

Rainfall Observations in the Loxahatchee River Watershed

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Introduction

Rain is a common occurrence in south Florida, yet its presence or absence can dramatically affect our lives. Heavy rains can cause flooding, property damage, construction delays and forestall social activities. Surface waters are subject to pollution from the runoff of urban and agricultural storm water and the public health and safety can be jeopardized in time of heavy rain. Conversely, drought periods can destroy crops, turfgrasses and ornamental plants, dry up lakes, spark brush fires, cause saline intrusion and threaten public drinking water supplies. For these reasons, it is important that precipitation patterns are understood so that effective storm water, water use and surface water management plans can be designed and implemented under appropriate regulatory guidance.

The purpose of this report is to organize historic rainfall information in a format that may be used by a broad spectrum of the community and to offer views on typical and atypical conditions, trends and relationships. It is the goal of the District to provide a compendium of rainfall observations specific to the watershed of the Loxahatchee River, a basin of approximately 200 square miles located in northeastern Palm Beach and southeastern Martin counties.

The report is made possible by the work of dozens of organizations and individuals that have collected rainfall information over the past three and one-half decades. Appendix A provides a map showing the location of the rainfall gauging stations and a table listing the name of the entity recording the data and the period of record for the station. Appendix B presents the monthly rainfall amounts from the major rainfall sites within the watershed. For the majority of this report, five significant data sets, each with a period of record in excess of fifteen years, were used: Jonathan's Landing Golf Course, Jupiter Water Plant, Loxahatchee River District Plant, South Florida Water Management District at S-46 and Pratt and Whitney. Unless otherwise indicated, the observations reported are from the Loxahatchee River District site.

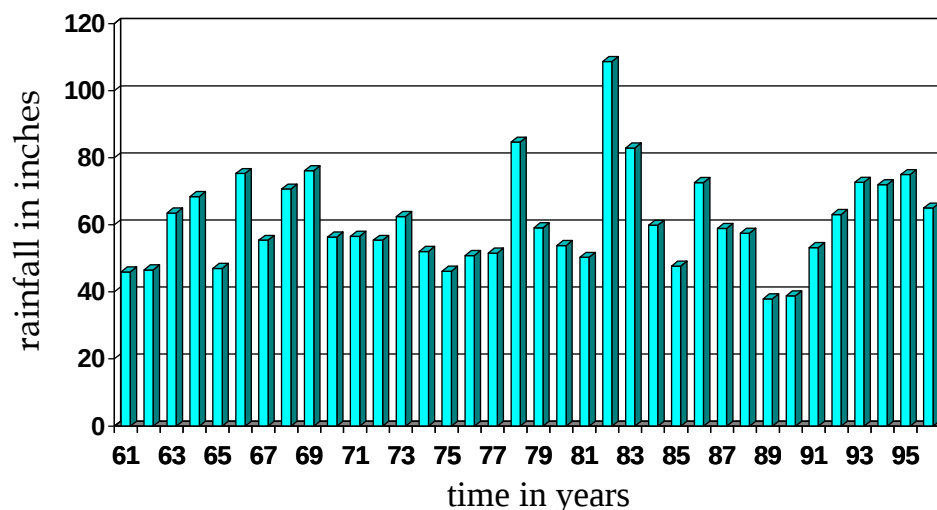
Annual Observations

In the early portion of this century, a parent organization to today's National Oceanic and Atmospheric Administration (NOAA) collected rainfall from a site in Jupiter. Daily rainfall from two periods, 1900 through 1908 and from 1921 through 1926, were recorded. Rainfall for this

historic 14 year period averaged 62.6 inches and ranged from a low near 40 inches in 1907 to a high of near 80 inches recorded in 1925.

In more recent times, rainfall has been continuously observed and recorded in the Loxahatchee River basin since the late 1950's. A long term record for the central portion of the watershed has been developed by combining the readings for 1960 through 1973 taken at the S-46 discharge structure by the Water Management District with the Loxahatchee River District data for 1974 through 1996 taken at its site located 0.6 miles to the south of S-46. Annual rainfall for this period of record is shown on Figure #1.

*Figure #1 : Annual Rainfall
at Jupiter, Florida 1961-1996*



The annual rainfall mean for the full 36 year period of record is 61.05 inches and the median annual rainfall is 57.15 inches, skewed lower by several very high rainfall years. A review of the distribution of annual rainfall shows that twelve of the 36 years fall in a fairly narrow range of six inches above or below the mean or an approximate 10% variance from the mean (from 55" to 67"). An additional twelve years exhibit rainfall amounts falling between 10% and 20% above or below the mean. Therefore, two-thirds of the recorded years exhibit rainfall amounts ranging from 49" to 73" or about one foot above or below the mean. The annual rainfall conditions observed in this range can be considered 'typical' and, unless combined with consecutive years of similar high or low rainfall or subjected to a significant individual month or event, do not tend to present severe environmental, economic or social problems to the community.

The remaining twelve years of the 36 year study period vary by more than 20%, usually between 20% and 40%, above or below the historic mean, with one major anomaly that was recorded in 1982, when the total annual rainfall was 75% above the norm. It is during these years, about one out of three, that significant and long duration problems are experienced.

Of the five driest years on record, two occurred concurrently in the early 1960's (46.01" in 1961 and 46.57" in 1962) and the third was the middle year (46.19" in 1975) of a three year period of below average rainfall in the mid 1970's. Most recently, back to back years of rainfall amounts well below the norm were recorded in 1989 and 1990 with yearly amounts of 37.87" and 38.78", respectively. In each of these years, the deficit rainfall resulted in significant periods of drought and substantial challenges to the water managers of the community.

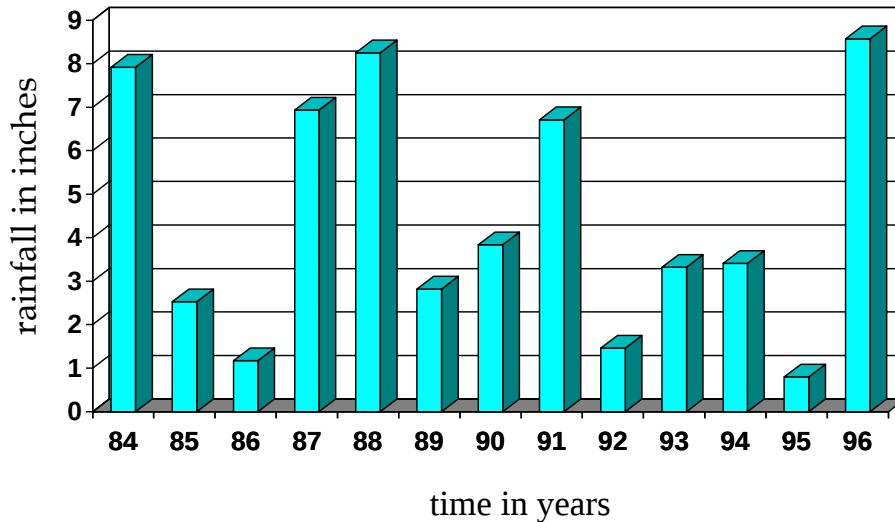
The five wettest years recorded during the 36 year period of record each exceeded 80" of total rainfall and each occurred in the past 18 years. In 1978, five months of significantly above average rainfall, highlighted by Hurricane David, resulted in 84.78" of rainfall. Just a few years later, in 1982 and 1983, back to back years of 108.71" and 82.85", respectively, fell in the central portion of the watershed. The other two wettest years vary dependent upon the location of the data base used. While high rainfall amounts were recorded for 1966 and 1969, the more recent years of 1994 and 1995 saw 86.26" and 83.89", respectively, fall on the coastal portions of the area. It should be noted that, while flooding occurred in each of the periods identified, significant flooding can also occur in years of lesser annual totals.

Seasonal and Monthly Observations

The year is normally divided into two seasons as relates to rainfall, the summer wet season from May through October and the winter dry season that runs from November through April. Calculations using the mean average monthly rainfall for the 36 year period of record from the central watershed area, show that two-thirds of the precipitation (40.63") falls in the wet season with the balance (20.42") coming in the dry season months. Given, however, that past observations have shown that conditions can vary substantially from one year to the next, a closer examination of the data was undertaken to determine if any keys or triggers to wet or dry conditions were apparent from the data.

The major outcome of this examination was that the first month of each season, May and November, can be more accurately described as transitional months. Specifically, both May and November, more so than any other months, can act as either a wet month or a dry month. For instance, Figure #2 gives monthly rainfall in the month of May for the past 13 years and shows that this 'typical' wet season month is just as likely, if not more likely, to behave as a dry season month. In a similar manner, a significant number of November's have recorded high rainfalls as compared to the long term average for this 'typical' dry month. These transitional months become key in many years to a drought or wet condition being either prolonged or relieved.

*Figure #2 : May Rainfall
at Jupiter, Florida 1984-1996*

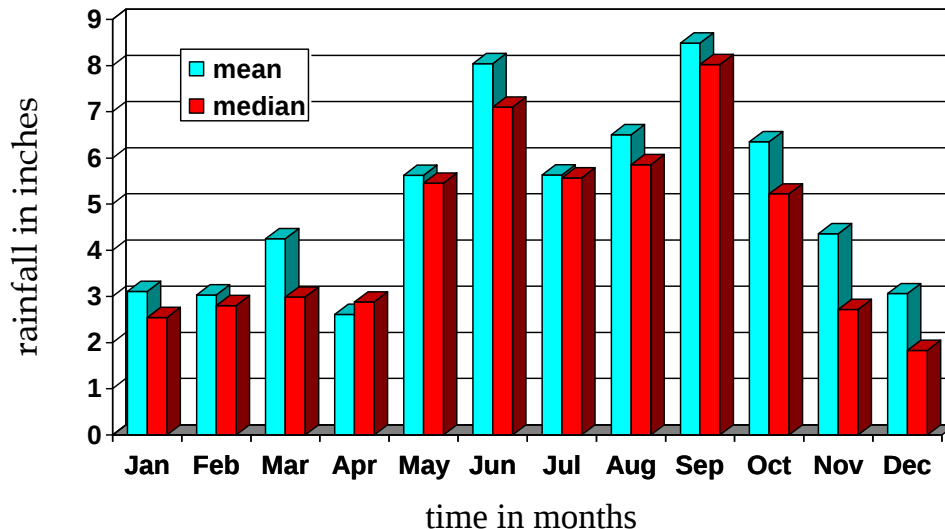


The monthly rainfall averages for the 1960-1996 time period are shown on Figure #3 and listed on the table below. Each month is expressed as both mean and median. As relates to the mean average monthly rainfall, the seasons are apparent with the wet season months averaging from 5.6" to 8.5" and the dry season months averaging 3.0" to 4.4". An even greater separation or difference is observed when the median average values are considered. The wet season months range from 5.2" to 8.0", lowered slightly from the arithmetic mean because of the presence of several very high individual months. Likewise, the dry season medians, ranging from 1.8" to 3.0" are skewed significantly lower by a few years when the rainfall for that particular month was atypically high. When considering average monthly rainfall, the mean is normally employed. More consideration, however should be given the median average since this expression more accurately and evenly divides the high and low months observed during the period of record.

Wet Season			Dry Season		
month	mean value	median value	month	mean value	median value
May	5.62	5.45	November	4.36	2.72
June	8.04	7.11	December	3.06	1.83
July	5.63	5.57	January	3.11	2.54
August	6.51	5.85	February	3.03	2.81
September	8.49	8.02	March	4.25	2.99
October	6.35	5.22	April	2.61	2.88

Large rainfall months are usually created by a tropical storm system or stalled frontal system. The frequency at which thirteen or more inches of rain falls in a month is once in 23 months, or 19 times since 1960. While records do not exist relating flood conditions to each of these observed rainfall months, it is believed that significant flooding within much of the watershed resulted in each of the 19 months. The three largest monthly rainfalls were each recorded at over 20 inches and include September of 1960 (20.26”), November of 1982 (21.95”) and October of 1995 (23.64”). Most of the large rainfall months were wet season months, however, about one-fourth of the largest monthly rainfalls were recorded in months typically considered as dry.

*Figure #3 : Monthly Rainfall
Averages at Jupiter, Florida, 1960-1996*



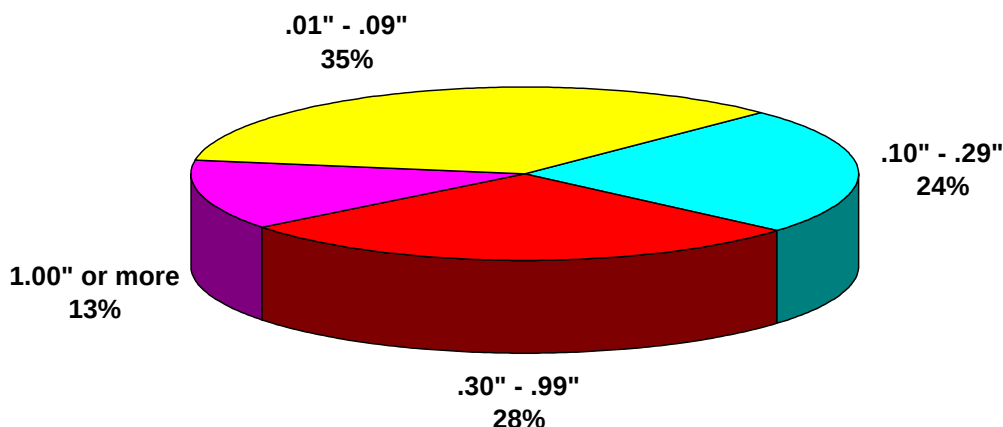
Monthly rainfall amounts of less than one-half inch have occurred at the same frequency of 19 occasions over the past 36 years or about once every 23 months. The five lowest months were all less than 0.20” and occurred in November of 1961, December of 1962, December of 1968, February of 1974 and December of 1987. February of 1974 was the only month of the 437 month period of study when no rainfall was recorded. All 19 of the low monthly rainfall totals occurred in months categorized as dry season months.

In addition to the very low rainfall years listed in the previous section and the extreme months identified in the above paragraph, water use restrictions, saline intrusion and other drought related problems can result from a series of months with below average rainfall, especially at the end of the dry season and extending into the early wet season. Examples of years exhibiting spring droughts from 3 to 9 months duration are 1981 and 1985.

Daily Observations Relating to Events, Frequency and Intensity

In 1994, in conjunction with storm water planning for the watershed, the Loxahatchee River District conducted a study of daily rainfall events with special emphasis on frequency and intensity. A 22 year period of record, from 1972 through 1993, was used and a summary of the results is shown on Figure #4.

Figure #4 : Rainfall Frequency and Intensity in the Loxahatchee Watershed



1972-1993, avg. 138 events annually

The study found that the number of rainfall event days per year ranged from 101 days in 1989 to 175 days in 1982 with the mean number of days with rainfall calculated to be 138 annually. The analysis then grouped the intensity of events into four categories shown on Figure #4. Very light rains, from 0.01" to 0.09", accounted for 35% of all events and light rains, from 0.10" to 0.29", made up an additional 24% of all events. Twenty-eight percent of all rains fell into a moderate category of from 0.30" to 0.99" and heavier rains of 1.00" or greater were observed during 13% of the events. A prime importance of this grouping is that the two categories containing the smaller rainfall events represent 59 % of all events but normally produce no runoff of stormwater to the surface waters of the watershed. Only during events of greater than 0.30" can some runoff be anticipated and, during the average year, this accounts for about sixty days. When combined with runoff of several day duration caused by big rain events and the combined effect of some smaller events occurring over several days or following a major event, the study estimated that surface runoff was to be expected during approximately 90 days during a typical year.

In a related study, the Loxahatchee River District looked at how frequently the daily rainfall amounts recorded over the past 25 years exceeded certain regulatory thresholds. Using rainfall amounts from the central watershed and 1990 isohyetal lines established by the Water Management District, it was found that the 1-day rainfall with a 25 year return period (10") was exceeded twice, the 1-day rainfall with a 10 year return period (8.5") was exceeded three times, the 1-day rainfall with a 5 year return period (7") was exceeded 5 times and the 1-day rainfall with a 3 year return period (5.5") had been exceeded on 11 occasions. Although records of flooding are not available for all events, it is believed that, at a minimum, localized flooding within the watershed results when rainfall exceeds 3.0 inches. The examination concluded that rain in excess of 3.0" fell on 42 separate occasions over the 25 year period of study.

Some of the most severe flooding experienced in the Loxahatchee River watershed corresponded to the five largest single day rainfall events, each of which exceeded 7".

March 29, 1982	7.34 inches
November 16, 1994	7.95 inches
November 8, 1982	9.50 inches
November 13, 1978	10.11 inches
October 17, 1995	17.90 inches

The substantial flooding associated with each of the above events was accompanied by significant property damage, public health and safety warnings and a week or more of inconvenience and lost time to the families and businesses of the community. Additionally, the runoff generated by large rainfall events caused serious environmental degradation and loss of aquatic habitat throughout the estuary. It is important to note that severe flooding and runoff can and does also occur as the result of other conditions such as the accumulation of heavy rainfall over several consecutive days.

Spatial Relationships

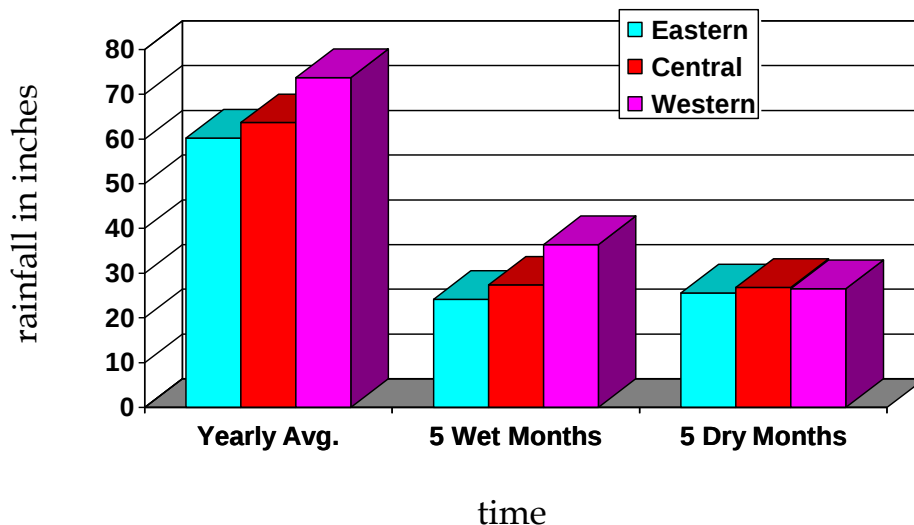
In the early 1980's, the Area Planning Board of Palm Beach County established a network of over 20 rainfall gauges in the eastern half of the Loxahatchee River watershed. The purpose of the program was to distinguish spatial trends and relationships. Although the program became limited due to the loss of participants and a short two year time frame, some interesting findings were made. The major observation was the extreme variability in daily rainfall amounts from one sampling station to another. Summer squalls would bring significant precipitation to the coastal stations while inland stations would record no rainfall. Conversely, summer storms would produce rain over the western study area leaving coastal areas dry. Daily observations from stations located along a north-south axis could also be quite divergent.

The South Florida Water Management District has published many reports on rainfall in south Florida. In one report, the author, Thomas K. MacVicar, states that the predominance of convective rainfall in south Florida during the wet season creates much higher rainfall totals inland than along the coast. He suggests that the rainfall values within one mile of the coast could

be 15%-20% less than the associated inland values. Another conclusion of SFWMD published reports is that rainfall in the lower east coast basin of south Florida, from Palm Beach County south, exhibits a higher annual average than other basins.

Specific to the Loxahatchee River watershed, unpublished work by David Welter of the Loxahatchee River District in 1993 and a more recent hydrologic modeling study of the Loxahatchee slough by consultants to the City of West Palm Beach, both indicate that inland rainfall is higher during the summer wet season. Figure #5 shows a comparison of seasonal rainfall over a 15 year study period at three stations: Jonathan's Landing Golf Course (eastern) located one mile from the Atlantic shoreline, Loxahatchee River District site (central) located nearly five miles inland and the Pratt and Whitney site (western) located approximately 17 miles from the ocean. It should be noted that this analysis used 5 month wet and dry seasons and excluded the transitional months of May and November. The assertion of earlier researchers is supported by this data. While dry season rainfall is similar at all three stations, wet season rainfall at the Jonathan' Landing site is 12% less than observed at the Loxahatchee River District site and 34% lower than at the Pratt and Whitney site. Summer rainfall in the central portion of the watershed, as represented by the Loxahatchee River District site near the I-95 corridor, is 25% lower than experienced at the western edge of the watershed. This spatial observation is important when planning for basin-wide management.

Figure #5 : Spatial Differences in Rainfall - Jupiter, Florida 1982-1993



The central rainfall sites within the Loxahatchee River watershed, the Jupiter Water and Loxahatchee River District sites, were also compared to long term rainfall averages recorded at

West Palm Beach, 20 miles to the south, and a site 20 miles to the north in the City of Stuart. Results of this analysis revealed that annual rainfall in the study area averages several inches higher than the northern station and marginally higher than the site in West Palm Beach.

Summary

All major studies of rainfall in south Florida agree that a high degree of variability will be associated with any short term observations and that longer term averaging is needed to realize any significant findings. This analysis is no different and its conclusions are based on periods of record ranging from 15 to 36 years.

Listed below are the more salient, longer term observations taken from a study of rainfall information in the Loxahatchee River watershed.

... mean annual rainfall for the 36 year period of record is 61 inches and the median rainfall is 57 inches per year

... for two-thirds of the recorded years, annual rainfall is about one foot above or below the mean (approximately 20% variance) and can be considered typical

... in one out of three years there exists the potential for significant drought or flood related problems

... on average, two-thirds of the annual rain falls in the May through October wet season with the balance coming in the November through April dry season

... the wet season months average from 5.6" to 8.5" and the dry season months typically exhibit rainfall amounts between 3.0" and 4.4"

... the basin will experience a month of rainfall exceeding 13" about once every two years and will experience rainfall of less than 0.2" a month at about the same frequency

... the months of May and November act as transitional months and can be key to prolonging or relieving a drought or wet condition

... it rains between 101 and 175 days per year with an average of 138 rain days annually

... nearly 60% of the rainfall days can be categorized as very light or light and produce little or no surface water runoff

... the local rainfall observations fit well with long term reports on event frequencies in south and central Florida

... wet season rainfall has been observed to be significantly higher at inland locations

... the recorded rainfall in the Loxahatchee River watershed exceeds rainfall totals from stations in basins located to the north and south

Rainfall information will continue to be collected from several sites within the watershed of the Loxahatchee River. It is the intent of the Loxahatchee River District to extend the period of record, evaluate new information in light of the established record and provide summary reports on a schedule of once every four years.