APPENDIX C

Rainfall

Figures

Tables

C.1: SFWMM V5.5 RAINFALL

Source: Final Documentation for the South Florida Water Management Model (v5.5)

The NSRSM base condition uses the rainfall dataset developed for the SFWMM.

In all South Florida Water Management Model (SFWMM) runs, rainfall is assumed to have the same temporal and spatial distribution as that which occurred historically over the period of simulation. Since rainfall is the main driving force in the hydrology of South Florida, it serves as a good control variable for evaluating alternative ways of managing the system as a whole. For the distributed mesh portion of the model, a daily time series of rainfall depths for each grid cell is used. For Lake Okeechobee and other lumped hydrologic systems, a single daily time series of rainfall depths is input and assumed to apply over the spatial extent of the basin. The general procedure for the development of the rainfall data set in the SFWMM can be described as follows: data collection and associated quality assurance/quality control (QA/QC) or screening of rainfall station data; and transformation of rainfall point data into grid-based data.

2.2.1 Quality Assurance/Quality Control of Rainfall Data

Rainfall data was collected with the goal of generating a 2-mile x 2-mile “super grid” covering nearly the entire South Florida Water Management District (SFWMD or District) for the 1914 to 2000 period of record. The spatial extent of the super grid was determined to be larger than that of the computational grid for the SFWMM in order to allow for determination of rainfall in the Natural System Model (NSM) as well as to provide rainfall information for the lumped portions of the SFWMM. The primary reason for creating a rainfall data file with a greater period of record than required by the modeling period of simulation (1965 to 2000) was to support identification of monthly and annual data trends.

Because of data availability issues, the rainfall data for the period from 1914 to 1998 were processed separately from the period of 1999 to 2000; however, the exact same procedure was used for both time periods. For the period from 1914 to 1998, there were 860 rainfall stations covering 11 counties (Broward, Highlands, Martin, Palm Beach, Collier, Glades, Monroe, Miami-Dade, Hendry, St. Lucie and Okeechobee). For the period 1999-2000, rainfall data at 964 stations covering the same counties were available. Figure C.1-1 identifies the location of rainfall stations used in the creation of the SFWMM data set.

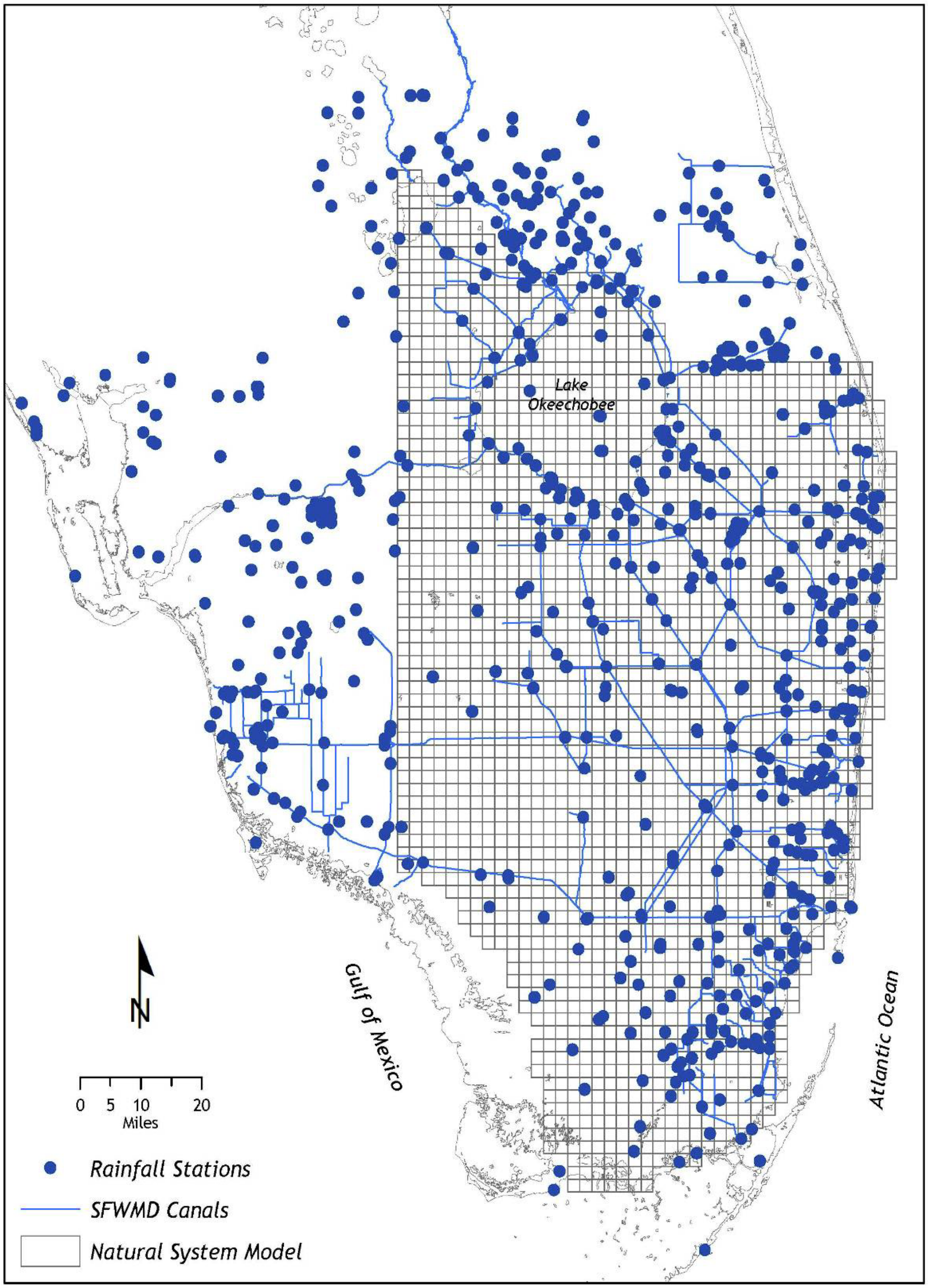


Figure C.1-1 Location of Rainfall Stations

QA/QC of rainfall station data sets was carried out in five phases, with a number of methodical steps to complete each phase. The five phases were as follows:

1. Review and classification of daily data having extreme values.
2. Testing and elimination of some extreme daily values.

3. Screening of data with zero monthly rainfall.
4. Screening of rainfall data having extreme low annual values and high monthly values.
5. Data screening through visualization.

The first two phases were designed to identify and remove daily values that were highly questionable according to a prescribed classification scheme, while the third and fourth phases were designed to identify and remove data associated with stations that were not consistent with monthly and annual trends. The last phase provides final QA/QC through data visualization. Appendix P presents a memorandum describing, in detail, the phases and steps used. Short descriptions of the QA/QC phases are provided in the following sections. It is important to note that during these phases, screening criteria were developed from both the raw rainfall station data and from analysis of the gridded representation of the data. The methodology for the development of the gridded data will be discussed in Section 2.2.2.

Phase I: Identification and Classification of Extreme Daily Rainfall Values

In the first pass, daily rainfall values greater than 16 inches were flagged as questionable. Additionally, daily rainfall values less than 16 inches but higher than 5.5 inches in Miami-Dade, Broward and Palm Beach counties, and 5 inches in the other counties of the SFWMD area were flagged as questionable. The lower threshold values for questionable data represent approximately the 99.9 percentile in each respective county. For each day when at least one questionable data point was identified, values from the nearest six stations were extracted into a data set. For each of the resulting data sets, a classification scheme (having seven classes based on distance and value difference) was used to automatically accept or mark values for further review. After automatic acceptance of two of the classes, and marking the other five classes as questionable, the rainfall data set was recreated and reviewed using grid summaries and viewing programs.

Phase II: Examination of Extreme Daily Rainfall Data

During this phase, the values identified as questionable in Phase I, were further analyzed for either acceptance or rejection. Using the nearest six stations, a manual examination of the questionable values was conducted which included consideration for: distance, direction, difference in values, number of neighbors with high values, time of year, frequency of reoccurrence in the period of record and known tropical storm events.

Phase III: Examination of Daily Data Corresponding to Zero Monthly Rainfall

In this phase, efforts were made to identify and verify rainfall data for calendar months with zero rainfall. The objective was to reject or accept such data based on prescribed criteria. Part of this process was automated and part was performed manually. For each county, calendar months with zero rainfall data are extracted into a file and the average rainfall was calculated (excluding the site under investigation) and compared to the questionable site. A monthly value of zero during dry seasons was not considered unreasonable, however zero monthly rainfall values during the wet season where nearby stations averaged > 5 inches, were considered highly suspect. Considerations for acceptance or rejection of data included: the nearby averages, historical monthly average tables which included surrounding areas, the repetition of zero values from other sites for the same month, seasonality, the number of consecutive zero values at a given site, and whether or not the nearby site average was below the long-term monthly average. A final evaluation was made for stations with zero rainfall for three or more consecutive months by examining the quality of the daily rainfall.

Phase IV: Examination of Annual Rainfall below 30 Inches and Monthly Rainfall above 20 Inches

Visual examination of the data set showed annual rainfall was below 30 inches in some areas. Similarly, the monthly rainfall was greater than 20 inches in some areas. The examination of such data was carried out in three steps: investigation of the corresponding data, comparison with rainfall local statistics, and a visual inspection of annual snapshots extracted from the revised rainfall data set.

The investigation of the corresponding data consisted of a visual review of the daily data for the records that did not meet the criteria. About 6 percent of cases that had annual rainfall below 30 inches, 22 years of daily data were found to be of poor quality (a combination of unrealistically low and missing values) and were consequently removed. Of the cases that had a monthly rainfall that was greater than 20 inches, only month of rainfall was rejected where high rainfall was reported in an area with an average rainfall of 0.65 inches; the rest of the cases were accepted.

For the cases that had annual rainfall below 30 inches and had a maximum of two months of missing data, the following statistics were generated: the average, the standard deviation, the annual rainfall excluding the missing months, and the annual rainfall after counting for the missing month {(using the following approximation: Adjusted value = [(value)(12) / [(12 – number of missing months)]}. If the number of stations used to compute the statistics was two or less, discretion (based on a visual evaluation) was used to either reject or accept the daily data set for the year. In cases where the number of stations used to compute the statistics is more than two, the daily data set for a given year was rejected if the associated adjusted value was as follows:

1. Below 20 inches; or
2. Less than 1/2 of the average rainfall (for the given county and given year based on all locations except the one of interest); or
3. Less than (AVG-2.5)(STD) where STD is the standard deviation of annual rainfall within that county and that year. Of the 98 cases identified, 53 daily data sets were rejected.

Phase V: Final QA/QC through Data Visualization

During Phase V, a visual examination of daily, monthly, and annual snapshots of the rainfall data set was performed. Some areas of very low rainfall still existed. Associated stations were identified and a visual inspection of the daily values was performed. At some stations, daily data were of poor quality as indicated by an overwhelmingly large number of missing data for a given year. As a result of the visual evaluation, six records were rejected for at least one year, one record was rejected for two years, and three stations were dropped for the entire period of record.

2.2.2 Transformation to Grid-Based Data Set

Once the rainfall data QA/QC was completed, a Triangular Irregular Network (TIN) approximation method was performed to assign a representative rainfall depth for each day and grid cell. This was necessary because rainfall gauging stations do not normally coincide with the centroid of the grid cells and most grid cells do not contain rainfall gauging stations.

The normal TIN approximation involves using the centroid of the grid cell as a reference point for determining which three rainfall stations are used for estimating the daily rainfall value. If rainfall stations are fairly sparse, model grid cells are small, or rain events are spatially large, this would be a suitable application. However, in South Florida, the rainfall stations are not sparsely located, the model grid cells are large (4 square miles each), and heavy rainfall events can be localized. Therefore, a variation of the normal TIN approximation method was developed for this application.

The new method involved dividing each model grid cell into 100 sub-cells. Because each cell was equally divided horizontally and vertically by 10, the methodology is referred to as TIN-10. The sub-cells were over-laid by a triangular pattern of rainfall stations (with stations at each apex as shown in Figure C.1-2). For the sub-cells contained within a single triangle, a daily rainfall value was calculated based on the rainfall stations at each apex. The calculated values were the weighted (based on distance from each station to each sub-cell centroid) average of the three nearest stations. Once the daily rainfall for each sub-cell was determined, the values were averaged to compute the grid cell daily rainfall value used by the model.

From Figure C.1-2, the normal TIN approximation method would apply the rainfall at stations B, C, and D to the centroid of the grid cell even though only 38 percent of the sub-cells fell within the triangle. Consequently, the influence of two other rainfall stations would not be considered for the remaining 42 percent of sub-cells. For the TIN-10 method, the influences of the other two stations would be included in the approximation.

A comparison between the two methods revealed only small differences in annual averages with the TIN-10 method being slightly lower. The monthly average differences were generally less than 0.2 inches with the TIN-10 method having consistently lower maxima. The differences between the two methods were more evident during the wet season months. The TIN-10 method tends to decrease the dominance of any one station thus minimizing the effect of a localized rain event on a grid cell.

Average annual results of the generation of the rainfall data set by the process for data collection, QA/QC and transformation to grid are provided in Figure C.1-3. The seasonal variability of the end product is shown in Figure C.1-4.

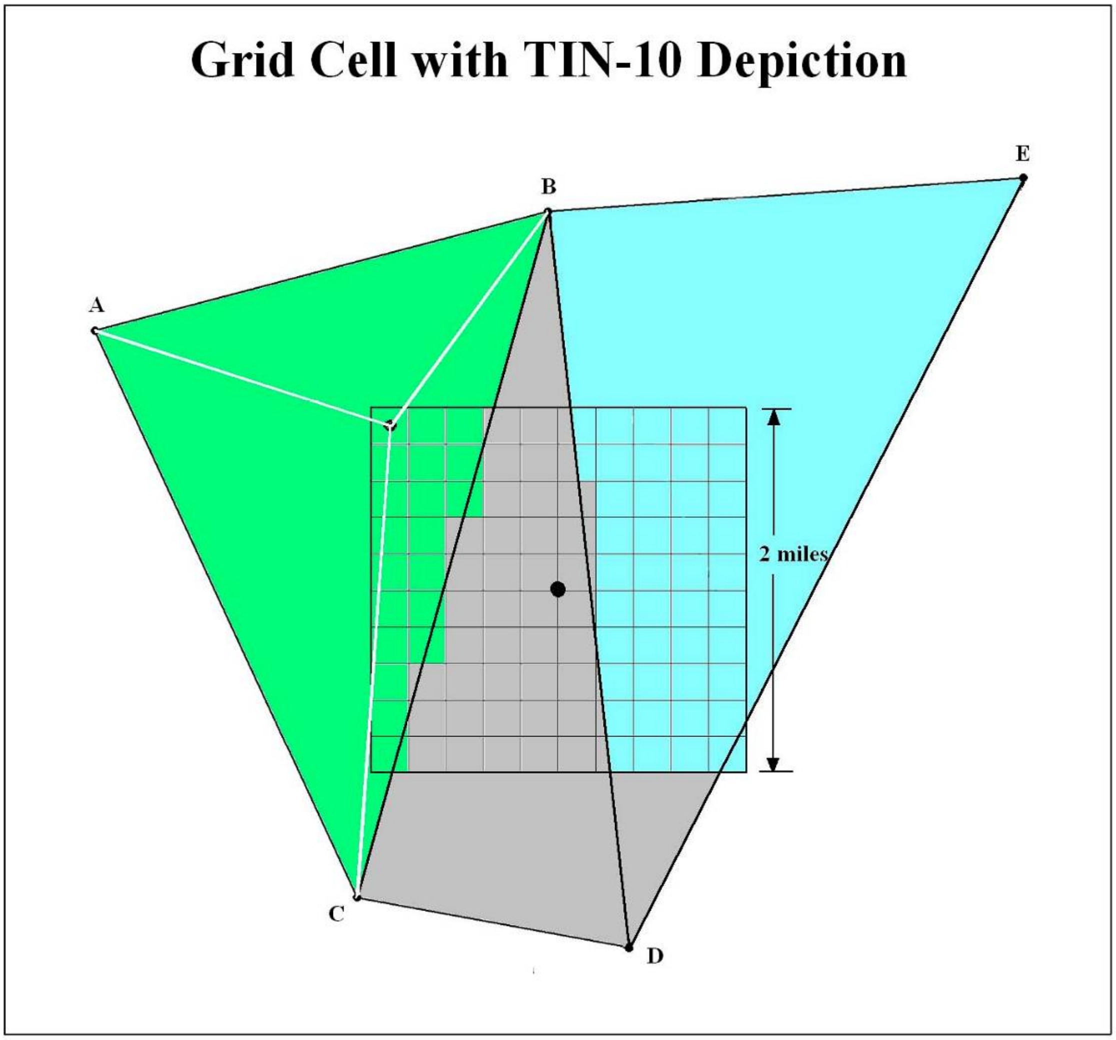


Figure C.1-2 Example of TIN-10 Estimation for Model Grid Cell

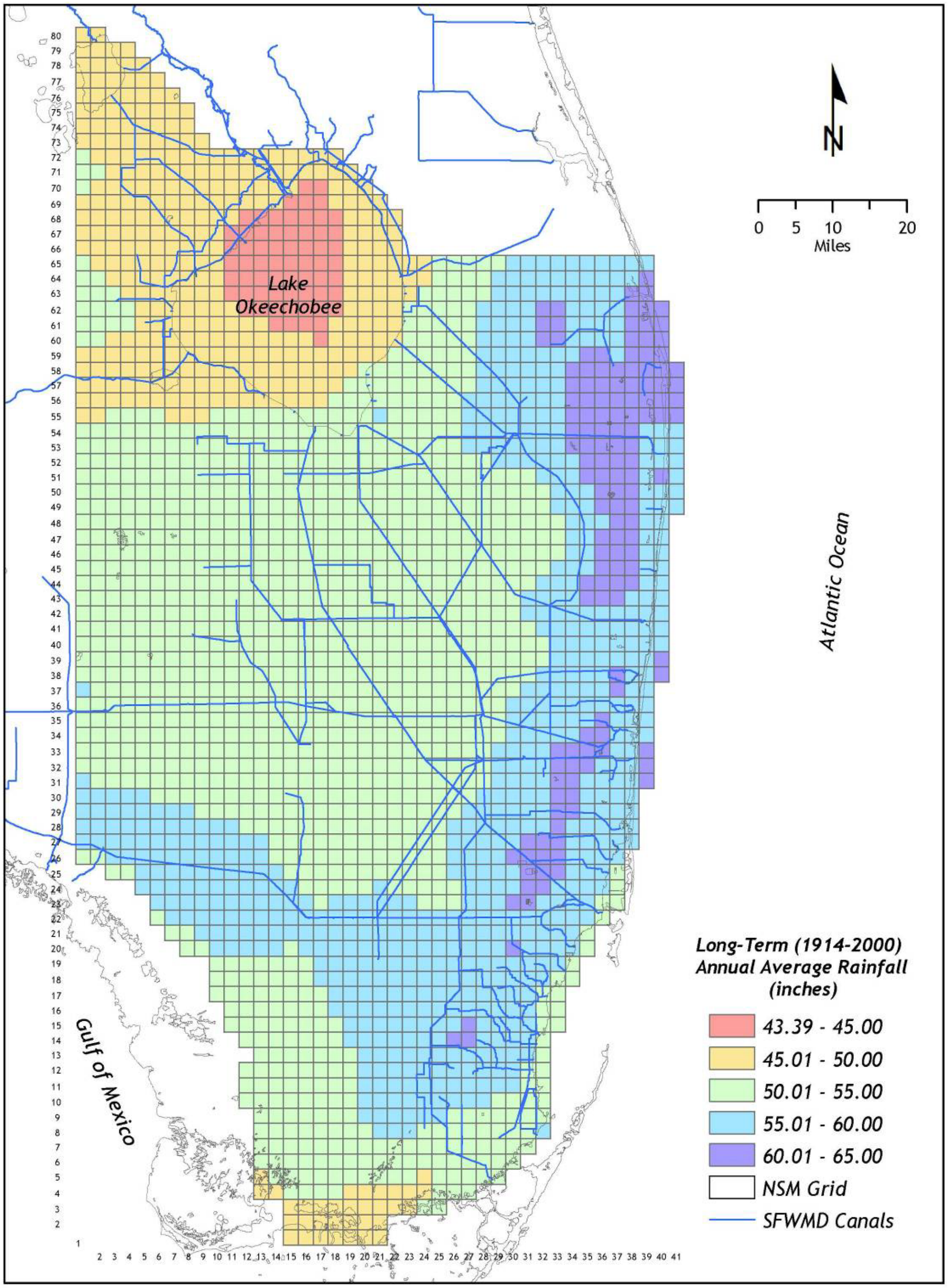


Figure C.1-3 Grid Values of Annual Average Rainfall

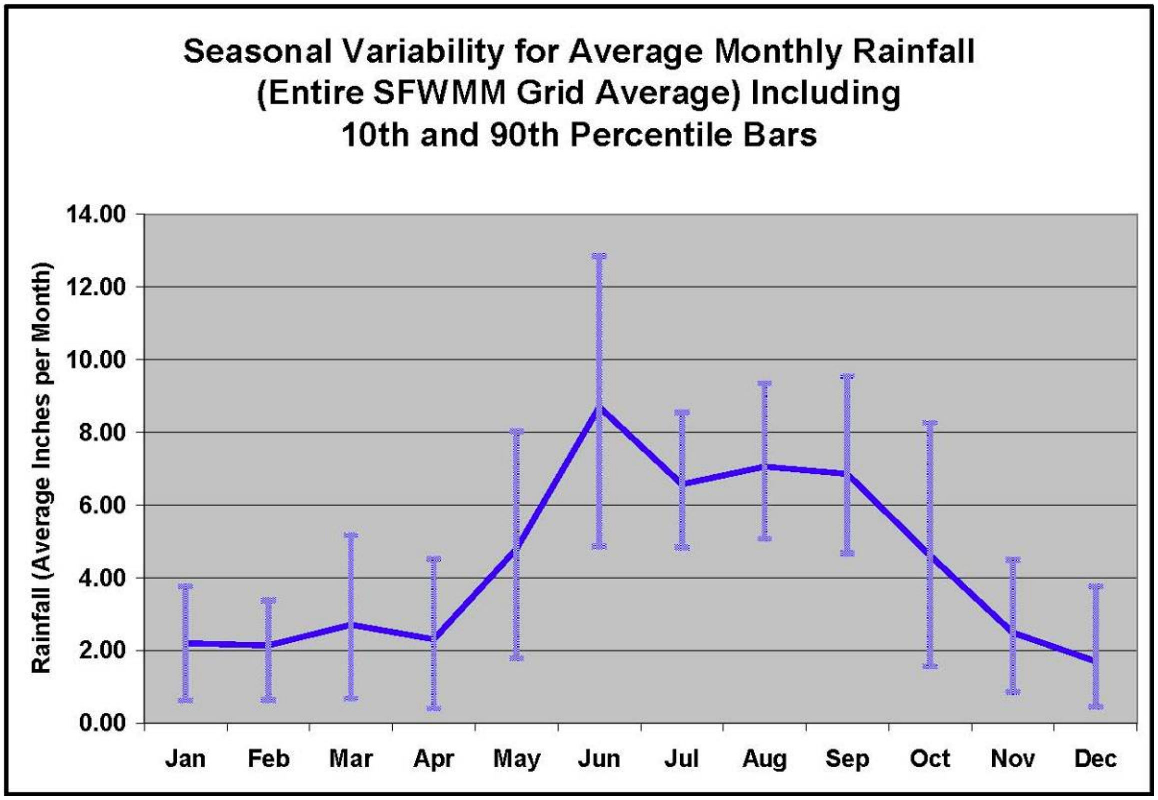


Figure C.1-4 Monthly Mean with 10th and 90th Percentile Bars for Rainfall

C.2: PRISM RAINFALL FREQUENCY ANALYSIS

STATISTICAL ANALYSIS (ALI AND ABTEW, 1999) APPLIED TO MONTHLY PRISM RAINFALL

STATISTICAL ANALYSIS OF THE MONTHLY PRISM SYNTHETIC RAINFALL DATA FOR CENTRAL AND SOUTH FLORIDA

for

The South Florida Water Management District

West Palm Beach, Florida

March 13, 2006

Table of Contents

INTRODUCTION

The South Florida Water Management District (SFWMD) area covers South Florida and part of Central Florida. In this area, rainfall represents the most important component of the water budget. Rainfall depth resulting from a storm event occurring with a given frequency is an essential variable for the evaluation of simulated hydroperiods in a model. Rainfall is usually analyzed for various durations and various frequencies using probability distribution functions (PDFs).

The SFWMD Office of Modeling is currently developing the Natural System Regional Simulation Model (NSRSM) to represent the pre-drained Everglades. This next generation Natural System Model (NSM) is being created concurrently with the *managed* system South Florida Regional Simulation Model (SFRSM). The objective of the NSRSM is the same as its “NSM 2x2” predecessor; to simulate the natural system hydrology of South Florida. Additionally, this model will have the advantage of improved data sets and refined parameter input resulting in simulations more closely representing pre-drainage hydrology. NSRSM currently includes daily rainfall data for the entire 99 year period of simulation from 1895 through 1993. A goal of the NSRSM project is to extend the input data to 2005 for a 111 year period of record.

The rainfall data utilized by this study is from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM). PRISM is an analytical model that uses point data and a digital elevation model to generate gridded estimates of monthly and annual precipitation and temperature. The data is serially complete, high quality, topographically sensitive, high resolution grids for the coterminous United States. Christopher Daly and George Taylor of Oregon State University worked with Tim Kittel and Dave Schimel of the National Center for Atmospheric Research on the project. The resulting data sets are unprecedented in their combination of high quality, temporal extent and spatial detail. The PRISM data is monthly and at approximately four (4) kilometer resolution. The main data repository is at the Spatial Climate Analysis Service (SCAS) on the web at http://www.ocs.orst.edu/prism/. The files are in monthly, Gzipped ArcInfo ASCII grid format. Monthly data was downloaded from SCAS for the 1895 through 2005 period of record for use in this study.

The data were divided into 15 rainfall basins previously defined by SFWMD. The purpose of this study was to perform statistical analyses to generate basin averages and magnitudes of rainfall for various probabilities of occurrence (return periods). Regional frequency analysis involves a combined time series from several locations within a specific region or rainfall basin. Results include rainfall depth over the entire region for a given duration and frequency. The District performed a similar study in 1999, titled *Regional Rainfall Frequency Analysis for Central and South Florida* (WRE#380) and authored by Ali and Abtew. This previous study extended from about 1900 to 1995 with different periods of record for different areas. A new study was necessary to include the very wet years between 2000 and 2006 and establish their influence on return periods. This study uses the same statistical methods employed in Ali and Abtew’s 1999 statistical analysis of available data for the same area.

Histograms are plotted for monthly, seasonal (dry and wet) and annual basin areal rainfall. Basic statistics such as average, standard deviation, skewness and kurtosis are also reported.

Frequency analysis was performed on monthly, seasonal (dry and wet) and annual basin areal rainfall. Also, monthly, seasonal and annual rainfall departures from the historical average are presented graphically. The results show significant variations of rainfall from the corresponding averages.

For convenience in comparing the results, this report is organized in a similar manner as the earlier report by Ali and Abtew.

RAINFALL BASINS AND DATA PREPARATION

The South Florida Management District (SFWMD) has divided the District area into fifteen rainfall basins. In this study, each basin was analyzed as a region, including Everglades National Park. Figure C.2-1 shows the rainfall basins overlain with the rainfall version 2.1 model input grid that covers the entire district. The daily data for each basin were derived from the PRISM monthly precipitation grid file using the SFWMD grid cut utility “gr_cut”. Another Grid_io utility, “gr_summary”, was used to generate monthly and annual data for each basin. The result was a 111 year time series of monthly rainfall depths for each basin. Three additional time series for each basin were generated from these data: total rainfall depth for the wet season (June through October), the dry season (November and December of the previous year and January through May of the current year), and for the entire calendar year (January through December). Note that with these definitions, the annual total is not the sum of the wet season and the dry season. The time series for the annual and wet season data are each 111 years while the dry season time series is 110 years, as the November and December data for 1894 were not available. The long term average rainfall for the entire period of record is shown in Figure C.2-2.

STATISTICAL SUMMARY

Histograms

A histogram is a non-parametric visual method for examining the frequency distribution of a given set of rainfall data. A value on the histogram indicates the relative frequency of the occurrence of rainfall depth within a prescribed range (interval width). To construct a histogram, an interval (bin) width must be prescribed. Too short of a bin-width provides an “under-smoothed looking” histogram due to a lack of data points within each bin. On the other hand, too large of a bin-width provides an “over-smoothed looking” histogram due to an excess of data points within each bin leading to the damping of variability. There are many methods for estimating the “optimal” bin-width including visual judgment. Following the methodology of Ali and Abtew, Sturges’ empirical formula was used (Haan, 2002). For a given month, and a given basin, this formula is given as:

$$BinWidth = \frac{DataRange}{\left|1 + 3.32\log(n)\right|}$$

where n is the number of data points and

DataRange = (maximum rainfall depth) – (minimum rainfall depth). For convenience, all bin-width values were rounded to the nearest 0.1 inch.

The histograms for the dry, and wet seasons and the annual totals for each basin along with the mean (μ), standard deviation (σ), skew (γ), and kurtosis (κ) are presented in Figures C.2-3 through C.2-5. The monthly histograms are presented as Figures A1 through A12 in Appendix A.

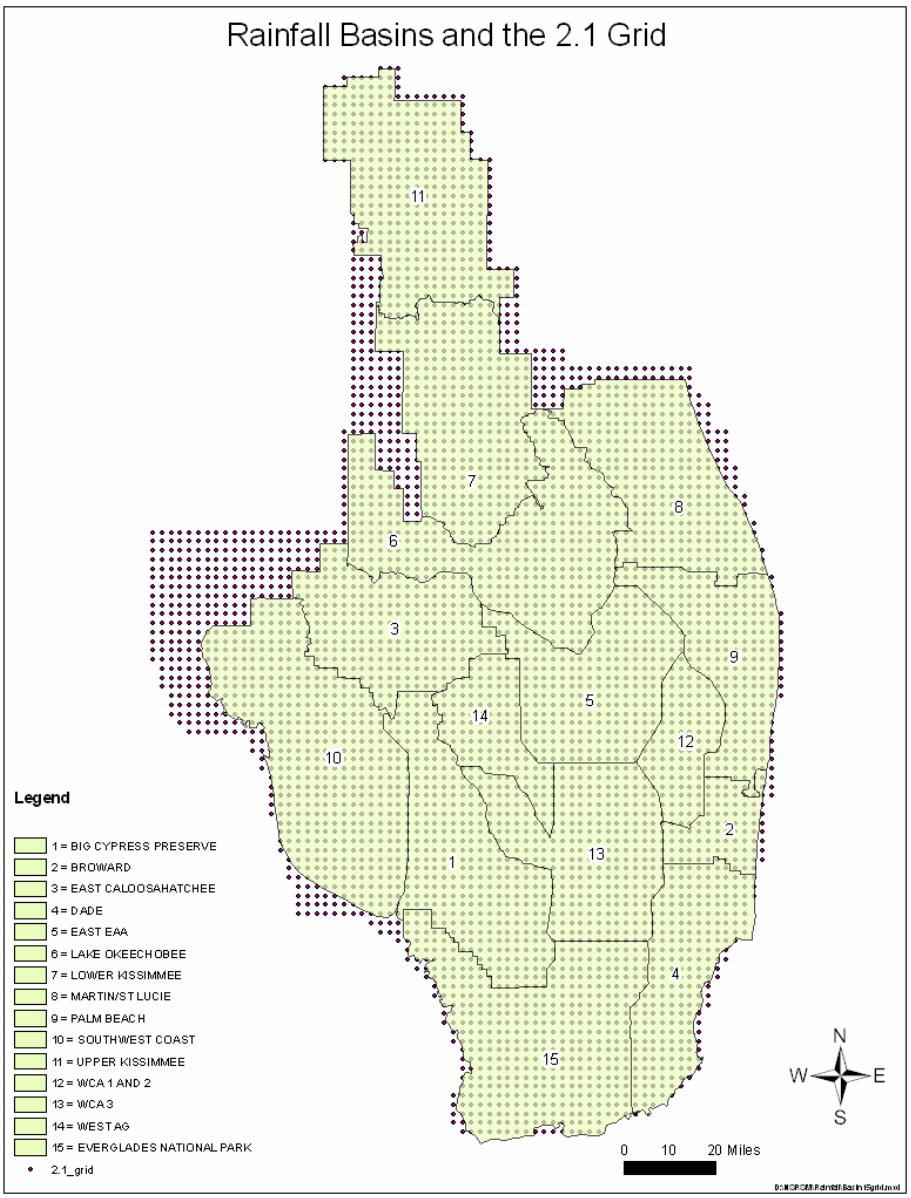


Figure C.2-**1**. The Rainfall Basins Overlain by the Rainfall Version 2.1 Grid.

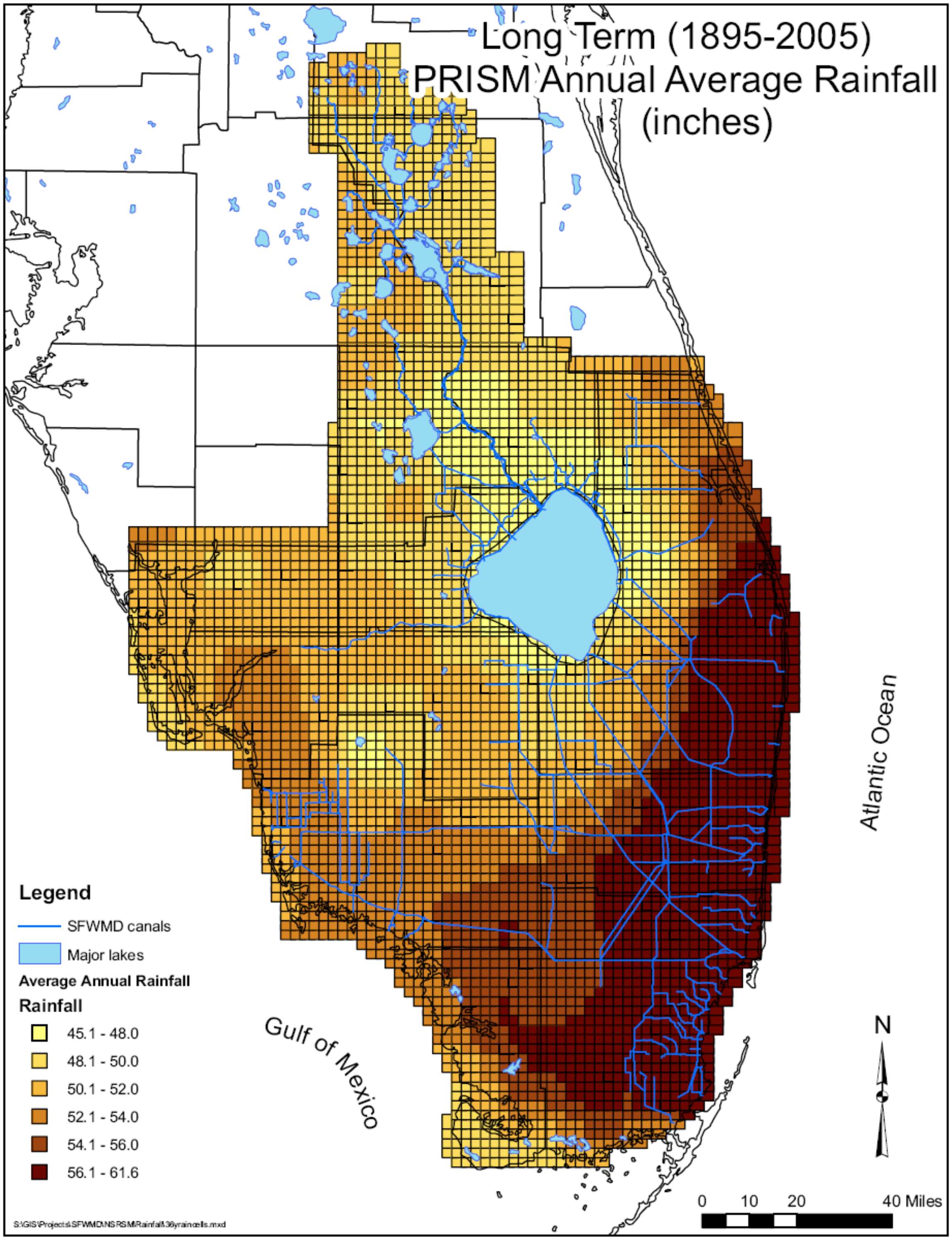


Figure C.2-2. Long Term Average Rainfall based on PRISM data.

From these figures and statistical measures it is clear that

1. During the wet season months (June through October) the skew is more positive (higher frequency of small rainfall depths relative to large depths) than during the dry season. This indicates that the distribution is clearly not normal and will be better fit with a lognormal or other probability distribution function (PDF) with a positive skew.

2. During the dry season (November through May) the skew is smaller but still positive. The distributions are closer to normal during the dry season.

Monthly, Seasonal, and Annual Average Rainfall

Average rainfall for each rainfall basin is presented in Table 1. Table 2 presents the historical cumulative average rainfall for the 12 months of the year in each basin. Figure C.2-6 is a graphical representation of the monthly data from Table 1. Figure C.2-7 presents the dry season, wet season, and annual average rainfall of each basin. The following conclusions can be made based on Table 1 and Figures C.2-6 and C.2-7:

1. The highest annual rainfall is in the Broward Basin and near the Southeast coast (Broward County, Dade County, WCA 1 & 2, WCA3 and Palm Beach).

2. The lowest annual rainfall is in the Lake Okeechobee and the Lower/Upper Kissimmee areas.

3. May and October represent significant break points in the rainfall seasonal patterns for all basins.

Departures from the Historical Average

Wet season, dry season, annual, and monthly rainfall departures from the historical averages illustrate the variability of rainfall from year to year. Time series of this departure are presented in Figures B1 through B15 in Appendix B of this report. From these figures, it is clear that there are significant departures from the historical means of the monthly, annual, and seasonal rainfall of all basins.

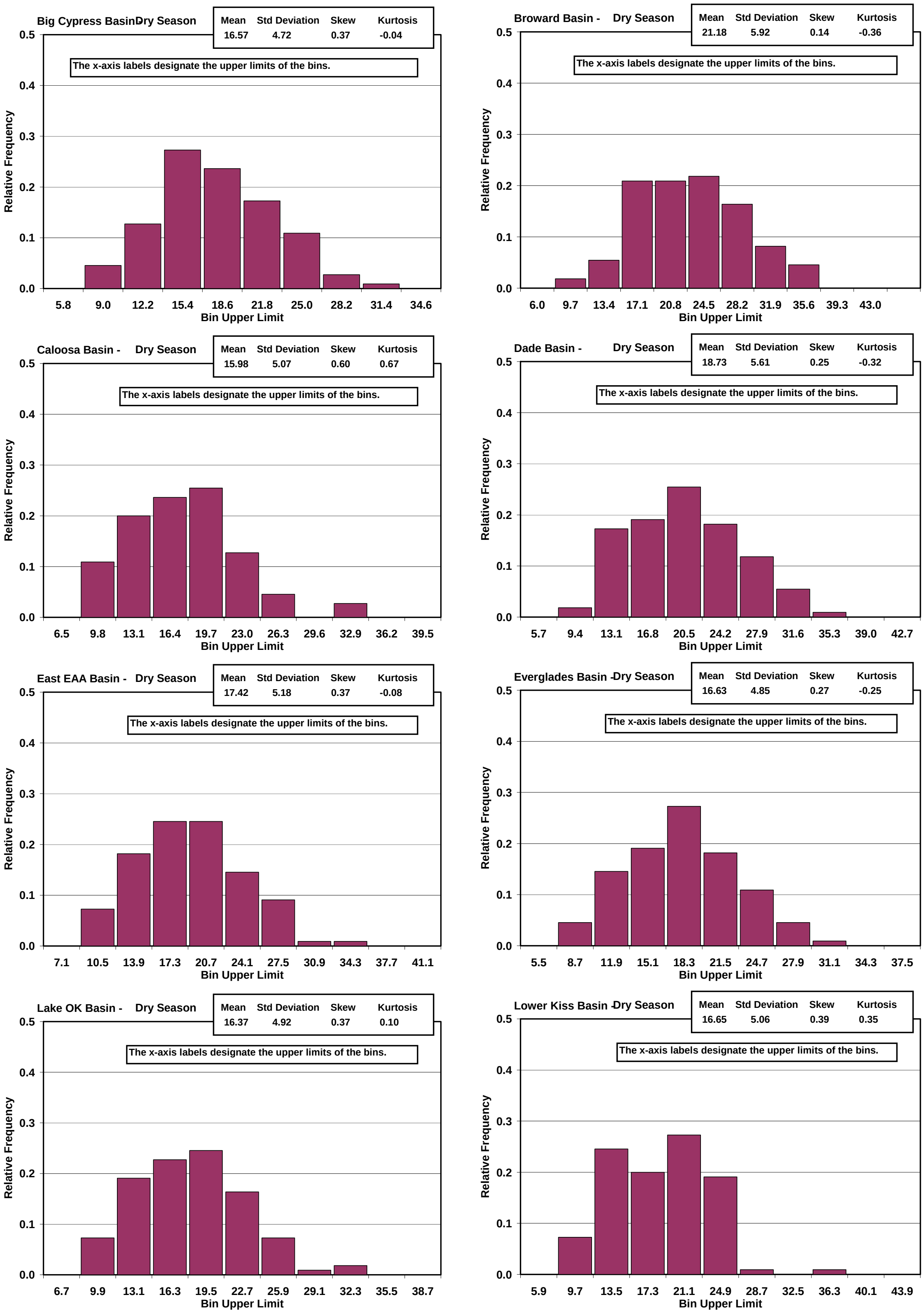
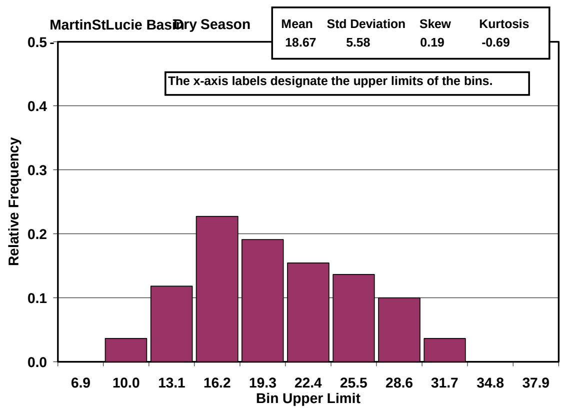
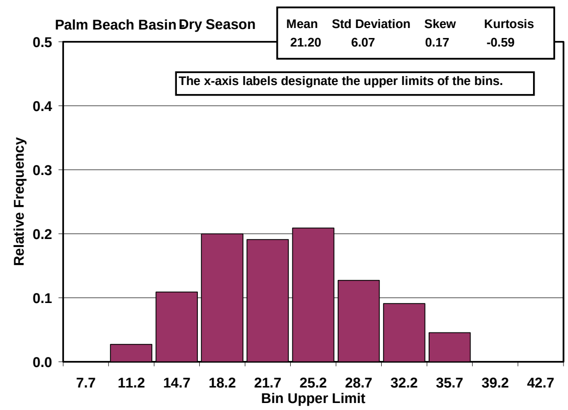
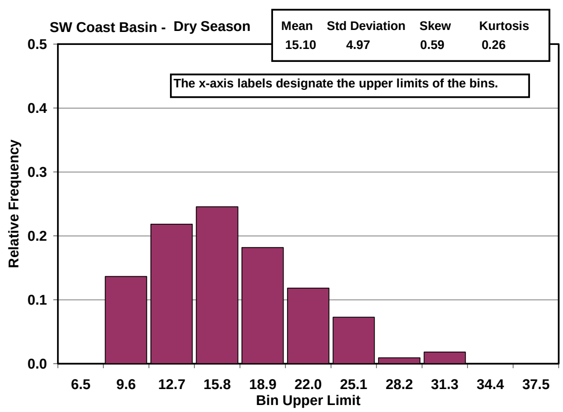
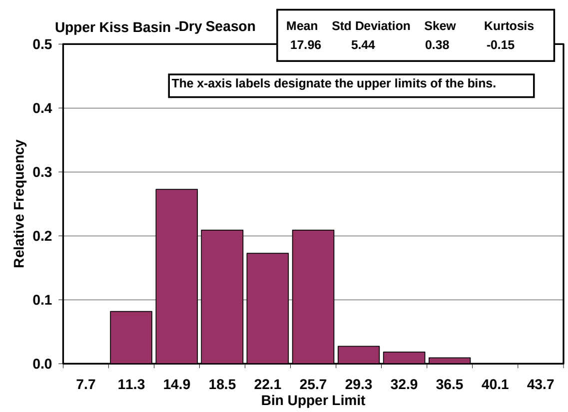


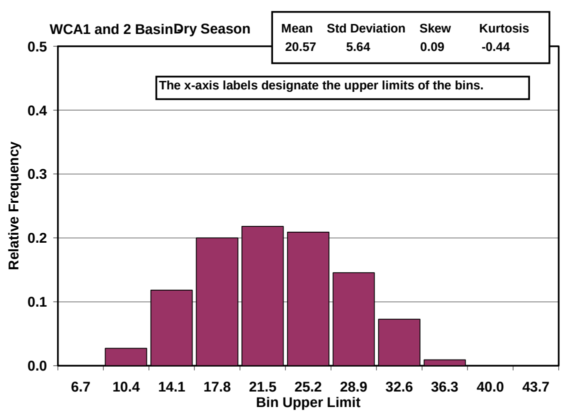
Figure C.2-3. Histograms for Dry Season Rainfall.

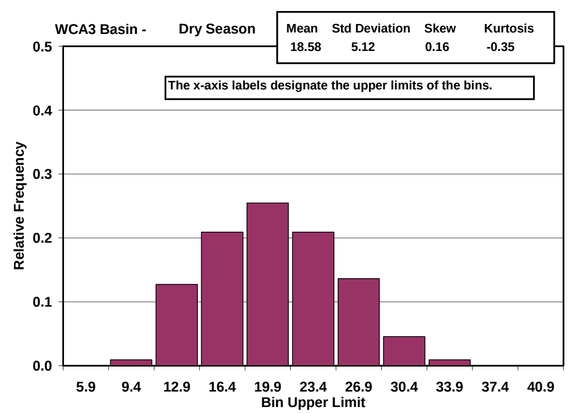












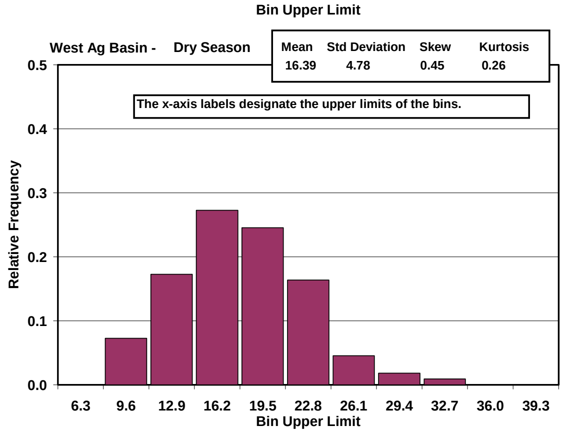


Figure C.2-3 (continued). Histograms for Dry Season Rainfall.

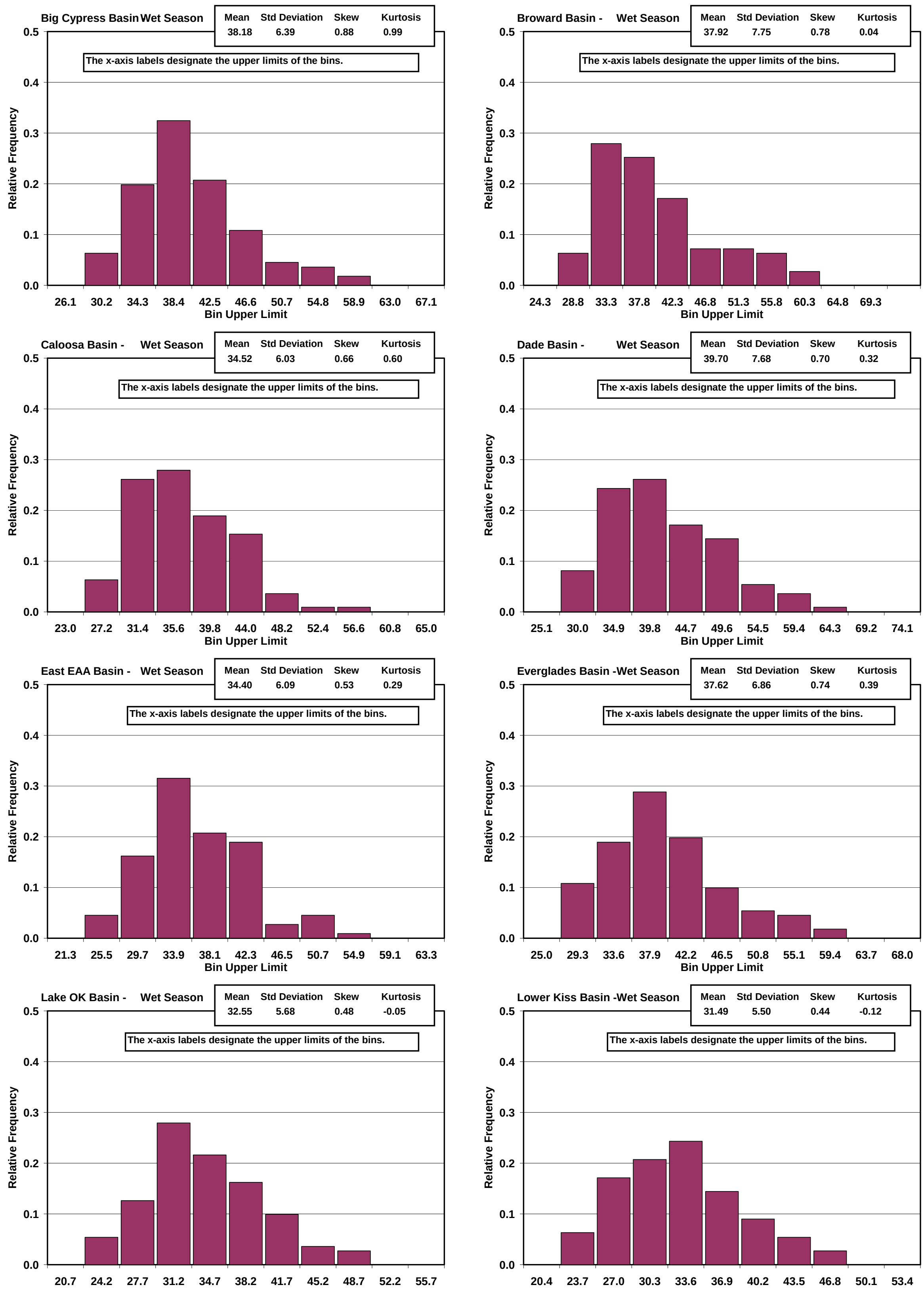


Figure C.2-4. Histograms for Wet Season Rainfall.

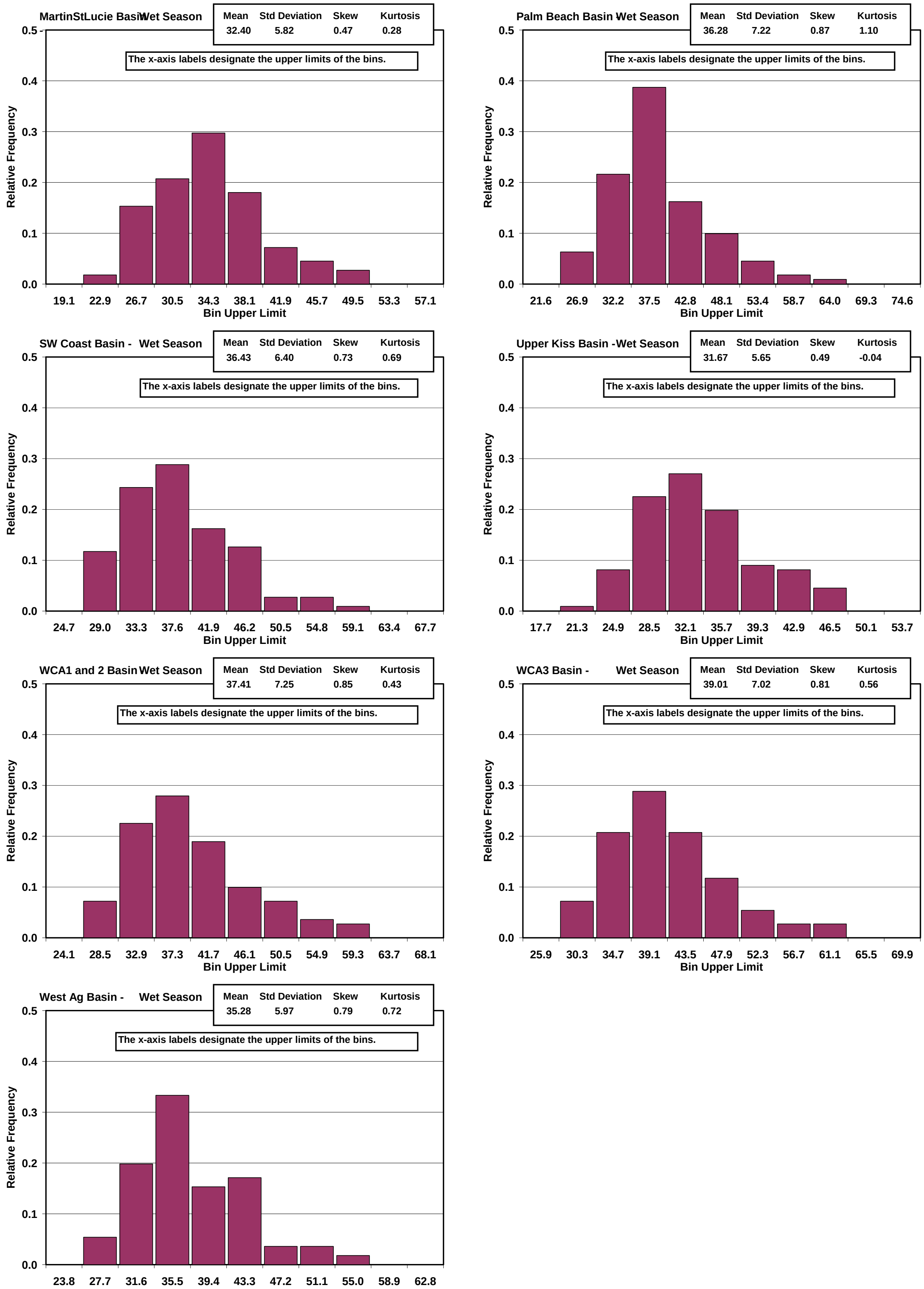


Figure C.2-4 (continued). Histograms for Wet Season Rainfall.

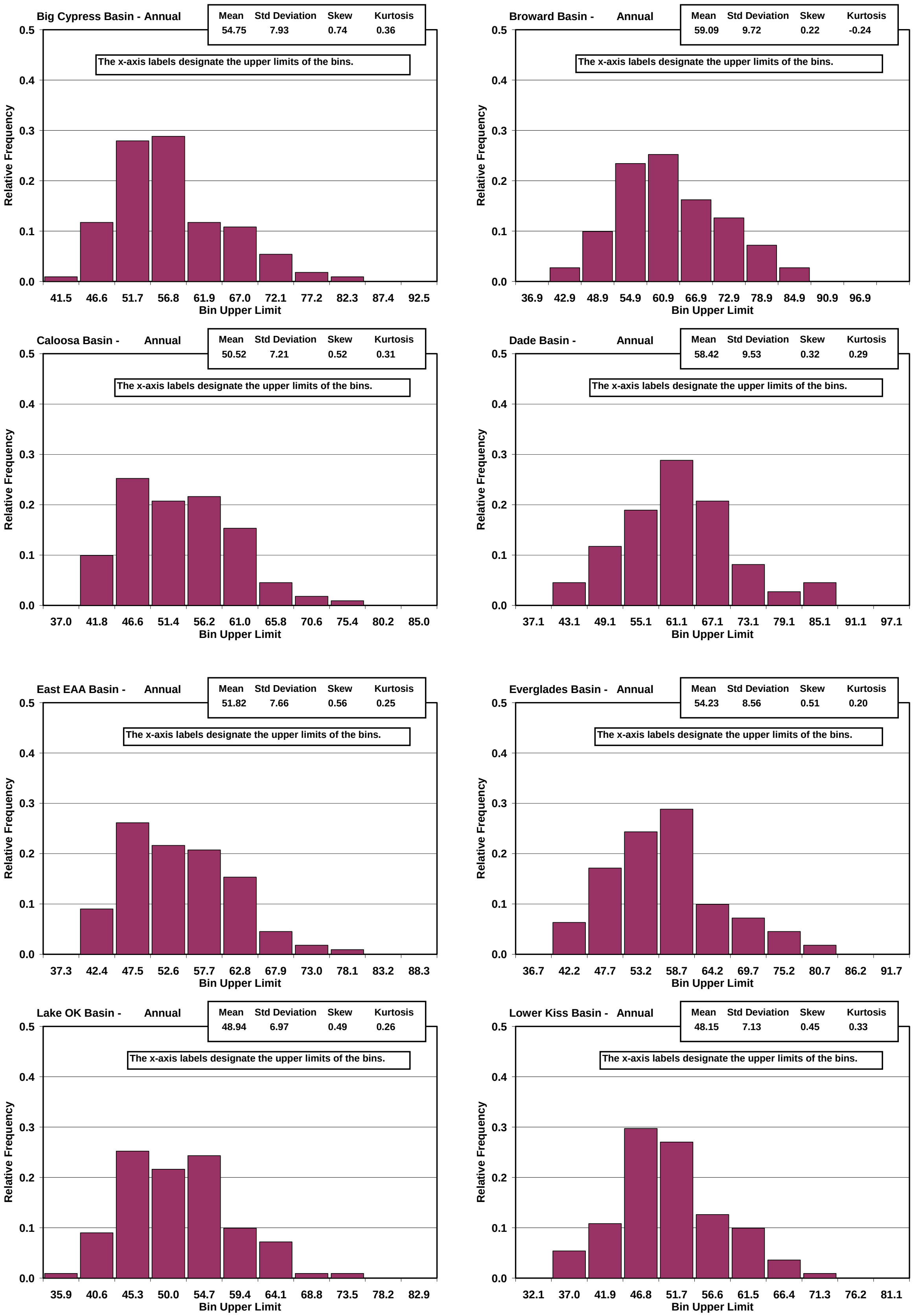
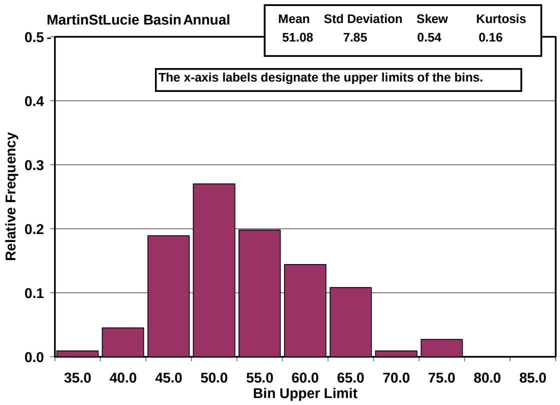
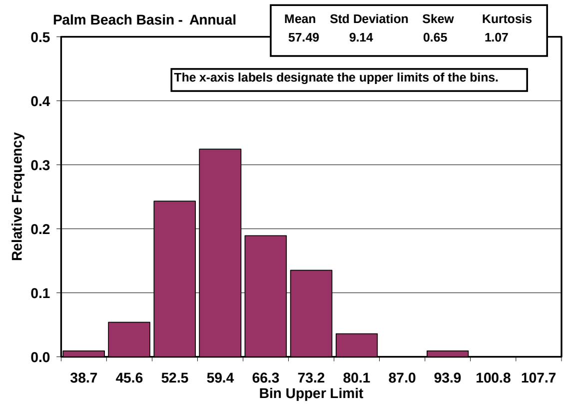
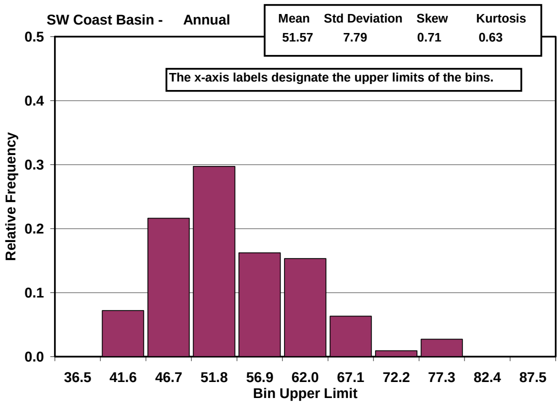
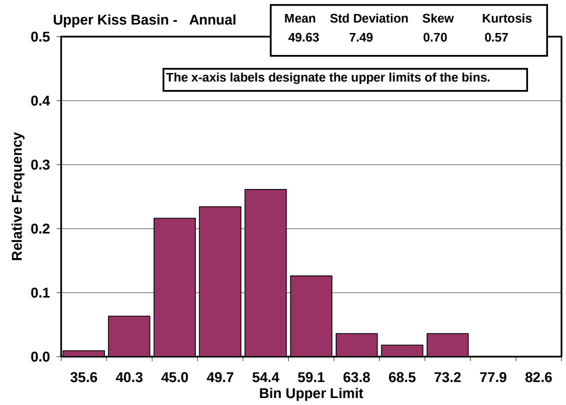


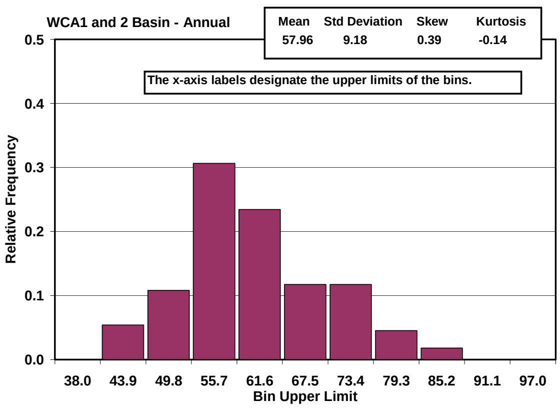
Figure C.2-5. Histograms for Annual Rainfall.

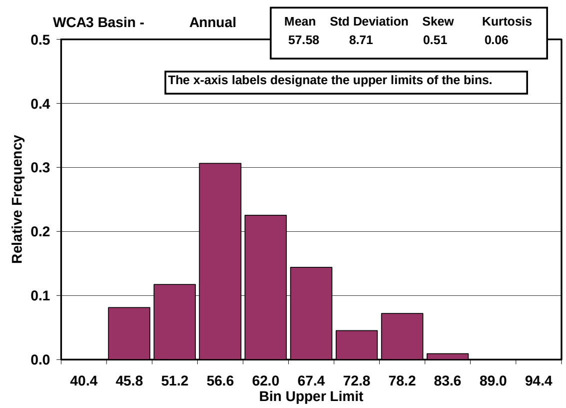












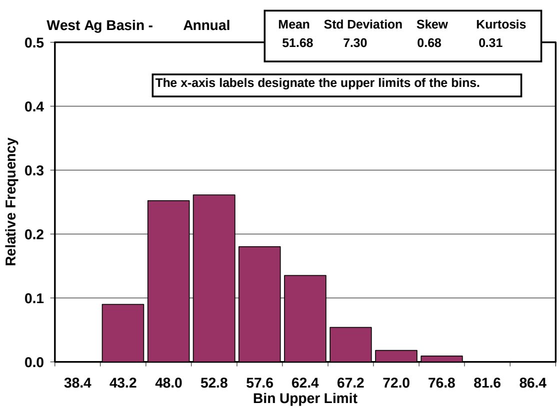


Figure C.2-5 (continued). Histograms for Annual Rainfall.

Table C.2-1. Average Rainfall for each Basin.

Month	Big Cypress	Broward	Caloosa	Dade	East EAA	Ever-glades	Lake Okee	Lower Kiss	Martin/ St Lucie	Palm Beach	SW Coast	Upper Kiss	WCA 1&2	WCA 3	WestAG
January	1.71	2.23	1.87	1.86	1.97	1.72	1.85	1.97	2.13	2.51	1.81	2.20	2.22	1.88	1.80
February	1.66	2.10	2.09	1.78	1.89	1.63	2.07	2.30	2.31	2.23	2.04	2.63	2.07	1.76	1.84
March	2.21	2.46	2.53	2.13	2.65	1.93	2.67	2.82	3.04	3.12	2.17	3.09	2.61	2.27	2.42
April	2.55	3.49	2.35	3.11	2.62	2.56	2.48	2.49	2.74	3.13	2.27	2.42	3.27	3.07	2.52
May	5.36	5.66	4.03	5.99	4.58	5.46	4.04	3.81	4.25	4.99	3.80	3.75	5.44	5.77	4.67
June	9.21	8.41	8.46	9.01	8.13	8.77	7.86	7.43	7.02	8.10	8.31	7.35	8.49	9.18	8.58
July	7.68	6.30	7.71	7.00	7.15	6.89	7.16	7.02	6.38	6.57	8.19	7.53	6.62	7.28	7.61
August	7.83	6.90	7.53	7.66	7.14	7.56	6.99	6.70	6.33	6.70	7.74	6.95	7.06	7.50	7.35
September	8.45	8.30	7.13	8.91	7.36	8.62	6.80	6.56	7.19	8.18	8.10	6.48	8.12	8.54	7.41
October	5.02	8.00	3.69	7.12	4.62	5.78	3.74	3.78	5.47	6.73	4.10	3.36	7.11	6.51	4.33
November	1.74	3.12	1.58	2.38	2.10	1.97	1.72	1.67	2.39	3.07	1.50	1.82	2.91	2.26	1.72
December	1.34	2.12	1.55	1.47	1.60	1.35	1.55	1.59	1.82	2.15	1.54	2.04	2.03	1.55	1.43
Dry	16.57	21.18	15.98	18.73	17.42	16.63	16.37	16.65	18.67	21.20	15.10	17.96	20.57	18.58	16.39
Wet	38.18	37.92	34.52	39.70	34.40	37.62	32.55	31.49	32.40	36.28	36.43	31.67	37.41	39.01	35.28
Annual	54.75	59.09	50.52	58.42	51.82	54.23	48.94	48.15	51.08	57.49	51.57	49.63	57.96	57.58	51.68

Table C.2-2. Cumulative Monthly Average Rainfall for each Basin.

Month	Big Cypress	Broward	Caloosa	Dade	East EAA	Ever-glades	Lake Okee	Lower Kiss	Martin/ StLucie	Palm Beach	SW Coast	Upper Kiss	WCA 1&2	WCA 3	WestAG
January	1.71	2.23	1.87	1.86	1.97	1.72	1.85	1.97	2.13	2.51	1.81	2.20	2.22	1.88	1.80
February	3.37	4.33	3.96	3.64	3.86	3.35	3.92	4.27	4.44	4.74	3.85	4.83	4.29	3.64	3.64
March	5.58	6.79	6.49	5.77	6.51	5.28	6.59	7.09	7.48	7.86	6.02	7.92	6.90	5.91	6.06
April	8.13	10.28	8.84	8.88	9.13	7.84	9.07	9.58	10.22	10.99	8.29	10.34	10.17	8.98	8.58
May	13.49	15.94	12.87	14.87	13.71	13.30	13.11	13.39	14.47	15.98	12.09	14.09	15.61	14.75	13.25
June	22.70	24.35	21.33	23.88	21.84	22.07	20.97	20.82	21.49	24.08	20.40	21.44	24.10	23.93	21.83
July	30.38	30.65	29.04	30.88	28.99	28.96	28.13	27.84	27.87	30.65	28.59	28.97	30.72	31.21	29.44
August	38.21	37.55	36.57	38.54	36.13	36.52	35.12	34.54	34.20	37.35	36.33	35.92	37.78	38.71	36.79
September	46.66	45.85	43.70	47.45	43.49	45.14	41.92	41.10	41.39	45.53	44.43	42.40	45.90	47.25	44.20
October	51.68	53.85	47.39	54.57	48.11	50.92	45.66	44.88	46.86	52.26	48.53	45.76	53.01	53.76	48.53
November	53.42	56.97	48.97	56.95	50.21	52.89	47.38	46.55	49.25	55.33	50.03	47.58	55.92	56.02	50.25
December	54.75	59.09	50.52	58.42	51.82	54.23	48.94	48.15	51.08	57.49	51.57	49.63	57.96	57.58	51.68

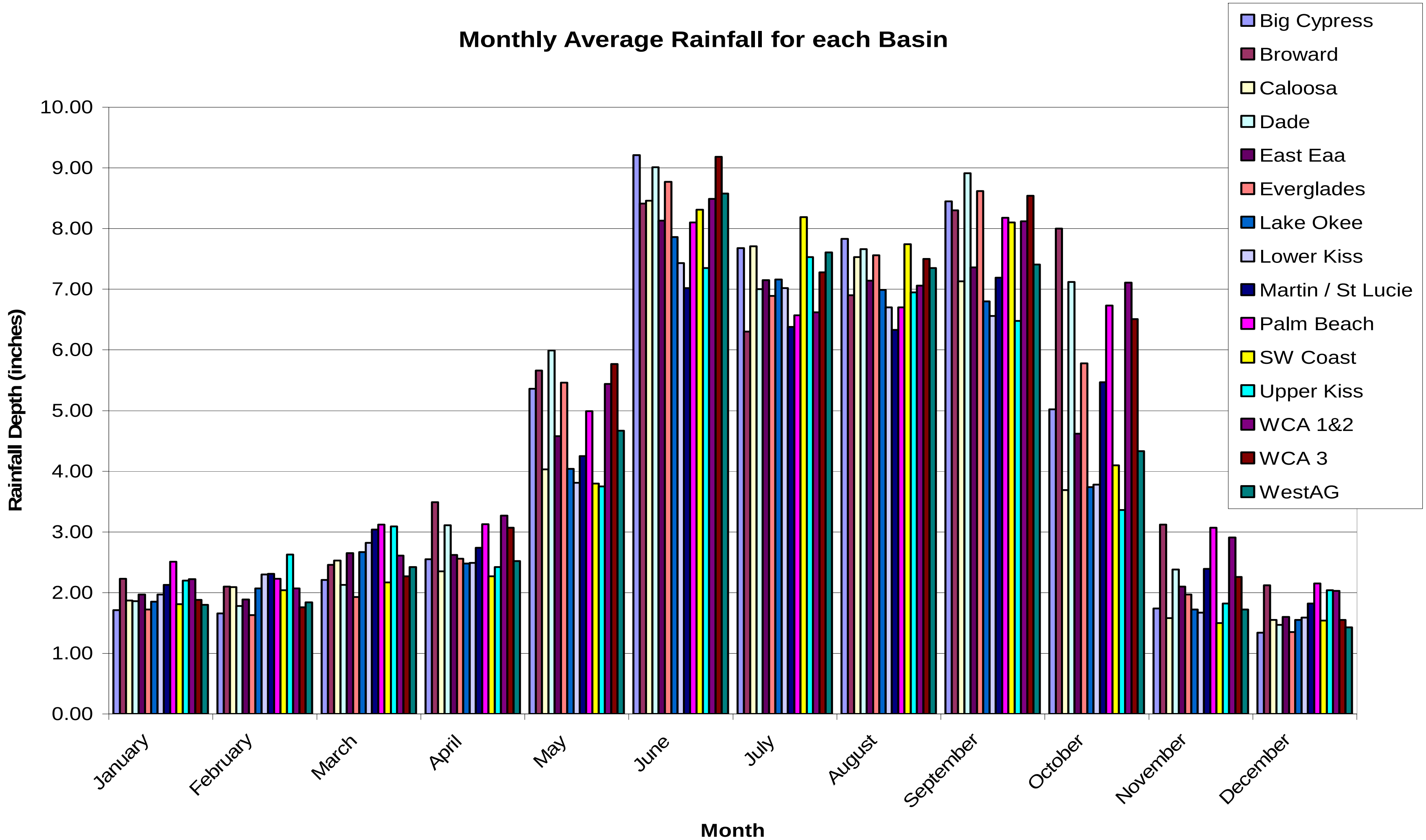


Figure C.2-6. Monthly Average Rainfall for each Basin.

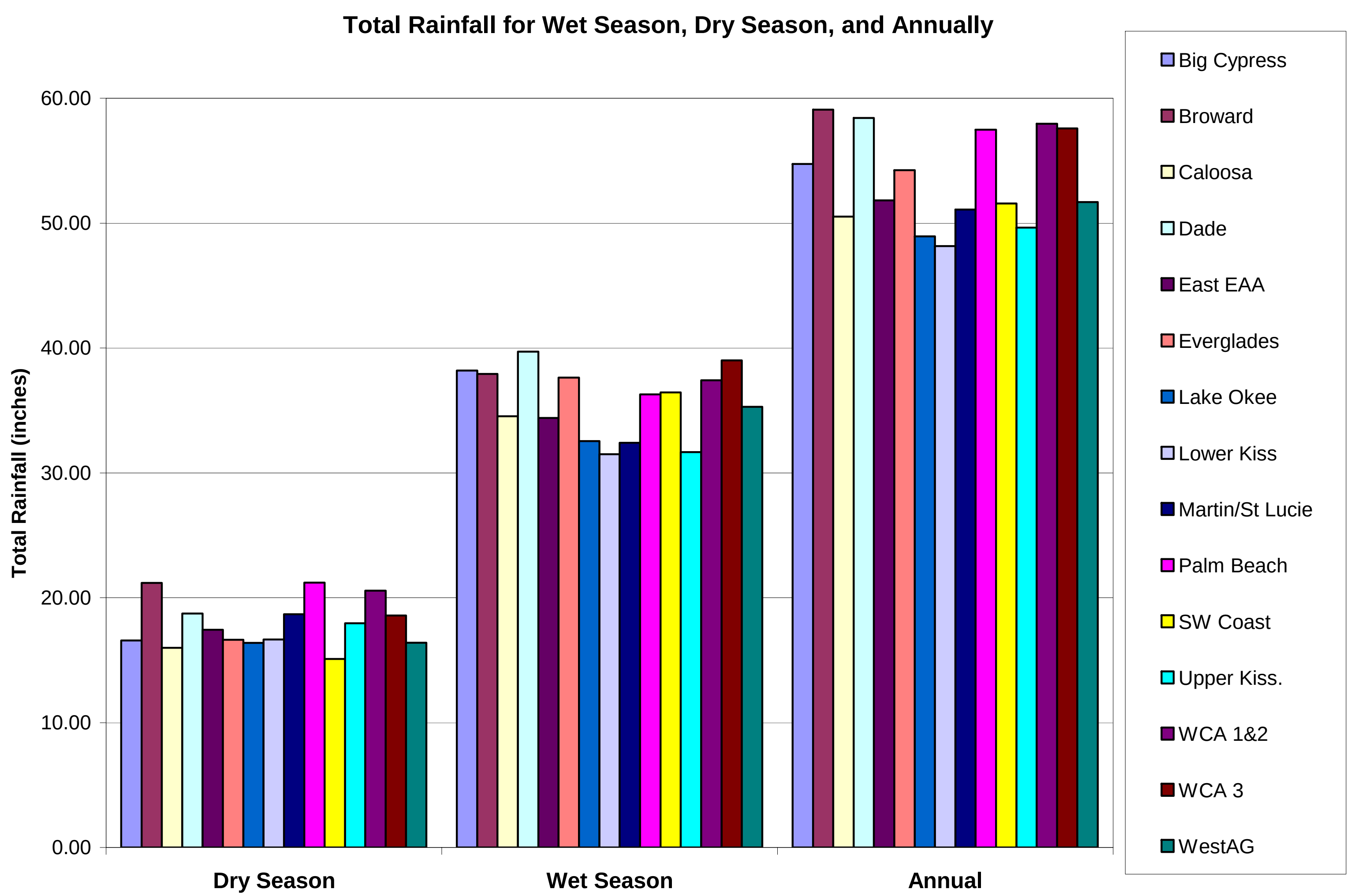


Figure C.2-7. Average Rainfall for the Seasonal and Annual Average of each Basin.

FREQUENCY ANALYSIS

The objective of frequency analysis is to select the best "parametric" Probability Density Function (PDF) that fits a given data set. The selection approach of a PDF is to test the "goodness of fit" of the major and commonly applied distributions for each month, season, and annual data of every basin. The parameters of the best-fit probability distribution are then identified for each month and each season for each basin. The candidate distributions are Normal, Log Normal (2-parameter), Log Normal (3-parameter), Gamma (2-parameter), Gamma (3-parameter), Weibull and Log Pearson Type III. Table 3 lists the distributions and their corresponding abbreviations used in the graphs and tables in this report.

Table C.2-3. Distribution Abbreviations.

Distribution	Abbreviation
Normal	NO2
Log Normal (2-parameter)	LN2
Log Normal (3-parameter)	LN3
Gamma (2-parameter)	GM2
Gamma (3-parameter)	GM3
Weibull	WB2
Log Pearson Type III	LP3

The seven PDFs were fitted, and both tabular and computed Chi-square (χ^2) values were determined for each season, the annual data and each month for each basin. These computations were carried out using a frequency analysis program (Freq20) written by Hosung Ahn, (Ahn, 1990-2005). The ratio of the computed to the tabular χ^2 was used as a comparative measure of the distribution's relative goodness of fit. A lower than 1 Chi-square ratio indicates acceptance. Graphical presentations of the Chi-square value against rainfall basins for monthly, seasonal, and annual rainfall are provided to aid the selection of the best probability distribution (Figures C.2-8 and C.2-9). The PDF used for frequency analysis of each month, each season, and the annual times series of each basin was the one with the lowest χ^2 ratio of the seven PDF's tested. The results show that there were five minimum Chi-square ratio values greater than one (1) but less than 1.26.

From these PDFs a series of rainfall depths was estimated for a series of return periods for each basin. The estimated depths are for the dry return period (DRP) and the wet return period (WRP) of the 100, 50, 20, 10, and 5 year return periods. Tables 4, 5, and 6 present these results and the historical average rainfall for the dry season, wet season and annual data. From these tables, for example, the probability in a given year that the wet season rainfall (Table 5) for the Palm Beach Basin will be less than or equal to 25.95 inches, is 0.05 (5 percent), or once every 20 years over a long time period. There is also a 5 percent chance that the wet season rainfall for Palm Beach Basin will be greater than 48.88 inches. The results of the monthly data for each basin are presented in Figures D1 through D12 in Appendix D.

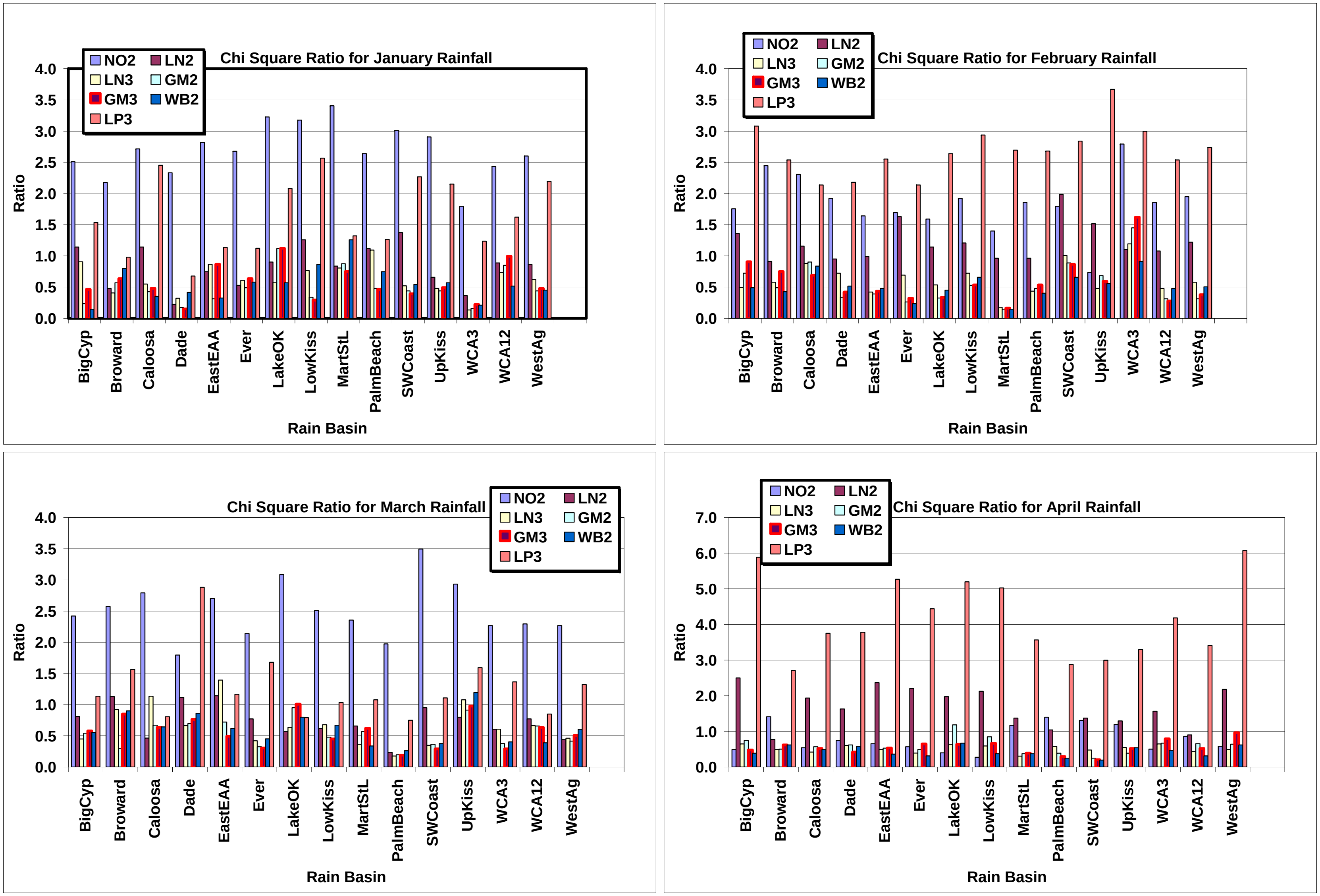


Figure C.2-8. Chi Squared Ratios for Monthly Data for Each PDF for Each Basin

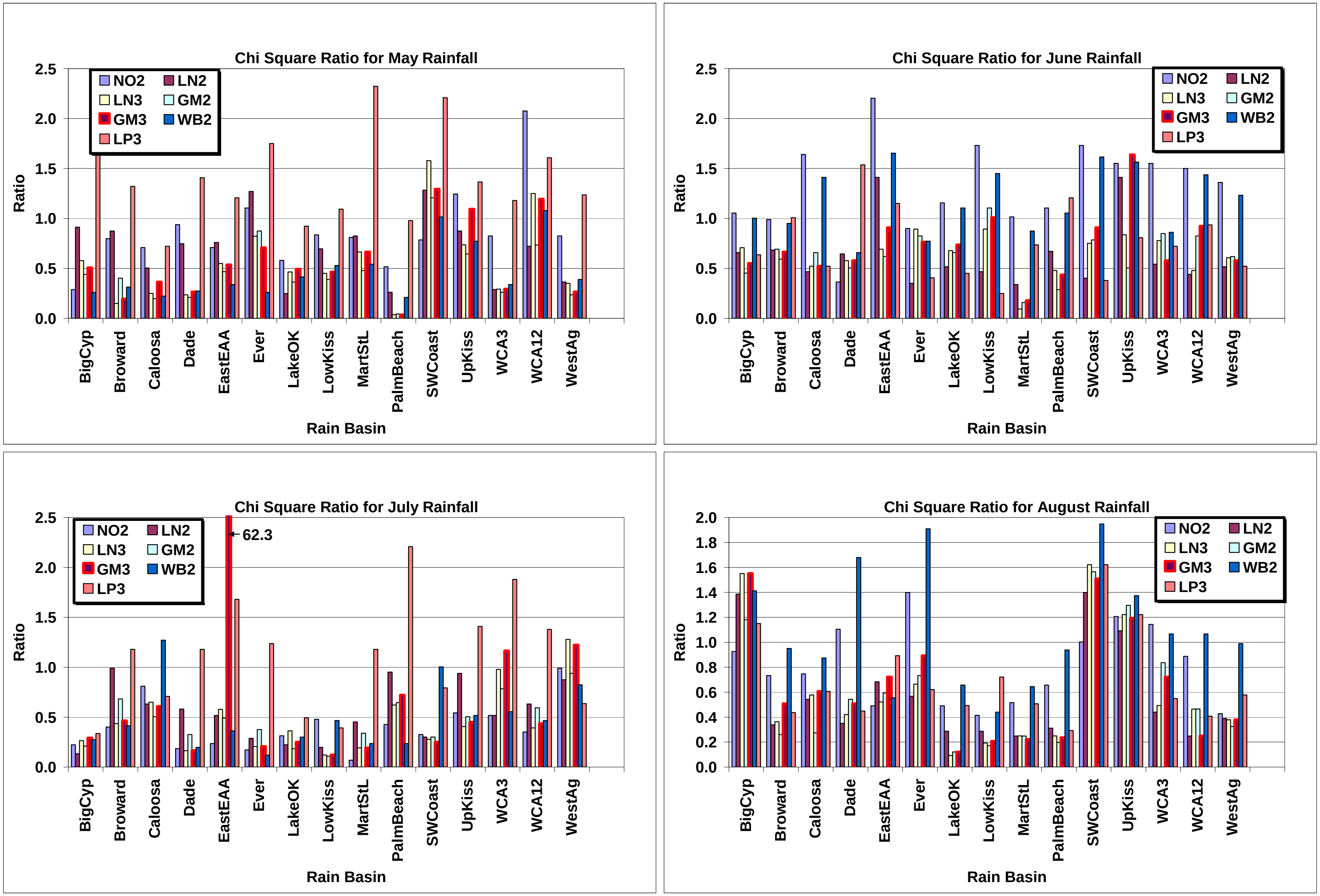


Figure C.2-8 (continued). Chi Squared Ratios for Monthly Data for Each PDF for Each Basin

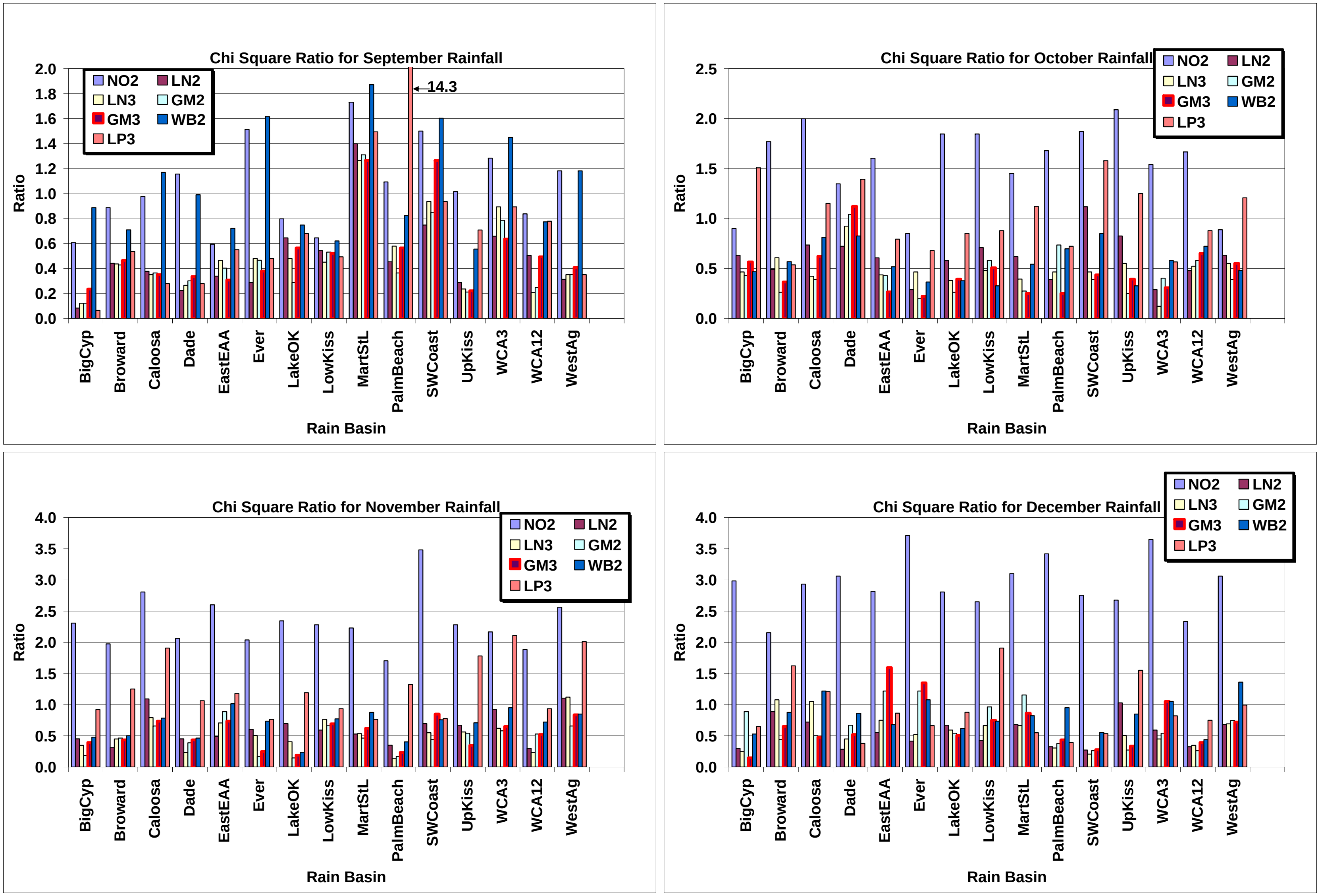
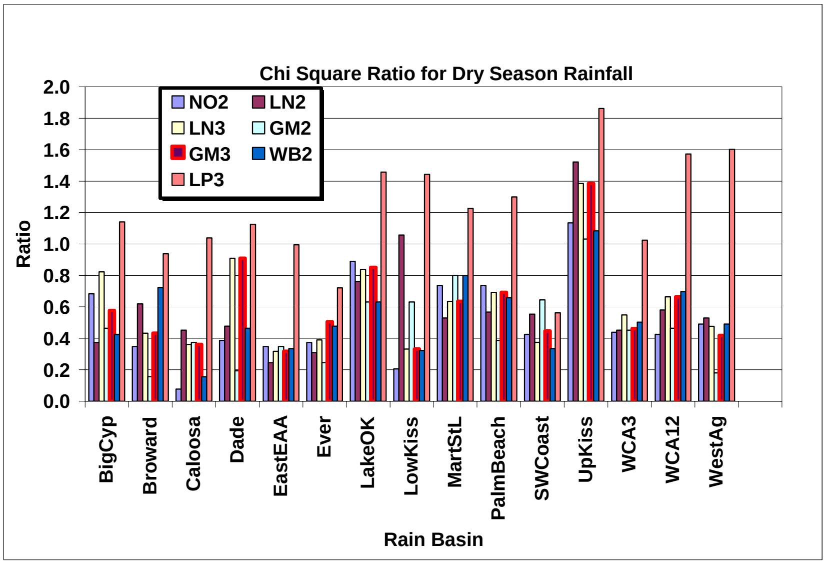
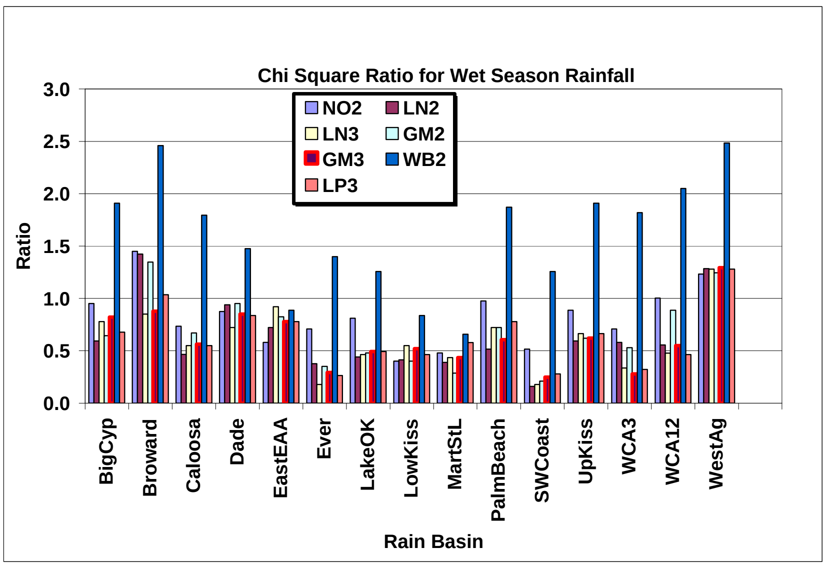


Figure C.2-8 (continued). Chi Squared Ratios for Monthly Data for Each PDF for Each Basin





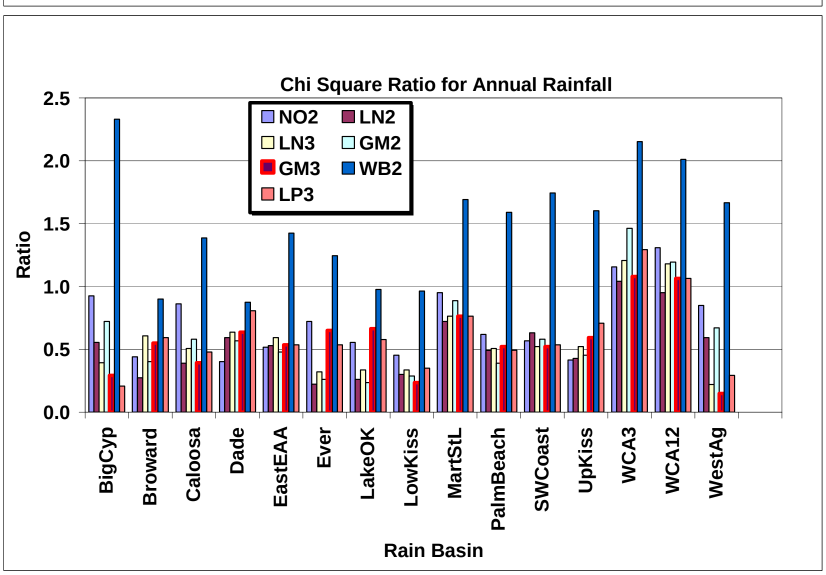


Figure C.2-9. Chi Squared Ratios for Dry Season, Wet Season, and Annual Data for each PDF for each Basin

Table C.2-4. Dry Season Rainfall Depth-Return Period Estimates and Historical Averages for each Basin.

Basin	Distrib	2 Ratio	100 DRP (inches)	50 DRP (inches)	20 DRP (inches)	10 DRP (inches)	5 DRP (inches)	Average (inches)	5 WRP (inches)	10 WRP (inches)	20 WRP (inches)	50 WRP (inches)	100 WRP (inches)
Big Cypress	LN2	0.37	7.95	7.83	9.18	10.49	12.25	16.67	20.77	23.52	25.96	28.90	30.98
Broward	GM2	0.15	9.51	10.53	12.18	13.79	15.93	21.18	26.09	29.32	32.19	35.62	38.04
Caloosahatchee	NO2	0.08	4.19	5.58	7.11	9.49	11.72	15.98	20.25	22.48	24.85	26.39	27.77
Dade	GM2	0.19	7.94	8.86	10.37	11.84	13.81	18.73	23.31	26.37	29.08	32.35	34.67
East EAA	LN2	0.25	8.07	8.78	9.98	11.17	12.81	17.42	21.62	24.79	27.75	31.52	34.31
Everglades	GM2	0.25	7.26	8.07	9.39	10.68	12.38	16.63	20.59	23.21	25.53	28.33	30.30
Lake Okeechobee	GM2	0.63	7.01	7.81	9.12	10.40	12.11	16.37	20.34	22.99	25.33	28.16	30.16
Lower Kissimmee	NO2	0.21	4.88	6.26	7.79	10.17	12.39	16.65	20.90	23.13	25.50	27.03	28.41
Martin St Lucie	LN2	0.53	8.49	9.25	10.54	11.83	13.62	18.67	23.27	26.77	30.05	34.23	37.34
Palm Beach	GM2	0.39	9.41	10.43	12.10	13.72	15.88	21.20	26.18	29.46	32.37	35.86	38.33
SW Coast	WB2	0.34	4.31	5.31	7.00	8.68	10.85	15.10	19.54	21.74	23.51	25.46	26.73
Upper Kissimmee	GM2	1.03	7.66	8.54	9.98	11.39	13.27	17.96	22.33	25.24	27.83	30.94	33.14
WCA 1&2	NO2	0.43	7.44	8.98	10.69	13.34	15.82	20.57	25.31	27.80	30.44	32.15	33.69
WCA 3	NO2	0.44	6.67	8.07	9.62	12.02	14.27	18.58	22.88	25.13	27.54	29.09	30.48
WestAg	GM2	0.18	7.27	8.06	9.35	10.61	12.27	16.39	20.24	22.78	25.03	27.73	29.63

(DRP, WRP = Dry and Wet Return Periods in years)

Table C.2-5. Wet Season Rainfall Depth-Return Period Estimates and Historical Averages for each Basin.

Basin	Distrib	χ^2 Ratio	100 DRP (inches)	50 DRP (inches)	20 DRP (inches)	10 DRP (inches)	5 DRP (inches)	Average (inches)	5 WRP (inches)	10 WRP (inches)	20 WRP (inches)	50 WRP (inches)	100 WRP (inches)
Big Cypress	LN2	0.59	25.88	27.05	28.89	30.64	32.90	38.18	43.16	46.34	49.14	52.50	54.86
Broward	LN3	0.85	25.31	26.20	27.71	29.25	31.41	37.92	43.63	48.24	52.64	58.32	62.59
Caloosahatchee	LN2	0.47	22.83	23.92	25.65	27.30	29.44	34.52	39.29	42.37	45.09	48.36	50.68
Dade	LN3	0.72	26.19	27.27	29.05	30.81	33.20	39.70	45.57	49.88	53.86	58.84	62.49
East EAA	NO2	0.58	20.23	21.89	23.73	26.59	29.27	34.40	39.52	42.20	45.06	46.91	48.57
Everglades	LN3	0.18	25.80	26.71	28.23	29.75	31.82	37.62	42.82	46.73	50.38	54.99	58.39
Lake Okeechobee	LN2	0.44	21.44	22.48	24.12	25.69	27.73	32.55	37.10	40.04	42.64	45.77	47.98
Lower Kissimmee	NO2	0.40	18.69	20.19	21.86	24.44	26.86	31.49	36.12	38.54	41.12	42.79	44.29
Martin St Lucie	GM2	0.29	20.52	21.70	23.55	25.28	27.49	32.40	37.11	39.95	42.41	45.28	47.27
Palm Beach	LN2	0.52	22.76	23.98	25.95	27.83	30.29	36.28	41.87	45.57	48.88	52.88	55.73
SW Coast	LN2	0.16	24.11	25.26	27.09	28.83	31.09	36.43	41.46	44.70	47.57	51.02	53.46
Upper Kissimmee	LN2	0.59	20.64	21.66	23.29	24.84	26.86	31.67	36.20	39.14	41.75	44.89	47.11
WCA 1&2	LP3	0.46	25.23	26.16	27.27	29.24	31.35	37.41	42.78	46.97	52.24	56.08	59.94
WCA 3	GM3	0.28	27.21	28.04	29.47	30.96	33.05	39.01	44.39	48.36	51.98	56.46	59.68
WestAg	NO2	1.23	21.40	23.02	24.83	27.63	30.26	35.28	40.30	42.93	45.73	47.54	49.17

(DRP, WRP = Dry and Wet Return Periods in years)

Table C.2-6. Annual Rainfall Depth-Return Period Estimates and Historical Averages for each Basin.

Basin	Distrib	2 Ratio	100 DRP (inches)	50 DRP (inches)	20 DRP (inches)	10 DRP (inches)	5 DRP (inches)	Average (inches)	5 WRP (inches)	10 WRP (inches)	20 WRP (inches)	50 WRP (inches)	100 WRP (inches)
Big Cypress	LP3	0.21	40.82	41.94	43.27	45.61	48.06	54.75	60.79	65.25	70.72	74.62	78.49
Broward	LN2	0.27	39.57	41.41	44.33	47.09	50.67	59.09	67.06	72.16	76.66	82.06	85.87
Caloosahatchee	LN2	0.39	36.04	37.45	39.67	41.76	44.43	50.52	56.32	59.92	63.07	66.81	69.43
Dade	NO2	0.40	36.25	38.84	41.73	46.20	50.40	58.42	66.43	70.63	75.10	77.99	80.58
East EAA	GM2	0.48	35.94	37.57	40.10	42.45	45.41	51.82	58.01	61.65	64.77	68.40	70.89
Everglades	LN2	0.22	37.25	38.87	41.43	43.85	46.98	54.23	61.10	65.45	69.28	73.85	77.06
Lake Okeechobee	GM2	0.24	34.39	35.89	38.22	40.37	43.09	48.94	54.60	57.92	60.76	64.06	66.32
Lower Kissimmee	GM3	0.24	34.12	35.41	37.48	39.47	42.05	48.15	53.91	57.57	60.77	64.59	67.25
Martin St Lucie	LN2	0.72	35.48	36.98	39.35	41.57	44.44	51.08	57.36	61.32	64.79	68.94	71.85
Palm Beach	GM2	0.39	38.69	40.59	43.57	46.34	49.85	57.49	64.87	69.24	73.00	77.39	80.40
SW Coast	LN3	0.52	37.34	38.55	40.53	42.44	45.00	51.57	57.60	61.81	65.62	70.33	73.72
Upper Kissimmee	NO2	0.41	32.20	34.24	36.51	40.03	43.33	49.63	55.93	59.23	62.75	65.02	67.06
WCA 1&2	LN2	0.95	39.66	41.40	44.16	46.77	50.13	57.96	65.38	70.09	74.22	79.17	82.65
WCA 3	LN2	1.04	40.21	41.88	44.52	47.01	50.21	57.58	64.57	68.96	72.81	77.40	80.62
WestAg	GM3	0.15	39.17	40.06	41.60	43.18	45.40	51.68	57.35	61.50	65.29	69.96	73.32

(DRP, WRP = Dry and Wet Return Periods in years)

SUMMARY

The objective of this study was to utilize monthly rainfall data to provide monthly, seasonal (dry and wet), and annual representative rainfall statistics and frequency estimates for each basin. Data used in this study were extracted from the synthetic PRISM data obtained from the Spatial Climate Analysis Service (SCAS). Monthly, seasonal, and annual statistics of the basin average rainfall have been provided. Monthly, seasonal, and annual depth-frequency analyses for each basin were also presented.

The results of this study are mainly sets of tables and figures presented in the text and in Appendices A through D [Appendices not provided in this document – available online at the NSRSM Peer Review website[1]]. These appendices provide detailed information about basin average rainfall statistics and frequencies within Central and South Florida. Histograms of these data and statistics such as mean, standard deviation, skewness, and kurtosis are depicted in Appendix A for each basin and each month. Appendix B presents time series of monthly rainfall departures from historical monthly average for each basin and each month. Appendix C presents time series of seasonal and annual rainfall departures from respective historical averages. Appendix D provides average rainfall and frequency estimates for monthly rainfall in each basin.

The results show a significant variation around the historical mean for all basins and all months. The Lower East Coast has generally the highest rainfall at any time of the year, while Lake Okeechobee and the Kissimmee River areas have the corresponding lowest rainfall depths. May and October represent transitional months between the dry and wet seasons. June through October are considered wet season months, while November through May of the following year are considered dry season months.

Monthly, seasonal, and annual regional frequency analyses were performed for each basin. For each average rainfall data set, a distribution testing was performed to select one among seven distributions. The PDF selected for frequency analysis of each data set was that with the lowest χ^2 ratio. The frequencies of interest were 5-year, 10-year, 20-year, 50-year, and 100-year, dry and wet return periods.

[1]https://my.sfwmd.gov/portal/page?_pageid=1314,2555966,1314_2608149:1314_2564292&_dad=portal&_schema=PORTAL

REFERENCES

Ahn, H. (2005). FREQ (Version 2.0) [Computer Software]. Homestead, FL: Everglades National Park.

Ali, A. and W. Abtew. 1999. Regional Rainfall Frequency Analysis for Central and South Florida. Technical Publication WRE #380. South Florida Water Management District. West Palm Beach, Florida.

Haan, C. 2002. Statistical Methods in Hydrology, Second Edition. The Iowa State Press, Ames, Iowa.

C.3: PRISM RAINFALL ANALYSIS FOR WET, DRY AND AVERAGE YEARS

Alaa Ali, SFWMD

An analysis was conducted using PRISM rainfall long-term data to determine representative wet, dry and average rainfall years for model evaluation.

The results are tabulated in 4 columns in Table C.3-1 below.

Column 1: Rainfall year (1895-2005)

Column 2: Quantiles of annual rainfall for overall district-wide rainfall. The annual rainfall (district-wide) represents on the quantile scale (11.7% means there is 11.7% dryer years and 88.3% wetter years than the given year).

Column 3: Average of the 15 quantiles is calculated for a specified year for the 15 rainfall basins. We can also calculate the standard deviation of the quantiles across the 15 basins.

Column 4: The standard deviation of basin quantiles across the 15 basins. The objective is to select some years that represent dry, average and wet conditions. Here are the factors:

for dry

1. Years of District wide quantiles as close as possible to 10%
2. Years where the basin averaged quantiles and District wide quantile are close to each other
3. Years where the basin quantile standard deviation is low (measure of rainfall spatial homogeneity)

You consider the same factors for 50% and 90% for average and wet (hopefully in annual rainfall the median and average are close enough).

Data meeting the criteria above are highlighted in Table C.3-1.

Table C.3-1. Representative wet, dry and average rainfall years for model evaluation, where Red = Dry, Green = Average, Blue = Wet

Year	Quantile regional	Avg quantile basins	std of basin quantiles
1896	0.08	0.11	3.58
1897	0.67	0.60	18.00
1898	0.15	0.17	4.49
1899	0.75	0.70	8.15
1900	0.25	0.29	14.06
1901	0.32	0.35	9.78
1902	**0.50**	**0.51**	**6.60**
1903	0.63	0.58	10.43
1904	0.21	0.27	11.33
1905	0.20	0.25	4.79

Year	Quantile regional	Avg quantile basins	std of basin quantiles
1906	0.43	0.42	17.31
1907	0.15	0.19	8.85
1908	**0.13**	**0.17**	**5.97**
1909	0.69	0.64	14.33
1910	0.28	0.33	14.91
1911	0.44	0.44	8.61
1912	0.54	0.54	19.11
1913	0.83	0.82	8.08
1914	0.06	0.11	6.17
1915	0.30	0.34	11.65

Year	Quantile regional	Avg quantile basins	std of basin quantiles
1916	0.55	0.57	22.98
1917	0.23	0.28	22.35
1918	0.41	0.43	10.69
1919	0.38	0.44	16.65
1920	0.42	0.42	14.73
1921	0.37	0.40	19.49
1922	0.19	0.22	10.59
1923	0.92	0.86	16.62
1924	0.72	0.64	12.74
1925	0.62	0.59	18.15
1926	0.65	0.61	13.54
1927	0.49	0.53	17.47
1928	0.05	0.11	6.71
1929	0.53	0.54	12.70
1930	**0.94**	**0.92**	**3.29**
1931	0.86	0.85	5.73
1932	0.01	0.03	3.72
1933	0.81	0.78	14.15
1934	0.66	0.60	27.86
1935	0.36	0.41	14.79
1936	0.74	0.64	16.62
1937	0.85	0.83	12.81
1938	0.14	0.16	10.00
1939	0.05	0.10	6.95
1940	0.76	0.67	18.25
1941	0.87	0.83	10.83
1942	0.70	0.61	21.81
1943	**0.12**	**0.16**	**4.10**
1944	0.35	0.36	14.65
1945	0.07	0.11	9.64
1946	0.45	0.42	22.41
1947	0.80	0.77	9.21
1948	1.00	0.99	1.50
1949	0.56	0.54	19.37
1950	0.75	0.68	10.24
1951	0.24	0.28	14.18
1952	0.39	0.41	30.10
1953	0.71	0.63	19.66
1954	**0.90**	**0.87**	**9.03**
1955	0.51	0.55	18.52
1956	0.11	0.16	12.30
1957	0.34	0.38	23.99
1958	0.93	0.87	11.94
1959	0.73	0.66	17.16
1960	0.99	0.98	1.35
1961	0.85	0.86	5.31

Year	Quantile regional	Avg quantile basins	std of basin quantiles
1962	0.02	0.04	2.63
1963	0.47	0.44	24.78
1964	**0.57**	**0.56**	**12.47**
1965	0.25	0.33	16.37
1966	0.61	0.59	21.34
1967	0.60	0.59	21.65
1968	0.22	0.31	17.72
1969	0.97	0.95	4.69
1970	0.96	0.96	4.30
1971	0.03	0.04	2.97
1972	0.46	0.48	22.27
1973	0.45	0.43	10.59
1974	0.17	0.21	14.12
1975	0.27	0.33	26.93
1976	0.26	0.31	12.32
1977	0.33	0.34	13.62
1978	0.68	0.62	17.56
1979	0.64	0.59	11.79
1980	0.78	0.70	13.74
1981	0.04	0.10	14.17
1982	0.55	0.53	17.95
1983	0.98	0.97	4.16
1984	0.65	0.59	13.58
1985	0.18	0.22	13.87
1986	0.40	0.45	21.55
1987	0.52	0.53	28.42
1988	0.31	0.35	21.66
1989	0.16	0.19	17.56
1990	**0.09**	**0.12**	**13.25**
1991	0.59	0.54	21.57
1992	0.77	0.72	8.46
1993	0.82	0.78	10.96
1994	0.48	0.53	19.20
1995	0.88	0.86	9.43
1996	0.95	0.92	5.50
1997	0.58	0.58	20.22
1998	**0.95**	**0.94**	**3.02**
1999	0.35	0.42	14.54
2000	0.89	0.85	14.90
2001	0.10	0.19	18.34
2002	0.84	0.83	5.90
2003	0.91	0.83	12.59
2004	0.79	0.75	10.61
2005	0.29	0.32	27.92