Estimation of Recharge Through Selected Drainage Wells and Potential Effects from Well Closure, Orange County, Florida

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
	Area	
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
cubic foot (ft^3)	0.028317	cubic meter
	Flow	
foot per day (ft/d)	0.3048	meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
gallons per day (gal/d)	0.003785	cubic meter per day
million gallons per day (Mgal/d)	0.04381	kilometer per hour
inch per year (in/yr)	25.4	millimeter per year
	Acceleration	
feet per second squared (ft^2/s)	0.3048	meters per second squared
	Miscellaneous	
$ft^{1/2}/s$	0.3048	
in per year per acre (in/yr)/acre	1.0279	centimeter per year per hectare

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft3d)/ft2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Abbreviations

I-4	Interstate 4
SR	State Road

Estimation of Recharge Through Selected Drainage Wells and Potential Effects from Well Closure, Orange County, Florida

By L.A. Bradner

Abstract

Drainage wells have been used in Orange County, Florida, and surrounding areas to alleviate flooding and to control lake levels since 1904. Over 400 drainage wells have been drilled in the county, but many are now redundant because of surface drainage systems that have been installed within the last two or three decades. Most of the drainage wells emplace water into the Upper Floridan aquifer, a zone of high transmissivity within the Floridan aquifer system.

In 1992, the Orange County Stormwater Management Department identified 23 wells that were considered noncritical or redundant for current drainage control. These wells were targeted for closure to eliminate maintenance and possible contamination problems.

A 3-year study (1992 through 1994) encompassed several drainage basins in the county. Inflow to 18 of the 23 drainage wells on the noncritical list and the effects of closure of these noncritical wells on the potentiometric surface of the Upper Floridan aquifer were estimated. Three sites were chosen for intensive study and were used for further extrapolation to other noncritical sites.

The total average annual recharge rate through the 18 selected wells was estimated to be 9 cubic feet per second, or about 6 million gallons per day. The highest rate of long-term recharge, 4.6 cubic feet per second, was to well H-35. Several wells on the noncritical list were already plugged or had blocked intakes. Yields, or the sum of surface-water outflows and drainage-well recharge, from the drainage basins ranged from 20 to 33 inches per year. In some of the basins, all the yield from the basin was recharge through a drainage well. In other basins, most of the yield was surface outflow through canals rather than to drainage wells.

The removal of the recharge from closure of the wells was simulated by superposition in a three-dimensional ground-water flow model. As a second step in the model, water was also applied to two sites in western Orange County that could receive redirected surface water. One of the sites is CONSERV II, a distribution system used to apply reclaimed water to the surficial aquifer system through rapid infiltration basins and grove irrigation. The second site, Lake Sherwood, has an extremely high downward recharge rate estimated to be at least 54 inches per year.

The results from the simulations showed a decline of 1 foot or less in the potentiometric surface of the Upper Floridan aquifer with removal of the recharge and a mound of about 1 foot in the vicinity of the two sites in western Orange County. The Lake Sherwood site seems to reduce the declines caused by closure of the wells to a greater degree than the CONSERV II site, partly because the Lake Sherwood site is closer to the drainage-well basins.

INTRODUCTION

Drainage wells have been used to alleviate flooding and control lake levels in the area of Orange County since 1904, a year of extreme flooding. By the 1970's, more than 400 drainage wells had been drilled in Orange County. Most of these wells emplace water from the surface directly into the Upper Floridan aquifer, a zone of high transmissivity within the Floridan aquifer system. Many were installed as a less-costly alternative to major drainage systems. Some of these wells remain the only feasible drainage system on some closed-basin lakes. Other wells are either redundant or unnecessary for drainage in interconnected drainage basins.

As the city of Orlando and surrounding Orange County developed in the late 1800's and early 1900's, residents became concerned about their property because of the rise of lake levels during extreme wet seasons. A large part of the more developed areas contains closed-basin lakes that have either no surface outflow or outflow only at higher lake levels. Most of the topography in the developed areas is flat and the surface area of the lakes increases greatly with only a small increase in lake stage.

Drainage wells are used for control of lake levels, control of water levels in wetlands, disposal of stormwater, and disposal of water from water-cooled air conditioning systems and generators. From about 1910 to as late as 1960, disposal of effluent from breweries, dairies, community septic tanks, industry, and citrus-processing plants was through drainage wells. Most of these wells have been abandoned or converted to other uses. Contamination of the Upper Floridan aquifer from these effluent-disposal wells has been documented in several areas within the county.

The U.S. Geological Survey, in cooperation with the Orange County Stormwater Management Department, St. Johns River Water Management District, and South Florida Water Management District, began a 3-year study in 1992 to estimate the average annual recharge through noncritical drainage wells (fig. 1) and to evaluate the effects of well closure on the potentiometric surface of the Upper Floridan aquifer, the primary source of drinking water for the area. Because of increasing maintenance costs for aging wells and public concerns over quality of the recharge water, the Orange County Stormwater Management Department created two drainage-well categories—critical and noncritical. The critical drainage wells are located in areas where expensive retrofitting would be needed to replace the current drainage patterns. Noncritical wells in the current drainage system (table 1) are mostly redundant and could be eliminated and the water rerouted. Possible consequences of well closures which are of concern to Orange County include flooding (if further urbanization affects the volume of water redirected to surface-water drainage systems) and reduction of recharge (by closure of noncritical wells) which could lower the potentiometric surface of the Upper Floridan aquifer.

Purpose and Scope

This report presents estimates of recharge through 18 of 23 noncritical drainage wells. The estimated drainage-well recharge was used in a ground-water flow model to evaluate changes in the potentiometric surface of the Upper Floridan aquifer. Results from the simulation of well closure and the redistribution of recharge on the potentiometric surface of the Upper Floridan aquifer are presented.

Previous Studies

Numerous reports have been written about drainage wells in the Orange County area. Reports by Sellards and Gunter (1910), Stringfield (1933), Unklesbay (1944), Telfair (1948), and Lichtler and others (1968) documented the increasing number of drainage wells in Orange County in response to continued development. The quality of drainage-well recharge was discussed in these reports and later publications by Black, Crow, and Eidsness, Inc. (1968); Kimrey (1978); Schiner and German (1983); Kimrey and Fayard (1984); Rutledge (1987); German (1989); and Bradner (1991). The reader is referred to these reports also for a complete description of the hydrogeology of the area.

Lichtler (1972) and Tibbals (1990) estimated recharge through drainage wells in Orange County; Lichtler qualitatively estimated that average annual recharge could be 50 Mgal/d or more. A more quantitative, lower estimate of 33 Mgal/d was determined by Tibbals (1990) using a ground-water flow model.

Acknowledgments

The author wishes to thank the Orange County Stormwater Management Department and the city of

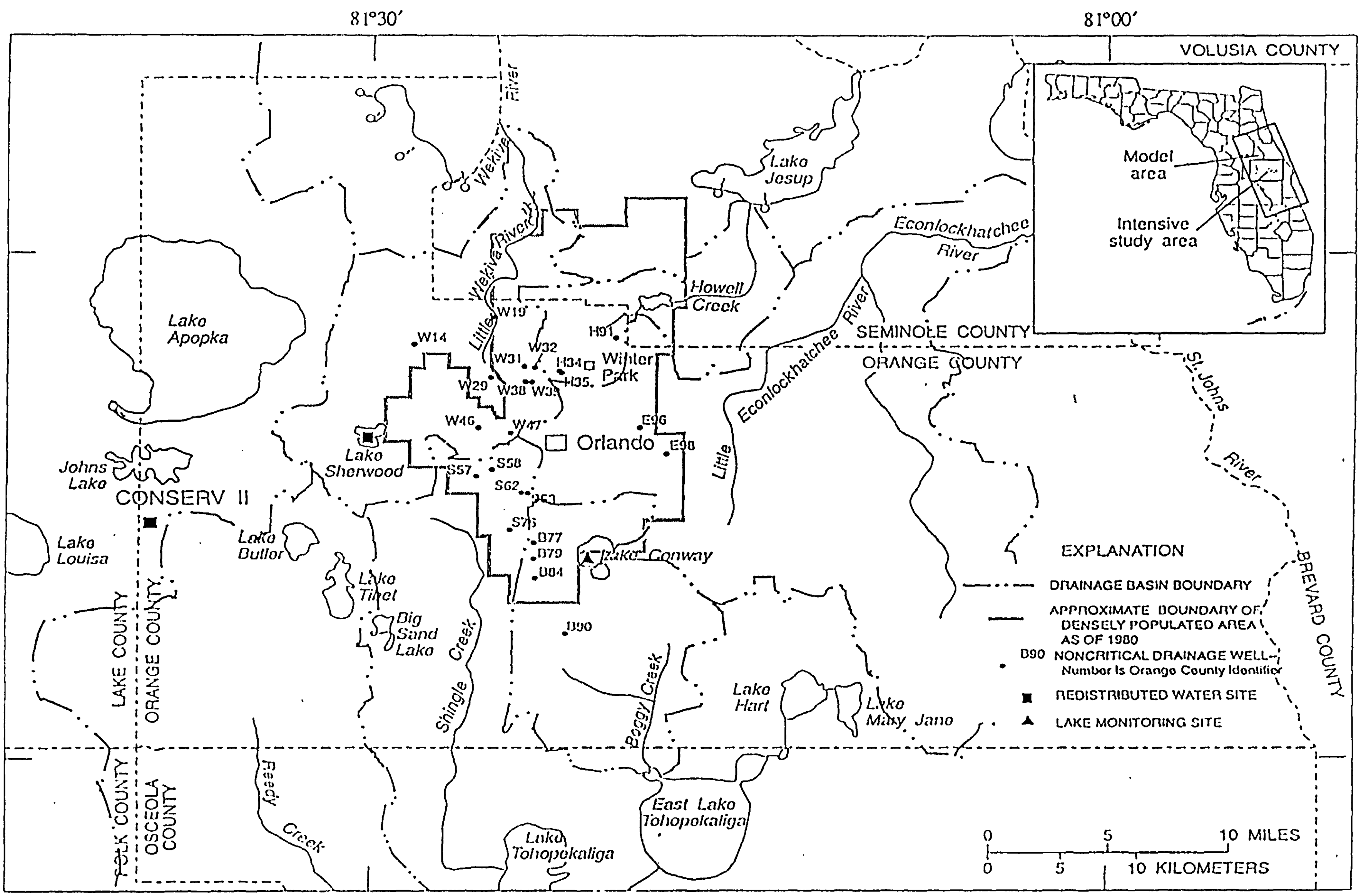

Figure 1. Drainage basins and locations of monitored drainage wells within the intensive study area.

Table 1. Noncritical drainage wells in Orange County

Orange County well number	Location	Latitude	Longitude	Drainage area, in acres	Well-inflow source	Well diameter, in inches
	Boggy Creek drainage basin					
B-77	Lake Jessamine canal	282904	0812333	104	Lake, canal	12
B-79	Lake Tyner	282842	0812330	48	Lake	6
B-84	Lancaster Road	282753	0812325	6	Street, intake blocked	12
B-90	Taft--B-14 Canal	282534	0812206	72	wetland, street	12
	Econlockhatchee River drainage basin					
E-96	Little Lake Barton	283328	0811857	162	Lake	10
E-98	Yucatan Drive retention pond	283240	0811752	623	Retention pond	18
	Howell Branch drainage basin					
H-34	Lake Killarney-Ohio Street	283546	0812232	1645	Lake	20
H-35	Lake Killarney-Cambridge Street	283548	0812246	1645	Lake	20
H-91	Via Tuscany sinkhole	283704	0812024	21	Lake, well plugged	4
	Shingle Creek drainage basin					
S-57	Lake Mann-Florence Street	283144	0812542	1260	Lake, street	16
S-58	Goldwin Road	283145	0812506	2	Street	8
S-62	Nashville Avenue and 24th Street	283101	0812355	43	Retention pond	12
S-63	Nashville Avenue and 24th Street	283101	0812356	43	Street	8
S-76	Lake Buchanan	282938	0812429	208	Lake	6
	Little Wekiva River drainage basin					
W-14	Long Lake	283655	0812834	indeterminate	Lake, well plugged	12
W-19	Lake Eve	283743	0812532	61	Lake	6
W-29	Bay Breeze Road and W-5 canal	283540	0812523	indeterminate	Canal	12
W-31	Goddard Avenue	283559	0812406	128	Wetland, street	12
W-32	Lake Fair	283557	0812313	68	Lake	12
W-38	Lake Fairview	283528	0812352	2548	Lake	12
W-39	Little Lake Fairview	283529	0812328	535	Lake	18
W-46	Lake Lawne-Colony Way	283344	0812605	2842	Lake, intake blocked	16
W-47	Texas Avenue	283334	0812435	24	Lake, intake blocked	14

Orlando for their assistance in acquiring water-level and rainfall data and for providing access to well sites. The author also acknowledges the assistance provided by the Orange County Engineering Department in acquiring unpublished lake levels.

DESCRIPTION OF THE STUDY AREA

Orange County covers an area of about 1,000 mi^2 in central Florida (fig. 1). Land-surface altitudes are less than 250 ft within the county and the topography of the area varies markedly from west to east. The topography of the western part of the county is karstic, with internally drained lakes. The central part is characterized by numerous internally drained lakes and poorly defined, natural surface drainage. The eastern part of the county is relatively flat and has a somewhat defined surface drainage. Drainage wells are located mostly in the central part where immediate relief from flooding is needed, particularly on paved streets and lakes having insufficient storage capacity for stormwater runoff. Much of the drainage in the flat parts of the county has been augmented by canals that drain excess stormwater from the landscape.

The area has a subtropical climate and receives an annual average of 48 in. of rain based on 30 years of record from 1961 to 1990 (Owenby and Ezell, 1992). Orange County and the city of Orlando maintain several rain gages within the county because rainfall is highly variable for single thunderstorms.

Land use in the study area is mostly light commercial, residential, and open irrigated space, such as golf courses and school grounds. There are some small areas of agricultural, open, or forested land. Several drainage basins contain large areas of impervious streets and parking lots.

Surface-Drainage Basins

There are five major surface-drainage basins in Orange County (fig.1) that have noncritical drainage wells. Boggy Creek drains the south-central part of Orlando and Orange County. A comparison of long-term annual discharge at a gaging site near the county line indicates that flows have been increasing in the last several years, most likely because of urbanization and land-surface application of treated wastewater. The Little Econlockhatchee River and the Econlockhatchee River drain the eastern part of Orange County. Average surface runoff from these combined river basins is about 15 in/yr, the highest rate of all the basins in the county.

The Howell Branch drainage basin receives inflow from many of the lakes in the Winter Park area (Rao and others, 1994) and flows north of Winter Park into Seminole County. Urbanization of most of the drainage area has created problems in the management of lake levels during extreme wet seasons. Shingle Creek receives inflow from canals on the western and southern sides of Orlando and Orange County. This basin is being rapidly developed and flows will probably increase due to additional stormwater runoff and imported water for irrigation.

The Little Wekiva River basin drains the north-central part of the county and is in an area of high recharge to the Upper Floridan aquifer. Urbanization and the installation of several large outfall canals have caused severe flooding problems in the downstream parts of the river basin during wet seasons when large volumes of outflow from the larger lakes in the basin move rapidly through the dredged canals.

Surface-drainage basins for each of the noncritical drainage wells were previously defined by the Orange County Stormwater Management Department or the city of Orlando (Dyer, Riddle, Mills, and Precourt, Inc., 1982). These drainage areas also represent the approximate topographic drainage area, except in specific areas where culverts redirect flow to other lakes.

Drainage Wells

There are slightly fewer than 400 drainage wells in Orange County (as of 1995), with densities averaging about 5 wells per square mile in the outer areas and about 15 per square mile in the urban Orlando area. Direct street stormwater-drainage wells generally are 12 in. or less in diameter. Street runoff enters these wells by flowing over the top of the casing, with no flow controls except casing elevation. Most drainage wells used for lake-level control are 12 in. or more in diameter; water levels are controlled by stop-log weirs or by the elevations of the intake pipe or casing. Wetland water-level control wells are generally 12 in. or less in diameter. Inflow to these wells comes from drainage canals, detention ponds, or ground-water seeps. Less than 5 percent of drainage wells receive water from water-to-air cooling and heating systems.

The lake-level control wells receive a mix of rainfall, ground-water seepage, and stormwater runoff during the wet seasons and receive mostly ground-water seepage during the dry seasons. The wetland drainage wells receive short duration, high-intensity rainfall and stormwater runoff and low, but continuous, amounts of ground-water seepage nearly year round. The direct street stormwater-drainage wells receive runoff during rainfall events, but usually do not receive any ground-water seepage unless there are breaks in the concrete or tile-lined drainage culverts.

The noncritical drainage wells (figs. 1 and 2 and table 1) receive water from lakes, wetlands, and streets. Diameters of these wells range from 6 to 20 in. All noncritical drainage wells are completed in the Upper Floridan aquifer. The reader is referred to the reports listed in the section of previous studies for a description of the hydrogeology of the area.

STUDY APPROACH

This study was divided into two phases. In the first phase of the study, average annual recharge through selected drainage wells was estimated by applying discharge computation methods. In the second phase of the study, a ground-water flow model was used to simulate removal of recharge through the selected drainage wells and application of the recharge to upgradient sites within the study area.

Method for Estimation of Recharge

Recharge through selected wells was calculated using a rating equation and weir and orifice equations at three sites, and weir and orifice equations at three additional sites where monthly observed water-level data were available. These six sites are considered to be monitored sites because of the availability of water-

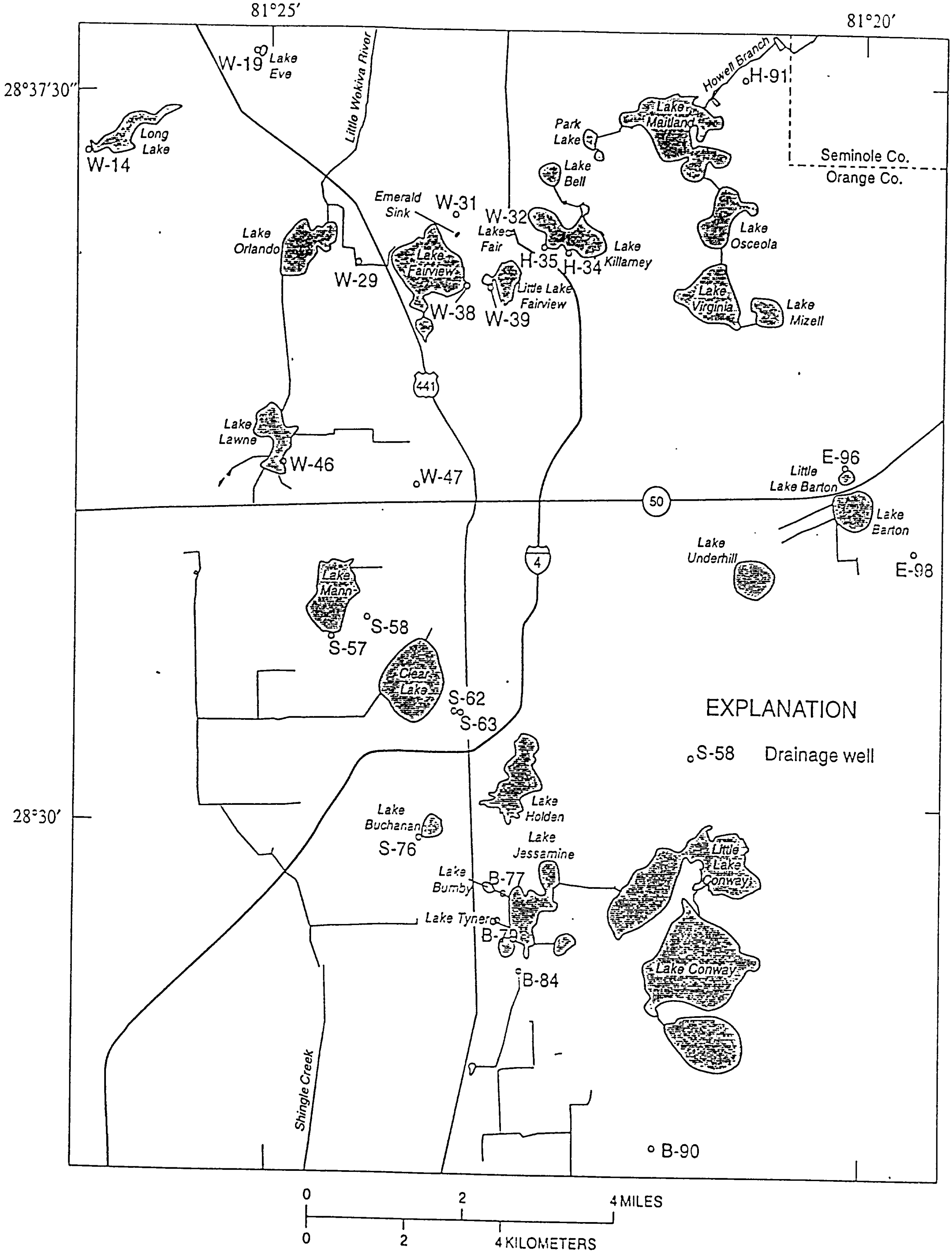

Figure 2. Location of noncritical drainage wells in the Boggy Creek and Shingle Creek drainage basins.

level data. Drainage-well recharge rates and surface-water outflow through canals estimated from the monitored sites were converted to a drainage-basin yield in inches per acre per year. These drainage-basin yields were extrapolated to nonmonitored sites (sites with no available water levels) and used to estimate drainage-well recharge and surface-water outflow. Field visits were made during wet and dry periods to determine a range of recharge to the wells. The wells and methods selected for analysis at each well are listed in table 2. All flow estimates were based on the existing configuration of the well intakes, debris restrictors, and weirs. Recharge estimates were considered to be the highest long-term rate for each well so that the maximum decline in the potentiometric surface of the Upper Floridan aquifer could be determined if the wells were closed.

Recharge Estimates for Monitored Sites

Long-term recharge through lake-overflow wells was calculated by using 25 years of monthly observations of water levels available in county files, weir and submerged-orifice equations, and stage-recharge relations. Because of increasing urbanization of the area, a starting date of 1978 was used in the long-term analyses. At this time, most of the current drainage system was in place and monthly observed water levels from the lakes were being recorded. Some lakes have sporadic water-level readings until 1978, but most records are complete after that year. Most of the drainage basins that were studied were developed as residential and light commercial by that time.

The long-term recharge rates for the selected drainage wells are an average of the calculated recharge rates for the frequency distribution of monthly observations since 1978. The monthly water-level readings were assumed to represent a significant part of the total range of water levels for the lakes in the study. The validity of this assumption can be seen in a comparison of daily water levels to month-end water levels from Lake Conway, also in the study area (fig.1). As shown in figure 3, month-end water levels from 1978-94 follow the same frequency distribution as the daily water-level observations, but the upper and lower ends of these distributions do not encompass about 2 percent of the full extent of the daily stages.

Table 2. Methods used for calculation of estimated inflows to the noncritical drainage wells in Orange County

[b, blocked or plugged well; blank entries in columns, not applicable]

Reference number	Location	Monitored site	Long-term water levels	Methods: Stage-discharge rating	Methods: Weir and orifice Formulas	Methods: Basin yield estimate	Methods: Estimates from field visits
B-77	Lake Jessamine canal		X		X		X
B-79	Lake Tyner (b)						
B-84	Lancaster Road (b)						
B-90	Taft--B-14 Canal					X	X
E-96	Little Lake Barton	X	X	X	X		X
E-98	Yucatan Drive retention pond					X	X
H-34	Lake Killarney-Ohio Street	X	X				X
H-35	Lake Killarney-Cambridge Street	X	X	X	X		X
H-91	Via Tuscany sinkhole (b)						
S-57	Lake Mann-Florence Street	X	X		X	X	X
S-58	Goldwin Road						X
S-62	Nashville Avenue and 24th Street					X	X
S-63	Nashville Avenue and 24th Street					X	X
S-76	Lake Buchanan					X	X
W-14	Long Lake (b)		X				
W-19	Lake Eve					X	X
W-29	Bay Breeze Road and W-5 canal						X
W-31	Goddard Avenue	X		X	X		X
W-32	Lake Fair					X	X
W-38	Lake Fairview	X	X		X	X	X
W-39	Little Lake Fairview	X	X		X	X	X
W-46	Lake Lawne-Colony Way (b)		X				
W-47	Texas Avenue (b)						

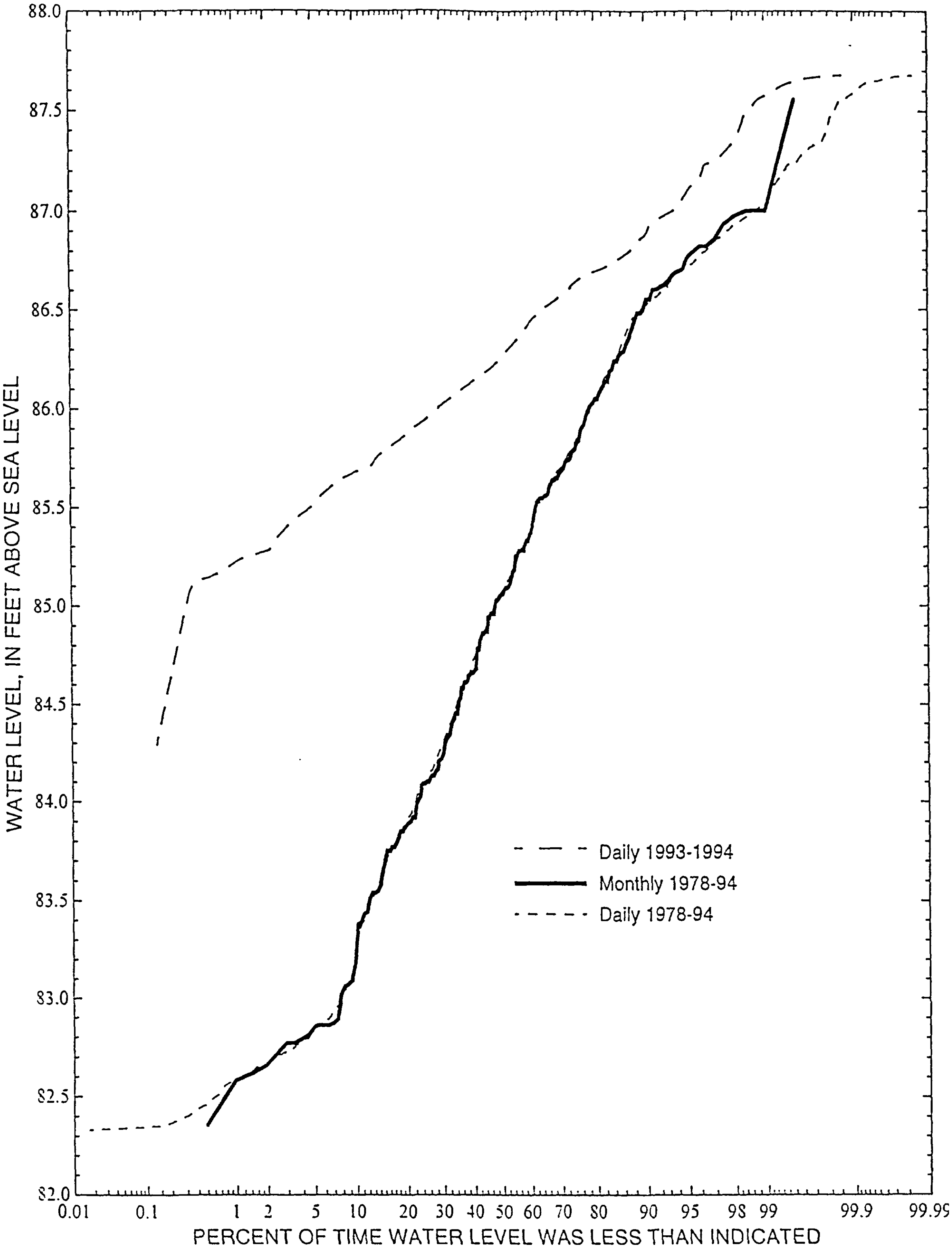

Figure 3. Cumulative frequency of water levels for Lake Conway at Pinecastle, 1978-94.

To compensate for the upper and lower 1 percent of the flows, additional values of the highest and lowest water-level readings were repeated to extend the duration curve (2 percent of highs and lows). Recharge rates computed from these water levels were included in the long-term average. In most cases, the repeated low water-level readings represented periods of no flow into the drainage wells or flow over surface-outfall weirs. If the high-water levels for a lake are not represented during a shorter period of comparison, a drainage well could be receiving a significant amount of water that is poorly represented by monthly observations (unless backwater and debris control are major problems in recharge to the well). The high-range extension may slightly increase the long-term flow at some sites because of the inclusion of the high-flow rates into the calculations for the long-term average. During the study, field measurements of flow during times of high-water levels indicate less flow than was calculated from the equations; however, conditions of historical unobstructed flow were assumed for the long-term calculations because the condition of each site during high-rate recharge was unknown.

The 1993-94 frequency curve (fig. 3) indicates that there was no extreme dry period during those 2 years, but lake levels covered a range of about 60 percent of the levels on the long-term daily curve. During the period of study, the water levels for the lakes reached the higher range on the stage-duration curves for water levels since 1978, but in previous years—such as 1960 during extreme flooding—water levels for most of the lakes were higher.

Stage-Recharge Relations

Stage-recharge relations were determined by plotting results of periodic recharge measurements as a function of stage at the time of measurement. Rating equations computed by regression analyses that fit the relation were generated from these plots. Daily mean recharges were computed by applying the daily mean stages to the equations.

Daily mean recharge was determined using the shifting-control method for the period in 1993 when daily mean stages were computed. Using this method, correction factors (based on periodic recharge measurements and on notes of the personnel making the measurements) were applied to the stages before the recharges were determined from the equations. No corrections to the ratings were applied in computations based on monthly water-level data.

Weir- and Orifice-Flow Equations

For the wells where stage-relation curves were not prepared but long-term lake levels were available, the weir and submerged-orifice equations were used to compute a recharge volume (Brater and King, 1976, chaps. 4 and 5). The weir equation for well recharge is:

$$Q = C_1 L H^{3/2}, \tag{1}$$

where

Q is recharge, in ft^3/s;
C_1 is a coefficient, 3.22 $ft^{1/2}/s$ for sharp-crested weirs;
L is the length of weir (well circumference), in ft; and
H is the head above the weir, in ft.

At higher flows to the wells, hydraulic conditions change because the volume of water exceeds the capacity of the casing to accept inflow, creating backwater conditions. Depending on the casing diameter, weir flow equals orifice flow at some critical height above the casing; when this occurs, the submerged orifice equation was used to calculate recharge. The submerged orifice flow equation is:

$$Q = C_2 A \sqrt{2gh}, \tag{2}$$

where

Q is recharge, in ft^3/s;
C_2 is a coefficient, 0.602 for sharp-edged circular orifices;
A is the area of opening, in ft^2;
g is the acceleration due to gravity (32.17 ft/s^2); and
h is head above the orifice, in ft.

For several wells that had debris restrictors in the form of iron bars, the weir length (or well circumference (L) in the weir-flow equation) was reduced by the combined width of the iron bars. No correction for the opening restrictions from iron bars could be made in the submerged orifice-flow equation because the circular opening to the well was not obstructed. However, the presence of a raised iron-bar cage usually caused turbulence in the water flowing into the well and trapped debris in the slotted openings and reduced inflow to an unknown extent.

The weir equation also was used in computing the surface-water outflow through canals from several lakes, assuming a broad-crested weir coefficient of 2.63 $ft^{1/2}/s$. The weirs were thick boards, metal beams, or concrete ledges and were too thick to be treated as sharp crested, as in the case of the half-inch thick well casings. No checks were done to verify these coefficients, but discharge measurements were made during high-water periods to quantify the flow over the weirs. These measurements indicated that the coefficients probably would be accurate for ideal flow conditions with no obstructions or other factors inhibiting the flow over the weir.

Recharge Estimates for Nonmonitored Sites

Correlation of the recharge rates from monitored sites was necessary to evaluate sites where no long-term water levels were available and no measurement technique was accurate enough to estimate long-term recharge to a drainage well. The total outflow (Q) from drainage-well recharge and surface-water outflow from each monitored drainage system was divided by the total drainage area of each system (A) in order to convert the outflows to a yield per acre for each basin. These yield results were compared to designate a range of yields to use in estimating the outflows from the nonmonitored sites. The resulting range of outflow rates from the basins was then compared to the field visits and adjusted accordingly.

The yields from the individual basins were plotted against the percent impervious surface within a basin to determine if the yield per acre increased with paved surfaces. Impervious surface was estimated by digitizing aerial photographs and calculating the total area covered by various types of land use within the drainage areas as defined by Orange County Stormwater Management Department or by the city of Orlando (Dyer, Riddle, Mills, and Precourt, Inc.,1982). Values for the average percent impervious areas for the land uses in the basins are given in Wanielista and Yousef (1993, table 2.2). This comparison seemed to indicate a slight correlation in the increase in basin yield with the increase in impervious surfaces, but insufficient data were available to conclude the existence of a definite relation. This uncertainty is most likely caused by the greater water use in residential areas with more pervious surfaces as opposed to more runoff and less evaporation in light-commercial areas with more impervious paved surfaces.

Method for Simulation of Ground-Water Flow

A digital computer model published by Tibbals (1981, 1990) was used to simulate steady-state ground-water flow conditions in east-central Florida. The area in Orange County was more finely discretized within the model using the same hydraulic parameter values as documented by Tibbals (1981, 1990). The computer program MODFLOW (McDonald and Harbaugh, 1988) was used to solve the ground-water flow equation subject to imposed boundary conditions. The reader is referred to those reports for discussions of the steady-state model calibration, boundary conditions, and the spatial distribution of confining-unit leakances and transmissivity. The original model was evenly subdivided into a finite-difference grid of 24 rows of 50 columns. Each cell in the original model by Tibbals was 4 mi on a side, but this level of resolution was too coarse to separate the effects of individual wells. This necessitated rediscretizing the grid to a finer level, with the smallest cells being 1,000 ft on a side. Smaller cells were used primarily within Orange County because it was the area of interest. The remainder of the model area was discretized by increasingly larger cells away from Orange County, resulting in a variably spaced grid of 80 rows of 93 columns. The largest cells in the new model covered about 500 mi^2 and were located far from the area of interest (fig. 4). The rediscretized grid in figure 4 represents the same area as that covered by the original model (inset, fig. 1).

Recharge through drainage wells and at surface-application sites was simulated as direct application of water to the Upper Floridan aquifer. The effects caused by closing drainage wells and applying water to surface-application sites were determined by the superposition principle which can be used because the ground-water flow equations are linear. This principle implies that the change in potentiometric surface associated with an individual drainage well or surface-application site can be determined independently of the change in the potentiometric surface produced by other system stresses.

RECHARGE

The total maximum long-term average annual recharge to the Upper Floridan aquifer through the noncritical drainage wells is estimated to be about

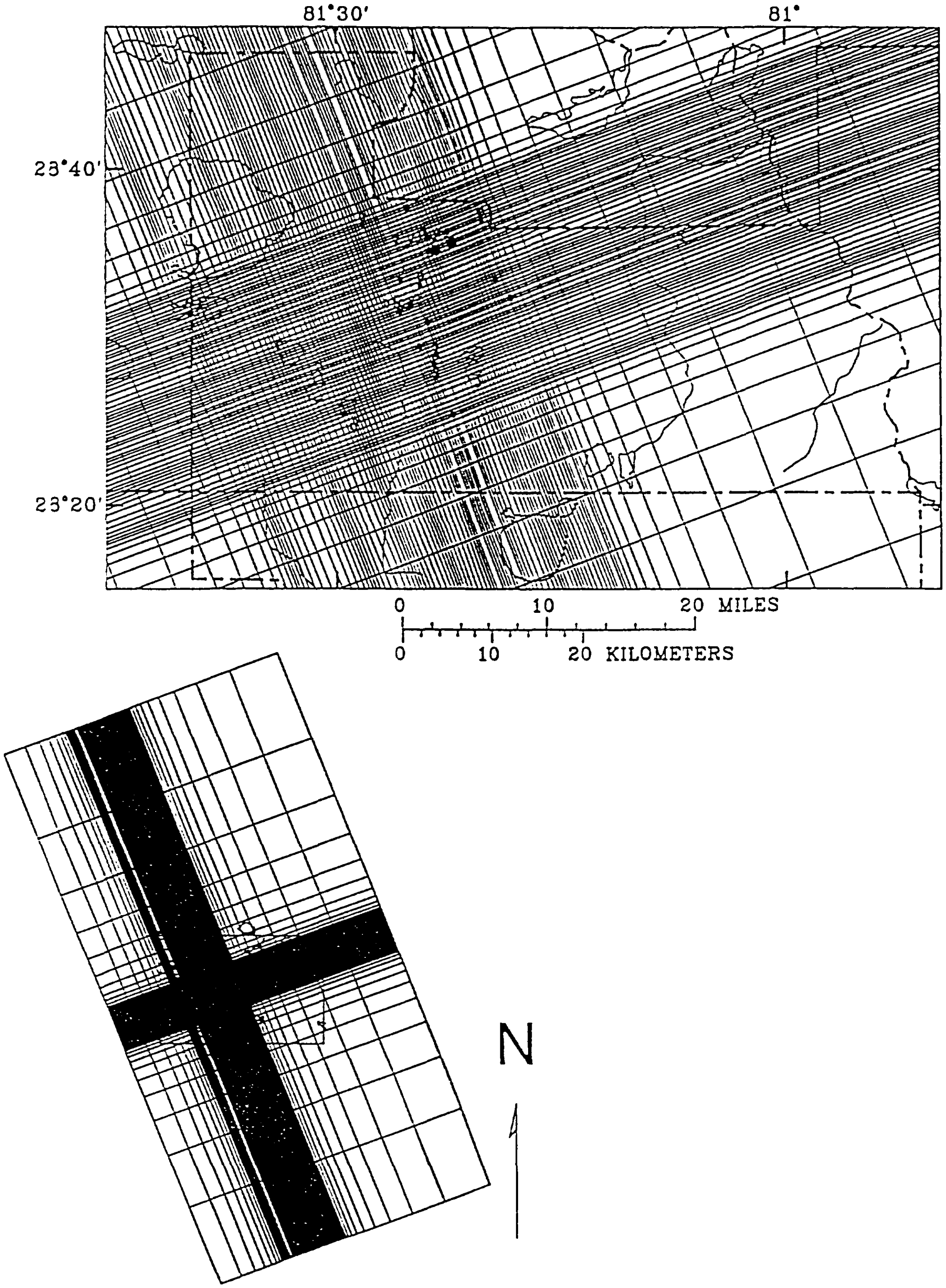

Figure 4. Model grid for the study area rediscretized from Tibbals, 1990.

9.0 ft^3/s or 6.0 Mgal/d. This recharge rate represents approximately 19 percent of the total rate of 33 Mgal/d recharge to the Floridan aquifer system through drainage wells in central Florida as estimated by Tibbals (1990). The recharge rate through well H-35 on Lake Killarney is the largest single rate and is estimated to be 4.6 ft^3/s, or about 3.0 Mgal/d. The noncritical drainage wells and the estimated recharge rates for each well are listed in table 3.

There is error in estimating the recharge through the drainage wells. The low-volume, poorly maintained unmonitored sites could have as much as 50 percent error, but the range of error probably is 25 percent or less for the monitored sites and the higher-volume nonmonitored sites. The error in the total yield probably is 25 percent or less.

Field visits were made to measure instantaneous recharge rates to the wells and surface outflow rates from several lakes. A summary of the visits is listed in table 4. These visits were used to qualify some of the high recharge rates calculated from the weir and submerged-orifice equations and to qualify the recharge estimates to wells that were not monitored.

Several wells on the noncritical list have blocked intakes or have been plugged since the county report on drainage wells was published (1992). No recharge for these wells was included in the final recharge rates for the wells in table 3. Wells W-14 and H-91 have been plugged with cement. Wells W-46, W-47, and B-84 have received recharge in the past, but have had blocked intakes for several years. Wells B-77 and B-79 have had no inflow in over 30 years because surface-water connections to Lake Jessamine have lowered the lake level of Lakes Tyner and Bumby (fig. 2).

Table 3. Estimated recharge to the noncritical drainage wells and surface outflows from selected lakes in Orange County.

[Average long-term annual well recharge and average surface outflow are in cubic feet per second. --, no data]

Reference number	Location	Average long-term annual well recharge	Type of additional surface outflow	Average annual surface outflow
B-77	Lake Jessamine canal	0.0	Canal to Lake Jessamine	--
B-79	Lake Tyner	0	Canal to Lake Jessamine	--
B-84	Lancaster Road	0	Canal system	--
B-90	Taft--B-14 canal	0.17	Canal system	--
E-96	Little Lake Barton	0.9	Culvert	--
E-98	Yucatan Drive retention pond	0.5	Canal system	0.9
H-34	Lake Killarney-Ohio Street	0.1	Controlled weir	--
H-35	Lake Killarney-Cambridge Street	4.6	Controlled weir	--
H-91	Via Tuscany sinkhole	0	Pump station	--
S-57	Lake Mann-Florence Street	0.05	Canal system	3.6
S-58	Goldwin Road	0.01	Canal system	--
S-62	Nashville Avenue and 24th Street	0.08	none	--
S-63	Nashville Avenue and 24th Street	0.04	none	--
S-76	Lake Buchanan	0.7	Canal system	--
W-14	Long Lake	0	Retention pond	--
W-19	Lake Eve	0.14	Overflow ditch	--
W-29	Bay Breeze Road and W-5 canal	0.05	Canal system	--
W-31	Goddard Avenue	0.3	Retention pond	--
W-32	Lake Fair	0.04	Culvert	0.12
W-38	Lake Fairview	0.1	Weir and canal to Wekiva River	6.1
W-39	Little Lake Fairview	1.3	Culvert to Lake Fairview	0.4
W-46	Lake Lawne-Colony Way	0	Weir and canal to Wekiva River	--
W-47	Texas Avenue	0	Canal to Lake Lawne	--

Table 4. Summary of field-visit data

[Well recharge data are in cubic feet per second]

Reference number	Location	Number of field visits	Number of visits with observed flow	Well recharge: Minimum measured or estimated	Well recharge: Maximum measured or observed	Comments
B-77	Lake Jessamine canal	2	0	0	0	
B-79	Lake Tyner	2	0	0	0	
B-84	Lancaster Road	1	0	0	0	Intake blocked
B-90	Taft--B-14 canal	4	4	0.05	0.1	Intake partially plugged
E-96	Little Lake Barton	14	12	0	3.1	maximum culvert inflow 1.8 ft^3/s
E-98	Yucatan Drive retention pond	4	1	0	0.1	Debris blocking water flow
H-34	Lake Killarney-Ohio Street	25	2	0	0.86	Partially blocked intake
H-35	Lake Killarney-Cambridge Street	25	25	0.67	8.65 (15.0e)	Continuous flow
H-91	Via Tuscany sinkhole	1	0	0	0	Plugged with cement
S-57	Lake Mann-Florence Street	4	0	0	0	Surface-water weir control
S-58	Goldwin Road	2	0	0	0	Stormwater only
S-62	Nashville Ave. and 24th Street	3	3	.01	0.05	None
S-63	Nashville Ave. and 24th Street	3	1	0	0.05	None
S-76	Lake Buchanan	3	3	0.5	1.7	Continuously receives water
W-14	Long Lake	1	0	0	0	Plugged with cement
W-19	Lake Eve	2	2	0	0.1	Overflow ditch has reverse flow at times
W-29	Bay Breeze Road and W-5 canal	2	1	0	0.5	Canal system
W-31	Goddard Avenue	15	15	0.06	0.95	Continuous ground-water inflow to canal
W-32	Lake Fair	3	0	0	0	Culvert
W-38	Lake Fairview	4	2	0	0.5	Weir and canal to Wekiva R
W-39	Little Lake Fairview	4	2	0	2.6	Culvert to Lake Fairview
W-46	Lake Lawne-Colony Way	3	0	0	0	Intake buried in mud
W-47	Texas Avenue	1	0	0	0	Intake blocked

Recharge Rates for Monitored Well Sites

Stage-recharge rating equations were used to calculate recharge through drainage wells H-35, E-96, and W-31. The daily monitoring sites represent two of the three basic types of drainage wells in Orange County–lake-level control and wetland. Well H-35 is adjacent to Lake Killarney, a large lake with a large drainage basin. Well E-96 also is a lake-level control well, but it is adjacent to Little Lake Barton, a small lake with a relatively small drainage basin. Well W-31 is a wetland drainage well in a canal. The rating equations were applied to long-term water levels from Lake Killarney and Little Lake Barton (fig. 5) for the long-term recharge estimate.

Recharge to well H-34, a second drainage well on Lake Killarney, was negligible during the study period because cypress tree roots have almost completely obstructed the intake pipe. Although the well probably has received large amounts of inflow since being drilled in 1962, a recharge estimate of 0.1 ft^3/s was applied to reflect the current condition of the well intake. The estimate is based on long periods of no flow to the well and the low rates of flow during periods of higher lake levels. Well H-34 could receive as much or more inflow as well H-35 because the casing is slightly larger in diameter and is 0.12 ft lower than well H-35.

Long-term periodic water levels also are available for three lakes (Lake Fairview, Little Lake Fairview, and Lake Mann) in Orange County that did not have daily water levels (fig. 6). The weir and submerged-orifice flow equations were used to calculate drainage-well recharge and surface outflow from these drainage basins.

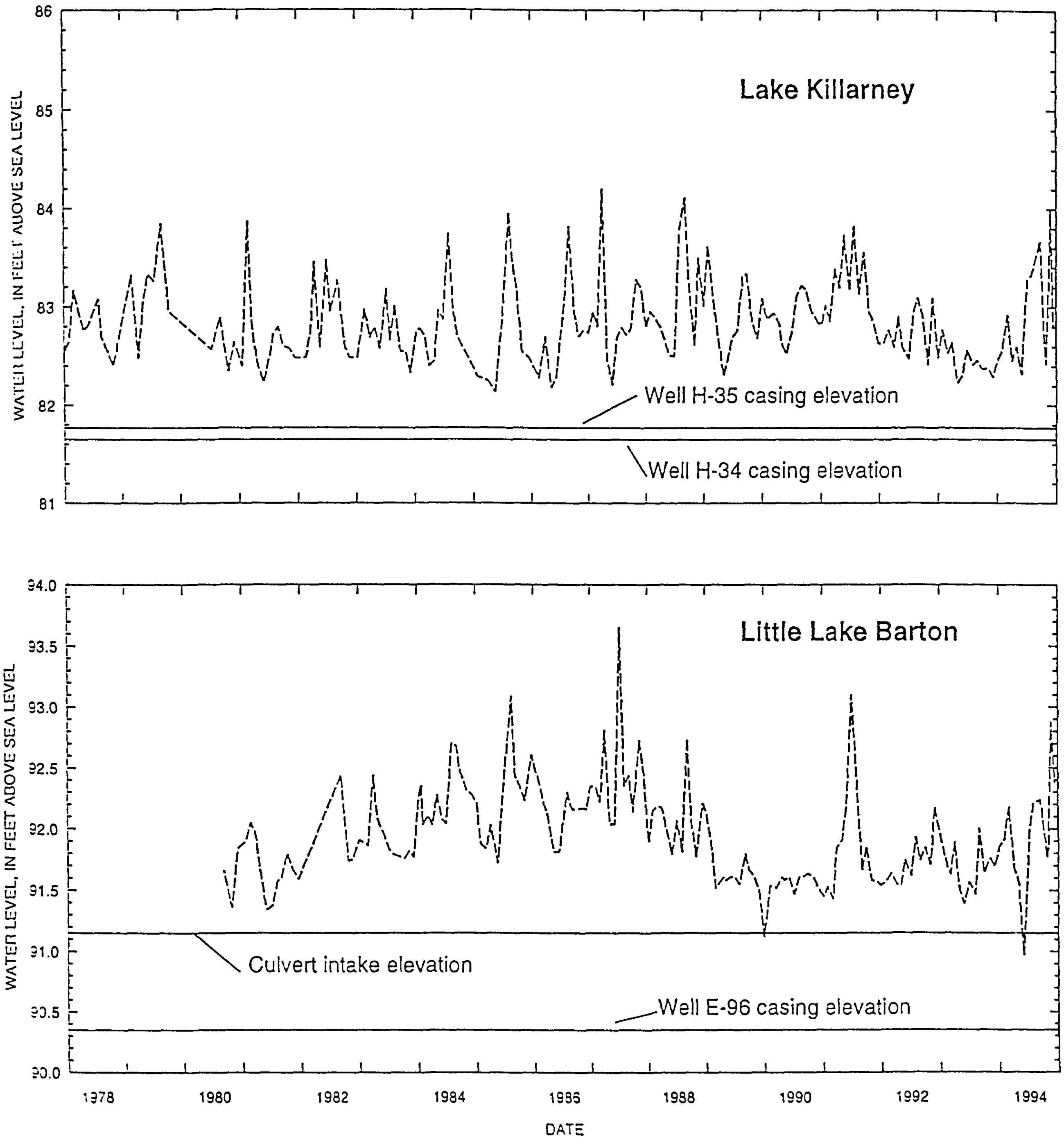

Figure 5. Periodic water levels from Lake Killarney and Little Lake Barton, Orange County, Fla.

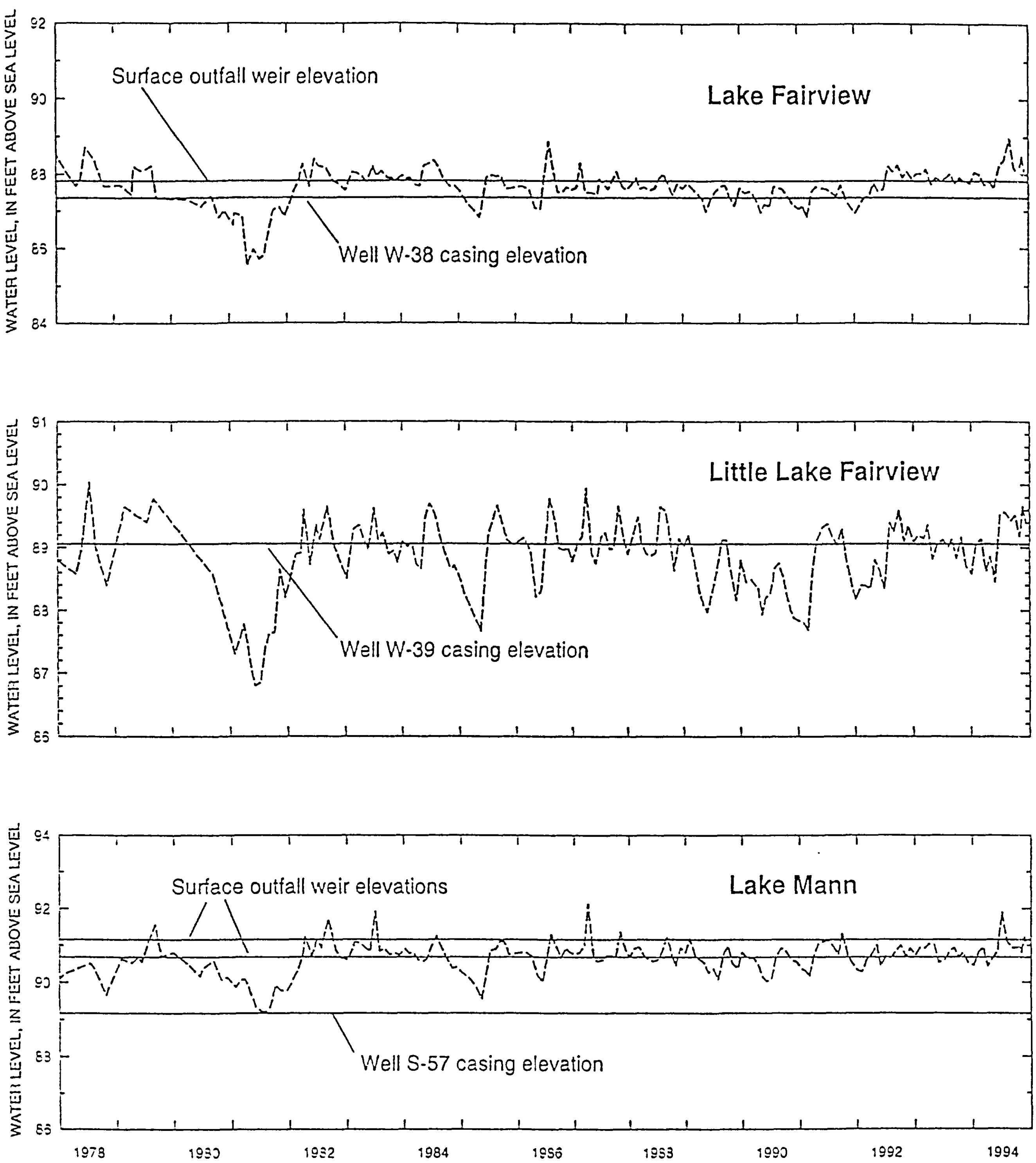

Figure 6. Periodic water levels from Lake Fairview, Little Lake Fairview, and Lake Mann, Orange County, Fla.

Recharge Estimates from Stage-Recharge Ratings

Field measurements of recharge to the three wells, H-35, E-96, and W-31, are shown in figure 7 along with the stage-recharge ratings and theoretical flow calculated from the weir and orifice flow equations, which are discussed later. The dashed lines represent the applied ratings for each site. Long-term recharge rates were calculated by applying the rating equation to the monthly observed water levels for the selected period of record discussed for each site.

Two ratings were necessary for wells H-35 and E-96 because of the reduction in flow at higher water levels. As the water levels reach the critical height above the casing where weir flow changes to orifice flow, the closure of the whirlpool above the casing and the resulting hydraulic jump is created mostly by trapped air and flow patterns in the well. Trapped air within the casing is buoyant and creates backpressure against the water entering the well. Trapped air bubbles within the aquifer also cause a loss in hydraulic conductivity. This phenomenon can be observed in many drainage wells in the county. Some wells, such as well E-96, geyser if the air pressure builds up sufficiently and the high-pressure spray can cause damage to the well casing and manhole.

Generally, recharge rates during rising high water followed the pattern indicated by the rating. Occasionally during the period when decreasing water levels reached the critical depth of the hydraulic jump, recharge rates decreased uniformly throughout the range of stage. This condition probably occurred when no air was trapped in the casing and there was no backpressure.

Lake Killarney Well H-35

The mean daily recharge to well H-35 was 4.7 ft^3/s from February through November 1993. The recharge through well H-35 calculated from the two ratings and the water level of Lake Killarney for the study period are shown in figure 8. The mean annual recharge calculated from the rating table and monthly observed water levels from Orange County records from 1978 through 1994 was 4.6 ft^3/s. The long-term mean is lower than the 1993 mean because several dry years (1981, 1985, and 1990) are included in the longer period.

Because of a howling sound of air escaping from well H-35 during periods of high recharge and complaints from local homeowners, county maintenance crews removed the iron-bar cage on top of the well in September 1994 and replaced the vented manhole lid with a heavy, solid lid. The recharge through the well increased for a given water level, most likely due to the lack of flow restriction from the iron bars. This should not significantly increase the average annual recharge, but should tend to decrease lake levels at a faster rate in the future.

Little Lake Barton Well E-96

The recharge through well E-96 and water level in Little Lake Barton for the study period are shown in figure 9. The average for the study period in 1993 was 0.44 ft^3/s. The average long-term recharge through well E-96 was estimated to be about 0.9 ft^3/s. This rate was based on the stage-recharge rating and the observed monthly water levels from Orange County records. Flows could have been higher in the past if configuration of the intake had been different, or lower if the direction of flow through the culvert from SR 50 had been directed toward Lake Barton south of SR 50.

During much of the study period, Little Lake Barton received surface inflow estimated at 0.3 ft^3/s (average of 10 measurements) through the stormwater-culvert connection from SR 50. Flow through this culvert is almost continuous because of ground-water seepage or cooling-system discharge to the deep storm-sewer system. In extreme high-water conditions, stormwater is stored within the culvert and gradually drains to Little Lake Barton as the loss of water to the drainage well lowers the lake level.

Drainage well E-96 currently is the only outfall for Little Lake Barton for a wide range of water levels. Little Lake Barton is connected to Big Lake Barton at very high stages by a culvert under SR 50. The water level in Big Lake Barton generally is 0.5 to 1.0 ft higher than Little Lake Barton; water levels in both lakes would equilibrate if the connection between the lakes were lowered, and would probably average higher than current levels of Little Lake Barton.

The average recharge to well E-96 from the Little Lake Barton drainage basin is extremely high and may be a combination of four factors: (1) Although the basin has been defined by culvert drawings, several cross-connections were identified during the study and more may exist. These cross connections could significantly enlarge the existing drainage basin size. (2) A significant amount of inflow though the stormwater culvert from SR 50 enters the lake. The average inflow to Little Lake Barton through the culvert from 10 miscellaneous measurements was 0.3 ft^3/s, 33 percent of

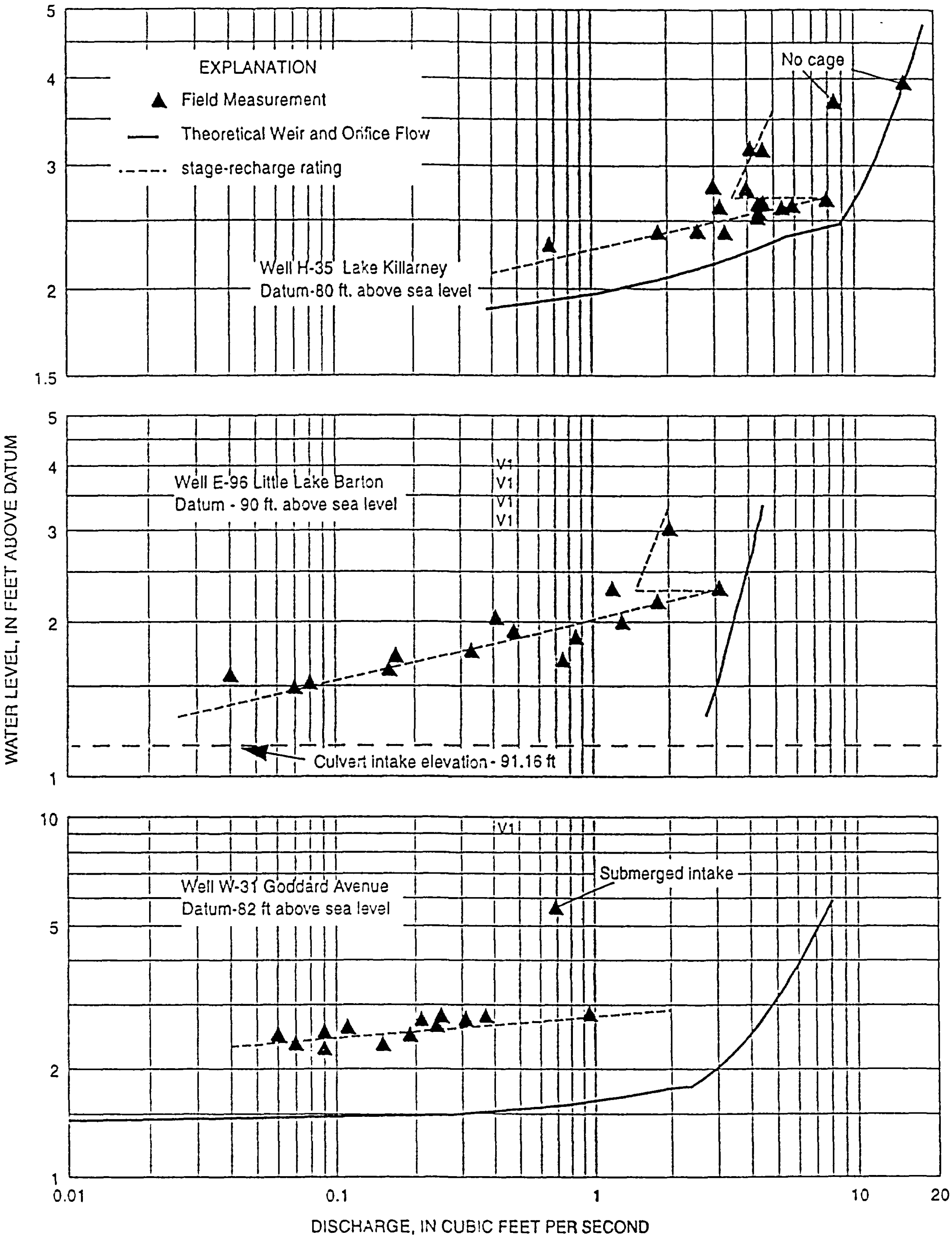

Figure 7. Stage-discharge ratings for three non-critical drainage wells.

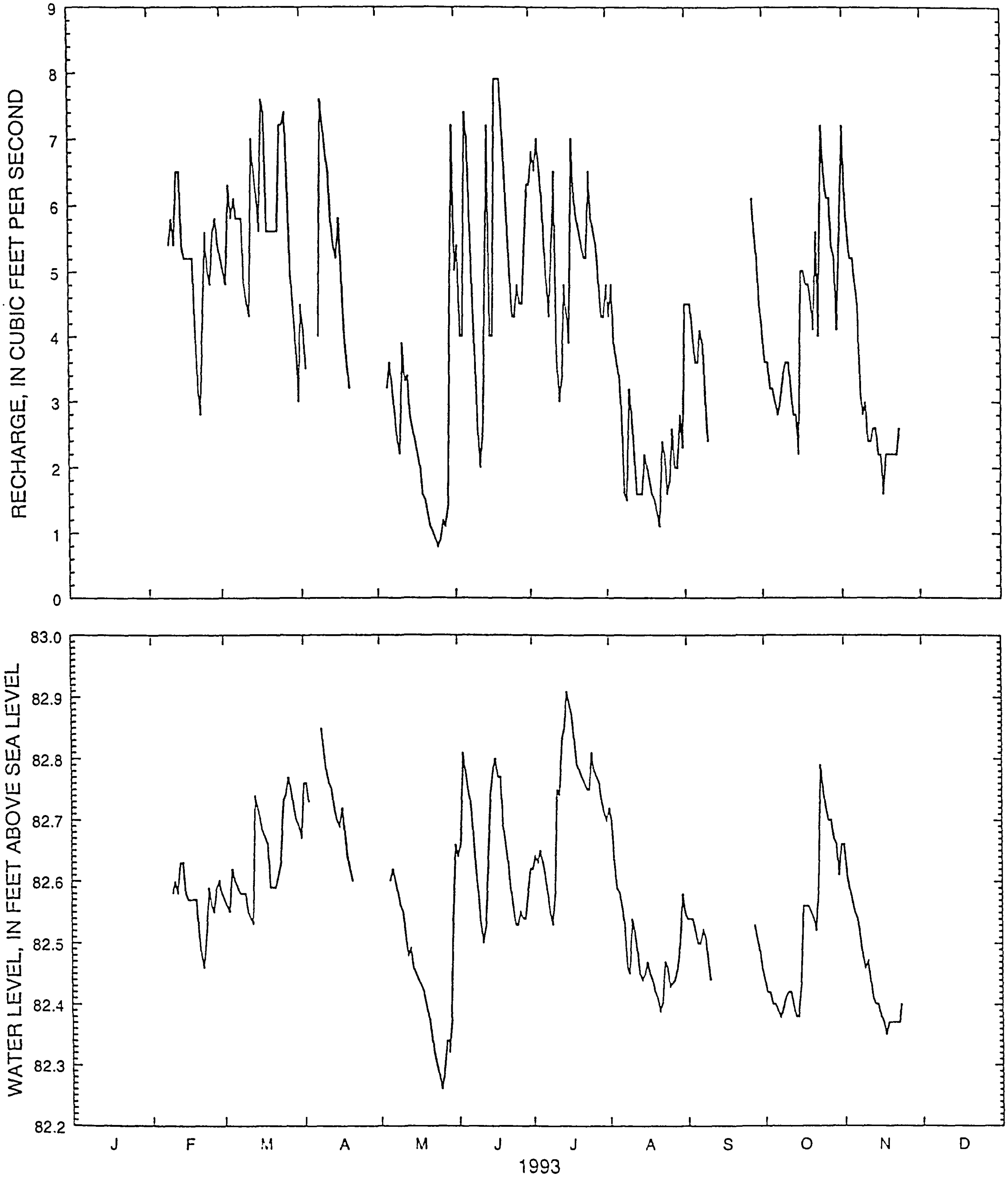

Figure 8. Lake Killarney water levels and recharge into well H-35 from February through November 1993.

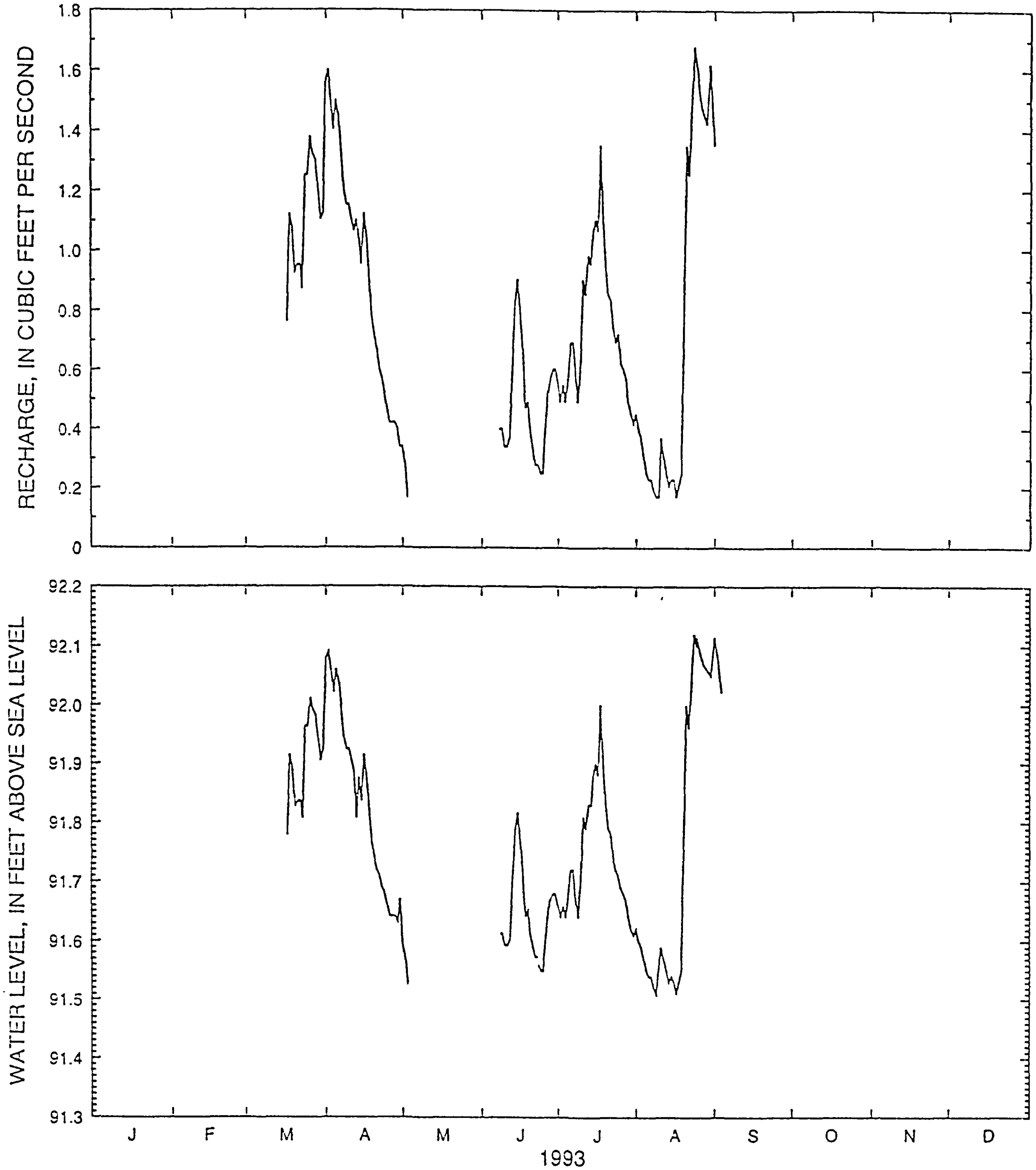

Figure 9. Water levels for Little Lake Barton at Orlando and recharge into well E-96 from March through September 1993.

the total flow to the drainage well. (3) Imported water is added to the basin through the residential areas serviced by septic systems. (4) Ground-water seepage is most likely moving to Little Lake Barton from Lake Barton (the lake level is about 0.5 to 1.0 ft higher than that of Little Lake Barton).

Goddard Avenue Well W-31

A low-water stage-recharge rating was developed for well W-31 (fig. 7). The intake to the well is submerged when water levels rise more than 1 ft in the canal draining to the well. Higher recharge rates were estimated by calculating the change in storage in the canal following cessation of stormwater inflow. The recharge rates computed for high water levels were less accurate than those computed using a rating. Storm events cause an immediate rise in canal water level in the vicinity of the well, but the water drains quickly, usually within hours.

Water-level and recharge data (fig.10) indicate that flow remains low and stable almost year round due to ground-water seepage. The canal is dredged several feet lower than the elevation of the water level in the surficial aquifer system and therefore acts as a drain for the area. Flow is marked by occasional spikes due to stormwater runoff also entering the canal. The mean recharge rate for the study period was 0.3 ft^3/s. No water-level records for the site were available for long-term calculations, so the 0.3 ft^3/s average also was used as a long-term average. This assumption was based on the current configuration of the site and the steady-state conditions that occurred during part of the time the site was being monitored. Although more storm events may occur in years with more rainfall, the long-term recharge is mostly influenced by the steady flow from ground-water seepage to the canal.

Recharge Estimates from Weir- and Orifice-Flow Equations

The weir and submerged-orifice equations are used to calculate the maximum possible inflow to a well—if all conditions are ideal—such as the intake allowing free flow of water, no obstruction of the lip of the well casing by debris restrictors and buildup of debris, and no back pressure from trapped air at higher water levels. The stage-recharge ratings for wells H-35 and E-96 and the curve for theoretical weir and orifice flow at each site are shown in figure 7. The recharge, as determined from the stage-recharge ratings, was considerably lower than that of the theoretical recharge rates based on weir- and orifice-flow equations.

Weir and submerged-orifice equations were applied to the long-term water levels for Little Lake Fairview, Lake Fairview, and Lake Mann (fig. 6) to estimate long-term recharge to wells W-38, W-39, and S-57. The weir equation also was applied to the surface-outfall weirs on Lakes Fairview and Mann to estimate long-term surface outflow from those drainage basins. Flow rates calculated from these equations may be higher than actual rates, but probably are not lower than actual rates. The flows were verified by field visits and measurements where possible.

Little Lake Fairview Well W-39

Well W-39 on Little Lake Fairview has a submerged well intake that has a fairly smooth interior surface which allows free flow to the well, and has no debris cage on the casing. The long-term maximum theoretical recharge to the well was calculated to be about 1.3 ft^3/s. The calculated theoretical-recharge rate may be too high for the extreme high water periods, but flows cannot be verified because of the configuration of the well intake. The surface outflow from Little Lake Fairview through a drainage ditch to Lake Fairview also was measured during a period of high water levels and was estimated to be about 30 percent of the long-term recharge to the well, or about 0.4 ft^3/s. The long-term total outflow from the lake was estimated to be about 1.7 ft^3/s.

Lake Fairview Well W-38

The long-term theoretical recharge rate through well W-38 on Lake Fairview, assuming the intake was unobstructed, was calculated to be about 1.8 ft^3/s using the weir/orifice equations. However, lack of debris protection and the heavy emergent growth around the well site significantly restricts flow to the well. Based on observations of extensive debris buildup during the study and estimations of instantaneous recharge to the well, the mean recharge to the drainage well could be 0.1 ft^3/s or less.

The major surface-water outflow from Lake Fairview is a large canal with a 20-ft wide stop-log weir to the Little Wekiva River. A mean annual outflow of 6.1 ft^3/s was calculated from the sharp-crested weir equation and monthly observed water levels. There was no compensation for the debris and sand buildup in the channel or for any backwater conditions that could occur in the downstream channel.

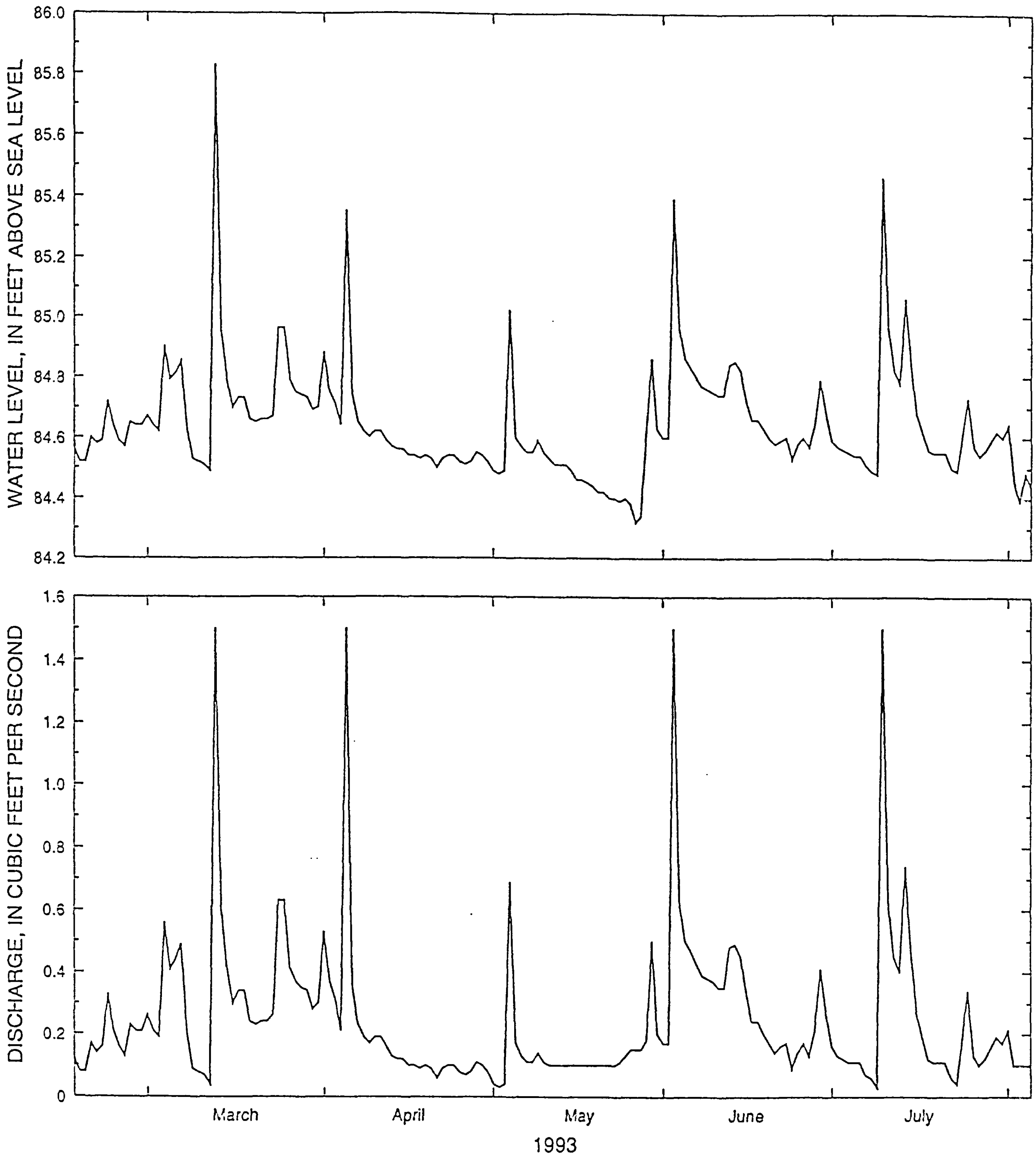

Figure 10.-- Canal water levels near Goddard Avenue in Orlando and recharge to well W-31, March through August 1993.

The total outflow from the Lake Fairview system includes the drainage-well recharge to wells W-31 at Goddard Avenue, W-38 on Lake Fairview, W-39 on Little Lake Fairview, and the surface outflow. The sum of these outflows could be as high as 9.5 ft^3/s if wells W-38 and W-39 received the theoretical recharge of 3.4 ft^3/s, or 7.8 ft^3/s if well W-38 had an average recharge rate of 0.1 ft^3/s.

The total outflow from Lake Fairview may be affected by significant amounts of imported water because much of the residential area around Lake Fairview has septic systems and a golf course near Little Lake Fairview irrigates with water from the Upper Floridan aquifer. In the past, the drainage basin also included some small wastewater percolation ponds from trailer parks.

Lake Mann Well S-57

Average recharge to Well S-57 could be less than 0.05 ft^3/s, according to the current intake design of the well. The initial recharge estimate of 8 ft^3/s for the well calculated from Lake Mann water levels and weir and submerged orifice equations appeared to be extremely high. The estimate should be reduced significantly because the bottom elevation of the intake ditch is higher than the well casing and emergent growth in the lake and ditch restricts flow to the well. Field visits indicated that water did not flow into the well at a lake level of 91.46 ft, even though the casing elevation is 89.16 ft.

The major outflow from Lake Mann is over a 50-ft wide surface-outfall weir through a canal. Long-term discharge over the weir was calculated to be about 3.6 ft^3/s. Thus, the total theoretical outflow from Lake Mann could be as high as 11.6 ft^3/s, but a likely estimate would be 3.65 ft^3/s or less.

Recharge Rates for Nonmonitored Sites

The methods previously described to estimate recharge were applied to sites where water levels are available. The remaining wells generally are in places where no water levels are available and/or the intakes may be submerged or inaccessible for accurate measurements. At the wells where these conditions exist, an area-based recharge rate was estimated. The nonmonitored wells include B-90, E-98, W-32, S-58, S-76, S-62, S-63, W-19, and W-29. Recharge to wells S-58 and W-29 is estimated to be about 0.01 ft^3/s each because they only receive water from street runoff or when high water levels cause backwater.

The yields derived from total outflow divided by total drainage area (*Q*/*A*) from six sites previously discussed were compared to the remaining seven nonmonitored wells to determine a relation between the sites. Selected information on the yields from the basins is listed in table 5. With the exception of the Little Lake Barton basin, all of the values fall within a range of 20 to 30 in/yr.

Estimations for recharge through the remaining seven nonmonitored wells were based on the type of drainage area compared to the type of well from the monitored-well sites. The estimated yields were slightly lower than the yields for monitored wells because of the unknown conditions resulting from debris and condition of intake.

A yield of 20 in/yr was chosen for wells B-90, E-98, W-19, and W-32. Wells B-90 and E-98 are considered wetland drainage wells that receive ground water and stormwater from canals that incise the water table and are comparable to well W-31. A recharge rate of 0.5 ft^3/s for well E-98, estimated from field visits, was separated from the drainage-basin yield of 1.4 ft^3/s. Well W-19 on Lake Eve is in a high-rate recharge area to the Upper Floridan aquifer; the intake elevation for the drainage well is relatively high. Unknown surface-water inflow and outflow to the lake may influence the rate of recharge to the well. Well W-32 on Lake Fair has a higher intake than the surface outfall of the lake; thus, most of the stormwater runoff leaves the basin to the Little Lake Fairview and Lake Fairview basins. Recharge to the drainage well was estimated to be about 25 percent of the yield from the basin, or about 0.04 ft^3/s, and surface outflow was estimated to be about 0.12 ft^3/s. Some of the ground water may seep toward the Lake Killarney basin which is the original topographic drainage basin.

A basin yield of 24 in/yr was used to calculate recharge to wells S-62, S-63, and S-76. These wells are located in the same area as Lake Mann, which has an estimated basin yield of 25.4 in/yr. Yields from these basins could be greater than 25 in/yr, but probably are slightly less because there is less impervious area in these basins than in the Lake Mann drainage basin. The yield from the basin that contains both S-62 and S-63 was divided: 0.11 ft^3/s for well S-62, located within a retention basin that receives long-term low-rate recharge, and 0.01 ft^3/s for well S-63, a stormwater-runoff well.

Table 5. Total yields from selected drainage basins and previously modeled areas

[ft³/s, cubic feet per second; in/yr, inch per year. X, equation-based estimates using water levels; Y, yield-based estimates; --, no data]

Monitoring site	Estimate method	Drainage-well recharge		Surface-water outflow		Total outflow		Surface-water inflow		Drainage-basin yield	
		ft^3/s	in/yr	ft^3/s	in/yr	ft^3/s	in/yr	ft^3/s	in/yr	ft^3/s	in/yr
Lake Killarney H-34 and H-35	X	4.7	24.8	--	--	4.7	24.8	--	--	4.7	24.8
Goddard Avenue W-31	X	.3	20.3	--	--	.3	20.3	--	--	.3	20.3
Little Lake Barton E-96	X	.9	48.4	--	--	.9	48.4	.3	16.1	.6	32.3
Lake Fairview W-31, W-38, W-39	X	1.7	5.8	6.1	20.8	7.8	26.6	.12	.4	7.68	26.2
Little Lake Fairview W-39	X	1.3	21.1	.4	6.5	1.7	27.6	.12	1.9	1.58	25.7
Lake Mann S-57	X	.05	.4	3.6	24.8	3.65	25.4	--	--	3.65	25.4
Lake Buchanan S-76	Y	.7	24	--	--	.7	24	--	--	.7	24
Lake Fair W-32	Y	.04	5.1	.12	14.9	.16	20	--	--	.16	20
Nashville Street S-62 and S-63	Y	.12	24	--	--	.12	24	--	--	.12	24
Taft B-14 canal B-90	Y	.17	20	--	--	.17	20	--	--	.17	20
Yucatan Drive E-98	Y	.5	7	.9	13	1.4	20	--	--	1.4	20
Lake Eve W-19	Y	.14	20	--	--	.14	20	--	--	.14	20
Study total (10.4 mi²)		9.04	11.8	10.5	13.7	19.54	25.5	.3	.4	19.24	25.1
Previously modeled area (80 mi²)		51[b]	8.7[b]	66.6[a]	11.3[a]	127.6	20	--	--	127.6	20

[a] U.S. Geological Survey surface runoff estimates.

[b] Tibbals (1990) recharge estimates.

Comparison of Recharge Rates

The range of yields (20-30 in/yr) for the drainage-well basins included in the study is more than the range of yields for surface-water discharge from Orange County. Yields from the drainage basins in Orange County range from 5.2 in/yr from the Little Wekiva River basin to 15.2 in/yr from the Econlockhatchee River basin (based on files of the U.S. Geological Survey). The Little Wekiva River basin has many sinkholes and a high recharge rate to the Upper Floridan aquifer. Much of the Econlockhatchee River basin is undeveloped and has little impervious-surface coverage and low water use, and the river basin has fewer sinkholes than does the Little Wekiva River basin. All the surface-drainage basins in Orange County contain drainage wells that also account for a part of the yield from each basin.

Table 5 includes a comparison of the recharge rate of 9.0 ft³/s from this study of 23 wells to the approximate total annual recharge through all the drainage wells (400) in Orange County, 51 ft³/s or 33.1 Mgal/d (Tibbals, 1990). The surface outflows were estimated by applying the average runoff rate from each surface-drainage basin covered by the same area in Tibbals' model containing drainage-well recharge. This comparison indicates that the yield estimates from this study are 20 percent higher than those of Tibbals (1990). This increase may be the result of estimation error, increasing urbanization of the area which causes more runoff to reach the wells, reduction of evapotranspiration because of increased impervious surfaces, or expanded use of imported water for irrigation or septic systems.

In further comparison, a yield of 22.5 in/yr was calculated to be recharged through a drainage well in the highly urbanized Lake Underhill drainage basin in Orlando (Bradner, 1991). There are additional drainage wells within this basin that also receive runoff from smaller areas; thus, the total yield from the Lake Underhill basin may be as much as 24 to 25 in/yr.

Water-use information indicates that urbanization of an area can cause large quantities of water to be added to a natural system. The development of residential neighborhoods, particularly areas that use septic systems, can import large amounts of water from public-supply wells that will affect the previously stable outflow from a drainage basin. Imported water from septic systems has been estimated to be about 135 gal/d per average household containing 2.46 persons (Marella, 1994), or about 1.8 (in/yr)/acre for one household on 1 acre of land, or up to 7.2 (in/yr)/acre for 4 households on quarter-acre lots—a typical residential neighborhood in Orange County. Application rates for irrigation water can be as high as 28 to 57 in/yr for lawns and gardens in central Florida (Augustin, 1981; Bradner, 1992; and Duerr and Trommer, 1982).

POTENTIAL EFFECTS FROM WELL CLOSURE

One objective of this study was to assess the effect that closure of noncritical drainage wells would have on the potentiometric surface of the Upper Floridan aquifer. Because urbanization is causing an increase in the use of water from the Floridan aquifer system, the potentiometric surface of the Upper Floridan aquifer in Orange County is declining in some areas. The mounding caused by recharge through drainage wells counteracts some of the decline associated with the higher withdrawal rates from the Floridan aquifer system by the public-water supplies in the urban area even though much of the ground water withdrawn is from the Lower Floridan aquifer. Reduction of recharge through well closure could cause further declines in the potentiometric surface. The potentiometric surface changes were evaluated using the ground-water flow model discussed earlier, with the numerical simulations and results representing steady-state conditions. By the principle of superposition, error in the estimation of potentiometric surface changes is equal to the error in estimation of drainage-well recharge (probably less than 25 percent).

Reduction of Well Recharge

The simulated decline in the potentiometric surface that could occur if all the noncritical wells considered in this analysis were closed and the estimated total well recharge of 9 ft^3/s was removed is shown in figure 11. Recharge estimates were considered to be the highest long-term rate for each well so that the maximum decline in the potentiometric surface of the Upper Floridan aquifer could be determined if the wells were closed. Most of the decline in the potentiometric surface would be near the large volume lake-overflow wells at Lake Killarney, Little Lake Fairview, Lake Fairview, and Little Lake Barton. With removal

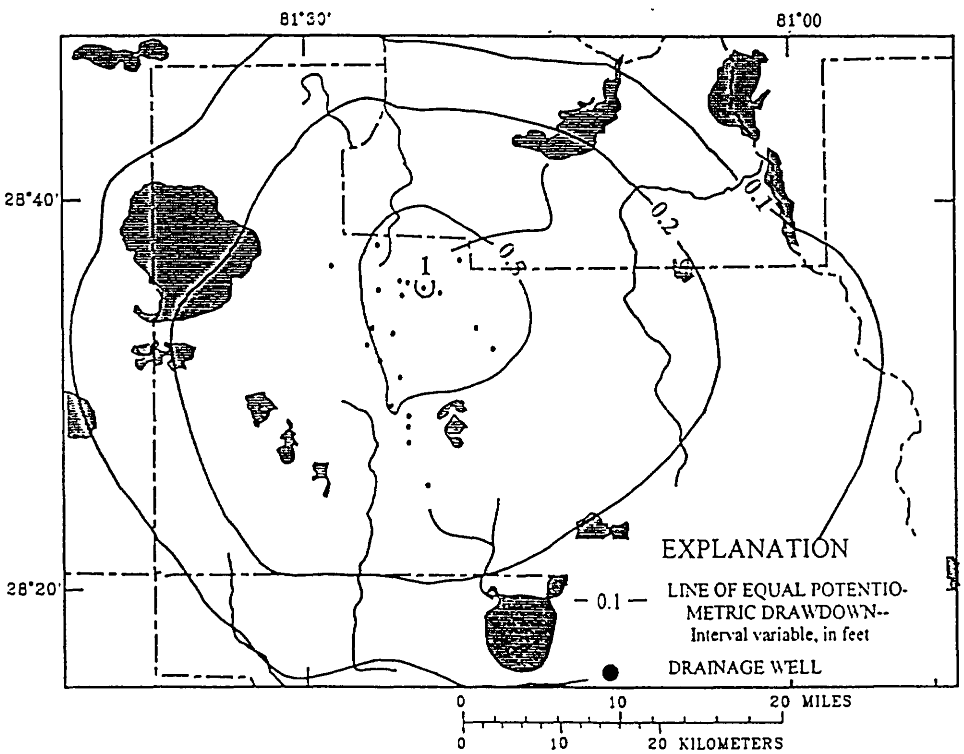

Figure 11. Simulated decline of the potentiometric surface of the Upper Floridan aquifer resulting from removal of 9.0 ft3/s recharge through noncritical drainage wells.

of all the inflow through the noncritical wells, the potentiometric surface may decline about 0.5 ft in about an 8-mi diameter area, a significant part of the urban area of Orlando.

As estimated by Tibbals (1990), the declines that would occur if all the drainage wells (about 400) in central Florida were closed are shown in figure 12. The decrease in recharge would cause a maximum decline of 3 to 4 ft in the current (1995) average potentiometric surface, mostly in the center of the Orlando-Winter Park urban area.

Results depicted in figures 11 and 12 assume that surficial aquifer system heads are unaffected by drainage-well closure in the steady-state simulation. Effects of potentiometric-surface decline from well closure could be slightly less than predicted if surface water is retained in the surface drainage basin to each well. Water levels in the surficial aquifer system may increase as a result of well closure, which in turn could slightly increase the recharge rate to the Upper Floridan aquifer. Most likely, the increased recharge rate caused by increasing surficial aquifer system heads when the wells are closed would be minimal in most of the drainage basins to the wells because of the large head difference between the surficial and Floridan aquifer systems (as much as 40 ft). Also, by raising water levels in the surficial aquifer system, the evapotranspiration rates may be higher and water would be lost through that mechanism.

Redistribution of Recharge

The effects of transferring recharge that would have gone through drainage wells to high rate recharge sites upgradient of the drainage-well basins were simulated. Redirected water could be applied to lakes or percolation ponds in western Orange County that have no surface outflow. The two sites selected were CONSERV II, a system for distributing treated wastewater to rapid infiltration basins and irrigating systems, and Lake Sherwood (fig. 1).

The CONSERV II site was selected because of the existing pipelines to the site and the high rate of recharge to the Upper Floridan aquifer. A single application site immediately adjacent to the main storage tanks for the distribution system of CONSERV II was chosen, although the area covered by the distribution system is much larger. Hydraulic parameters and mounding effects could be different if the recharge were applied in another area of the distribution system.

The mounding from the induced recharge at the CONSERV II site could cause a maximum increase of 1 ft to the potentiometric surface in the western part of the county (fig. 13). The central part of Orange County would continue to be affected by the removal of the recharge from the noncritical drainage wells. The results are based on the assumption that surficial aquifer system heads are unaffected by the closure of the rapid infiltration basins. The rate of recharge would be increased if the head difference between the surficial and Floridan aquifer systems were increased and may not occur at the same rate as if the recharge were applied directly through wells.

Lake Sherwood, in western Orange County, was selected for simulation of redirected recharge because it has an extremely high recharge rate to the Floridan aquifer system through the bottom of the lake and it could be the terminus of a lake interconnect system that currently connects several large lakes in the area. According to Lichtler and others (1976), the recharge rate to the Upper Floridan aquifer in the bottom of the northern lobe of the lake was about 54 in. during 1967. The level of the lake is about 5 to 10 ft above the potentiometric surface of the Upper Floridan aquifer.The lake also has the largest range of water levels (33 ft) recorded in Orange County. The lake level during extreme high water is controlled by a drainage well rather than by surface outflow; thus, any excess water would become direct recharge through the well.

The mounding effect caused by redirecting the drainage-well recharge to Lake Sherwood is shown in figure 14. The western Orlando and Winter Park areas of the county would be most affected by the recharge, particularly in the vicinity of some of the well fields. The maximum mounding in the potentiometric surface would be about 1 ft. Redirecting recharge to Lake Sherwood would result in a a smaller area of decline (from the closure of drainage wells) than would redirecting recharge to the CONSERV II site. The results for the Lake Sherwood site are limited by the same assumptions made for the recharge application at the CONSERV II site.

SUMMARY

Orange County, Florida, and surrounding areas have used drainage wells to alleviate flooding and to control lake levels since 1904. Many of the drainage wells were drilled as the area became urbanized, but before any major drainage systems were designed. In

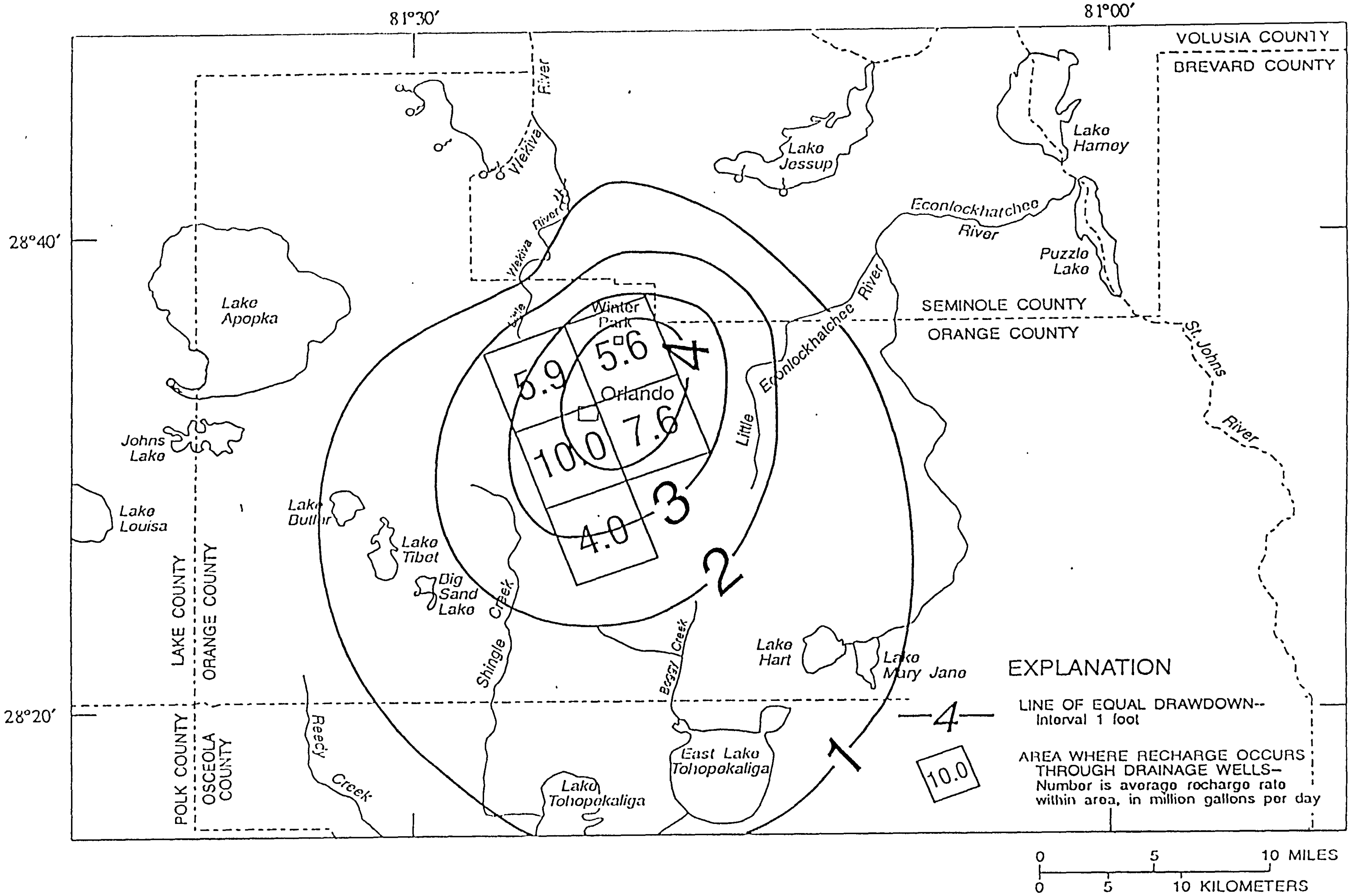

Figure 12. Simulated decline of the potentiometric surface of the Upper Floridan aquifer resulting from removal of 51ft^3/s recharge through all drainage wells in Orange County.

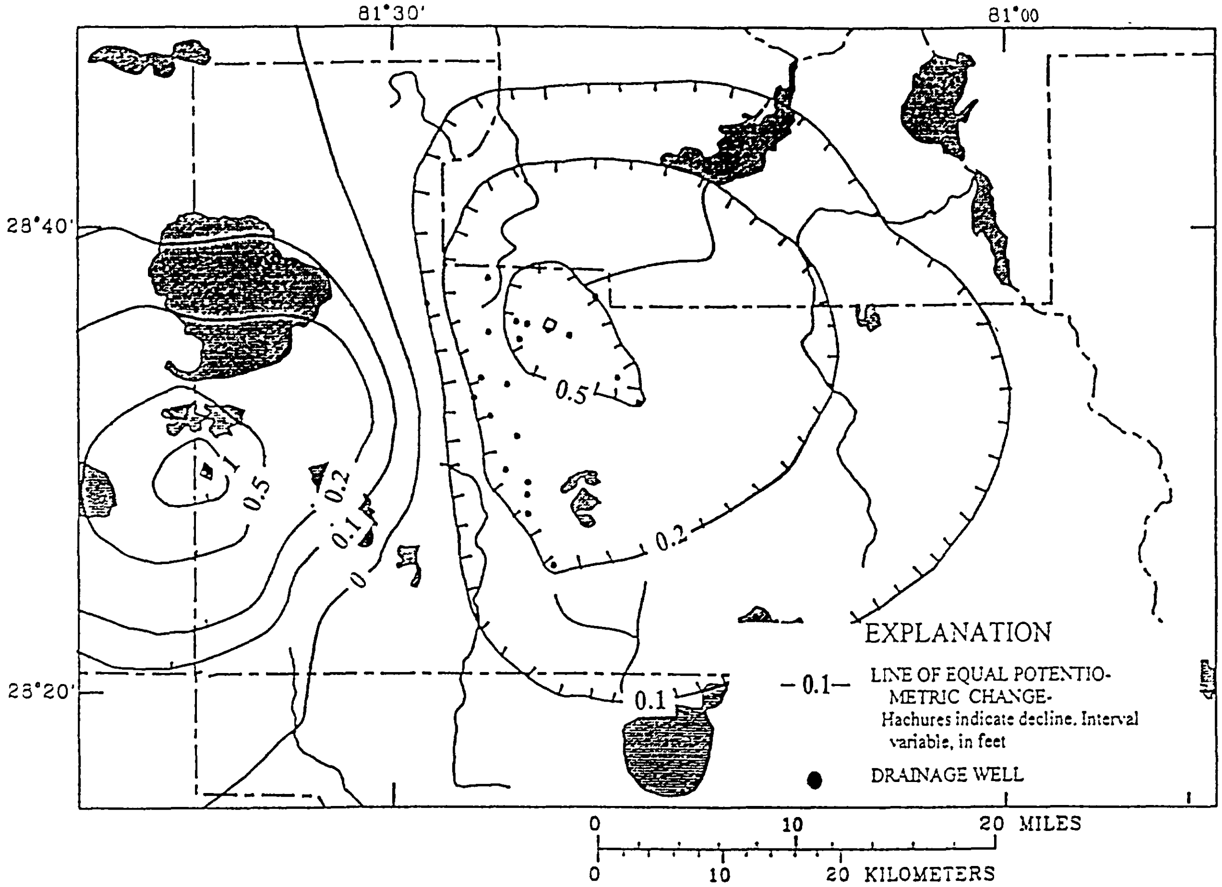

Figure 13. Change in the potentiometric surface of the Upper Floridan aquifer resulting from removal of 9.0 ft^3/s recharge through the noncritical drainage wells and redistribution of water to the CONSERV II area in west Orange County.

1992, the Orange County Stormwater Management Department identified 23 wells that were considered noncritical or redundant for current drainage control. These wells were targeted for closure to eliminate maintenance and possible contamination problems.

Long-term inflow to 18 of the 23 drainage wells on the noncritical list was estimated and the effects on the potentiometric surface of the Upper Floridan aquifer caused by closing the noncritical wells were evaluated through simulation. Recharge estimates were considered to be the highest long-term rate for each well so that the maximum decline in the potentiometric surface of the Upper Floridan aquifer could be determined if the wells were closed.

Recharge through three selected noncritical drainage wells was estimated by computing a stage-recharge rating. Short-term recharge to these wells was estimated using regression equations derived from the ratings and mean daily water levels. Long-term recharge was calculated using these equations and monthly observed water levels from 1978-94 for two of the three sites. Recharge to three other noncritical wells was calculated using weir and orifice-flow equations with long-term water levels from 1978. Recharge to seven other noncritical drainage wells was calculated by extrapolation from the six monitored sites by estimating a drainage-basin yield. All drainage-well recharge calculations were based on the current design of the intakes and configuration of debris restrictors. The surface-water outflow calculations using sharp-crested and broad-crested weir equations were based on the current design of the outflow weirs for the lakes.

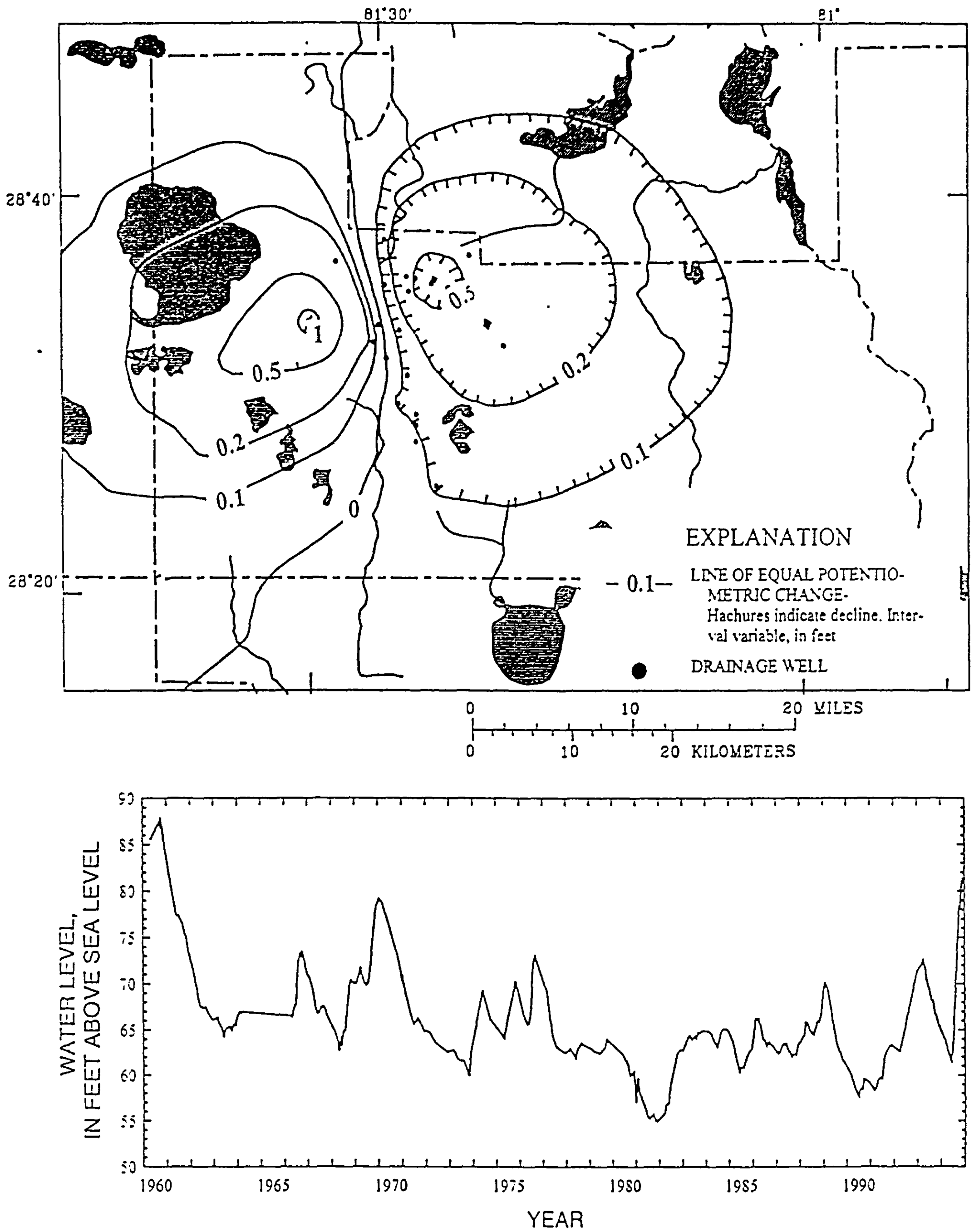

Figure 14. Change in the potentiometric surface of the Upper Floridan aquifer resulting from removal of 9.0 ft^3/s recharge through noncritical drainage wells and redistribution of water to Lake Sherwood in west Orange County, and a graph showing periodic water levels of Lake Sherwood, 1960-94.

Total recharge to the noncritical drainage wells was estimated to be about 9 cubic feet per second (ft^3/s) or 6.0 million gallons per day. These rates are about 19 percent of the total volume of recharge through all 400 drainage wells in Orange County estimated by previous simulations in a model of the Floridan aquifer system.

There is error in estimating the recharge through the drainage wells. The low-volume, poorly maintained unmonitored sites could have as much as 50 percent error, but the range of error probably is 25 percent or less for the monitored sites and the higher-volume nonmonitored sites. The error in the total yield probably is 25 percent or less.

Well H-35 on Lake Killarney in Winter Park received 4.6 ft^3/s, the highest average annual recharge. Recharge to the well was continuous during the study. The next highest recharge rates were 1.3, 0.9, and 0.7 ft^3/s for lake-overflow wells W-39 on Little Lake Fairview, E-96 on Little Lake Barton, and S-76 on Lake Buchanan, respectively. Several wells have been plugged or have received very little recharge.

A digital computer model was rediscretized for Orange County using the same hydraulic parameter values as documented by Tibbals (1990). Rediscretization created a grid of 80 rows and 93 columns covering the same area as the original model.

Based on the simulations, with removal of all the 9 ft^3/s inflow through the noncritical wells, the potentiometric surface of the Upper Floridan aquifer could decline about 0.5 feet in about an 8-mile-diameter area. This area would cover a significant part of urban Orlando. Most of the decline in the potentiometric surface would occur near the large volume lake-overflow wells at Lake Killarney (wells H-34 and H-35), Little Lake Fairview (well W-39), and Little Lake Barton (well E-96). Declines of more than 1.0 foot could occur in the potentiometric surface in the area of Lake Killarney.

The redirected flows to two selected sites were treated as direct recharge to the Upper Floridan aquifer. Redirection of recharge to the CONSERV II area and Lake Sherwood in western Orange County could result in high-volume recharge to the Upper Floridan aquifer. The mounding (about 1 foot) in the potentiometric surface as a result of the redirection of water to either of these two areas could offset the drawdowns from public-supply well fields in the urban areas of the county.

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