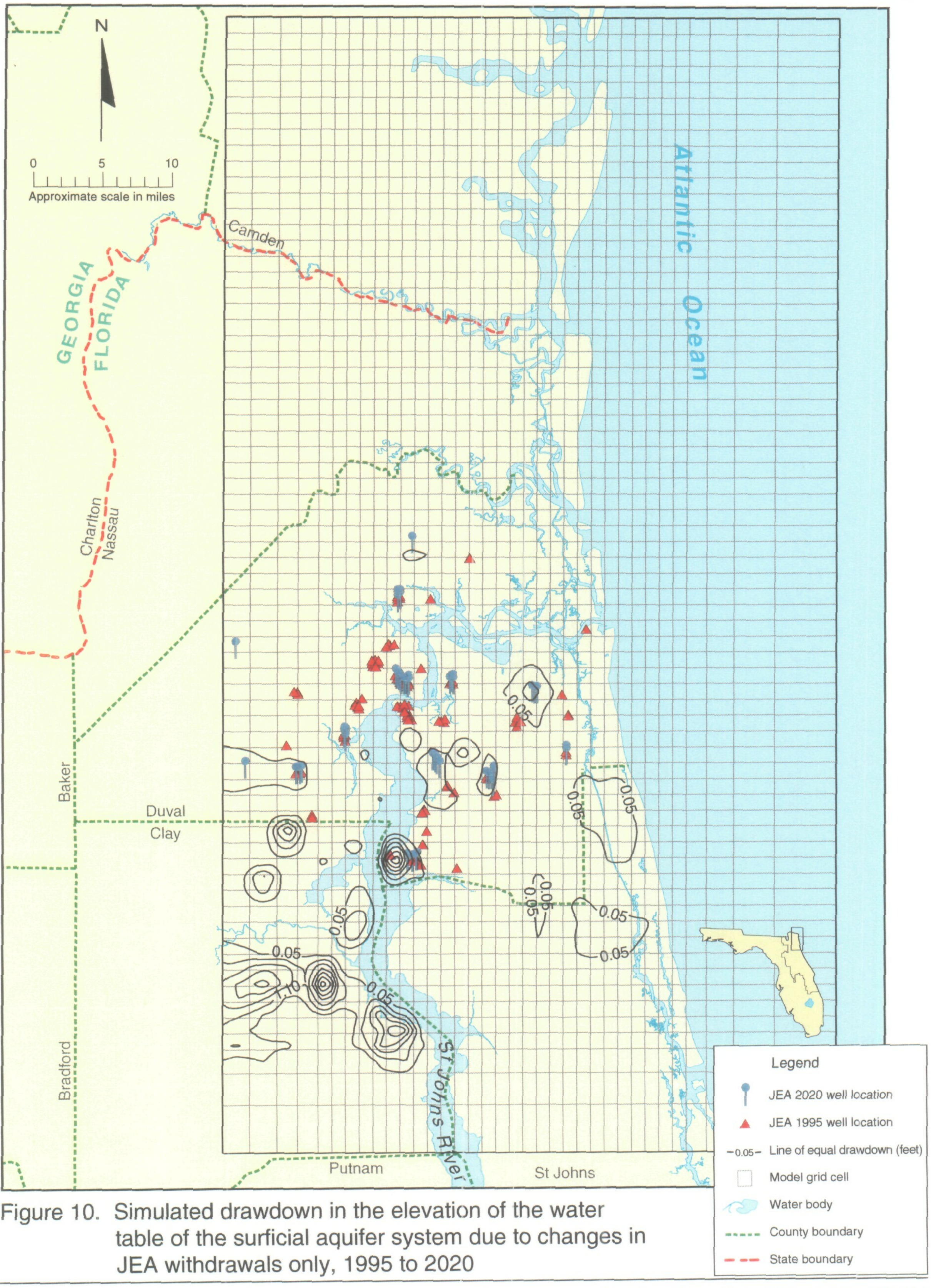


Figure 10. Simulated drawdown in the elevation of the water table of the surficial aquifer system due to changes in JEA withdrawals only, 1995 to 2020

south grid with wells deep enough to penetrate into the Lower Floridan aquifer is the Arlington WTP. Hence, the present simulation involved backplugging to the Upper Floridan aquifer the wells of the JEA Arlington WTP that are deep enough to extend into the Lower Floridan aquifer. All other JEA wells were included also, and their representation was unchanged (Figures 2 and 11 and Appendix A).

In all other simulations of the present study, multi-aquifer wells were represented as two separate wells—one that is open only to the Upper Floridan aquifer and another that is open only to the Lower Floridan aquifer. The discharge from such wells is distributed between Upper and Lower Floridan aquifers based on model transmissivity values (see Durden 1997 for details). Wells are "backplugged" from the Lower Floridan aquifer to the Upper Floridan aquifer in the model by eliminating the simulated well that is used to represent the discharge from the Lower Floridan aquifer and assigning the entire discharge to the simulated well used to represent discharge from the Upper Floridan aquifer.

The southgrid area is the focus of this investigation because most problem wells in Duval County have been located either in the south grid or the coastal areas (Spechler 1994). Backplugging wells that penetrate the Lower Floridan aquifer up to the Upper Floridan aquifer offers the possibility of providing additional protection from saltwater degradation.

Upper Floridan Aquifer

As a result of backplugging, a 4-ft drawdown contour that previously encompassed the JEA Brierwood and Deerwood WTPs was extended northward to encompass the JEA Arlington WTP also (Figures 2, 9, and 11). Otherwise, there is little noticeable response to the backplugging of the multi-aquifer wells of the JEA Arlington wellfield.

Surficial Aquifer System

Generally, simulated backplugging resulted in no noticeable increases in the simulated drawdowns of the elevation of the water table of the surficial aquifer system (Figures 10 and 12).

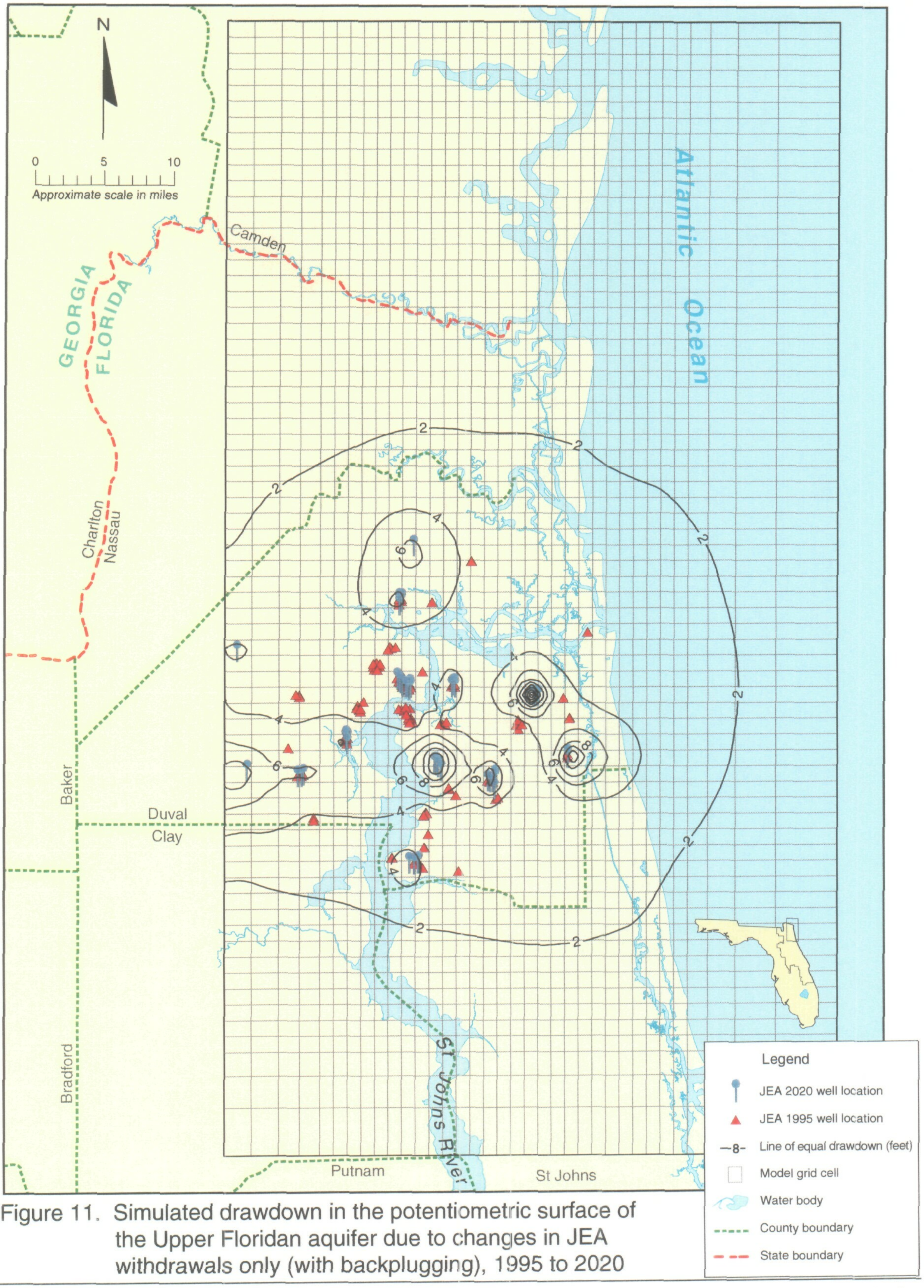


Figure 11. Simulated drawdown in the potentiometric surface of the Upper Floridan aquifer due to changes in JEA withdrawals only (with backplugging), 1995 to 2020

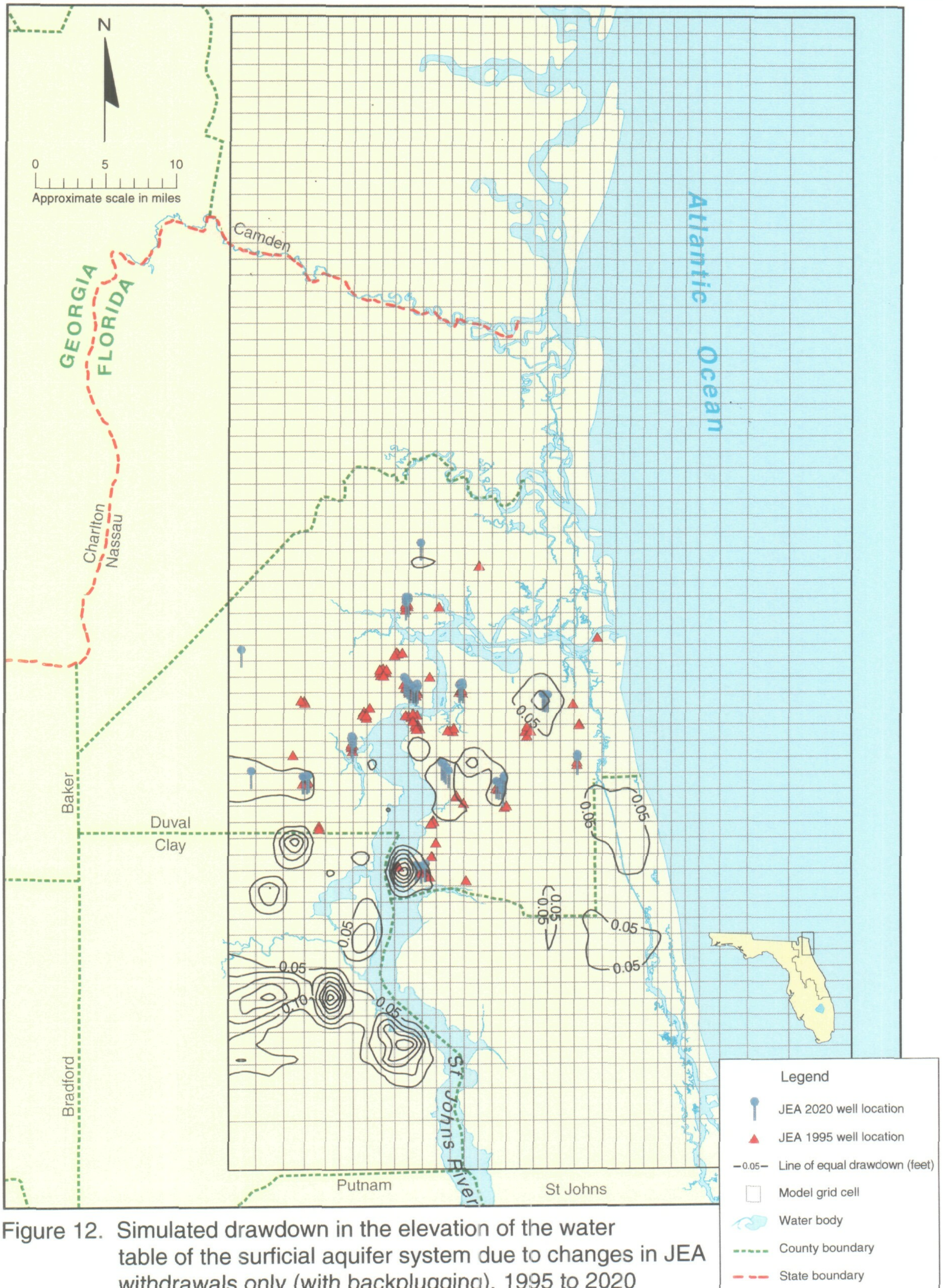


Figure 12. Simulated drawdown in the elevation of the water table of the surficial aquifer system due to changes in JEA withdrawals only (with backplugging), 1995 to 2020

Impacts Due to Changes in Coastal Withdrawals Only—Simulation 4

Upper Floridan Aquifer

A simulation was performed which included only coastal area users. The coastal area of concern in this case is the Atlantic coast between St. Augustine and Mayport (Figure 1). This area extends about 10 miles inland in St. Johns County and about 2 miles inland in Duval County (Figure 13 and Appendix A). Drawdowns in the potentiometric surface of the Upper Floridan aquifer due to these users generally fall within the range of about 1 to 3 ft. In the area of northeast St. Johns and southeast Duval counties, however, the drawdowns are greater. The simulated drawdowns in northeastern St. Johns County range approximately from 3 to 6 ft. In coastal Duval County, the drawdowns range from approximately 3 to 5 ft. In northern St. Johns County, the drawdowns due to a proposed new wellfield for St. Johns County range from approximately 2 to 4 ft.

Surficial Aquifer System

Simulated drawdowns in the elevation of the water table of the surficial aquifer system due to coastal area users appear in both Clay and St. Johns counties (Figure 14). In St. Johns County, drawdowns range up to about 0.15 ft. In Clay County, drawdowns range up to about 0.25 ft. Again, the locations of the drawdowns in the elevation of the water table of the surficial aquifer system do not coincide necessarily with the general locations of the largest drawdowns in the potentiometric surface of the Upper Floridan aquifer. The drawdowns in the elevation of the water table of the surficial aquifer system tend to be located in areas in which the leakance of the intermediate semiconfining unit is relatively high.

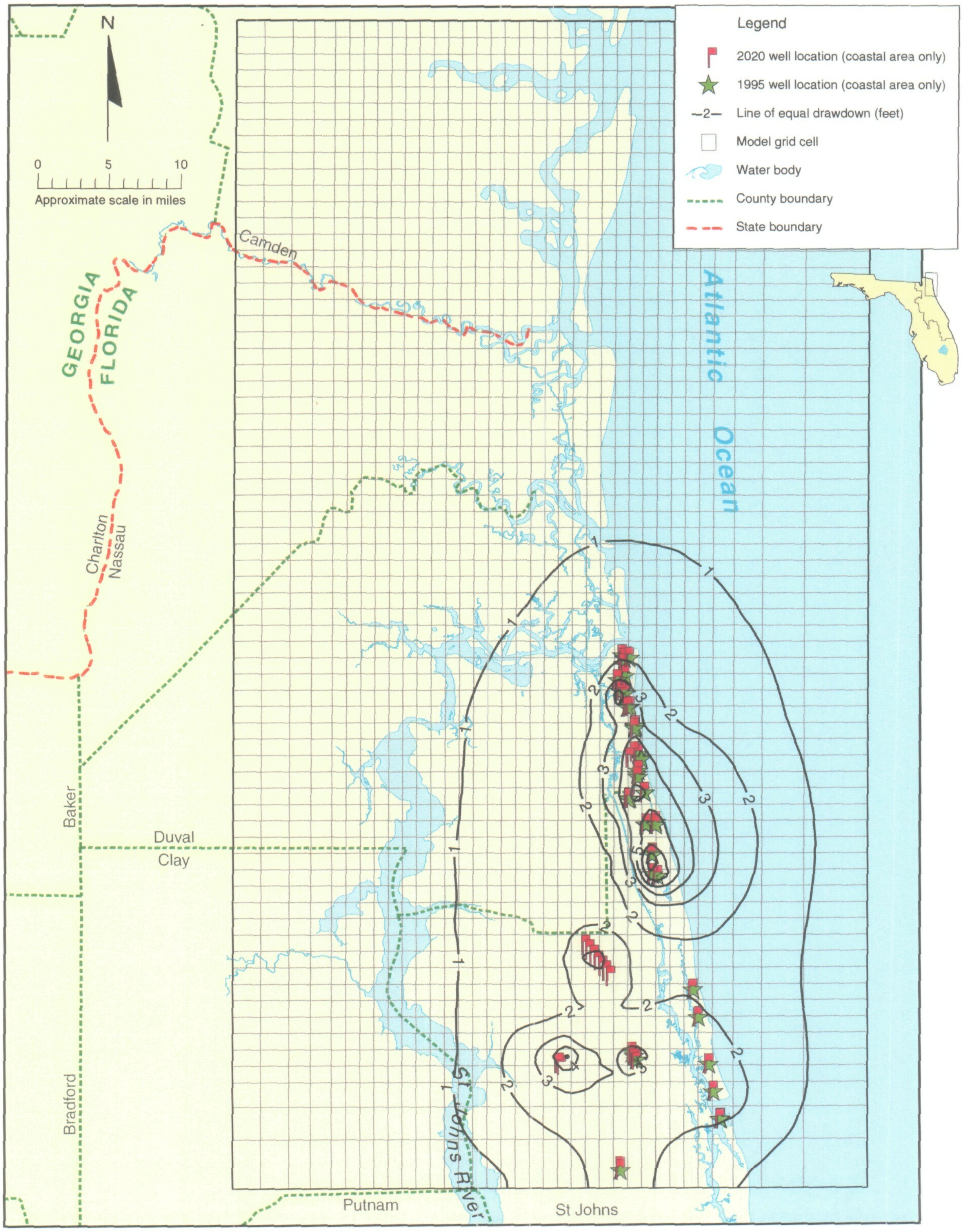


Figure 13. Simulated drawdown in the potentiometric surface of the Upper Floridan aquifer due to changes in coastal area withdrawal rates, 1995 to 2020

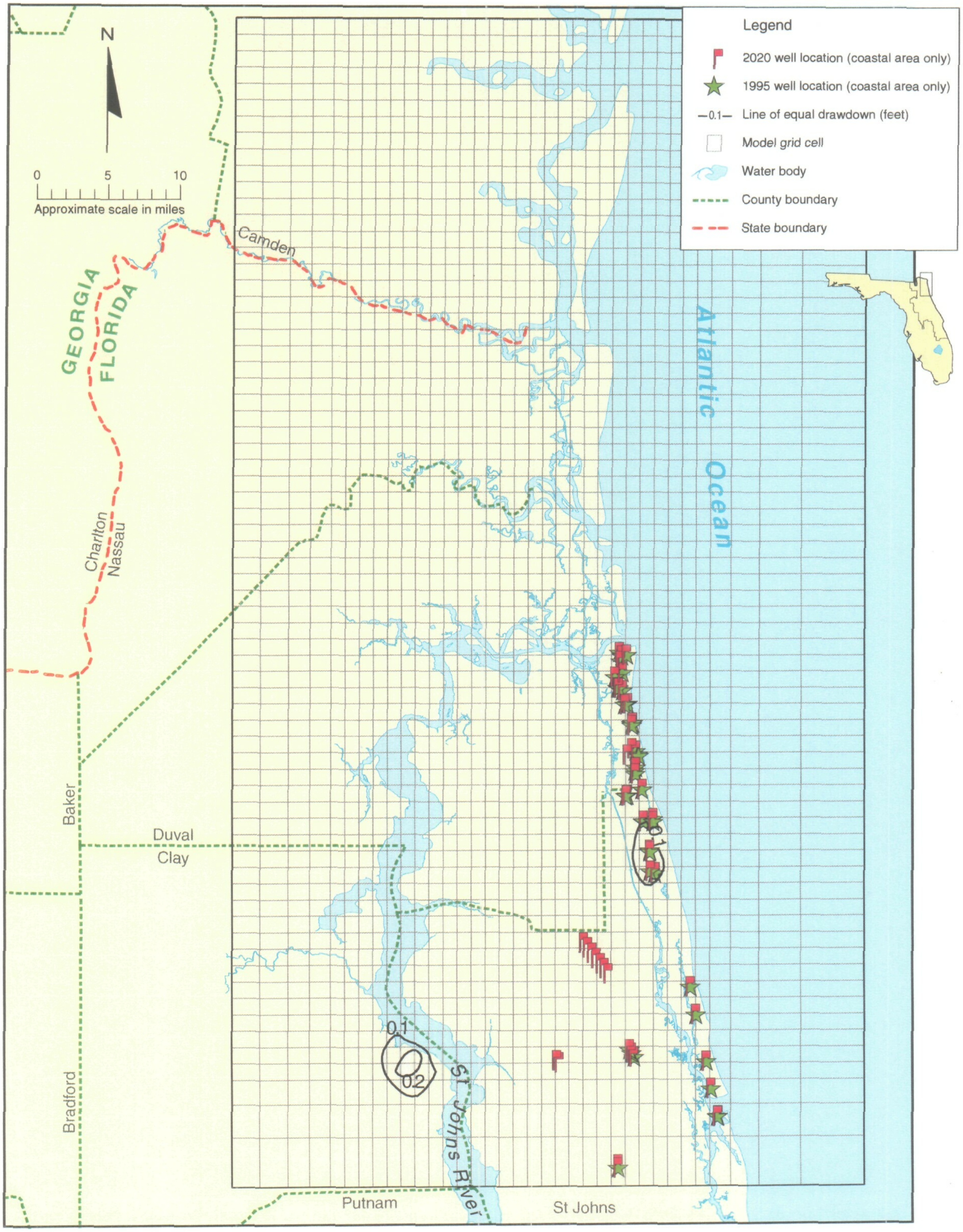


Figure 14. Simulated drawdown in the elevation of the water table of the surficial aquifer system due to changes in coastal area withdrawal rates, 1995 to 2020

REFERENCES

Bermes, B.J., G.W. Leve, and G.R. Tarver. 1963. *Geology and ground water resources of Flagler, Putnam, and St. Johns counties, Florida.* Report of Investigations 32. Tallahassee, Fla.: Florida Geological Survey.

Brown, D.P. 1984. *Impact of development on availability and quality of ground water in eastern Nassau County, Florida, and southeastern Camden County, Georgia.* Water Resources Investigations Report 83-4190. Tallahassee, Fla.: U.S. Geological Survey.

Causey, L.V., and G.G. Phelps. 1978. *Availability and quality of water from the shallow aquifer system in Duval County, Florida.* Open-File Report FL-75001. Tallahassee, Fla.: U.S. Geological Survey.

CH2M HILL. 1999a. Supplemental information for consumptive use permit application. Written response to Caroline Silvers of the St. Johns River Water Management District in response to request for additional information for consumptive use permit.

———. 1999b. Brierwood water treatment plant—construction and testing of water supply wells no. 1 through 5. Written report in support of the JEA application to the St. Johns River Water Management District for consumptive use permit.

———. 1999c. Deerwood water treatment plant no. 3—construction and testing of emergency water supply wells no. 4, 5, and 6. Written report in support of the JEA application to the St. Johns River Water Management District for consumptive use permit.

———. 1999d. Mandarin/CommunityHall water treatment plant—construction and testing of water-supply well number 5. Written report in support of the JEA application to the St. Johns River Water Management District for consumptive use permit.

Clark, W.E., R.H. Musgrove, C.G. Menke, and J.W. Cagle Jr. 1964. *Water resources of Alachua, Bradford, Clay, and Union counties, Florida.* Report of Investigations 35. Tallahassee, Fla.: Florida Geological Survey.

Clarke, J.S., C.M. Hacke, and M.F. Peck. 1990. *Geology and ground water resources of the coastal area of Georgia.* Bulletin 13. Atlanta, Ga.: Georgia Department of Natural Resources.

Durden, D.W. 1997. *Finite-difference simulation of the Floridan aquifer system in northeast Florida and Camden County, Georgia.* Technical Publication SJ97-2. Palatka, Fla.: St. Johns River Water Management District.

Fairchild, R.W. 1972. *The shallow-aquifer system in Duval County, Florida.* Report of Investigations 59. Tallahassee, Fla.: Florida Bureau of Geology.

Fanning, J.L. 1997. *Water use in Georgia by county for 1995.* Information circular 101. Atlanta, Ga.: Georgia Department of Natural Resources.

Florence, B.L. 1997. *Annual water use survey: 1995.* Technical Publication SJ97-4. Palatka, Fla.: St. Johns River Water Management District.

Franks, B.J. 1980. *The surficial aquifer at the U.S. Naval Station near Mayport, Florida.* Open-File Report 80-765. Tallahassee, Fla.: U.S. Geological Survey.

Huang, C.T., and S.A. Williams. 1996. *An iterative modeling procedure to evaluate drawdowns in a coupled-aquifer system: SURFDOWN and MODFLOW models.* Technical Publication SJ96-2. Palatka, Fla.: St. Johns River Water Management District.

Leve, G.W. 1966. *Ground water in Duval and Nassau counties, Florida.* Report of Investigations 43. Tallahassee, Fla.: Florida Geological Survey.

McDonald, M.G., and A.W. Harbaugh. 1988. *A modular three-dimensional finite-difference ground water flow model.* Techniques of Water-Resources Investigations 6-A1. Washington, D.C.: U.S. Geological Survey.

Miller, J.A. 1986. *Hydrogeologic framework of the Floridan aquifer system in Florida and in parts of Georgia, Alabama, and South Carolina.* Professional Paper 1403-B. Washington, D.C.: U.S. Geological Survey.

Motz, L.H. 1978. Steady-state drawdowns in coupled aquifers. In *Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division.* Vol. 104, No. HY7.

Phelps, G.G., and R.M. Spechler. 1997. *The relation between hydrogeology and water quality of the Lower Floridan aquifer in Duval County, Florida, and implications for monitoring movement of saline water.* Water-Resources Investigations Report 96-4242. Tallahassee, Fla.: U.S. Geological Survey.

Schiner, G.R., and E.C. Hayes. 1985. *Potentiometric surface of the Upper Floridan aquifer in the St. Johns River Water Management District and vicinity, Florida,* *September 1985.* Open-File Report 85-644. Tallahassee, Fla.: U.S. Geological Survey.

Scott, T.M. 1983. *The Hawthorn Formation of northeastern Florida: Part 1.* Report of Investigations 94. Tallahassee, Fla.: Florida Bureau of Geology.

Spechler, R.M. 1994. *Saltwater intrusion and quality of water in the Floridan aquifer system, northeastern Florida.* Water-Resources Investigations Report 92-4174. Tallahassee, Fla.: U.S. Geological Survey.

Tibbals, C.H. 1990. *Hydrology of the Floridan aquifer system in east-central Florida.* Professional Paper 1403-E. Washington, D.C.: U.S. Geological Survey.

Vergara, B.A., ed. 1994. *Water supply needs and sources assessment, 1994: St. Johns River Water Management District.* Technical Publication SJ94-7. Palatka, Fla.: St. Johns River Water Management District.

———. *Water supply assessment, 1998: St. Johns River Water Management District.* Technical Publication SJ98-2. Palatka, Fla.: St. Johns River Water Management District.

White, W.A. 1970. *The geomorphology of the Florida peninsula.* Geological Bulletin 51. Tallahassee, Fla.: Florida Bureau of Geology.

APPENDIX A— ESTIMATED 1995 WATER USE AND PROJECTED 2020 WATER USE

Table A1. Estimated 1995 water use

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Gilman Paper Company	-999	-999	Well 4	19	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 5	18	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 6	18	17	316,369	251,087	567,456
Gilman Paper Company	-999	-999	Well 8	18	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 9	19	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 10	18	17	607,988	-999	607,988
Gilman Paper Company	-999	-999	Well 11	19	17	607,988	-999	607,988
Kings Bay Naval Base	Facility 1082	-999	Well 1	15	16	66,609	-999	66,609
Kings Bay Naval Base	Facility 2019	-999	Well 2	15	16	66,609	-999	66,609
Kings Bay Naval Base	Facility 4034	-999	Well 6	15	17	66,609	-999	66,609
Kingsland, City of	-999	-999	Well 1	15	9	80,340	-999	80,340
Kingsland, City of	-999	-999	Well 2	15	9	80,340	-999	80,340
St. Marys Kraft-Bag	-999	-999	Well 4	18	16	935,829	-999	935,829
St. Marys, City of	-999	-999	Well 2	18	16	37,685	-999	37,685
St. Marys, City of	-999	-999	Well 3	17	16	37,685	-999	37,685
St. Marys, City of	-999	-999	Well GWC	18	11	37,685	-999	37,685
St. Marys, City of	-999	-999	Well PP	19	19	37,685	-999	37,685
Union Carbide	-999	-999	Well 1	6	20	44,275	-999	44,275
Woodbine, City of	-999	-999	Well 1	5	7	7,963	-999	7,963
Woodbine, City of	-999	-999	Well 2	5	8	7,963	-999	7,963
Clay County Utility Authority	Tanglewood	Well A	Well 1	55	3	26,921	-999	26,921
Clay County Utility Authority	Tanglewood	Well B	Well 2	55	3	26,921	-999	26,921
Clay County Utility Authority	Ridaught	Well A	Well 1	57	3	13,428	-999	13,428
Clay County Utility Authority	Ridaught	Well B	Well 2	57	2	13,428	-999	13,428
Clay County Utility Authority	Greenwood	Well A	Well 1	56	3	38,352	-999	38,352
Clay County Utility Authority	Meadow Lake	Well A	Well 1	60	3	4,864	12,814	17,678
Clay County Utility Authority	Meadow Lake	Well B	Well 2	60	3	5,139	13,539	18,678
Clay County Utility Authority	Branscomb Road	Well C	Well 3	60	2	1,255	-999	1,255
Clay County Utility Authority	Fleming Oaks	Well A	Well 1	58	7	23,647	-999	23,647
Clay County Utility Authority	Fleming Oaks	Well B	Well 2	58	7	5,502	18,145	23,647
Clay County Utility Authority	Pace Island	Well C	Well 3	56	7	18,078	59,268	77,346
Clay County Utility Authority	Orange Park South	Well A	Well 1	57	4	4,100	14,740	18,840
Clay County Utility Authority	Orange Park South	Well B	Well 2	57	4	29,332	-999	29,332

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Clay County Utility Authority	Lucy Branch	Well D	Well 1	54	5	56,956	-999	56,956
Clay County Utility Authority	Lucy Branch	Well E	Well 2	54	5	56,939	-999	56,939
Clay County Utility Authority	Lucy Branch	Well F	Well 3	54	5	56,939	-999	56,939
Clay County Utility Authority	Ridgecrest	Well G	Well 1	54	4	97,656	104,091	201,747
Clay County Utility Authority	Ridgecrest	Well H	Well 2	54	4	71,011	130,737	201,748
Clay County Utility Authority	Meadowbrook	Well A	Well 1	52	5	22,722	66,321	89,043
Clay County Utility Authority	Meadowbrook	Well B	Well 2	52	5	26,096	62,921	89,017
Clay County Utility Authority	Meadowbrook	Well C	Well 3	52	5	29,374	59,642	89,016
Clay County Utility Authority	Pier Station	Well 1	Well 1	64	4	4,912	-999	4,912
Green Cove Springs, City of	-999	Well A	Well HR-1	62	8	11,048	71,488	82,536
Green Cove Springs, City of	-999	Well G	Well RS-1	64	10	20,072	-999	20,072
Green Cove Springs, City of	-999	Well H	Well RS-2	64	10	18,965	-999	18,965
J-M Manufacturing Co., Inc.	-999	Well A	Well 1	64	9	10,717	-999	10,717
J-M Manufacturing Co., Inc.	-999	Well B	Well 2	64	9	10,717	-999	10,717
Orange Park, City of	-999	Well A	Well 1	52	7	113,223	-999	113,223
Orange Park, City of	-999	Well B	Well 2	52	7	102,934	-999	102,934
RGC Mineral Sands	-999	-999	Well A	68	7	77,803	103,100	180,903
Atlantic Beach, City of	WTP No. 1	Well A	Well 1	43	26	41,129	-999	41,129
Atlantic Beach, City of	WTP No. 1	Well B	Well 2	43	25	73,119	-999	73,119
Atlantic Beach, City of	WTP No. 2	Well C	Well 3	42	25	167,057	-999	167,057
Atlantic Beach, City of	WTP No. 3	Well H	Well 3W	42	25	39,145	-999	39,145
Atlantic Beach, City of	WTP No. 3	Well K	Well 6S	42	25	39,145	-999	39,145
Atlantic Beach, City of	WTP No. 4	Well F	Well 1N	41	25	31,108	-999	31,108
Atlantic Beach, City of	WTP No. 4	Well G	Well 2S	41	25	31,108	-999	31,108
Bolles School	-999	-999	-999	48	12	1,891	4,234	6,125
Bolles School	-999	-999	-999	48	12	1,891	4,234	6,125
Building Products (Celotex)	-999	Well A	-999	39	16	16,017	-999	16,017
Bush, Boake, and Allen, Inc.	-999	Well 1	Well 1	42	5	71,990	0	71,990
Bush, Boake, and Allen, Inc.	-999	Well 2	Well 2	42	5	57,837	14,176	72,013
Bush, Boake, and Allen, Inc.	-999	Well 4	Well 4	42	5	72,013	0	72,013
Bush, Boake, and Allen, Inc.	-999	Well 5	Well 5	42	5	15,835	-999	15,835
Castleton Beverages Company	-999	Well A	-999	35	12	4,046	8,616	12,662
Florida Water Services	Beacon Hill	-999	Well 1	40	19	45,777	-999	45,777

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Florida Water Services	Beacon Hill	-999	Well 2	40	19	45,777	-999	45,777
Florida Water Services	Cobblestone	-999	-999	41	21	79,862	-999	79,862
Florida Water Services	Woodmere	-999	Well 1	40	14	24,357	-999	24,357
Florida Water Services	Woodmere	-999	Well 2	40	13	48,722	-999	48,722
Jacksonville Beach, City of	WTP No. 1	Well A	Well D-482	45	26	34,965	105,245	140,210
Jacksonville Beach, City of	WTP No. 1	Well B	Well D-484	46	26	1,302	2,541	3,843
Jacksonville Beach, City of	WTP No. 1	Well C	Well D-483	46	26	9,741	31,678	41,419
Jacksonville Beach, City of	WTP No. 2	Well D	Well D-2747	47	26	1,281	-999	1,281
Jacksonville Beach, City of	WTP No. 2	Well E	Well D-2707	46	26	93,706	-999	93,706
Jacksonville Beach, City of	WTP No. 2	Well F	Well D-3034	47	26	107,719	-999	107,719
Jacksonville Electric Authority	Northside Generating Plant	Well 1	Well JEA 1	37	17	33,031	-999	33,031
Jacksonville Electric Authority	Northside Generating Plant	Well 2	Well JEA 2	37	17	33,031	-999	33,031
Jacksonville Electric Authority	Northside Generating Plant	Well 3	Well JEA 3	38	17	33,031	-999	33,031
Jacksonville Electric Authority	Northside Generating Plant	Well 4	Well JEA 4	38	17	33,031	-999	33,031
Jacksonville Electric Authority	SJR Power Park	-999	Well A	37	16	159,202	-999	159,202
Jacksonville Electric Authority	SJR Power Park	-999	Well B	37	17	159,154	-999	159,154
Jacksonville Electric Authority	SJR Power Park	-999	Well C	37	17	159,154	-999	159,154
Jacksonville International Airport	-999	-999	South Well	33	9	10,682	-999	10,682
Jacksonville International Airport	-999	-999	North Well	33	9	10,682	-999	10,682
Jacksonville Naval Air Station	Building 873 Well	-999	Well 9	50	10	892	-999	892
Jacksonville Naval Air Station	WTP No. 1	-999	Well 1	49	9	2,280	28,992	31,272
Jacksonville Naval Air Station	WTP No. 1	-999	Well 2	49	9	4,423	54,185	58,608
Jacksonville Naval Air Station	WTP No. 1	-999	Well 3	49	9	4,423	54,185	58,608
Jacksonville Naval Air Station	WTP No. 2	-999	Well 4	49	9	4,245	14,291	18,536
Jacksonville Naval Air Station	WTP No. 4	-999	Well 6	50	9	11,918	-999	11,918
Jacksonville Port Authority	Blount Island	Well 1	Well 1	39	17	817	-999	817
Jacksonville Port Authority	Blount Island	Well 2	Well 2	39	17	817	-999	817
Jacksonville Port Authority	Blount Island	Well 3	Well 3	39	17	662	3,424	4,086
Jacksonville Port Authority	Blount Island	Well 4	Well 4	39	17	487	3,599	4,086
Jacksonville University	-999	-999	Well 1	41	14	20,114	-999	20,114
Jacksonville University	-999	-999	Well 2	41	14	5,831	29,373	35,204
Jacksonville Electric Authority	Arbor Point	Well A	Well N101	43	22	13,003	-999	13,003

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jacksonville Electric Authority	Argyle Forest	Well FA	Well 0901	51	4	28,961	-999	28,961
Jacksonville Electric Authority	Argyle Forest	Well FB	Well 0902	51	4	28,961	-999	28,961
Jacksonville Electric Authority	Arlington	Well E	Well 5402	43	14	13,686	146,636	160,322
Jacksonville Electric Authority	Arlington	Well F	Well 5403	43	14	59,698	68,530	128,228
Jacksonville Electric Authority	Arlington	Well G	Well 5404	42	14	240,482	-999	240,482
Jacksonville Electric Authority	Arlington	Well H	Well 5405	42	14	147,077	53,289	200,366
Jacksonville Electric Authority	Fairfax	Well BL	Well 0301	41	8	17,047	96,101	113,148
Jacksonville Electric Authority	Fairfax	Well BO	Well 0302	41	9	13,018	77,489	90,507
Jacksonville Electric Authority	Fairfax	Well BK	Well 0303	41	8	11,163	79,344	90,507
Jacksonville Electric Authority	Fairfax	Well BI	Well 0304	41	9	5,662	39,563	45,225
Jacksonville Electric Authority	Fairfax	Well BH	Well 0305	41	9	11,469	56,396	67,865
Jacksonville Electric Authority	Fairfax	Well BM	Well 0306	41	8	9,907	53,419	63,326
Jacksonville Electric Authority	Fairfax	Well BJ	Well 0307	41	9	8,477	54,849	63,326
Jacksonville Electric Authority	Fairfax	Well BN	Well 0308	41	9	4,941	35,802	40,743
Jacksonville Electric Authority	Hendricks	Well U	Well 5001	44	11	6,528	43,007	49,535
Jacksonville Electric Authority	Hendricks	Well V	Well 5002	44	10	6,315	43,201	49,516
Jacksonville Electric Authority	Hendricks	Well W	Well 5003	44	10	3,915	25,794	29,709
Jacksonville Electric Authority	Hendricks	Well Y	Well 5501	44	11	4,755	28,916	33,671
Jacksonville Electric Authority	Hendricks	Well X	Well 5502	44	11	5,122	28,549	33,671
Jacksonville Electric Authority	Highlands	Well CQ	Well 0601	37	10	66,544	122,724	189,268
Jacksonville Electric Authority	Highlands	Well CP	Well 0602	37	10	66,544	122,724	189,268
Jacksonville Electric Authority	Highlands	Well CT	Well 0603	37	10	33,734	155,534	189,268
Jacksonville Electric Authority	Highlands	Well CS	Well 0604	37	10	43,201	146,068	189,269
Jacksonville Electric Authority	Highlands	Well CR	Well 0605	37	10	50,252	139,016	189,268
Jacksonville Electric Authority	Lakeshore	Well CI	Well 0501	46	6	2,426	25,860	28,286
Jacksonville Electric Authority	Lakeshore	Well CL	Well 0502	46	6	2,298	25,989	28,287
Jacksonville Electric Authority	Lakeshore	Well CH	Well 0503	46	6	2,426	25,860	28,286
Jacksonville Electric Authority	Lakeshore	Well CJ	Well 0504	46	6	2,758	31,192	33,950
Jacksonville Electric Authority	Lakeshore	Well CG	Well 0505	46	6	2,915	25,371	28,286
Jacksonville Electric Authority	Lovegrove	Well AB	Well 5201	45	13	13,907	111,260	125,167
Jacksonville Electric Authority	Lovegrove	Well AC	Well 5202	45	14	11,665	113,502	125,167
Jacksonville Electric Authority	Lovegrove	Well AD	Well 5203	45	14	100,144	-999	100,144
Jacksonville Electric Authority	Lovegrove	Well AE	Well 5204	45	13	11,880	128,302	140,182

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jacksonville Electric Authority	Main Street	Well BX	Well 0101	43	11	4,856	45,903	50,759
Jacksonville Electric Authority	Main Street	Well BW	Well 0102	43	11	5,757	63,882	69,639
Jacksonville Electric Authority	Main Street	Well BT	Well 0103	42	10	13,943	81,007	94,950
Jacksonville Electric Authority	Main Street	Well BY	Well 0104	43	11	5,415	57,862	63,277
Jacksonville Electric Authority	Main Street	Well BV	Well 0105	42	11	8,199	51,966	60,165
Jacksonville Electric Authority	Main Street	Well BZ	Well 0106	43	11	5,613	57,664	63,277
Jacksonville Electric Authority	Main Street	Well BR	Well 0107	42	10	8,623	54,654	63,277
Jacksonville Electric Authority	Main Street	Well BS	Well 0108	43	11	5,318	43,713	49,031
Jacksonville Electric Authority	Main Street	Well BQ	Well 0119	42	10	13,009	75,579	88,588
Jacksonville Electric Authority	Main Street	Well BP	Well 0120	42	10	13,009	75,579	88,588
Jacksonville Electric Authority	Mandarin/Community Hall	Well K	Well M501	54	12	80,044	-999	80,044
Jacksonville Electric Authority	Mandarin/Community Hall	Well L	Well M502	54	12	80,044	-999	80,044
Jacksonville Electric Authority	Mandarin/Community Hall	Well M	Well M503	54	12	200,026	-999	200,026
Jacksonville Electric Authority	Mandarin/Community Hall	Well N	Well M504	54	11	200,027	-999	200,027
Jacksonville Electric Authority	Mandarin/Hood Landing	Well Z	Well M701	54	15	659	-999	659
Jacksonville Electric Authority	Mandarin/Julington Hills	Well AA	Well M601	54	12	5,366	-999	5,366
Jacksonville Electric Authority	Mandarin/Mandarin Point	-999	Well M401	53	10	10,435	-999	10,435
Jacksonville Electric Authority	Mandarin/Mandarin Point	-999	Well M402	53	10	10,435	-999	10,435
Jacksonville Electric Authority	Mandarin/Mandarin Terrace	-999	Well M301	53	12	7,716	-999	7,716
Jacksonville Electric Authority	Mandarin/Mandarin Terrace	-999	Well M302	53	12	7,716	-999	7,716
Jacksonville Electric Authority	Mandarin/Pickwick	Well AP	Well M101	50	12	15,265	32,751	48,016
Jacksonville Electric Authority	Mandarin/Pickwick	Well AQ	Well M102	50	12	40,842	-999	40,842
Jacksonville Electric Authority	Mandarin/Pickwick	Well AR	Well M103	51	12	48,048	-999	48,048
Jacksonville Electric Authority	Mandarin/Pickwick	Well AS	Well M104	51	12	12,969	35,079	48,048
Jacksonville Electric Authority	Mandarin/Pickwick	Well J	Well M105	51	12	20,462	51,594	72,056
Jacksonville Electric Authority	Mandarin/Pickwick	-999	Well M801	51	12	16,370	41,275	57,645
Jacksonville Electric Authority	Mandarin/Southwood	-999	Well M201	52	12	2,101	6,894	8,995
Jacksonville Electric Authority	Marietta	Well DM	Well 0701	43	3	65,319	184,855	250,174
Jacksonville Electric Authority	Marietta	Well DN	Well 0702	43	3	75,753	214,382	290,135
Jacksonville Electric Authority	Marietta	Well DL	Well 0703	43	3	60,673	189,500	250,173
Jacksonville Electric Authority	Marietta	Well DJ	Well 0704	43	3	48,580	201,594	250,174
Jacksonville Electric Authority	McDuff	Well CB	Well 0201	44	7	21,942	116,753	138,695
Jacksonville Electric Authority	McDuff	Well CE	Well 0202	43	8	13,142	153,321	166,463

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jacksonville Electric Authority	McDuff	Well CA	Well 0203	44	7	10,615	72,617	83,232
Jacksonville Electric Authority	McDuff	Well CC	Well 0204	44	7	15,440	89,977	105,417
Jacksonville Electric Authority	McDuff	Well CF	Well 0205	44	7	13,288	97,640	110,928
Jacksonville Electric Authority	McDuff	Well CD	Well 0206	44	7	13,704	97,224	110,928
Jacksonville Electric Authority	Norwood	Well CZ	Well 0401	40	10	11,423	73,528	84,951
Jacksonville Electric Authority	Norwood	Well CY	Well 0402	40	10	12,877	72,074	84,951
Jacksonville Electric Authority	Norwood	Well BF	Well 0403	40	9	17,274	67,677	84,951
Jacksonville Electric Authority	Norwood	Well DA	Well 0404	40	10	28,970	72,964	101,934
Jacksonville Electric Authority	Oakridge	Well AJ	Well 5301	45	19	81,895	71,171	153,066
Jacksonville Electric Authority	Oakridge	Well AK	Well 5302	45	19	42,454	110,684	153,138
Jacksonville Electric Authority	Oakridge	Well AL	Well 5303	45	19	37,362	97,409	134,771
Jacksonville Electric Authority	Oakridge	Well AM	Well 5304	45	19	20,721	114,049	134,770
Jacksonville Electric Authority	Oakridge	Well AN	Well 5305	45	19	153,139	0	153,139
Jacksonville Electric Authority	River Oaks	Well AT	Well 5101	45	11	2,368	44,866	47,234
Jacksonville Electric Authority	River Oaks	Well AU	Well 5102	45	11	5,981	75,545	81,526
Jacksonville Electric Authority	River Oaks	Well AV	Well 5104	45	11	1,572	19,860	21,432
Jacksonville Electric Authority	River Oaks	Well AW	Well 5105	45	11	11,651	18,396	30,047
Jacksonville Electric Authority	River Oaks	Well AX	Well 5107	45	11	64,338	-999	64,338
Jacksonville Electric Authority	River Oaks	Well AY	Well 5108	44	11	8,479	55,859	64,338
Jacksonville Electric Authority	River Oaks	Well AZ	Well 5110	45	11	9,522	97,723	107,245
Jacksonville Electric Authority	Southwest	Well DF	Well 0801	48	4	41,870	265,177	307,047
Jacksonville Electric Authority	Southwest	Well DG	Well 0802	48	4	46,043	260,912	306,955
Jacksonville Electric Authority	Southwest	Well DE	Well 0803	48	3	40,124	266,832	306,956
Jacksonville Electric Authority	Sunni Pines	Well BC	Well N302	44	23	32,236	-999	32,236
Jacksonville Electric Authority	Sunni Pines	Well BB	Well N301	45	23	32,236	-999	32,236
Jacksonville Electric Authority	Brierwood Main	Well DU	Well 1D01	49	14	6,857	39,337	46,194
Jacksonville Electric Authority	Brierwood Main	Well DV	Well 1D02	49	14	25,894	-999	25,894
Jacksonville Electric Authority	Brierwood Plaza	Well DW	Well 1D03	49	14	12,187	-999	12,187
Jacksonville Electric Authority	Mayport	Well DZ	Well 8A01	39	24	6,935	9,631	16,566
Jacksonville Electric Authority	Sheffield Village	Well EB	Well D101	35	16	764	-999	764
Jacksonville Electric Authority	Sheffield Village	Well EC	Well D102	35	16	764	-999	764
Jacksonville Electric Authority	Springtree Village/Shadowrock	Well ED	Well D401	46	3	6,193	-999	6,193
Jacksonville Electric Authority	Springtree Village/Shadowrock	Well EE	Well D402	46	3	3,096	-999	3,096

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jacksonville Electric Authority	Buckman	Well A	-999	42	12	69,786	-999	69,786
Jacksonville Electric Authority	District II	Well A	Well D301	37	13	1,983	8,531	10,514
Jacksonville Electric Authority	Deerwood No. 1	Well O	Well 5601	50	17	13,735	11,476	25,211
Jacksonville Electric Authority	Deerwood No. 1	Well P	Well 5602	50	18	48,458	1,969	50,427
Jacksonville Electric Authority	Deerwood No. 3	Well Q	Well 5701	48	17	196,477	-999	196,477
Jacksonville Electric Authority	Deerwood No. 3	Well R	Well 5702	49	17	252,613	-999	252,613
Jacksonville Electric Authority	Deerwood No. 3	Well S	Well 5703	49	17	252,613	-999	252,613
Jacksonville Electric Authority	Southeast	Well BD	Well 5801	47	23	82,228	-999	82,228
Jacksonville Electric Authority	Southeast	Well BE	Well 5802	47	23	82,228	-999	82,228
Jefferson Smurfit, Jacksonville	-999	-999	Well 1	41	12	40,768	121,860	162,628
Jefferson Smurfit, Jacksonville	-999	-999	Well 2	41	12	15,205	66,109	81,314
Jefferson Smurfit, Jacksonville	-999	-999	Well 3	41	12	15,205	66,109	81,314
Jefferson Smurfit, Jacksonville	-999	-999	Well 4	41	12	15,205	66,109	81,314
Jefferson Smurfit, Jacksonville	-999	-999	Well 5	41	12	15,205	66,109	81,314
Jefferson Smurfit, Jacksonville	-999	-999	Well 7	41	12	203,330	-999	203,330
Jefferson Smurfit, Jacksonville	-999	-999	Well 8	41	12	159,883	43,446	203,329
Lamplighter Mobile Home Park	-999	-999	-999	45	2	3,886	-999	3,886
Lamplighter Mobile Home Park	-999	-999	-999	45	2	3,886	-999	3,886
Mayport Naval Station	-999	Well B	Well B	39	25	32,116	-999	32,116
Mayport Naval Station	-999	Well C	Well C	40	25	58,031	-999	58,031
Mayport Naval Station	-999	Well D	Well D	40	25	45,841	-999	45,841
Mayport Naval Station	-999	Well E	Well E	40	26	55,977	-999	55,977
Millennium Specialty Chemicals	-999	-999	Well 5	40	10	13,761	34,660	48,421
Millennium Specialty Chemicals	-999	-999	Well 7	40	10	48,421	-999	48,421
Millennium Specialty Chemicals	-999	-999	Well 9	40	10	48,421	-999	48,421
Millennium Specialty Chemicals	-999	-999	Well 10	40	10	48,421	-999	48,421
Millennium Specialty Chemicals	-999	-999	Well 11	40	10	48,421	-999	48,421
Neighborhood Utilities	-999	Well A	-999	46	2	3,260	-999	3,260
Neighborhood Utilities	-999	Well B	-999	46	2	3,260	-999	3,260
Neptune Beach, City of	-999	-999	-999	44	26	40,303	-999	40,303
Neptune Beach, City of	-999	-999	-999	44	26	40,303	-999	40,303
Neptune Beach, City of	-999	-999	-999	44	26	40,303	-999	40,303
Neptune Beach, City of	-999	-999	-999	44	26	40,303	-999	40,303

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Normandy Village Utilities	-999	-999	Well 1	26	4	6,703	19,500	26,203
Normandy Village Utilities	-999	-999	Well 2	46	4	26,203	-999	26,203
Oaks of Atlantic Beach MHP	-999	-999	Well 1	41	25	10,336	-999	10,336
Ortega Utility Company	Airport	-999	-999	34	11	11,283	-999	11,283
Ortega Utility Company	Airport	-999	-999	34	11	11,283	-999	11,283
Ortega Utility Company	Blanding	-999	-999	50	6	26,968	24,200	51,168
Ortega Utility Company	Blanding	-999	-999	50	6	26,968	24,200	51,168
Regency Utilities, Inc.	-999	-999	-999	43	17	80,456	-999	80,456
Regency Utilities, Inc.	-999	-999	-999	43	17	80,456	-999	80,456
Reichhold Chemicals, Inc.	-999	-999	-999	43	5	1,843	16,870	18,713
Simplex Products	-999	-999	-999	36	13	31,765	-999	31,765
Simplex Products	-999	-999	-999	36	13	31,765	-999	31,765
Stone Container Corporation	-999	Well 4	Well 4	37	14	28,620	196,761	225,381
Stone Container Corporation	-999	Well 5	Well 5	37	14	35,699	200,809	236,508
Stone Container Corporation	-999	Well 7	Well 7	37	14	28,887	207,622	236,509
Stone Container Corporation	-999	Well 8	Well 8	37	14	31,274	205,235	236,509
Stone Container Corporation	-999	Well 9	Well 9	36	14	35,872	200,637	236,509
Swisher International	-999	Well 2	-999	41	11	13,296	-999	13,296
United States Gypsum	-999	-999	Well A	40	12	24,098	-999	24,098
United States Gypsum	-999	-999	Well B	40	12	30,128	-999	30,128
United Water Florida	Alderman Park onsite	Well A	Well 1	43	16	13,079	27,024	40,103
United Water Florida	Alderman Park offsite	Well B	Well 2	43	16	7,040	14,545	21,585
United Water Florida	Columbine	Well C	-999	42	15	16,419	55,140	71,559
United Water Florida	Elvia	Well D	-999	42	16	11,079	92,038	103,117
United Water Florida	Forest Brook	Well A	Well A	48	6	6,205	-999	6,205
United Water Florida	Green Forest	Well B	Well B	48	4	6,048	32,254	38,302
United Water Florida	Holly Oaks	Well A	-999	41	18	527	-999	527
United Water Florida	Hyde Grove	Well A	Well A	45	4	19,423	-999	19,423
United Water Florida	Lake Forest	Well A	Well 1	39	9	22,617	0	22,617
United Water Florida	Lake Lucina	Well E	-999	42	14	10,431	75,588	86,019
United Water Florida	Magnolia Gardens	Well A	Well 1	40	8	22,914	-999	22,914
United Water Florida	Monument Road	Well C	Well 1	42	18	131,100	-999	131,100
United Water Florida	Oak Hill	Well A	-999	48	4	3,407	35,209	38,616

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
United Water Florida	Ortega Hills subdivision	Well B	Well 2	50	7	5,799	-999	5,799
United Water Florida	Ortega Hills subdivision	Well A	Well 1	50	7	5,082	5,228	10,310
United Water Florida	Queen Akers	Well B	-999	43	18	20,559	-999	20,559
United Water Florida	Royal Lakes (offsite)	Well A	Well 1	50	16	9,716	149,200	158,916
United Water Florida	Royal Lakes (onsite)	Well B	Well 2	50	16	16,684	248,175	264,859
United Water Florida	San Jose	Well A	Well 1	48	12	7,659	68,241	75,900
United Water Florida	San Jose	Well B	Well 2	48	13	8,718	68,058	76,776
United Water Florida	San Jose	Well C	Well 3	48	12	12,309	127,273	139,582
United Water Florida	San Pablo/Marshview	Well A	-999	46	24	24,024	-999	24,024
United Water Florida	San Pablo/Marshview	Well B	-999	46	24	38,441	-999	38,441
United Water Florida	University Park	Well F	-999	41	14	38,089	-999	38,089
United Water Florida	Venetia Terrace	Well A	Well A	48	7	7,212	-999	7,212
United Water Florida	Wheat Road	Well C	-999	47	5	12,593	75,759	88,352
Callahan, City of	-999	Well A	-999	29	2	9,810	-999	9,810
Callahan, City of	-999	Well B	-999	29	2	11,774	-999	11,774
Florida Public Utilities	WTP No. 1	Well A	Well 5	22	23	111,633	-999	111,633
Florida Public Utilities	WTP No. 1	Well D	Well 8	24	23	152,963	-999	152,963
Florida Public Utilities	WTP No. 2	Well B	Well 6	24	23	90,482	-999	90,482
Florida Public Utilities	WTP No. 2	Well C	Well 7	22	23	74,872	-999	74,872
Florida Water Services	Amelia Island	Well A	Well 1	28	23	75,179	-999	75,179
Florida Water Services	Amelia Island	Well B	Well 2	28	23	75,179	-999	75,179
Jefferson Smurfit, Fernandina Beach	-999	Well D	Well 4	22	23	245,642	-999	245,642
Jefferson Smurfit, Fernandina Beach	-999	Well F	Well 6	21	23	245,386	-999	245,386
Jefferson Smurfit, Fernandina Beach	-999	Well I	Well 9	22	23	414,618	-999	414,618
Jefferson Smurfit, Fernandina Beach	-999	Well J	Well 10	22	23	414,618	-999	414,618
Jefferson Smurfit, Fernandina Beach	-999	Well L	Well 12	22	23	414,618	-999	414,618
Jefferson Smurfit, Fernandina Beach	-999	Well N	Well 14	22	23	414,618	-999	414,618

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jefferson Smurfit, Fernandina Beach	-999	Well H	Well 8	22	22	414,618	-999	414,618
Rayonier	-999	Well A	Well 1	23	22	261,535	-999	261,535
Rayonier	-999	Well E	Well 5	24	22	222,984	-999	222,984
Rayonier	-999	Well F	Well 6	24	22	236,877	-999	236,877
Rayonier	-999	Well G	Well 7	23	21	48,080	-999	48,080
Rayonier	-999	Well K	Well 11	23	22	358,752	-999	358,752
Rayonier	-999	Well L	Well 12	25	22	349,348	-999	349,348
Rayonier	-999	Well M	Well 13	23	21	344,246	-999	344,246
Rayonier	-999	Well O	Well 15	23	22	220,393	-999	220,393
Fruit Cove Oaks subdivision	-999	Well A	Well 1	56	12	1,838	-999	1,838
Fruit Cove Oaks subdivision	-999	Well B	Well 2	56	12	4,289	-999	4,289
Intercoastal Utilities	WTP No. 1 (Sawgrass)	Well A	Well 1	52	27	29,214	-999	29,214
Intercoastal Utilities	WTP No. 1 (Sawgrass)	Well B	Well 2	52	27	29,214	-999	29,214
Intercoastal Utilities	WTP No. 2 (Plantation)	Well C	Well 3	53	28	42,658	-999	42,658
Intercoastal Utilities	WTP No. 2 (Plantation)	Well D	Well 4	53	27	42,658	-999	42,658
JCP Utility	GDU, Julington Creek subdivision	Well A	Well 1	56	14	18,341	-999	18,341
JCP Utility	GDU, Julington Creek subdivision	Well B	Well 2	56	14	18,341	-999	18,341
North Beach Utilities	-999	Well A	Well 1	66	32	7,474	-999	7,474
North Beach Utilities	-999	Well B	Well 2	66	32	22,421	-999	22,421
St. Augustine, City of	-999	Well K	Well 8-2	64	26	23,936	-999	23,936
St. Augustine, City of	-999	Well L	Well 9	64	26	28,987	-999	28,987
St. Augustine, City of	-999	Well M	Well 10-2	64	26	29,226	-999	29,226
St. Johns County	Mainland	Well O	Well TR42	68	25	160,160	-999	160,160
St. Johns Service Company	Inlet Beach	Well 2	Well B	50	27	65,453	-999	65,453
St. Johns Service Company	Inlet Beach	Well 3	Well C	50	27	65,453	-999	65,453
St. Johns Service Company	Marsh Landing	Well 1	Well D	48	26	52,362	-999	52,362
St. Johns Service Company	Marsh Landing	Well 2	Well E	48	26	78,544	-999	78,544
United Water Florida	Ponte Vedra North	Well A	Well 1	48	27	41,393	-999	41,393
United Water Florida	Corona Road	Well B	Well 1	50	27	50,100	-999	50,100
United Water Florida	Corona Road	Well C	Well 2	60	30	72,155	-999	72,155
United Water Florida	A1A South	Well D	Well A1AS	64	31	689	-999	689
United Water Florida	A1A North	Well E	Well A1AN	62	31	1,275	-999	1,275
United Water Florida	Ponce de Leon	Well C	-999	48	27	10,679	-999	10,679

Table A1—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
United Water Florida	Ponce de Leon	Well B	Well 2	50	27	10,679	-999	10,679
United Water Florida	St. Johns Forest	Well A	-999	59	18	455	-999	455
United Water Florida	St. Johns Forest	Well H	-999	59	18	1,546	-999	1,546
United Water Florida	St. Johns Forest	Well K	-999	59	18	545	-999	545
United Water Florida	St. Johns Forest	Well L	-999	59	18	1,546	-999	1,546
United Water Florida	St. Johns North	Well A	Well 1	57	13	7,911	-999	7,911
United Water Florida	St. Johns North	Well B	Well 2	58	13	8,329	-999	8,329
United Water Florida	St. Johns North	Well C	Well 3	57	13	27,758	-999	27,758
Wesley Manor Retirement Center	-999	Well 1	-999	55	12	3,927	4,618	8,545
Total								30,526,941

Note: cfd = cubic feet per day
CUP = consumptive use permit
MHP = mobile home park

-999 indicates that well does not draw from the Lower Floridan aquifer.

Table A2. Projected 2020 water use

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Gilman Paper Company	-999	-999	Well 4	19	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 5	18	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 6	18	17	316,369	251,087	567,456
Gilman Paper Company	-999	-999	Well 8	18	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 9	19	17	567,456	-999	567,456
Gilman Paper Company	-999	-999	Well 10	18	17	607,988	-999	607,988
Gilman Paper Company	-999	-999	Well 11	18	17	607,988	-999	607,988
Kings Bay Naval Base	Facility 1082	-999	Well 1	15	16	66,609	-999	66,609
Kings Bay Naval Base	Facility 2019	-999	Well 2	15	16	66,609	-999	66,609
Kings Bay Naval Base	Facility 4034	-999	Well 6	15	17	66,609	-999	66,609
Kingsland, City of	-999	-999	Well 1	15	9	80,340	-999	80,340
Kingsland, City of	-999	-999	Well 2	15	9	80,340	-999	80,340
St. Marys Kraft-Bag	-999	-999	Well 4	18	16	935,829	-999	935,829
St. Marys, City of	-999	-999	Well 2	18	16	37,685	-999	37,685
St. Marys, City of	-999	-999	Well 3	17	15	37,685	-999	37,685
St. Marys, City of	-999	-999	Well GWC	18	11	37,685	-999	37,685
St. Marys, City of	-999	-999	Well PP	19	19	37,685	-999	37,685
Union Carbide	-999	-999	Well 1	6	20	44,275	-999	44,275
Woodbine, City of	-999	-999	Well 1	5	7	7,963	-999	7,963
Woodbine, City of	-999	-999	Well 2	5	8	7,963	-999	7,963
Clay County Utility Authority	Tanglewood	Well A	Well 1	55	3	52,037	-999	52,037
Clay County Utility Authority	Tanglewood	Well B	Well 2	55	3	52,037	-999	52,037
Clay County Utility Authority	Ridaught	Well A	Well 1	57	3	25,955	-999	25,955
Clay County Utility Authority	Ridaught	Well B	Well 2	57	2	25,955	-999	25,955
Clay County Utility Authority	Greenwood	Well A	Well 1	56	3	74,133	-999	74,133
Clay County Utility Authority	Meadow Lake	Well A	Well 1	60	3	9,402	24,769	34,171
Clay County Utility Authority	Meadow Lake	Well B	Well 2	60	3	9,934	26,171	36,105
Clay County Utility Authority	Branscomb Road	Well C	Well 3	60	2	2,426	-999	2,426
Clay County Utility Authority	Fleming Oaks	Well A	Well 1	58	7	45,707	-999	45,707
Clay County Utility Authority	Fleming Oaks	Well B	Well 2	58	7	10,634	35,073	45,707
Clay County Utility Authority	Pace Island	Well C	Well 3	56	7	34,944	114,561	149,505
Clay County Utility Authority	Orange Park South	Well A	Well 1	57	4	7,926	28,491	36,417
Clay County Utility Authority	Orange Park South	Well B	Well 2	57	4	56,697	-999	56,697
Clay County Utility Authority	Lucy Branch	Well D	Well 1	54	5	110,092	-999	110,092

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Clay County Utility Authority	Lucy Branch	Well E	Well 2	54	5	110,059	-999	110,059
Clay County Utility Authority	Lucy Branch	Well F	Well 3	54	5	110,059	-999	110,059
Clay County Utility Authority	Ridgecrest	Well G	Well 1	54	4	188,763	201,201	389,964
Clay County Utility Authority	Ridgecrest	Well H	Well 2	54	4	137,259	252,706	389,965
Clay County Utility Authority	Meadowbrook	Well A	Well 1	52	5	43,920	128,194	172,114
Clay County Utility Authority	Meadowbrook	Well B	Well 2	52	5	50,441	121,622	172,063
Clay County Utility Authority	Meadowbrook	Well C	Well 3	52	5	56,778	115,285	172,063
Clay County Utility Authority	Pier Station	Well 1	Well 1	64	4	9,494	-999	9,494
Green Cove Springs, City of	-999	Well A	Well HR-1	62	8	17,981	116,347	134,328
Green Cove Springs, City of	-999	Well G	Well RS-1	64	10	32,667	-999	32,667
Green Cove Springs, City of	-999	Well H	Well RS-2	64	10	30,866	-999	30,866
J-M Manufacturing Co., Inc.	-999	Well A	Well 1	64	9	17,352	-999	17,352
J-M Manufacturing Co., Inc.	-999	Well B	Well 2	64	9	17,352	-999	17,352
Orange Park, City of	-999	Well A	Well 1	52	7	122,547	-999	122,547
Orange Park, City of	-999	Well B	Well 2	52	7	111,410	-999	111,410
RGC Mineral Sands	-999	-999	Well A	68	7	85,096	-999	85,096
Atlantic Beach, City of	WTP No. 1	Well A	Well 1	43	26	105,979	-999	105,979
Atlantic Beach, City of	WTP No. 1	Well B	Well 2	43	25	188,408	-999	188,408
Atlantic Beach, City of	WTP No. 2	Well C	Well 3	42	25	430,463	-999	430,463
Atlantic Beach, City of	WTP No. 3	Well H	Well 3W	42	25	100,868	-999	100,868
Atlantic Beach, City of	WTP No. 3	Well K	Well 6S	42	25	100,868	-999	100,868
Atlantic Beach, City of	WTP No. 4	Well F	Well 1N	41	25	80,156	-999	80,156
Atlantic Beach, City of	WTP No. 4	Well G	Well 2S	41	25	80,156	-999	80,156
Bolles School	-999	-999	-999	48	12	2,496	5,589	8,085
Bolles School	-999	-999	-999	48	12	2,496	5,589	8,085
Building Products (Celotex)	-999	Well A	-999	39	16	33,422	-999	33,422
Bush, Boake, and Allen, Inc.	-999	Well 1	Well 1	42	5	94,229	0	94,229
Bush, Boake, and Allen, Inc.	-999	Well 2	Well 2	42	5	75,705	18,555	94,260
Bush, Boake, and Allen, Inc.	-999	Well 4	Well 4	42	5	94,260	0	94,260
Bush, Boake, and Allen, Inc.	-999	Well 5	Well 5	42	5	20,727	-999	20,727
Castleton Beverages Company	-999	Well A	-999	35	12	5,340	11,374	16,714
Florida Water Services	Beacon Hills	-999	Well 1	40	19	160,428	-999	160,428
Florida Water Services	Beacon Hills	-999	Well 2	40	19	160,428	-999	160,428
Florida Water Services	Woodmere	-999	Well 1	40	14	38,249	-999	38,249

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Florida Water Services	Woodmere	-999	Well 2	40	13	76,510	-999	76,510
Jacksonville Beach, City of	WTP No. 1	Well A	Well D-482 (11)	45	26	80,928	-999	80,928
Jacksonville Beach, City of	WTP No. 1	-999	-999	45	26	80,928	-999	80,928
Jacksonville Beach, City of	WTP No. 1	-999	-999	45	26	80,928	-999	80,928
Jacksonville Beach, City of	WTP No. 2	Well D	Well D-2747	47	26	1,676	-999	1,676
Jacksonville Beach, City of	WTP No. 2	Well E	Well D-2707	46	26	122,636	-999	122,636
Jacksonville Beach, City of	WTP No. 2	Well F	Well D-3034	47	26	140,976	-999	140,976
Jacksonville Electric Authority	Northside Generating Plant	Well 1	Well JEA 1	37	17	33,422	-999	33,422
Jacksonville Electric Authority	Northside Generating Plant	Well 2	Well JEA 2	37	17	33,422	-999	33,422
Jacksonville Electric Authority	Northside Generating Plant	Well 3	Well JEA 3	38	17	33,422	-999	33,422
Jacksonville Electric Authority	Northside Generating Plant	Well 4	Well JEA 4	38	17	33,422	-999	33,422
Jacksonville Electric Authority	SJR Power Park	-999	Well A	37	16	228,655	-999	228,655
Jacksonville Electric Authority	SJR Power Park	-999	Well B	37	17	228,587	-999	228,587
Jacksonville Electric Authority	SJR Power Park	-999	Well C	37	17	228,587	-999	228,587
Jacksonville International Airport	-999	-999	South Well	33	9	14,101	-999	14,101
Jacksonville International Airport	-999	-999	North Well	33	9	14,101	-999	14,101
Jacksonville Naval Air Station	Bldg 873 well (Kemen Test Cell)	-999	Well 9	50	10	1,319	-999	1,319
Jacksonville Naval Air Station	WTP No. 1	-999	Well 1	49	9	3,372	42,890	46,262
Jacksonville Naval Air Station	WTP No. 1	-999	Well 2	49	9	6,543	80,161	86,704
Jacksonville Naval Air Station	WTP No. 1	-999	Well 3	49	9	6,543	80,161	86,704
Jacksonville Naval Air Station	WTP No. 2	-999	Well 4	49	9	6,280	21,142	27,422
Jacksonville Naval Air Station	WTP No. 4	-999	Well 6	50	9	17,631	-999	17,631
Jacksonville Port Authority	Blount Island	Well 1	Well 1	39	17	1,078	-999	1,078
Jacksonville Port Authority	Blount Island	Well 2	Well 2	39	17	1,078	-999	1,078
Jacksonville Port Authority	Blount Island	Well 3	Well 3	39	17	874	4,519	5,393
Jacksonville Port Authority	Blount Island	Well 4	Well 4	39	17	643	4,750	5,393
Jacksonville University	-999	-999	Well 1	41	14	26,249	-999	26,249
Jacksonville University	-999	-999	Well 2	41	14	7,610	38,333	45,943
Jacksonville Electric Authority	Arlington	Well E	Well 5402	43	14	20,570	220,388	240,958
Jacksonville Electric Authority	Arlington	Well F	Well 5403	43	14	89,723	102,999	192,722
Jacksonville Electric Authority	Arlington	Well G	Well 5404	42	14	361,436	-999	361,436
Jacksonville Electric Authority	Arlington	Well H	Well 5405	42	14	221,051	80,091	301,142

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jacksonville Electric Authority	Brierwood	-999	Well 1	47	13	133,690	-999	133,690
Jacksonville Electric Authority	Brierwood	-999	Well 2	47	13	133,690	-999	133,690
Jacksonville Electric Authority	Brierwood	-999	Well 3	47	13	133,690	-999	133,690
Jacksonville Electric Authority	Brierwood	-999	Well 4	48	13	133,689	-999	133,689
Jacksonville Electric Authority	Brierwood	-999	Well 5	48	13	133,689	-999	133,689
Jacksonville Electric Authority	Cecil Field	-999	-999	48	1	541,444	1,624,331	2,165,775
Jacksonville Electric Authority	Highlands	Well CQ	Well 0601	37	10	141,950	261,793	403,743
Jacksonville Electric Authority	Highlands	Well CP	Well 0602	37	10	141,950	261,793	403,743
Jacksonville Electric Authority	Highlands	Well CT	Well 0603	37	10	71,960	331,783	403,743
Jacksonville Electric Authority	Highlands	Well CS	Well 0604	37	10	92,155	311,589	403,744
Jacksonville Electric Authority	Highlands	Well CR	Well 0605	37	10	107,196	296,547	403,743
Jacksonville Electric Authority	Lakeshore	Well CI	Well 0501	46	6	30,872	329,048	359,920
Jacksonville Electric Authority	Lakeshore	Well CL	Well 0502	46	6	29,237	330,683	359,920
Jacksonville Electric Authority	Lakeshore	Well CH	Well 0503	46	6	30,872	329,048	359,920
Jacksonville Electric Authority	Lakeshore	Well CJ	Well 0504	46	6	35,091	396,888	431,979
Jacksonville Electric Authority	Lakeshore	Well CG	Well 0505	46	6	37,095	322,825	359,920
Jacksonville Electric Authority	Main Street	Well BX	Well 0101	43	11	10,515	99,389	109,904
Jacksonville Electric Authority	Main Street	Well BW	Well 0102	43	10	12,465	138,315	150,780
Jacksonville Electric Authority	Main Street	Well BT	Well 0103	42	10	30,189	175,394	205,583
Jacksonville Electric Authority	Main Street	Well BY	Well 0104	43	11	11,725	125,280	137,005
Jacksonville Electric Authority	Main Street	Well BV	Well 0105	42	11	17,752	112,515	130,267
Jacksonville Electric Authority	Main Street	Well BZ	Well 0106	43	11	12,152	124,853	137,005
Jacksonville Electric Authority	Main Street	Well BR	Well 0107	42	10	18,671	118,335	137,006
Jacksonville Electric Authority	Main Street	Well BS	Well 0108	43	11	11,515	94,645	106,160
Jacksonville Electric Authority	Main Street	Well BQ	Well 0119	42	10	28,166	163,641	191,807
Jacksonville Electric Authority	Main Street	Well BP	Well 0120	42	10	28,166	163,641	191,807
Jacksonville Electric Authority	N.W. Regional/Mall	-999	-999	34	11	464,572	1,393,717	1,858,289
Jacksonville Electric Authority	Mandarin/Community Hall	Well K	Well M501	54	12	48,075	-999	48,075
Jacksonville Electric Authority	Mandarin/Community Hall	Well L	Well M502	54	12	48,075	-999	48,075
Jacksonville Electric Authority	Mandarin/Community Hall	Well M	Well M503	54	12	192,299	-999	192,299
Jacksonville Electric Authority	Mandarin/Community Hall	Well N	Well M504	54	11	243,476	-999	243,476
Jacksonville Electric Authority	Mandarin/Community Hall	-999	Well M505	54	11	214,741	-999	214,741
Jacksonville Electric Authority	Ridenour	-999	Well 5901	43	20	677,294	-999	677,294
Jacksonville Electric Authority	Ridenour	-999	Well 5902	43	20	677,294	-999	677,294

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jacksonville Electric Authority	Ridenour	-999	Well 5903	43	20	677,294	-999	677,294
Jacksonville Electric Authority	Deerwood No. 3	Well Q	Well 5701	48	17	226,761	-999	226,761
Jacksonville Electric Authority	Deerwood No. 3	Well R	Well 5702	49	17	283,492	-999	283,492
Jacksonville Electric Authority	Deerwood No. 3	Well S	Well 5703	49	17	283,492	-999	283,492
Jacksonville Electric Authority	Deerwood No. 3	-999	Well 4	49	17	283,492	-999	283,492
Jacksonville Electric Authority	Deerwood No. 3	-999	Well 5	48	17	283,492	-999	283,492
Jacksonville Electric Authority	Deerwood No. 3	-999	Well 6	48	17	283,656	-999	283,656
Jacksonville Electric Authority	Southeast	Well BD	Well 5801	47	23	655,080	-999	655,080
Jacksonville Electric Authority	Southeast	Well BE	Well 5802	47	23	655,080	-999	655,080
Jacksonville Electric Authority	Southwest	Well DF	Well 0801	48	4	88,739	562,015	650,754
Jacksonville Electric Authority	Southwest	Well DG	Well 0802	48	4	97,584	552,975	650,559
Jacksonville Electric Authority	Southwest	Well DE	Well 0803	48	3	85,038	565,521	650,559
Jacksonville Electric Authority	Westlake	-999	-999	40	1	508,022	1,524,065	2,032,087
Jefferson Smurfit, Jacksonville	-999	-999	Well 1	41	12	40,761	121,839	162,600
Jefferson Smurfit, Jacksonville	-999	-999	Well 2	41	12	15,202	66,097	81,299
Jefferson Smurfit, Jacksonville	-999	-999	Well 3	41	12	15,202	66,097	81,299
Jefferson Smurfit, Jacksonville	-999	-999	Well 4	41	12	15,202	66,097	81,299
Jefferson Smurfit, Jacksonville	-999	-999	Well 5	41	12	15,202	66,097	81,299
Jefferson Smurfit, Jacksonville	-999	-999	Well 7	41	12	203,294	-999	203,294
Jefferson Smurfit, Jacksonville	-999	-999	Well 8	41	12	159,855	43,439	203,294
Lamplighter Mobile Home Park	-999	-999	-999	45	2	5,091	-999	5,091
Lamplighter Mobile Home Park	-999	-999	-999	45	2	5,091	-999	5,091
Mayport Naval Station	-999	Well B	Well B	39	25	42,272	-999	42,272
Mayport Naval Station	-999	Well C	Well C	40	25	76,383	-999	76,383
Mayport Naval Station	-999	Well D	Well D	40	25	60,338	-999	60,338
Mayport Naval Station	-999	Well E	Well E	40	26	73,680	-999	73,680
Millennium Specialty Chemicals	-999	-999	Well 5	40	10	37,995	95,695	133,690
Millennium Specialty Chemicals	-999	-999	Well 7	40	10	133,690	-999	133,690
Millennium Specialty Chemicals	-999	-999	Well 9	40	10	133,690	-999	133,690
Millennium Specialty Chemicals	-999	-999	Well 10	40	10	133,690	-999	133,690
Millennium Specialty Chemicals	-999	-999	Well 11	40	10	133,690	-999	133,690
Neighborhood Utilities	-999	Well A	-999	46	2	4,270	-999	4,270
Neighborhood Utilities	-999	Well B	-999	46	2	4,270	-999	4,270
Neptune Beach, City of	-999	Well A	-999	44	26	72,193	-999	72,193

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Neptune Beach, City of	-999	Well B	-999	44	26	72,193	-999	72,193
Neptune Beach, City of	-999	Well C	-999	44	26	72,193	-999	72,193
Neptune Beach, City of	-999	Well D	-999	44	26	72,193	-999	72,193
Normandy Village Utilities	-999	Well A	Well 1	26	4	8,721	25,370	34,091
Normandy Village Utilities	-999	Well B	Well 2	46	4	34,091	-999	34,091
Oaks of Atlantic Beach MHP	-999	-999	Well 1	41	25	13,540	-999	13,540
Ortega Utility Company	Airport	-999	-999	34	11	14,854	-999	14,854
Ortega Utility Company	Airport	-999	-999	34	11	14,854	-999	14,854
Ortega Utility Company	Blanding	-999	-999	50	6	35,505	31,860	67,365
Ortega Utility Company	Blanding	-999	-999	50	6	35,505	31,860	67,365
Regency Utilities, Inc.	-999	-999	-999	43	17	105,241	-999	105,241
Regency Utilities, Inc.	-999	-999	-999	43	17	105,241	-999	105,241
Reichhold Chemicals, Inc.	-999	-999	-999	43	5	2,432	22,269	24,701
St. Joe Utilities, Inc.	Riverton	-999	-999	60	11	487,834	-999	487,834
Simplex Products	-999	-999	-999	36	13	32,086	-999	32,086
Simplex Products	-999	-999	-999	36	13	32,086	-999	32,086
Stone Container Corporation	-999	Well 4	Well 4	37	14	27,306	187,729	215,035
Stone Container Corporation	-999	Well 5	Well 5	37	14	34,061	191,592	225,653
Stone Container Corporation	-999	Well 7	Well 7	37	14	27,561	198,092	225,653
Stone Container Corporation	-999	Well 8	Well 8	37	14	29,838	195,815	225,653
Stone Container Corporation	-999	Well 9	Well 9	36	14	34,225	191,428	225,653
Swisher International	-999	Well 2	-999	41	11	17,550	-999	17,550
United States Gypsum	-999	-999	Well A	40	12	24,359	-999	24,359
United States Gypsum	-999	-999	Well B	40	12	30,454	-999	30,454
United Water Florida	Alderman Park onsite	Well A	Well 1	43	15	13,285	46,208	59,493
United Water Florida	Alderman Park offsite	Well B	Well 2	43	16	10,443	21,577	32,020
United Water Florida	Columbine	Well C	-999	42	15	24,358	81,799	106,157
United Water Florida	Elvia	Well D	-999	42	16	16,435	136,539	152,974
United Water Florida	Forest Brook	Well A	Well A	48	6	6,684	-999	6,684
United Water Florida	Green Forest	Well B	Well B	48	4	7,338	39,136	46,474
United Water Florida	Hyde Grove	Well A	Well A	45	4	25,445	-999	25,445
United Water Florida	Lake Forest	Well A	Well 1	39	9	30,749	0	30,749
United Water Florida	Lake Lucina	Well E	-999	42	14	15,475	112,135	127,610
United Water Florida	Magnolia Gardens	Well A	Well 1	40	8	18,717	-999	18,717

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
United Water Florida	Monument Road	-999	-999	42	18	149,659	-999	149,659
United Water Florida	Monument Road	Well C	-999	42	18	149,659	-999	149,659
United Water Florida	Oak Hill	Well A	-999	48	4	4,134	42,722	46,856
United Water Florida	Ortega Hills subdivision	Well B	Well 2	50	7	5,775	-999	5,775
United Water Florida	Ortega Hills subdivision	Well A	Well 1	50	7	5,061	5,206	10,267
United Water Florida	Queen Akers	Well B	-999	43	18	46,939	-999	46,939
United Water Florida	Royal Lakes (offsite inside)	Well A	Well 1	50	16	7,104	109,094	116,198
United Water Florida	Royal Lakes (onsite)	Well B	Well 2	50	16	12,197	181,432	193,629
United Water Florida	Royal Lakes (offsite outside)	Well C	Well 3	50	16	45,162	171,749	216,911
United Water Florida	San Jose	Well A	Well 1	48	12	8,058	71,797	79,855
United Water Florida	San Jose	Well B	Well 2	48	12	9,018	71,759	80,777
United Water Florida	San Jose	Well C	Well 3	48	12	12,950	133,905	146,855
United Water Florida	San Pablo/Marshview	Well A	Well 1	46	24	46,275	-999	46,275
United Water Florida	San Pablo/Marshview	Well B	Well 2	46	24	74,045	-999	74,045
United Water Florida	University Park	Well F	-999	41	14	56,505	-999	56,505
United Water Florida	Venetia Terrace	Well A	Well A	48	7	8,021	-999	8,021
United Water Florida	Wheat Road	Well C	-999	47	5	15,281	91,924	107,205
Callahan, City of	-999	Well A	-999	29	2	15,696	-999	15,696
Callahan, City of	-999	Well B	-999	29	2	18,839	-999	18,839
Florida Public Utilities	-999	Well A	Well 5	22	23	274,221	-999	274,221
Florida Public Utilities	-999	Well B	Well 6	24	23	375,745	-999	375,745
Florida Public Utilities	-999	Well C	Well 7	24	23	222,264	-999	222,264
Florida Public Utilities	-999	Well D	Well 8	22	23	183,920	-999	183,920
Florida Water Services	Amelia Island	Well A	Well 1	28	23	137,032	-999	137,032
Florida Water Services	Amelia Island	Well B	Well 2	28	23	137,032	-999	137,032
Jefferson Smurfit, Fernandina Beach	-999	Well D	Well 4	22	23	184,428	-999	184,428
Jefferson Smurfit, Fernandina Beach	-999	Well F	Well 6	21	23	184,235	-999	184,235
Jefferson Smurfit, Fernandina Beach	-999	Well I	Well 9	22	23	311,294	-999	311,294
Jefferson Smurfit, Fernandina Beach	-999	Well J	Well 10	22	23	311,294	-999	311,294

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
Jefferson Smurfit, Fernandina Beach	-999	Well L	Well 12	22	23	311,294	-999	311,294
Jefferson Smurfit, Fernandina Beach	-999	Well N	Well 14	22	23	311,294	-999	311,294
Jefferson Smurfit, Fernandina Beach	-999	Well H	Well 8	22	22	311,294	-999	311,294
Rayonier	-999	Well A	Well 1	23	22	276,160	-999	276,160
Rayonier	-999	Well E	Well 5	24	22	235,453	-999	235,453
Rayonier	-999	Well F	Well 6	24	22	250,123	-999	250,123
Rayonier	-999	Well G	Well 7	23	21	50,769	-999	50,769
Rayonier	-999	Well K	Well 11	23	22	378,813	-999	378,813
Rayonier	-999	Well L	Well 12	25	22	368,884	-999	368,884
Rayonier	-999	Well M	Well 13	23	21	363,496	-999	363,496
Rayonier	-999	Well O	Well 15	23	22	232,718	-999	232,718
Fruit Cove Oaks subdivision	-999	Well A	Well 1	56	12	3,309	-999	3,309
Fruit Cove Oaks subdivision	-999	Well B	Well 2	56	12	7,721	-999	7,721
Intercoastal Utilities	-999	Well A	Well 1	52	27	165,469	-999	165,469
Intercoastal Utilities	-999	Well B	Well 2	52	27	165,469	-999	165,469
Intercoastal Utilities	-999	Well C	Well 3	53	28	241,617	-999	241,617
Intercoastal Utilities	-999	Well D	Well 4	53	27	241,617	-999	241,617
JCP Utility	GDU, Julington Creek subdivision	Well A	Well 1	56	14	180,481	-999	180,481
JCP Utility	GDU, Julington Creek subdivision	Well B	Well 2	56	14	180,481	-999	180,481
North Beach Utilities	-999	Well A	Well 1	66	32	40,107	-999	40,107
North Beach Utilities	-999	Well B	Well 2	66	32	120,321	-999	120,321
Northwest Utilities	World Golf Village	-999	Well 1	65	21	213,235	-999	213,235
Northwest Utilities	World Golf Village	-999	Well 2	64	21	213,235	-999	213,235
St. Augustine, City of	-999	-999	Well 8-2	64	26	70,722	-999	70,722
St. Augustine, City of	-999	-999	Well 9	64	26	70,588	-999	70,588
St. Augustine, City of	-999	-999	Well 10-2	64	26	70,588	-999	70,588
St. Johns County	Mainland	Well W	Well TR41	68	25	192,513	-999	192,513
St. Johns County	Mainland	Well O	Well TR42	68	25	192,513	-999	192,513
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636

Table A2—*Continued*

User Name	Water Treatment Plant (WTP) Name	CUP Well Name	User Well Name	Model Row	Model Column	Upper Floridan Aquifer Discharge (cfd)	Lower Floridan Aquifer Discharge (cfd)	Total Discharge (cfd)
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636
St. Johns County	Proposed northern WTP	-999	-999	57	22	133,636	-999	133,636
St. Johns Service Company	Inlet Beach	Well 2	Well B	50	27	117,981	-999	117,981
St. Johns Service Company	Inlet Beach	Well 3	Well C	50	27	117,981	-999	117,981
St. Johns Service Company	Marsh Landing	Well 1	Well D	48	26	94,385	-999	94,385
St. Johns Service Company	Marsh Landing	Well 2	Well E	48	25	141,578	-999	141,578
United Water Florida	Ponte Vedra North	Well A	Well 1	48	27	44,298	-999	44,298
United Water Florida	Corona Road	Well B	Well 1	50	27	53,617	-999	53,617
United Water Florida	Corona Road	Well C	Well 2	60	30	77,219	-999	77,219
United Water Florida	A1A South	Well D	Well A1AS	64	31	1,776	-999	1,776
United Water Florida	A1A North	Well E	Well A1AN	62	30	3,288	-999	3,288
United Water Florida	Ponce de Leon	Well C	-999	48	27	27,548	-999	27,548
United Water Florida	Ponce de Leon	Well B	Well 2	50	27	27,548	-999	27,548
United Water Florida	St. Johns Forest	Well A	-999	59	18	5,199	-999	5,199
United Water Florida	St. Johns Forest	Well H	-999	59	18	17,678	-999	17,678
United Water Florida	St. Johns Forest	Well K	-999	59	18	6,237	-999	6237
United Water Florida	St. Johns Forest	Well L	-999	59	18	17,678	-999	17,678
United Water Florida	St. Johns North	Well A	Well 1	57	13	32,210	-999	32,210
United Water Florida	St. Johns North	Well B	Well 2	58	13	33,912	-999	33,912
United Water Florida	St. Johns North	Well C	Well 3	57	13	113,022	-999	113,022
Wesley Manor Retirement Center	-999	Well 1	-999	55	12	7,200	8,466	15,666
Total								367,016,148

Note: cfd = cubic feet per day
CUP = consumptive use permit
MHP = mobile home park

-999 indicates that well does not draw from the Lower Floridan aquifer.

APPENDIX B— COMPARISON OF MOTZ ANALYTICAL MODEL RESULTS TO U.S. GEOLOGICAL SURVEY MODFLOW MODEL RESULTS

Comparison of Motz Analytical Model Results to U.S. Geological Survey MODFLOW Model Results

Motz (1978) derived an analytical model for a steady-state coupled aquifer system consisting of an underlying semiconfined aquifer from which water is withdrawn by a fully penetrating well, an overlying unconfined aquifer, and an intervening semiconfining unit (Figure B1). The aquifer system is represented as homogeneous and isotropic. The drawdown in the unconfined aquifer occurs as a result of induced leakage across the semiconfining unit. This drawdown is assumed to be small relative to the saturated thickness of the unconfined aquifer, thus enabling the use of transmissivity in the specification of its permeability. The decline in the rate of evapotranspiration (ET) from the unconfined aquifer is approximated as varying linearly with the decline in its water level. The coefficient of proportionality in this relationship is referred to as the ET reduction coefficient (Motz 1978).

An equivalent numerical solution for the coupled aquifer system of Motz (1978) can be obtained using the U.S. Geological Survey MODFLOW code in its steady-state mode (Harbaugh and McDonald 1988). The model setup consists of three model layers. All hydraulic-head values in the uppermost layer are designated as constant, and the specified value of these heads is 0 feet, NGVD. The middle model layer represents the unconfined aquifer, although it is designated in the model as confined. Designation of the middle model layer as confined enables the use of transmissivity in the specification of its permeability. This representation is allowable so long as simulated drawdowns are small relative to the initial saturated thickness of the unconfined aquifer. A single value of transmissivity is used to represent the permeability of the unconfined aquifer, in accordance with the assumption of homogeneity in the analytical model.

The constant heads of the uppermost model layer and the VCONT value assigned to it are used to effect the reduction in the ET rate that occurs as the water table of the unconfined aquifer (represented by the middle model layer) is drawn down. The VCONT value assigned to the uppermost model layer is the ET reduction coefficient of the unconfined aquifer. Thus, drawdowns in the middle model layer have the effect of increasing flow into the middle model layer in proportion to the value of the ET reduction coefficient. This handling of evapotranspiration reduction is hydraulically equivalent to that of the analytical model. The

VCONT value assigned to the middle model layer is the leakance of the semiconfining unit that separates the unconfined aquifer from the confined aquifer. The lowermost model layer represents the confined aquifer. The permeabilities of the confined aquifer and overlying semiconfining unit are each represented by a single value of transmissivity and leakance, respectively, again, in accordance with the assumption of aquifer and semiconfining-unit homogeneity.

The model grid is discretized uniformly. To enable symmetry in the resulting drawdown distributions, the production well is assigned to the center node of the lowermost model layer. The specified number of rows and columns is equal and odd. The odd number of rows and columns is necessary to enable the centering of the production well.

Model lateral boundary conditions are represented using general-head boundary (GHB) conditions, the implementation of the head-dependent flux boundary condition in the MODFLOW code. A GHB condition is prescribed for each grid cell of the outermost rows and columns of the middle and lowermost model layers. The source heads of the GHB conditions are specified at points outside the model domain. Each GHB-condition source head is specified at the end of an imaginary line segment that is perpendicular to the edge of the model grid and that emanates from the node of the grid cell to which the GHB condition is prescribed. The distance between the node location and the point at which the GHB-condition source head is specified is the same as that between adjacent model nodes (i.e., the width of the model rows and columns). Because of the uniformity of the model grid and placement of the GHB-condition source heads, the value of the conductances of the GHB conditions of a given model layer is equivalent to the transmissivity of the model layer. The specified value of the source heads of all the GHB conditions is 0 ft NGVD.

The starting heads of the middle and lowermost model layers can theoretically be any value because the model is steady-state. However, the author has found that convergence can be achieved more readily if values other than 0 ft NGVD, are specified. Apparently, starting the simulation with a flat head surface is more challenging from the standpoint of the available solver routines. The absolute values of the resulting hydraulic heads are equivalent to the drawdowns due to the simulated well withdrawal.

As a comparison of the results of the analytical model to the numerical model, the following aquifer parameters were specified:

Transmissivity of the unconfined aquifer—5,000 ft^2/day

Transmissivity of confined aquifer—30,000 ft^2/day

ET reduction coefficient—2.74E-04 day^{-1}

Leakance of semiconfining unit—1.0e-05 day^{-1}

Well-withdrawal rate—668,449.2 ft^3/day (i.e., 5 million gallons/day)

The numerical model grid was specified as 101 rows by 101 columns. The width of the rows and columns was specified as 5,000 ft.

The analytical simulation was performed using a FORTRAN implementation of the analytical solution. The simulated drawdown distributions resulting from the analytical and numerical solutions compare extremely well everywhere except in the vicinity of the grid cell to which the withdrawal well was assigned (Figures B2 and B3). This difference is to be expected in that area because of the averaging effects of the numerical solution.

An area of *potential* discrepancy is in the vicinity of the lateral boundaries of the numerical model. This discrepancy arises whenever the simulated rate of withdrawal is so large that a significant drawdown would be expected to occur at the locations of the GHB-condition source heads. Drawdowns at the locations of the GHB-condition source heads cannot, of course, be simulated in the numerical model, and this limitation causes the error. This type of error is known as boundary-constraint error. As a result of boundary-constraint error, a limit exists on the rates of well withdrawals for which accurate solutions can be obtained using the numerical model. At a given level of grid refinement, the only way to raise this limit is to extend the model grid.

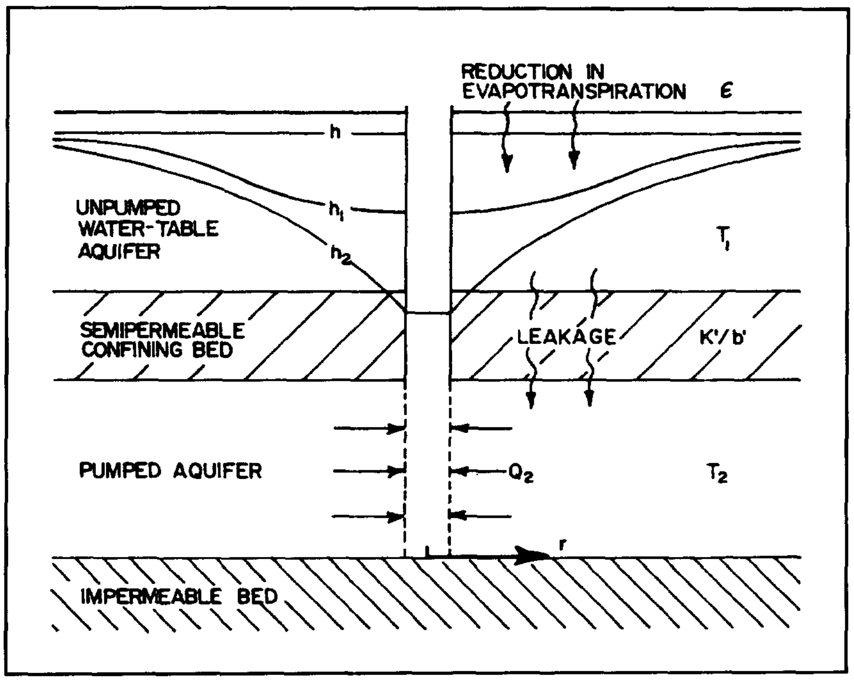


Figure B1. Definition sketch for coupled water table and artesian aquifers (Motz 1978)

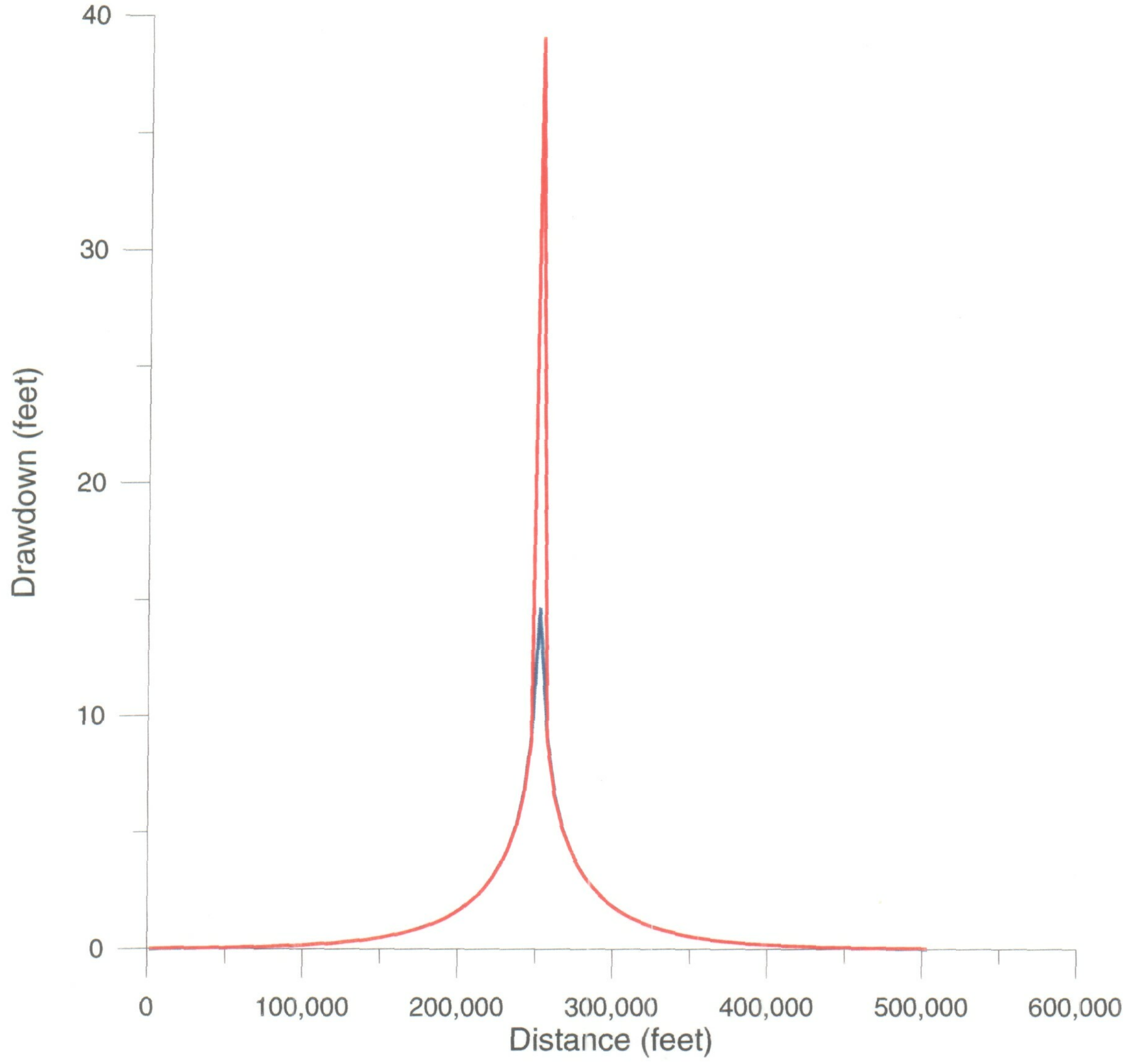


Figure B2. Drawdown in a semiconfined aquifer as derived from the Motz (1978) analytical solution (red) versus the drawdown as derived from a MODFLOW model of equivalent configuration (blue)

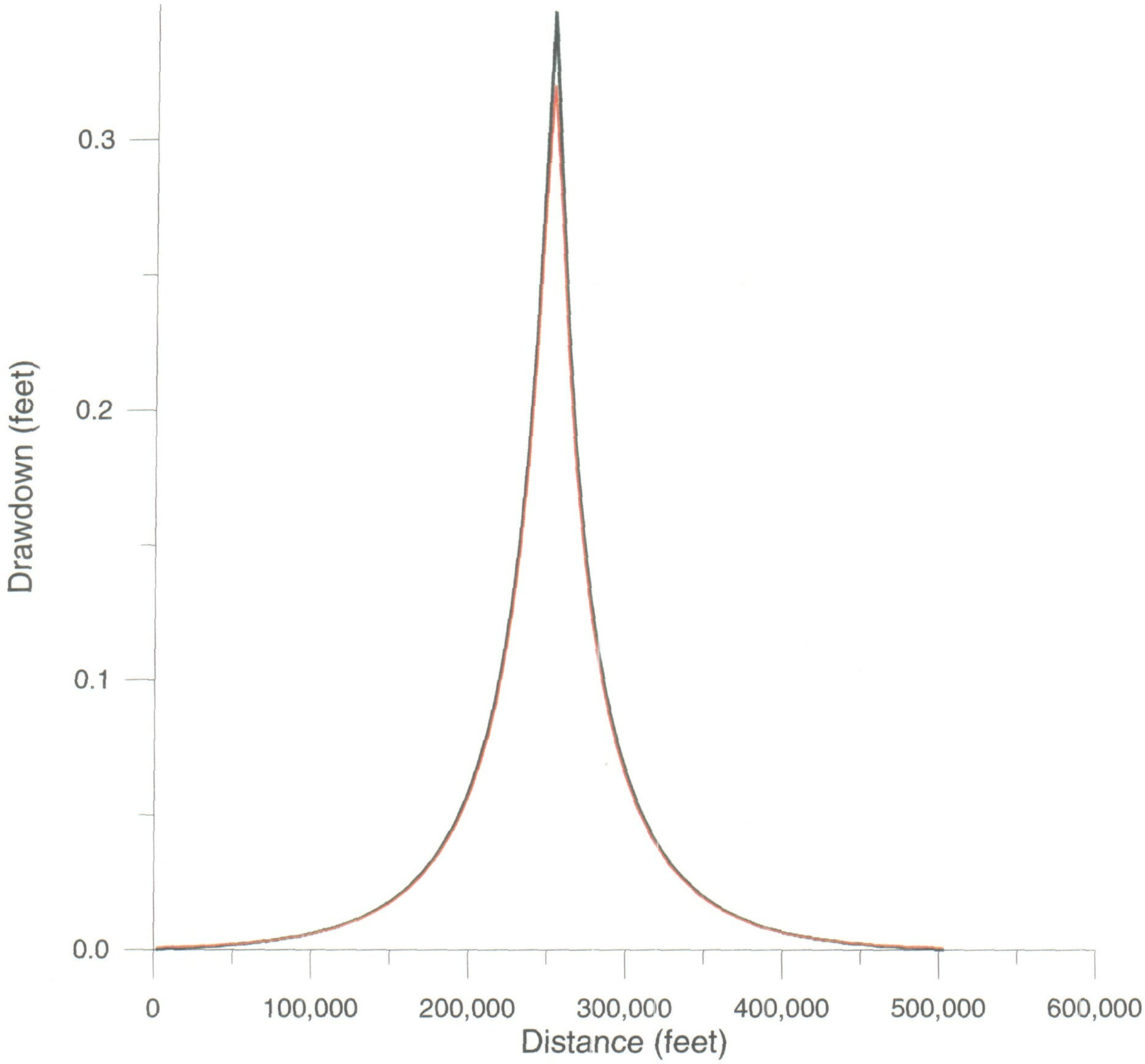


Figure B3. Drawdown in an unconfined aquifer as derived from the Motz (1978) analytical solution (orange) versus the drawdown as derived from a MODFLOW model of equivalent configuration (green)