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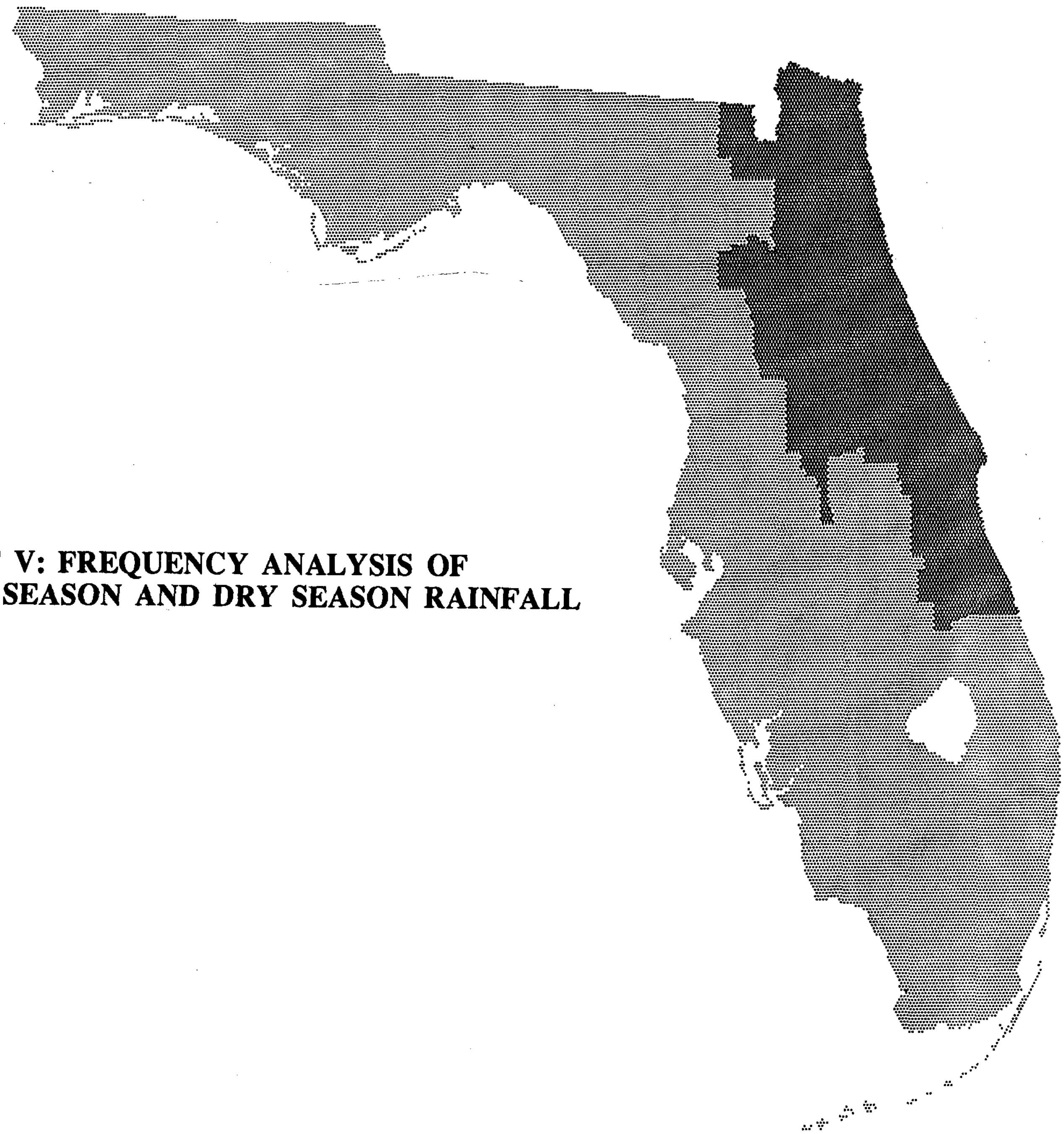
RAINFALL ANALYSIS FOR NORTHEAST FLORIDA



PART V: FREQUENCY ANALYSIS OF WET SEASON AND DRY SEASON RAINFALL

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
P.O. BOX 1429 PALATKA, FLORIDA 32178-1429

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PART V: FREQUENCY ANALYSIS OF WET SEASON AND DRY SEASON RAINFALL

By

Donthamsetti V. Rao

S. Abe Jenab

and

David A. Clapp

St. Johns River Water Management District

Palatka, Florida

1990

Project No. 10 200 02

CONTENTS

LIST OF FIGURES.. v

INTRODUCTION... 1

BASIC DATA 5

RAINFALL SEASONS 7
Warm Season Rainfall 7
Cold Season Rainfall 7
Wet and Dry Season Rainfall 10

FREQUENCY ANALYSIS 11

ISOPLUVIAL MAPS 15

REFERENCES 17

FIGURES

FIGURE		PAGE
1	State of Florida water management districts	2
2	Rain gage stations used in this study	9
3	Maximum and minimum events at desired probability level	12

INTRODUCTION

Rainfall data are an essential element of basic data input to many hydrologic and engineering studies. Peak rainfall data are used in designing stormwater management systems and in determining the flooding potential of various frequency storm events. Daily or hourly data are required in continuous hydrologic simulation procedures. Monthly and seasonal rainfall data are used in determining supplementary irrigation water requirements, and in engineering studies related to storage analyses, water supply, and reservoir management.

The St. Johns River Water Management District (SJRWMD) (Fig. 1) is responsible for management of the water resources of the District, which includes all or parts of nineteen counties in northeast Florida. The District makes extensive use of rainfall data in its consumptive use and management and storage of surface waters (MSSW) permit activities and in its hydrologic and engineering studies related to surface water basin management plans. For example, in the SJRWMD's consumptive use program, agricultural withdrawals are permitted based on certain monthly and/or seasonal drought conditions. Also, when certain thresholds are exceeded, surface water management systems are required to satisfy conditions based on the 10- and 25-year maximum storm discharges and the 100-year flood elevation.

This project, "Rainfall Analysis for Northeast Florida," has been undertaken to fulfill the needs of the District and to

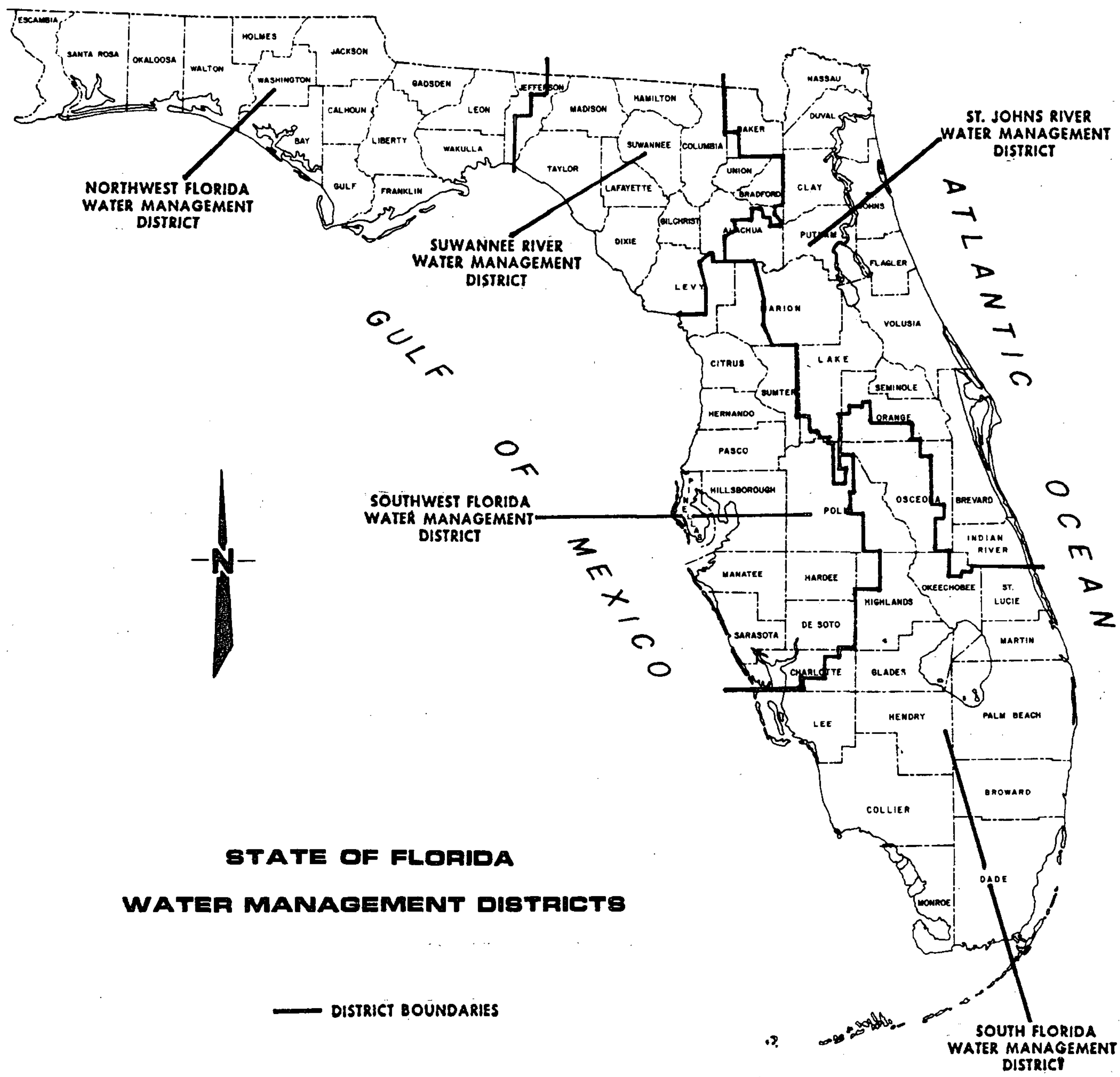


Figure 1. State of Florida water management districts

provide the same information to interested organizations and individuals. The project objective is the production of a series of reports, each report based on the collection and detailed analysis of rainfall data and directed at a specific hydrologic/engineering study goal. This report, presenting the results of frequency analysis of wet season and dry season rainfall, is Part V of the series. The series consists of six reports. The first three reports present basic rainfall data and the final three reports present the results of specific analyses. (Part I) 24-Hour to Ten-Day Maximum Rainfall Data; (Part II) Summary of Monthly and Annual Rainfall Data; (Part III) Seasonal Rainfall Data; (Part IV) Frequency Analysis of Warm Season and Cold Season Rainfall; (Part V) Frequency Analysis of Wet Season and Dry Season Rainfall; and (Part VI) 24-Hour to 96-Hour Maximum Rainfall for Return Periods 10 years, 25 years, and 100 years.

BASIC DATA

The main sources of rainfall data for northeast Florida are the publications of the National Oceanic and Atmospheric Administration, NOAA [formerly the U. S. Weather Bureau (through 1965) and the Environmental Sciences Services Administration (1965-1970)]. The rainfall recording program in northeast Florida was initiated in the latter half of the 1800s. The monthly bulletins titled Climatological Data provide daily precipitation data. Hourly rainfall data are published in Hydrologic Bulletin (1940-1948), Climatological Data (1948-1951), and since 1951 in the monthly publications titled Hourly Precipitation Data. State and local agencies including the SJRWMD and some other organizations also maintain rain gage stations. This project uses primarily NOAA rain gage stations. Data collected by the SJRWMD and other organizations are used to estimate missing data or to extend data for discontinued stations.

Monthly rainfall data are readily available (in summary form) in the NOAA publications entitled Climatic Summary of the United States and the Annual Summaries of Climatological Data. Data from these publications were compiled with updates, as necessary, and published as Part II of this series, "Summary of Monthly and Annual Rainfall Data" (Jenab et al. 1986). The same data were used to compute the seasonal rainfall data presented in Part III of this series, "Seasonal Rainfall Data" (Rao et al.

1989). A frequency analysis was performed on these data to estimate maximum and minimum seasonal rainfall values for various return periods.

RAINFALL SEASONS

Based on rainfall distributions for northeast Florida, a year can be divided into a rainy or wet season (June-October) and a dry season (November-May). In addition, the warm season (June-September) and cold season (December-March) rainfall are of interest in agricultural studies related to crop consumptive use. This report estimates maximum and minimum rainfall totals for various return periods for two of these seasons (wet season and dry season). The seasonal rainfall data presented for 43 long-term stations in Part III of this series were used in frequency analysis. The names of these rain gage stations are given in Table 1; their locations are shown in Figure 2.

Warm Season Rainfall

During the four warmest months of the year, June through September, crops have their highest consumptive use requirements. In Florida, this season is also the wettest period of the year. The distribution of warm season rainfall determines the supplemental irrigation needs of the summer crops. This information is used by the SJRWMD in permitting agricultural irrigation water withdrawals.

Cold Season Rainfall

The four coldest months of the year, December through March,

Table 1. Rain gage stations used in this study

PRINCIPAL STATION AND COUNTY	NOAA NUMBER	PERIOD OF RECORD	SUPPLEMENTARY STATIONS
AVON PARK (HIGHLANDS)	0369	(1902-1984)	
BARTOW (POLK)	0478	(1887-1984)	
BITHLO (ORANGE)	0758	(1947-1984)	CHRISTMAS*
BUSHNELL 2E. (SUMTER)	1163	(1937-1984)	
CLERMONT (LAKE)	1641	(1893-1984)	
CRESCENT CITY (PUTNAM)	1978	(1897-1984)	
DAYTONA BEACH AIRPORT (VOLUSIA)	2158	(1923-1984)	NEW SMYRNA BCH*
DELAND (VOLUSIA)	2229	(1909-1984)	ORANGE CITY*
FEDERAL POINT (PUTNAM)	2915	(1892-1984)	
FELLSMERE (INDIAN RIVER)	2936	(1912-1984)	
FERNANDINA BCH. (NASSAU)	2944	(1902-1984)	
FORT DRUM (OKEECHOBEE)	3137	(1943-1984)	
FT. PIERCE (ST. LUCIE)	3207	(1901-1984)	
GAINESVILLE (ALACHUA)	3321	(1897-1984)	UNIV. OF. FLA.*
GLEN ST. MARY (BAKER)	3470	(1896-1984)	
HART LAKE (ORANGE)	3840	(1943-1978)	
HIGH SPRINGS (ALACHUA)	3956	(1945-1984)	
HILLIARD (NASSAU)	3978	(1909-1984)	FOLKSTON*
INVERNESS (CITRUS)	4289	(1899-1984)	
ISLEWORTH (ORANGE)	4332	(1916-1982)	WINTER GARDEN*
JACKSONVILLE AIRPORT (DUVAL)	4358	(1867-1984)	JAX CITY*
JACKSONVILLE BCH. (DUVAL)	4366	(1945-1984)	
KISSIMMEE (OSCEOLA)	4625	(1892-1984)	KISSIM FLD STA*
LAKE ALFRED EXP.STA. (POLK)	4707	(1925-1984)	
LAKE CITY (COLUMBIA)	4731	(1893-1984)	
LAKELAND WSO CI (POLK)	4797	(1915-1984)	
LISBON (LAKE)	5076	(1891-1984)	EUSTIS*
LYNNE (MARION)	5237	(1942-1984)	
MARINELAND (FLAGLER)	5391	(1942-1984)	
MELBOURNE (BREVARD)	5612	(1939-1984)	
MOUNTAIN LAKE (POLK)	5973	(1922-1984)	
NITTAW (OSCEOLA)	6251	(1943-1984)	
OCALA (MARION)	6414	(1891-1984)	
OKEECHOBEE (OKEECHOBEE)	6485	(1913-1984)	
ORLANDO WSO MCCOY (ORANGE)	6628	(1892-1984)	ORLANDO*
PALATKA (PUTNAM)	6753	(1923-1984)	PALATKA SJRWMD*
ST. AUGUSTINE R.TWR (ST.JOHNS)	7826	(1877-1984)	ST.AUGUSTINE*
SANFORD EXP.STA. (SEMINOLE)	7982	(1913-1984)	SANFORD*
STARKE (BRADFORD)	8527	(1896-1984)	CAMP BLANDING*
TITUSVILLE (BREVARD)	8942	(1878-1984)	MERRITT ISLAND*
USHER TOWER (LEVY)	9120	(1956-1984)	
VERO BCH. (INDIAN RIVER)	9219	(1943-1984)	VERO BCH AIRPT*
WINTER HAVEN (POLK)	9707	(1941-1984)	

* - DATA COMBINED WITH PRINCIPAL STATION DATA

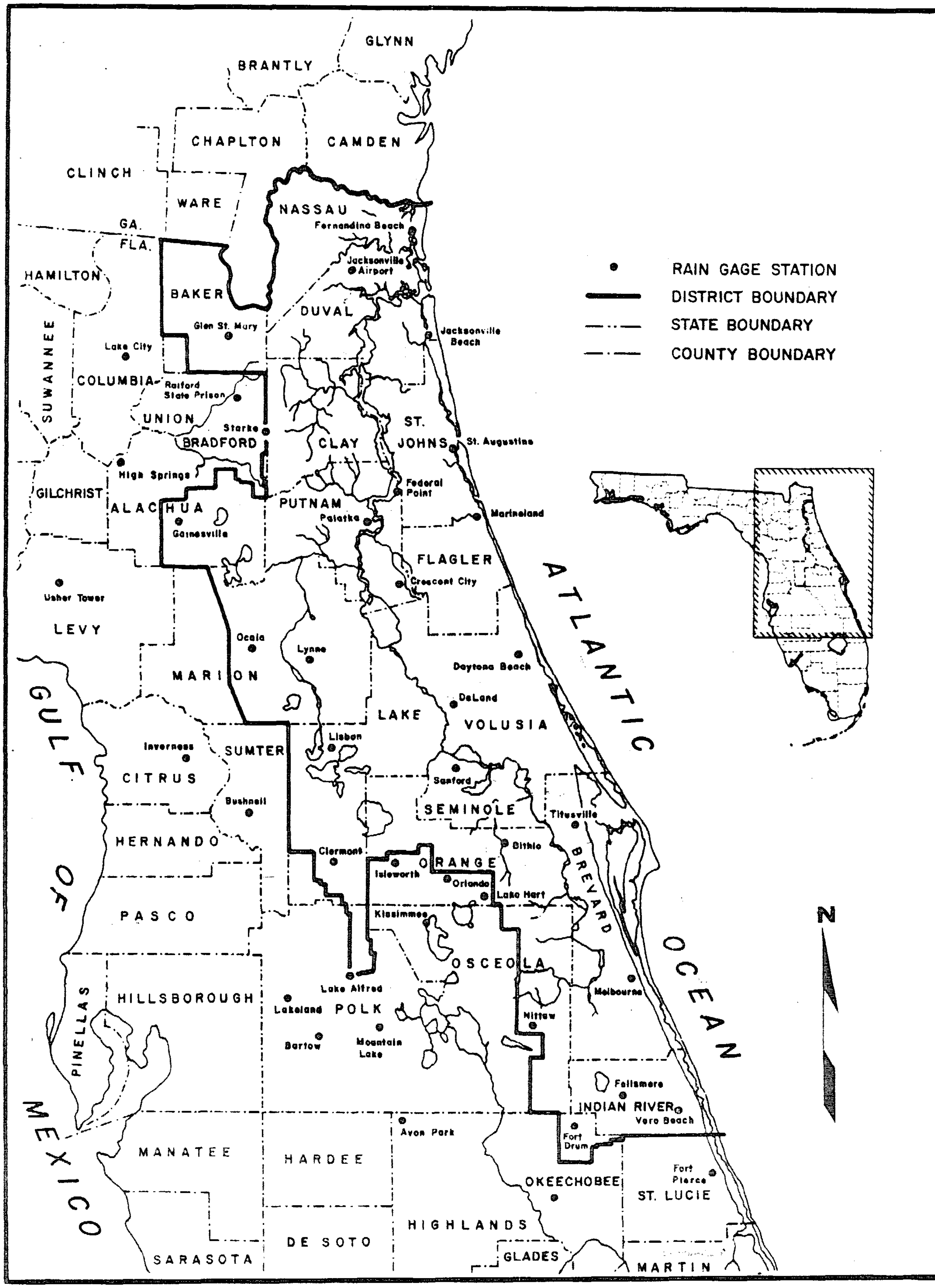


Figure 2. Rain gage stations used in this study

coincide with the period of lowest precipitation in northeast Florida (about 22 percent of the annual rainfall). The distribution of cold season rainfall is useful for estimating the irrigation requirements of winter crops and the water needed for frost and freeze protection. The SJRWMD uses this information for allocating cold season agricultural irrigation water withdrawals. (The results of frequency analysis of warm season and cold season rainfall are presented in Part IV of this series.)

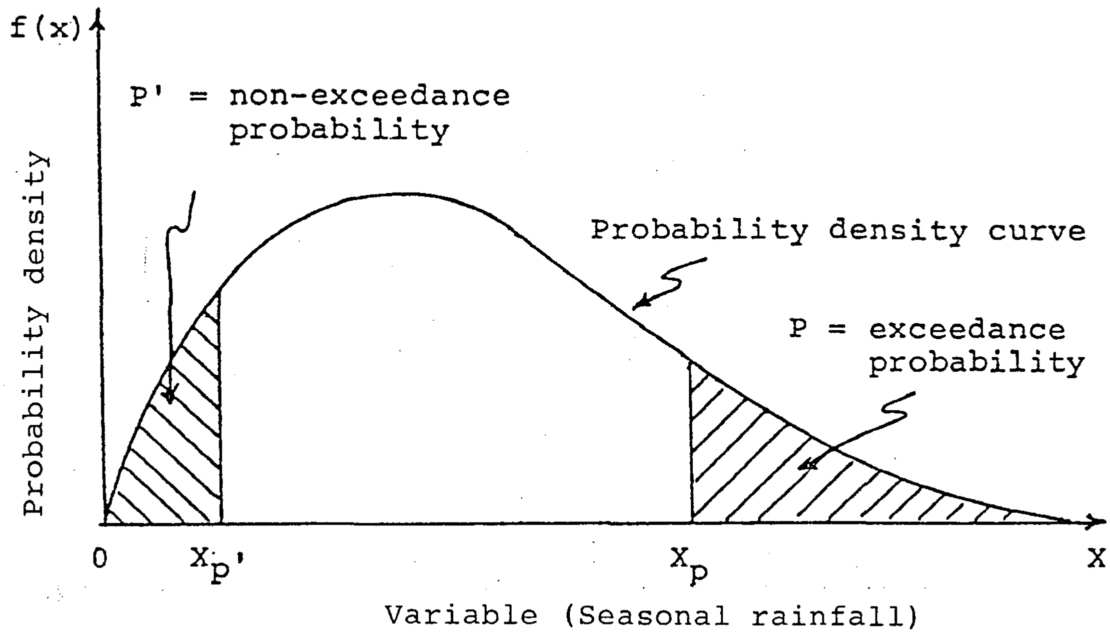
Wet and Dry Season Rainfall

The five months June through October receive about 60 percent of the annual rainfall in northeast Florida and are thus considered the wet season of the year. The seven-month period November through May is considered the dry season. Wet season, dry season, and annual rainfall data provide information for comparing current rainfall with historic extremes and making certain managerial decisions, e.g., whether a water shortage warning should be declared when rainfall is less than, for example, a 50-year low. These seasonal rainfall values also are useful in storage analysis, water supply studies, and reservoir planning.

FREQUENCY ANALYSIS

This report presents both maximum and minimum seasonal rainfall values for return periods, T = 5 yr, 10 yr, 25 yr, and 100 yr. The methodology for estimating maximum and minimum values consists of choosing an appropriate probability distribution and fitting it to data samples by one of the available statistical procedures. The fitted distribution provides the magnitudes of the events (x) at desired probability levels. The maximum events are determined from an annual exceedance probability, P (i.e., in a given year, there is a 100P percent chance that the actual rainfall may equal or exceed the value, X_P. See Figure 3.) The minimum values are determined from the non-exceedance probability, P' (Figure 3).

Several probability distributions have been used to determine the frequencies of hydrologic variables (Chow 1964, Markovic 1965, Matalas 1963). These vary in complexity from the simple two-parameter Gumbel distribution (1958) to the five-parameter Wakeby distribution (Houghton 1978). A distribution widely used in storm rainfall analysis (Hershfield 1961 and Miller 1964) is the Extreme Value Type I distribution using a fitting procedure suggested by Gumbel (the Gumbel Method). This distribution, however, has some properties which are not hydrologically appealing. It inherently has a constant skewness coefficient (CS = 1.14) and its lower bound extends to $-\infty$. The latter property implies that part of the data should be negative.



$X_{p'}$ = Minimum event; $T = 1/P'$

X_p = Maximum event; $T = 1/P$

Figure 3. Maximum and minimum events at desired probability level

At a coeffcient of variation CV = 0.5, theoretically 0.07 percent of the data represented by the Gumbel distribution is negative, but this percentage increases to 13 percent at CV = 1.0. Rao (1981) quantitatively illustrates how these inconformities of Gumbel distribution with real data affect the design estimates. For the seasonal rainfall data samples analyzed in this study, the skewness coefficient had a range of -0.5 to 5.0, and CV varied from 0.15 to 1.22. Gumbel's suggested fitting procedure was also found to be misleading. Therefore, the use of the method was discouraged by Lettenmaier and Burges (1982).

The Log Pearson Type 3 distribution, a more flexible (three-parameter) distribution than the Gumbel, is selected for this study. The applicability of this distribution to hydrologic data was discussed at length by Bobee (1975) and Rao (1980a).

For each station, the Log Pearson Type 3 distribution was fit to warm season and cold season rainfall data by the Method of Mixed Moments-1 (MXM1). The MXM1 method has been found to possess superior statistical properties (Rao 1980, 1983; Arora and Singh 1989). The method was described in detail elsewhere (Rao 1986, 1988).

The maximum seasonal rainfall values for various return periods were taken directly from the Log Pearson fit. However, in the case of minimum values, a theoretical distribution may not always provide a satisfactory fit (Riggs, 1972). For this reason, the minimum values were always plotted on normal probability paper using the Weibul plotting position formula and compared with the Log Pearson fit. Where the plotted data deviated significantly from the Log Pearson fit, greater weight was given to plotted data in determining low rainfall values for different return periods.

ISOPLUVIAL MAPS

The results of this study are presented as isopluvial maps, i.e., maps showing lines of equal rainfall for the study area (northeast Florida). Drawing isopluvial lines through a field of rainfall frequency data is similar to drawing contour maps for a land surface area from topographic survey data. In developing these maps, the isopluvial lines were initially drawn by a Tektronix plotter using the District-developed MCONTOUR computer program. The Tektronix plots were manually smoothed and extended and/or adjusted where necessary to produce the final isopluvial maps.

This report presents the following isopluvial maps:

- Annual normal rainfall (Fig. 4)
- Annual maximum rainfall for return periods T = 5 yr, 10 yr, 25 yr, 50 yr, and 100 yr (Figs. 5-9)
- Annual minimum rainfall for return periods T = 5 yr, 10 yr, 25 yr, 50 yr, and 100 yr (Figs. 10-14)
- Wet season normal rainfall (Fig. 15)
- Wet season maximum rainfall for return periods T = 5 yr, 10 yr, 25 yr, 50 yr, and 100 yr (Figs. 16-20)
- Wet season minimum rainfall for return periods T = 5 yr, 10 yr, 25 yr, 50 yr, and 100 yr (Figs. 21-25)
- Dry season normal rainfall (Fig. 26)
- Dry season maximum rainfall for return periods T = 5 yr, 10 yr, 25 yr, 50 yr, and 100 yr (Figs. 27-31)

- Dry season minimum rainfall for return periods T = 5 yr, 10 yr, 25 yr, 50 yr, and 100 yr (Figs. 32-36)

The normal rainfall, which is revised for each decade, is an accepted standard for comparing the current rainfall conditions. For the decade of 1981-1990, the average for 1951-1980 is the normal. The normal rainfall charts (Figs. 4, 5, and 26) and the other T-yr seasonal rainfall maps presented in this report provide a means for determining how dry (or how wet) the rainfall conditions of a given season (or a year) are. Other seasonal values like 5-yr or 10-yr minimum rainfalls give a quantitative indication of the expected rainfall deficits so that farmers may design their irrigation systems for appropriate crop protection.

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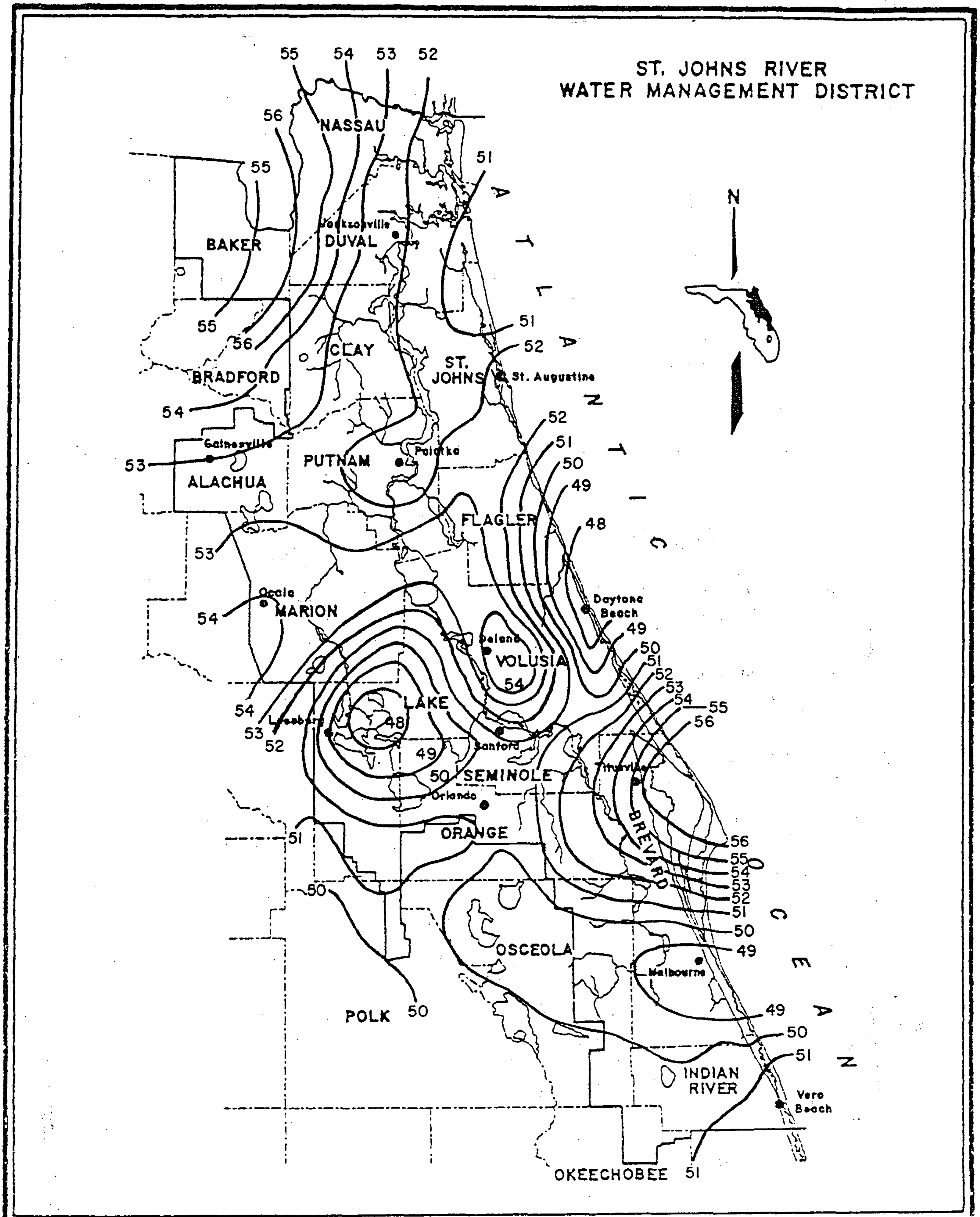

Figure 4. Annual normal rainfall, inches

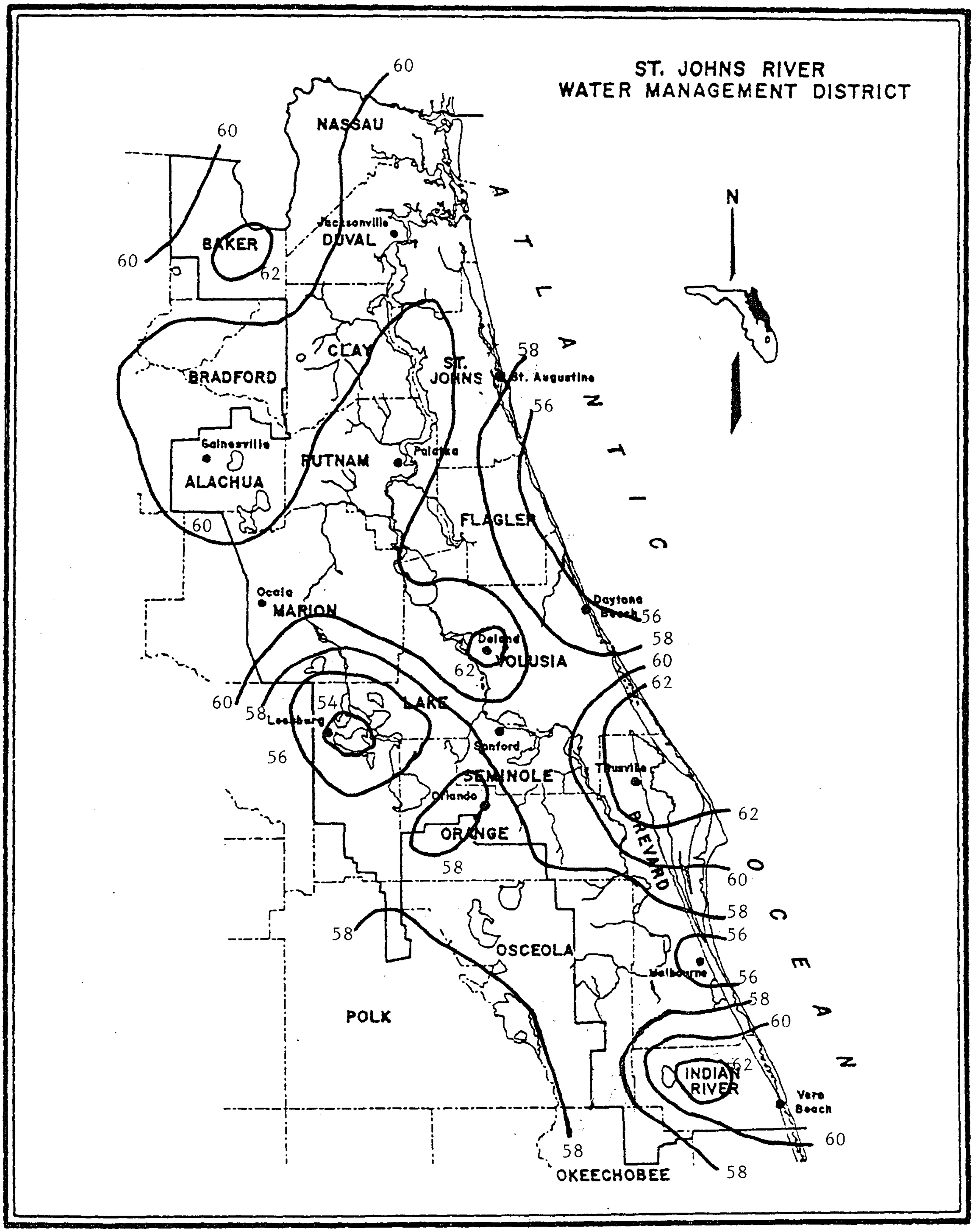

Figure 5. Annual maximum rainfall, inches, T = 5 yr

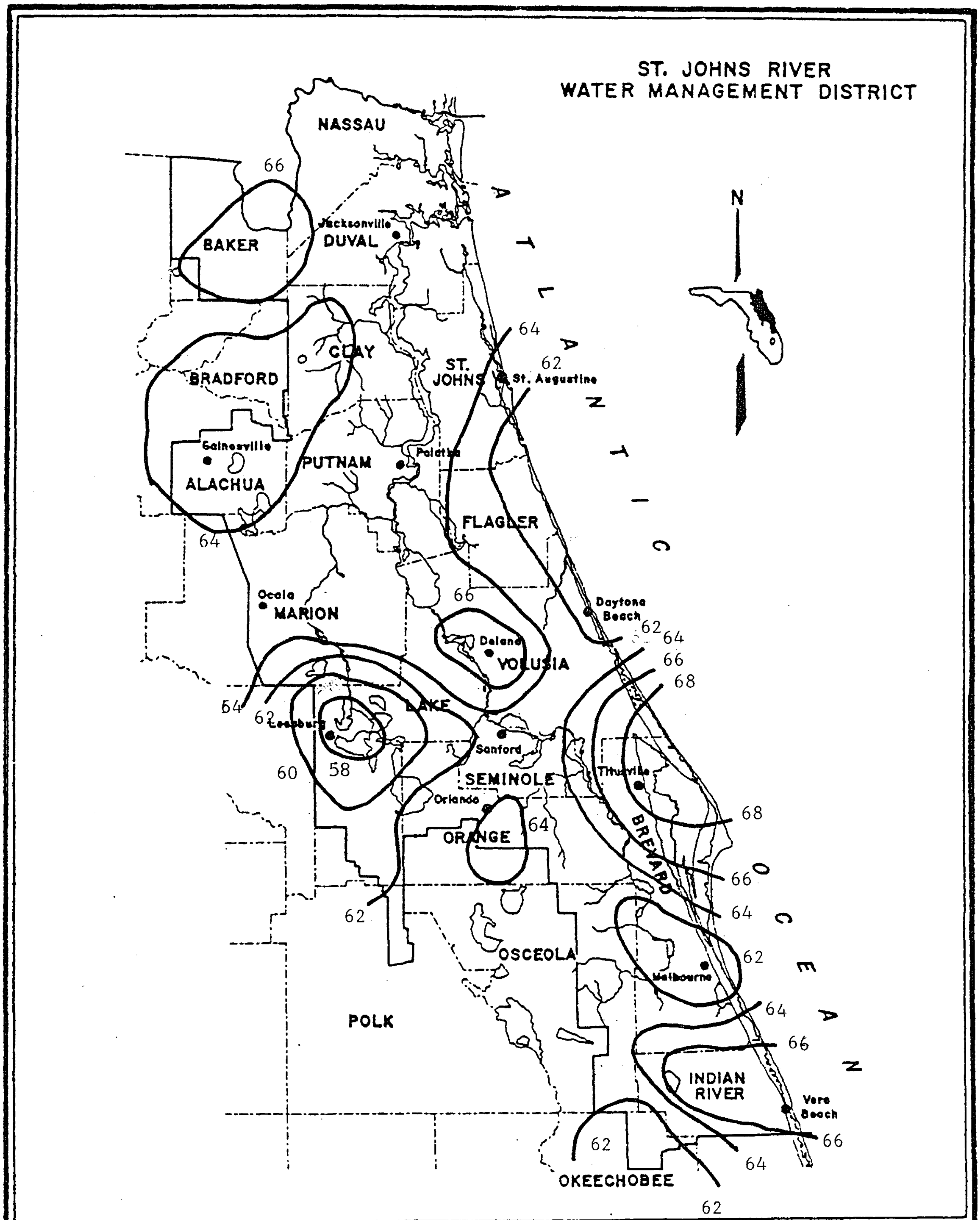

Figure 6. Annual maximum rainfall, inches, T = 10 yr

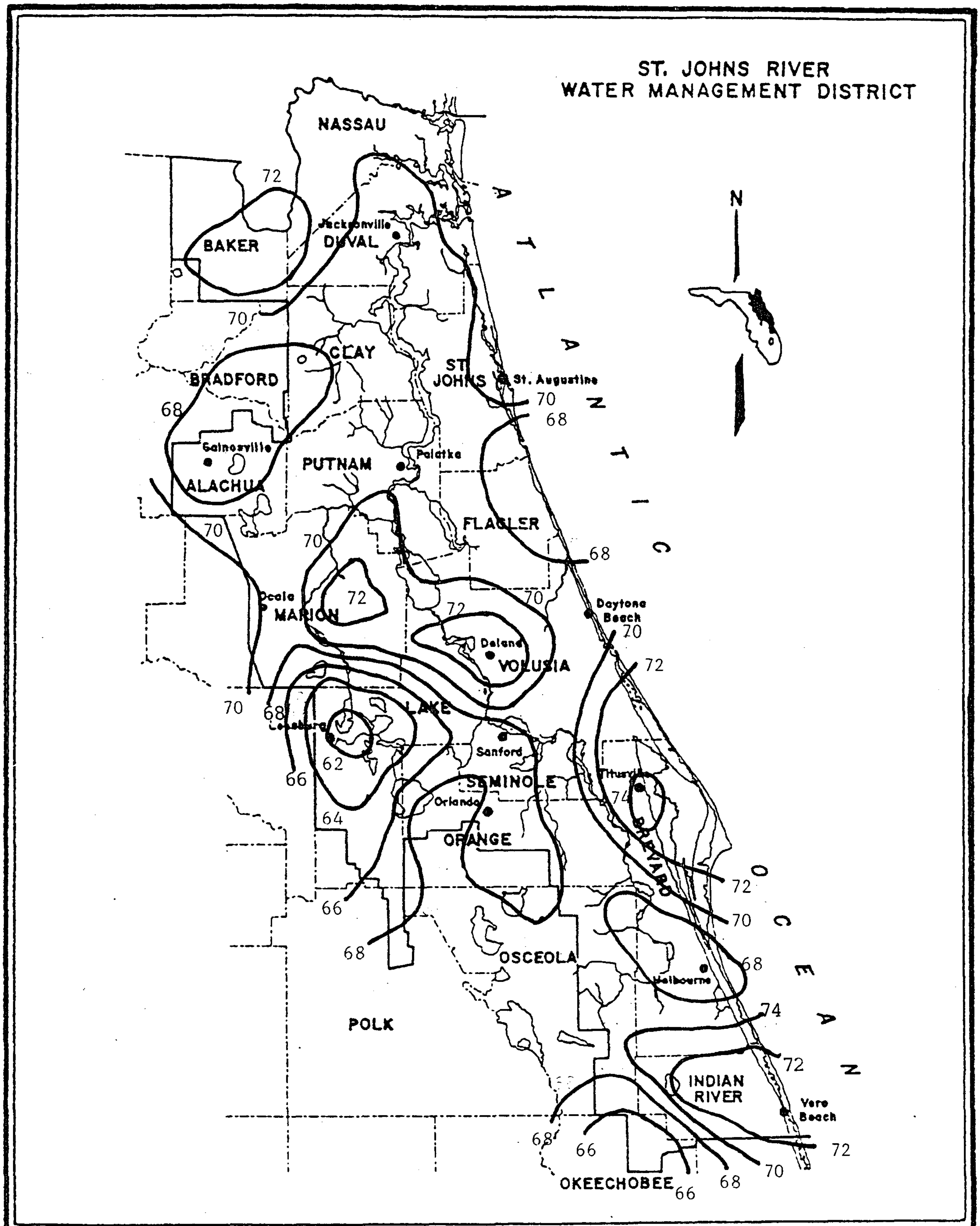

Figure 7. Annual maximum rainfall, inches, T = 25 yr

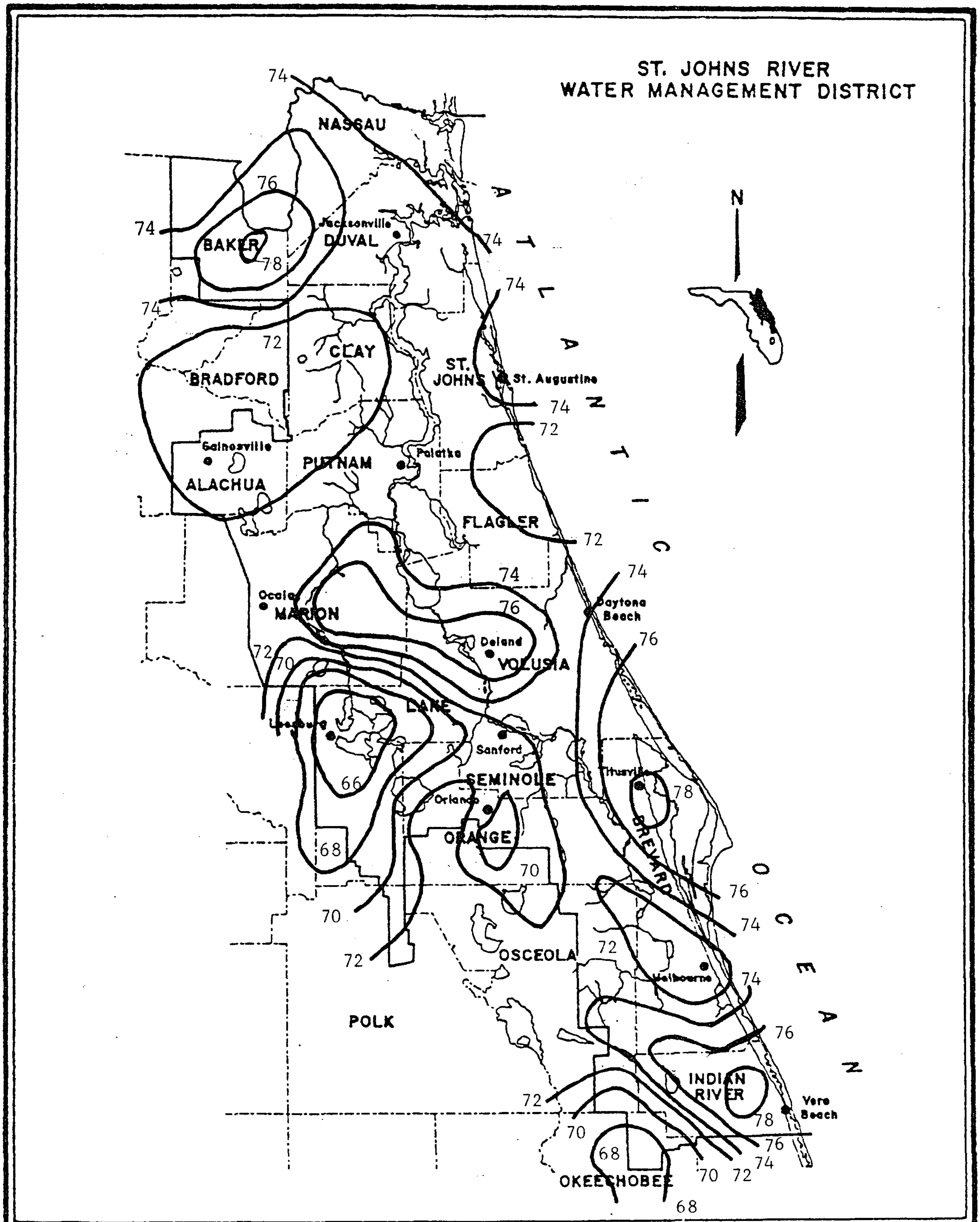

Figure 8. Annual maximum rainfall, inches, T = 50 yr

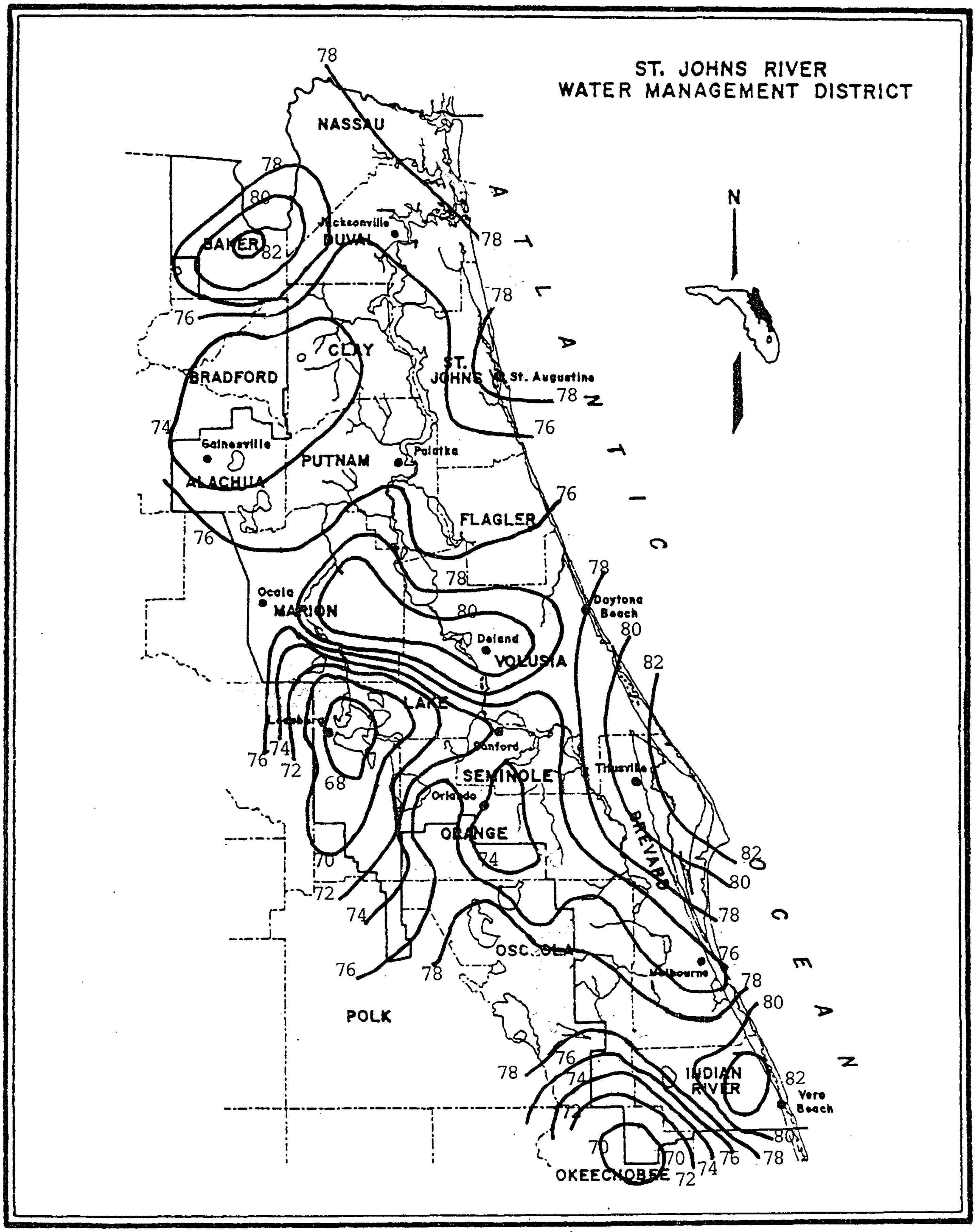

Figure 9. Annual maximum rainfall, inches, T = 100 yr

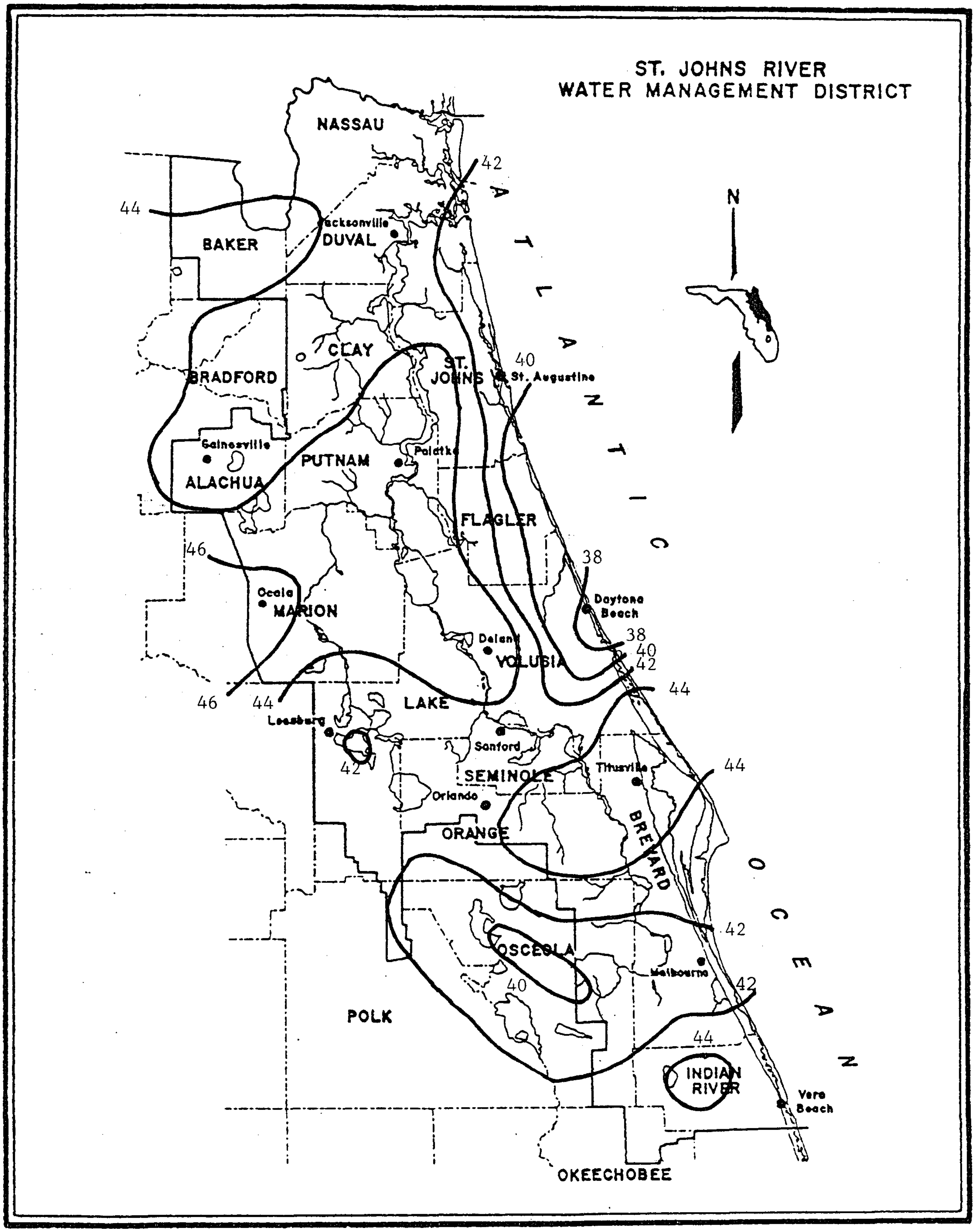

Figure 10. Annual minimum rainfall, inches, T = 5 yr

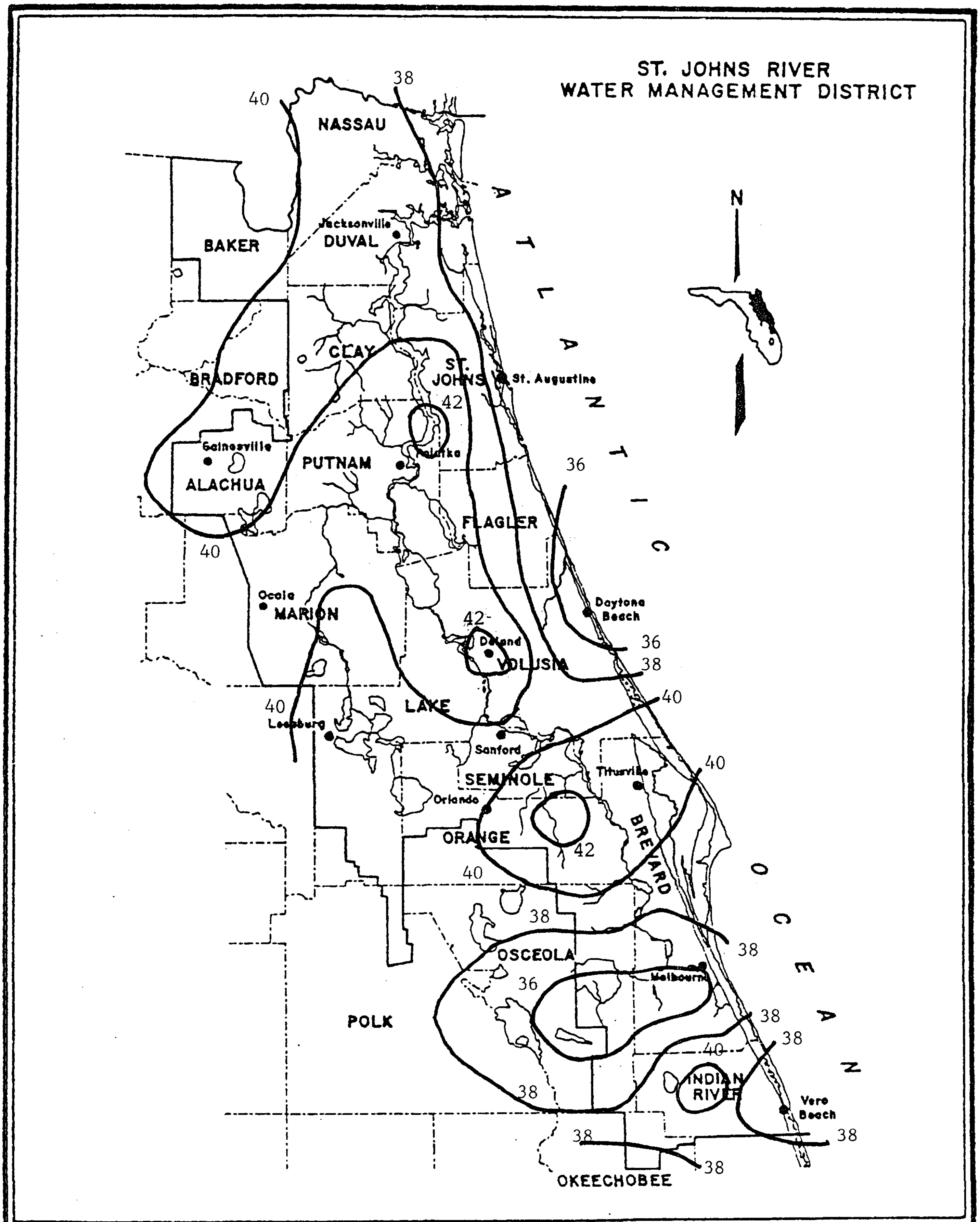

Figure 11. Annual minimum rainfall, inches, T = 10 yr

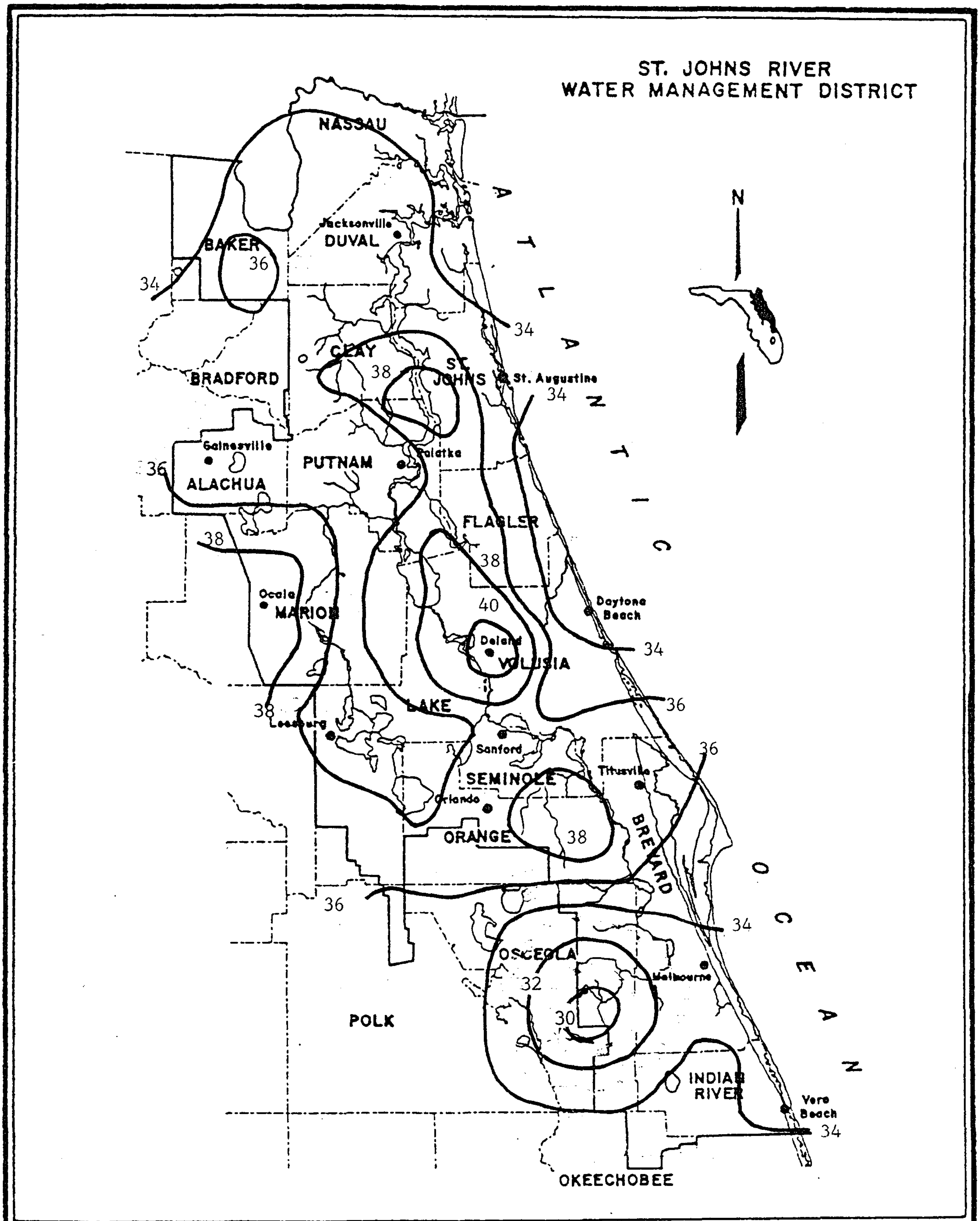

Figure 12. Annual minimum rainfall, inches, T = 25 yr

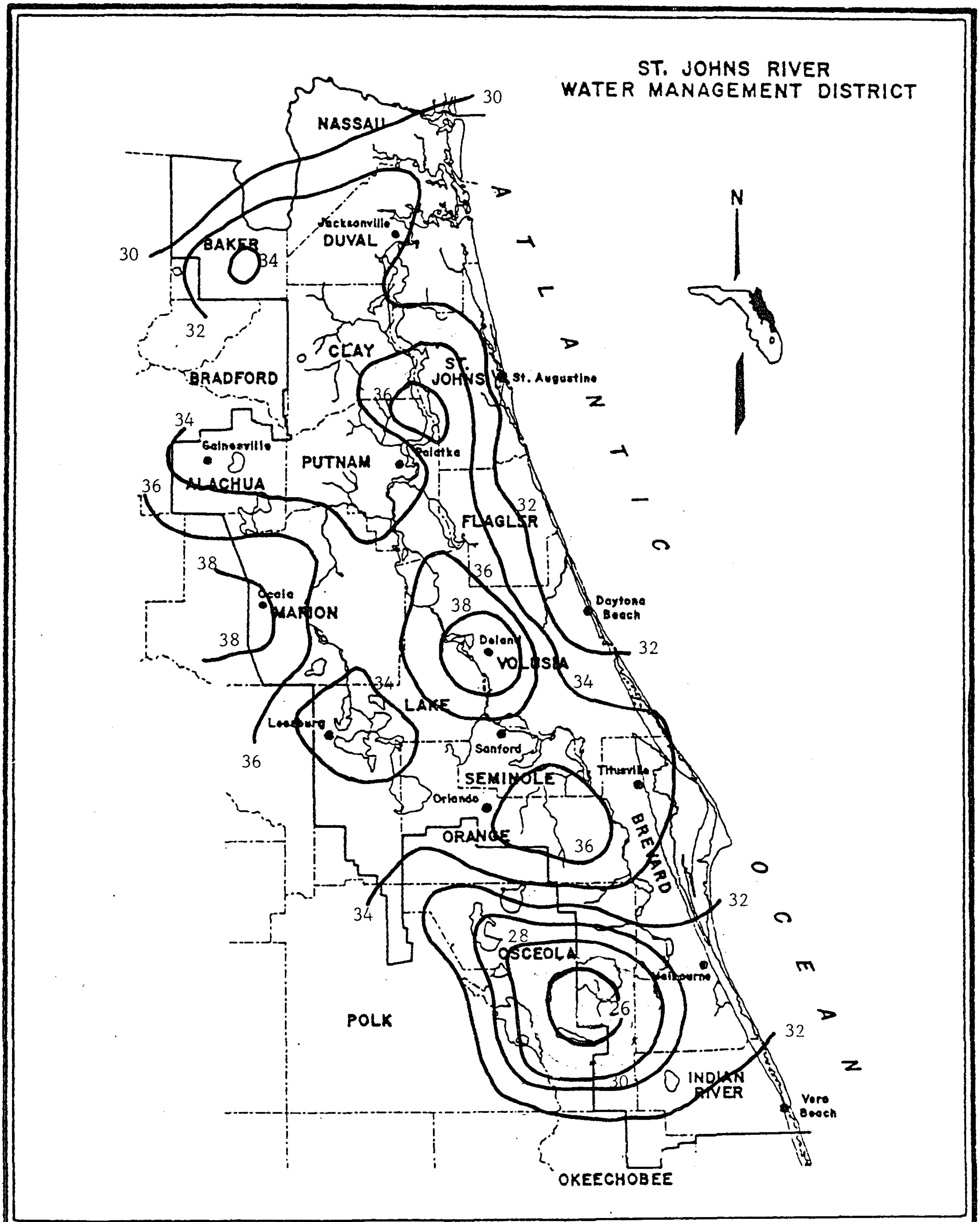

Figure 13. Annual minimum rainfall, inches, T = 50 yr

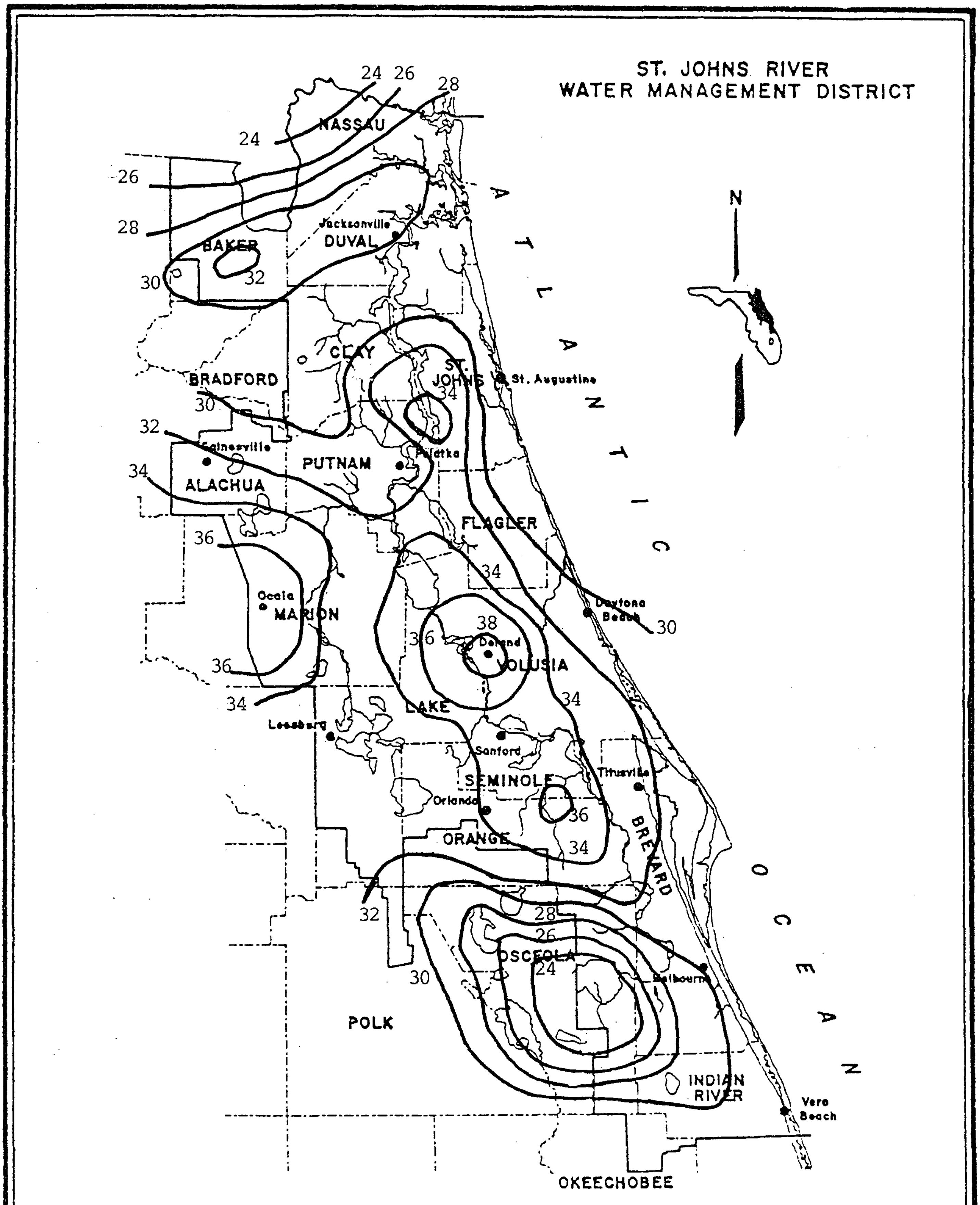

Figure 14. Annual minimum rainfall, inches, T = 100 yr

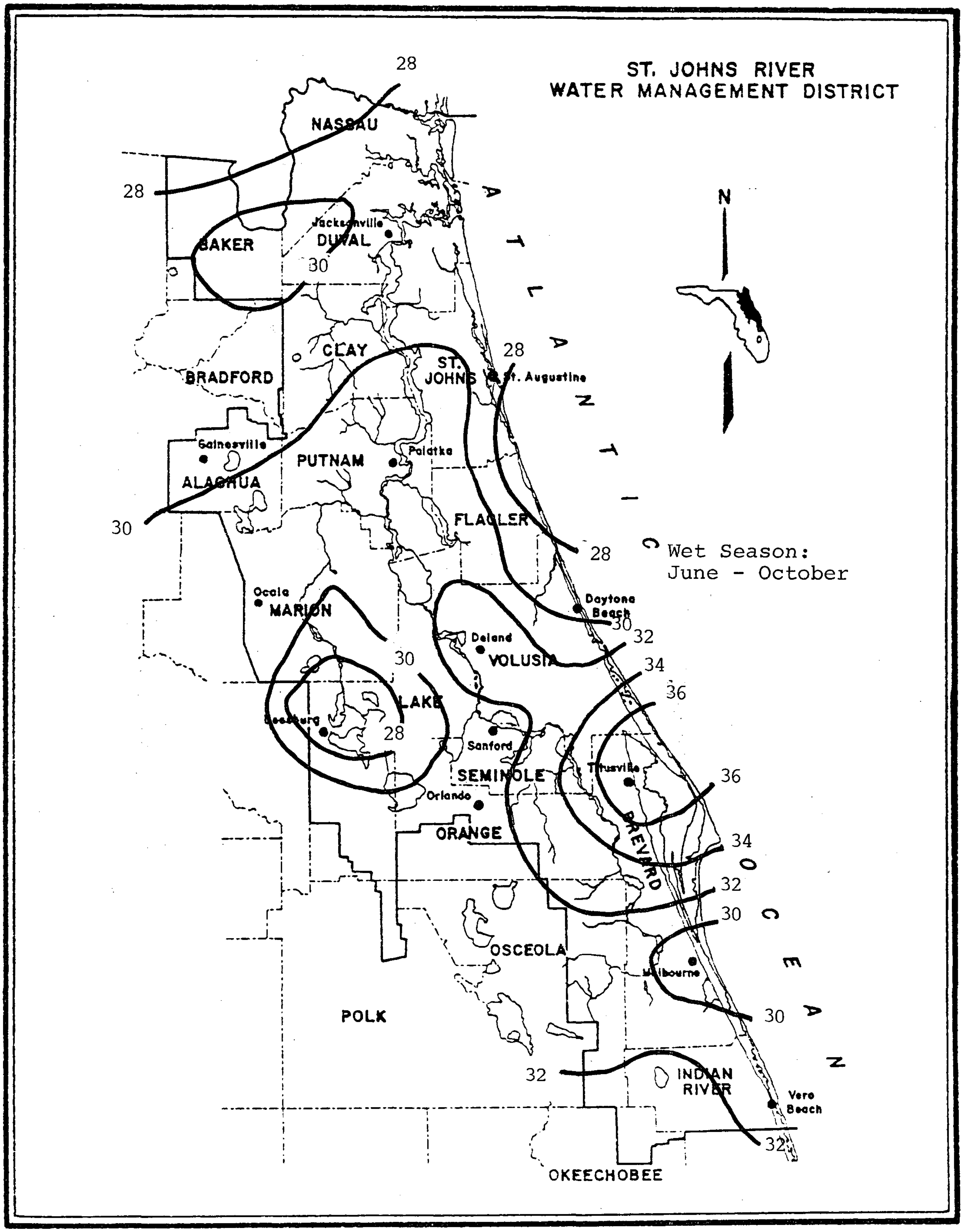

Figure 15. Wet season normal rainfall, inches

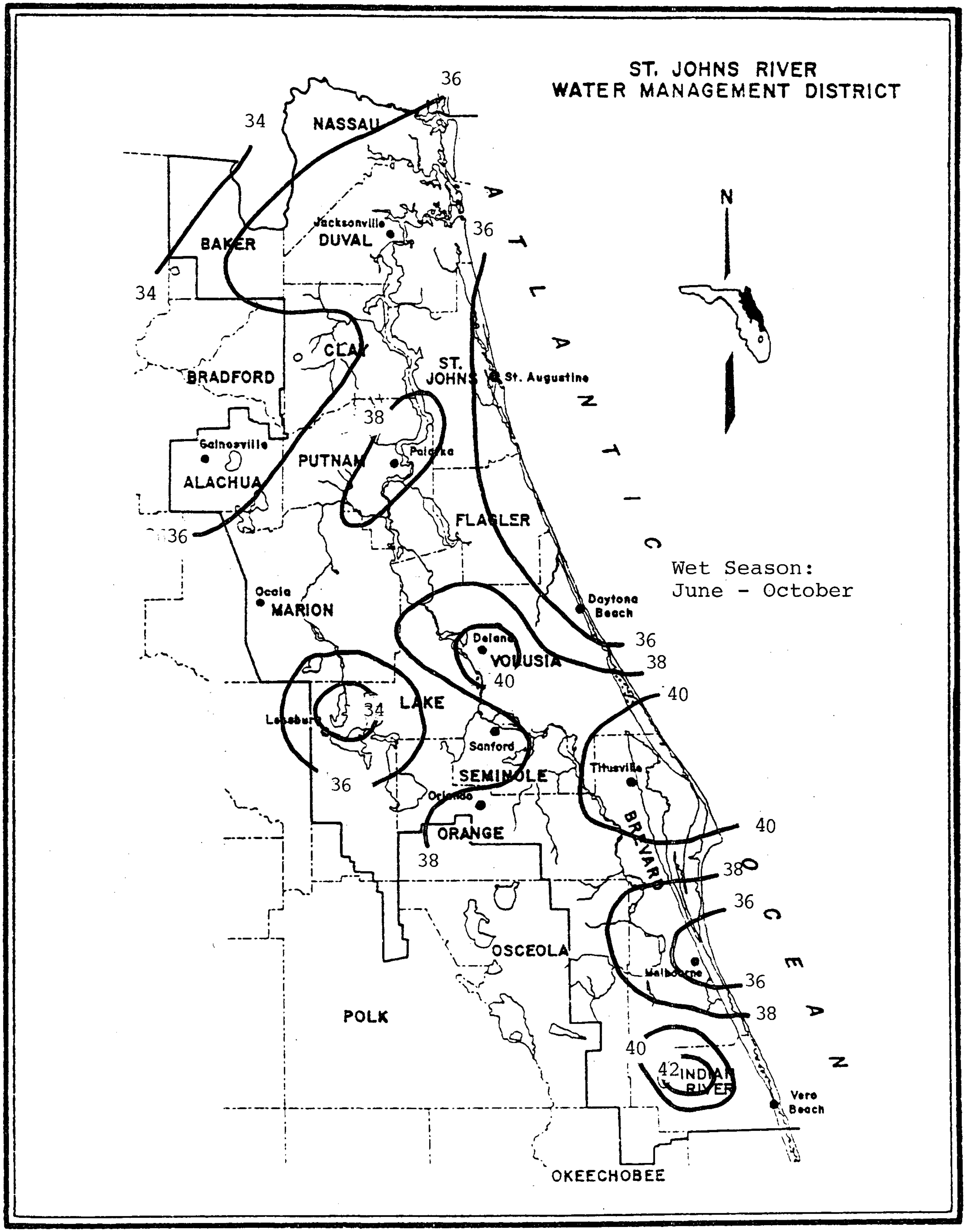

Figure 16. Wet season maximum rainfall, inches, T = 5 yr

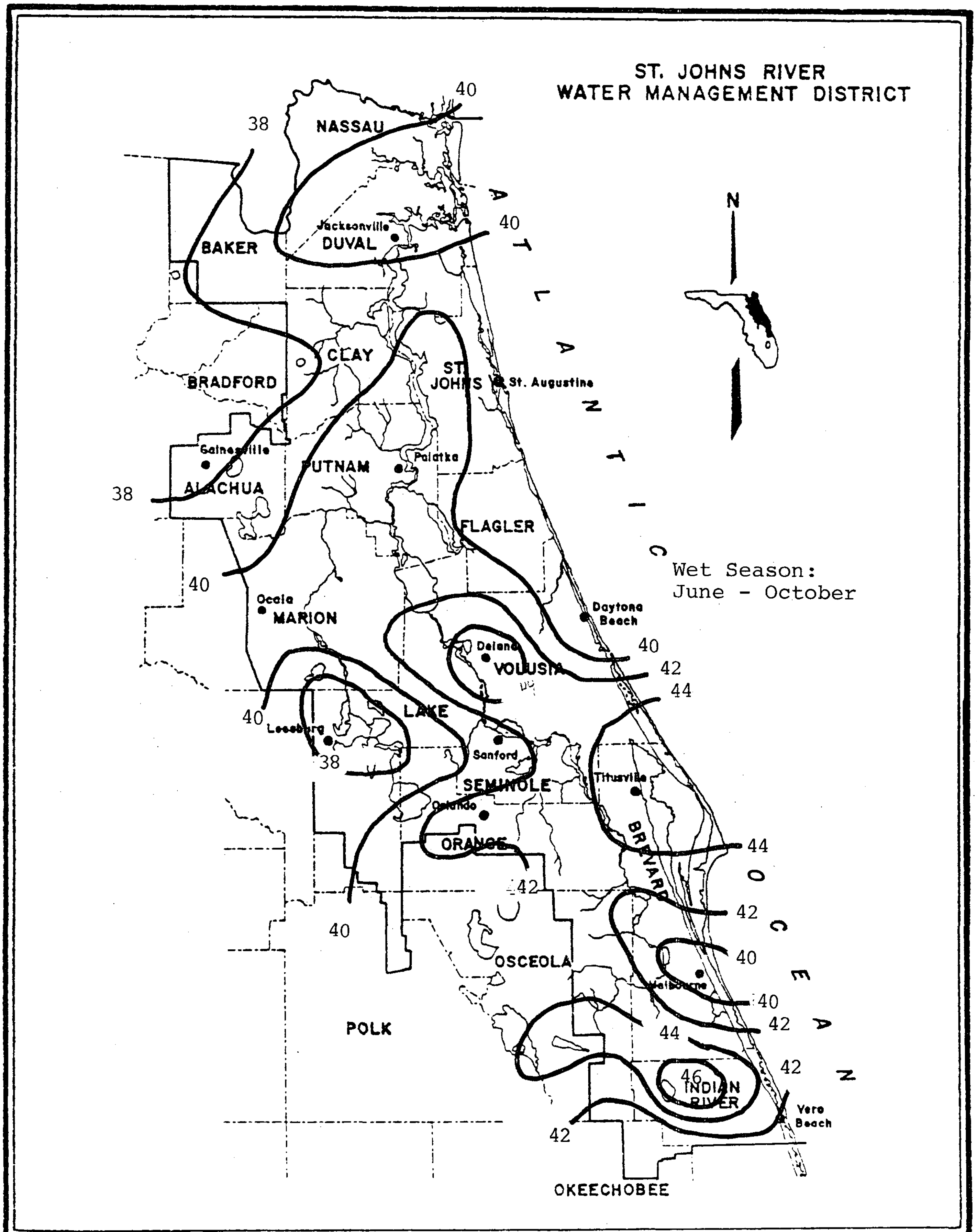

Figure 17. Wet season maximum rainfall, inches, T = 10 yr

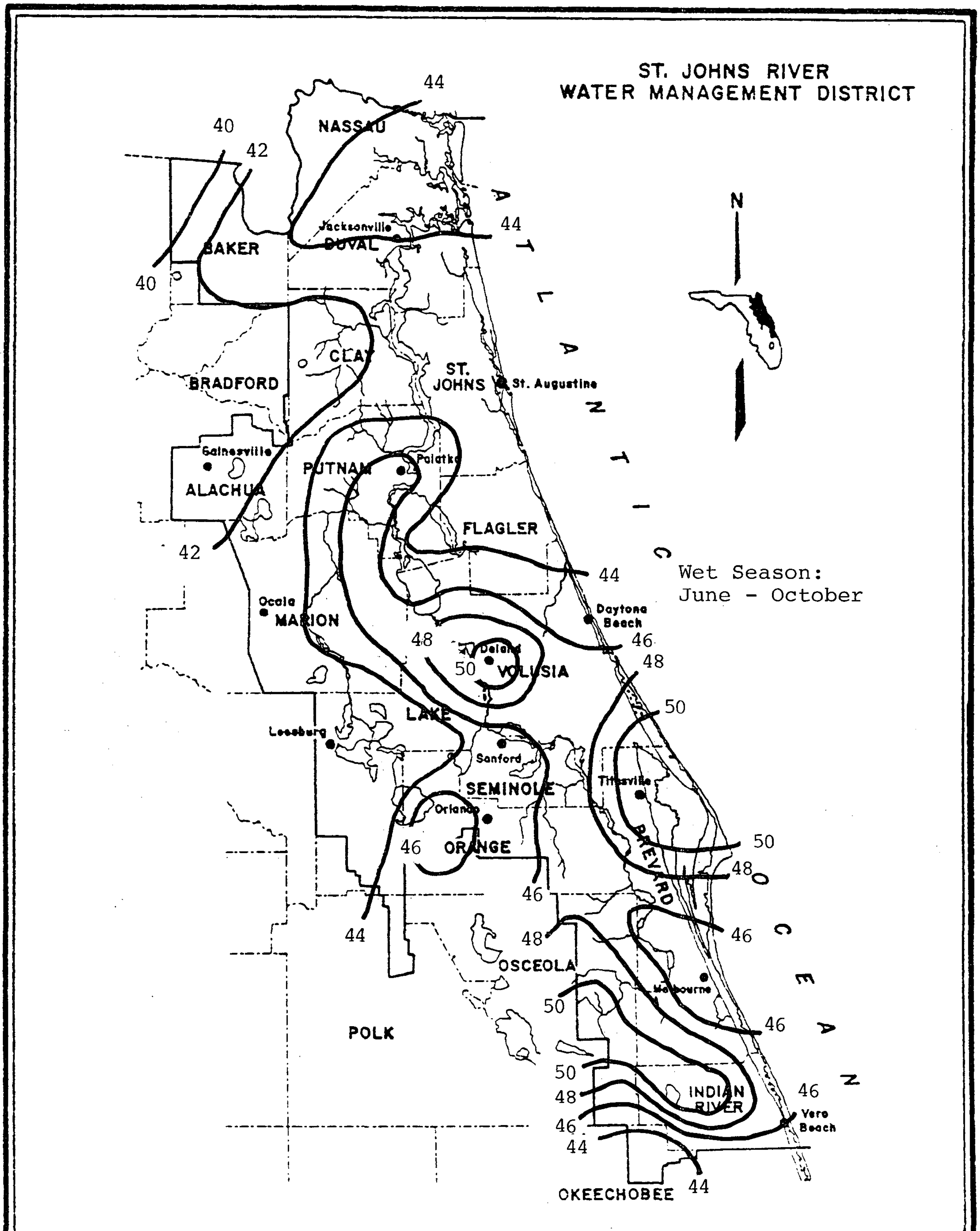

Figure 18. Wet season maximum rainfall, inches, T = 25 yr

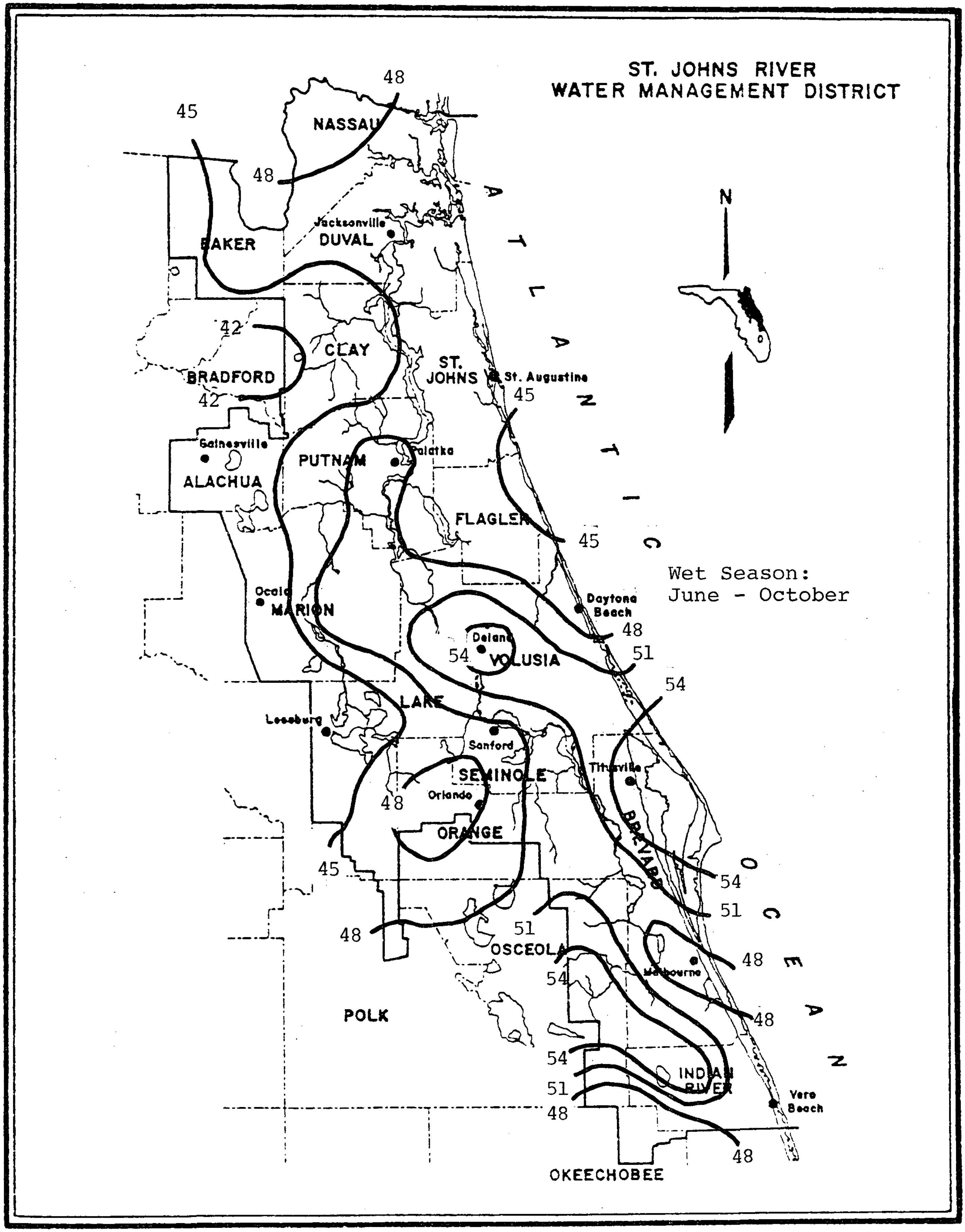

Figure 19. Wet season maximum rainfall, inches, T = 50 yr

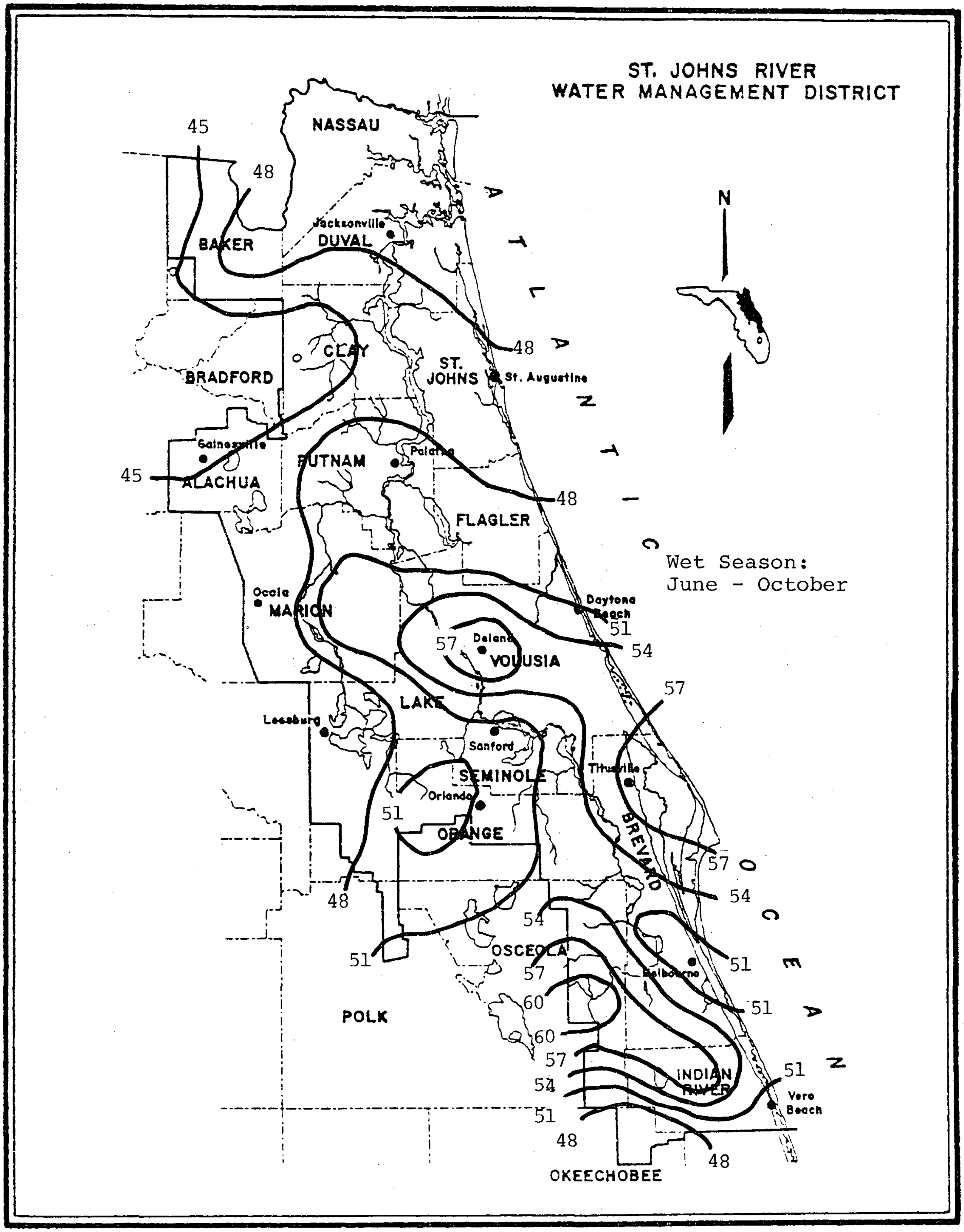

Figure 20. Wet season maximum rainfall, inches, T = 100 yr

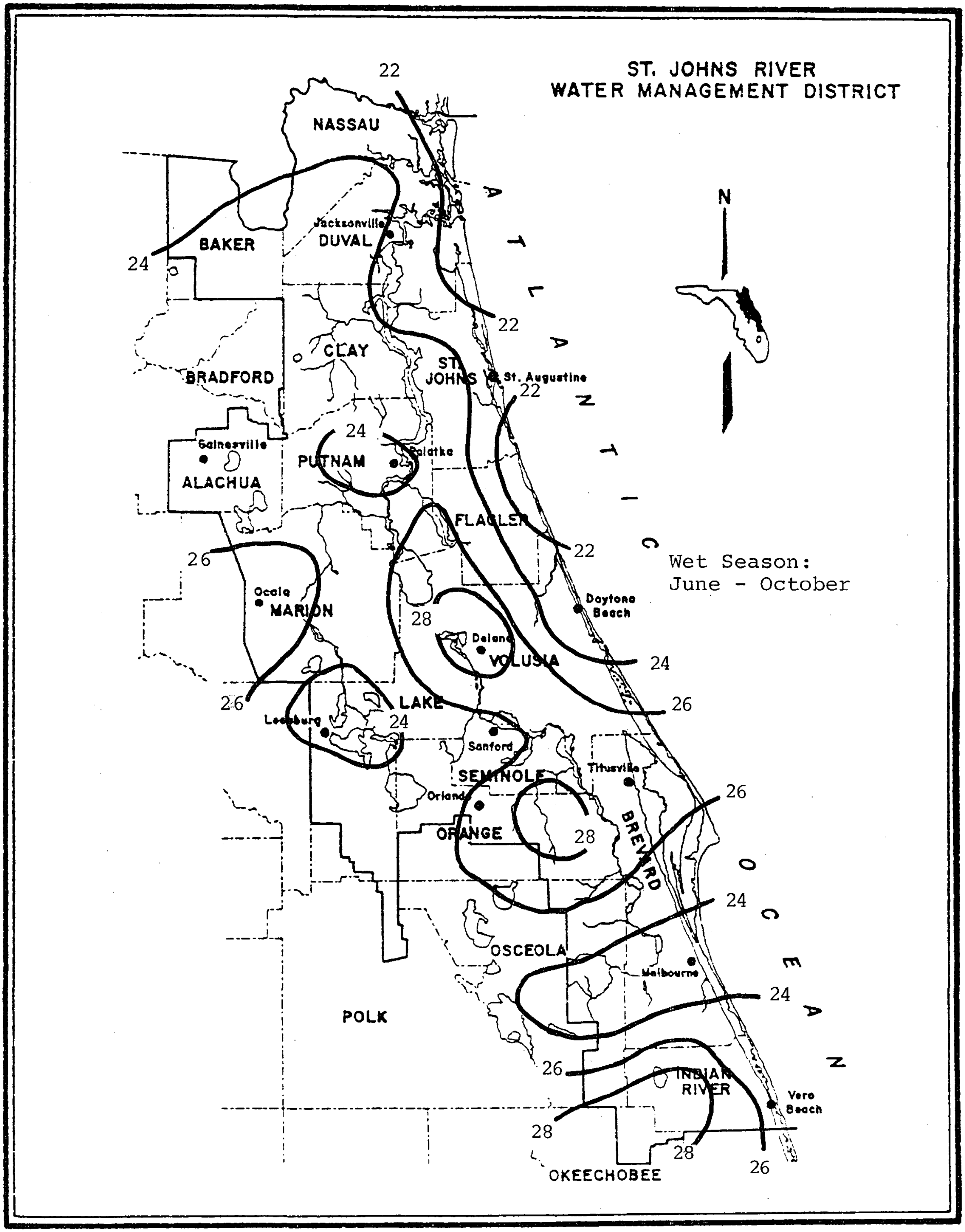

Figure 21. Wet season minimum rainfall, inches, T = 5 yr

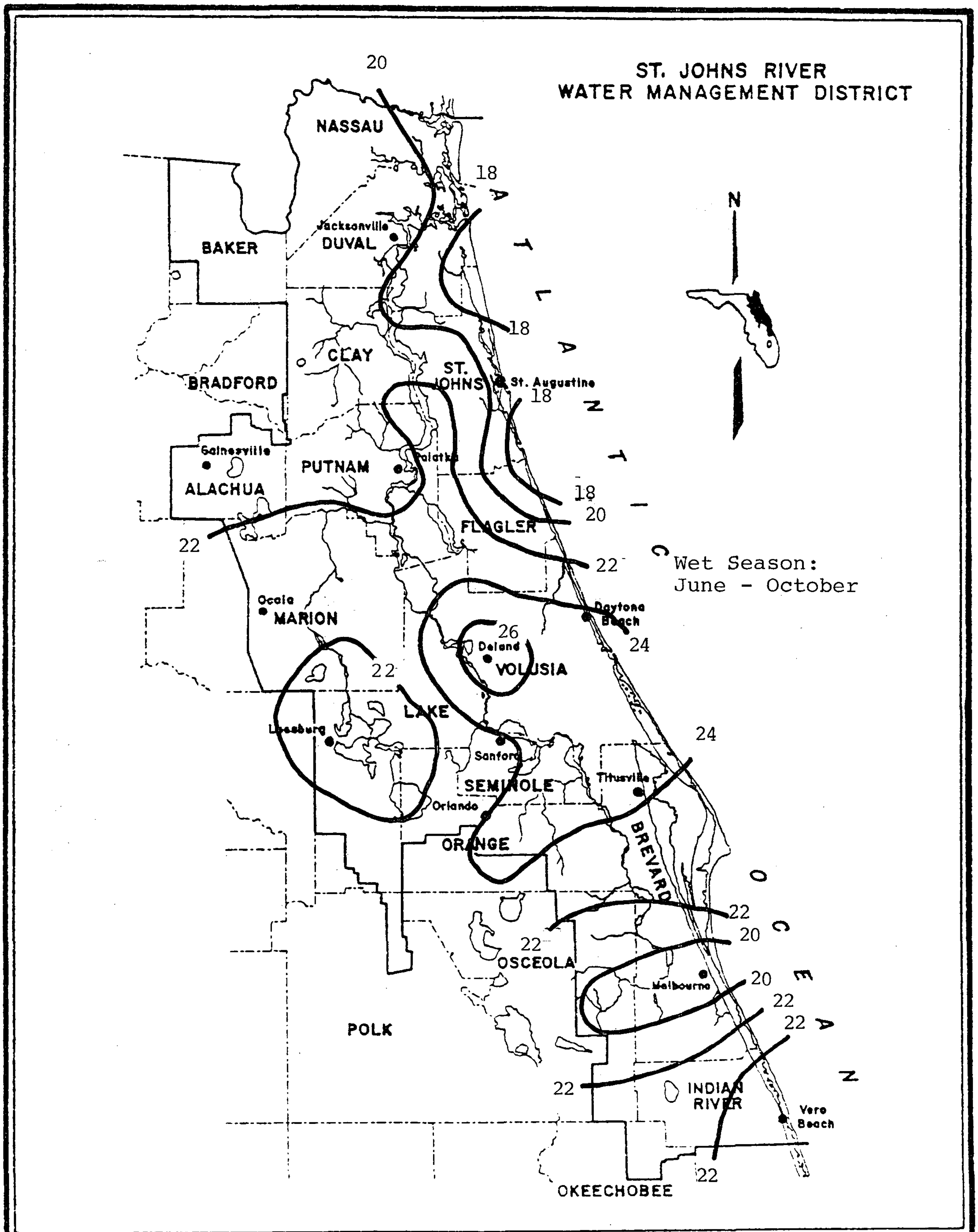

Figure 22. Wet season minimum rainfall, inches, T = 10 yr

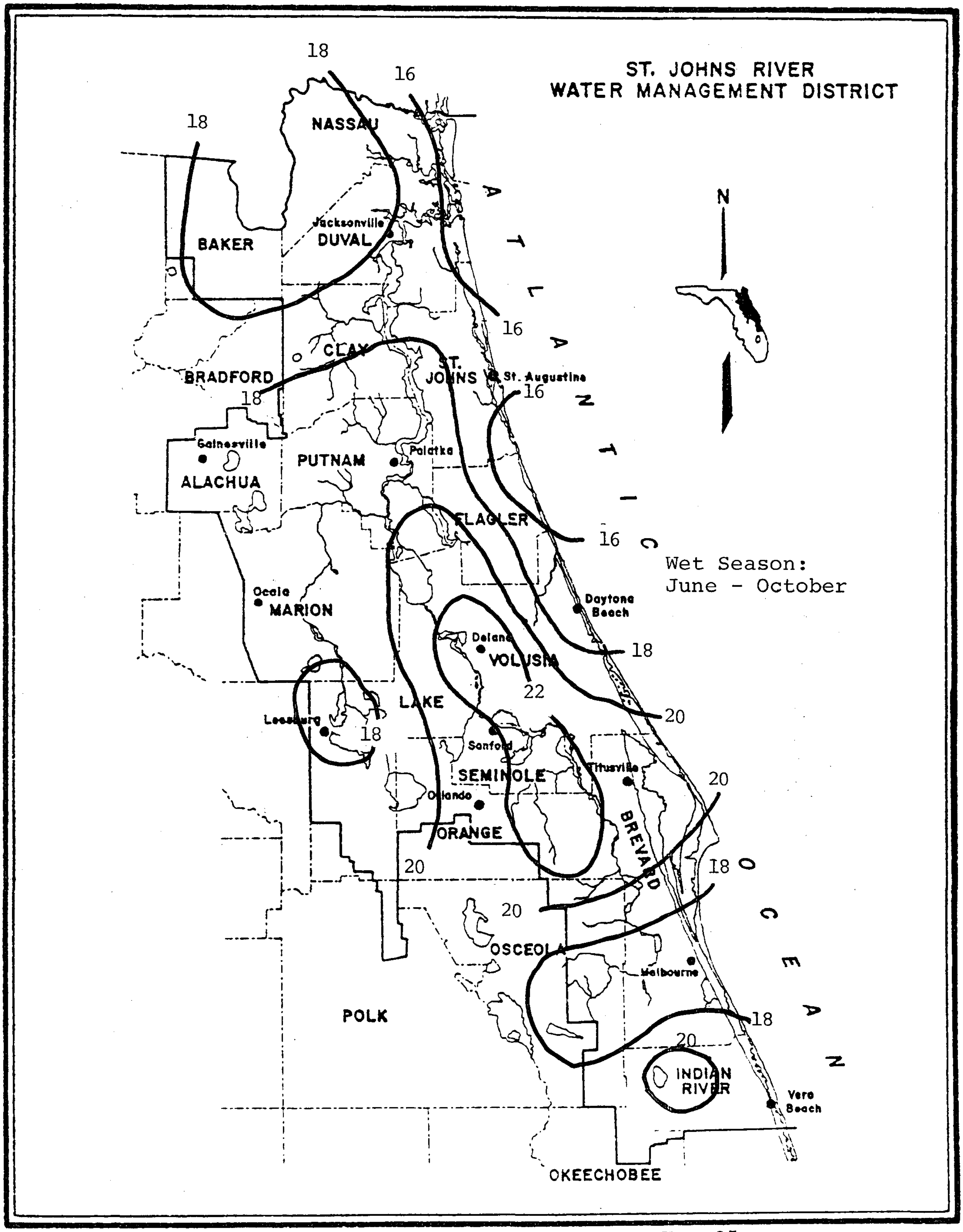

Figure 23. Wet season minimum rainfall, inches, T = 25 yr

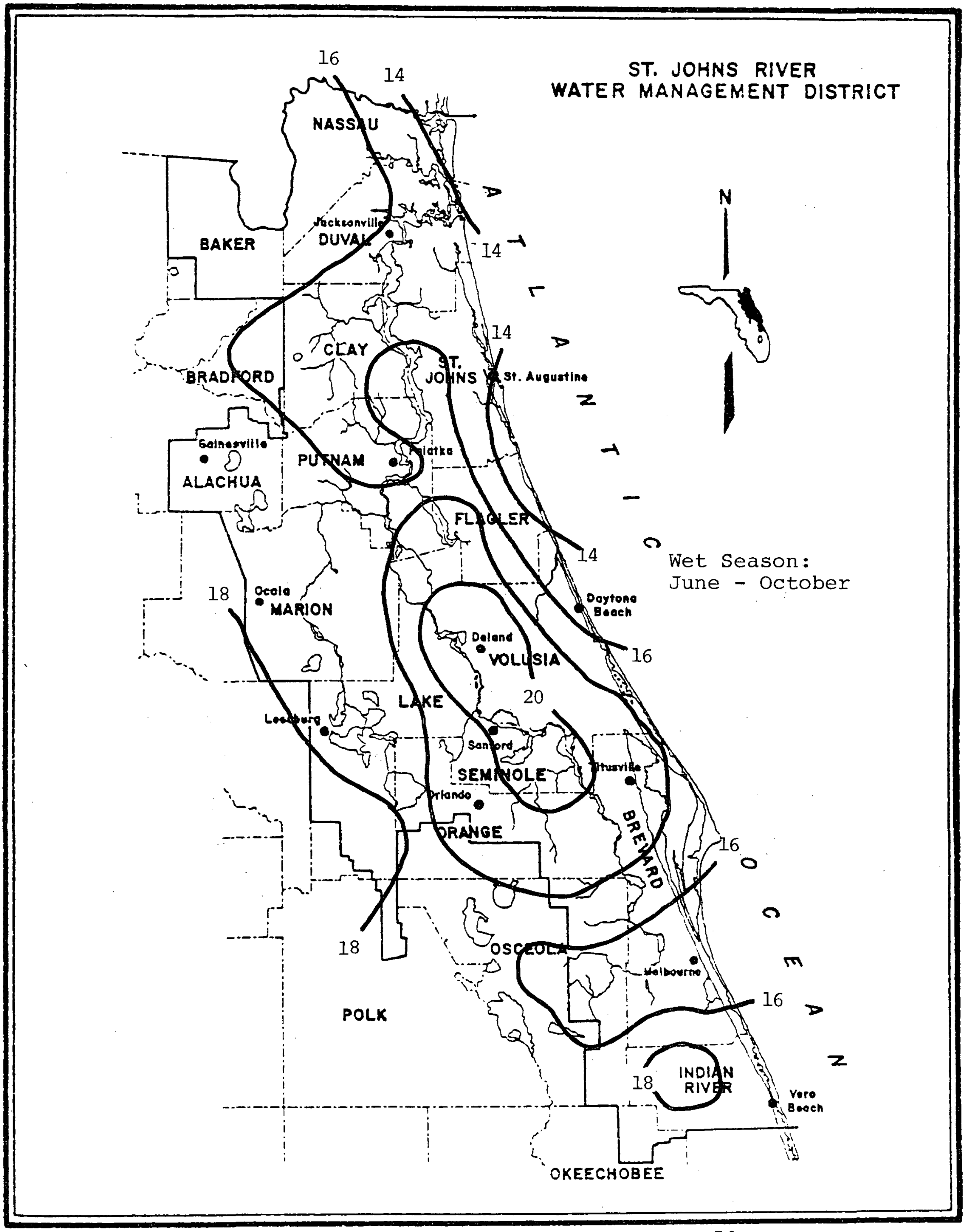

Figure 24. Wet season minimum rainfall, inches, T = 50 yr

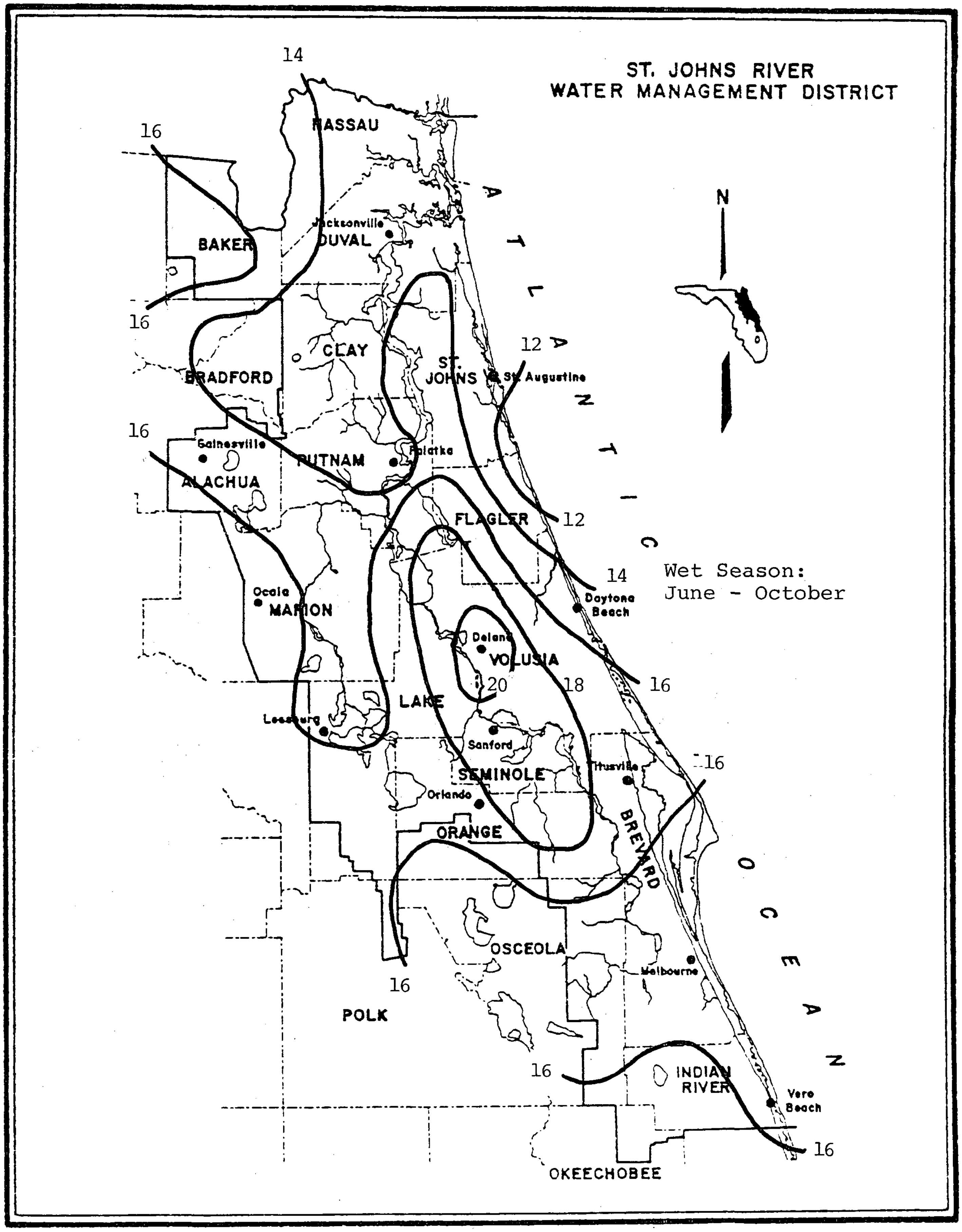

Figure 25. Wet season minimum rainfall, inches, T = 100 yr

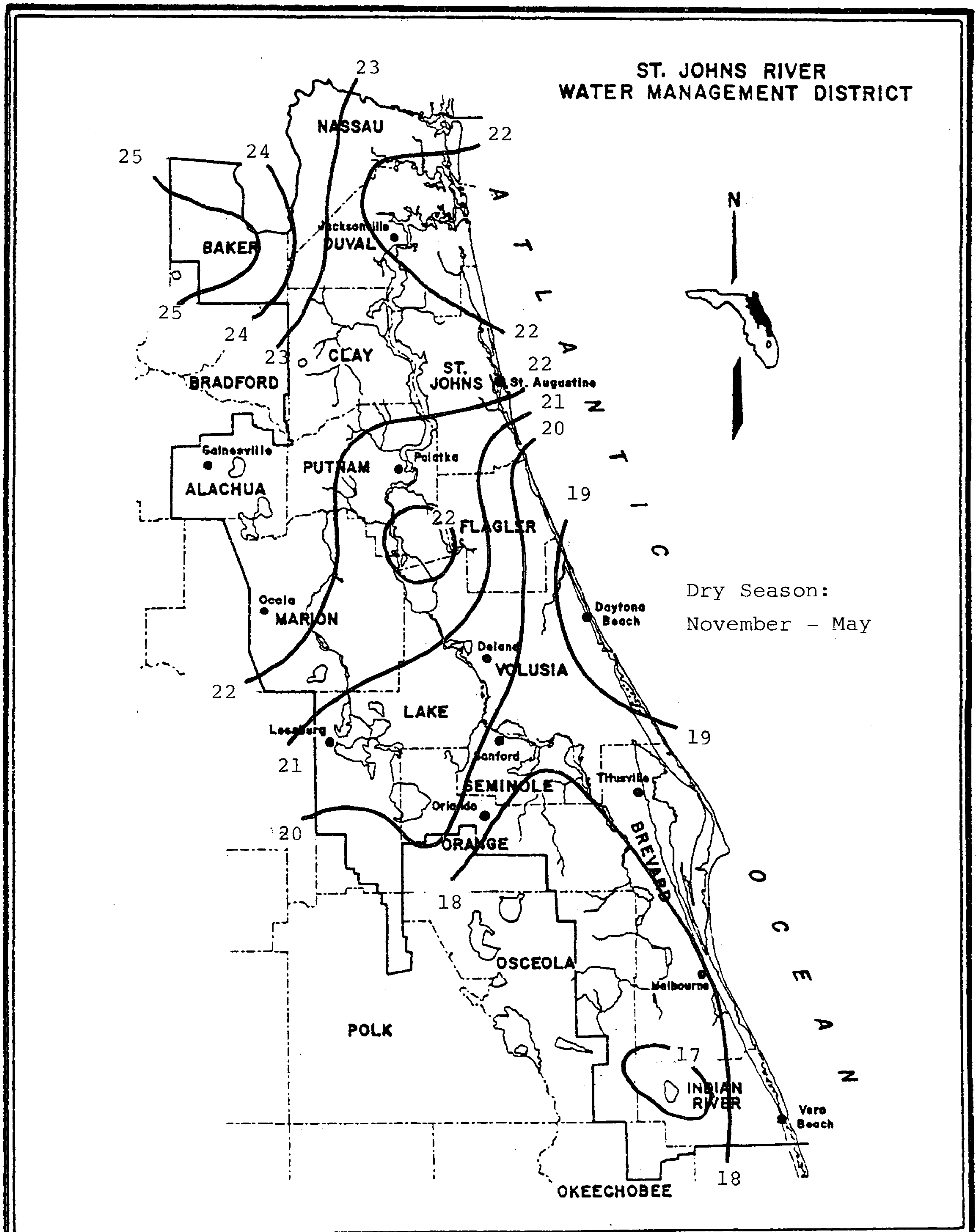

Figure 26. Dry season normal rainfall, inches

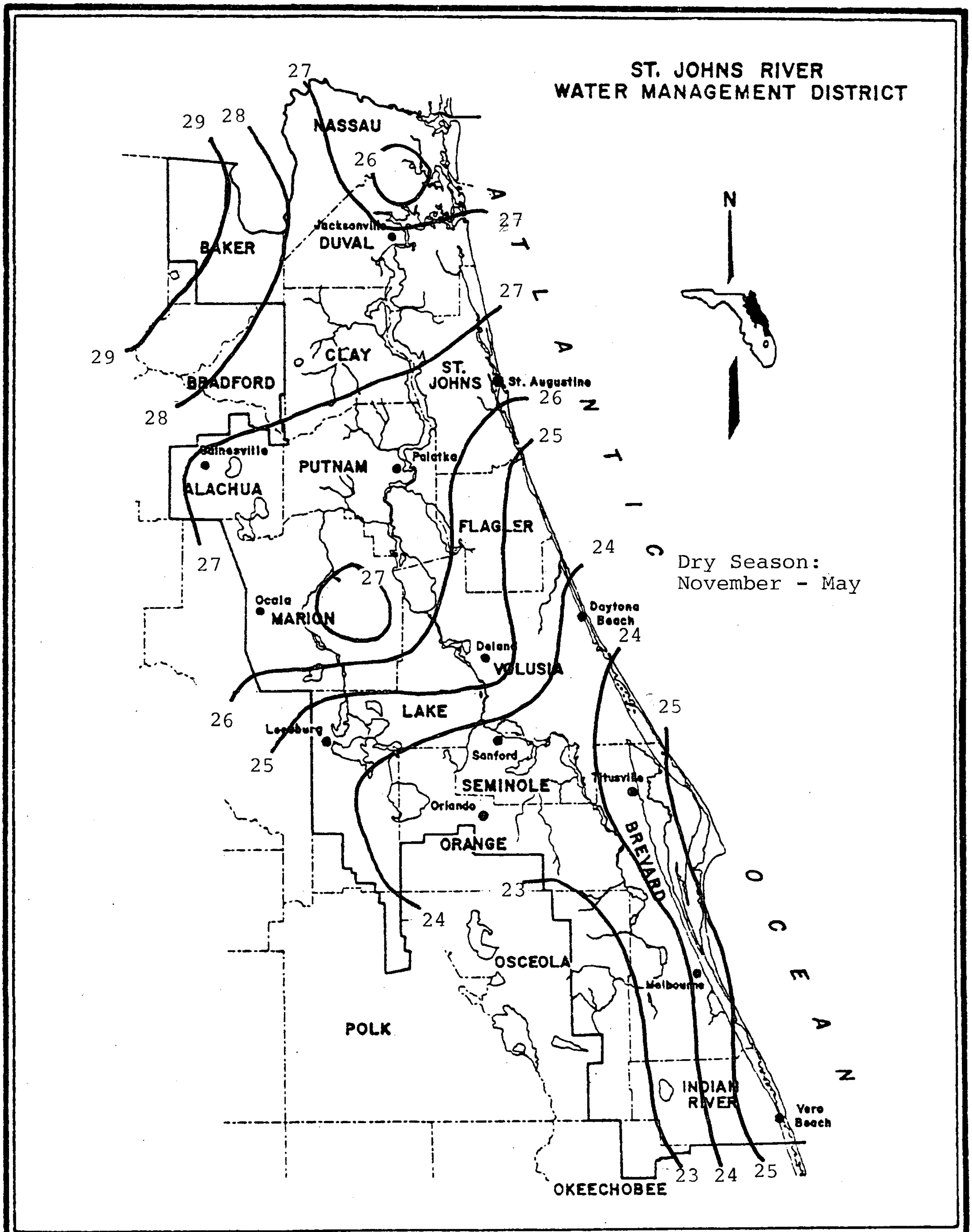

Figure 27. Dry season maximum rainfall, inches, T = 5 yr

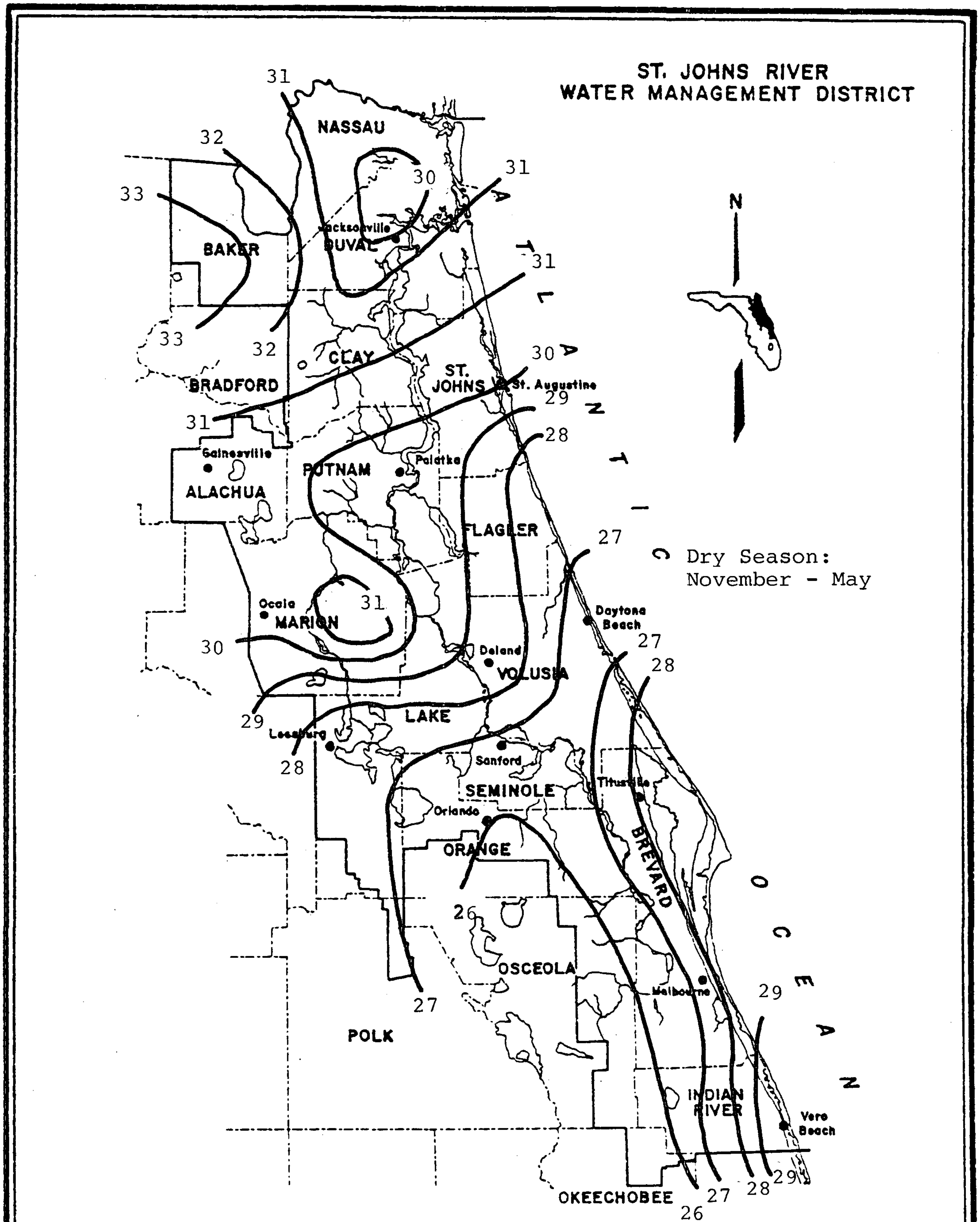

Figure 28. Dry season maximum rainfall, inches, T = 10 yr

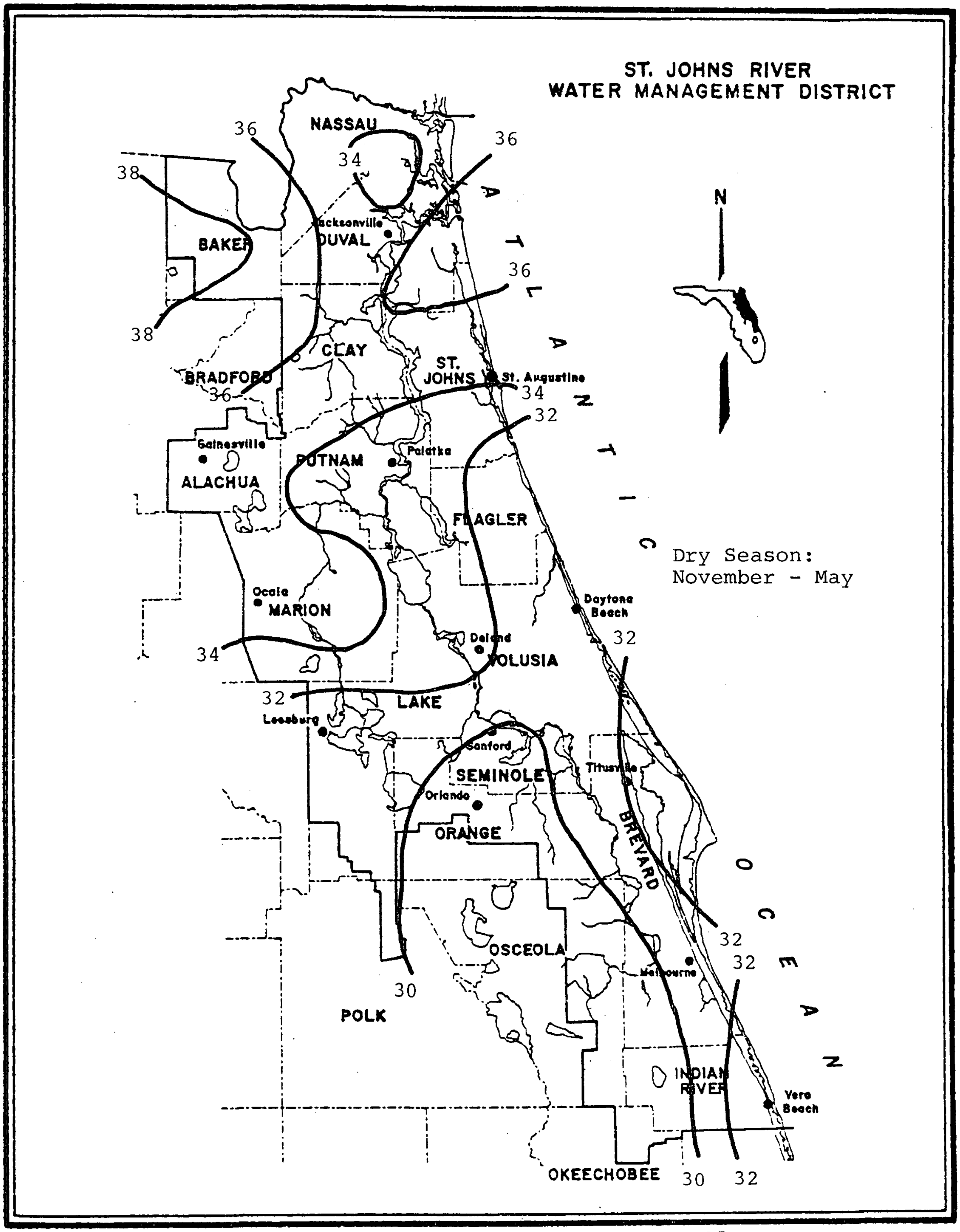

Figure 29. Dry season maximum rainfall, inches, T = 25 yr

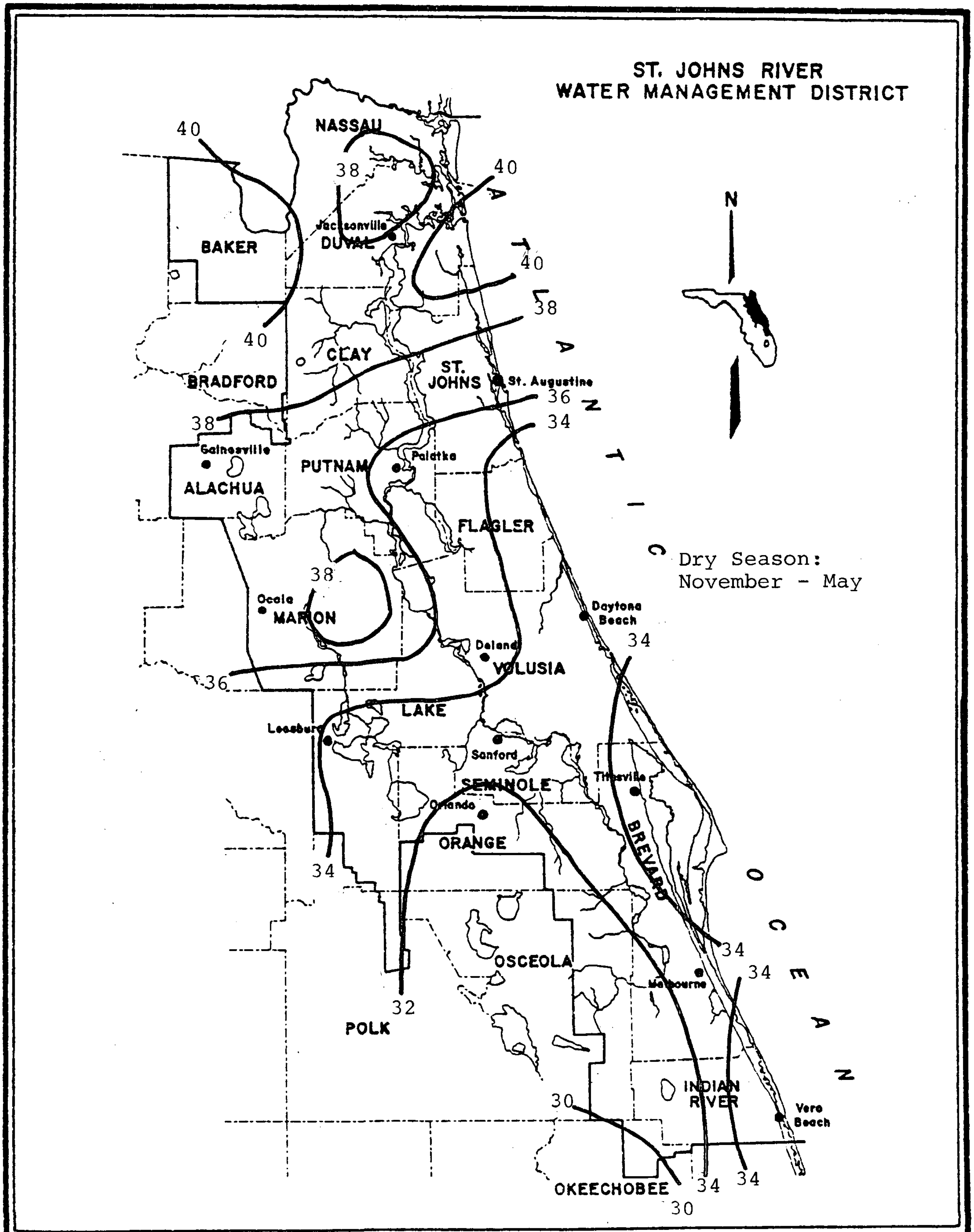

Figure 30. Dry season maximum rainfall, inches, T = 50 yr

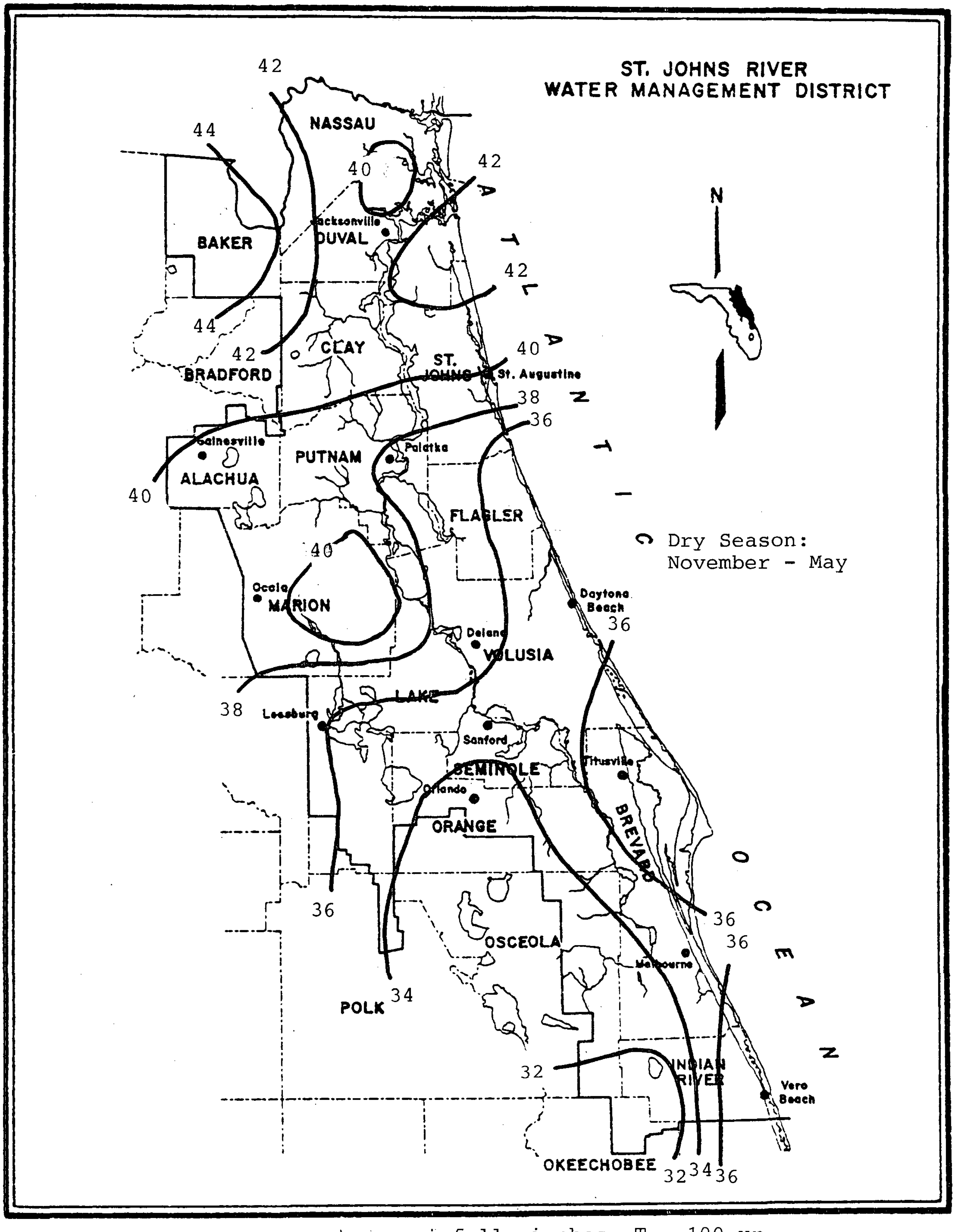

Figure 31. Dry season maximum rainfall, inches, T = 100 yr

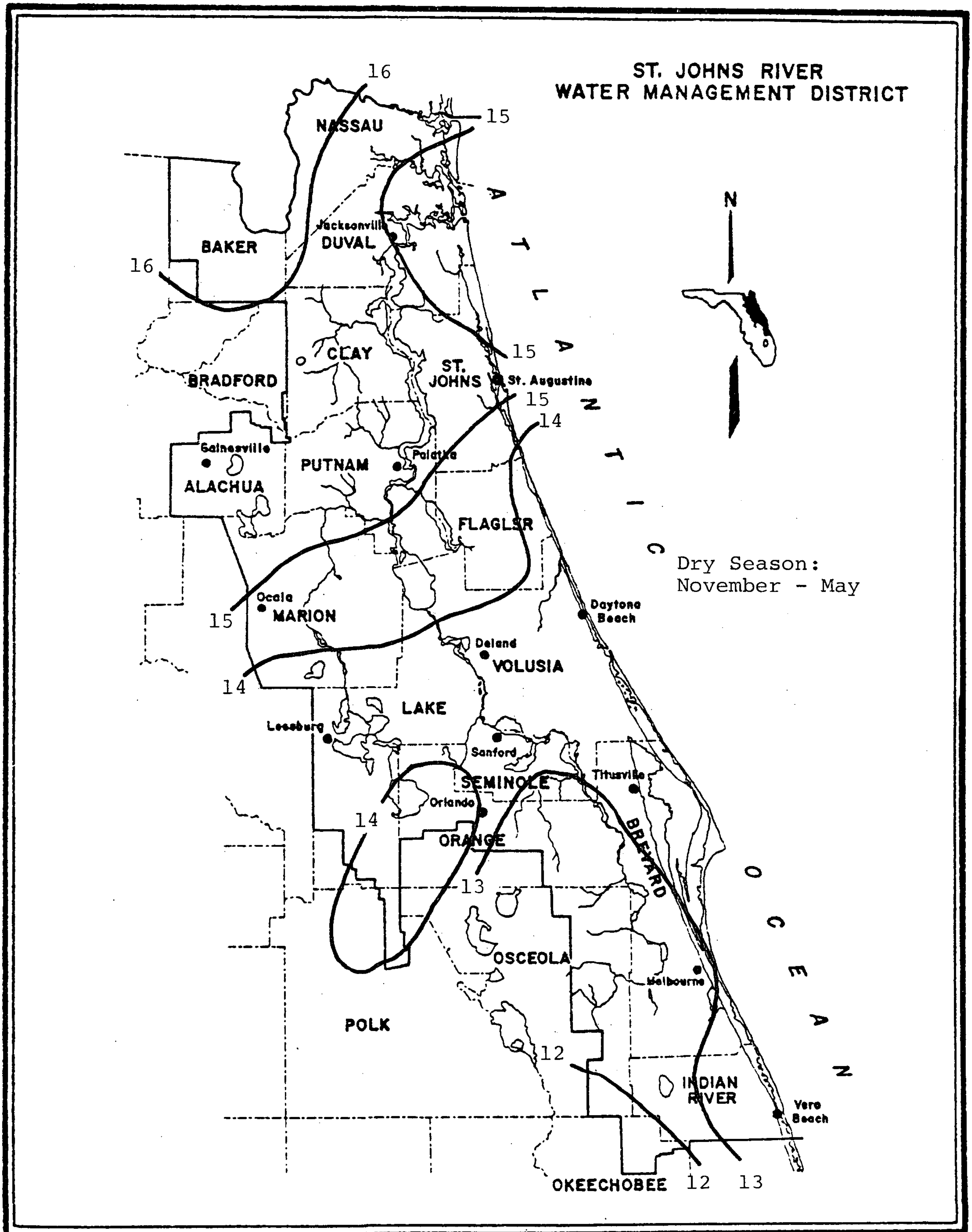

Figure 32. Dry season minimum rainfall, inches, T = 5 yr

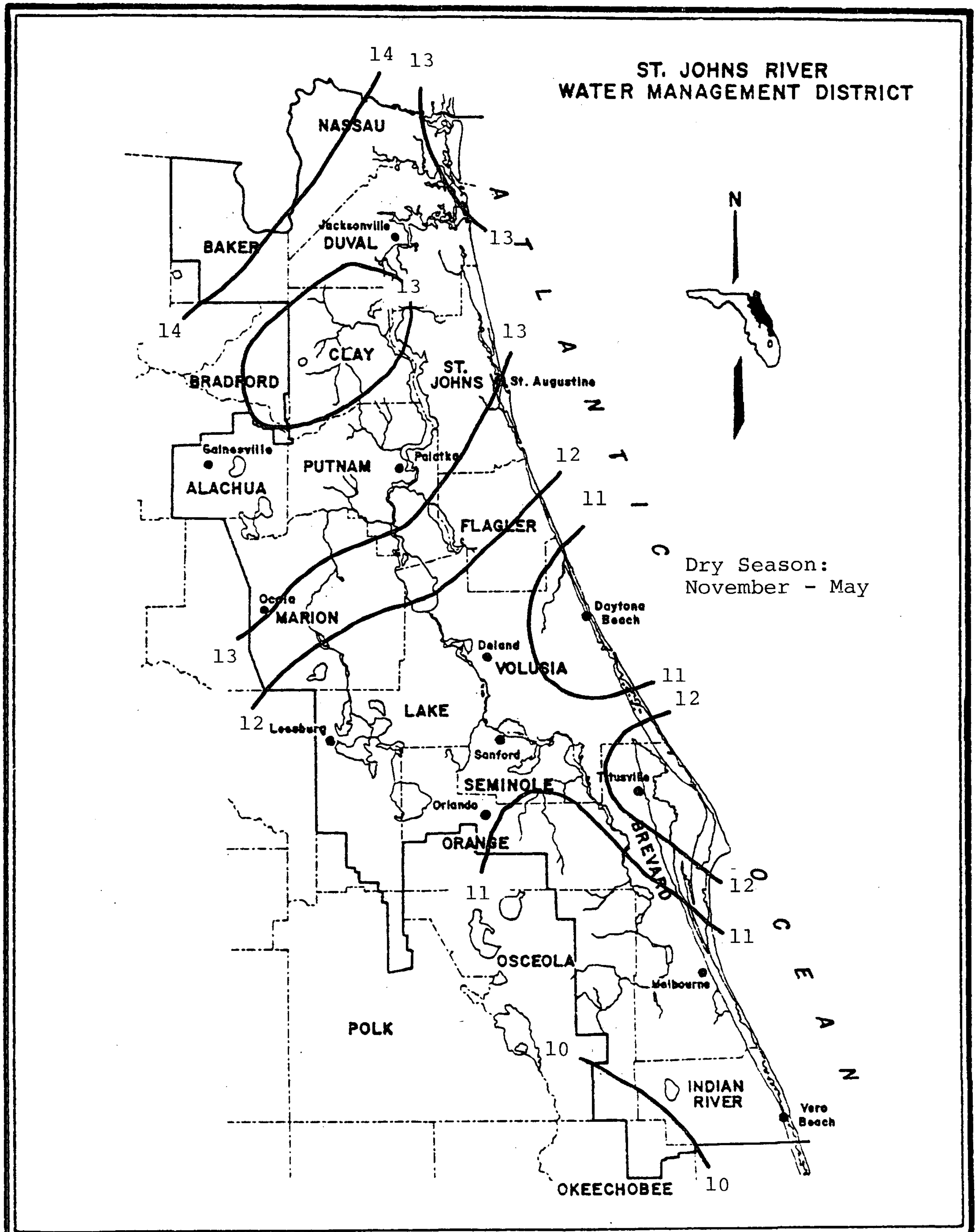

Figure 33. Dry season minimum rainfall, inches, T = 10 yr

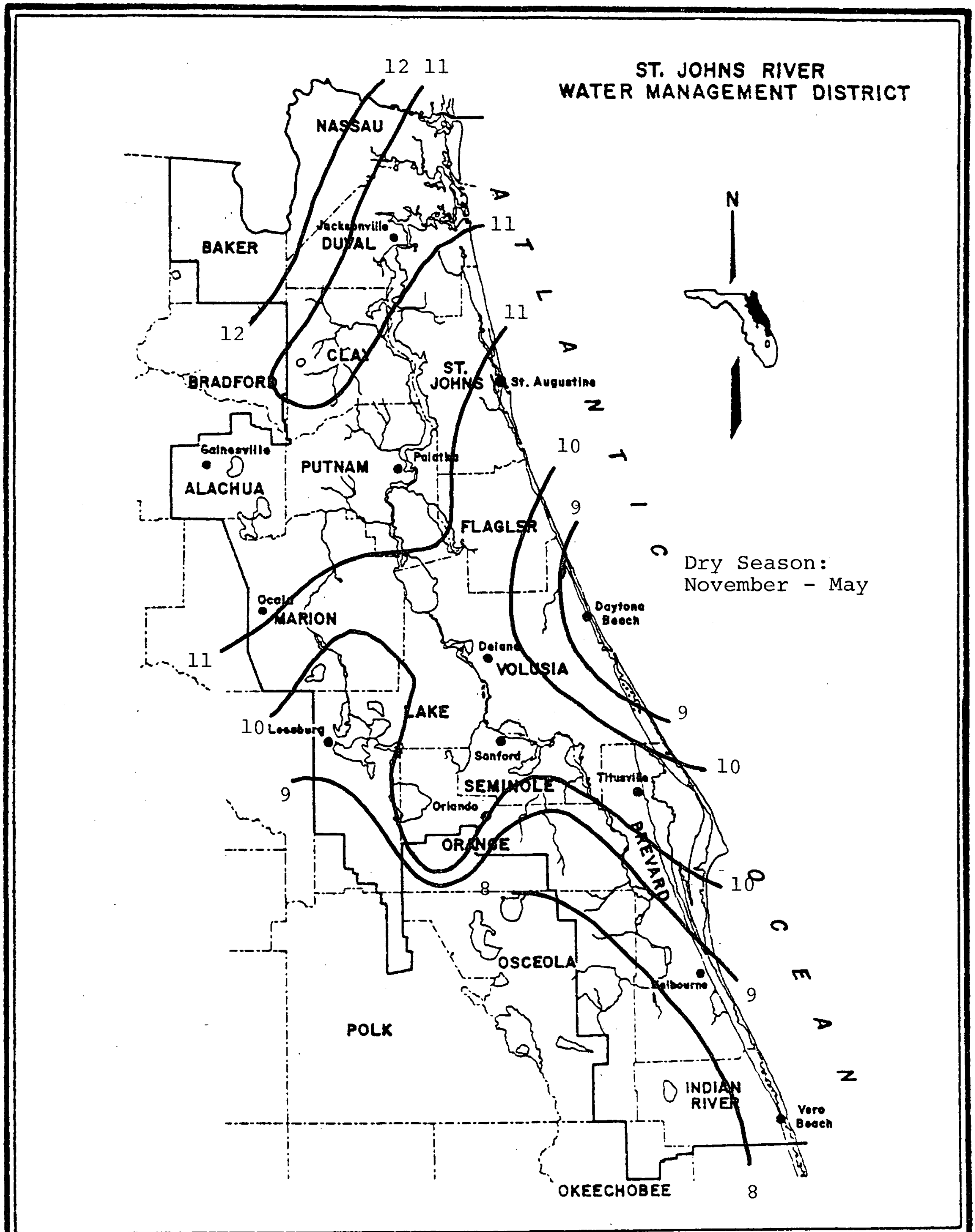

Figure 34. Dry season minimum rainfall, inches, T = 25 yr

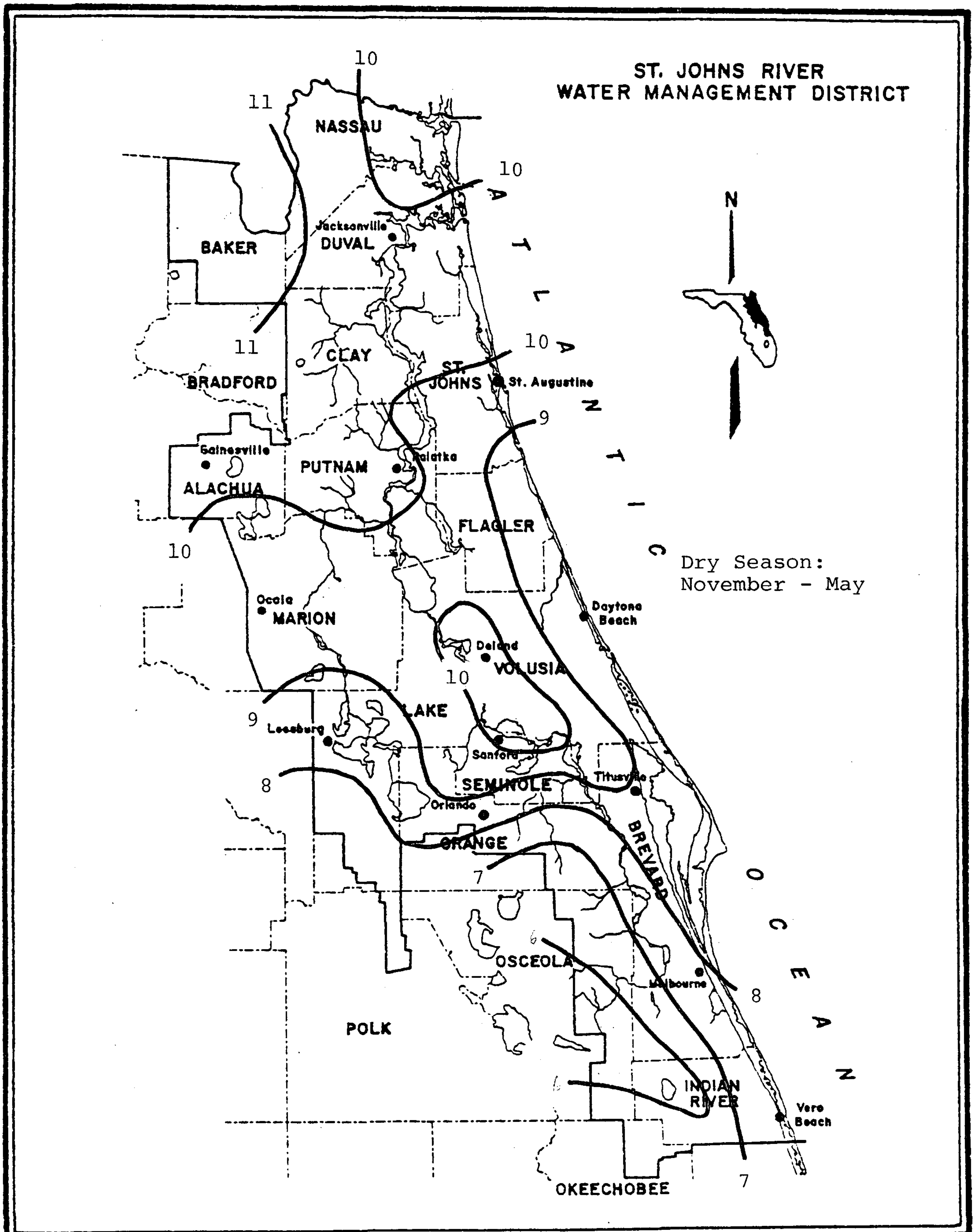

Figure 35. Dry season minimum rainfall, inches, T = 50 yr

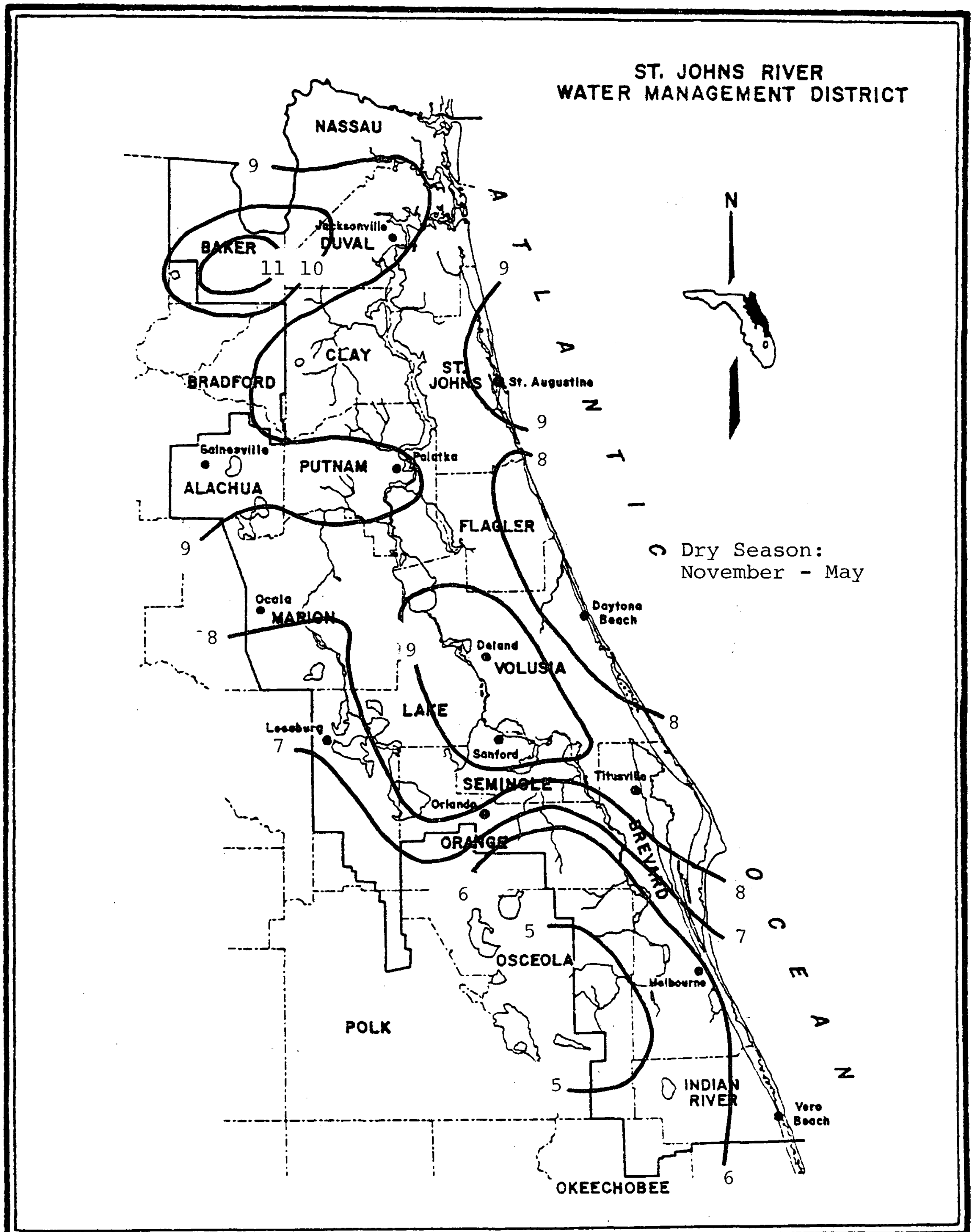

Figure 36. Dry season minimum rainfall, inches, T = 100 yr