REGIONAL GROUNDWATER FLOW MODELING FOR EAST-CENTRAL FLORIDA WITH EMPHASIS ON EASTERN AND CENTRAL ORANGE COUNTY

Prepared for

St. Johns River Water Management District
Orange County Public Utilities
City of Cocoa

January, 1991

Special Publication SJ 91-SP4

REGIONAL GROUNDWATER FLOW MODELING

FOR EAST-CENTRAL FLORIDA WITH

EMPHASIS ON EASTERN AND CENTRAL ORANGE COUNTY

Phase I of Contract No. 90G110: East Central

Florida Ground Water Modeling Study

Prepared for

St. Johns River Water Management District
Orange County Public Utilities
City of Cocoa

Prepared by

T. Neil Blandford, Tiraz Birdie
and John B. Robertson

HydroGeoLogic, Inc.
Herndon, Virginia

January, 1991

TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The Floridan aquifer is the primary source of water supply for the east-central Florida region. Rapid growth in the four-county region comprised of Brevard, Orange, Osceola, and Seminole counties is creating an ever increasing demand for fresh water. In most of Brevard County and eastern-most Orange County, however, the Floridan aquifer contains water with chloride concentrations that exceed the EPA recommended limit of 250 mg/L for public supplies. Fresh water for central Brevard County is obtained from the Cocoa well field in eastern Orange County. Increased demands on the Floridan aquifer in Orange and Osceola counties, along with anticipated increases in water demand in the rapidly growing urban areas of western Orange and northwestern Osceola counties, have demonstrated the need for regional water resource management efforts.

The study described in this report is a portion of an ongoing program to address the pressing need for a long-term, environmentally sound water resources management policy, under joint funding by the St. Johns River Water Management District (SJRWMD), the City of Cocoa, and the Orange County Public Utilities Division (OCPUD). The primary purpose of this study is to provide the technical basis needed to determine the optimal allocations of groundwater resources in eastern Orange and Osceola counties. The major emphasis is on the Floridan aquifer system.

It was decided that the best technical approach to address the given problem would be a series of three, mutually dependent, numerical modeling studies that incorporate the large amount of hydrogeological data available for the east-central Florida region. The first phase concerns the development of a regional, three-dimensional groundwater flow model encompassing all of Orange and Seminole counties and significant portions of Lake, Volusia, Brevard, Osceola and Polk counties as technical considerations warranted. The primary purpose of the first phase effort is to provide boundary conditions and estimates of regional aquifer parameters for the modeling efforts in the following phases. The second phase involves the development of a vertical cross-section model extending in an east-west direction through the major pumping areas in Orange County. The purpose of this phase of the study is to assist with the conceptualization of the flow system using density-dependent groundwater flow and solute transport simulations. The third and final phase of the study involves the construction of a three-dimensional density-dependent flow and transport model for a sub-regional area in Orange County. The first phase of this study, hereafter referred to as Phase I, is the topic of this report.

1.2 Purpose and Scope of Work

The primary purpose of the Phase I modeling effort is to synthesize boundary conditions and estimate regional aquifer parameters to support the Phase II and Phase III modeling tasks. This goal was to be achieved through the construction and calibration of a regional, three-dimensional, steady-state groundwater flow model. The scope of work for the Phase I modeling includes the following activities:

- Review all existing and pertinent hydrogeologic information concerning the project area
- Construct and calibrate a three-dimensional, steady-state, regional groundwater flow model for the study area
- Utilize EPA's WHPA software package to delineate wellhead protection areas for the well field conditions in Orange County
- Fully document all the data sources and procedures used, and the assumptions made for the entire technical effort

Note that the scope of work includes the delineation of wellhead protection zones within Orange County using the WHPA code. The delineation of these wellhead protection areas was based on the results of the calibrated steady-state flow model.

1.3 Organization of Report

This report is divided into seven chapters designed to lead the reader through the technical effort in a sequential and logical manner. Chapter 1 provides background introductory materials, and Chapter 2 outlines the general technical approach. Chapter 3 provides a synopsis of the hydrogeological setting. Chapter 4 presents the data types and sources used, as well as any technical analysis performed on the raw data. Chapter 5 provides the specifics of the groundwater modeling effort, including the details of the model construction and calibration. Chapter 6 is devoted to the delineation of wellhead protection areas within the study area, and Chapter 7 consists of technical conclusions. Basic data are included in the Appendices, as well as on a diskette (primarily in the form of Lotus spreadsheet files) provided with the original report. Copies of the diskette are available from SJRWMD upon request.

2 TECHNICAL APPROACH

2.1 Overall Approach

The overall technical approach for Phase I of the current study consisted of five major steps. First, the relevant hydrogeological literature for the study area was reviewed, with particular emphasis placed on previous modeling studies such as Tibbals (1990), Skipp (1988), CH2M Hill (1988), and Jamaal and Associates (1990). Secondly, the available data required for input to the flow model were collected, reviewed, and where appropriate, analyzed. Once the initial model of the study region was constructed, a series of sensitivity model runs were conducted to determine the effect of varying certain model input parameters (e.g. transmissivity or recharge) on the predicted hydraulic head field. Using this information in conjunction with the relatively well defined physical limits of the model input parameters, the groundwater flow model was calibrated by adjusting the transmissivity and recharge of the Upper Floridan aquifer (model layer 1) as well as the leakance between the Upper and Lower Floridan Aquifers. Finally, the delineation of time-related capture zones (wellhead protection areas) was performed using the calibrated model results.

2.2 Data Review and Acquisition

The data reviewed and used for this study were obtained from various reliable sources such as publications of the United States Geological Survey (USGS), SJRWMD, the Florida Agricultural Statistics Service, and private consultants. An extensive bibliography of reports concerning the geology and hydrogeology of east-central Florida is presented in Appendix A. No new field work was conducted to support this effort.

A large portion of the raw data used in the Phase I modeling was supplied by the SJRWMD. Most of this data consisted of groundwater withdrawal rates and locations for municipal, industrial and agricultural purposes throughout the study area. The SJRWMD also assisted the modeling effort by supplying a number of base maps for the study area. The base maps constructed and supplied by the SJRWMD include:

- general base map showing the location of roads and surficial hydrology (lakes and streams) throughout the study area
- overlay map with the finite difference grid, county boundaries, and pumping locations (Upper and Lower Floridan)
- overlay map with the sections, townships and ranges designated

2.3 Code Selection

2.3.1 Groundwater Modeling

The USGS three-dimensional groundwater flow code MODFLOW (McDonald and Harbaugh, 1988) was selected for use in this study because it is a well-accepted, public domain groundwater code developed by the USGS; it has been used in many previous studies to model regional groundwater flow in various parts of Florida, including Orange, Brevard and Osceola counties; it has the capability to incorporate the appropriate system features; and it is computationally efficient and relatively easy to use. There is also a great deal of accessory software, such as ModelCad (Geraghty and Miller, 1989), that enhances use of the model by providing efficient pre- and postprocessing capabilities.

MODFLOW is designed to simulate steady-state or transient groundwater flow through heterogeneous, anisotropic porous media in three dimensions, subject to a variety of complex boundary conditions. The code, therefore, is quite versatile in that it can be used to simulate a wide variety of hydrogeological conditions that may exist in the field. There are, however, certain intrinsic limitations associated with MODFLOW. These limitations, primarily as they relate to the current work, are listed below.

- MODFLOW is designed to simulate groundwater flow in porous media; the code may not be used to explicitly model flow in individual fractures, faults, or solution cavities.
- The effects of density and/or temperature on the groundwater flow field are not considered.
- The aquifer material within individual grid cells is assumed to be homogeneous, and the grid is assumed to be aligned with the principal directions of hydraulic conductivity if the aquifer material is anisotropic.
- Stresses applied to a grid cell (e.g. pumping) are assumed to be distributed uniformly over the cell face.

2.3.2 Wellhead Protection Area Delineation

EPA's WHPA code (Blandford and Huyakorn, 1990) was selected to perform the delineation of wellhead protection zones for selected well fields in Orange County. WHPA has the capability to take the output hydraulic head field from MODFLOW for each layer and perform groundwater flow pathline analysis to delineate time-related capture zones. The code is very efficient, accurate, and easy to use. Although the WHPA code is intrinsically two-dimensional, it should provide reasonable results for each model layer since the exchange of water between the Upper and Lower Floridan aquifers is relatively small compared to horizontal flow components.

3 HYDROGEOLOGICAL SETTING

3.1 Introduction

The geological and hydrogeological setting of the study region has been described by numerous authors (see Appendix A). One of the most recent and comprehensive discussions is provided by Tibbals (1990). The following Sections are not intended to reproduce, but rather to summarize, the previous body of relevant literature as it pertains to the study at hand.

3.2 Geological Framework

A simplified geological section and corresponding hydrogeologic units, adapted from Tibbals (1990), is illustrated in Figure 3.1. Only about the upper 2,500 ft of sediments and geologic formations are of concern in this study. In general, the subsurface within the study area is dominated by the Lower Tertiary Ocala Limestone and the Avon Park, Oldsmar and Cedar Keys Formations. This thick sequence of carbonate rocks is overlain by the Hawthorn Formation, which consists of marine interbedded sands and clays that are often phosphatic. The Hawthorn Formation is in turn overlain by surficial Quaternary deposits consisting of undifferentiated sands, silts and clays. A series of isopach and depth-to-surface maps for the major units within the study area were produced by Miller (1982) and are reproduced in Tibbals (1990). The correlation of principal geologic and hydrologic units is based primarily on the permeability of the geologic media (which is closely related to lithology), and is discussed in Section 3.4.

Structural discontinuities within the Tertiary carbonate rocks exist due to faulting and sinkhole formation. The major faults within the study area tend to be aligned with major rivers such as the St. Johns, Kissimmee and Indian. However, except in the vicinity of Blue Springs, vertical displacement due to faulting is relatively minor (Tibbals, 1990). Sinkholes occur due to the dissolution of carbonate rocks over time. As a sufficient volume of rock is

GEOLOGIC UNITS

Geologic Age	Thickness (feet)	Lithology/ Hydrogeology
Quaternary	20-100	Primarily quartz sand with varying amounts of clay and shell. Forms major portion of the surficial aquifer.
Miocene- Hawthorn Formation	0-200+	Marine interbedded quartz sand, silt and clay, often phosphatic. Generally relatively impermeable, but may form secondary artesian aquifer locally due to presence of limestone, shell and sand beds.
Upper Eocene- Ocala Limestone	0-125	Cream to tan, fine, soft to firm marine limestone. Moderately high transmissivity; forms the top of the Upper Floridan.
Middle Eocene- Avon Park Formation	600-1600	Upper section mostly cream to tan crystalline porous limestone. Lower section is brown, crystalline layers of dolomite alternating with chalky, fossilferous layers of limestone. Upper portion forms about lower 2/3 of Upper Floridan. Lower portion forms Lower Floridan. Central portion has decreased porosity and forms middle semi-confining unit.
Paleocene- Cedar Keys Formation	500-2200	Marine dolomite with considerable anhydrite and gypsum. Forms impermeable base of Floridan aquifer.

PRINCIPAL HYDROGEOLOGIC UNITS

Surficial Aquifer
Upper Semi-Confining Unit
Upper Floridan Aquifer
Middle Semi-Confining Unit
Lower Floridan Aquifer
Lower Confining Unit
Basement Rocks

Figure 3.1. Principal geologic and corresponding hydrogeologic units in east-central Florida. Based on Faulkner (in Tibbals, 1990), Lichtler et al. (1968), and McKenzie-Arenberg and Szell (1990).

dissolved and carried away by groundwater, the remaining infrastructure will eventually collapse under the weight of the overburden. The collapse may be sudden or occur very gradually over time. If the resulting circular depression is filled with water, the feature is referred to as a "sinkhole lake". There are many such lakes in the western and central regions of the study area.

3.3 Surface Water

Surface water features within the study area consist of rivers, lakes, swamps, canals and ditches. Three major surface water drainage basins intersect within the study area. The St. Johns River drains the east and east-central portion of the study area; the Okalwaha River (which is a major tributary to the St. Johns River north of the study area) drains the western portion of the study area; and the Kissimmee River drains the south-central portion of the study region.

There are numerous lakes within the study area, many of which are connected by natural streams and rivers or by manmade ditches and canals. Numerous swamps are also present; they occur primarily in the eastern portion of the study area and in the vicinity of major springs and streams. Depending upon their location, the surface water bodies may be either recharge areas or discharge areas for the groundwater flow system (see Fig. 4.6). The St. Johns and Kissimmee Rivers, and their associated lakes and swamps, are dominant discharge areas within the study region.

3.4 Groundwater

3.4.1 Surficial Aquifer

Three distinct aquifers separated by two semiconfining units compose the groundwater flow system in east-central Florida. The surficial aquifer is unconfined and is composed of interbedded, Quaternary-age sands, silts, clays and some peat. Thickness of the surficial aquifer sediments range from about 20 ft to a value perhaps as high as 100 ft. Although the surficial aquifer is capable of supplying limited quantities of water to wells, due to its high iron content and the highly productive nature of underlying aquifers, the surficial aquifer is used only locally for irrigation and (primarily near the coast) domestic supply. The water table is generally at or near the land surface in the vicinity of lakes and swamps, but may be tens of feet below land surface in the rolling highlands, where it tends to mimic the topography.

The primary sources of recharge to the surficial aquifer are rainfall, irrigation return flow, seepage from surface water bodies such as lakes, streams and ditches, and (in Floridan aquifer discharge areas) upward leakage from the underlying Floridan aquifer system. The primary sources of discharge from the surficial aquifer are evapotranspiration, seepage to surface water bodies, downward leakage to the Floridan aquifer system (in Floridan aquifer recharge areas) and pumping.

Depending upon the relative differences in hydraulic head, the primary hydrologic function of the surficial aquifer on a regional scale is to either recharge the underlying Upper Floridan aquifer, or to discharge groundwater to surface water bodies such as lakes, streams, ditches and swamps.

3.4.2 Upper Confining Unit

The upper confining unit, which is composed of sands, sandy-clay and clay (often phosphatic) of the Hawthorn Formation and other Miocene and post-Miocene sediments, separates the surficial aquifer from the highly productive Tertiary limestones that form the Floridan aquifer system. Throughout the study area, the primary hydrologic functions of the upper confining unit are to confine the Floridan aquifer system under artesian pressure, and to transmit water between the surficial and Upper Floridan aquifers. The interchange of water decreases with decreasing head difference between the two aquifers, decreasing hydraulic conductivity of the confining bed, and increasing confining bed thickness.

It is important to note that the sediments of the upper confining unit confine the underlying Floridan aquifer system because their permeability is substantially less than that of the Upper Floridan aquifer. However, in the vicinity of the Cocoa well field, portions of the Hawthorn Formation form what is called the secondary artesian aquifer (or the "intermediate aquifer system"), which is considered as a potential source of water supply (CH2M Hill, 1988 and Tibbals and Frazee, 1976). McKenzie-Arenberg and Szell (1990) report that the intermediate aquifer occurs randomly throughout large portions of the study area at depths of 60-150 ft below land surface. Occurrence of the secondary artesian aquifer is related to the presence of highly permeable lenses of sand and shell within the Hawthorn Formation. On a regional scale, these lenses are relatively local geologic features (Tibbals and Frazee, 1976), and they therefore have limited regional significance.

3.4.3 Floridan Aquifer System

The Floridan aquifer system lies below the upper confining unit and is the major source of groundwater within the study area. Tibbals (1990) states "The top of the Floridan is defined as the first occurrence of vertically persistent, permeable, consolidated, carbonate rocks." The thickness of the Floridan aquifer system ranges from about 2,000 ft in the northwest corner of the study area to about 2,800 ft in the southeast corner of the study area (Miller, 1982d in Tibbals, 1990).

The Floridan aquifer system has two distinct producing zones separated by a middle semiconfining unit. The upper production zone is referred to as the Upper Floridan aquifer, or simply the "Upper Floridan". The Upper Floridan consists entirely of the Tertiary age Ocala Limestone and the top portion of the Avon Park Formation. These marine limestones form an extremely prolific aquifer due to their high secondary porosity. The thickness of the Upper Floridan is approximately 300-400 ft throughout the study area.

The middle semiconfining unit separates the Upper Floridan and Lower Floridan production zones. This unit is composed of the Middle Eocene members of the Avon Park Formation, which are less permeable dolomitic limestones. The thickness of the middle semiconfining unit ranges from about 100 ft at the western edge of the study area to about 800 ft in the central and some far eastern portions of the study area (Miller, 1982a in Tibbals, 1990). The flow of groundwater between the Upper and Lower Floridan is controlled by the relative head differences between each zone as well as the permeability and thickness of the middle semiconfining unit.

The Lower Floridan is composed primarily of the Middle Eocene Avon Park Formation and the Lower Eocene Oldsmar Formation. Although capable of providing vast quantities of water, utility of the Lower Floridan for municipal water supply is limited in the eastern portion of the study area due high saline content. In the central portion of the study area, however, the Lower Floridan supplies high quality water to several major pumping centers in the vicinity of Orlando and Apopka. The Paleocene Cedar Keys Formation forms the base of the Lower Floridan throughout the study area. These beds are relatively impermeable due to high amounts of gypsum and anhydrite.

Hydrogeologic data for the Lower Floridan is very limited, and it is difficult to accurately determine aquifer parameters. Tibbals (1990) determined through computer simulations of the Floridan aquifer system that the exchange of water between the Upper and Lower Floridan is relatively small compared to flow occurring within the Upper Floridan.

Recharge to the Upper Floridan is primarily by downward leakage from the surficial aquifer, except in the vicinity of Orlando where there are numerous drainage wells completed in the Upper Floridan scattered about the city. Discharge from the Upper Floridan occurs as spring flow, pumping and upward leakage to the surficial aquifer. The source of recharge to the Lower Floridan in downward leakage from the Upper Floridan through the middle semiconfining unit. Discharge from the Lower Floridan occurs as upward leakage to the Upper Floridan and pumping.

Most pumping in east-central Florida for municipal, industrial and agricultural purposes occurs in the Upper Floridan, except in the vicinity of Orlando, where withdrawals are limited to small public supplies because of high bacterial levels (Schiner and German, 1983).

4 DATA ANALYSIS

4.1 Potentiometric Surface Maps

Potentiometric surface maps for the Upper Floridan aquifer are constructed bi-annually by the USGS for the months of May and September. These two periods are believed to be indicative of the extreme potentiometric surface fluctuations within the Floridan aquifer system. The May map represents the potentiometric surface following the relatively dry period in Spring, which is usually a period of relatively large aquifer withdrawals. The September map represents the effects of recharge to the Upper Floridan following the wet summer period, which is usually a period of relatively small aquifer withdrawals.

It has been noted by many researchers that, in general, the potentiometric surface of the Upper Floridan does not change appreciably from year to year. During the initial phases of this study, the potentiometric surface maps for 1987, 1988 and 1989 were compared and this was indeed found to be the case. Furthermore, although seasonal fluctuations were observed in some regions of the study area, in the vicinity of the boundaries of this study seasonal fluctuations were found to be relatively small. These observations suggest that the groundwater flow regime in the Upper Floridan aquifer exists in a quasi steady-state condition with a superimposed cyclic variation due to seasonal changes in climate and pumping.

Since the primary objective of Phase I is to establish the regional flow field, boundary conditions and hydrogeologic parameters of the Floridan aquifer system, the model calibration was performed using an average potentiometric surface for the calendar year 1988. The average Upper Floridan potentiometric surface map for 1988 (Fig. 4.1) was derived by averaging the respective potentiometric surface maps for May (Fig. 4.2) and September (Fig. 4.3). The procedure used is as follows: 1) the potentiometric surface maps for May and September 1988 were digitized; 2) each of the maps was plotted using the

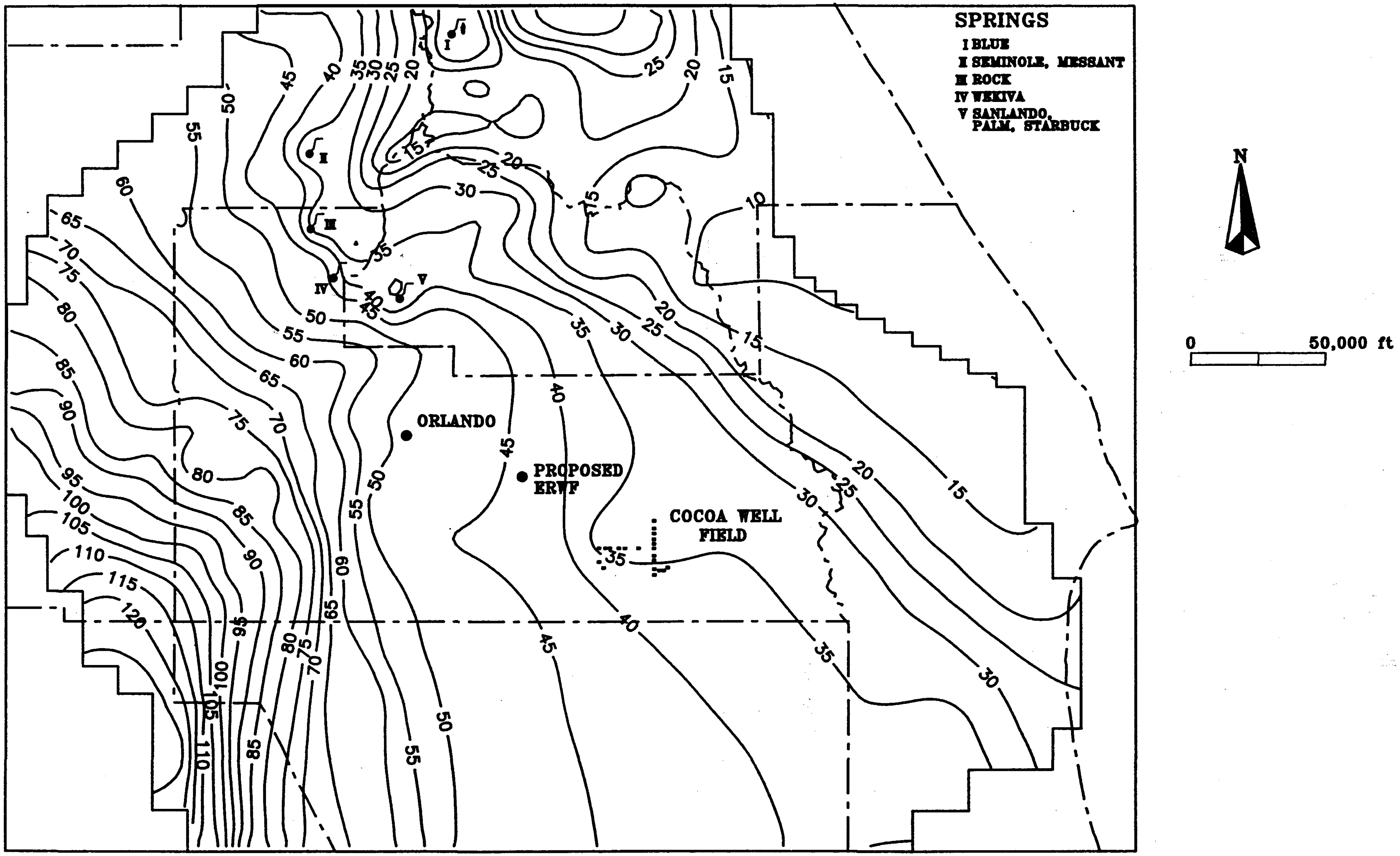


Figure 4.1. Average Upper Floridan potentiometric surface map for 1988 in feet above msl.

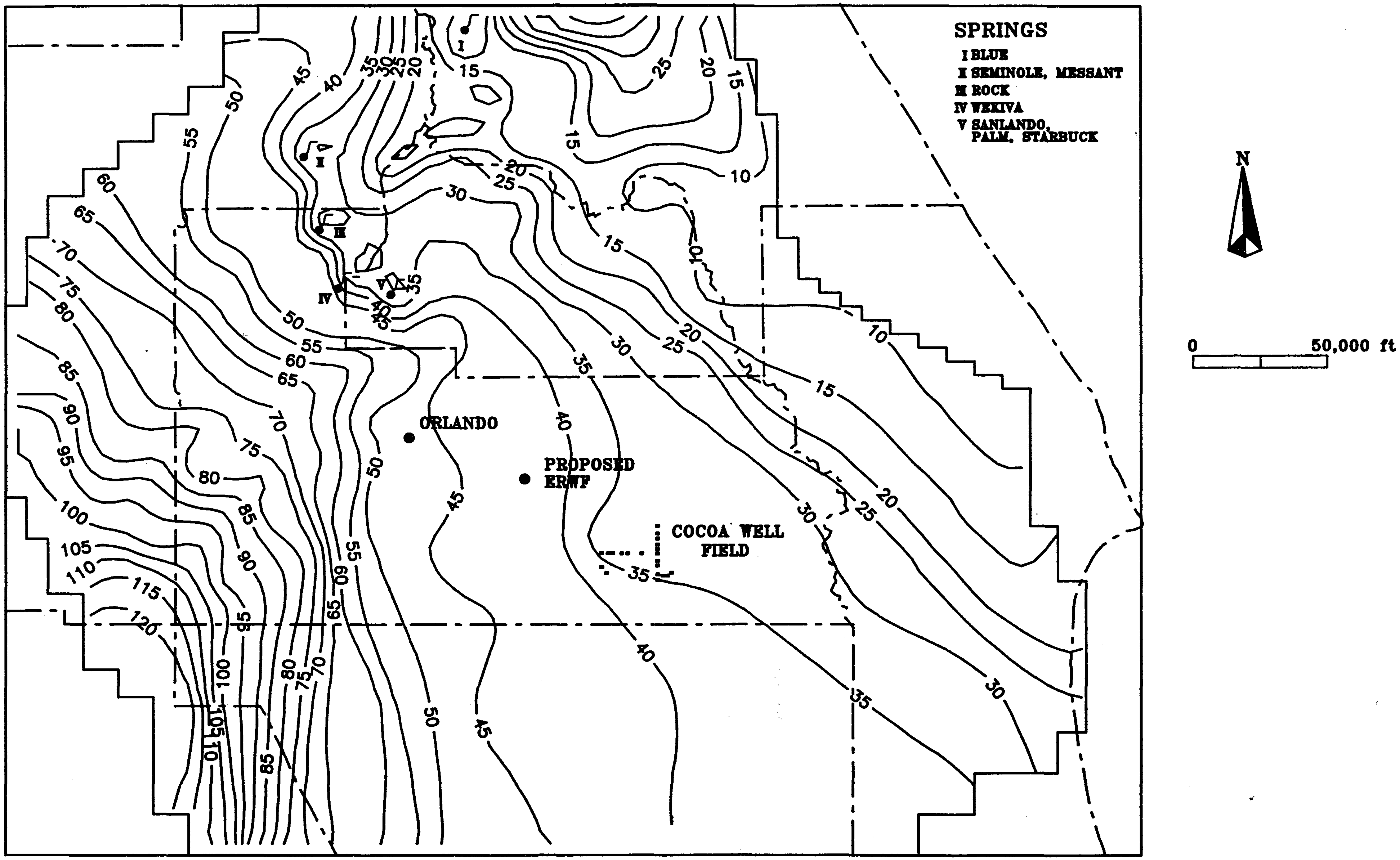


Figure 4.2. Upper Floridan potentiometric surface map for May, 1988 in feet above msl. Reproduced from Schiner, 1988.

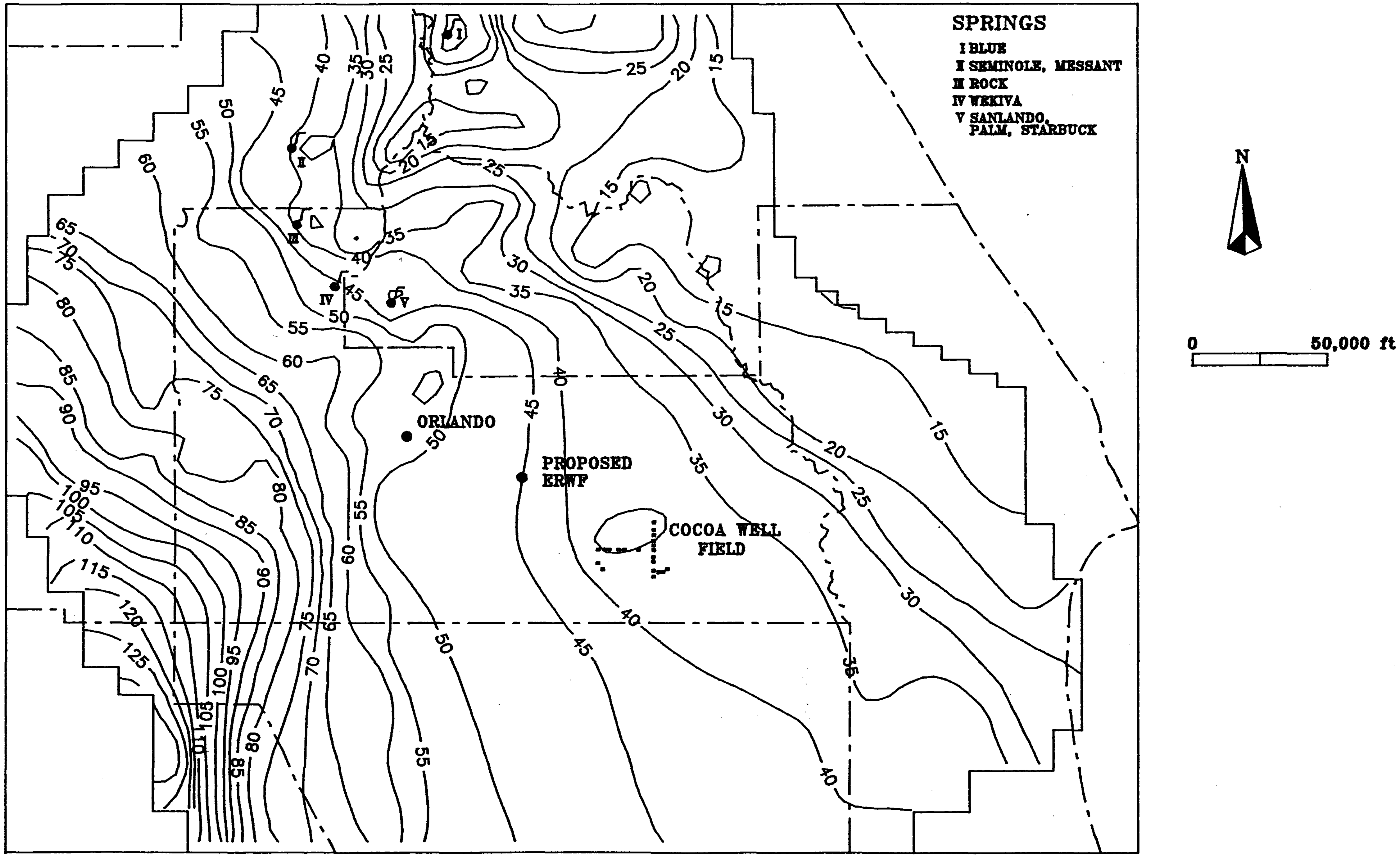


Figure 4.3. Upper Floridan potentiometric surface map for September, 1988 in feet above msl. Reproduced from Rodis, 1989.

SURFER software package (Golden Software) to ensure that the potentiometric surface could be accurately reproduced; 3) the SURFER grid files for May and September were averaged to obtain the average 1988 head field; and 4) the contour plot produced using the averaged head file was spot-checked manually to ensure its accuracy.

Figure 4.1 clearly illustrates many of the major features of the groundwater flow system within the study area. The pronounced cone of depression about the Cocoa well field is clearly displayed by the 35 ft contour line in eastern Orange County. Discharge points formed by the Sanlando, Palm and Starbuck Springs trio; Wekiva Spring and Miami Spring; Rock Spring; Seminole Spring and Messant Spring; and Blue Springs are all evident. The steepest gradients and the highest potentiometric surface values are in the southwest quarter of the project area, which lies just east of the Green Swamp potentiometric high (Pride et al., 1966). Along the eastern edge of the study area in central and northern Brevard County, groundwater tends to move due north, approximately parallel to the coast, due to the presence of a groundwater trough in this region. In general, groundwater in the Upper Floridan moves from the southwest towards the northeast within the study area.

The 45 ft potentiometric surface contour (Fig. 4.1) shows a pronounced inflection west of the Cocoa well field. At first glance, this contour would seem to be indicative of a cone of depression. However, there are no major pumping centers within this particular region. The May and September potentiometric surface maps each show similar inflections west of the Cocoa well field, although they are less pronounced. On the May map, the inflection lies to the west of its location in Figure 4.1, and on the September map, the inflection lies well east of its location on Figure 4.1. Although this 45 ft contour inflection should probably be slightly less pronounced (more rounded) than it is on the average potentiometric surface map, its existence may not be attributed to the averaging process. The physical processes or properties that cause this inflection are unknown, although it is due in part to drawdown effects caused by the Cocoa well field.

4.2 Groundwater Withdrawal Rates

Groundwater withdrawals within the study area can be classified into three major categories: 1) municipal and industrial (MI) pumping; 2) agricultural (citrus and non-citrus) pumping; and discharge due to abandoned flowing wells. The MI pumping accounted for about 73% of the total withdrawals, while agricultural pumping for citrus and non-citrus crop irrigation accounted for about 16% and 10% of the total pumping respectively (Table 4.1). The combined withdrawal estimates assigned to each grid block within the study area are listed in Appendix B.1. Aside from some municipal pumping in the vicinity of Orlando and east of Lake Apopka, and several locations that have pumping from both the Upper and Lower Floridan, all of the withdrawals were derived from the Upper Floridan. The values listed in Appendix B.1 are considered average pumping rates for 1988, and may or may not be valid for other years. The data sources used, and the assumptions made to obtain the MI and agricultural pumping estimates are outlined in the following two Sections.

4.2.1 Municipal and Industrial Withdrawals

The MI pumping rates used in this study were supplied by SJRWMD (Appendix B.2) in raw form as pumping per well or well field in mgm (million gallons per month) or mgd (million gallons per day). Only pumping centers with withdrawal rates greater than about 0.1 mgd were considered in this study. Where lumped discharge values were provided for multiple wells or a well field, the total discharge for 1988 was divided by the number of wells to obtain an average pumping rate per well. For a small number of pumping centers, primarily those within the Reedy Creek Improvement District, 1988 discharge values were not available and 1989 values were used instead.

The MI pumping is documented in the LOTUS files "UPPERAQ.WK1", "LOWERAQ.WK1" and "UPLOWAQ.WK1" on the diskette provided with the original report (copies of the diskette are available upon request from SJRWMD). The first two files, "UPPERAQ.WK1" and "LOWERAQ.WK1", contain the discharges for pumping

Table 4.1. Total pumpage estimates for 1988 by category.

Source of Pumping	Discharge (ft^3/d)	Percent of Total
MI - Upper Floridan	25,529,578	53.75
MI - Lower Floridan	9,368,231	19.72
Agriculture - Citrus	7,376,614	15.53
Agriculture - Non-Citrus	4,887,203	10.29
Abandoned Flowing Wells	336,979	0.71
Total	47,498,605	100.00

centers that withdraw from the Upper and Lower Floridan, respectively. The third file "UPLOWAQ.WK1" contains the discharges for pumping centers that have wells withdrawing water from both the Upper and Lower Floridan. For these wells, the pumping was apportioned using the depth of the well below the casing, and the casing diameter.

Locations of the pumping centers were identified and plotted on a base map by SJRWMD. The location of model cells that had MI pumping specified within them are shown for the Upper Floridan and Lower Floridan model layers in Figures 4.4 and 4.5, respectively. The model grid and boundary conditions are also presented in these figures; a detailed discussion of these features is provided in Chapter 5.

4.2.2 Agricultural Withdrawals

4.2.2.1 Irrigation Requirement for Citrus Crops

A table of citrus tree acreage and location (by section, township and range) was obtained from the Florida Agricultural Statistics Service (FASS). FASS compiled the table using areal photography, and they also field checked an unknown portion of the determined acreage. In general, only sections with more than 50 acres of citrus were included in the table. This information was used by SJRWMD staff to compute the 1988 irrigation requirement for citrus crops within the study area using the SJRWMD's modified Blaney-Criddle method (Appendix B.3). The required temperature and rainfall input data were obtained from National Oceanic and Atmospheric Administration (NOAA) climatological stations. Major assumptions used to obtain the listed irrigation requirements include:

- the average irrigation efficiency for 1988 was 82.5%
- the irrigation requirement per section was supplied entirely by pumpage from the Upper Floridan
- the irrigation requirements are average rates spread evenly throughout the year.

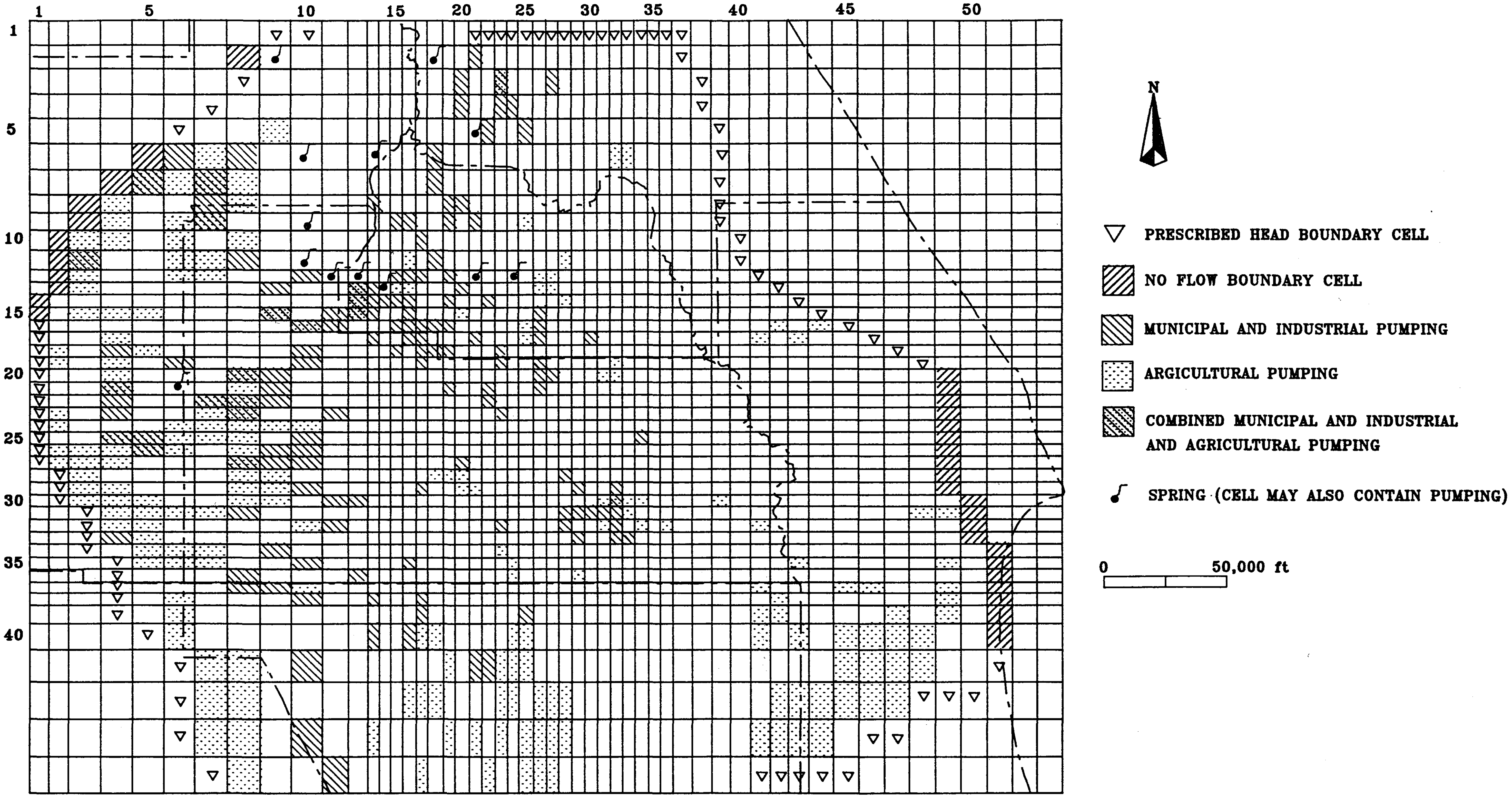


Figure 4.4. MI and agricultural (citrus and/or non citrus) pumping locations, spring locations, and boundary conditions for Upper Floridan (model layer 1).

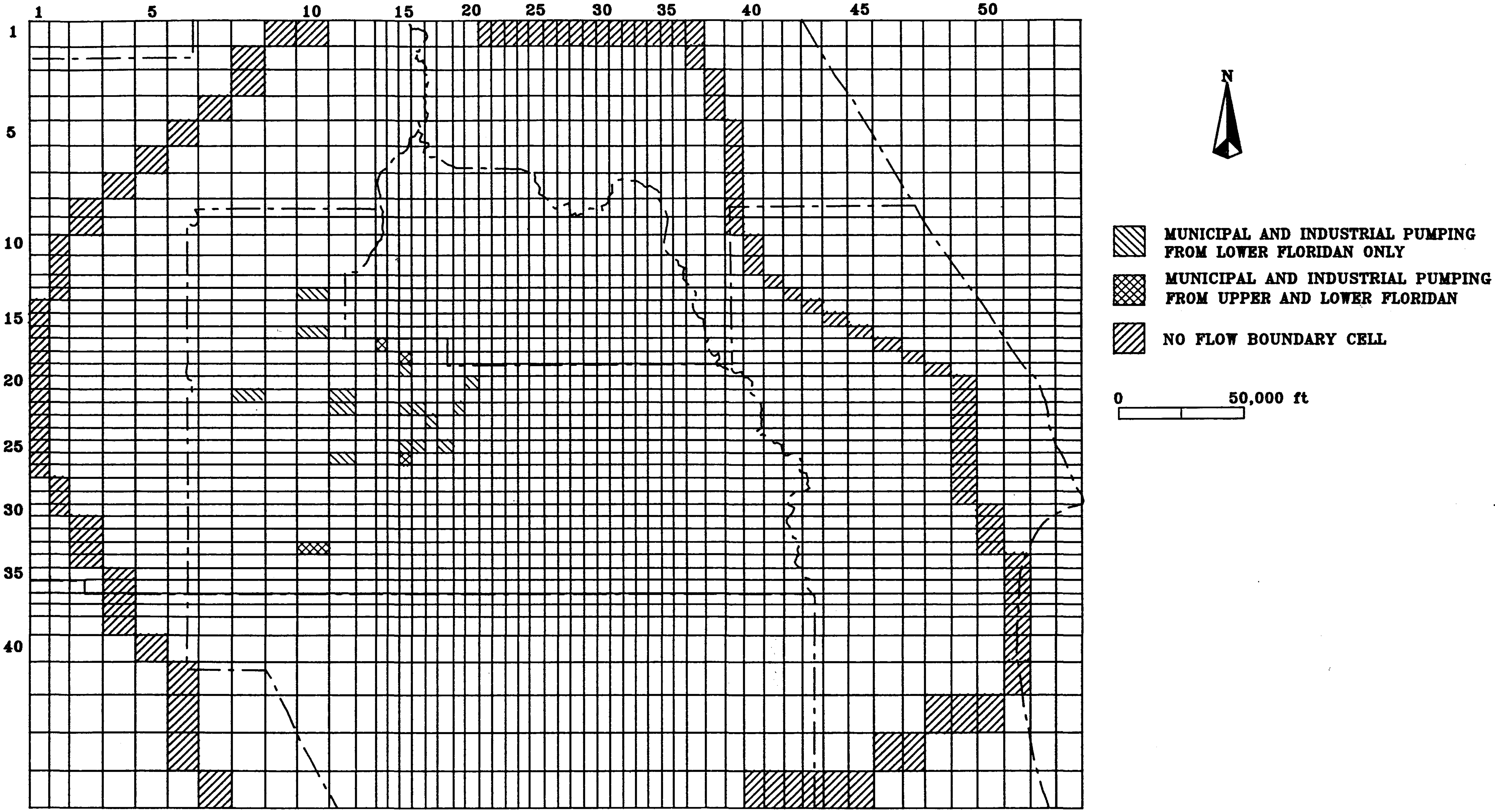


Figure 4.5. MI pumping locations and boundary conditions for Lower Floridan (model layer 2).

The location of each section that had a citrus irrigation requirement was plotted on the base map, and the estimated requirement (pumping) was assigned to the model cell that incorporated the center of the designated section (Fig. 4.4). The major assumptions involved in this method of estimating agricultural pumping for citrus are: 1) the irrigation requirements calculated using the Blaney-Criddle method are indicative of actual average withdrawal rates, and 2) the irrigation wells reside close to the section centers for which a citrus irrigation requirement was reported.

An effort was made to independently verify the estimated citrus irrigation requirements using the Benchmark Farms Project citrus groves within the study area. The comparison in Table 4.2 shows that the irrigation requirements computed using the modified Blaney-Criddle method lie between the two extreme values measured at Benchmark Farms sites that were reported to have "good" quality data. The Benchmark Farms reported values differed considerably at several sites that were in close proximity to one another. The reason(s) for this are unknown, although the differences might be due primarily to local variation in meteorological variables such as rainfall. Although the Blaney-Criddle estimates of the citrus irrigation requirements are undoubtedly averaged values (the extreme high and extreme low local values are not accounted for), in light of the purposes of this study they are believed to be reasonable estimates of average pumping for the irrigation of citrus during 1988. It is also interesting to note that if the Benchmark Farms average requirement is taken neglecting the three lowest values, an average irrigation requirement very close to the average requirement calculated using the modified Blaney-Criddle method is obtained. The Benchmark Farms citrus sites and their associated data are contained in the BMFWU.WK1 spreadsheet file.

4.2.2.2 Irrigation Requirement for Non-Citrus Crops

Non-citrus crops within the study area irrigated using groundwater from the Upper Floridan include watermelons, corn, sorghum, ferns, flowers, woody ornamentals, mushrooms, watercress, celery, cabbage, sod, pasture land and golf course turf. The crop type, location

Table 4.2. Comparison of irrigation requirements computed using the Blaney-Criddle method and measured at Benchmark Farms sites.

Data Source	Irrigation Requirement (in/yr)		
	High	Low	Average
Blaney-Criddle Method	17.05	8.66	13.82
Benchmark Farms	26.3	0.0013	9.37

* Note - out of the 13 Benchmark Farms sites with good data quality in the study area, if the lowest 3 sites are deleted from the data set, the average requirement becomes 13.5 in/year.

and acreage obtained from the SJRWMD consumptive use permit (CUP) files for 1988 are presented in Appendix B.4. Only CUP's with allocations greater than 9 million gallons per month or greater than approximately 50 acres were considered in this study.

The irrigation requirement for each crop type (Table 4.3) was calculated using information obtained from the SJRWMD Annual Water Use Survey for 1988 (Florence, 1990). The water use survey contains estimates of irrigated acreage organized by county and crop type, as well as the total amount of water used for irrigation. Using these numbers, irrigation requirements for each crop type in each county were back-calculated; these are the values documented in Table 4.3. Discharge estimates for 1988 non-citrus crop irrigation were obtained by multiplying the acreages in Appendix B.4 by the irrigation requirement factors listed in Table 4.3, for all crop types except golf courses (see below).

Pumping centers for non-citrus crop irrigation were located and assigned to grid cells in the same manner as the citrus pumping values. The center of each section with an irrigation requirement was plotted on the base map, and the corresponding discharge value was assigned to the center of the cell that contained the plotted point (Fig. 4.4). Again, this procedure is valid assuming that the irrigation well(s) supplying a given area is in reasonably close proximity to that area.

The irrigation requirements backed out for certain crops using information contained in the SJRWMD Annual Water Use Survey (Florence, 1990) were compared to data available from Benchmark Farms sites for non-citrus crops. The comparison is outlined in Table 4.4. The numbers compare very well for woody ornamentals, and marginally well for ferns, flowers and foliage, and golf courses. Because five Benchmark Farms golf course sites with accurate data were available, the Benchmark Farms irrigation requirement was used to obtain the pumpages due to golf courses. For the other crop types listed in Table 4.4 the Annual Water Use Survey values were used because they were close to the Benchmark Farms value (woody ornamentals) or because the number of Benchmark Farms sites was limited (ferns).

Table 4.3. Irrigation requirements by county and crop type in ft^3/d/acre. Calculated using data from Florence, 1990.

Crop	County						
	Brevard	Lake	Orange	Osceola	Polk	Seminole	Volusia
Cabbage		140.36	142.04			142.59	141.70
Sweet Corn	229.93	194.64	194.49		173.78	200.52	
Field Corn	217.90	208.54	173.78			200.52	
Sweet/Field Corn Average	223.92	201.59	184.14				
Ferns		580.17	568.14			601.56	581.37
Flowers & Foliage	534.72	479.02	540.70		534.72	532.33	548.09
Golf Course	366.79	316.38	326.01			325.84	282.24
Pasture	109.40	109.16		109.53	160.42	109.13	109.61
Sod	319.50		300.78			200.52	198.85
Sorghum	152.25	124.77	180.45				
Vegetables		100.26	121.26			54.31	120.31
Watercress						6,960.27	
Watermelon	93.58	90.90	89.12			100.26	86.89
Woody Ornamentals	1,224.23	1,216.79	1,216.17		1,229.86	977.24	1,229.86

Table 4.4. Comparison between average irrigation requirements in ft^3/d/acre for non-citrus crops obtained from Benchmark Farms data and the SJRWMD Annual Water Use Survey (Florence, 1990).

Crop	Annual Water Use Survey	Benchmark Farms (# sites)	
Golf Course	312.48	494.66	(5)
Ferns	582.81	961.85	(1)
Flowers & Foliage	528.26	337.50	(4)
Woody Ornamentals	1,174.04	1,181.08	(1)

The primary users of groundwater for the irrigation of non-citrus crops in the southeast quarter of the study area are Deseret Ranches and the Duda Sod Farm. Because the irrigation of pasture and sod was areally extensive in this region, a slightly different approach was taken to estimating withdrawals due to these two users. The eleven CUP quadrangles that cover the holdings of Deseret Ranches and the Duda Sod Farm (Narcoossee; Narcoossee NW, NE, and SE; Lake Poinsett and Lake Poinsett NW and SW; Cocoa; Deer Park and Deer Park SE; and Eau Gallie) were supplied by SJRWMD. Using these quadrangle maps in conjunction with the consumptive use permitting files, the wells that belonged to Deseret Ranches, the Duda Sod Farm and several smaller users were plotted on the model grid. The number of wells in each respective grid block and the owners were then easily tabulated.

The next step was to assign discharge estimates to each of the wells. Crop types and acreages were categorized by user using the CUP files. A summary of this information is presented in Table 4.5. The largest users were Deseret Ranches with 14,120 acres of pasture, and the Duda Sod Farm with 23,295 acres of pasture and 730 acres of sod. It is not known how closely these totals agree with the actual irrigated acreage for 1988. However, in the 1988 Water Use Survey (Florence, 1990), a total of 11,180 acres of irrigated improved pasture is listed for Osceola County. This value should be due almost exclusively to Deseret Ranches (Pers. Comm., Brian McGurk, SJRWMD); and it is relatively close to the CUP estimate of 14,120 acres. Similarly, the Water Use Survey reports a total of 1,000 irrigated acres of sod in Brevard County - a value that is reasonably close to the CUP estimate for Duda Sod Farm of 730 acres. It was initially concluded, therefore, that the CUP estimates of irrigated acreage for 1988 in the region of concern, although undoubtedly somewhat in error, were reasonable. It was determined later during the model calibration stage of Phase I that these values of irrigated acreage were probably overestimated by approximately 50 percent. This conclusion is discussed in Chapter 5.

Finally, the estimated irrigated crop acreages were multiplied by the estimated irrigation requirement factors derived from the Annual Water Use Survey (Table 4.3). This procedure

Table 4.5. Major agricultural users in Deseret Ranches/Duda Sod Farm area.

Owner	Acreage	Crop	County
Deseret Ranches	13,480	Pasture	Orange, Osceola, Brevard
Duda & Sons, Inc.	23,295	Pasture	Brevard
	730	Sod	
Indian River Colony Club	165	Urban Landscape	Brevard
	70	Golf Course	
Tucker & Sons	160	Improved Pasture	Brevard
Tucker & Sons	315	Improved Pasture	Brevard
Deseret Ranches	640	Pasture Land	Orange
	5,000	Beef Cattle*	

* Beef cattle were not included in the agricultural withdrawal estimates

provided a total discharge per user. For users that had multiple wells (Deseret Ranches had 112 and Duda Sod Farm had 95), the total discharge was divided by the number of wells to provide an average discharge per well.

4.2.3 Abandoned Flowing Wells

Abandoned flowing (artesian) wells within the study area that had, or were likely to have, discharges greater than 70 gpm (13,475 ft^3/d) were selected from the SJRWMD abandoned well inventory (Steele, 1990). Appendix B.5 provides a listing of the selected wells, along with their locations, and reported or assigned discharges. Although these wells were included in this study for the sake of completeness, their effect on the regional flow field, as determined through the numerical simulations discussed in Chapter 5, was insignificant. However, it is not known how complete the existing abandoned well inventory is within the study area. All flow from abandoned wells was assumed to be from the Upper Floridan.

4.3 Spring Discharges

There were 16 documented springs within the study area, 9 of which had gauged discharge values for 1988. Each spring, the row and column numbers within which it was located, and its discharge are listed in Table 4.6. The spring locations are plotted in Figure 4.4. All of the spring discharge was assumed to come from the Upper Floridan.

The measured spring discharge values in Table 4.6 were obtained from the Water Resources Data Report for Florida (USGS, 1989 and 1990). For most of the springs, the May and September reported discharges were averaged to obtain an average discharge for 1988. Seminole Springs and Messant Springs only had May values reported, and these were used as input to the model. Blue Springs is by far the largest spring in the study area, and it is monitored on a bi-monthly basis. For this spring, each of the six discharge estimates available for the 1988 water year were averaged to obtain an average discharge of 12,340,800 ft^3/d.

Table 4.6. Spring placement and discharge.

Spring	Row	Col	Discharge (ft^3/d)	Discharge (ft^3/s)
Apopka	21	6	1,010,880*	11.7
Rock	9	10	5,054,400	58.5
Witherington	11	10	345,600*	4.0
Wekiva	12	11	6,004,800	69.5
Miami	12	12	444,960	5.15
Sanlando	13	14	1,684,800	19.5
Palm	13	14	540,000	6.25
Starbuck	13	14	1,252,800	14.5
Lake Jessup	12	21	56,160*	0.65
Clifton	12	24	112,320*	1.3
Seminole	6	10	3,369,600	39.0
Messant	6	10	1,209,600	14.0
Island	6	13	518,400*	6.0
Gemini	5	21	691,200*	8.0
Blue	2	18	12,340,800	142.83
Camp La-No-Che	2	9	60,480*	0.7
TOTAL			34,696,800	401.58

* Estimate from Tibbals (1990)

For the six springs denoted by asterisks in Table 4.6, annual discharge measurements are not performed. Flows for these springs were estimated using data provided in Tibbals (1990). Observations were reported for four of the springs at various times as follows; Clifton Spring (5/73), Island Springs (5/82), Gemini Spring (4/72) and Camp La-No-Che Spring (3/72). To determine whether or not the observed spring flows in 1972, 1973 and 1982 are indicative of 1988 conditions, a comparison was made between spring flows reported by Tibbals (1990) and those reported in the Water Resources Data Report (USGS, 1989). The comparison is presented in Table 4.7, and one can see that the spring flow measurements reported by Tibbals (1990) for 1973 and 1981 compare quite favorably with those measured in 1988. Therefore, for the four springs listed above the discharges measured at earlier times are deemed reasonable for use as 1988 spring flows.

For Apopka Spring and Witherington Spring, Tibbals respective values of 11.7 ft^3/s and 4 ft^3/s derived from a numerical simulation for the year 1978 were used. For Lake Jessup Spring, a value one-half that of Clifton Spring was used after data reported in Tibbals (1990).

The springs within the study area have a very significant impact on the regional flow system. Figure 4.1 illustrates the pronounced depressions in the average potentiometric surface of the Upper Floridan north of Orlando. The combined spring discharge of 34,696,800 ft^3/d (402 ft^3/s) is approximately equal to the total withdrawals from the Upper and Lower Floridan for municipal and industrial purposes.

4.4 Areal Recharge and Discharge

Figure 4.6 is a map of recharge and discharge areas for the Upper Floridan adapted from Tibbals (1990). The accuracy of this map was spot-checked for 1988 hydrologic conditions using measured lake level elevations and the May and September potentiometric surface maps for the Upper Floridan. Using the relative heads in the vicinity of approximately 19 lakes,

Table 4.7. Comparison of spring discharges documented at various times.

Spring	Date	Discharge (ft^3/s)[a]	Date	Discharge (ft^3/s)[b]
Wekiva	5/73	72	5/88	67
Rock	5/73	62	5/88	58
Miami	5/73	5	5/88	4.9
Sanlando	5/73	20	5/88	19
Palm	5/73	9	5/88	6.1
Starbuck	5/73	15	5/88	15
Seminole	4/81	32	5/88	39
Messant	4/81	14	5/88	14
TOTAL		229		223

[a] From Tibbals (1990)
[b] From USGS (1989)

Note: 1 ft^3/s = 86,400 ft^3/d

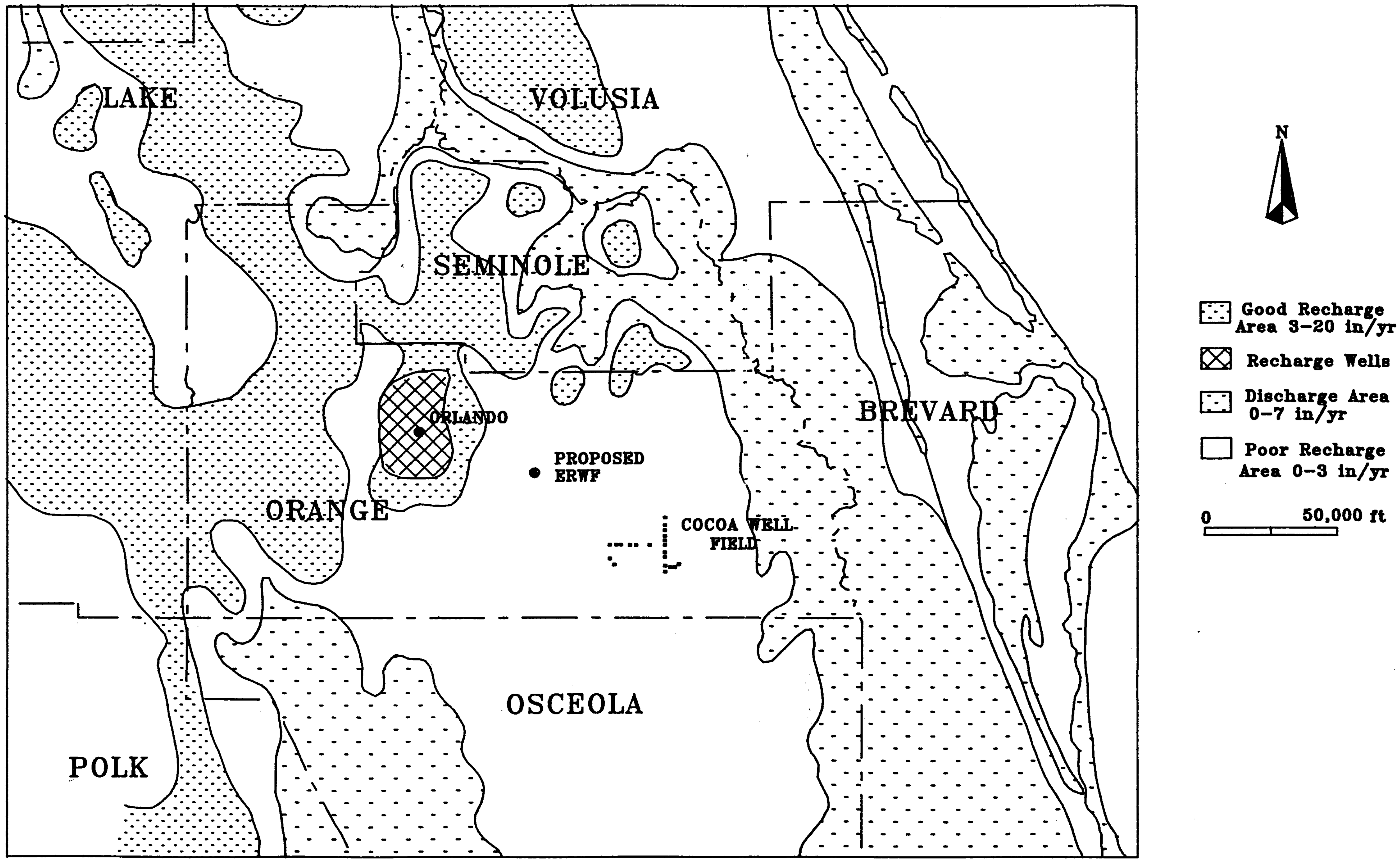


Figure 4.6. Areal recharge-discharge map for Upper Floridan in east-central Florida. Adapted from Tibbals (1990).

the direction of groundwater flow (downward for recharge or upward for discharge) could be determined. At each of the selected locations, the relationship indicated in Figure 4.6 could be verified. The general features of the map were also cross-checked against other publications such as Aucott (1988), Phelps (1984) and McKenzie-Arenberg and Szell (1990). The direction of leakage is far easier to determine than the quantity of leakage, and therefore the recharge/discharge patterns and magnitudes in Figure 4.6 were viewed as a general guideline of actual hydrologic conditions.

Figure 4.6 also shows the region about Orlando within which there are numerous drainage wells. Szell (1987) reports 374 active drainage wells used to dispose of storm water runoff from roads, lakes and creeks; industrial wastes of various types; air conditioning cooling water; and sewage effluent. Out of the 374 active drainage wells, only ten are open to the Lower Floridan (Szell, 1987). Tibbals (1990) reports an average recharge due to the drainage wells of 33 mgd, while Kimrey (1978) suggested a higher value of perhaps as much as 50 mgd.

Another source of artificial recharge are the City of Orlando's and Orange County's Conserv II project rapid infiltration basins. These large, sand-lined basins are located west of Orlando near the Lake/Orange County border, and they dominate Sections 9, 16, 17, 19, 29 and 32 in Township 23 South, Range 27 East.

4.5 Floridan Aquifer Parameters

4.5.1 Transmissivity

Transmissivity (T) is defined as the hydraulic conductivity of an aquifer multiplied by the aquifer thickness; this physical parameter is a measure of the aquifer's ability to transmit groundwater flow. Table 4.8 provides a list of the high and low aquifer parameter values used in several previous modeling studies that incorporated all or part of the study region. In general, the high and low values are of the same order of magnitude. There have been a

Table 4.8. Ranges of transmissivities for the Upper and Lower Floridan and leakance of the middle semiconfining units from selected modeling studies in east-central Florida.

Study	Upper Floridan T (ft^2/d)		Lower Floridan T (ft^2/d)		Leakance of Middle Semiconfining Unit (d^{-1})	
	High	Low	High	Low	High	Low
Tibbals (1990)	400,000	10,000	130,000	30,000	5×10^{-5}*	5×10^{-5}
CH2M Hill (1988)	133,680	6,684	66,840	6,684	1.3×10^{-2}	1.3×10^{-2}
Jammal & Associates, Inc. (1990)	250,000	40,000	275,000	100	8.6×10^{-2}	1×10^{-5}

* Tibbals used a constant leakance except in the vicinity of Blue Springs, where he used a large value.

number of aquifer tests conducted in the Upper Floridan, but the results are often viewed with skepticism on a regional scale because many of the wells only partially penetrate the aquifer, and the high secondary porosity of the limestone aquifer creates extreme local contrasts in aquifer permeability.

Only one aquifer test, conducted by Lichtler et al. (1968), is known to have been conducted in the Lower Floridan. This test yielded a transmissivity of about 570,000 ft^2/d. The transmissivity values listed in Table 4.8 were obtained by model calibration only.

4.5.2 Leakance

The leakance (or "leakage coefficient") is defined as the ratio of the vertical hydraulic conductivity of a confining bed to the thickness of the confining bed. Tibbals (1990) reports a range of leakances for the upper semiconfining unit of $1 \times 10^{-6}\ d^{-1}$ to $6 \times 10^{-4}\ d^{-1}$. However, no measured values for leakance of the middle semiconfining unit within the modeled region are available. The values in Table 4.8 range from $5 \times 10^{-5}\ d^{-1}$ to $8.6 \times 10^{-2}\ d^{-1}$ and were obtained through model calibration. Tibbals (1990) comments that the middle semiconfining unit leakance may be quite high in the vicinity of Blue Springs, where a fault probably extends through the Upper Floridan and into the Lower Floridan. Also, based on the middle semiconfining unit thickness maps of Miller (in Tibbals 1990), one might expect higher leakance values in the western portion of the study area where the thicknesses are relatively small (100-200 ft).

5 GROUNDWATER FLOW MODELING

As detailed in Chapter 2, the USGS computer code MODFLOW (McDonald and Harbaugh, 1988) was selected to perform the steady-state regional groundwater flow analysis. This chapter is devoted primarily to discussions of the conceptual modeling framework, model calibration procedure and subsequent sensitivity analysis.

5.1 Conceptual Model and Modeling Assumptions

The conceptual model adopted for the quantitative analysis of flow in the Floridan aquifer system in east-central Florida is illustrated in Figure 5.1. The basic model is that of a dual aquifer system separated by a semiconfining unit. The system is bounded at its base by an impermeable boundary, and at its top by a confining unit that provides areally distributed recharge or discharge directly to the Upper Floridan. Pumpage occurs in both aquifers.

The approach of dividing the Floridan aquifer system into two distinct producing zones separated by a semiconfining unit is well accepted and has been used in numerous modeling studies. In this approach, only the vertical leakage of water (up or down) through the middle semiconfining unit is simulated; horizontal groundwater flow through the semiconfining unit is assumed to be insignificant and is not accounted for. The error associated with this assumption is insignificant because of the large contrast in hydraulic conductivities between the Upper and Lower Floridan production zones and the middle semiconfining unit. Conversely, groundwater flow within the Upper and Lower Floridan is assumed to be horizontal. This is a reasonable assumption throughout the study area, although it could be violated somewhat in the vicinity of very high recharge and discharge (e.g. springs) areas.

Recharge to, and discharge from, the Upper Floridan is specified directly in the model. In reality, groundwater that flows vertically to or from the Upper Floridan must pass through the upper semiconfining unit and into, or out of, the surficial aquifer. Areal recharge (note

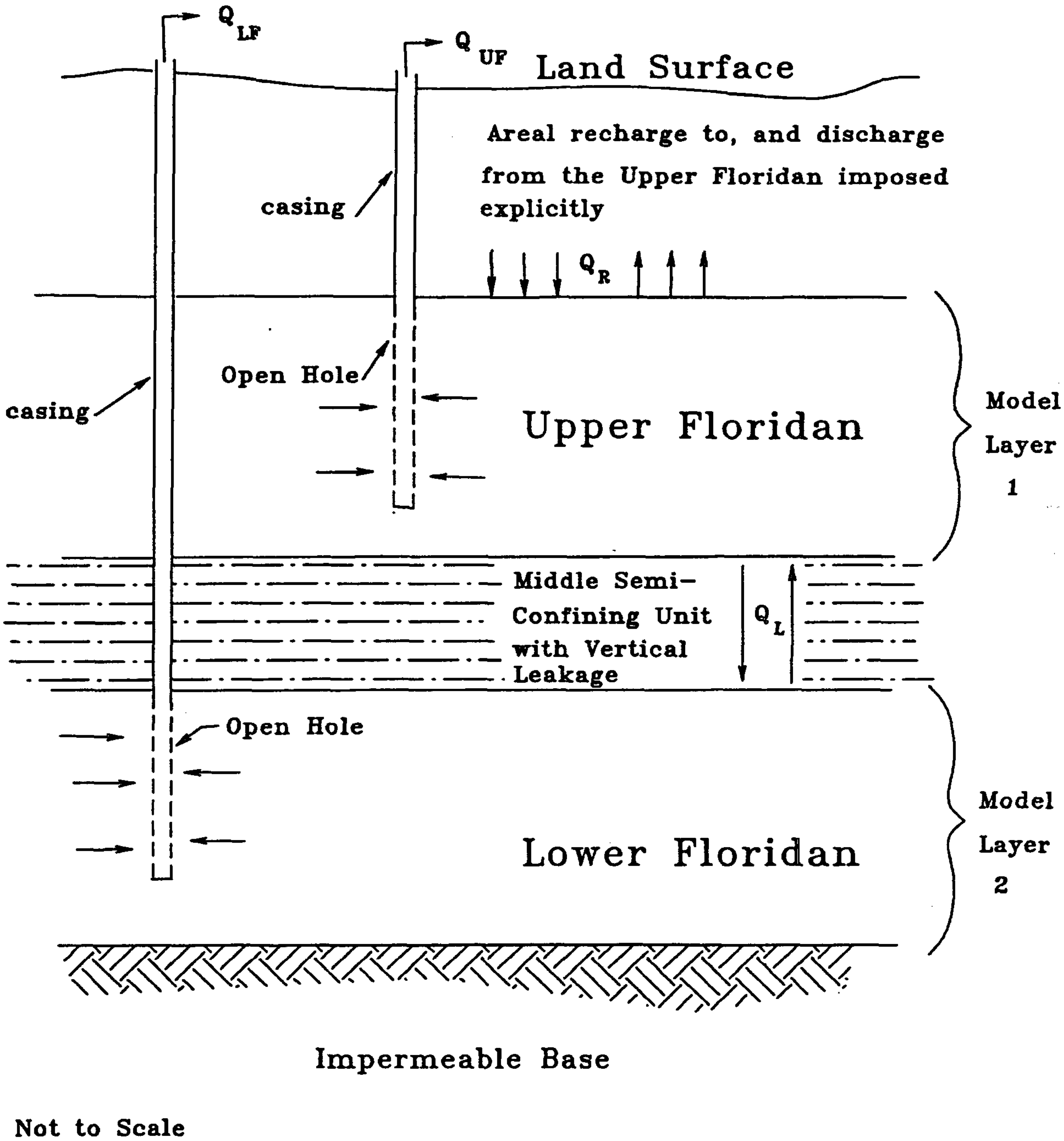


Figure 5.1. Conceptual model for modeling Floridan aquifer system in east-central Florida.

that discharge is simply negative recharge) is a function of the hydraulic head in the surficial aquifer (h_s), the hydraulic head in the Upper Floridan (h_u), the hydraulic conductivity of the upper semiconfining unit (K') and the thickness of the upper semiconfining unit (b'). All of these values exhibit significant spatial variability. Although the hydraulic head in the Upper Floridan is known relatively well throughout the study area, it would be extremely difficult to derive a detailed configuration of h_s, K', and b' given the regional scale of this modeling effort. Therefore, due to the high degree of uncertainty associated with characterizing the variables required to model recharge through the surficial aquifer explicitly (i.e. h_s, K', and b'), the approach of specifying recharge directly is appropriate. Furthermore, most information that exists concerning recharge to the Upper Floridan through the surficial aquifer is presumably incorporated within the published maps such as Tibbals (1990) and Phelps (1984).

The approach of specifying recharge directly, rather than modeling the flow of water through the upper semiconfining unit explicitly, may be used because of the steady-state flow field assumption. Under steady state, all of the variables that control leakage (h_s, h_u, K' and b') do not vary in time. If the system were treated as a transient system, the values of h_s and/or h_u could change with time, and therefore the leakage (recharge) to the Upper Floridan could become a transient process. Justification for modeling the Floridan Aquifer within the study area as a steady-state system was presented in Section 4.1.

The effects of the drainage wells (recharge) in the vicinity of Orlando and pumpage for heat pumps, lawn irrigation and domestic uses (discharge) in Brevard County were also incorporated into the recharge applied to the Upper Floridan. Similar approaches were adopted by CH2M Hill (1988) and Jammal and Associates (1990). Obtaining accurate data to model these two physical processes directly would be very difficult if not impossible. Maps of the locations of the drainage wells about Orlando exist (Tibbals, (1990) and Kimrey (1978)), but detailed estimates of the flux that may be attributed to each well does not. Maps of well density in Brevard County for small diameter irrigation wells, domestic wells and groundwater heat pump wells for the year 1976 are also available (Brevard County Division of Natural Resources, 1989), but the accuracy of these maps relative to 1988 conditions is unknown, and again there is no detailed flux data available for each of these categories of pumping.

All stresses (pumpage, spring flow, etc.) to the Floridan aquifer system were averaged over the calendar year; pumping values were input in ft^3/d and areal recharge was entered in ft/d. Therefore, even though some pumpage was seasonal, such as that for irrigation, the amount of pumpage was assumed to be spread evenly throughout 1988. This approach is reasonably accurate for determining Floridan aquifer parameters for the regional system over the long term.

5.2 Grid Design

The model grid is a two-layer, block-centered grid representing the Lower and Upper Floridan, and encompassing all of Orange and Seminole counties, and significant portions of Lake, Volusia, Brevard, Osceola and Polk counties (Fig. 5.2). Each layer of the grid consists of 44 rows and 53 columns. Thus, the total number of nodes in the grid is $44 \times 53 \times 2 = 4{,}664$; of which only 3,846 were active due to the configuration of the boundary conditions. Because the main area of interest is east Orange County in the vicinity of the City of Cocoa's well field and Orange County's proposed Eastern Regional well field, this region was given the finest discretization ($\Delta x = \Delta y = 1$ mi). The grid block dimensions were then increased progressively moving towards the boundaries (Table 5.1).

The outer boundaries of the grid were placed in such a way as to allow the utilization of natural boundary conditions that occur about the region of interest. Such boundary conditions include the Green Swamp potentiometric high in the southwestern corner of the study region, and dividing groundwater flow pathlines that exist along the southern, northwestern, and to some extent the northern boundaries of the study region.

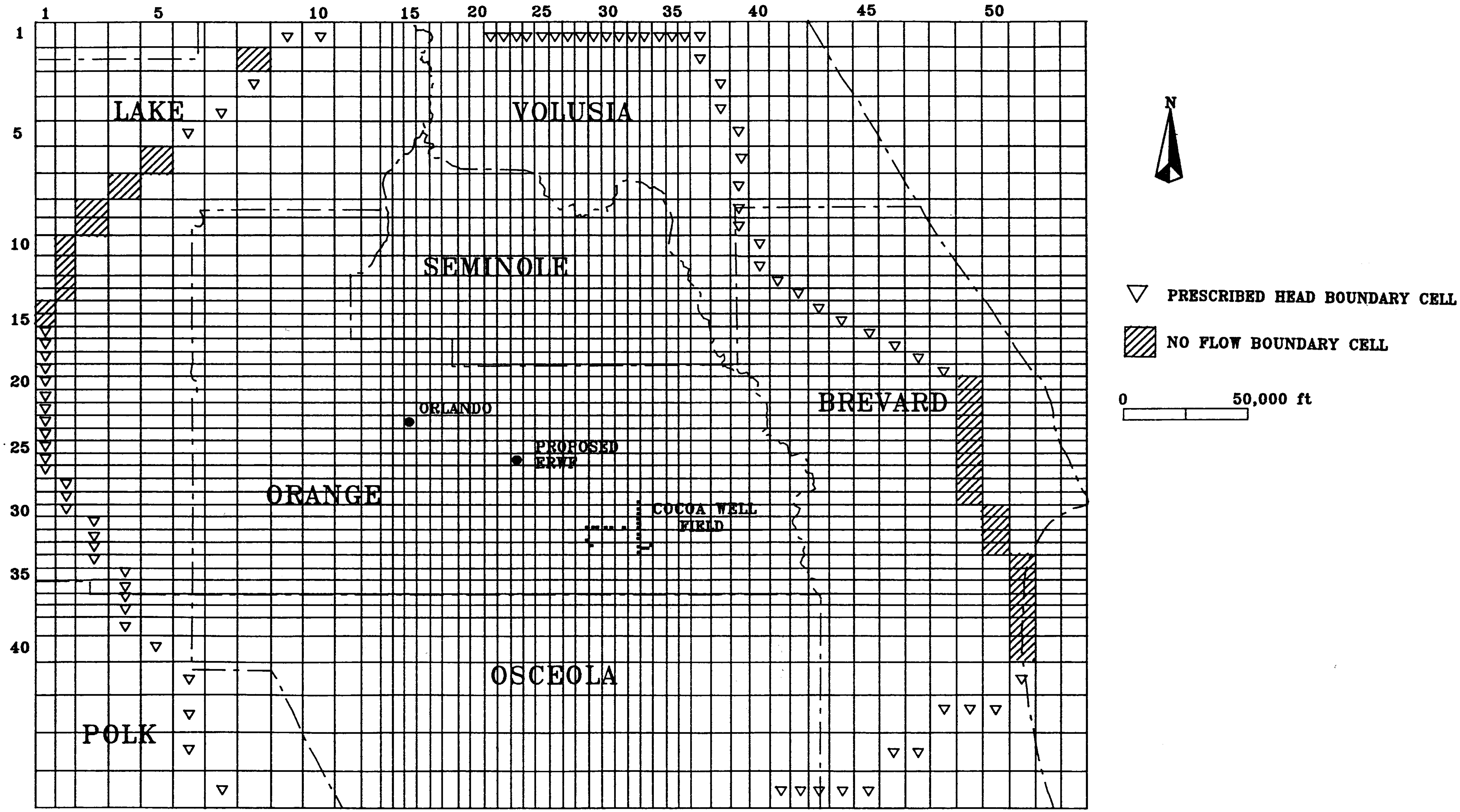


Figure 5.2. Model grid and Upper Floridan boundary conditions used in east-central Florida modeling study.

Table 5.1. Gridline spacings for MODFLOW finite-difference mesh for east-central Florida modeling study.

Column	Δx (miles)	Row	Δy (miles)
1	1.5	1	2.0
2	1.5	2	2.0
3	2.5	3	2.0
4	2.5	4	2.0
5	2.5	5	2.0
6	2.5	6	2.0
7	2.5	7	2.0
8	2.5	8	1.5
9	2.5	9	1.5
10	2.5	10	1.5
11	2.0	11	1.5
12	1.5	12-38	1.0
13-36	1.0	39	1.5
37-43	1.5	40	2.0
44-53	2.0	41	2.5
		42	3.0
		43	3.0
		44	3.0
TOTAL	81		62

Because MODFLOW requires that pumping values be specified at grid-block centers, the grid was designed so that most major pumping centers would be located near the centers of grid blocks. However, due to the large number of pumping locations within the study area, as well as their random distribution, this goal could not always be achieved.

5.3 Model Input Data

5.3.1 Boundary Conditions

The boundary conditions used for the Upper Floridan in the simulations are also illustrated in Figure 5.2. No-flow conditions were specified along groundwater flow pathlines for the northwest boundary, portions of the northern boundary, much of the southern boundary, and a significant portion of the east-central boundary. Elsewhere a prescribed head condition was used. The prescribed head values and the position of the pathlines were determined using the average Upper Floridan 1988 potentiometric surface map (Fig. 4.1). Note that along the northern and southern boundaries where there is no boundary condition symbol, MODFLOW will use a no-flow boundary condition by default.

It is possible to "over constrain" the solution to the groundwater flow problem by prescribing head values for too many model cells. The distribution between no-flow and prescribed head boundary cells for the Upper Floridan is approximately fifty-fifty; there are 75 no-flow boundary cells and 80 prescribed head boundary cells. The prescribed head model cells used were required to obtain reasonable calibration results. It is felt that the prescribed head boundaries used in this study are reasonable and do not over constrain the solution to the physical problem.

The boundary conditions for the Lower Floridan were set as no-flow on all sides of the domain. This was the modeling framework adopted by Tibbals (1990). The justification for such an approach is as follows. If one considers the Floridan aquifer system on a statewide scale, the Lower Floridan is recharged by the Upper Floridan in areas where the Upper Floridan is receiving high recharge from the surficial aquifer, where the middle semiconfining unit is thin or permeable, and where a vertically downward hydraulic gradient between the Upper and Lower Floridan exists. These conditions are by and large prevalent near the center of the state, which is the vicinity of the western study area boundary. Furthermore, a hydraulic groundwater flow divide should exist approximately along the peninsular divide. On one side of the divide, groundwater recharge will flow towards the Atlantic Ocean, and on the other side it will flow towards the Gulf of Mexico. Once water moves vertically into the Lower Floridan, it will move laterally away from the recharge areas toward the discharge areas, which for the Lower Floridan roughly extends from the St. Johns River to the coastline. As groundwater in the Lower Floridan approaches this region, it will be forced upward by existing water of increasing salinity.

The western no-flow boundary, therefore, is conceptualized as approximating the hydraulic flow divide near the center of the state; the northern and southern no-flow boundaries follow approximately groundwater flow pathlines from the central regions of the state toward the coast, and the eastern (coastal) no-flow boundary is associated with the "pinching out" zone of the flow field at the lateral saltwater-freshwater interface. This conceptualization is only approximate at best. In reality, there are undoubtedly some lateral fluxes at depth to and from the Lower Floridan. However, in consideration of the extremely limited data available for the Lower Floridan, as well as the fact that flow in the Lower Floridan seems to have a limited effect upon flow in the Upper Floridan, the stated Lower Floridan boundary conditions are thought to be reasonable on a regional scale.

5.3.2 Physical Parameters

The physical parameters input into the modal are as follows: areal recharge (discharge) for the Upper Floridan, transmissivities for the Upper and Lower Floridan, leakance of the semiconfining unit between the Upper and Lower Floridan, the discharges due to pumping in the Upper and Lower Floridan, and the discharges due to springs in the Upper Floridan. The pumping rates and spring discharges used were detailed in Chapter 4. The initial values of recharge rate, aquifer transmissivities, and leakance used were those documented in Tibbals (1990).

5.4 Model Calibration

Model calibration is the general procedure of adjusting model input parameters within reasonable ranges until the model output (in this case hydraulic head in the Upper Floridan) resembles conditions observed in the field within some prescribed error tolerance. In this study, the calibration parameters were transmissivity of the Upper Floridan, areal recharge to the Upper Floridan, leakance between the Upper and Lower Floridan, and agricultural pumpage in the southeastern corner of the study area. The observed field condition that the model was calibrated to is the 1988 average potentiometric surface map for the Upper Floridan (Fig. 4.1). Due to insufficient data, the potentiometric surface in the Lower Floridan could not be calibrated. Hydraulic head values are available for the Lower Floridan only at a very limited number of locations within the study area, most of which are in the vicinity of Orlando.

5.4.1 Calibration Procedure

Model calibration should not be performed in a random fashion. A well-calibrated model should make full use of, and incorporate to the extent possible, existing hydrogeological data and knowledge concerning the groundwater flow system. The model calibration in this study was conducted in the following fashion:

- The model grid and input data were set up for the Upper Floridan (model layer 1) only. At this point, a series of model sensitivity runs were conducted to investigate the effects that adjusting recharge and transmissivity had on the flow system.
- The Lower Floridan (model layer 2) and its associated input data was added to the model.

- Calibration of the Upper Floridan was conducted to the extent possible by adjusting recharge and transmissivity.
- The leakance (leakage coefficient) of the middle semiconfining unit was included as a calibration parameter after the match between the observed and model calculated heads could not be substantially improved by varying recharge or transmissivity in the Upper Floridan.
- The final calibration was conducted by fine-tuning the middle semiconfining unit leakance coefficient and the Upper Floridan transmissivity and recharge values.

Note that all of the initial model input parameters (aquifer transmissivities, recharge and leakance) were taken from Tibbals (1990).

When varying the physical input parameters during the calibration process, certain general guidelines were followed. Recharge was varied within the constraints of spatial location and magnitude illustrated in Figure 4.6. Transmissivity values for the Upper Floridan were kept within the 10,000 ft^2/d - 400,000 ft^2/d range reported in Tibbals (1990). No measured values were available for the leakance of the middle semiconfining unit within the model region. In general, this parameter was confined to lie within an order of magnitude of Tibbals (1990) average value of 5×10^{-5} d^{-1}, except in the vicinity of Blue Springs where it was set very high (0.01 d^{-1}) to simulate good connection between the Upper and Lower Floridan.

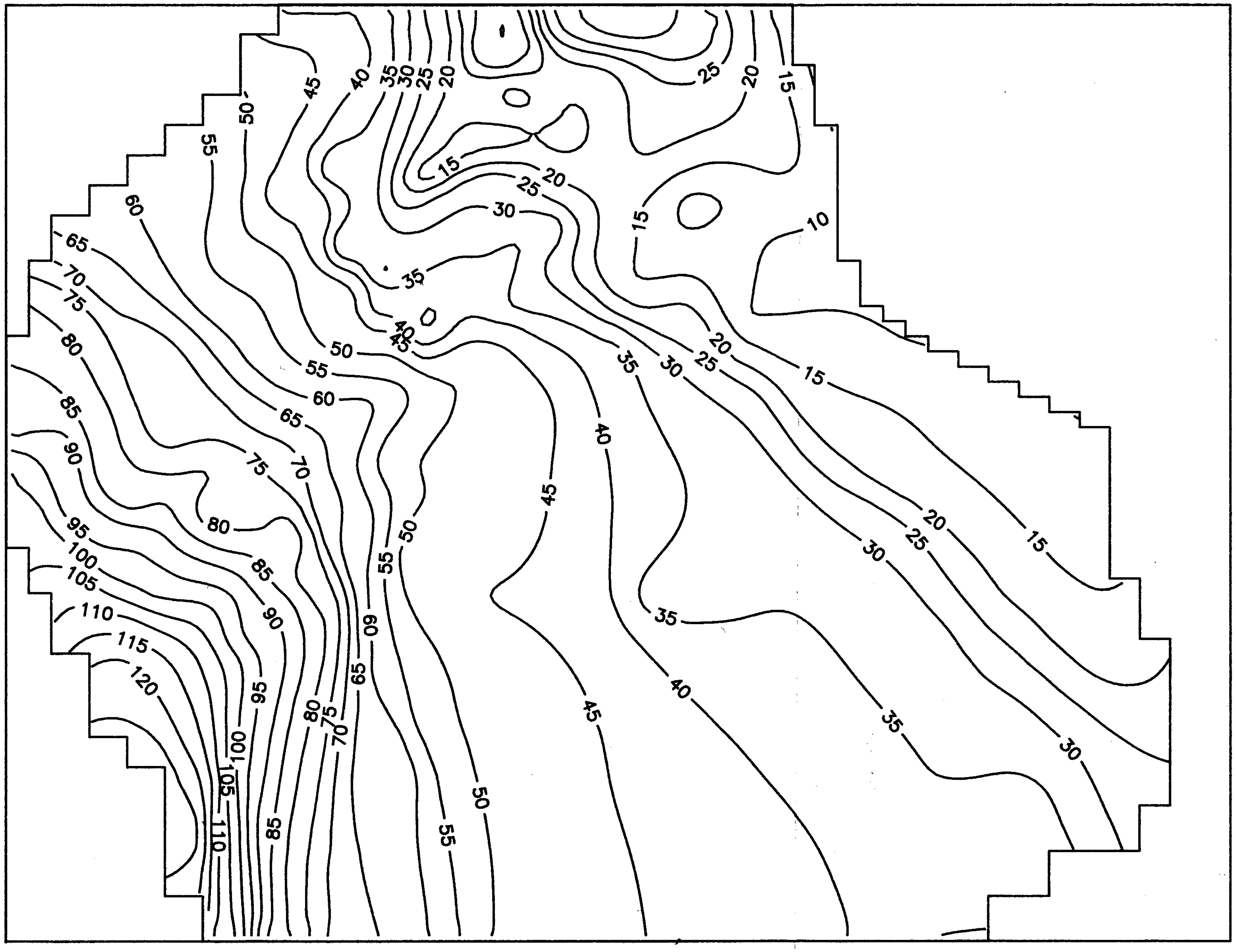
The physical parameters obtained through model calibration are "effective" or "average" parameters over a grid block. The degree of local variation that may be accounted for is necessarily restricted by the grid block size. Furthermore, model calibrated parameters may not be unique; or, in other words, the same potentiometric surface might be obtained using different combinations and values of model parameters. The goal of this modeling study was to obtain realistic calibration parameters that conform to the overall hydrogeologic framework, and that lie within a reasonable range that may be verified using field observations.

5.4.2 Calibration Results

The average 1988 Upper Floridan potentiometric surface simulated by the calibrated flow model is presented, along with an overlay of the observed potentiometric surface, in Figure 5.3. Figure 5.4 is a contour map of the difference between the simulated and observed potentiometric surfaces. Throughout most of the study area, the differences are less than 2 ft. In the vicinity of the Cocoa well field and Orange County's proposed Eastern Regional well field, the differences are close to zero. The purpose of the box plotted in the center of Figure 5.4 is explained in the following Section on sensitivity analysis.

The highest observed difference between the observed and simulated potentiometric surfaces is about 6 ft; local highs exist in the northwest and west-central regions of the study area. Each of these areas is a region of very steep hydraulic gradient caused in the northwest region by substantial spring discharge, and in the west-central region by high areal recharge. In addition, the observed potentiometric surfaces in these regions exhibit a complex curvature, presumably due to unknown local effects of aquifer parameters and recharge or discharge. It would be quite difficult to improve the match significantly in these regions using a regional-scale model. Furthermore, although the hydraulic heads do not match as closely in these regions as in others, in general the overall hydraulic gradient is preserved; it is the gradient which is of primary importance in groundwater modeling, rather than heads, because gradient determines the flux. Finally, the two areas in question have relatively small influence on the primary area of concern, which is central and eastern Orange County.

Figures 5.5 and 5.6 illustrate the final, calibrated values of transmissivity and recharge in the Upper Floridan respectively. In general, the recharge values follow the patterns and have magnitudes within the ranges reported by Tibbals (1990). The transmissivities also lie within


45
40
35
30
25
20
25
20
15
50
55
15
20
25
30
15
10
60
65
35
70
75
40
45
80
50
55
20
25
30
35
15
60
85
65
70
90
40
75
45
80
20
95
100
105
110
115
120
85
90
95
100
105
110
85
80
75
70
65
60
55
50
50
55
45
30
25
15
35
40
35
30
45

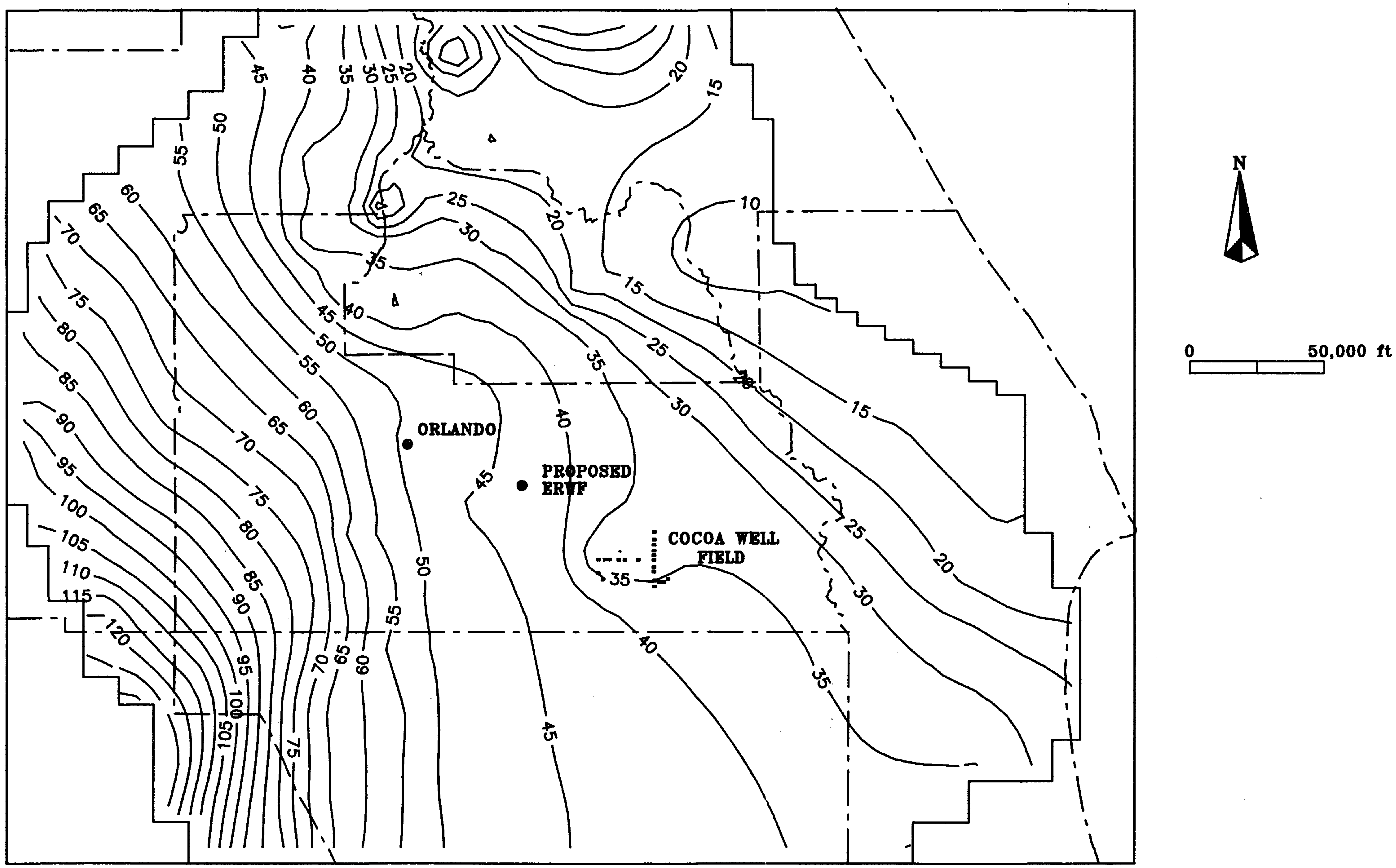


Figure 5.3. Final simulated Upper Floridan potentiometric surface and observed potentiometric surface (overlay) for 1988 in feet above msl.

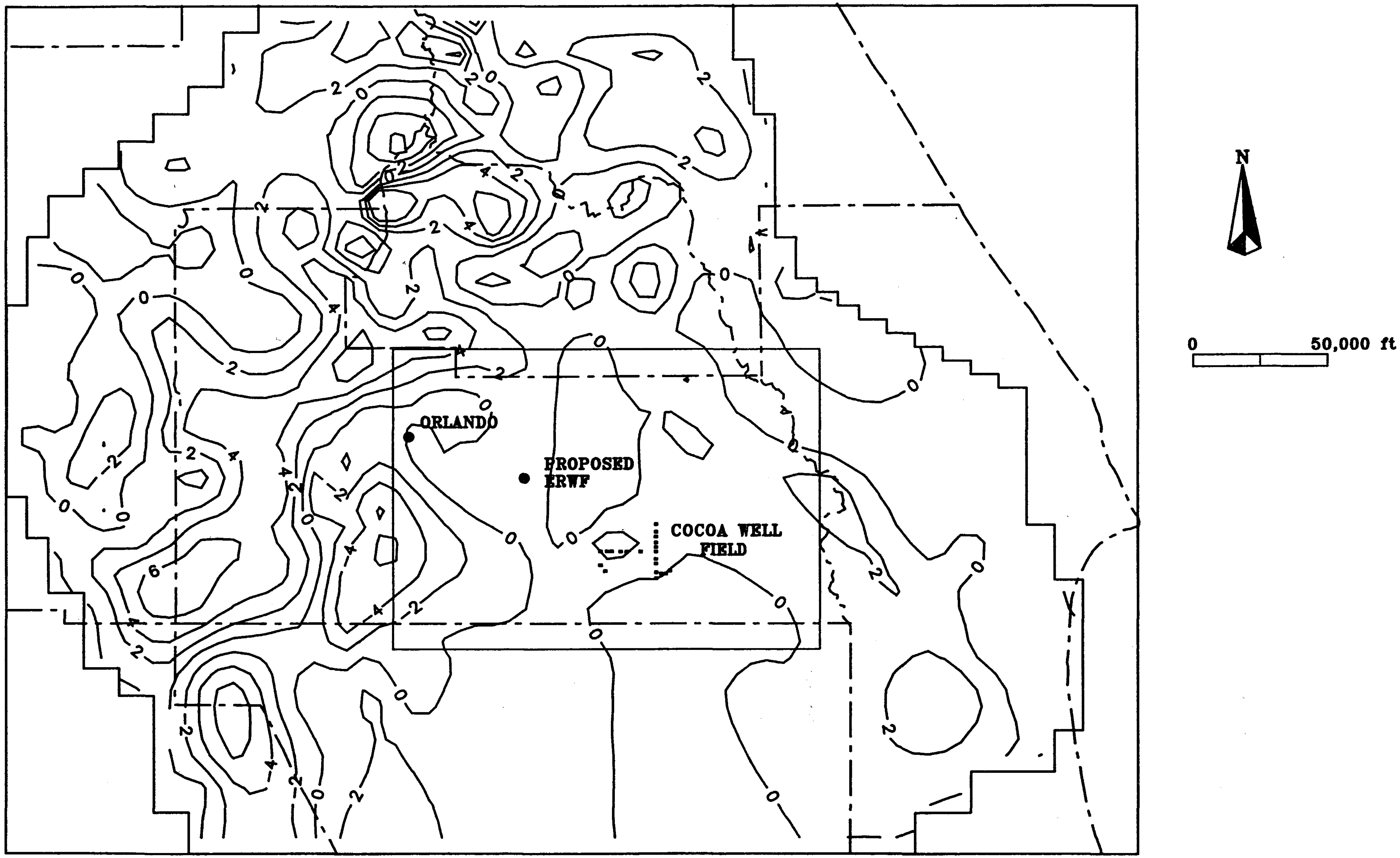


Figure 5.4. Difference between final simulated 1988 Upper Floridan potentiometric surface and observed potentiometric surface in feet above msl.

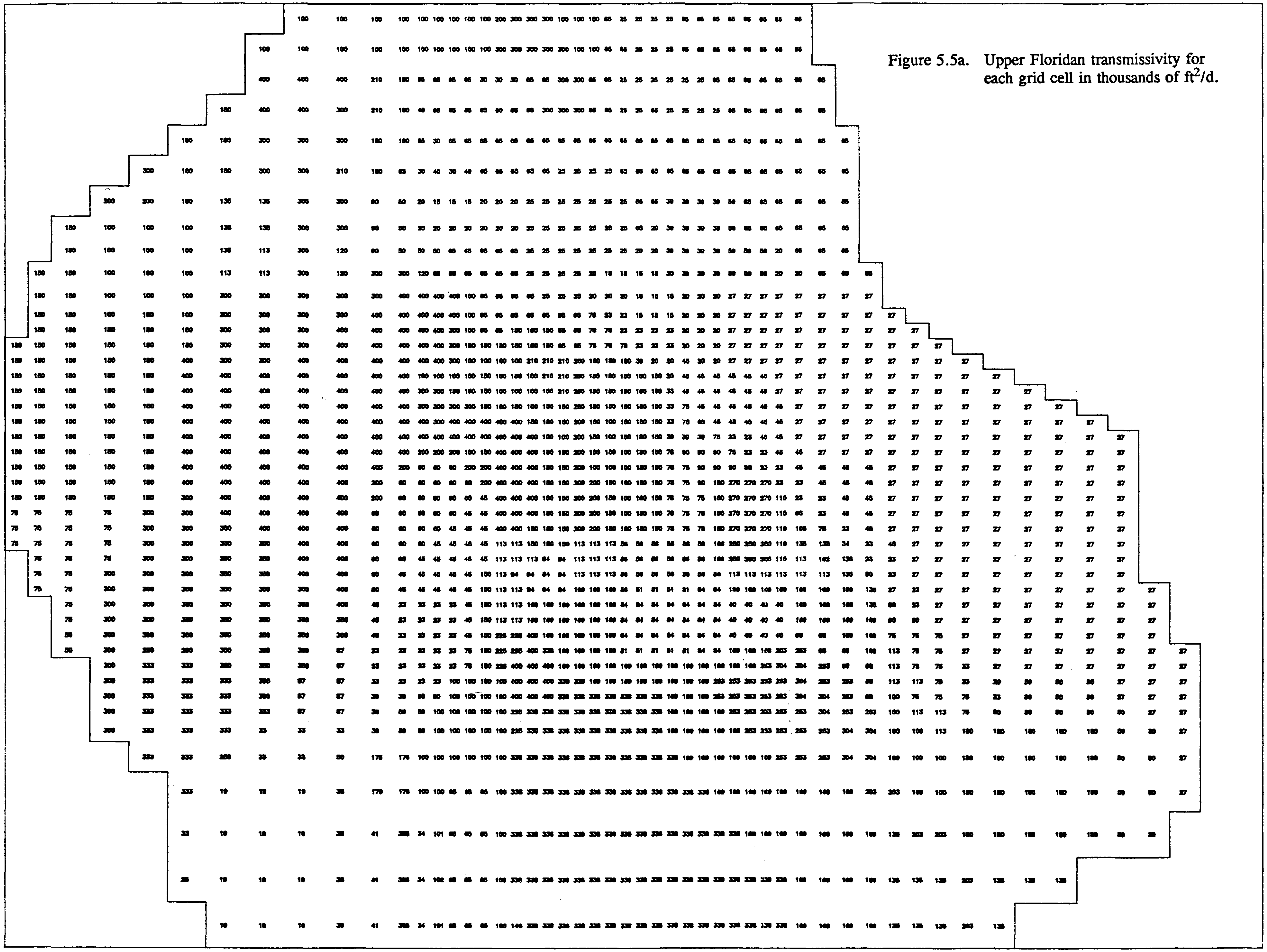


Figure 5.5a. Upper Floridan transmissivity for each grid cell in thousands of ft^2/d.

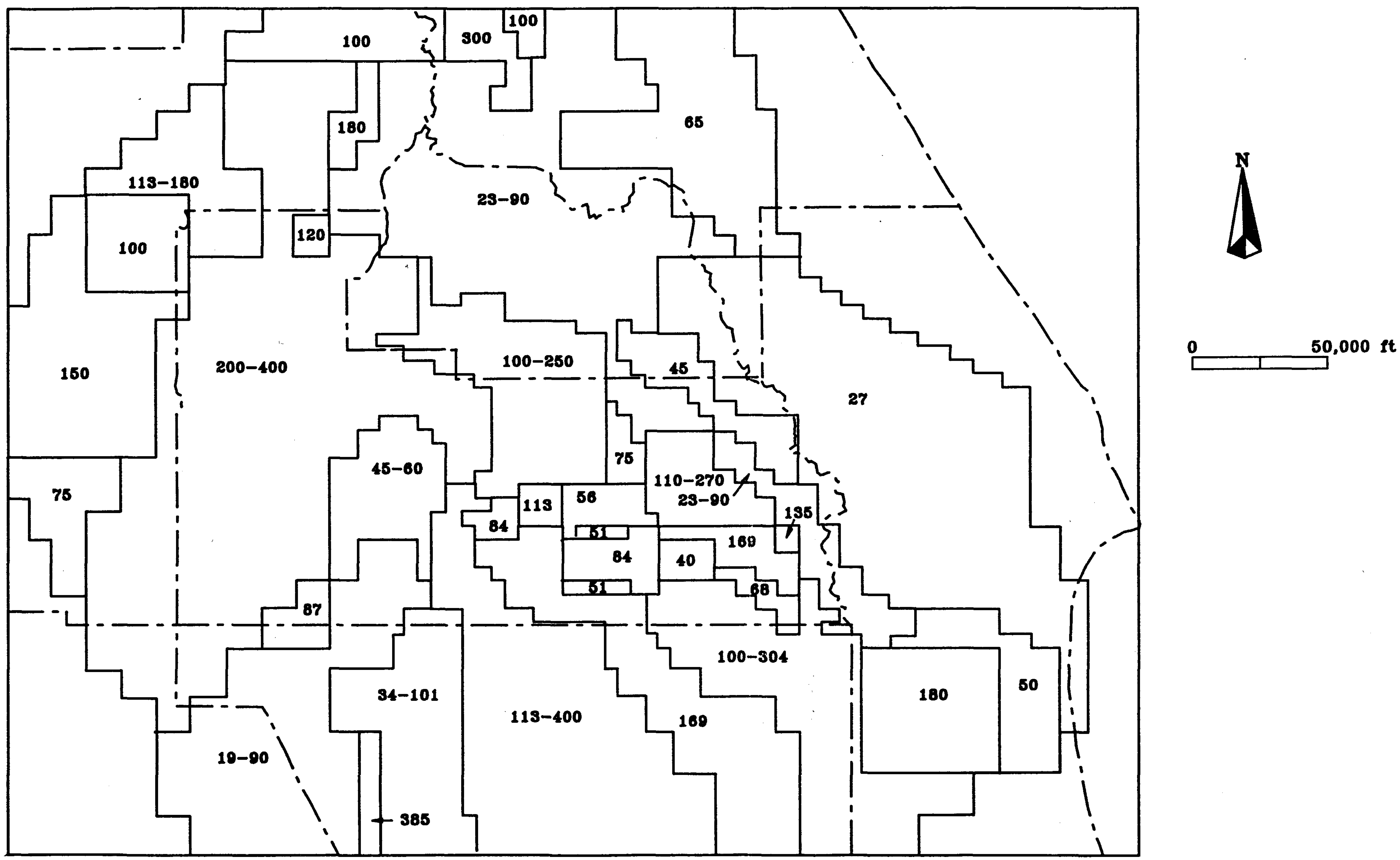


Figure 5.5b. Upper Floridan transmissivity in thousands of ft^2/d.

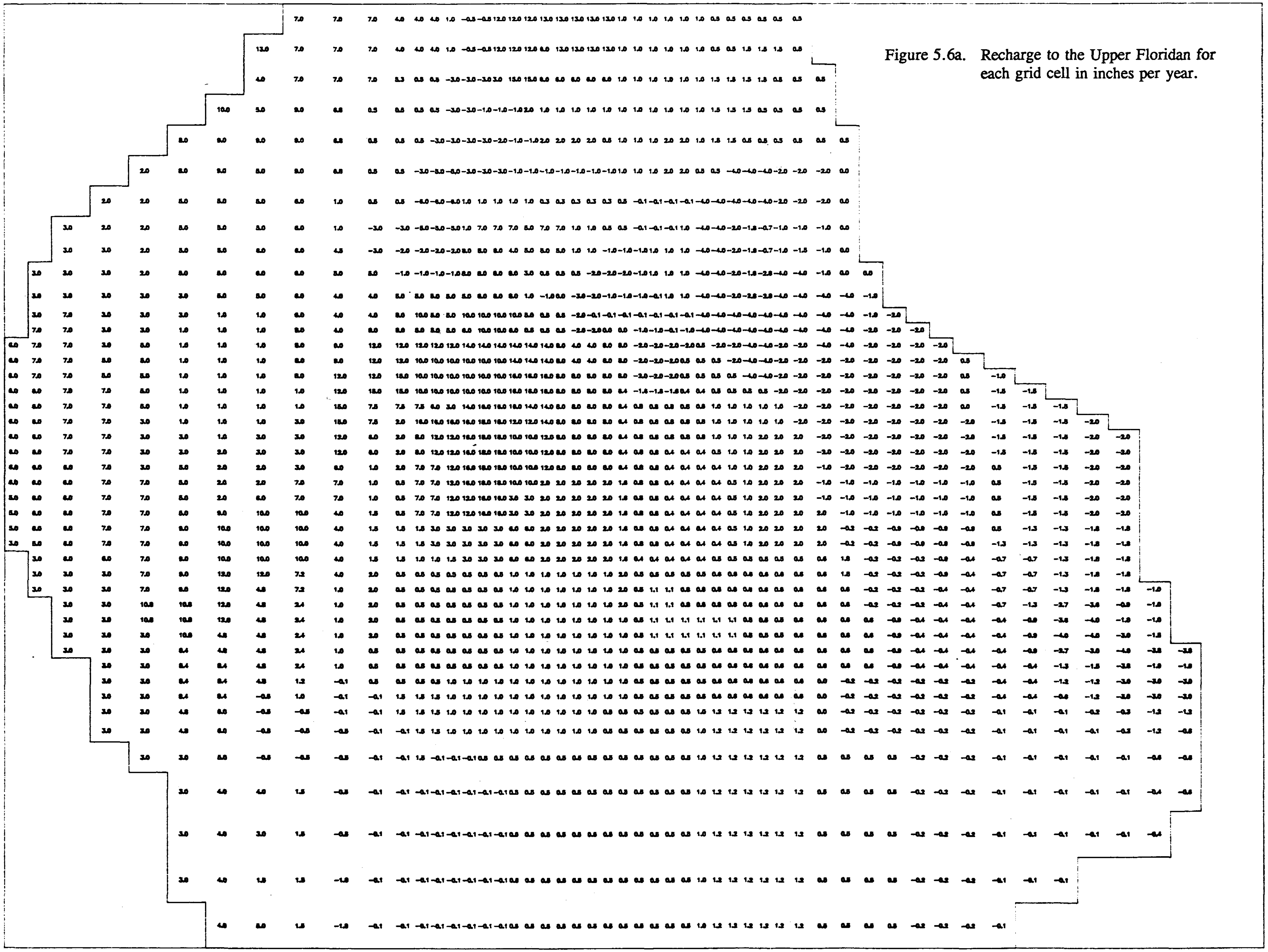


Figure 5.6a. Recharge to the Upper Floridan for each grid cell in inches per year.

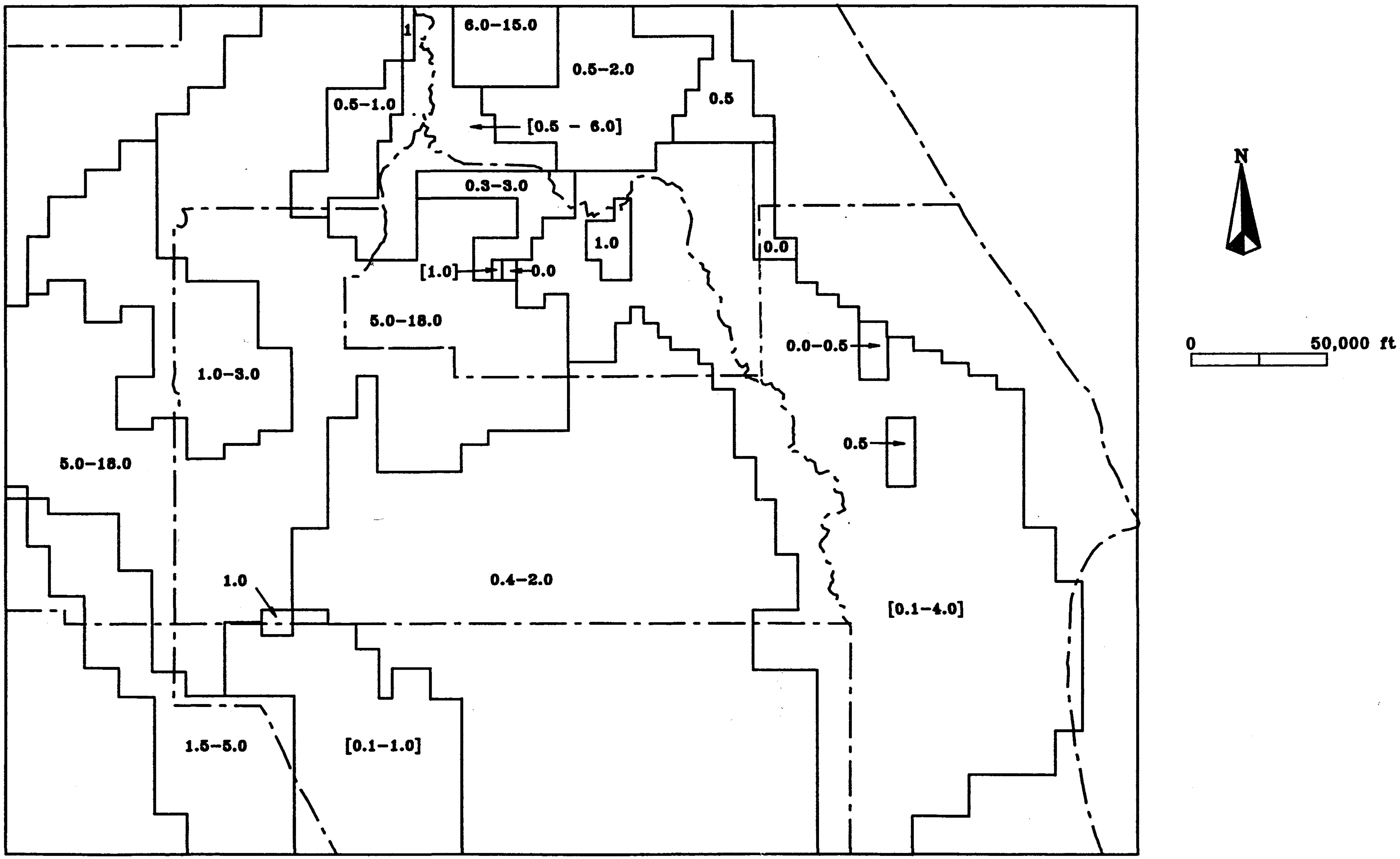


Figure 5.6b. Recharge to the Upper Floridan in inches per year. Brackets indicate discharge.

the bounds used by previous authors (see Table 4.8). The highest values of transmissivity (400,000 ft^2/d) generally occur just north and west of Orlando. Relatively low values of transmissivity (about 30,000 ft^2/d or less) occur in the eastern quarter of the study area and in the southwest corner of the study area. The central portion of the study area is in general a high transmissivity zone (60,000 - 400,000 ft^2/d), except in the vicinity of the Cocoa well field where values of 40,000 - 80,000 ft^2/d were required to reproduce the pronounced cone of depression caused by the Cocoa wells. This range of values in the vicinity of the Cocoa well field matches well with other modeling studies such as Jammal and Assoc. (1990) and CH2M Hill (1988), but is slightly lower than that reported by Tibbals (1990).

The zoning of transmissivities in the Upper Floridan is fairly complex; this is due to two reasons. First of all, the original estimates of transmissivity were taken from Tibbals (1990), who had rather complex zonings in his model. Second, and most importantly, local variations in transmissivity were required to reproduce local irregularities in the potentiometric surface. The concept of large local variations in transmissivity is conceptually linked to the fact that the primary cause of Floridan aquifer permeability is secondary porosity, such as fractures and solution cavities. Therefore, hydraulic conductivity of the Floridan aquifer system would expectedly be spatially variable, with large contrasts in transmissivities likely. This reasoning is supported by the results of numerous aquifer tests within the study area, many of which are in close proximity and indicate markedly different values of transmissivity. For example, three aquifer tests in the vicinity of the Cocoa well field indicated Upper Floridan transmissivities of 74,000, 210,000 and 510,000 ft^2/d (Tibbals 1990). Of course, some of the variation in transmissivities obtained from aquifer tests is due to factors such as differing degrees of well penetration and the length and type of analysis performed.

Figure 5.7 illustrates the final calibrated values of leakance between the Upper and Lower Floridan. Model results for the Upper Floridan were found to be only moderately sensitive to changes in leakance of the middle semiconfining unit. The default leakance value of 5×10^{-5} d^{-1} was only changed in regions where it was felt that transmissivity and recharge could

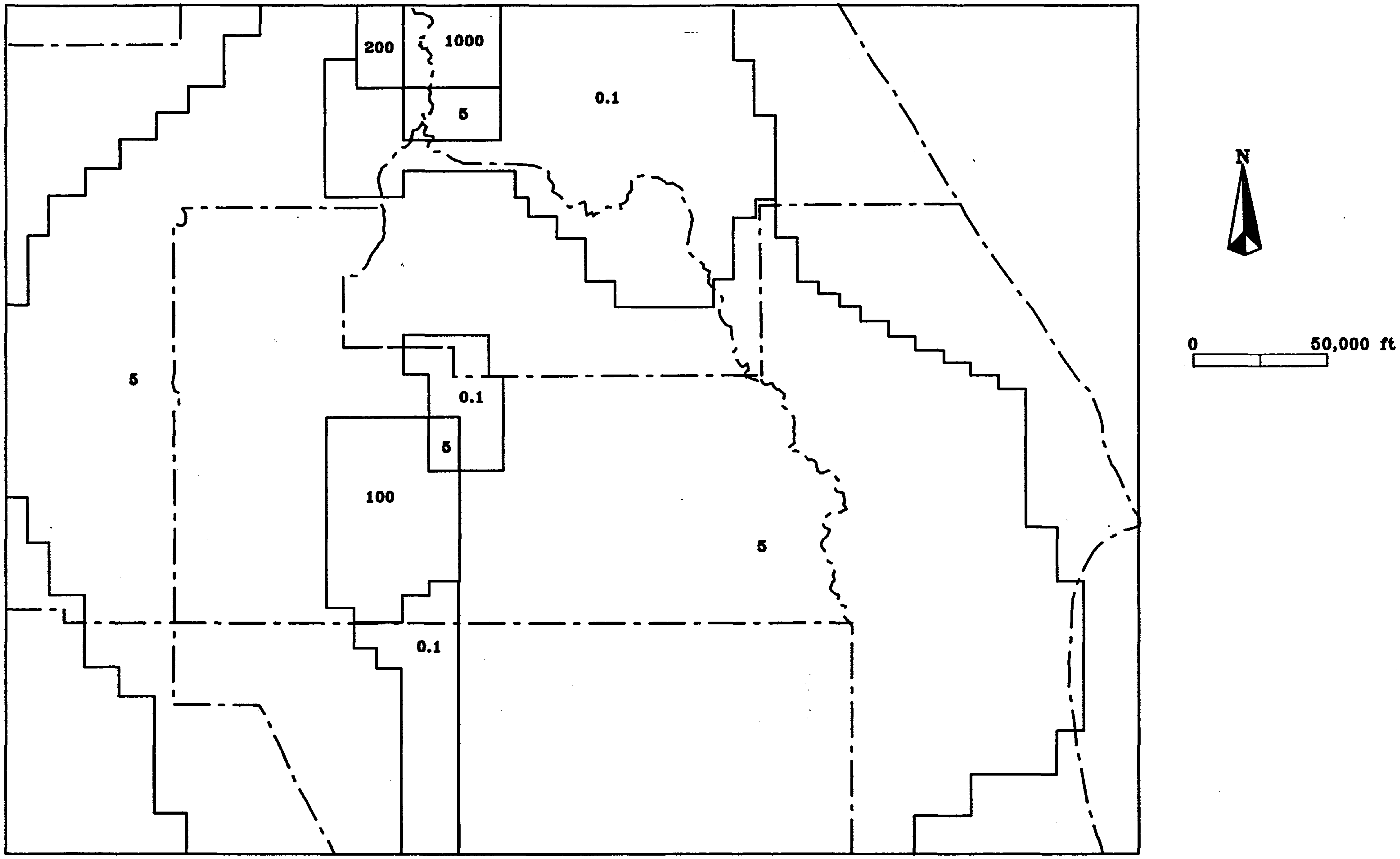


Figure 5.7. Leakance of the middle semiconfining unit times 10^{-5} d^{-1}.

not be adjusted further. Three major areas of decreased leakance (1×10^{-6} d^{-1}) occur in the northeast, south-central, and central (in the vicinity of Orlando) regions of the study area. An area of relatively high leakance (1×10^{-3} d^{-1}) was specified southwest of Orlando, and an area of very high leakance (1×10^{-2} d^{-1}) was specified in the vicinity of Blue Springs to simulate the good hydraulic connection between the Upper and lower Floridan in that region (Tibbals, 1990).

Figure 5.8 illustrates the Lower Floridan transmissivities used. These values were taken directly from Tibbals (1990) and were not adjusted during the calibration process.

One additional parameter, the agricultural pumpage due to Deseret Ranches and the Duda Sod Farm, was adjusted during the calibration process. The initial pumpage estimates for these users were decreased by 50 percent in order to obtain a reasonable match between the simulated and observed potentiometric surface in the southeastern corner of the study area. Given the manner in which these pumpages were initially estimated (see Section 4.2.2.2), this decrease is thought to be reasonable. A similar approach was followed by Skipp (1988).

5.4.3 Sensitivity Analysis

A series of nine sensitivity runs were conducted to determine how sensitive the model results are to variations in the calibrated model parameters. Because the primary aim of Phase 1 was to determine appropriate aquifer parameters for eastern and central Orange County, in all except one of the runs the aquifer parameters were adjusted only in the center of the study region. This region, hereafter referred to as the "sub-area", is the box outlined in Figure 5.4 and the following figures. The only sensitivity run that had parameters adjusted outside this region was the run where Lower Floridan transmissivity was decreased along the eastern edge of the study area to simulate a "pinching out" effect due to a lateral saltwater boundary. The results of each of the sensitivity runs are presented in the following Sections as a series of Upper Floridan potentiometric surface difference maps. The contours in Figures 5.9 -

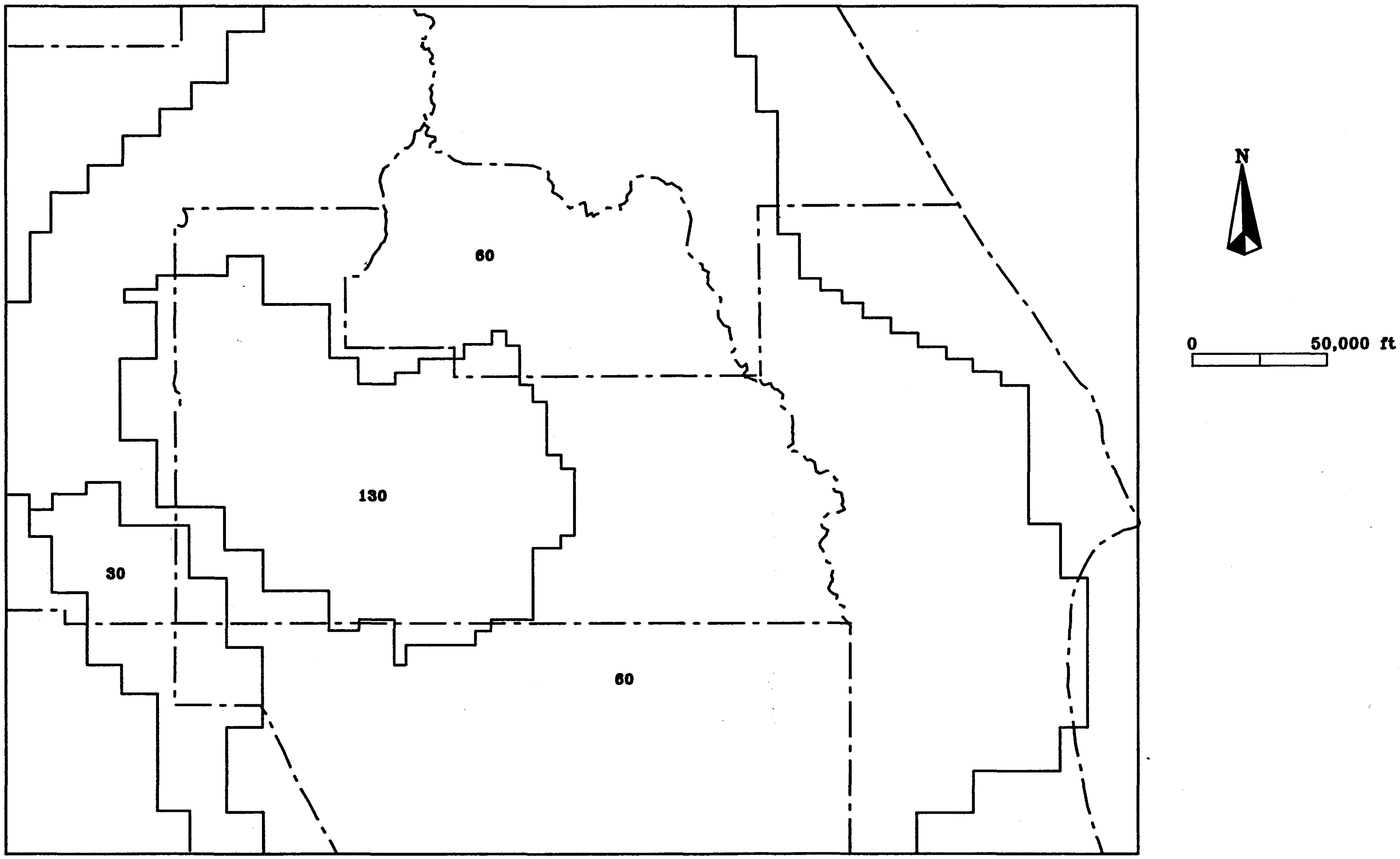


Figure 5.8. Transmissivity of Lower Floridan in thousands of ft^2/d, after Tibbals (1990).

5.17 represent the difference between the final simulated potentiometric surface illustrated in Figure 5.3 and the potentiometric surface obtained using the adjusted input parameters.

5.4.3.1 Upper Floridan Transmissivity

Figures 5.9 and 5.10 illustrate the effects of a two-fold increase, and a 50 percent reduction respectively in the Upper Floridan transmissivity. It can be seen from Figure 5.9 that increasing transmissivity causes a maximum potentiometric surface increase within the sub-area of 8 ft in the vicinity of the Cocoa well field. The differences become less substantial away from the well field and are generally 2 ft or less throughout most of the sub-area.

Decreasing the Upper Floridan transmissivity by 50 percent caused an 8 ft decrease in the potentiometric surface in the vicinity of the Cocoa well field (Fig. 5.10). The change in the potentiometric surface throughout the rest of the sub-area was generally less than 2 ft. It is evident from this analysis that the Upper Floridan potentiometric surface within the sub-area is highly sensitive to transmissivity variations within the local area about the Cocoa well field, but only moderately sensitive to such variations throughout the remainder of the sub-area.

5.4.3.2 Upper Floridan Recharge

Figures 5.11 and 5.12 illustrate the effects of a two-fold increase, and a 50 percent reduction in recharge to the Upper Floridan, respectively. Increasing recharge raised the potentiometric surface by as much as 18 ft, while decreasing recharge decreased the potentiometric surface by over 9 ft in some areas. Figures 5.11 and 5.12 also illustrate that adjusting the recharge in the sub-area may have substantial effects outside of the sub-area. The Upper Floridan potentiometric surface is highly sensitive to the applied recharge rate.

The Upper Floridan potentiometric surface is very sensitive to recharge and transmissivity. Because each of these parameters can have similar effects on the steady-state flow field, it is

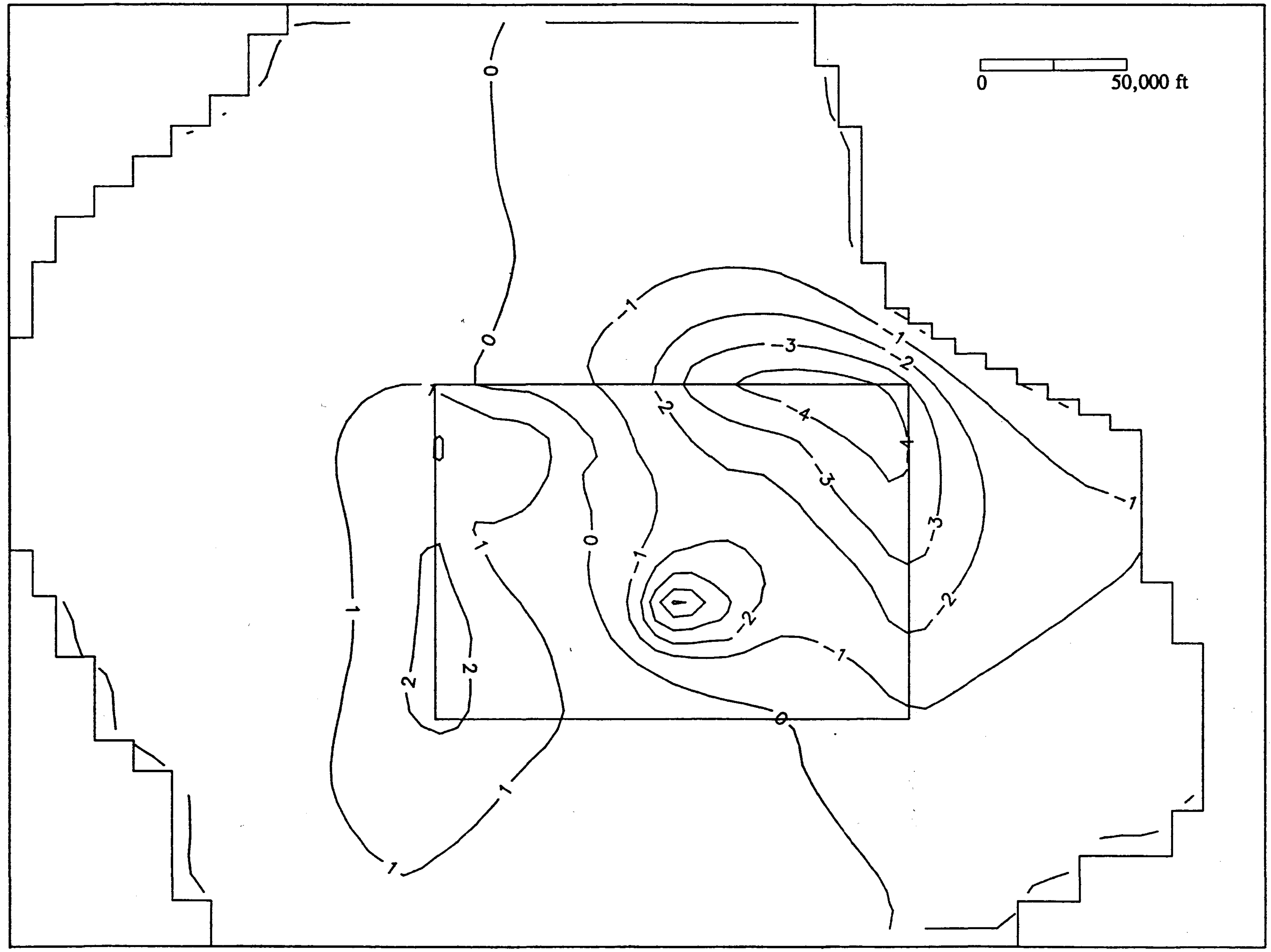


Figure 5.9. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using a two-fold increase in Upper Floridan transmissivity within the sub-area in feet above msl.

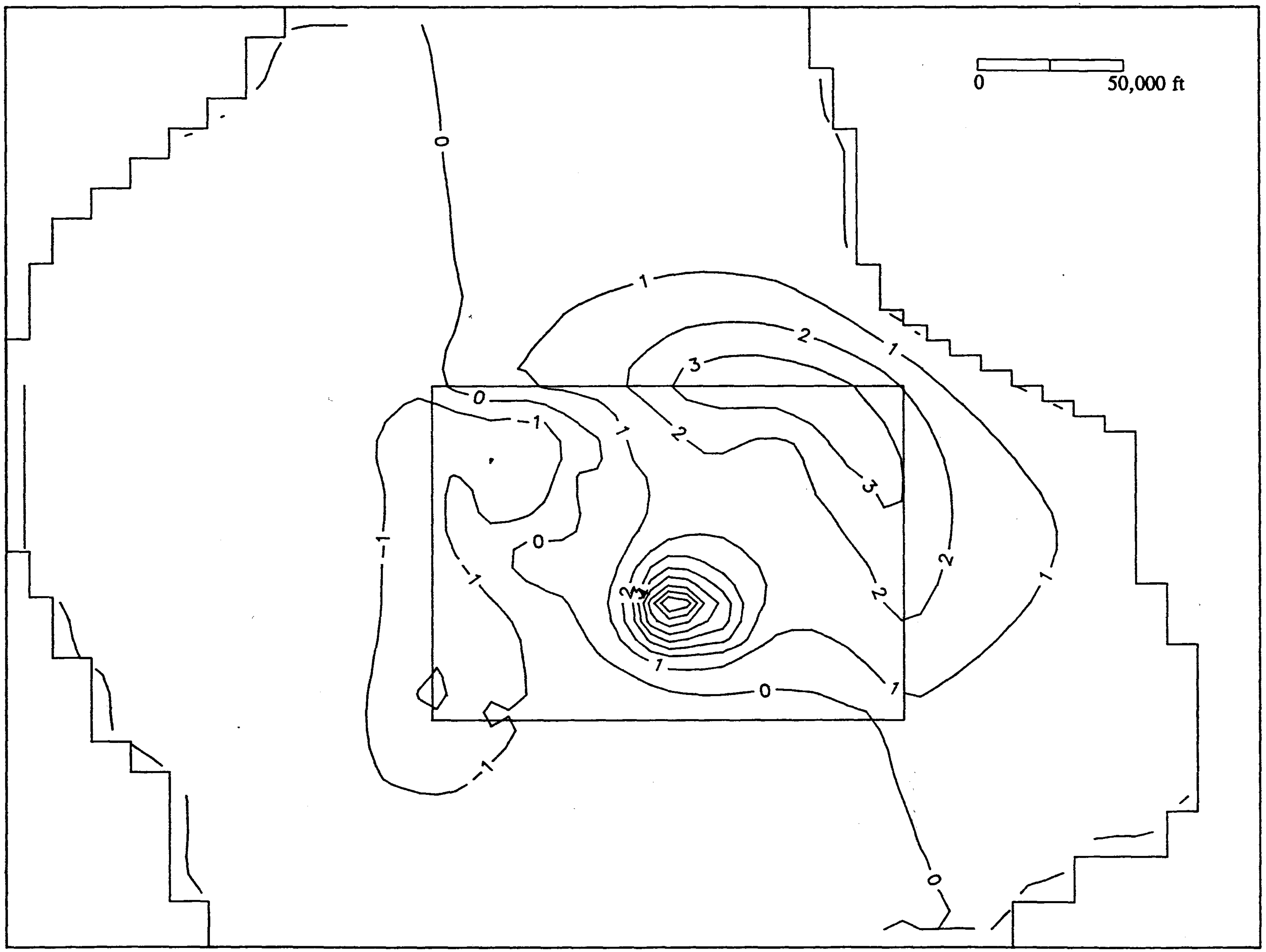


Figure 5.10. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using a 50 percent decrease in Upper Floridan transmissivity within the sub-area in feet above msl.

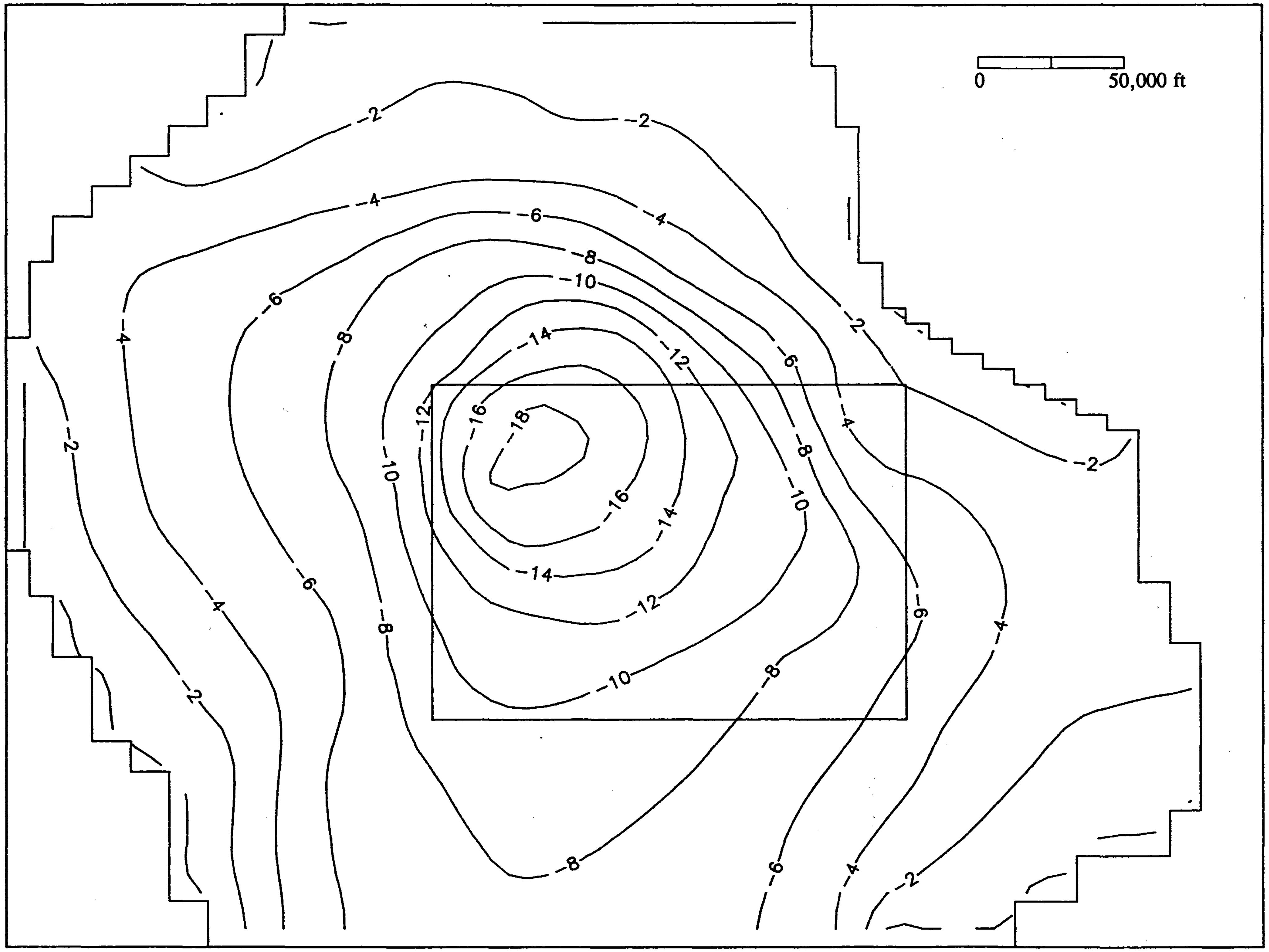


Figure 5.11. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using a two-fold increase in recharge to, and discharge from, the Upper Floridan within the sub-area in feet above msl.

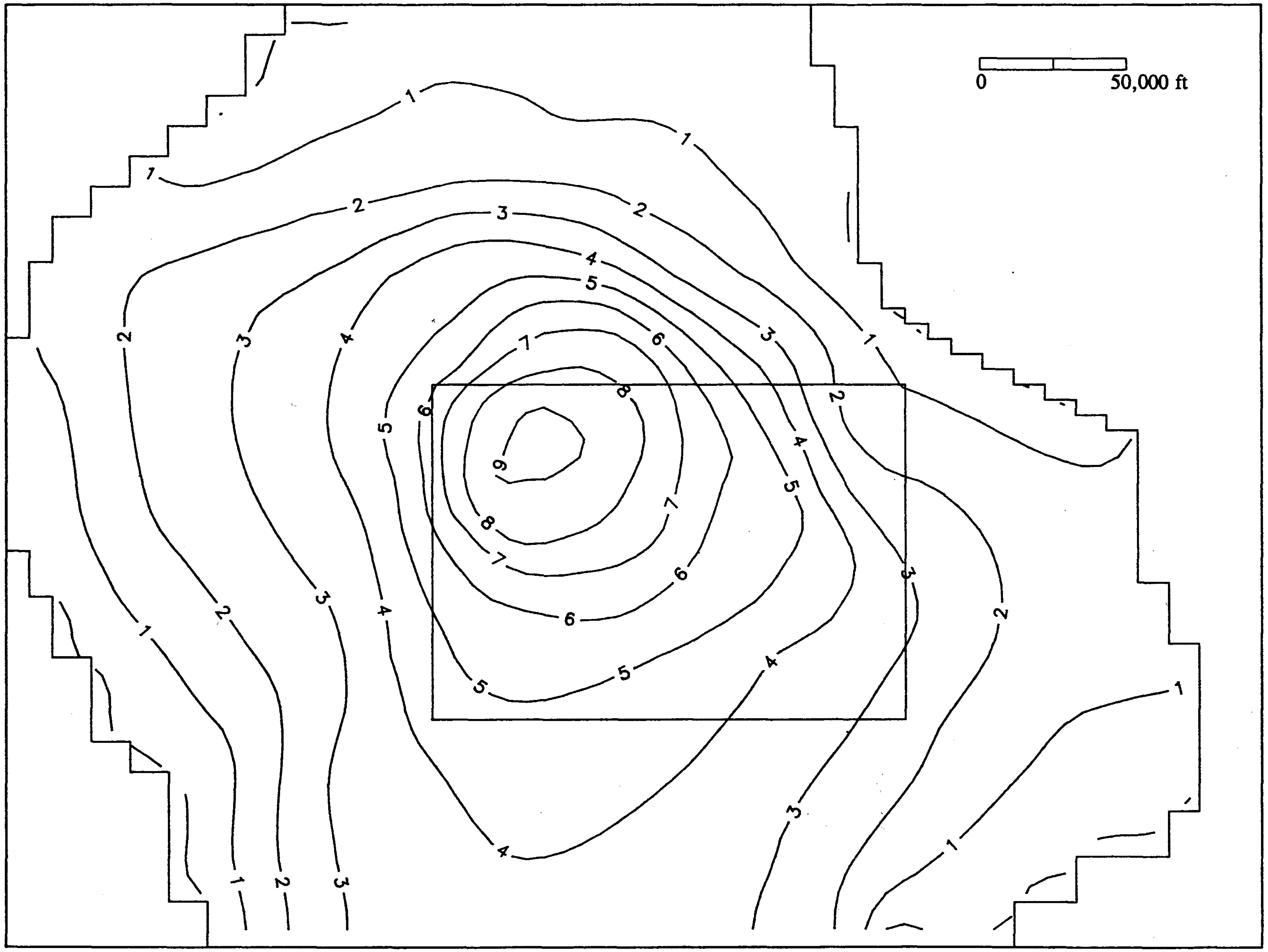


Figure 5.12. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using a 50 percent reduction in recharge to, and discharge from, the Upper Floridan within the sub-area in feet above msl.

very important to restrict the appropriate ranges for each parameter. Fortunately, recharge was calibrated using the map from Tibbals (1990): this map was spot checked using 1988 lake levels and the Upper Floridan potentiometric surface map, and it was found to be quite accurate. Because the recharge conditions are fairly well constrained throughout the study area, more confidence can be placed in the Upper Floridan transmissivity estimates than would otherwise be the case.

5.4.3.3 Leakance of Middle Semiconfining Unit

The effect of leakance on the Upper Floridan potentiometric surface was investigated by increasing the leakances within the sub-area by an order of magnitude (Fig. 5.13) and decreasing them by an order of magnitude (Fig. 5.14). Leakance was increased and decreased by a factor of 10 rather than 2 because for adjustments less than 10, observed changes in the potentiometric surface were very small. In general, the potentiometric surface in the sub-area is relatively insensitive to the leakance values. The Upper Floridan potentiometric surface was decreased by about 1 ft in the northwestern corner of the sub-area and increased by about a foot in the northeast corner of the sub-region when the leakances were multiplied by 10. When the leakances were divided by 10, the potentiometric surface in the northwest corner of the sub-area increased by a maximum of 3 ft.

5.4.3.4 Lower Floridan Transmissivity

Figures 5.15 and 5.16 illustrate the changes in the Upper Floridan potentiometric surface due to a two-fold increase and a 50 percent reduction in the transmissivity of the Lower Floridan respectively. Increasing the Lower Floridan transmissivity caused a maximum decrease in the Upper Floridan potentiometric surface of 2 ft in the southwest corner of the sub-area, and a maximum increase of about 1 ft in the northeast corner of the sub-area. The opposite is true for decreasing the transmissivity of the Lower Floridan.

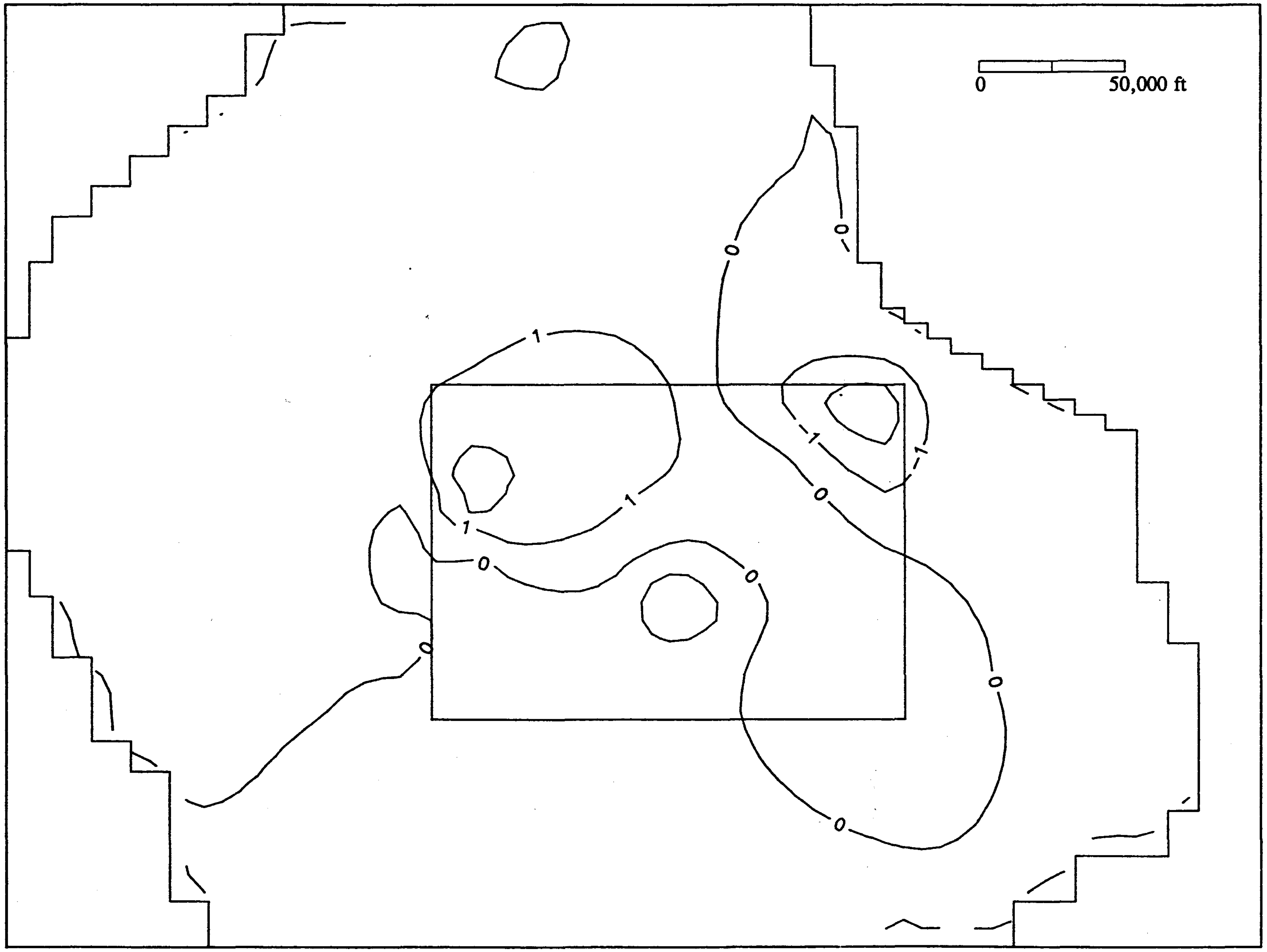


Figure 5.13. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using middle semiconfining unit leakances increased by an order of magnitude within the sub-area in feet above msl.

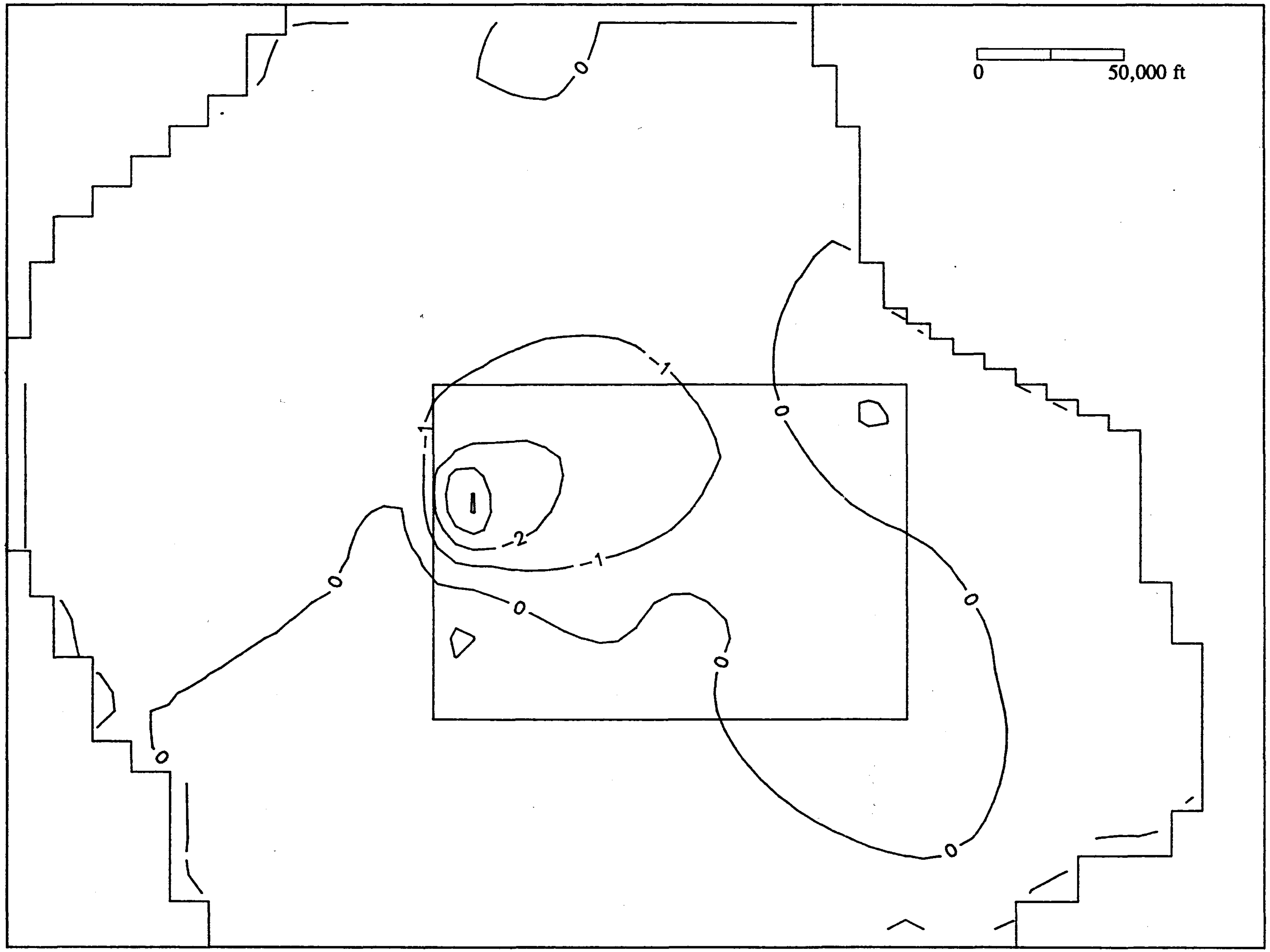


Figure 5.14. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using middle semiconfining unit leakances decreased by an order of magnitude within the sub-area in feet above msl.

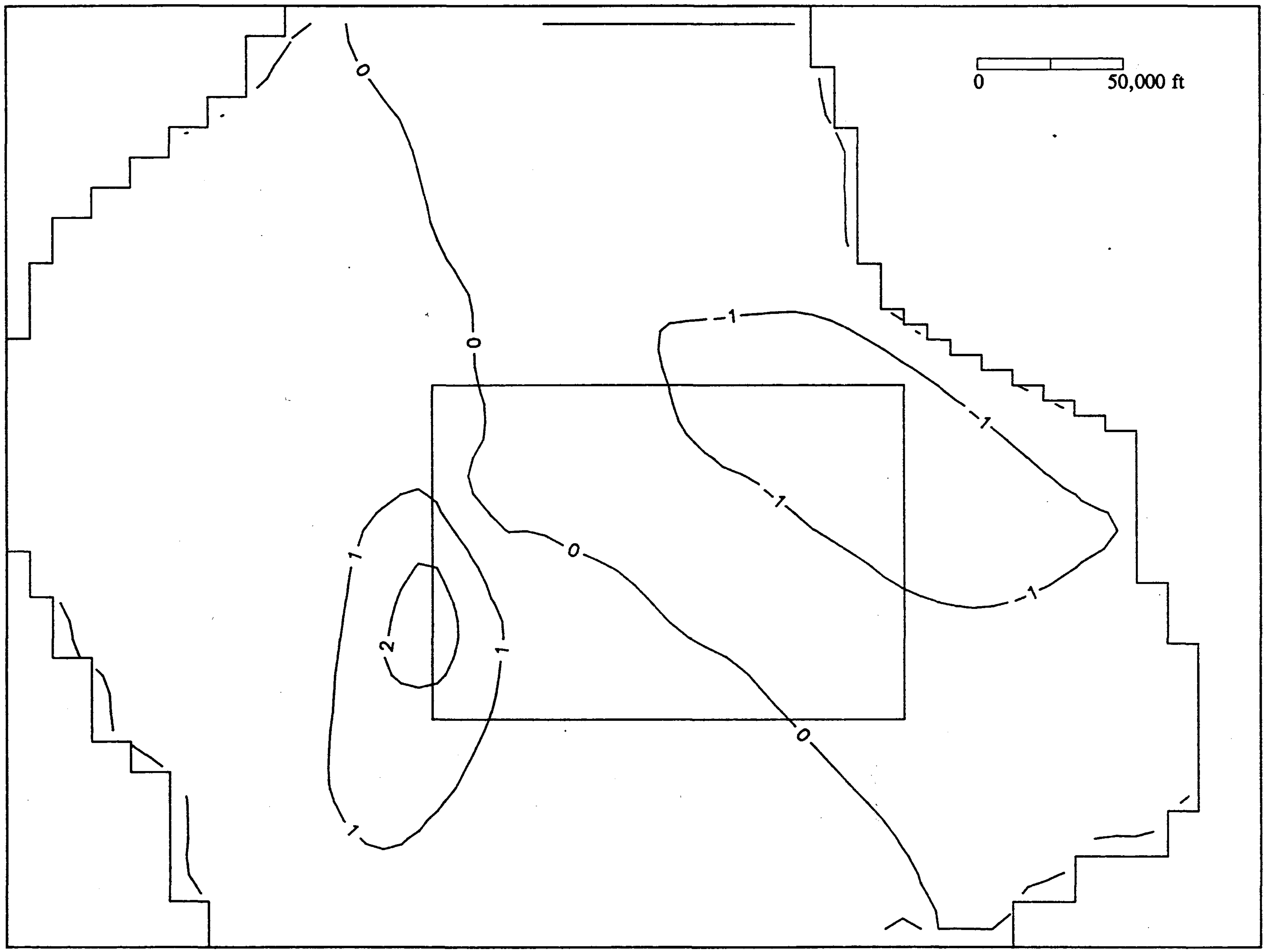


Figure 5.15. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using a two-fold increase in Lower Floridan transmissivity within the sub-area in feet above msl.

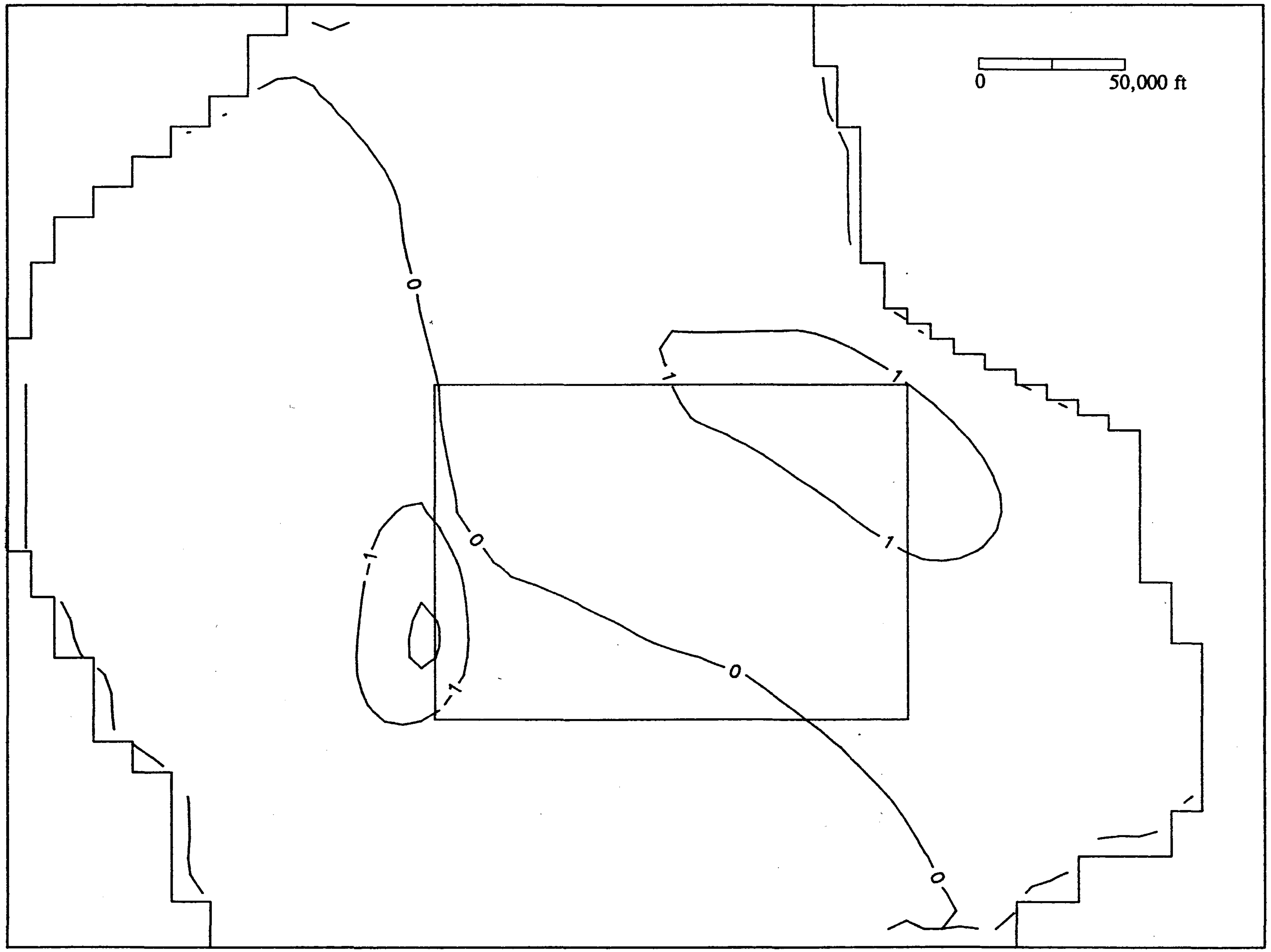


Figure 5.16. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using a 50 percent decrease in the Lower Floridan transmissivity within the sub-area in feet above msl.

The largest changes occur in the southwestern corner of the sub-area due to the high leakance values in that region (see Fig. 5.7). The changes occur in the northeastern corner of the sub-area because it is a discharge area for the Lower Floridan, and the potentiometric surface of the Upper Floridan must remain less than that of the Lower Floridan in this region. Generally, the Upper Floridan potentiometric surface is relatively insensitive to changes in Lower Floridan transmissivity values.

5.4.3.5 "Pinching Out" of Lower Floridan Transmissivity

The effects of variable density on the flow of groundwater were neglected during the Phase I study. For the most part, this should not be a bad assumption for the Upper Floridan throughout most of the study area. However, in the eastern portion of the study area, the Lower Floridan water becomes highly saline due to the presence of a lateral freshwater/saltwater interface. As the less dense freshwater approaches the freshwater/saltwater interface, it will be forced to rise above the saltwater body. When this occurs the thickness of the freshwater aquifer is effectively decreased.

This effect of decreasing transmissivity (due to a decreasing thickness of the freshwater flow regime) was not incorporated into the model due to, among other things, a lack of data concerning Lower Floridan concentration distributions. To investigate whether or not the model results are sensitive to the phenomena, a final sensitivity run was conducted where the Lower Floridan transmissivity along the eastern edge of the study region was decreased 75 percent (from 60,000 ft^2/d to 15,000 ft^2/d); the results are illustrated in Figure 5.17.

The model results within the sub area are relatively insensitive to the "pinching out" of Lower Floridan transmissivity. The maximum change within the sub area is -0.5 ft. This is the smallest potentiometric surface change observed out of all of the sensitivity runs. A maximum change in the potentiometric surface of 3 ft is observed along the portion of the eastern boundary that was specified as no-flow (see Fig.5.2).

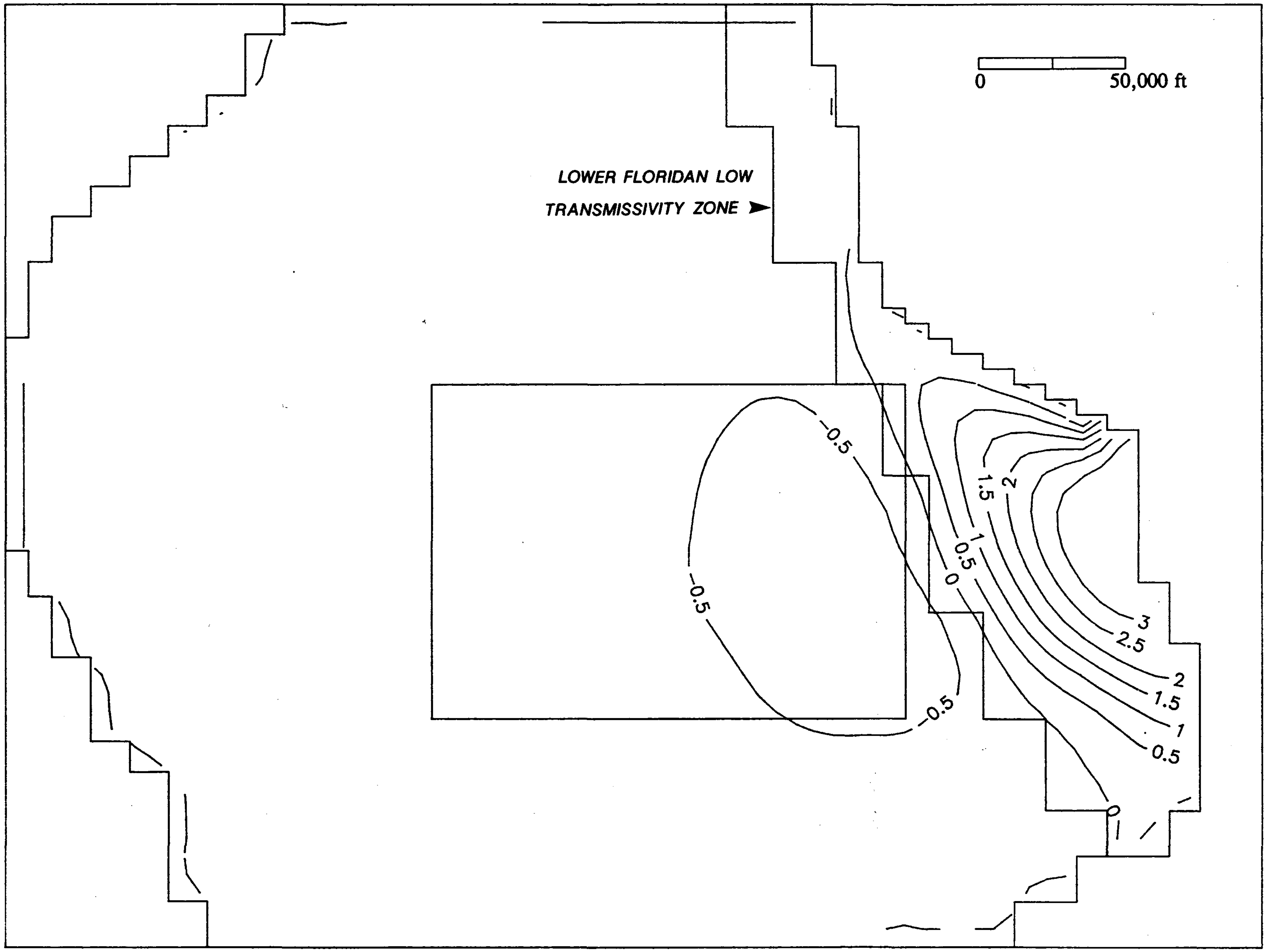


Figure 5.17. Difference between final simulated Upper Floridan potentiometric surface and potentiometric surface obtained using small Lower Floridan transmissivities along the eastern edge of the study area in feet above msl.

6 WELLHEAD PROTECTION AREA DELINEATION

6.1 Introduction

One of the Phase I modeling study tasks is the delineation of Wellhead Protection Areas (WHPAs) for Orange County municipal supply wells. This task is to be performed using EPA's WHPA code (Blandford and Huyakorn, 1990). A WHPA is defined in the Amendments to the Safe Drinking Water Act (SDWA), which were passed in 1986, as "the surface and subsurface area surrounding a water well or well field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or well field."

Although WHPA's may be delineated based upon a number of technical methods and institutional constraints (US EPA, 1987), the most common and perhaps most technically defensible method of WHPA delineation is the delineation of capture zones. A capture zone is defined as the zone surrounding a pumping well that will supply groundwater recharge to the well. The WHPA code was designed specifically for the delineation of capture zones, subject to a variety of hydrogeological conditions that may exist in the field.

6.2 WHPA Modeling Assumptions

The GPTRAC numerical option of the WHPA code has the capability to perform the delineation of groundwater flow pathlines using a hydraulic head field computed by MODFLOW. Additional inputs to the code are the aquifer transmissivities, thicknesses and porosities, the time for which pathlines are to be delineated, pumping well locations and discharge rates and the MODFLOW grid parameters (x and y spacings). WHPA delineates capture zones by computing the location of multiple pathlines that emanate from the well of interest. The area enclosed by all of the pathlines is the capture zone. For details on WHPA model input and capture zone delineation procedures, see Blandford and Huyakorn (1990).

Capture zones delineated using the WHPA model are intrinsically two-dimensional; vertical components of flow between or within aquifers is not accounted for. The capture zones computed in this study were done so using a "layer by layer" approach. That is, the capture zones were delineated sequentially using the respective head field for each layer of the model. The delineation for each scenario does not incorporate explicitly the effects of vertical flow components between layers. This approach is conservative in that the areal extent of the capture zone will not be underestimated.

To use the MODFLOW code, the discharges of all the wells within a grid cell must be lumped to the node at the center of that grid cell. Therefore, when the WHPA code is used to delineate capture zones, the well locations are assumed to reside at the centers of grid blocks. These constraints will obviously affect the accuracy of the delineated capture zones because the physical location of the well(s) may be misrepresented. The error may be quite significant for wells that reside near the edges of large grid blocks. The only way to circumvent this problem is to use a finer grid.

Another, more serious problem was encountered when capture zones were delineated using the regional model results. Due to the highly transmissive nature of the Floridan aquifer, many of the municipal wells that had small to moderate discharges formed what are called "weak sinks". Weak sinks form when pumping wells exist within a grid cell, but do not affect the regional flow pattern significantly in the vicinity of that cell. When this happens, a well-formed capture zone does not occur on the regional scale, and the WHPA code may not produce reliable results. For this reason, capture zones were delineated for only a portion of the municipal wells in Orange County (those with the largest pumpage). Another problem associated with the regional modeling scale was the restriction on the times for which capture zones could be delineated. For short capture zone times (e.g. 5-10 years), if the capture zone does not extend outside the grid cell that contains the well(s), reasonable results might not be obtained. To obtain a detailed and highly accurate delineation of WHPAs in Orange County, a series of local models should be constructed. The simplest way to achieve this would be to "zoom in" on a portion of the regional model, and use a finer grid locally about areas of interest.

In addition to the MODFLOW hydraulic head field and transmissivity, two additional parameters, the aquifer thickness and the aquifer porosity, are required to delineate the capture zones. For both the Upper and Lower Floridan, the porosity was assumed to be 0.2. The thickness of the Upper Floridan was obtained from Miller (in Tibbals, 1990). The Upper Floridan thickness was determined to be 325 ft in western and central Volusia County; 350 ft in western Orange County; 250-275 ft in central Orange County; and 300 ft in eastern Orange County. These thickness estimates compared well with the open hole depths that were available for some of the Upper Floridan municipal wells. The effective thickness of the Lower Floridan (the thickness of aquifer that contributes water to wells) was assumed to be 600 ft. This value was determined primarily from Orlando Utilities Commission (OUC) Lower Floridan well records.

Finally, although WHPAs were delineated for municipal wells that are producing from the Lower Floridan, the Lower Floridan was not calibrated in this study due to a lack of data. The Lower Floridan WHPA results, therefore, should be viewed as qualitative, general guidelines for protection rather than accurately delineated WHPAs.

6.3 WHPA Delineation Results

The results of the WHPA delineation effort for the Upper Floridan are presented in Figures 6.1 and 6.2, which illustrate the 50-year and 100-year capture zones for selected municipal supply wells in Orange County. As was mentioned in the previous Section, WHPAs could not be delineated for shorter time periods due to the regional nature of the groundwater flow model. The Orange County Public Utilities Division (OCPUD) municipal wells for which WHPAs were delineated are Conway, Econ, Mt. Plymouth Lakes and Orange Wood. WHPAs were delineated for all of the City of Cocoa wells except for 7A and 10. Capture

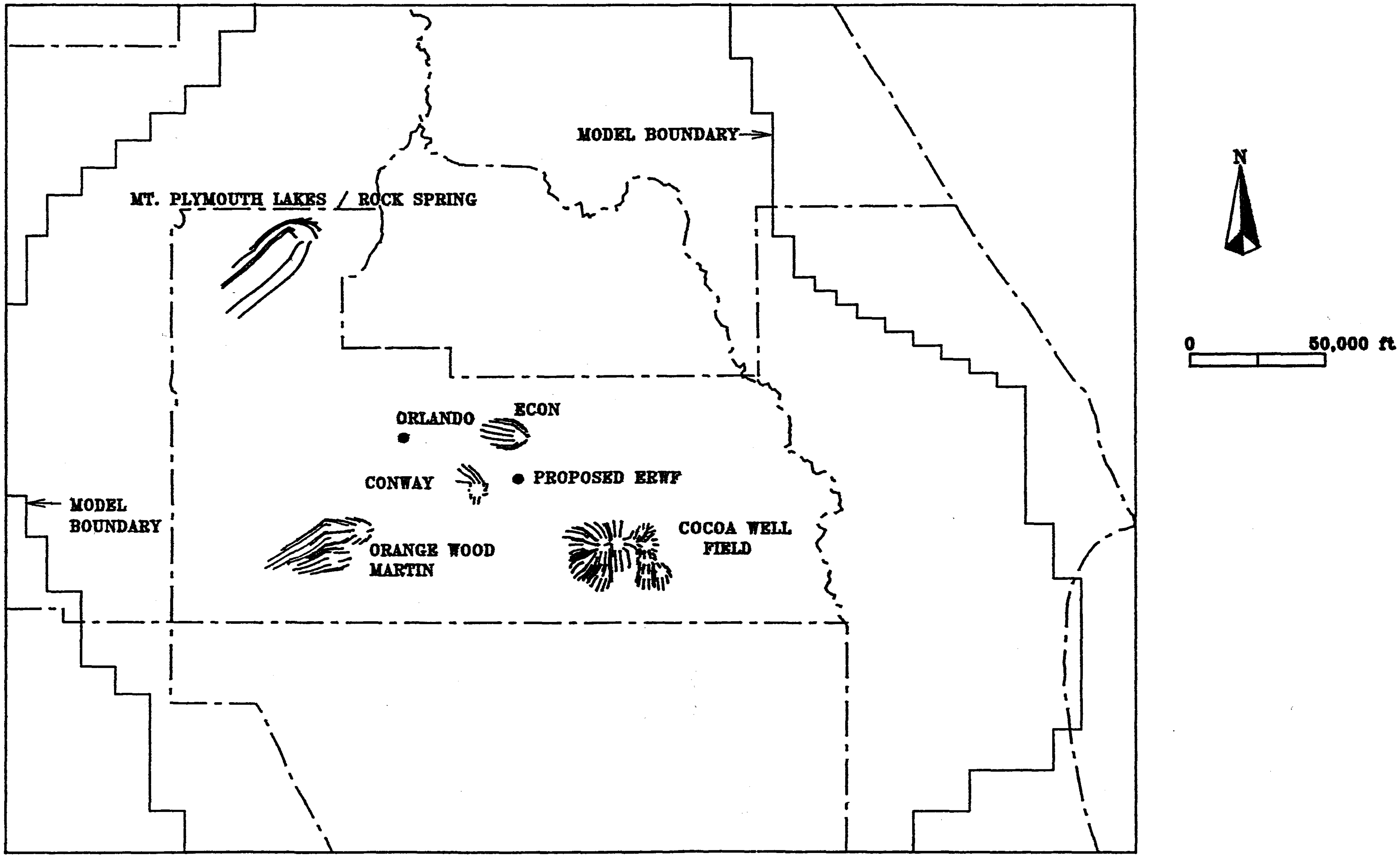


Figure 6.1. Fifty-year capture zones for selected OCPUD, OUC and City of Cocoa Upper Floridan wells.

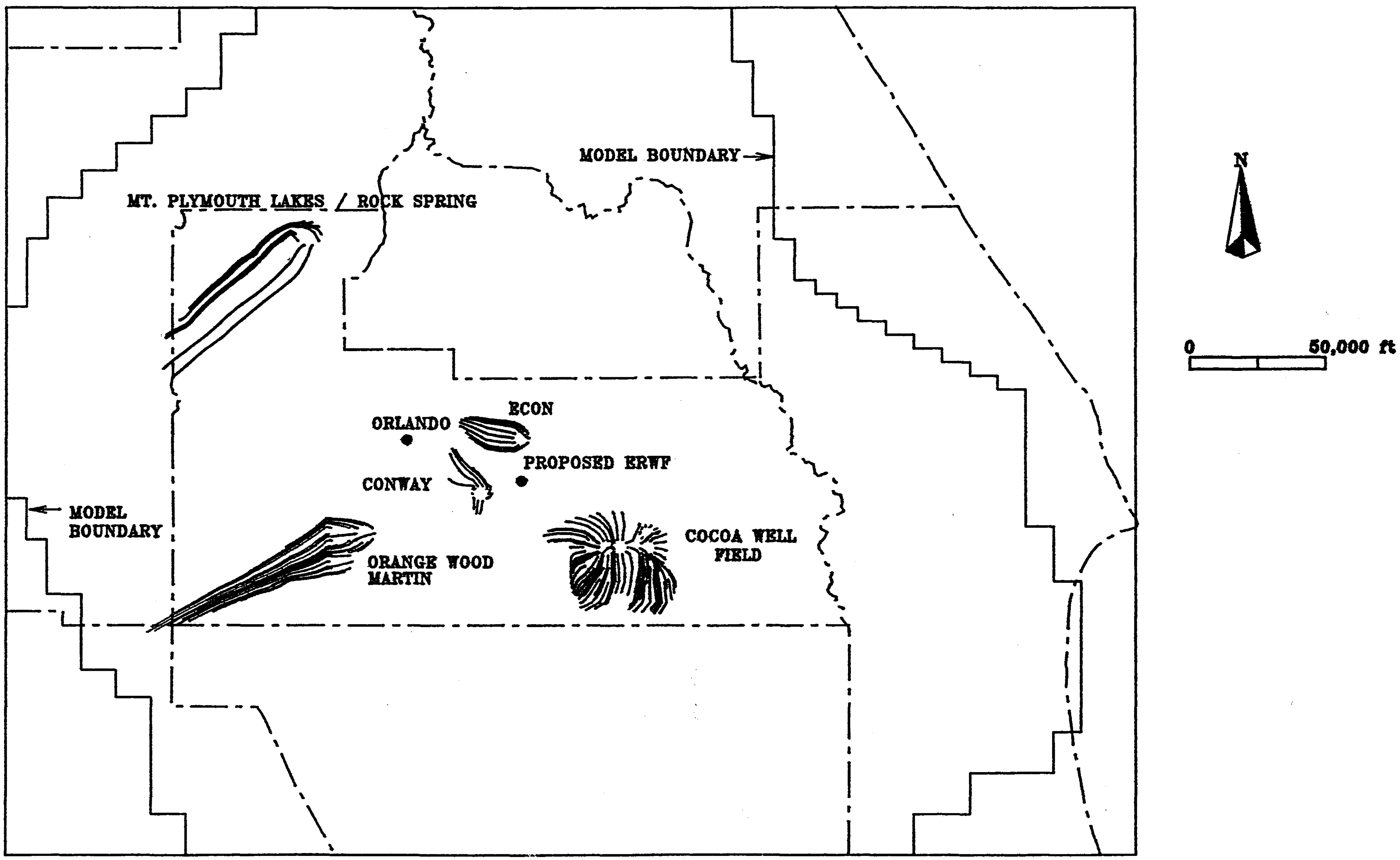


Figure 6.2. One-hundred-year capture zones for selected OCPUD, OUC and City of Cocoa Upper Floridan wells.

zones were also delineated for OUC's Martin well field. Other municipal wells could not be analyzed using the current regional model scale. Note that the Mt. Plymouth Lakes well field was located in the same grid cell as Rock Spring; since Rock Spring has a discharge far greater than that of the municipal wells, the delineated capture zone is indicative of the spring capture zone, rather than the well-field capture zone.

The 100-year capture zones for the Lower Floridan OUC wells Pine Hill, Highland, Navy, Primrose, Kuhl, Conway and Kirkman are illustrated in Figure 6.3. Several City of Winter Park pumping centers were incorporated as well. The Lower Floridan capture zones are smaller than those of the Upper Floridan for equivalent time periods due to the lower transmissivity (in general) and greater thickness of the Lower Floridan. It should again be stressed that, due to the lack of calibration in the Lower Floridan, these capture zones should be viewed qualitatively rather than quantitatively.

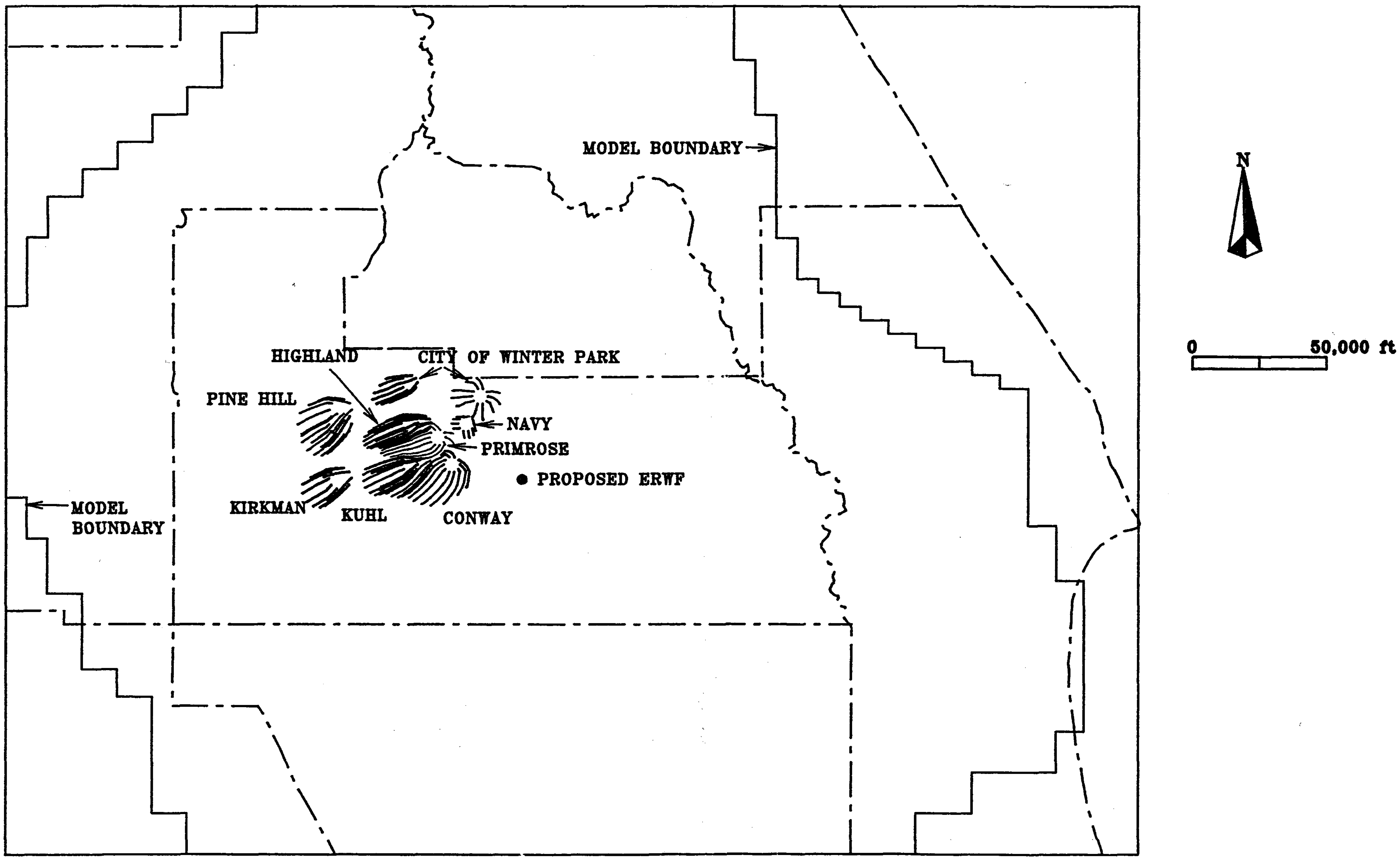


Figure 6.3. One-hundred-year capture zones for selected OUC and City of Winter Park Lower Floridan wells.

7 SUMMARY AND CONCLUSIONS

The primary purpose of the Phase I study was to determine regional aquifer parameters and boundary conditions in the vicinity of eastern and central Orange County so that they could be used for more localized density-dependent groundwater flow and solute transport analysis. To accomplish this goal, a steady-state, three-dimensional groundwater flow model was constructed and calibrated. A wealth of information from various published sources and files of the SJRWMD was analyzed and incorporated into the modeling effort. The current effort was also assisted by the fact that three previous regional modeling studies, incorporating all or part of the present study area, had been conducted.

Within the primary area of interest, the differences between the observed Upper Floridan potentiometric surface and that simulated by the model were generally less than 1 ft. Outside the primary area of interest, the differences between the observed and simulated potentiometric surfaces were generally less than 2-3 ft, with some local differences of up to 6 ft occurring in some high gradient areas. Overall, it is felt that the simulated average potentiometric surface for 1988 is reasonable throughout the study area.

A subsequent sensitivity analysis illustrated that the Upper Floridan potentiometric surface was highly sensitive to Upper Floridan recharge, and only moderately or slightly sensitive to transmissivity of the Lower Floridan and leakance of the middle semiconfining unit. It was critical, therefore, to determine appropriate values for Upper Floridan transmissivity and recharge. Recharge was calibrated using a map provided in Tibbals (1990). This map was spot-checked using 1988 data and was found to be accurate within the study region. Furthermore, the calibrated Upper Floridan transmissivity values lie within a reasonable range as determined by aquifer tests and previous modeling studies. It is, therefore, felt that the calibrated model parameters are reasonable on a regional scale. The lack of piezometric head data for the Lower Floridan precluded a calibration of this model layer. It would be quite useful to have more information on this aquifer, and the SJRWMD may consider more intensive data collection for the Lower Floridan in the future. Data on the Lower Floridan would be particularly useful in the vicinity of Orlando and eastern Orange County.

Although the flow model was calibrated for average 1988 conditions, it should prove as a useful tool for the SJRWMD, Orange County and the City of Cocoa to use for predictive purposes. The model utility could prove to be two-fold; 1) it could be used to predict future changes in the Upper Floridan potentiometric surface due to future additional pumping loads on the aquifer, and 2) sub-sections of the model could be "extracted" and used as a basis for more refined, local analysis. A good example of the latter use would be refinement of certain model areas for detailed delineations of Wellhead Protection Areas (WHPAs). WHPAs for the major municipal supply wells in Orange County were delineated in this report, but due to the regional nature of the model the accuracy of the delineations was necessarily restricted.

The Phase I modeling results are appropriate for incorporation into the cross-sectional and fully three-dimensional density-dependent transport analysis of Phases II and III. The calibrated potentiometric surface values may be interpolated for any sub-region of the grid to provide boundary conditions for more localized and detailed analysis. Similarly, the calibrated aquifer parameters may by used as initial estimates for any sub-region of the grid.

REFERENCES

Aucott, W.R., 1988. Areal Variation in Recharge to and Discharge from the Floridan Aquifer System in Florida. U.S.G.S. Water Resources Investigations Report 88-4057, 1 sheet.

Blandford, T.N. and P.S. Huyakorn, 1990. A Modular Semi-Analytical Model for the Delineation of Wellhead Protection Areas. U.S. EPA, Office of Ground-Water Protection, Washington, D.C. 20460.

Brevard County Division of Natural Resources, Water Resources Section, 1979. Brevard County 208 Area Wide Waste Treatment Management Plan. Published by Post, Buckley, Schuh and Jernigan, Inc., Orlando, Fla.

CH2M-Hill, 1988. Groundwater Flow and Solute Transport Modeling in Support of the Consumptive Use Permit Application for the City of Cocoa. Unpublished Report.

Florence, B. 1990. Annual Water Use Survey: 1988. St. Johns River Water Management District Technical Publication 90-12. Palatka, Fla.

Golden Software, Inc. SURFER, Version 4 Reference Manual. Golden, Colorado 80402.

Jamaal and Assoc., 1990. Ground Water Modeling in Support of the Consumptive Use Permit Application for Orange County's proposed Southeast Regional Well Field. Unpublished Report.

Kimrey, J.O., 1978. Preliminary Appraisal of the Geohydrologic Aspects of Drainage Wells, Orlando Area, Central Florida. U.S. Geological Survey Water Resource Investigations Report, 24 p.

Lichtler, W.F., W. Anderson and B.F. Joyner, 1968. Water Resources of Orange County, Florida. Division of Geology, Florida Board of Conservation, Report of Investigation No. 50, 150 p.

McDonald, M.G. and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite Difference Ground-Water Flow Model. Techniques of Water-Resource Investigations of the USGS, Book 6 Chapter A1.

Miller, J.A., 1982a, Configuration of the Base of the Upper Permeable Zone of the Tertiary Limestone Aquifer System, Southeastern United States. U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1177, 1 sheet.

Miller, J.A., 1982b, Geology and Configuration of the Base of the Tertiary Limestone Aquifer System, Southeastern United States. U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1176, 1 sheet.

Miller, J.A., 1982c, Geology and Configuration of the Top of the Tertiary Limestone Aquifer System, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1178, 1 sheet.

Miller, J.A., 1982d, Thickness of the Tertiary Limestone Aquifer System, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1124, 1 map sheet.

McKenzie-Arenberg, M. and G. Szell, 1990. Middle St. Johns Ground Water Basin Resource Availability Inventory. St. Johns River Water Management District Technical Publication 90-11, 56 p.

Phelps, C.G., 1984. Recharge and Discharge Areas of the Floridan Aquifer in the St. Johns River Water Management District and Vicinity, Florida. U.S. Geological Survey Water Resources Investigations Report 82-4058, 1 sheet.

Pride, R.W., Meyer, F.W. and Cherry, R.N., 1966. Hydrology of Green Swamp Area in Central Florida. Florida Geological Survey Report of Investigations No. 42.

Rodis, H.G., 1989. Potentiometric Surface of the Upper Floridan Aquifer in the St. Johns River Water Management District and Vicinity, September 1988. U.S. Geological Survey Open-File Report 89-65, 1 sheet.

Schiner, G.R., 1988. Potentiometric Surface of the Upper Floridan Aquifer in the St. Johns River Water Management District and Vicinity, May 1988. U.S. Geological Survey Open-File Report 88-460, 1 sheet.

Schiner, G.R., German, 1983. Effects of Recharge From Drainage Wells on Quality of Water in the Floridan Aquifer in the Orlando Area, Florida, U.S. Geological Survey Water Resources Investigations Reports 82-4094, 124 pp.

Skipp, D., 1988. Ground-Water Flow Model of Brevard, Indian River, Orange, Osceola, and Seminole Counties, Florida. St. Johns River Water Management District Technical Publication 88-2. Palatka, Florida.

Steele, C., 1990. Annual Report on Abandoned Artesian Wells 1989. St. Johns River Water Management District Special Publication SJ90-SP5.

Szell, G.P., 1987. Deep Monitoring Well Network for the Metropolitan area of Orlando, Orange County, Florida and vicinity. SJRWMD Technical Publication 87-2, 51 p.

Tibbals, C.H. 1990. Hydrology of the Floridan Aquifer System in East-Central Florida. U.S. Geological Survey Professional Paper 1403 - E.

Tibbals, C.H., and Frazee, J.M., 1976. Ground Water Hydrology in the Cocoa Well-Field Area. U.S. Geological Survey Open-File Report 75-676, 67 p.

US EPA, Office of Ground-Water Protection, 1987. Guidelines for Delineation of Wellhead Protection Areas. Washington, DC. EPA 440/6-87-010.

USGS, 1989. Water Resources Data for Florida, Water Year 1989, Vol. 1a, Northeast Florida Surface Water, Vol. 1b, Northeast Florida Ground Water, and Vol. 3b, Southwest Florida Ground Water. U.S. Geological Survey Water Data Reports FL-89-1a, FL-89-1b and FL-89-3b.

APPENDIX A

BIBLIOGRAPHY FOR GROUNDWATER MODELING STUDY OF EAST-CENTRAL FLORIDA

FLORIDA BUREAU OF GEOLOGY PUBLICATIONS

SELECTED REFERENCES

Anderson, W. and G.H. Hughes, 1975. Hydrology of Three Sinkhole Basins in Southwestern Seminole County, Florida. Florida Bureau of Geology Report of Investigations 81.

Barraclough, Jack T., 1962. Ground Water Resources of Seminole County, Florida. Florida Geological Survey Report of Investigations No. 27, 91 p.

Brown, D.W., W.E. Kenner, J.W. Crooks, and J.B. Foster, 1962. Water Resources of Brevard County, Florida. Florida Bureau of Geology Report of Investigations No. 28, 104 p.

Knochenmus, D.D., 1974. Hydrologic Concepts of Artificially Recharging the Floridan Aquifer in Eastern Orange County, Florida - A Feasibility Study. Bureau of Geology Report of Investigations 72, 36 p.

Lichtler, W.G., 1972. Appraisal of Water Resources in the East Central Florida Region. Florida Bureau of Geology Report of Investigations No. 61, 52 p.

Lichtler, W.F., Warren Anderson, and B.F. Joyner, 1962. Water Resources of Orange County, Florida. Florida Bureau of Geology Report of Investigations No. 50, 150 p.

Pride, R.W., Meyer, F.W. and Cherry, R.N., 1966. Hydrology of Green Swamp Area in Central Florida. Florida Geological Survey Report of Investigations No. 42.

Putnam, A.L., 1975. Summary of Hydrologic Conditions and Effects of Walt Disney World Development in the Ready Creek Improvement District, 1966-73. Bureau of Geology, Florida Department of Natural Resources, Report of Investigations No. 79, 115 pp., 30 fig., 13 tables.

Robertson, A.F., 1973. Hydrologic Conditions in the Lakeland Ridge Area of Polk County, Florida. Florida Bureau of Geology Report of Investigations No. 64.

Rosenau, J.C., et al., 1977. Springs of Florida (Revised). Florida Bureau of Geology, Florida Department of Natural Resources, Bulletin No. 31, 461 pp.

Scott, T.M., 1988. The Lithostratigraphy of the Hawthorn Group (Miocene) of Florida. Florida Department of Natural Resources, Florida Geological Survey Geological Bulletin No. 59. Tallahassee, Florida.

Scott, T.M., and Hajishafi M., 1980. Top of Floridan Aquifer in the St. Johns River Water Management District. Florida Bureau of Geology Map Series No. 95, Size: 22 x 36 inches.

Snell, L.J. and Warren Anderson, 1970. Water Resources of Northeast Florida. Florida Geological Survey Report of Investigation No. 54, 77 p.

Southeastern Geological Society, 1986. Hydrogeological Units of Florida. Florida Geological Survey Special Publication 28. Tallahassee, Fla.

Stewart, J.W., 1980. Areas of Natural Recharge to the Floridan Aquifer in Florida. Bureau of Geology, Florida Department of Natural Resources, Map Series No. 98, Size: 17 1/2 x 22 inches.

Stewart, Herbert G., 1966. Ground-Water Resources of Polk County. Florida Geological Survey, Report of Investigations No. 44, 170 pp.

White, W., 1970. Geomorphology of the Florida Peninsula. Florida Bureau of Geology Bulletin No. 51, Tallahassee.

U.S. GEOLOGICAL SURVEY REPORTS

SELECTED REFERENCES

Anderson, W., 1971. Hydrologic Considerations in Draining Lake Apopka--A Preliminary Analysis. U.S. Geological Survey Open-File Report FL - 71004.

Aucott, W.R., 1988. Areal Variation in Recharge to and Discharge from the Floridan Aquifer System in Florida. U.S.Geological Survey Water Resources Investigations Report 88-4057, 1 sheet.

Bush, P.W., 1979. Connector Well Experiment to Recharge the Floridan Aquifer, East Orange County, Florida. U.S. Geological Survey Water-Resources Investigations 78-73.

Bush, P.W., 1982. Predevelopment Flow in the Tertiary Limestone Aquifer; Southeastern United States; A Regional Analysis from Digital Modeling. U.S. Geological Survey Water-Resources Investigations, 82-905, 41 p.

Fayard, L., 1990. Cocoa Ground Water Monitoring Network: Annual Data Summary for 1989. U.S.Geological Survey Unpublished Data Report.

Frazee, James M., 1980. Ground Water in Osceola County, Florida. U.S. Geological Survey, Open File Report 79-1595, 1 sheet.

Grubb, Hayes, F. and A.T. Rutledge, 1979. Long-Term Water Supply Potential, Green Swamp Area, Florida. U.S. Geological Survey Water Resources Investigations Report 78-99, 76 pp.

Johnston, R.H., R.E. Krause, R.W. Meyer, P.D. Ryder, C.H. Tibbals and J.D. Hunn, 1980. Estimated Potentiometric Surface for the Tertiary Limestone Aquifer System, Southeastern United States, Prior to Development. U.S. Geological Survey Open File Report 80-406, 1 sheet.

Kimrey, J.O., 1978. Preliminary Appraisal of the Geohydrologic Aspects of Drainage Wells, Orlando Area, Central Florida. U.S. Geological Survey Water Resource Investigations Report, 24 p.

Kimrey, J.O. and L.D. Fayard, 1982. Geohydrologic Reconnaissance of Drainage Wells in Florida - An Interim Report. U.S. Geological Survey Open-File Report 82-860, 59 pp.

Kimrey, J.O. and L.D. Fayard, 1984. Geohydrologic Reconnaissance of Drainage Wells in Florida. U.S. Geological Survey Water Resources Investigations Report 84-4021, 67 pp.

Knochenmus, D.D. and G.H. Hughes, 1976. Hydrology of Lake County, Florida. U.S. Geological Survey, Water Resource Investigations 76-72, 100 p.

Miller, J.A., 1984. Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, South Carolina and Alabama. U.S. Geological Survey Professional Paper 1403-B, 91 p., 33 plates.

Navoy, A.N., 1986. Hydrogeologic Data from a 2,000-foot Deep Core Hole at Polk City, Green Swamp Area, Central Florida. U.S. Geological Survey Water Resources Investigations Report 84-4257, 89 p.

Phelps, G.G. and K.P. Rohrer, 1987. Hydrogeology in the Area of a Freshwater Lens in the Floridan Aquifer System, Northeast Seminole County, Florida. U.S. Geological Survey Water Resources Investigations Report 86-4078.

Phelps, G.G., 1984. Recharge and Discharge Areas of the Floridan Aquifer in the St. Johns River Water Management District. U.S. Geological Survey Water Resources Investigations 82-4058, 1 sheet.

Planert, M. and W.R. Aucott, 1985. Water-Supply Potential of the Floridan Aquifer in Osceola, Eastern Orange, and Southwestern Brevard Counties, Florida. U.S. Geological Survey Water Resources Investigation 84-4135. Tallahassee, Fla.

Rhodis, A.G. and D.A. Munch, 1983. Potentiometric Surface of the Floridan Aquifer and Its Use in Management of Water Resources. U.S. Geological Survey Water-Resources Investigations 83-4176. St. Johns River Water Management District, Palatka, Fla.

Ryder, P.D., 1982. Digital Model of Predevelopment Flow in the Tertiary Limestone (Floridan) Aquifer System in West-Central Florida. U.S. Geological Survey Water Resources Investigations 81-54, 82 p.

Schiner, G.R. and German, 1983. Effects of Recharge From Drainage Wells on Quality of Water in the Floridan Aquifer in the Orlando Area, Florida. U.S. Geological Survey, Water Resources Investigations Reports 82-4094, 124 pp.

Schiner, G.R., 1989. Potentiometric Surface Mmap of the Floridan Aquifer in the St. Johns River Water Management District and Vicinity, Florida, May, 1989. U.S. Geological Survey Open-File Report 89-417.

Schiner, G.R., C.P. Laughlin and D.J. Toth, 1988. Geohydrology of Indian River County, Florida. U.S. Geological Survey Water Resources Investigations 88-4073, Tallahassee, Fla.

Tibbals, C.H., 1978. Effects of Paved Surfaces on Recharge to the Floridan Aquifer in East-Central Florida--A conceptual Model. U.S. Geological Survey Water Resources Investigations 78-76, 42 pp.

Tibbals, C.H. and Frazee, J.M., 1976. Ground Water Hydrology in the Cocoa Well-Field Area. U.S. Geological Survey Open-File Report 75-676, 67 p.

Tibbals, C.H., 1981. Computer Simulation of the Steady-State Flow System of the Tertiary Limestone (Floridan) Aquifer System in East-Central Florida. U.S. Geological Survey Water Resources Investigations, Open File Report 81-681, 31 p.

Tibbals, C.H., 1977. Availability of Ground Water in Seminole County and Vicinity, Florida. U.S. Geological Survey Water Resources Investigations 76-97.

Tibbals, C.H. 1990. Hydrology of the Floridan Aquifer System in East-Central Florida. U.S. Geological Survey Professional Paper 1403-E.

U.S. Geological Survey, 1989. Water Resources Data for Florida, Water Year 1989, Vol. 1a, Northeast Florida Surface Water, Vol. 1b, Northeast Florida Ground Water, and Vol. 3b, Southwest Florida Ground Water. U.S. Geological Survey Water Data Reports FL-89-1b and FL-89-3b.

Wood, W.D. and L.J. Snell, 1978. Hydrologic Maps of the Orlando West Quadrangle, Florida. U.S. Geological Survey Water Resources Investigations 77-135, 1 sheet.

Wood, W.D. and L.J. Snell, 1978. Hydrologic Maps of the Orlando East Quadrangle, Florida.
U.S. Geological Survey Water Resources Investigations 77-134, 1 sheet.

MISCELLANEOUS REPORTS AND PUBLICATIONS

CH2M Hill, 1988. Groundwater Flow and Solute Transport Modeling in Support of the Consumptive Use Permit Application for the City of Cocoa. Unpublished Report.

CH2M Hill, November 1979. The Effects of Groundwater Withdrawals in the Orlando Area. Prepared for the Orlando Utilities Commission.

Dohrenwend, R.E., 1977. Evapotranspiration Patterns in Florida. Florida Academy of Sciences, Journal of Florida Scientist, v. 40, no. 2, p. 184-192.

Geraghty and Miller, Inc., 1977. Feasibility of Deep-Well Waste Water Disposal at the Sand Lake Road Treatment Facility, Orange County, Florida. Tampa, Fla. (13902 North Dale Mabry Highway), Geraghty and Miller, Inc. (consulting ground-water hydrologists and geologists), 77 p. (EPA project C120314.010).

Jamaal and Assoc., 1990. Ground Water Modeling in Support of the Consumptive Use Permit Application for Orange County's Proposed Southeast Regional . Unpublished Report.

Mercer, J.W., B.H. Lester, S.D. Thomas, and R.L. Bartel, 1986. Simulation of Saltwater Intrusion in Volusia County, Florida. Water Resources Bulletin, Vol. 22, No. 6, 951-965.

Smajstrla, A.G. and Clark, G.A., 1982. Potential Evapotranspiration Probabilities for Orlando, Florida. University of Florida, Institute of Food and Agricultural Sciences Report 82-22, 5 p.

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT, PALATKA, FLORIDA

SELECTED REFERENCES

Florence, B., 1990. Annual Water Use Survey, 1988. St. Johns River Water Management District Technical Publication 90-12.

Johnson, Richard, 1984. Stratigraphic Analysis of Geophysical Logs from Water Wells in Peninsula, Florida. St. Johns River Water Management District Technical Publication SJ 84-16.

Johnson, Richard A., 1981. Structural Geologic Features and Their Relationship to Salt Water Intrusion in West Volusia, North Seminole, and Northeast Lake Counties, Florida. St. Johns River Water Management District Technical Publication SJ 81-1, 32 p.

Marella, R.L., 1990. Annual Water Use Survey, 1987. St. Johns River Water Management District Technical Publication 90-4, 124 p.

Marella, R.L., 1988. Water Withdrawals, Use and Trends in the St. Johns River Water Management District, 1986. St. Johns River Water Management District Technical Publication SJ 88-7.

McKenzie-Arenberg, M. and G. Szell, 1990. Middle St. Johns Ground Water Basin Resource Availability Inventory. St. Johns River Water Management District Technical Publication 90-11, 56 p.

McKenzie-Arenberg, M., 1989. Volusia Ground Water Basin Resource Available Inventory. St. Johns River Water Management District Technical Publication 89-4, 40 p.

McKenzie-Arenberg, M. and D.J. Toth, 1990. Upper St. Johns Ground Water Basin Resource Availability Inventory. St. Johns River Water Management District Technical Publication 90-10, 53 p.

Mercer, James W., S.D. Thomas, B.H. Lester and R.W. Broome, 1984. Saltwater Intrusion in Volusia County, Florida, Due to Ground Water Withdrawals - Technical Summary. St. Johns River Water Management District, Publication 85-1.

Skipp, D., 1988. Ground-Water Flow Model of Brevard, Indian River, Orange, Osceola and Seminole Counties, Florida. St. Johns River Water Management District Technical Publication 88-2.

Szell, G.P., 1990. Aquifer Parameters in the St. Johns River Water Management District. St. Johns River Water Management District Technical Publication, 90-14 (draft).

Szell, G.P., 1987. Deep Monitoring Well Network for the Metropolitan Area of Orlando, Orange County, Florida and Vicinity. St. Johns River Water Management District Technical Publication 87-2, 51 p.

Toth, D., K.P. Rohrer and D.A. Munch, 1989. Water Quality Assessment of the Floridan Aquifer in the Wekiva River Basin of Orange, Lake and Seminole Counties. St. Johns River Water Management District Technical Publication 89-5, 46 p.

Toth, D., 1988. Test Drilling Report for Observation Wells at Sebastian Inlet State Park, Brevard County, Florida. St. Johns River Water Management District Technical Publication SJ 85-6.

Toth, D., 1987. Appraisal of the Floridan Aquifer Producing Zones in the Sebastian Freshwater Lens. St. Johns River Water Management District Technical Publication SJ 87-1.

Toth, D.J., 1988. Salt Water Intrusion in Coastal Areas of Volusia, Brevard and Indian River Counties. St. Johns River Water Management District Technical Publication SJ 88-1.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

SELECTED PUBLICATIONS

Alvarez, J.A. and D.D. Bacon, 1988. Production Zones of Major Public Water Supply s for the Counties in the South Florida Water Management District. Technical Publication 88-04, Part 1, Appendix I.

Alvarez, J.A. and D.D. Bacon, 1988. Production Zones of Major Public Water Supply s for the Counties in the South Florida Water Management District. Technical Publication 88-04, Part 2, Appendix II.

Mooney, III, R. Thomas, 1980. The Stratigraphy of the Floridan Aquifer System East and Northwest of Lake Okeechobee, Florida: South Florida Water Management District Technical Water Management District. Technical Publication 80-9, 45 p.

Reece, D., R. Belles and M. Brown, 1984. Hydrogeologic Data Collected from the Kissimmee Planning Area. South Florida Water Management District Technical Publication 84-02.

Shaw, J.E. and S. Trost, 1984. Hydrogeology of the Kissimmee Planning Area. South Florida Water Management District Technical Publications 84-01, Part 2 - Appendices.

Shaw, J.E. and S. Trost, 1984. Hydrogeology of the Kissimmee Planning Area. South Florida Water Management District Technical Publication 84-01, Part 1 - Text.

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT TECHNICAL PUBLICATION

Southwest Florida Water Management District, 1987. Aquifer Characteristics Within the Southwest Florida Water Management District, 30 p.

APPENDIX B.1

TOTAL WITHDRAWALS BY GRID CELL WITHIN THE STUDY AREA

Layer	Row	Col	Flux (ft^3/d)
1	1	24	-29721.5*
1	1	40	-102904.5*
1	2	8	-5090.4*
1	2	9	-60480.0
1	2	18	-12340800.
1	2	21	-34626.2
1	2	39	-102904.5*
1	3	3	-26989.6*
1	3	5	-28875.5*
1	3	6	-76952.9*
1	3	8	-17590.6*
1	3	20	-125682.7
1	3	23	-234229.3
1	3	27	-194656.5
1	4	4	-43389.6*
1	4	5	-4535.8*
1	4	6	-596577.0*
1	4	7	-5958.8*
1	4	20	-37741.4
1	4	23	-194656.5
1	4	24	-194656.5
1	5	4	-95836.7*
1	5	5	-221074.7*
1	5	6	-4535.8*
1	5	9	-58919.0
1	5	21	-691200.0
1	5	22	-12685.5
1	5	25	-194656.5
1	5	43	-12998.2*
1	6	3	-75951.6*
1	6	5	-184429.1*
1	6	6	-45959.1
1	6	7	-14361.3
1	6	8	-178343.4
1	6	10	-4579200.0
1	6	13	-518400.0
1	6	18	-42297.1
1	6	23	-13475.0
1	6	32	-57147.0
1	6	33	-25758.0
1	7	5	-182755.0
1	7	6	-18028.1
1	7	7	-340815.6
1	7	8	-42625.7
1	7	18	-17468.1
1	7	23	-35062.0
1	8	4	-22611.5
1	8	7	-2779.0
1	8	8	-66762.0
1	8	13	-1704241.5
1	8	19	-242869.3
1	8	20	-16149.8
1	9	4	-33000.5
1	9	6	-21542.0
1	9	7	-31541.6
1	9	10	-5079922.9
1	9	15	-20507.7
1	9	16	-41784.4
1	9	19	-8459.4

Layer	Row	Col	Flux (ft^3/d)
1	9	21	-429635.5
1	9	25	-22646.4
1	9	26	-14804.0
1	10	3	-27194.9
1	10	4	-15889.1
1	10	6	-151720.2
1	10	8	-8021.0
1	10	17	-168126.2
1	11	1	-16805.8*
1	11	2	-20014.2*
1	11	3	-156200.8
1	11	6	-192175.0
1	11	7	-75766.0
1	11	8	-86864.6
1	11	10	-345600.0
1	11	16	-21114.0
1	11	18	-1940.9
1	11	28	-208808.0
1	12	2	-20167.0*
1	12	3	-63098.2
1	12	6	-37883.0
1	12	7	-37883.0
1	12	10	-26476.9
1	12	11	-6004800.0
1	12	12	-1197660.7
1	12	15	-454358.2
1	12	16	-167027.6
1	12	17	-104259.5
1	12	19	-78258.7
1	12	21	-56160.0
1	12	24	-112320.0
1	12	26	-222839.2
1	12	27	-220256.8
1	12	44	-16794.6*
1	13	3	-42472.9
1	13	9	-28395.1
1	13	11	-175992.0
1	13	12	-33016.8
1	13	13	-32665.8
1	13	14	-3477600.0
1	13	15	-39820.0
1	13	16	-39820.0
1	13	20	-83092.6
1	13	26	-208808.0
1	13	27	-208808.0
1	13	43	-11847.4*
1	13	44	-32157.1*
1	14	12	-12659.0
1	14	13	-3149.4
1	14	14	-58776.4
1	14	15	-86425.1
1	14	16	-3735.3
1	14	19	-291575.0
1	14	22	-235471.9
1	14	28	-3802.0
1	14	43	-13930.4*
1	14	44	-26819.3*
1	15	3	-2725.8
1	15	4	-15278.0

Layer	Row	Col	Flux (ft^3/d)
1	15	5	-14972.5
1	15	9	-57195.3
1	15	11	-67345.7
1	15	12	-521140.0
1	15	13	-140916.9
1	15	16	-12890.5
1	15	20	-33142.0
1	15	26	-104442.6
1	16	10	-25120.7
1	16	11	-8898.9
1	16	15	-18347.0
1	16	16	-427401.6
1	16	17	-145494.5
1	16	18	-170360.1
1	16	19	-103490.4
1	16	24	-22137.0
1	16	25	-65161.0
1	16	26	-50097.3
1	16	42	-16404.0
1	16	44	-15492.7
1	17	1	-21694.8*
1	17	4	-19403.1
1	17	13	-194029.9
1	17	16	-54920.8
1	17	17	-109841.5
1	17	21	-356796.7
1	17	25	-3802.0
1	17	26	-28564.3
1	17	30	-52294.5
1	18	1	-17111.4*
1	18	2	-16194.7
1	18	4	-14977.9
1	18	5	-27194.9
1	18	10	-5786.1
1	18	15	-108355.8
1	18	17	-109841.5
1	18	18	-238804.4
1	18	19	-249644.1
1	18	23	-20910.5
1	19	1	-19555.9*
1	19	2	-23069.8
1	19	4	-20472.6
1	19	6	-16589.2
1	19	10	-119310.6
1	19	17	-330795.9
1	19	23	-70092.3
1	19	26	-65575.7
1	19	32	-23739.1
1	20	1	-27806.0*
1	20	4	-15278.0
1	20	6	-20167.0
1	20	8	-20851.2
1	20	9	-38250.5
1	20	26	-32787.8
1	20	27	-99140.3
1	20	31	-35905.4
1	20	32	-30712.4
1	21	4	-60688.5
1	21	6	-1052130.7
1	21	8	-19403.1
1	21	9	-60209.1
1	21	19	-26778.6
1	21	22	-17797.7
1	21	26	-133666.0
1	22	1	-167906.5*
1	22	4	-121544.5
1	22	7	-70803.8
1	22	8	-90387.3
1	22	9	-88915.4
1	22	22	-26110.7

Layer	Row	Col	Flux (ft^3/d)
1	23	2	-23375.4
1	23	4	-69213.4
1	23	7	-13750.2
1	23	8	-297090.7
1	23	9	-49110.2
1	23	11	-13220.1
1	23	23	-477772.8
1	24	2	-13291.9
1	24	6	-18333.6
1	24	7	-37440.9
1	24	8	-131580.8
1	24	9	-32938.0
1	24	10	-15578.8
1	25	4	-30772.1
1	25	5	-386701.6
1	25	6	-60042.6
1	25	7	-87390.3
1	25	8	-79140.2
1	25	10	-29739.0
1	25	34	-17834.4
1	26	2	-13750.2
1	26	3	-17264.2
1	26	4	-51977.0
1	26	5	-195477.3
1	26	6	-25216.7
1	26	8	-40945.1
1	26	9	-5557.2
1	26	10	-6582.2
1	26	15	-8822.0
1	27	2	-16347.5
1	27	3	-40792.3
1	27	4	-17111.4
1	27	8	-94402.2
1	27	9	-1875.7
1	27	10	-220833.1
1	27	20	-455325.0
1	28	2	-27347.7*
1	28	3	-34463.0
1	28	8	-66001.1
1	28	9	-48813.5
1	28	18	-124316.9
1	28	19	-109480.0
1	28	20	-109480.0
1	28	28	-53722.7
1	29	2	-14055.8*
1	29	3	-46903.5
1	29	4	-54695.3
1	29	8	-102057.2
1	29	9	-71068.9
1	29	10	-712165.1
1	29	17	-10620.0
1	29	20	-109480.0
1	29	21	-109480.0
1	29	29	-117626.1
1	29	32	-25268.4
1	30	3	-38214.3
1	30	4	-61723.2
1	30	5	-18944.8
1	30	8	-52862.0
1	30	9	-17062.5
1	30	11	-817645.3
1	30	12	-408822.7
1	30	31	-6900.5
1	30	32	-48575.0
1	30	33	-6900.5
1	30	34	-6900.5
1	30	39	-6900.5
1	31	3	-27806.0*
1	31	4	-73640.1
1	31	5	-43236.8

Layer	Row	Col	Flux (ft^3/d)	Layer	Row	Col	Flux (ft^3/d)
1	31	6	-44153.5	1	40	16	-25524.0
1	31	7	-46598.0	1	40	17	-15133.7
1	31	8	-671655.5	1	40	18	-13946.7
1	31	28	-360788.3	1	40	24	-12611.4
1	31	29	-779730.5	1	40	25	-13353.2
1	31	30	-526900.4	1	40	41	-6900.5
1	31	31	-57081.8	1	40	43	-34502.5
1	31	32	-150946.0	1	40	45	-234249.1
1	31	33	-13801.0	1	40	46	-161046.3
1	31	48	-28875.0	1	40	47	-67314.3
1	31	49	-24062.0	1	40	48	-48125.0
1	32	4	-115374.7	1	41	2	-20472.6*
1	32	5	-69362.2	1	41	3	-14576.0*
1	32	10	-14540.2	1	41	5	-55083.8*
1	32	11	-410480.6	1	41	6	-239533.6*
1	32	23	-4534.0	1	41	7	-35084.1
1	32	28	-312778.4	1	41	8	-17796.3
1	32	31	-15578.7	1	41	10	-28358.8
1	32	32	-110338.5	1	41	19	-27505.8
1	32	34	-6900.5	1	41	21	-160599.6
1	32	36	-6900.5	1	41	22	-80299.8
1	32	41	-13801.0	1	41	23	-16101.4
1	33	4	-116146.6	1	41	24	-63036.6
1	33	5	-31320.0	1	41	25	-13728.6
1	33	10	-51710.8	1	41	45	-263530.3
1	33	29	-173363.0	1	41	46	-131765.1
1	33	32	-136778.8	1	41	47	-146405.7
1	33	33	-163145.8	1	41	48	-40979.1
1	34	5	-26889.3	1	42	3	-73460.6*
1	34	6	-25667.1	1	42	5	-36270.5*
1	34	7	-31472.7	1	42	6	-139226.9*
1	34	9	-316199.6	1	42	7	-31564.4
1	34	23	-31602.7	1	42	8	-69153.4
1	35	5	-16805.8	1	42	16	-33897.7
1	35	6	-57200.0	1	42	17	-29830.0
1	35	7	-63862.1	1	42	18	-14576.0
1	35	10	-140365.8	1	42	23	-15254.0
1	35	16	-10170.7	1	42	24	-77625.7
1	35	24	-39466.2	1	42	26	-80846.0
1	35	43	-19250.0	1	42	27	-60168.4
1	35	49	-19250.0	1	42	28	-45931.4
1	36	8	-745827.7	1	42	42	-82806.0
1	36	12	-15945.8	1	42	43	-13801.0
1	36	24	-44510.8	1	42	44	-29281.1
1	36	29	-16765.7	1	42	45	-58562.3
1	37	8	-128180.2	1	42	46	-43921.7
1	37	9	-40774.0	1	42	47	-175686.8
1	37	10	-211192.3	1	42	48	-29281.1*
1	37	41	-6900.5	1	43	1	-35592.6*
1	37	45	-6900.5	1	43	3	-59490.5*
1	37	46	-57857.5	1	43	4	-29321.5*
1	37	49	-23100.0	1	43	5	-45592.4*
1	38	6	-93348.7	1	43	6	-79151.1*
1	38	10	-131981.1	1	43	7	-253974.4
1	38	13	-274700.1	1	43	8	-44236.5
1	38	14	-11144.8	1	43	10	-54981.4
1	38	17	-204655.8	1	43	13	-17118.3
1	38	42	-27602.0	1	43	17	-14067.5
1	38	49	-15400.0	1	43	19	-13559.1
1	39	6	-92126.5	1	43	21	-18304.8
1	39	17	-12762.0	1	43	23	-22542.0
1	39	25	-15875.5	1	43	25	-57795.6
1	39	41	-41403.0	1	43	26	-15762.4
1	39	42	-55204.0	1	43	27	-17118.3
1	39	47	-13475.0	1	43	28	-14406.5
1	39	49	-13475.0	1	43	41	-37626.4
1	40	4	-12986.3*	1	43	42	-75905.5
1	40	5	-33306.1*	1	43	43	-69005.0
1	40	6	-32542.2	1	43	44	-62104.5
1	40	13	-236997.1	1	43	48	-43921.7*

Layer	Row	Col	Flux (ft^3/d)
1	44	1	-72541.1
1	44	2	-33728.2
1	44	3	-315099.8
1	44	4	-208300.4
1	44	5	-278130.6
1	44	6	-118826.6
1	44	7	-448660.0
1	44	8	-201013.4
1	44	11	-25976.6
1	44	17	-47626.3
1	44	22	-22033.5
1	44	25	-35931.6
1	44	26	-29491.0
1	44	27	-68134.4
1	44	42	-13801.0*
1	44	43	-55204.0*
1	44	44	-69005.0*
1	44	45	-41403.0*
2	13	10	-277402.7
2	16	10	-277402.7
2	17	13	-194029.9
2	18	15	-82381.2
2	19	15	-394516.1
2	20	20	-678657.0
2	21	8	-117479.6
2	21	11	-748328.2
2	22	11	-748328.2
2	22	15	-616778.4
2	22	16	-462583.8
2	22	19	-186363.4
2	23	17	-1073576.1
2	25	15	-748236.6
2	25	16	-374118.3
2	25	18	-1335268.5
2	26	11	-837115.5
2	26	15	-8822.0
2	33	10	-206843.2

* Pumping specified for grid cell that is outside the active model region; these values will not affect the simulation results.

APPENDIX B.2

SOURCES OF DATA FOR PUBLIC SUPPLY AND INDUSTRIAL WATER USERS - 1988
EAST-CENTRAL FLORIDA
GROUND WATER MODELING STUDY - PHASE ONE

I. UPPER FLORIDAN WELL SITES

MAP				DATA SOURCES	
NO.	OWNER	NAME	WELL #	LOCATION	PUMPAGE
1	COCOA	COCOA	2	A	A
2			3	A	A
3			4	A	A
4			4A1	A	A
5			5	A	A
6			6	A	A
7			7	A	A
8			7A	A	A
9			8	A	A
10			9	A	A
11			10	A	A
12			11	A	A
13			12A	A	A
14			12B	A	A
15			13	A	A
16			14	A	A
17			15	A	A
18			16	A	A
19			17	A	A
20			18	A	A
21			19	A	A
22	ECON UTIL	WEDGEFIELD	1	B,C	B
23			2	B,C	B
24			3	B,C	B
25			4	B,C	B
26	OUC	MARTIN	1	B,C,D,E	B
27			2	B,C,D,E	B
28			3	B,C,D,E	B
29	OUC	DR. PHILLIPS	1	B,C,D,E	B
30			2	B,C,D,E	B
31			3	B,C,D,E	B
32			4	B,C,D,E	B
33	FL DEPT	ORANGE CORR INST.	1	B,C	B
34	OF CORR		2	B,C	B
35			3	B,C	B
36			4	B,C	B
37	OUC-STANTON ENERGY CTR.		1	B,C,F	B
38			2	B,C,F	B
39	UCF	UNIV OF CENTRAL	1	B,C	B
40		FLORIDA	2	B,C	B
41			3	B,C	B
42			4	B,C	B
43			5	B,C	B
44			6	B,C	B
45			7	B,C	B
46			8	B,C	B
47			9	B,C	B
48			10	B,C	B
49			11	B,C	B
50			12	B,C	B
51	MAITLAND	(UPPER FLORIDAN)	#1	B,C	B
52			#2	B,C	B
53			#3	B,C	B
54			#4	B,C	B

55			#4A-	B,C	B
56	SO. STATES	UNIV SHORES/	1	B	B
57	UTIL.	BEL AIR	2	B	B
58	SO. STATES	LAKE CONWAY	1	B	B
59	UTIL.	PARK	2	B	B
60	SO. STATES	DAETWYLER	1	B	B
61	UTIL.	SHORES	2	B	B
62	SO. STATES	UNIV SHORES/	1	B	B
63	UTIL.	SUNCREST	2	B	B
64	UTIL OF FLA	CRESCENT HTS	1	B	B
65	SUN RESORTS	YOGI BEAR CAMP	1	B,C	C
66	WINTER PARK	PLANT #1	1	B,C,D,G	B
67			3	B,C,D,G	B
68	WINTER PARK	PLANT #4	8	B,C,D,G	B
69	OCOEE	KISSIMEE ST	NO. 1	B,C	B
70			NO. 1A	B,C	B
71	OCOEE	HACKNEY RD	NO. 2	B,C	B
72			NO. 3	B,C	B
73	OCOEE	WURST RD.	NO. 4	B,C	B
74			NO. 5	B,C	B
75	CITY OF OAKLAND		1	B	B
76	EATONVILLE		1	B,D,G	B
77	ROCK SPRINGS MOB. HOME PARK		1	B,G	B
78	SHADOW HILLS MOB. HOME PARK		1	B	B
79	WINTER	BOYD ST.	1	B,C	B
80	GARDEN		2	B,C	B
81	TANGERINE		1	B,C	B
82	STARLIGHT RANCH MHP		1	B	B
83	UTIL OF FLA	DAVIS SHORES	1	B	B
84	COCOA COLA	PLYMOUTH PLNT	1	B,C,G	B
85	WINTER GARDEN CITRUS PRODUCTS			B,C	B
86	REEDY CREEK	WELL FIELD A 9 & 10		H	D,E
87	(DISNEY)	WELL FIELD B: 2, 2A, & 17		H	D,E
88		WELL FIELD C: 6,16, & 5		H	D,E
89		TURKEY LAKE PARK	1	B,E	D
90	ORANGE/OSCEOLA	BUENAVENT.	1	B,E	D
91	UTILITIES	LAKES	2	B,E	D
92	KISSIMEE GOOD SAM		1	B,E	D
93	HYATT HOUSE ORLANDO		1	B,E	D
94			2	B,E	D
95	POINCIANA		IP-1	B,E	D
96	UTILITIES		IP-2	B,E	D
97			V2	B,E	D
98	POINCIANA	UTILITIES	CORE-1	B,E	D
99			CORE-2	B,E	D
100			CORE-3	B,E	D
101	CENTRAL FLA	PARKWAY	PD1	B,E	D
102	UTILITIES		PD2	B,E	D
103			PD3	B,E	D
104	CENTRAL FLA	CAMELOT	CD1	B,E	D
105	UTILITIES		CD2	B,E	D
106	CENTRAL FLA	FOUNTAIN	FP1	B,E	D
107	UTILITIES	PARK	FP2	B,E	D
108	ST. CLOUD		1	B,E	D
109			2	B,E	D
110			3	B,E	D
111	CITY OF	RUBY ST	3	B,E	D
112	KISSIMEE		4	B,E	D
113	CITY OF	NORTH	1	B,E	D
114	KISSIMEE	BERMUDA	2	B,E	D
115	SOUTHERN	TROPICAL PARK	1	B,E	D
116	STATES UTIL.		2	B,E	D
117	POINCIANA	POIN.	V7-1	B,E	D
118	UTILITIES	VILLAGE	V7-2	B,E	D
119	OSCEOLA SERVICE		1	B,E	D
120	BREWER	"THE STARS"	1	B,E	
121	ORANGE/OSCEOLA		1	B,E	
122	MANAGEMENT CORP.		2	B,E	
123	LAKE WALES UTILITY CO.		1	B	F
124	WINTER HAVEN	FF		B	F
125	WINTER HAVEN	INW		B	F
126	WINTER HAVEN	3ST		B	F
127	DUNDEE	#1		B	F

128 DUNDEE	#3		B	F
129 LAKE HAMILTON			B	F
130 DAVENPORT			B	F
131 LAKE ALFRED			B	F
132 HAINES CITY			B	F
133 HAINES CITY			B	F
134 ZELLWOOD	ZELLWOOD MHP	1	B,C	B
135 ZELLWOOD WATER USERS		1	B,C	B
136 MARG. C. CAMMACK			B	
137 TOWN OF MASCOTTE			B,C	B
138 SUN LAKE ESTATES			B,C	B
139 ORANGE BLOSSOM GARDENS			B	B
140 EUSTIS	HAZELTON AVE	1	B,C	B
141 EUSTIS	CR44A	1	B,C	B
142		2	B,C	B
143 EUSTIS	ARDICE PLACE	1	B,C	B
144		2	B,C	B
145 CLERMONT	GRAND	1	B	B
146 CLERMONT	FOURTH ST	1	B	B
147 FRUITLAND PARK		1	B	B
148 LEESBURG			B,C	B
149 HOWEY-IN-THE-HILLS			B,C	B
150 SO. STATES	PINEY WOODS		B	B
151 SO. STATES	PICCIOLA ISLAND		B	B
152 LAKE COUNTY UTIVAL. TERR.			B	B
153 CITY OF UMATILLA			B,C	B
154 J.P. GILLS	CLERBROOK		B	
155 STETLER, R.	COUNTRYSIDE PUD		B	
156 LAKEWOOD DEV.	PLANTATION		B	
157 POOLEY-TROYAN	BRAMALEA UTIL.		B	
158 CITY OF TAVARES			B,C	B
159 TOWN OF GROVELAND			B,C	B
160 CITY OF MT. DORA			B	B
161 CITY OF MINNEOLA			B	B
162 DEANZA MID-FLA LAKES			B	B
163 HAWTHORNE AT LEESBURG			B	B
164 SILVER LAKE ESTATES			B	B
165 STATE OF FL	LAKE CORR. FACILITY		B	
166 WATER OAK UTIL.	WATER OAK EST.		B	B
167 MONTEVERDE			B,C	B
168 UTIL., INC	AMBER HILLS		B	B
169 B & W CANNING			B,C	B
170 SILVER SAND	CLERMONT MINE		B,C	B
171 FLA. ROCK	LAKE SAND PLANT		B,C	B
172 AIRGROVES	LAKE SAND PLANT II		C	G
173 GOLDEN GEM	CITRUS PLANT		B,C	B
174 SILVER SPRINGS CITRUS			B,C	B
175 FLORIDA CRUSHED STONE			B,C	B
176 FLORIDA FOOD PRODUCTS			C	G
177 SUNDOR BRANDS, INC.			B,C	B
178 LONGWOOD	PLANT#1		B,C	B
179 LONGWOOD	PLANT#2		B,C	B
180 SEM. CTY.	GREENWOOD LAKES		B,G	B
181 SEM. CTY.	COUNTRY CLUB HTS.		B	B
182 SEM. CTY.	HANOVER WOODS		B,C	B
183 SEM. CTY.	LYNWOOD/BELAIRE		B,C	B
184 SEM. CTY.	INDIAN HILLS		C,G	B
185 SEM CTY	CONSUMER	1	C,G	B
186 SEM CTY	CONSUMER	2	C,G	B
187 SEM CTY	CONSUMER	3	C,G	B
188 SEM CTY	CONSUMER	4	C,G	B
189 SEM CTY	LAKE HAYES	1	C	B
190	LAKE HAYES	2	C	B
191	LAKE HAYES	3	C	B
192	LAKE HAYES	4	C	B
193	LAKE HAYES	5	C	B
194 SEM CTY	HEATHROW		B,C	B
195 OVIEDO	OVIEDO (OLD)	101	C	B
196	OVIEDO (OLD)	102	C	B
197	OVIEDO (OLD)	103	C	B
198 OVIEDO	ALAFAYA WOODS	203	C	B
199	ALAFAYA WOODS	204	C	B
200 SANFORD	WELL FIELD #1		C	B

201	SANFORD	WELL FIELD #2		C	B
202	CASSELBERRY	HOWELL PARK		C	B
203	CASSELBERRY	NORTH WTP		C	B
204	CASSELBERRY	SOUTH WTP		C	B
205	CASSELBERRY	CENTRAL V		C	B
206	UTILITIES	WEATHERSFIELD		G	B
207	INC., OF FL	OAKLAND SHORES		G	B
208		JANSEN		B	B
209		BEAR LAKE		B	B
210		LITTLE WEKIVA		B	B
211		PHILLIPS/CRYSTAL LAKE		B	B
212		RAVENNA PARK		G	B
213	SOUTHERN	APPLE VALLEY		G	B
214	STATES	DRUID HILLS/BRETTONWOODS		G	B
215	UTIL.	LAKE HARRIET		G	B
216		HARMONY HOMES/FERN PARK		G	B
217		DOL-RAY MANOR		G	B
218		MEREDITH MANOR		G	B
219		LAKE BRANTLEY		G	B
220	SO. STATES	CHULUOTA	1	C	B
221			2	C	B
222	ALTAMONTE	PLANT #1		C	B
223	SPRINGS	PLANT #2		C	B
224		PLANT #3		C	B
225		PLANT #4		C	B
226		PLANT #5		C	B
227	LAKE MONROE	I-4 INDUSTRIAL PK		B	B
228	WINTER	WTP #2		G	B
229	SPRINGS	WTP #3		G	B
230	SEM. UTIL.	TUSCAWILLA		C	B
231	SANLANDO	DESPIN/OVERSTREET		C,G	B
232	SANLANDO	WEKIVA		C,G	B
233	DEEP SOUTH PRODS.			G	B
234	FPL-SANFORD POWER PLANT			G	B
235	PALM VALLEY MHP			B	B
236	CENT. FLA RES. PARK			C	G
237	OCPUD	ECON	1	C	B
238			2	C	B
239			3	C	B
240			4	C	B
241		BONNEVILLE	1	C	B
242		CONWAY	1	C	B
243			2	C	B
244			3	C	B
245			4	C	B
246		CORRINE TERRACE	1	C	B
247			2	C	B
248		LAKE NONA	1	B,E	B
249		MEADOW WOODS		B,C	B
250		ORANGEWOOD		B,C	B
251		VISTANA		B,C	B
252		HIDDEN SPRINGS		B,E	B
253		KELSO		B,E	B
254		HUNTERS CREEK		B,E	B
255		CYPRESS WALK		B,E	B
256		MT PLYMOUTH		B,C	B
257		BENT OAKS		B,C,G	B
258		WINDERMERE		B,E	B
259		WINDERMERE DOWNS		B,E	B
260		WAUSEON RIDGE		B,E	B
261		MAGNOLIA WOODS		B,C	B
262		ORANGE VILLAGE		B,C	B
263		PLYMOUTH/PLY. HILLS		B,C,G	B
264	COCOA-COLA	LEESBURG		C	B
265	RALSTON PURINA-ZELLWOOD FARMS			B,C	B
266	CITY OF LAKELAND-LAKE PARKER			B	
267	FL DEPT.CORR - POLK CORR. INST.			B	F
268	LAKE REGION M.H. VILLAGE			B	F
269	ORCHID SPRINGS DEVEL CORP.			B	F
270	CITY OF LAKELAND			B	F
271	GRENELEFE CORP.			B	F
272	CONTINENTAL DEVEL. LTD			B	F
273	POLK CTY UTILITIES - NORTH LAKELAND			B	

274	POLK CTY UTILITIES - TIMBER RIDGE			B	
275	POLK CTY UTILITIES - JAN-PHYL UTIL.			B	
276	POLK CTY UTILITIES - FOUR CORNERS			B	
277	CITY OF AUBURNDALE		TPST	B	F
278	CITY OF AUBURNDALE		WLKE	B	F
279	CITY OF AUBURNDALE		WPLT	B	F
280	SO. STATES. UTILS. - LAKE GIBSON			B	F
281	CENTURY REALTY FUND - LTD.			B	F
282	JOHN R. MILLER			B	
283	CITY OF LAKELAND - POLK CITY			B	
284	WEKIVA FALLS			C	H
285	SEA WORLD OF FLA.		1	I	J
286	SEA WORLD OF FLA.		2	I	J
287	EDGEWATER	WEST WELL FIELD		J	B
288	EDGEWATER	PARK AVE. W.FIELD		J	B
289	LAKE HELEN		1	J	B
290			2	J	B
291	ORANGE CITY			J	B
292	VOLUSIA CTY	ORANGE CITY INDUS PK		J	B
293	VOLUSIA CTY	FOUR TOWNES		J	B
294	VOLUSIA CTY	BREEZEWOOD		J	B
295	VOLUSIA CTY	SWALLOWS		J	B
296	VOLUSIA CTY	LAKE MARIE		J	B
297	FPL	LK. MONROE PWR PLNT		B,G	B
298	DELTONA UTIL		15&17	C	B
299	DELTONA UTIL		#5	C	B
300	DELTONA UTIL		#4	C	B
301	DELTONA UTIL	EAST	9,12,14,1	C	B
302	DELTONA UTIL	WEST		C	B
303	POLK CO/BOARDWALK & BASEBALL			K	F
304	FLORIBRA USA, INC			B,E	I

II. LOWER FLORIDAN WELL SITES

MAP NO.	OWNER	WELL FIELD NAME	WELL #	DATA SOURCES LOCATION	PUMPAGE
1	OUC	HIGHLAND	1	B,C,D,E	B
2			2	B,C,D,E	B
3			3	B,C,D,E	B
4			4	B,C,D,E	B
5			5	B,C,D,E	B
6			6	B,C,D,E	B
7			7	B,C,D,E	B
8	OUC	PINE HILLS	8	B,C,D,E	B
9			16	B,C,D,E	B
10			21	B,C,D,E	B
11			26	B,C,D,E	B
12	OUC	PRIMROSE	9	B,C,D,E	B
13			12	B,C,D,E	B
14			15	B,C,D,E	B
15	OUC	KUHL	10	B,C,D,E	B
16			14	B,C,D,E	B
17			18	B,C,D,E	B
18	OUC	CONWAY	17	B,C,D,E	B
19			20	B,C,D,E	B
20			24	B,C,D,E	B
21	OUC	KIRKMAN	19	B,C,D,E	B
22			23	B,C,D,E	B
23			33	B,C,D,E	B
24	OUC	NAVY	22	B,C,D,E	B
25	MAITLAND	KELLER	#6	B,C	B
26	WINTER PARK	PLANT #5	#6	B,C	B
27			#7	B,C	B
28	WINTER PARK	PLANT #3	#5	B,C	B
29	WINTER GARDEN	PALMETTO		B,C	B
30	APOPKA	TERRACE		B,C	B
31	APOPKA	SHEELOR OAKS		B,C	B

III. WELL FIELD LOCATIONS WITH WELLS COMPLETED IN BOTH THE UPPER AND LOWER FLORIDAN AQUIFERS

MAP NO.	OWNER	WELL FIELD NAME	WELL #	DATA SOURCES LOCATION	PUMPAGE
1	OCPUD	OAK MEADOWS		B,C	B
2	OCPUD	RIVERSIDE		B,C,G	B
3				B,C,G	B
4				B,C,G	B
5	MAITLAND		NO. 5	B,C	B
6			NO. 5A	B,C	B
7	SOUTHERN FRUIT DISTRIB		1 - 4	B,C	C

IV. IDENTIFICATION OF DATA SOURCES

1. LOCATION:

A: USGS, 1989, Cocoa well field annual data summary for 1989
B: R. Marella, 1990, written communication (data tables compiled originally from SJRWMD, SFWMD, & SWFWMD CUP files)
C: SJRWMD consumptive use permit files
D: Szell, G. P., 1987, Deep monitoring well network for the metropolitan area of Orlando and vicinity, SJRWMD Technical Publication 87-2, 51 p.
E: Alvarez, J., and Bacon, D., 1988, SFWMD Technical Public. 88-4
F: Orlando Utilities Commission
G: Toth,D., et al, 1989, SJRWMD Technical Publication 89-5
H: Reedy Creek Inprovement District
I: Sea World of Florida, Inc.
J: local government draft comprehensive plans
K: Estimated from USGS 7.5 minute topographic map

2. 1988 PUMPAGE:

A: City of Cocoa
B: SJRWMD files (monthly operating reports from water treatment plants
C: Florence, B. 1990, SJRWMD Technical Publication 90-12
D: SFWMD Water Use Division files
E: Reedy Creek Improvement District
F: Tuttell, M., & Sorenson, L. A., 1989, 1987 Estimated Water Use in the Southwest Florida Water Management District, 99 p.
G: SJRWMD consumptive use permit allocations
H: measurements made by SJRWMD
I: Alvarez, J., & Bacon, D. D., 1988, SFWMD Technical Publication 88-4
J: Sea World of Florida, Inc.

APPENDIX B.3

ESTIMATES OF AVERAGE GROUND WATER IRRIGATION REQUIREMENTS FOR CITRUS EAST-CENTRAL FLORIDA PHASE ONE MODEL AREA -- CALENDAR YEAR 1988

SOURCES OF DATA:

CITRUS PUMPAGE LOCATIONS: FLORIDA AGRIC. STATISTICS SERVICE - CITRUS ACREAGE & TREE COUNTS CURRENT AS OF JAN. 1988

IRRIGATION REQUIREMENTS: ESTIMATED USING SJRWMD BLANEY-CRIDDLE MODEL FOR ESTIMATING CROP IRRIG. REQUIREMENTS (TEMPERATURE & RAINFALL DATA FROM N.O.A.A. CLIMATOLOGICAL STATIONS - 1988 AVG. MONTHLY VALUES)

ASSUMPTIONS: AVERAGE IRRIGATION EFFICIENCY IS 82.5%

THE IRRIGATION REQUIREMENT PER SECTION IS SUPPLIED TOTALLY BY PUMPAGE FROM THE UPPER FLORIDAN AQUIFER

RAINFALL IS SPREAD EVENLY THROUGHOUT EACH MONTH

I. N.O.A.A. STATION: SANFORD

CITRUS IRRIG. REQUIREMENT FOR 1988 = 8.66 in/yr per acre

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
VOLUSIA	1	19	34	151	1307.66
SEMINOLE	9	20	31	215	1861.9
SEMINOLE	34	20	31	163	1411.58
SEMINOLE	35	20	31	133	1151.78
LAKE	7	18	27	155	1342.3

II. N.O.A.A. STATION: CLERMONT 7S

CITRUS IRRIG. REQUIREMENT FOR 1988 = 15.37 in/yr per acre

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
LAKE	36	19	25	148	2274.76
LAKE	15	20	25	178	2735.86
LAKE	19	20	25	110	1690.7
LAKE	23	20	25	130	1998.1
LAKE	29	20	25	131	2013.47
LAKE	32	20	25	132	2028.84
LAKE	34	20	25	167	2566.79
LAKE	35	20	25	246	3781.02
LAKE	2	21	25	104	1598.48
LAKE	3	21	25	174	2674.38
LAKE	30	21	25	142	2182.54
LAKE	31	21	25	112	1721.44
LAKE	32	21	25	106	1629.22
LAKE	5	22	25	151	2320.87
LAKE	6	22	25	128	1967.36
LAKE	7	22	25	182	2797.34
LAKE	28	22	25	153	2351.61

LAKE	32	22	25	87	1337.19
LAKE	8	23	25	90	1383.3
LAKE	10	23	25	113	1736.81
LAKE	12	23	25	179	2751.23
LAKE	13	23	25	112	1721.44
LAKE	14	23	25	157	2413.09
LAKE	15	23	25	110	1690.7
LAKE	17	23	25	107	1644.59
LAKE	21	23	25	179	2751.23
LAKE	22	23	25	89	1367.93
LAKE	25	23	25	216	3319.92
LAKE	26	23	25	199	3058.63
LAKE	27	23	25	108	1659.96
LAKE	28	23	25	92	1414.04
LAKE	34	23	25	137	2105.69
LAKE	35	23	25	113	1736.81
LAKE	36	23	25	252	3873.24
LAKE	1	24	25	233	3581.21
LAKE	2	24	25	182	2797.34
LAKE	10	18	26	97	1490.89
LAKE	16	18	26	92	1414.04
LAKE	19	18	26	105	1613.85
LAKE	30	18	26	179	2751.23
LAKE	15	19	26	129	1982.73
LAKE	21	19	26	88	1352.56
LAKE	24	19	26	118	1813.66
LAKE	27	19	26	95	1460.15
LAKE	6	20	26	104	1598.48
LAKE	7	20	26	112	1721.44
LAKE	12	20	26	141	2167.17
LAKE	18	20	26	104	1598.48
LAKE	16	21	26	98	1506.26

II. N.O.A.A. STATION: CLERMONT 7S

CITRUS IRRIG. REQUIREMENT FOR 1988 = 15.37 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
LAKE	18	21	26	100	1537
LAKE	29	21	26	127	1951.99
LAKE	33	21	26	178	2735.86
LAKE	5	22	26	134	2059.58
LAKE	8	22	26	100	1537
LAKE	13	22	26	270	4149.9
LAKE	17	22	26	230	3535.1
LAKE	1	23	26	215	3304.55
LAKE	3	23	26	226	3473.62
LAKE	4	23	26	394	6055.78
LAKE	5	23	26	118	1813.66
LAKE	8	23	26	132	2028.84
LAKE	9	23	26	197	3027.89
LAKE	12	23	26	104	1598.48
LAKE	29	23	26	142	2182.54
LAKE	32	23	26	152	2336.24
LAKE	33	23	26	124	1905.88
LAKE	1	24	26	208	3196.96
LAKE	3	24	26	129	1982.73
LAKE	4	24	26	154	2366.98
LAKE	5	24	26	249	3827.13
LAKE	8	24	26	99	1521.63
LAKE	9	24	26	228	3504.36
LAKE	10	24	26	226	3473.62
LAKE	15	24	26	205	3150.85
LAKE	22	24	26	176	2705.12
LAKE	26	24	26	138	2121.06
LAKE	27	24	26	110	1690.7
LAKE	16	19	27	94	1444.78
LAKE	20	19	27	178	2735.86
LAKE	22	19	27	131	2013.47
LAKE	27	19	27	148	2274.76

ORANGE	8	20	27	89	1367.93
ORANGE	18	20	27	263	4042.31
ORANGE	7	22	27	132	2028.84
ORANGE	12	22	27	103	1583.11
ORANGE	13	22	27	127	1951.99
ORANGE	20	22	27	94	1444.78
ORANGE	21	22	27	240	3688.8
ORANGE	22	22	27	100	1537
ORANGE	25	22	27	162	2489.94
ORANGE	26	22	27	144	2213.28
ORANGE	29	22	27	90	1383.3
ORANGE	31	22	27	120	1844.4
ORANGE	33	22	27	245	3765.65
ORANGE	34	22	27	171	2628.27
ORANGE	35	22	27	444	6824.28
ORANGE	36	22	27	220	3381.4

II. N.O.A.A. STATION: CLERMONT 7S

CITRUS IRRIG. REQUIREMENT FOR 1988 = 15.37 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
ORANGE	1	23	27	101	1552.37
ORANGE	2	23	27	263	4042.31
ORANGE	3	23	27	154	2366.98
ORANGE	4	23	27	350	5379.5
ORANGE	5	23	27	222	3412.14
ORANGE	6	23	27	178	2735.86
ORANGE	11	23	27	168	2582.16
ORANGE	12	23	27	100	1537
ORANGE	13	23	27	100	1537
ORANGE	14	23	27	383	5886.71
ORANGE	15	23	27	121	1859.77
ORANGE	23	23	27	239	3673.43
ORANGE	24	23	27	193	2966.41
ORANGE	25	23	27	325	4995.25
ORANGE	26	23	27	128	1967.36
ORANGE	27	23	27	215	3304.55
ORANGE	34	23	27	127	1951.99
ORANGE	36	23	27	219	3366.03
ORANGE	4	24	27	155	2382.35
ORANGE	5	24	27	150	2305.5
ORANGE	6	24	27	81	1244.97
ORANGE	19	24	27	168	2582.16
ORANGE	21	24	27	206	3166.22
ORANGE	28	24	27	306	4703.22
ORANGE	29	24	27	112	1721.44
ORANGE	30	24	27	149	2290.13
POLK	25	25	25	85	1306.45
POLK	33	25	25	134	2059.58
POLK	11	25	26	314	4826.18
POLK	12	25	26	297	4564.89
POLK	13	25	26	448	6885.76
POLK	14	25	26	155	2382.35
POLK	24	25	26	213	3273.81
POLK	28	25	26	218	3350.66
POLK	36	25	26	125	1921.25

III. N.O.A.A. STATION: LAKE ALFRED

CITRUS IRRIG. REQUIREMENT FOR 1988 = 17.05 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
POLK	1	26	25	86	1466.3
POLK	33	26	25	93	1585.65
POLK	3	27	25	193	3290.65
POLK	5	27	25	117	1994.85

POLK	10	27	25	158	2693.9
POLK	13	27	25	87	1483.35
POLK	17	27	25	223	3802.15
POLK	21	27	25	199	3392.95
POLK	23	27	25	345	5882.25
POLK	24	27	25	262	4467.1
POLK	26	27	25	140	2387
POLK	27	27	25	141	2404.05
POLK	29	27	25	205	3495.25
POLK	34	27	25	114	1943.7
POLK	35	27	25	99	1687.95
POLK	36	27	25	226	3853.3
POLK	1	26	26	127	2165.35
POLK	3	26	26	175	2983.75
POLK	10	26	26	150	2557.5
POLK	15	26	26	82	1398.1
POLK	21	26	26	132	2250.6
POLK	2	27	26	149	2540.45
POLK	3	27	26	170	2898.5
POLK	4	27	26	99	1687.95
POLK	7	27	26	173	2949.65
POLK	15	27	26	119	2028.95
POLK	16	27	26	102	1739.1
POLK	18	27	26	206	3512.3
POLK	19	27	26	303	5166.15
POLK	20	27	26	218	3716.9
POLK	22	27	26	110	1875.5
POLK	23	27	26	1140	19437
POLK	24	27	26	133	2267.65
POLK	25	27	26	99	1687.95
POLK	26	27	26	179	3051.95
POLK	27	27	26	170	2898.5
POLK	30	27	26	153	2608.65
POLK	31	27	26	173	2949.65
POLK	34	27	26	115	1960.75
POLK	3	26	27	105	1790.25
POLK	4	26	27	102	1739.1
POLK	5	26	27	105	1790.25
POLK	6	26	27	413	7041.65
POLK	7	26	27	177	3017.85
POLK	18	26	27	121	2063.05
POLK	19	26	27	161	2745.05
POLK	20	26	27	95	1619.75
POLK	22	26	27	157	2676.85

III. N.O.A.A. STATION: LAKE ALFRED

CITRUS IRRIG. REQUIREMENT FOR 1988 = 17.05 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
POLK	25	26	27	113	1926.65
POLK	30	26	27	95	1619.75
POLK	31	26	27	143	2438.15
POLK	32	26	27	240	4092
POLK	5	27	27	349	5950.45
POLK	6	27	27	175	2983.75
POLK	8	27	27	314	5353.7
POLK	9	27	27	176	3000.8
POLK	10	27	27	173	2949.65
POLK	11	27	27	88	1500.4
POLK	14	27	27	352	6001.6
POLK	15	27	27	106	1807.3
POLK	16	27	27	211	3597.55
POLK	17	27	27	151	2574.55
POLK	19	27	27	141	2404.05
POLK	20	27	27	323	5507.15
POLK	23	27	27	441	7519.05
POLK	26	27	27	287	4893.35
POLK	28	27	27	103	1756.15
POLK	30	27	27	149	2540.45

POLK	31	27	27	112	1909.6
POLK	32	27	27	112	1909.6
POLK	33	27	27	273	4654.65
POLK	34	27	27	449	7655.45
POLK	35	27	27	271	4620.55
POLK	36	27	27	179	3051.95
OSCEOLA	24	26	29	112	1909.6
OSCEOLA	25	26	29	88	1500.4
OSCEOLA	9	27	29	101	1722.05
OSCEOLA	4	26	30	80	1364
OSCEOLA	29	26	30	86	1466.3
OSCEOLA	30	26	30	176	3000.8
OSCEOLA	32	26	30	83	1415.15
OSCEOLA	2	27	30	108	1841.4
OSCEOLA	4	27	30	80	1364
OSCEOLA	13	27	30	130	2216.5
OSCEOLA	18	27	30	281	4791.05
OSCEOLA	4	26	31	81	1381.05
OSCEOLA	5	26	31	266	4535.3
OSCEOLA	7	26	31	95	1619.75
OSCEOLA	13	26	31	96	1636.8
OSCEOLA	14	26	31	93	1585.65
OSCEOLA	17	26	31	273	4654.65
OSCEOLA	18	26	31	90	1534.5
OSCEOLA	20	26	31	185	3154.25
OSCEOLA	25	26	31	175	2983.75
OSCEOLA	26	26	31	262	4467.1
OSCEOLA	27	26	31	477	8132.85

III. N.O.A.A. STATION: LAKE ALFRED

CITRUS IRRIG. REQUIREMENT FOR 1988 = 17.05 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
OSCEOLA	34	26	31	93	1585.65
OSCEOLA	35	26	31	101	1722.05
OSCEOLA	36	26	31	85	1449.25
OSCEOLA	4	27	31	206	3512.3
OSCEOLA	6	27	31	133	2267.65
OSCEOLA	9	27	31	135	2301.75
OSCEOLA	21	27	32	212	3614.6
OSCEOLA	22	27	32	174	2966.7
OSCEOLA	23	27	32	149	2540.45
OSCEOLA	26	27	32	253	4313.65
OSCEOLA	32	27	32	465	7928.25
OSCEOLA	33	27	32	593	10110.65
OSCEOLA	34	27	32	588	10025.4
OSCEOLA	35	27	32	486	8286.3
OSCEOLA	3	27	34	222	3785.1

III. N.O.A.A. STATION: ORLANDO WSO MCCOY

CITRUS IRRIG. REQUIREMENT FOR 1988 = 14.93 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
ORANGE	17	21	28	129	1925.97
ORANGE	18	21	28	120	1791.6
ORANGE	18	22	28	148	2209.64
ORANGE	29	22	28	121	1806.53
ORANGE	30	22	28	210	3135.3
ORANGE	31	22	28	90	1343.7
ORANGE	32	22	28	132	1970.76
ORANGE	33	22	28	105	1567.65
ORANGE	19	23	28	121	1806.53
ORANGE	20	23	28	208	3105.44
ORANGE	29	23	28	207	3090.51
ORANGE	30	23	28	272	4060.96

ORANGE	31	23	28	115	1716.95
ORANGE	11	24	28	98	1463.14
ORANGE	20	23	30	100	1493
ORANGE	19	24	31	213	3180.09
ORANGE	29	24	31	266	3971.38
ORANGE	32	24	31	300	4479
ORANGE	3	22	32	160	2388.8
ORANGE	9	22	32	242	3613.06
ORANGE	10	22	32	207	3090.51
ORANGE	9	24	32	105	1567.65
ORANGE	31	24	32	113	1687.09
ORANGE	19	25	30	102	1522.86
ORANGE	29	25	30	94	1403.42
ORANGE	33	25	30	94	1403.42
ORANGE	16	25	31	107	1597.51
ORANGE	20	25	31	85	1269.05
ORANGE	21	25	31	90	1343.7
ORANGE	32	25	31	121	1806.53

III. N.O.A.A. STATION: TITUSVILLE

CITRUS IRRIG. REQUIREMENT FOR 1988 = 13.09 in/yr

COUNTY	SECTION	TWP.	RANGE	TOTAL ACRES	IRRIG. REQ. PER SECTION (acre-in/yr)
BREVARD	1	21	34	91	1191.19
BREVARD	23	21	34	126	1649.34
BREVARD	32	20	35	129	1688.61
BREVARD	51	20	35	94	1230.46
BREVARD	67	20	35	147	1924.23
BREVARD	68	20	35	162	2120.58
BREVARD	69	20	35	226	2958.34
BREVARD	70	20	35	133	1740.97
BREVARD	5	21	35	247	3233.23
BREVARD	7	21	35	107	1400.63
BREVARD	8	21	35	206	2696.54
BREVARD	20	21	35	119	1557.71
BREVARD	11	32	35	72	942.48

APPENDIX B.4

FLORIDAN AQUIFER AGRICULTURAL NON-CITRUS IRRIGATION PUMPING ESTIMATES

County	STR			Crop/Acres	Flux (ft^3/d)
Volusia	2	18	30	Golf Course/70	34,626.2
Volusia	7	18	31	Golf Course/80	39,572.8
Lake	36	17	27	Watermelons/14	1,272.6
Lake	1	18	27	Watermelons/14	1,272.6
Lake	2	18	27	Watermelons/14	1,272.6
Lake	3	18	27	Watermelons/14	1,272.6
Lake	11	18	27	Watermelons/14	1,272.6
Lake	10	18	27	Corn & Sorgham/25 each	8,159
Lake	15	18	27	Corn & Sorgham/25 each	8,159
Lake	26	18	26	Corn/22.5	4,535.76
Lake	27	18	26	Corn/22.5	4,535.76
Lake	34	18	26	Corn/22.5	4,535.76
Lake	35	18	26	Corn/22.5	4,535.76
Lake	24	18	26	Ferns/26	15,084
Lake	25	18	26	Ferns/26	15,084
Lake	6	19	28	Flowers & Foliage/123	58,919
Lake	34	19	27	Nursery/88 (Avg. Ferns, Flowers, Woody orn.)	66,762
Lake	15	20	27	Mushrooms/80 (use vegetable value)	8,021
Orange	19	20	27	Cabbage/142,	37,883
Orange	20	20	27	Vegetables/58 and	37,883
Orange	29	20	27	Corn/58	37,883
Orange	30	20	27		37,883
Orange	31	20	27		37,883
Orange	32	20	27		37,883
Lake	24	20	26	Corn/400	80,636
Orange	19	20	27	Corn/400	73,656
Orange	30	20	27	Corn/400	73,656
Volusia	10	19	32	Vegatables/475	57,147
Volusia	12	19	32	Turf/235 (used Pasture value)	25,758
Seminole	2	21	31	Watercress/30	208,808
Seminole	3	21	31	Watercress/30	208,808
Seminole	25	20	31	Watercress/30	208,808

Seminole	34	20	31	Watercress/30	208,808
Seminole	35	20	31	Watercress/30	208,808
Seminole	12	21	31	Celery/70	3,802
Seminole	21	21	31	Celery/70	3,802
Seminole	28	21	31	Celery/70 (used Vegetables value)	3,802
Seminole	21	21	31	Sod/306	61,359
Orange	20	23	30	Pasture/77, Sod/103	109,480
Orange	21	23	30	and Woody Orn./22	109,480
Orange	22	23	30	(Avg. rate = (300.78 + 1216.17	109,480
Orange	26	23	30	+109)/3 = 541.98	
Orange	27	23	30		109,480
Seminole	25	20	29	Nursery/30 Avg. (Ferns, Flowers, Woody Ovn.)	21,114
Seminole	15	21	30	Golf Course/67	33,142
Seminole	1	21	29	Golf Course/80.5	39,820
Seminole	2	21	29	Golf Course/80.5	39,820
Orange	22	21	28	Foliage/41.5	22,439
Seminole	5	21	29	Woody Orn. & Foliage (20 each)	30,197
Seminole	8	21	29	Turfs Urban Landscape/16	1,746
Seminole	17	21	29	Turfs Urban Landscape/15 (Used Pasture Value)	1,637

APPENDIX B.5

ABANDONED FLOWING WELLS
WITHIN THE STUDY AREA

Data Source: SJRWMD Abandoned Well Inventory (Steele, 1990)

Well ID	Q (gpm)	Q (ft^3/d)	Row	Col
BR0199	100	19,250	35	49
BR0204	100	19,250	35	43
BR0213	125	24,062	31	49
BR0233	150	28,875	40	48
BR0382*	200		43	49
BR0383*	275		43	49
BR0387	120	23,100	37	49
BR0388	80	15,400	38	49
BR0389	-	13,475	39	49
BR0400	220	42,350	37	46
BR0413*	175		44	50
BR0415	100	19,250	40	48
BR0419	150	28,875	31	48
BR0612*	-		26	49
BR0616*	-		25	49
BR0640	-	13,475	39	47
BR0659*	75		44	48
BR0711*	250		39	49
S-0100	30	5,775	16	24
S-0101	30	5,775	16	24
S-0102	-	5,775	16	24
S-0103	25	4,812	16	24
S-0504	29.6	5,698	7	23
S-0505	34.65	6,670	7	23
S-0513	0	0	9	25
S-0514	21.5	4,139	9	25
S-0520	55.25	10,636	7	23
S-0521	50.78	9,775	7	23
S-0523	11.86	2,283	7	23
S-0545	-	7,400	9	26
S-0546	38.46	7,404	9	26
V-0032	-	13,475	6	23
V-0375	200	38,500	6	19

*not in modeled region