# TECHNICAL MEMORANDUM
# WRE # 361

## Hydrologic Report of Lake Kissimmee Basin And Preferred Database Development

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**By**

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# ACKNOWLEDGEMENTS

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## EXECUTIVE SUMMMARY

This report provides a comprehensive summary for hydrologic data in Lake Kissimmee Basin, LKB, as part of Upper Kissimmee River Watershed (UKRW). The UKRW is a major water source in the South Florida water Management system.. Hydrologic data pertaining to this basin exist in the South Florida Water management District database, DBHYDRO. These data are mainly time series of Flow, Rainfall, Stages, and Evaporation. Such time series are sometimes interrupted by gaps of missing or questionable data. The estimation of such data and the summarization of all data is an essential component for hydrologic investigations.

In this study, a series of data estimation procedures have been developed to improve the quality of flow data, and to provide a concise representation of all data pertaining to LKB. The improved uninterrupted flow data are stored in new database keys called "preferred keys". The representation of data includes statistical measures, summary tables, and graphic presentation. Missing data estimation was conducted based on the hydrologic concepts of the basin and auto correlation analysis. Time series were summarized into basic monthly statistics such as Mean, Median, Standard Deviation, Minimum, and Maximum. Time series plots of the historical hydrologic data are also presented.

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# INTRODUCTION

The Upper Kissimmee River Watershed, UKRW, represents a major source of inflow contribution to Lake Okeechobee. This basin consists of a set of sub-basins connected through a chain of lakes and canals. Such a chain conveys water from the entire UKRW to Lake Okeechobee via the Kissimmee River. Figure 1a shows a layout of the sub-basins as well as the chain of lakes and canals comprising UKRW. A hydrologic description of this area can be found in the literature (Fan, 1986; Fan and Lin, 1984; Guardo, 1992). Extensive hydrologic data pertaining to UKRW are found in the District's main hydrologic database, DBHYDRO. These data are sets of time series of Rainfall, Pan Evaporation, Stage, and Flow sampled and/or computed at many locations, usually on a daily basis, over the UKRW. These data represent a major source of information that is essential to understanding the hydrology of this basin. Organized compilation, statistical measures, and graphical representation of such data are essential for hydrologic modeling, forecasting, and decision making. The objectives of this series of studies are: 1) to present a hydrologic data summary for each sub-basin of significant contribution to the UKRW hydrology, and 2) to use the available sources of information to develop continuous time series of flow data that will be stored in a preferred key in the database.

Preliminary review showed that some of the UKRW time series data have gaps. These gaps (missing, not processed, etc.) range from a few days to several months. The starting and ending dates are not necessarily the same across the data sets. Also, the range of records of these sets may or may not overlap. Therefore, complete records of all time series of hydrologic data may not be available. While data summary may be performed with only the available data, the assessment of the missing information and the improvement of the existing data are essential for preferred database key development. The preferred key is an alternate data set where missing gaps are filled with estimated data using nearby spatial and temporal data. Usually, the preferred key contains continuous time series within the period of record that can be used for hydrologic applications.

The largest sub-basin in the UKRW is Lake Kissimmee Basin, (LKB), and the largest lake in UKRW is Lake Kissimmee. The LKB has an area of 269.1 square miles, and Lake Kissimmee has an area of 55.5 square miles. Because of its significance, LKB receives the first attention in this series. This basin is approximately located within longitudes 81 05 00 and 81 27 30; and latitudes 27 45 00 and 28 02 00. Four medium-sized lakes drain into Lake Kissimmee. These lakes are Lake Rosalie, Lake Jackson, Lake Marian, and Lake Tiger (Figure 1b). Except for Lake Tiger, these lakes contribute insignificant flow to Lake Kissimmee due to flow control at their outlets. Lake Kissimmee has been regulated by the S65 structure since 1964 according to a specific regulation schedule (see Figure 1c). The reader is referred to Guardo, 1992, for more details about the hydrologic conditions and the hydrologic structures of LKB.

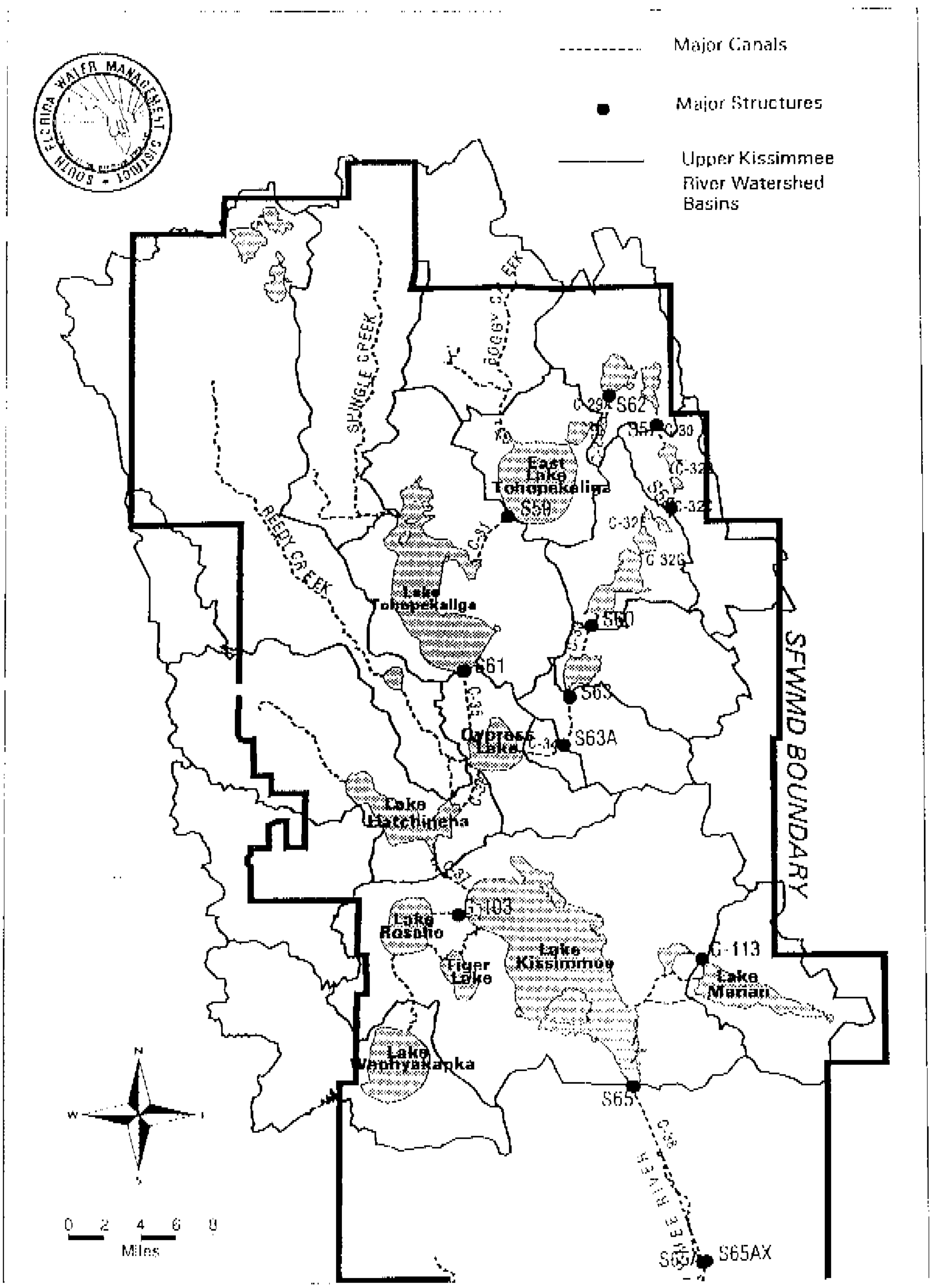



Figure 1a. Upper Kissimmee River Watershed.

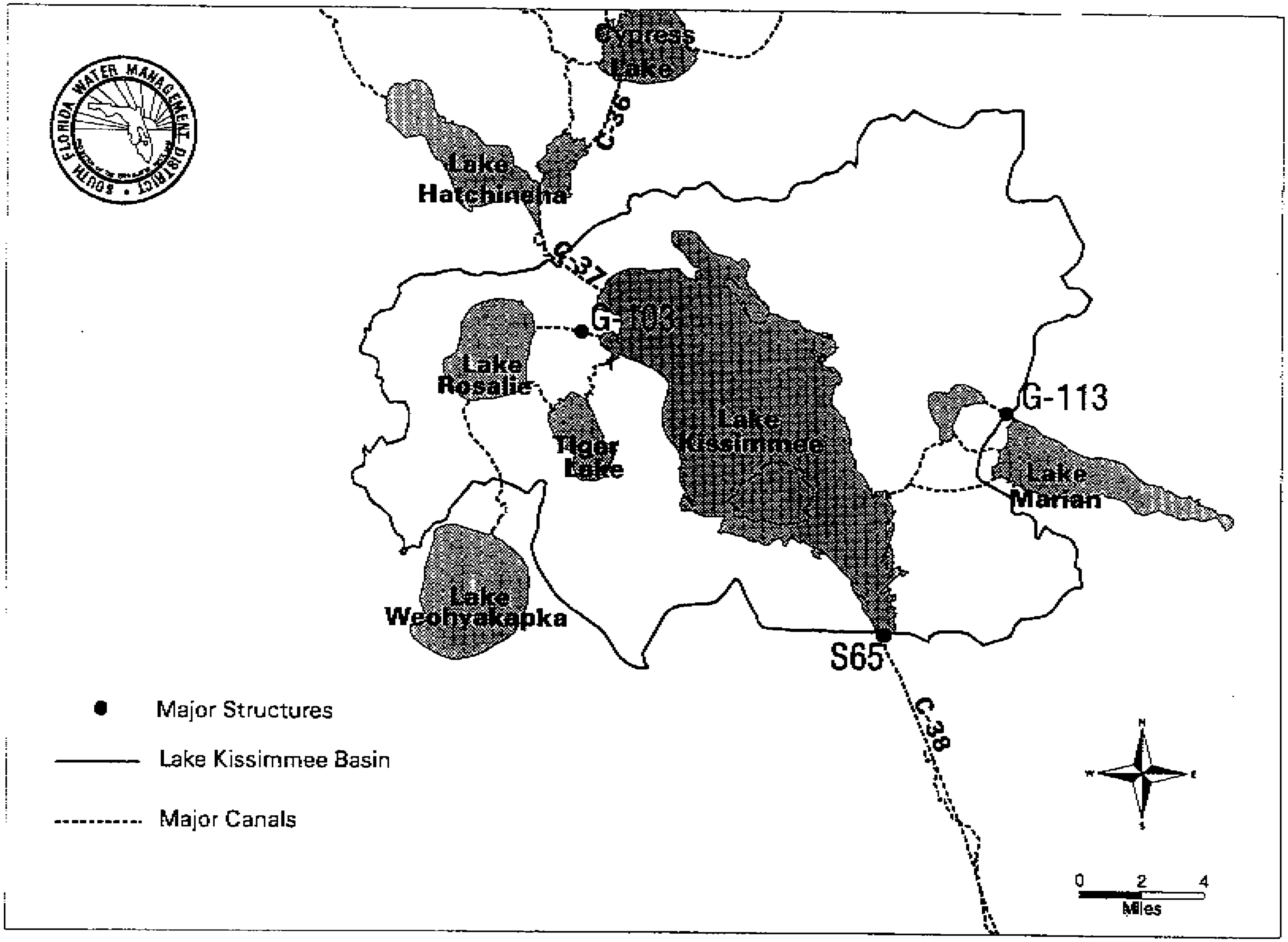
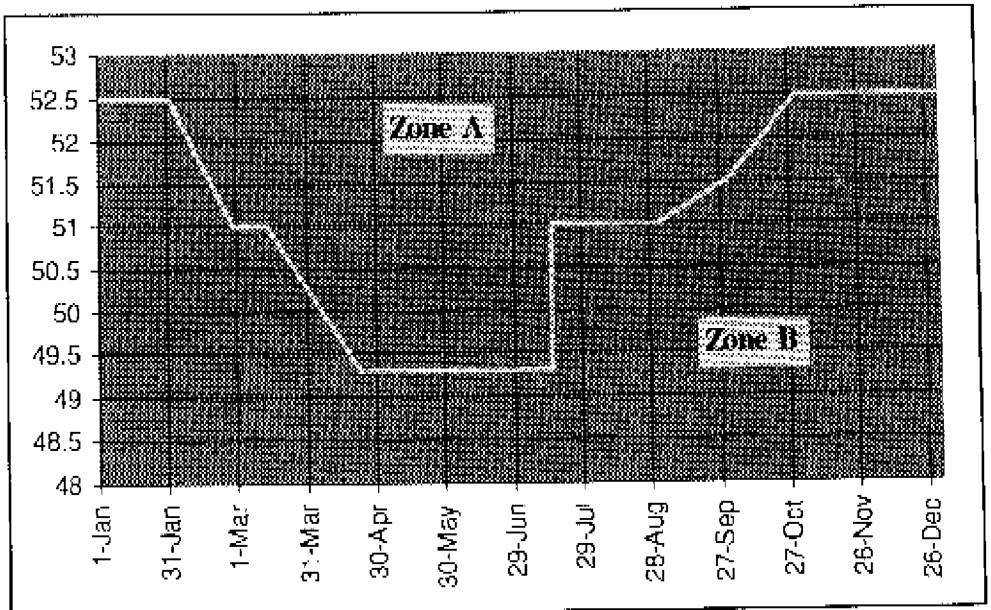



Figure 1b. Lake Kissimmee Basin.




| Zone | Releases S-65 |
|---|---|
| A | 3,000 cfs, up to design capacity (11,000 cfs) without exceeding design conditions downstream. When the lake is within 0.5 feet of desired stage, forecasts will then be made and releases start to bring the lake back to schedule within 15 days |
| B | To maintain minimum flows |

Figure 1c. Lake Kissimmee Basin Regulation Schedule.

This report presents a procedure for estimating missing data, reviewing the existing data, and providing a hydrologic data summary for LKB. The tools and strategy developed in this study will be utilized in subsequent studies. The main objectives of this study are to 1) outline development of preferred database keys (when possible) and 2) summarize the historical hydrologic data

The main body of this report consists of four sections covering the four hydrologic components (Flow, Rainfall, Stage, and Evaporation) in the UKRW. In each section, the available data are first presented. When applicable, data estimation methods for preferred key development are presented. Data summary and relevant statistics are then provided.

## FLOW

Inflow and outflow components of the LKB system are essential for water budget analysis. Unfortunately, many of these components have no records and, hence, water budget analysis is presently not feasible for the LKB. However, an overview and a summary of the available data, and a development of preferred database keys are presented in the following three subsections.

### Available Data

Table 1 presents detailed information about the flow stations available for this study. The spatial locations of these stations are presented in Figure 2. Inflow records from Lake Hatchineha are available from 1942 to 1968. Outflow records at the outlet of Lake Kissimmee (S65) or through Kissimmee River downstream of S65, are available from 1933 to 1997. Preliminary time series of the flow records show a significant change of the flow pattern after January 1964. Such a variation is due to the construction and the operation of the control structure S-65. These series were found to contain many gaps and some records were found to be inconsistent with the hydrologic characteristics of the UKRW in general and LKB in particular. Filling in the gaps, fixing the inconsistent records, and hence, developing preferred keys are necessary for completing the flow records. Such a process is presented below.

Table 1. Information about stations with inflow or outflow records within the LKB.

| Station | Dbkey | Method | Starting date | Ending date | Latitude | Longitude |
|---|---|---|---|---|---|---|
| L. Hatchineha * | 00175 | Daily Mean | Jan/42 | Sep./68 | 28 00 00 | 81 22 50 |
| C38.LK_O | 00189 | Daily Mean | Oct./33 | Sep./69 | 27 46 13 | 81 10 45 |
| S65_S | 00186 | Daily Mean | Oct/69 | Sep./97 | 27 48 13 | 81 11 54 |
| S65_S | G7446 | Daily Mean | Jul./97 | Sep./97 | 27 48 13 | 81 11 54 |

* Station located outside the LKB but it measures inflow to the LKB.

### Preferred Key Development

A preferred key is developed using two steps: 1) data review and 2) missing and questionable data estimation. A missing data point is the one that has no numerical record. A questionable data point is the one that looks unrealistic according to the characteristics of the flow through the basin. For example, negative flow values are often observed at the inlet and outlet locations of the LKB, which contradicts the hydrologic characteristics of the UKRW (see Fan 1986). To estimate the missing gaps, some statistical measures are used. To assure statistical homogeneity, these measures must represent one system (i.e., one population). As stated earlier, the LKB has changed from a natural system to a regulated one in 1964. Therefore, a set of statistical measures will be estimated for each system. To estimate the missing data at a given station during the period of a given system, the following procedure is followed.

1) Define the gaps that need estimation by identifying the missing and the questionable data.

2) For gaps with three consecutive days or less, perform a linear interpolation using the latest and the earliest observed data points. This step can not be applied to stations downstream a control structure where the flow travel time is less than or equal to three days.

3) For gaps with more than three consecutive days, apply the following procedure:

   i) Compute the Inflow-Outflow Auto Cross-Correlation Function (ACCF) regardless of the data gap location.

   ii) Evaluate the lag with maximum cross correlation (the flow travel time).

   iii) Find the linear regression relationship between the two time series at this lag.

   iv) Use the resulting relationship to estimate the missing data.

   v) Set minimum flow as zero when back flow is not expected.

4) Subjectively visualize the time series and make any necessary changes of any extremes or unrealistic value.

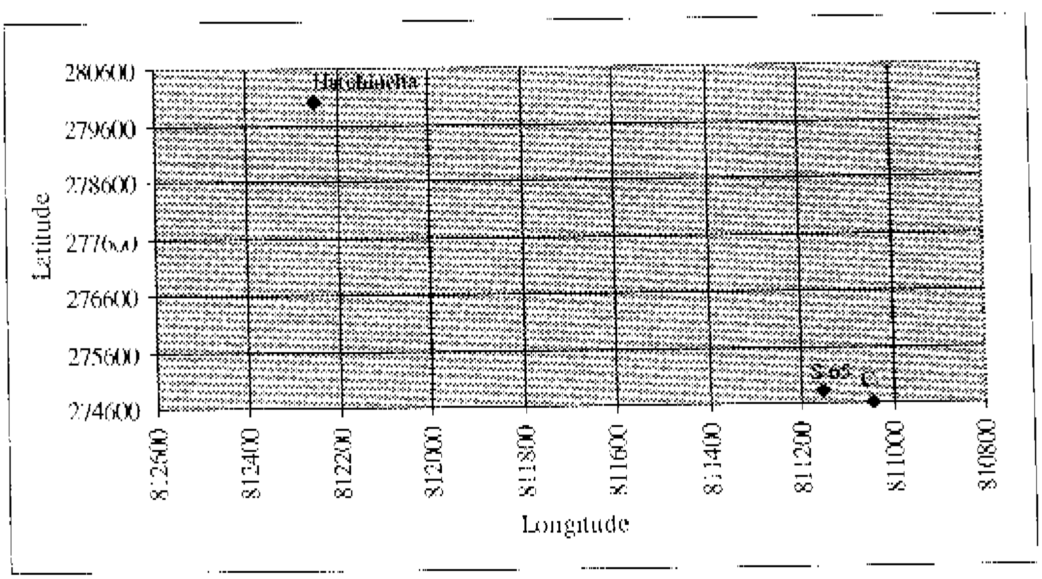



Figure 2. Locations of stations containing flow records within Lake Kissimmee Basin.

The above scheme was applied to the available flow data sets and, subsequently, the preferred keys for these sets were developed. The overlapping records (from 1942 to 1968) of the inflow and outflow stations (see Table 1) were divided into two sets: Pre-S65, and Post-S65. For each set, the Auto Correlation Function, ACF, and the Auto Cross-Correlation Function, ACCF, were computed. The results of this application are given below.

*Pre-S65 Construction*

The ACF and ACCF for time series prior to S65 construction is presented in Figure 3a. As shown, the ACF declines exponentially with obvious change in its second derivative at a 6-month lag reflecting the seasonal variation of the natural system. The ACCF exhibits similar behavior. Also, there is a clear difference between the Inflow-Outflow ACCF and the Outflow-Inflow ACCF. The earlier peaks after a 3-day lag and then declines. The later shows consistent decline and lower correlation values. This is consistent with the fact that Lake Kissimmee outflow is hydrologically dependent on the inflow from Lake Hatchineha, while the opposite is not true. The linear regression relationship between the outflow at time t, and the inflow three days earlier, is:

$$O_t = -175.5 + 1.76 * I_{t-3} \qquad (\rho\ (3) = 0.88) \qquad (1)$$

Where:

$O_t$ is Lake Kissimmee outflow on day (t)

$I_{t-3}$ is inflow from Lake Hatchineha on day (t-3 days)

$\rho$ (3) is the Inflow-Outflow ACCF at 3-day lag.

*Post-S65 Construction*

The ACF and ACCF for time series post-S65 construction are presented in Figure 3b. The construction and the operation of S65 have altered the natural system of the LKB. It is clear that the system statistical structure has significantly been altered. Compared to the natural system, the regulated system shows a lower correlation value at any lag where the ACF and ACCF decline much faster. The regulated system shows fluctuating ACF and ACCF beyond 90-day lag. The negative ACF and ACCF as well as the fluctuation could be due to the operation schedule. The Inflow-Outflow travel time has increased to 12 days. The linear regression relationship between the outflow at time t, and the inflow twelve days earlier, is:

$$O_t = -56.4 + 1.28 * I_{t-12} \qquad (\rho(12) = 0.83) \qquad (2)$$

Where

$\rho$ (12) is the Inflow-Outflow ACCF at 12-day lag.

Two preferred database keys (H0288 for the Hatchineha inflow data and H0289 for the LKB outflow data) have been created. The "preferred" time series for Lake Hatchineha inflow, period of record 1941 to 1968, and the LKB outflow, period of record 1933 to 1997, are presented in Figures 4 and 5 respectively.

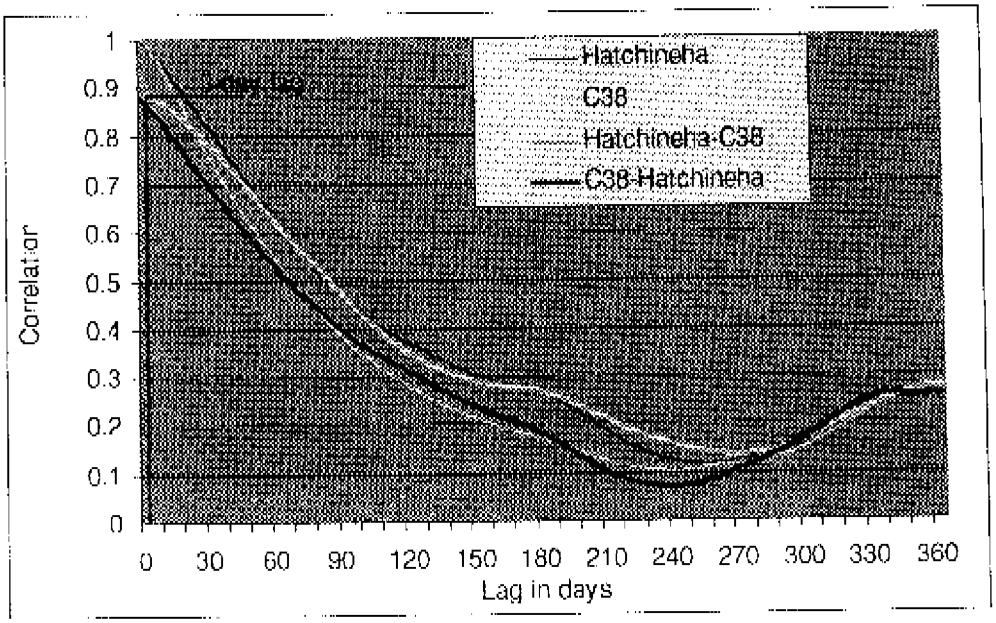



Figure 3a. Auto Correlation and Auto Cross-Correlation for time series within the LKB prior to S-65 Construction.

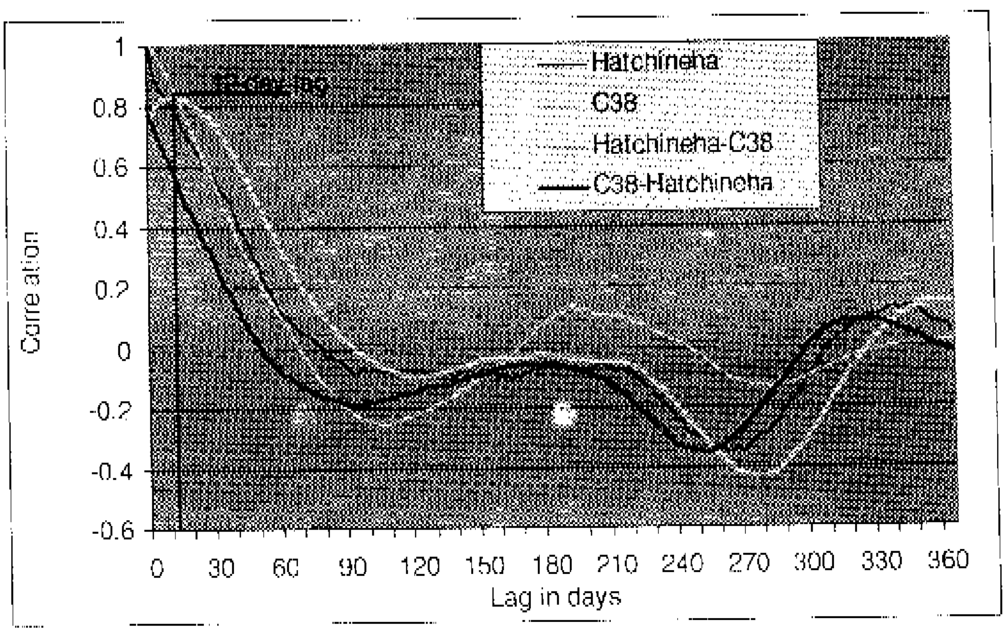



Figure 3b. Auto Correlation and Auto Cross-Correlation for time series within the LKB post S-65 Construction.

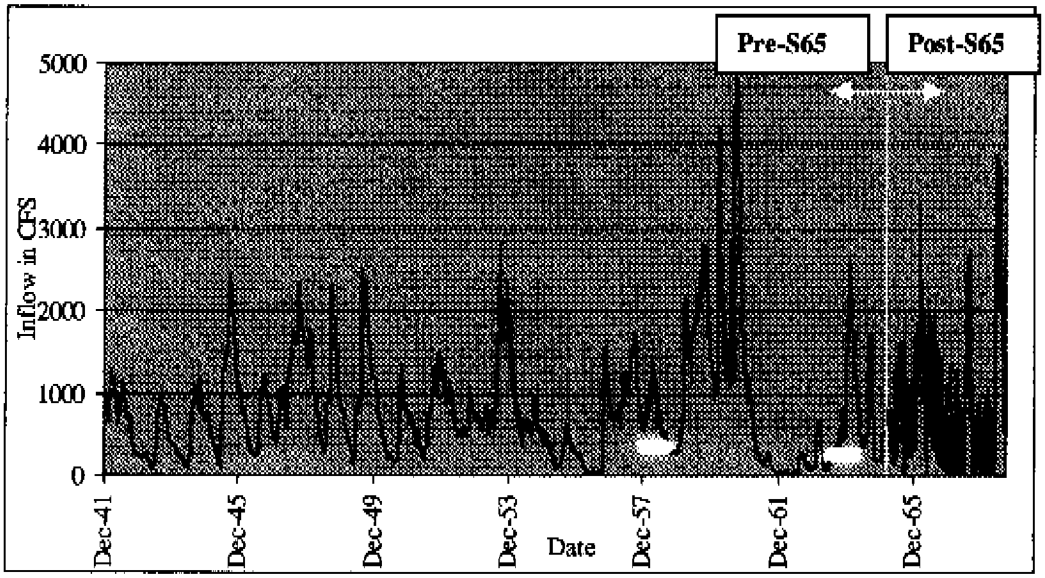



Figure 4. Time series of preferred inflow data from Lake Hatchineha to the LKB.

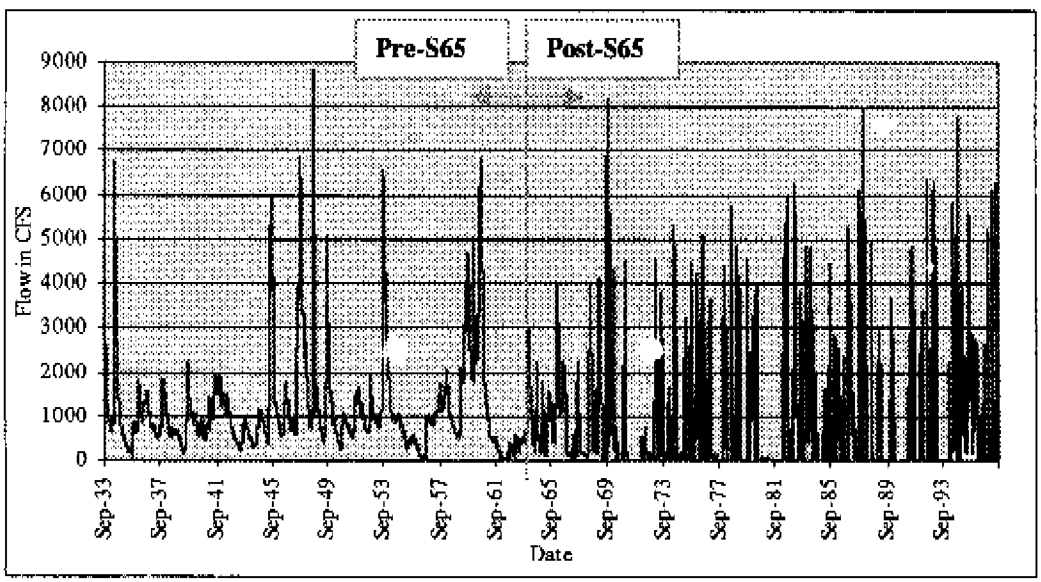



Figure 5. Time series of preferred outflow data for the LKB.

**Data Summary**

A hydrologic data summary is essential for understanding the historical behavior of the system, both annually and monthly. Figures 6 a-e show monthly statistics of the "preferred" inflow and outflow records. These statistics are the mean, median, standard deviation, minimum, and maximum representing the system before and after the operation of S65. Figure 6a shows that Lake Hatchineha is a major source of inflow to the LKB. A significant difference is observed in the flow seasonal patterns between the natural and the regulated systems. For example, during the period September through December, the LKB outflow in the regulated system is significantly less than that in the natural system. This outflow reduction results in a stage rise in lake Kissimmee and, hence, a decrease in the Hatchineha inflow. During January-May period, the flow is released. In June-August period, the Hatchineha inflow is higher than the LKB outflow (Lake Kissimmee is storing water). The seasonal flow pattern in the regulated system clearly reflects the regulation schedule of S65 (See Figure 1C) and the pattern of the stage monthly mean (see the stage section). Figure 6b shows that the monthly median is consistently lower than the monthly mean reflecting skewness in the monthly flow distribution. Figure 6c shows the monthly standard deviation for flows.

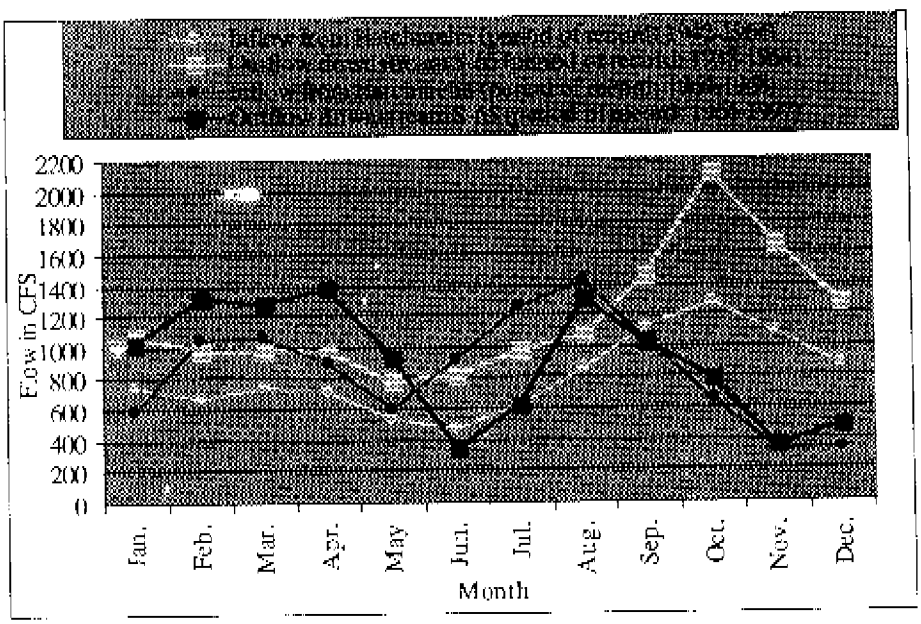



Figure 6a. Monthly mean of the Hatchineha inflow and the LKB outflow records before and after the construction of S65.

## RAINFALL

In this section, the objective is to provide a data summary for the historical rainfall average over the basin. While a weighted-average is desired using the Theissen polygon method, this presentation will be limited to an arithmetic average of the data. When a digital boundary of this basin is available, a weighted average will be performed. The available data and the data summary for rainfall are provided below.

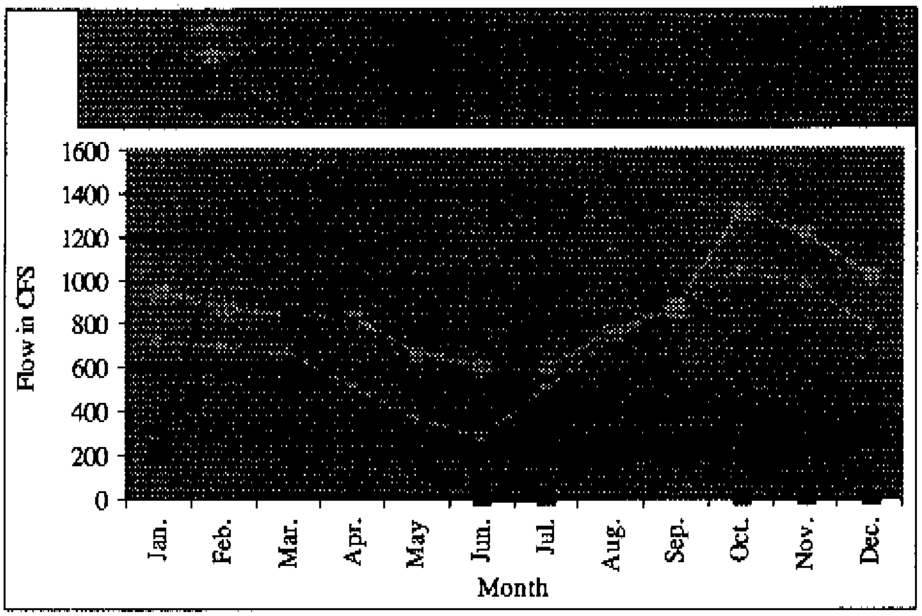



Figure 6b. Monthly median of the Hatchineha inflow and the LKB outflow records before and after the construction of S65.

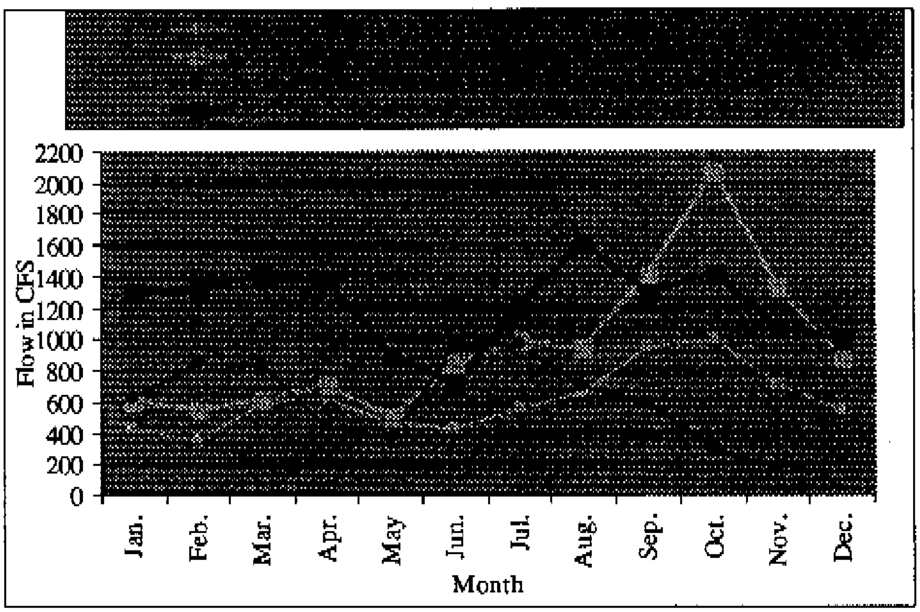



Figure 6c. Monthly standard deviation of the Hatchineha inflow and the LKB outflow records before and after the construction of S65.

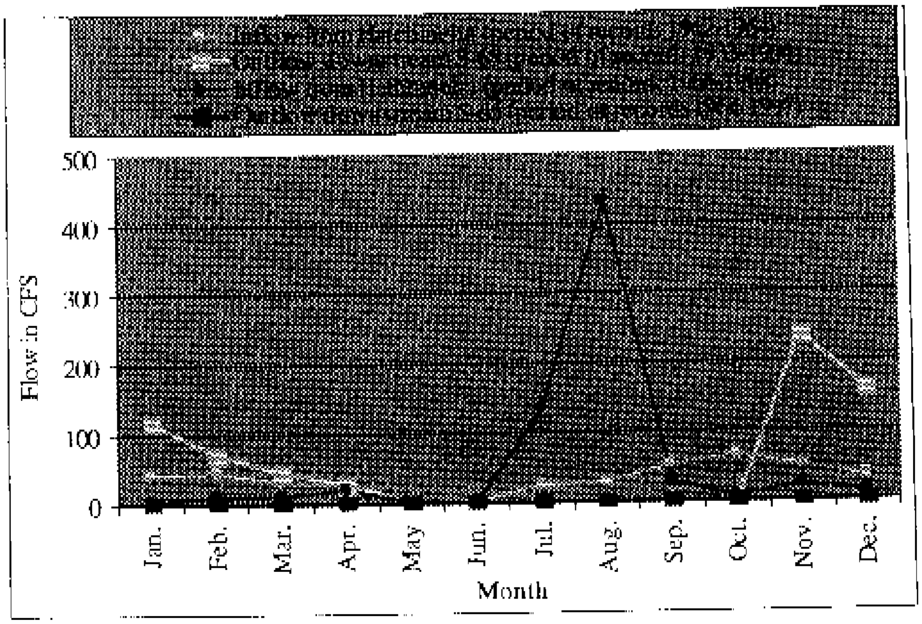



Figure 6d. Monthly minimum of the Hatchineha inflow and the LKB outflow records before and after the construction of S65.

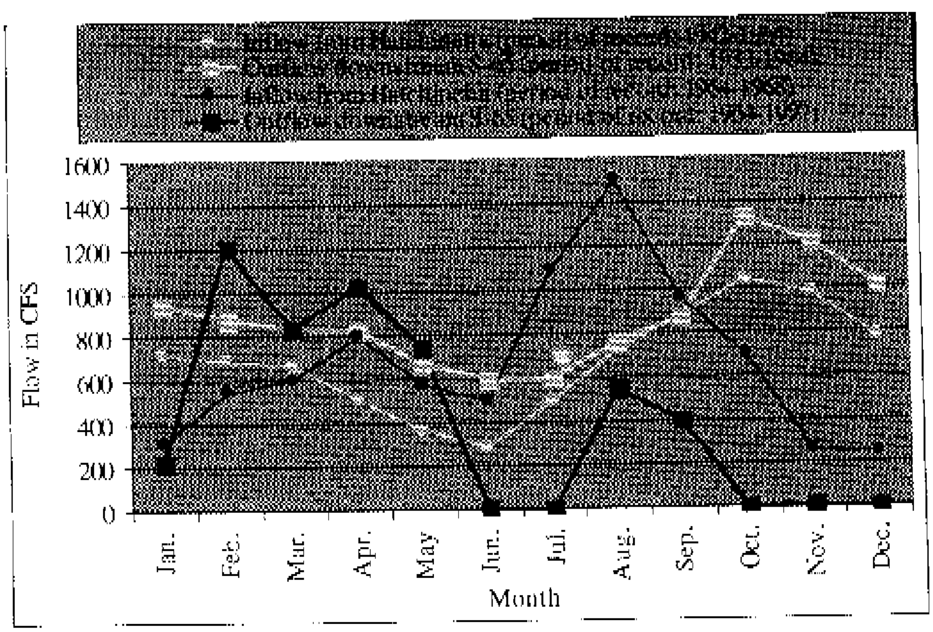



Figure 6e. Monthly maximum of the Hatchineha inflow and the LKB outflow records before and after the construction of S65.

## Available Data

Table 2 shows detailed information about the data from eight rainfall stations located in the study area. The period of record for the entire data sets is from 1960 to 1997. The spatial locations of these stations are presented in Figure 7. Time series for these records are presented in Appendix A.

Table 2. Information about stations with rainfall records within the LKB.

| Station | Dbkey | Method | Starting date | Ending date | Latitude | Longitude |
|---|---|---|---|---|---|---|
| MRF24 | 05912 | Daily Sum | Nov/67 | Oct/97 | 275817 | 812504 |
| MRF25 | 05921 | Daily Sum | Mar/65 | Jun/71 | 275342 | 810630 |
| MRF27 | 05940 | Daily Sum | Mar/65 | Sep/97 | 274813 | 811154 |
| MRF28 | 05946 | Daily Sum | Nov/68 | Nov/97 | 274715 | 811937 |
| MRF50 | 06112 | Daily Sum | Oct/69 | Jan/80 | 274726 | 811940 |
| MRF61 | 06200 | Daily Sum | Feb/60 | Mar/81 | 274800 | 811900 |
| MRF82 | 06295 | Monthly Sum | Jan/1930 | March/1943 | 274812 | 811152 |
| S65_R | 16571 | Daily Sum | Jan/91 | Nov/97 | 274813 | 811154 |
| KISS_SP_G | 16590 | Daily Sum | Jan/91 | Nov/97 | 275634 | 812118 |

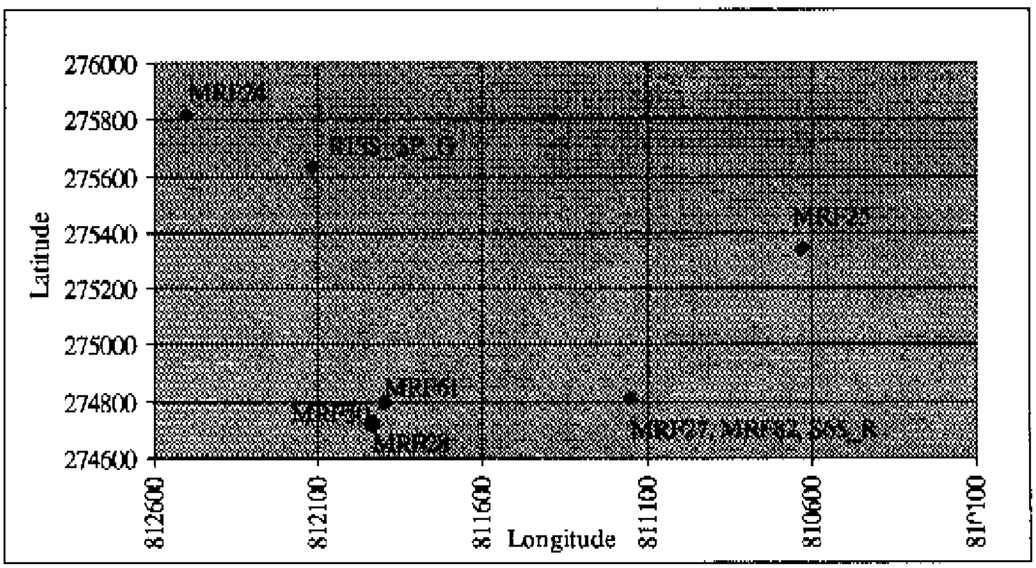



Figure 7. Station locations that contain rainfall records within the LKB.

## Data Summary

For each station, monthly rainfall data and the associated statistics are summarized in two tables presented in Appendix B. The procedures used for compiling these records are as follows:

1) Any month with a gap of more than 3 days of missing data is dropped from the monthly statistics.

2) Any month with gaps of less than or equal to 3 consecutive days of missing data is considered in the monthly statistics after such gaps are filled using the nearest gauge station.

3) Rainfall data are sometimes recorded as cumulative values of several days. Such a record is re-distributed evenly among those days.

4) For a given year, any station with a gap of more than 3 consecutive days in any month is excluded from the computation of annual rainfall average.

Monthly rainfall data presented in Appendix B were used to compute an arithmetic monthly time series averaged across the entire basin. The associated statistics (e.g. mean, median, standard deviation, and maximum) are presented in Figures 8a, b, c, and d. Figure 8a shows the monthly average over the period of record. The figures clearly reflect dry conditions in the period "October to April" with less than 4-inch monthly rainfall and wet conditions in the period "May to September" with more than 4-inch monthly rainfall. Also, the mean and the median are very close reflecting symmetry in the data distribution. The monthly time series was summarized into annual time series representing the entire basin (Figure 9). From this figure, it is observed that rainfall in years 1931, 1935, 1970, 1981, and 1985 was below 40 inch; and rainfall in years 1965, 1969, and 1973 was above 65 inches. The annual areal rainfall average is 49.7 inches with an annual standard deviation of 8.51 inches.

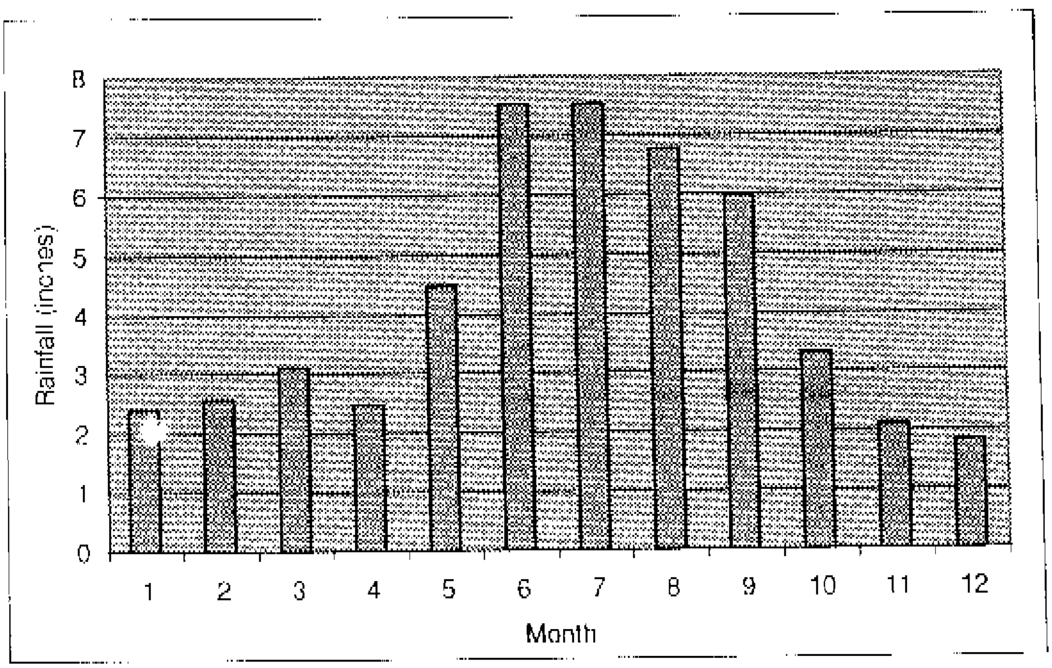



Figure 8a. Monthly mean of areal rainfall over the LKB.

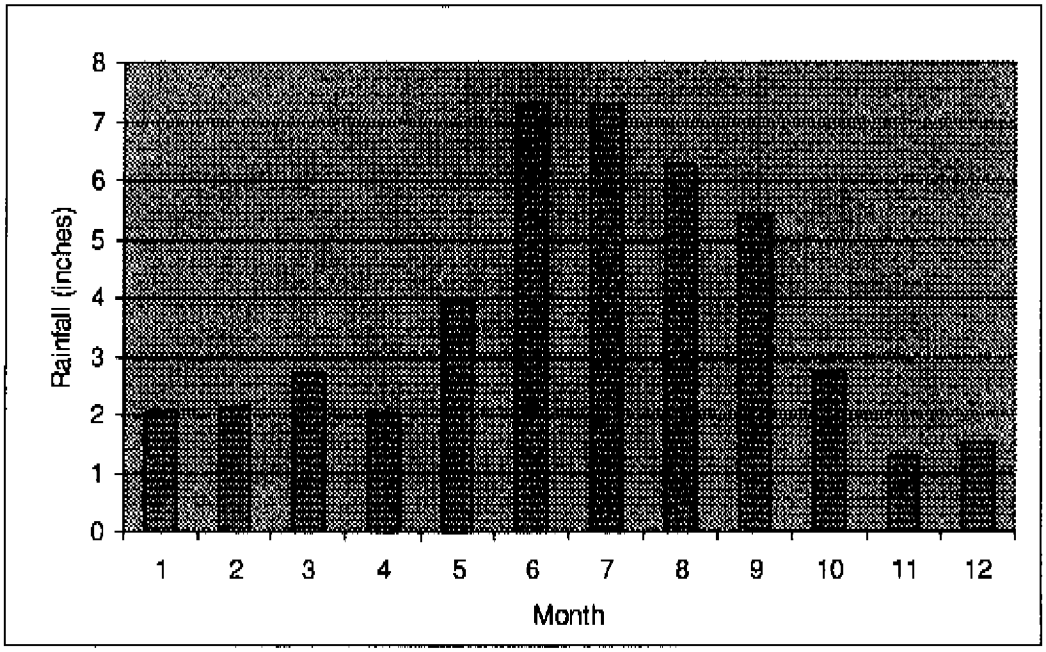



Figure 8b. Monthly median of areal rainfall over the LKB.

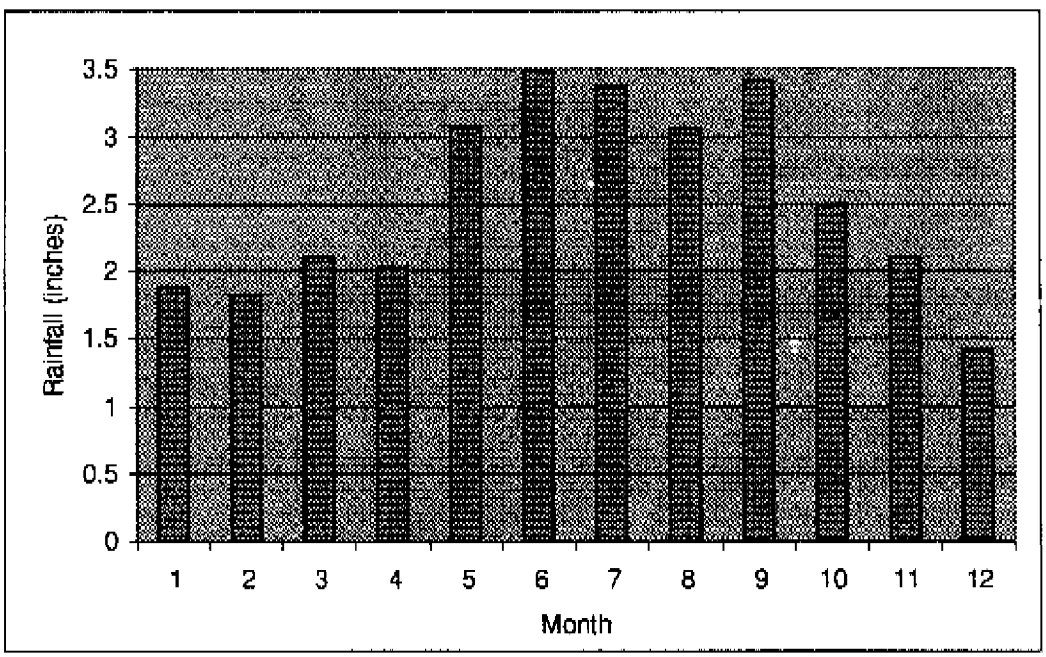



Figure 8c. Monthly standard deviation of areal rainfall over the LKB.

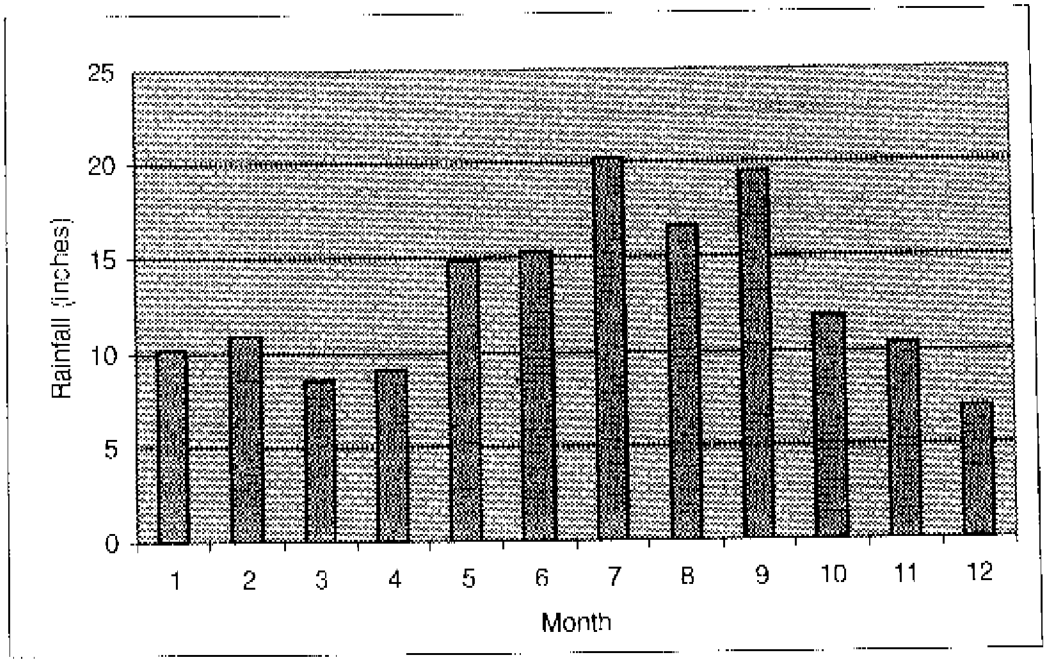



Figure 8d. Monthly maximum of areal rainfall over the LKB.

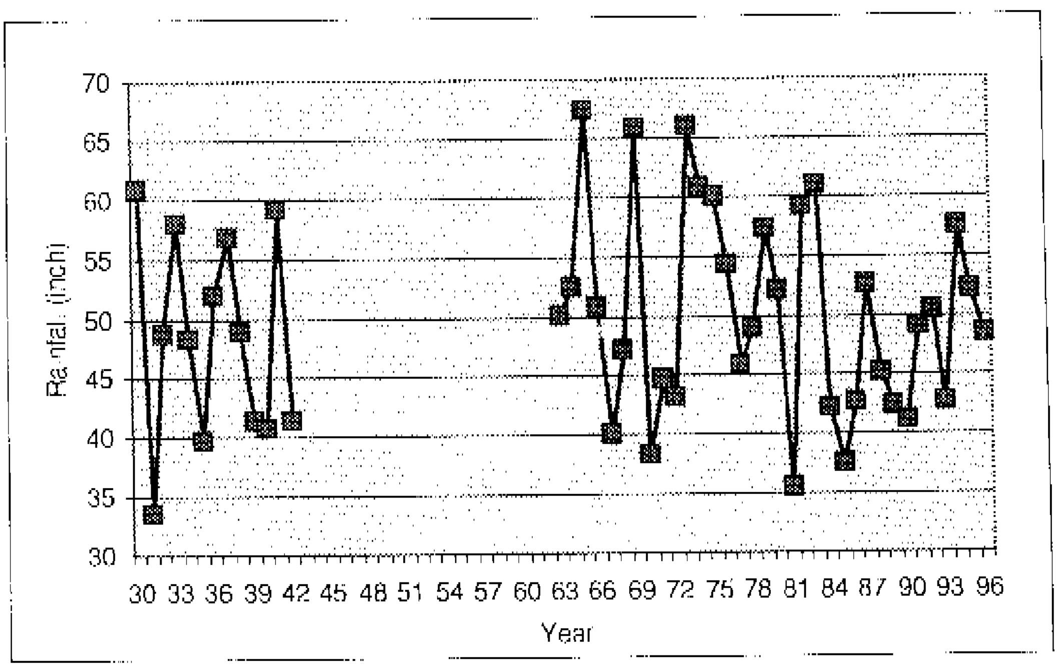



Figure 9. Historical annual areal rainfall averaged across the LKB.

## STAGE

Stages in some lakes within the LKB are controlled independently by structures constructed at the lake outlets. Therefore, it may be difficult to use stage in some lakes to predict the stage in other lakes. This section presents a hydrologic data summary for historical average stage for each important site within the LKB. These sites are S65 (Headwater), S65 (Tailwater), Lake Kissimmee, Lake Tiger, Lake Jackson, and Lake Rosalie. A presentation of the available data and the data summary are provided below.

### Available Data

Fifteen stations with daily mean stage records representing the six sites were available for the data summary in this study. Table 3 shows detailed information about these stations. The spatial locations of these stations are presented in Figure 10. Except for the S65 headwater, stage data periods of record start after S65 construction. A stage data summary is presented below.

Table 3. Information about stations with stage records within the LKB.

| Station | Dbkey | Method | Starting date | Ending date | Latitude | Longitude |
|---|---|---|---|---|---|---|
| L. Rosalie | 00180 | Daily mean | May/67 | Jan/95 | 275623 | 812514 |
| S65_H | 00185 | Daily mean | Aug/29 | Jan/95 | 274813 | 811154 |
| S65_T | 00187 | Daily mean | Oct/69 | Jan/96 | 274813 | 811154 |
| S65_H | 04122 | Daily mean | Oct/85 | Mar/87 | 274813 | 811154 |
| S65_T | 04124 | Daily mean | Oct/85 | Mar/87 | 274813 | 811154 |
| L Kissimmee | 05118 | Daily mean | Jul/84 | Dec/97 | 275636 | 812114 |
| L. Tiger | 05162 | Daily mean | Apr/83 | Oct/97 | 275220 | 812055 |
| L. Jackson | 09654 | Daily mean | May/88 | Apr/97 | 275441 | 810901 |
| S65_H | 12583 | Daily mean | May/88 | Oct/88 | 274813 | 811154 |
| S65_T | 12584 | Daily mean | May/88 | Oct/88 | 274813 | 811154 |
| S65_H | 15704 | Daily mean | Oct/94 | Dec/97 | 274813 | 811154 |
| L Kissimmee | 16059 | Daily mean | Oct/94 | Dec/97 | 275639 | 811835 |
| L Kissimmee | 16060 | Daily mean | Nov/94 | Dec/97 | 275337 | 811342 |
| L Kissimmee | 16061 | Daily mean | Oct/94 | Dec/97 | 274945 | 811228 |
| L. Jackson | FF852 | Daily mean | Apr/97 | Oct/97 | 275441 | 810901 |

### Data Summary

For each site, the daily stage records were averaged across all available stations in this site. Stage data are linearly interpolated when no records are found on a particular day. Figures 11 through 16 show time series and associated statistics for the average stage at Lake Rosalie, Lake Jackson, Lake Tiger, Lake Kissimmee, S-65 Headwater, and S-65 Tailwater. In general, the average stage exhibits relatively small variations over time. The seasonal variations are within 2-3 feet with lows occurring in wet season and highs occurring in dry season. It is also observed that the monthly median and mean are almost the same.

Lake Rosalie's average stage is primarily between elevations 52 and 54 ft with an approximate average of 53 ft. The stage of this lake is the highest among the lakes in LKB. Lake Jackson average stage is mainly between elevations 50 and 54 with approximated average of 52 ft.

The average stage in this lake is the second highest in the LKB. Lake Tiger's average stage is primarily between elevations 50 and 52 ft., with an approximate average of 51 ft. Lake Kissimmee's average stage is primarily between elevations 49 and 52 ft with an approximate areal average of 50.5 ft. The head water average stage is mainly between elevations 48 and 53 with an approximate areal average of 50.5 ft. Compared to the stage of the earlier three lakes, Lake Kissimmee and S65 headwater stages exhibit larger seasonal variations. The tailwater average stage at S65 has almost no variation with an average stage of 46.3 ft.

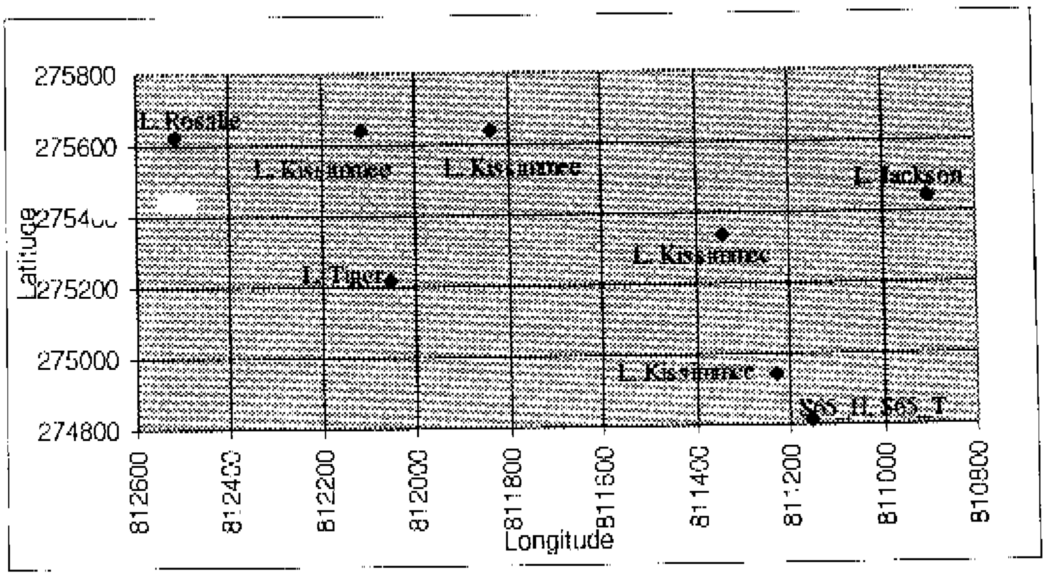



Figure 10. Locations of stations containing stage records within the LKB.

## EVAPORATION

This section estimates and presents the potential evaporation in the LKB using available pan evaporation data. These data are associated with a high degree of uncertainty and with a certain degree of bias as demonstrated by comparisons of pan evaporation data from all sources and other available information. The significant variation among the different pan evaporation stations could be due to site location, site management, and other external factors. The available pan evaporation data are first presented, followed by a discussion of data estimation procedures and a data summary.

### Available Data

The closest evaporation data set to the LKB area with a significant period of record (1965 to 1997) is the Lake Alfred station. The location of this station is 81 43 00 and 28 06 00 longitude and latitude respectively. More details about this station and other stations, within or close to UKRW, are presented in Table 4. Figure 17 shows the spatial locations of these stations.

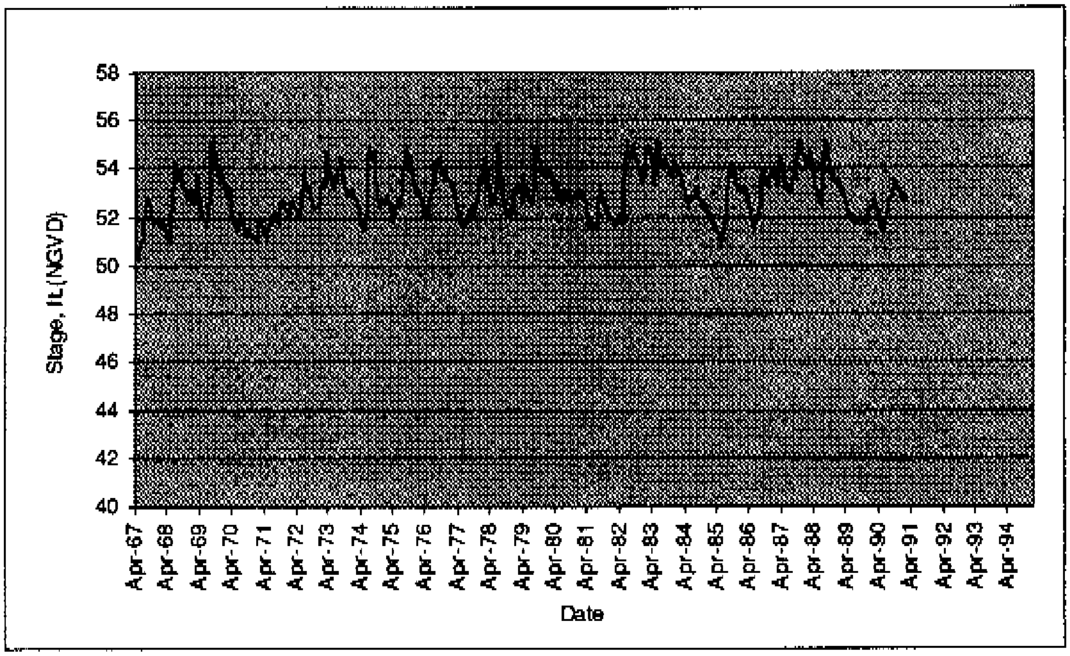



Figure 11a. Historical average stage at Lake Rosalie

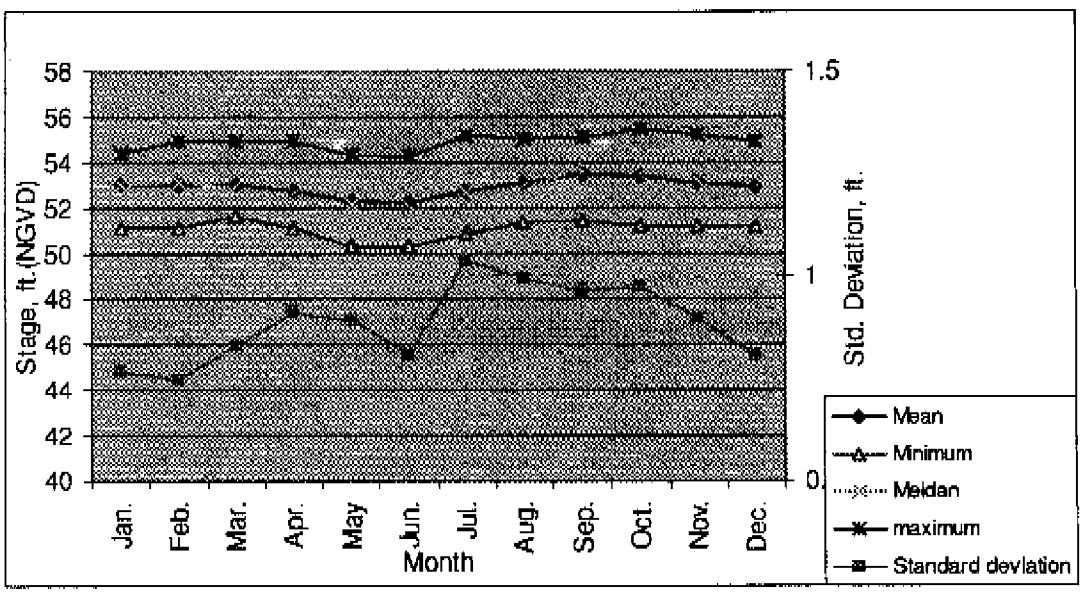



Figure 11b. Monthly statistics for average stage at Lake Rosalie.

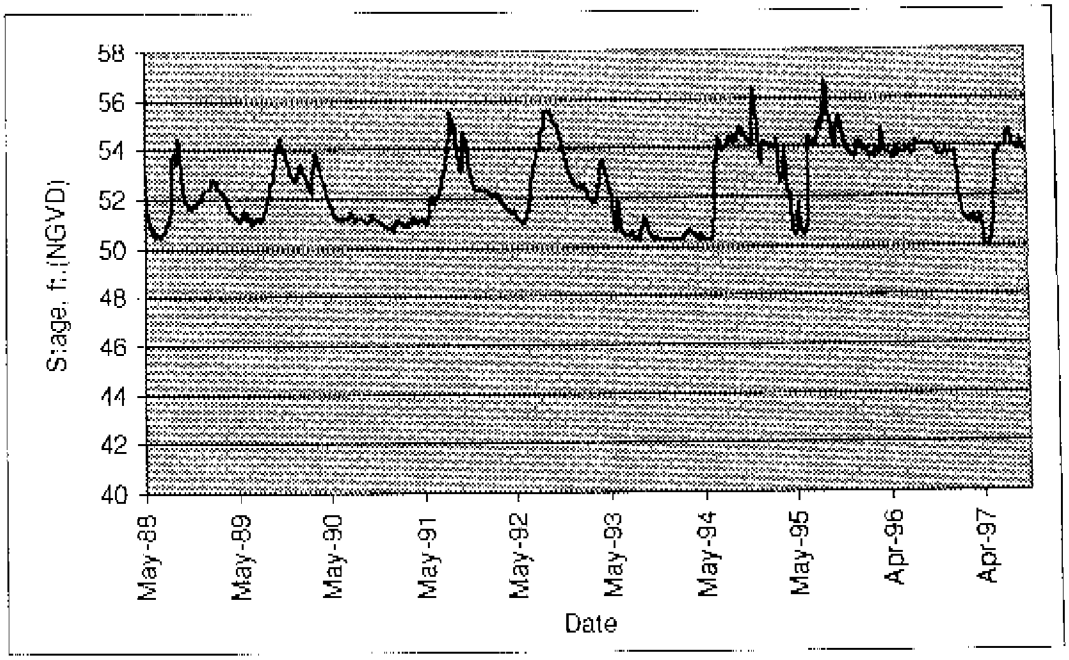



Figure 12a. Historical average stage at Lake Jackson

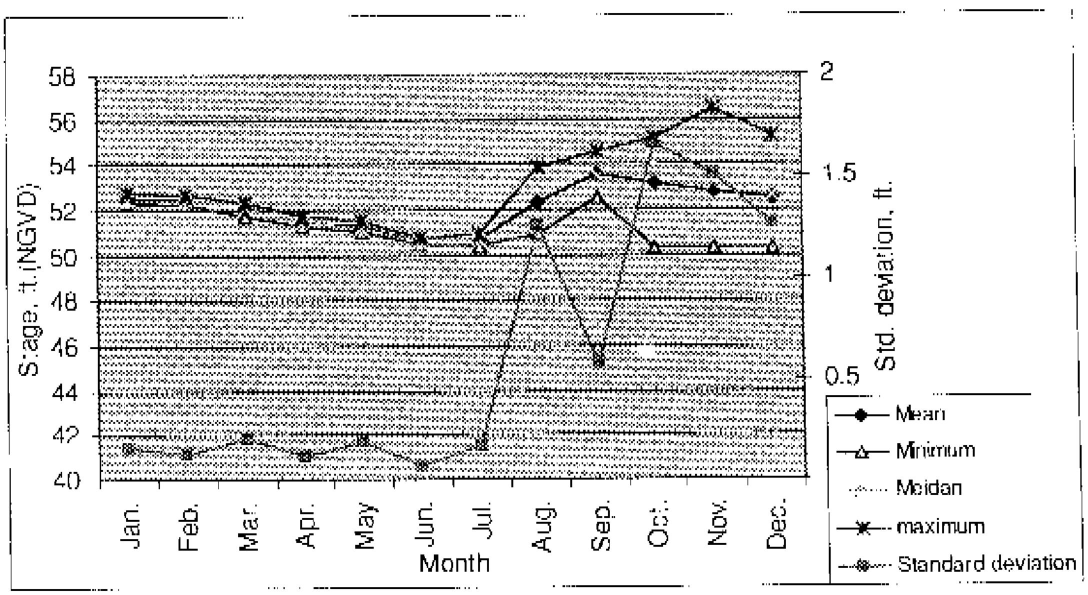



Figure 12b. Monthly statistics for average stage at Lake Jackson.

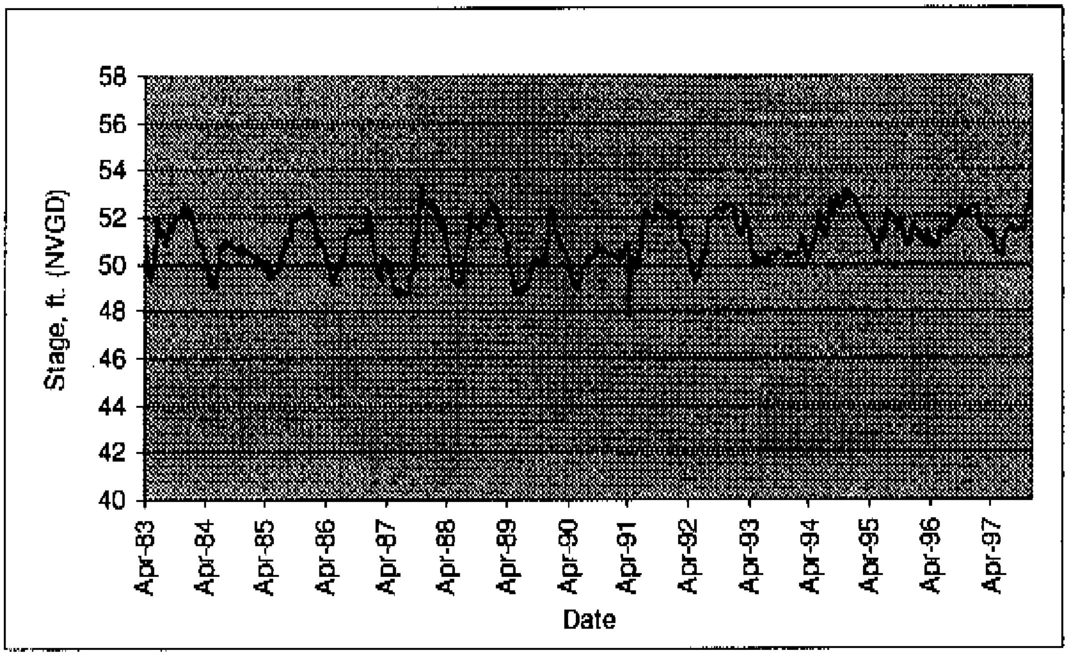



Figure 13a. Historical average stage at Lake Tiger

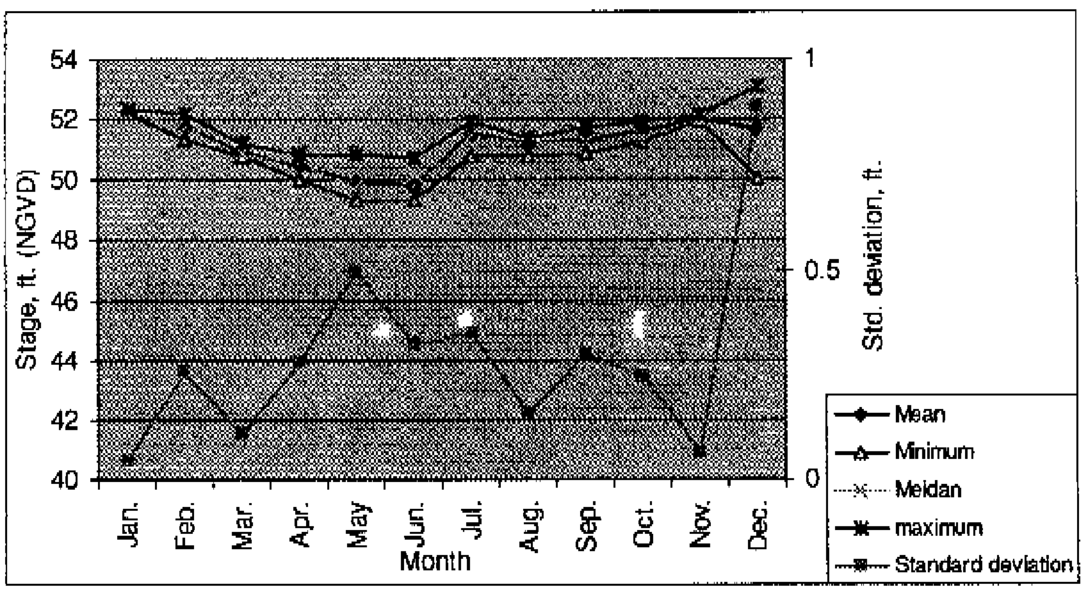



Figure 13b. Monthly statistics for average stage at Lake Tiger.

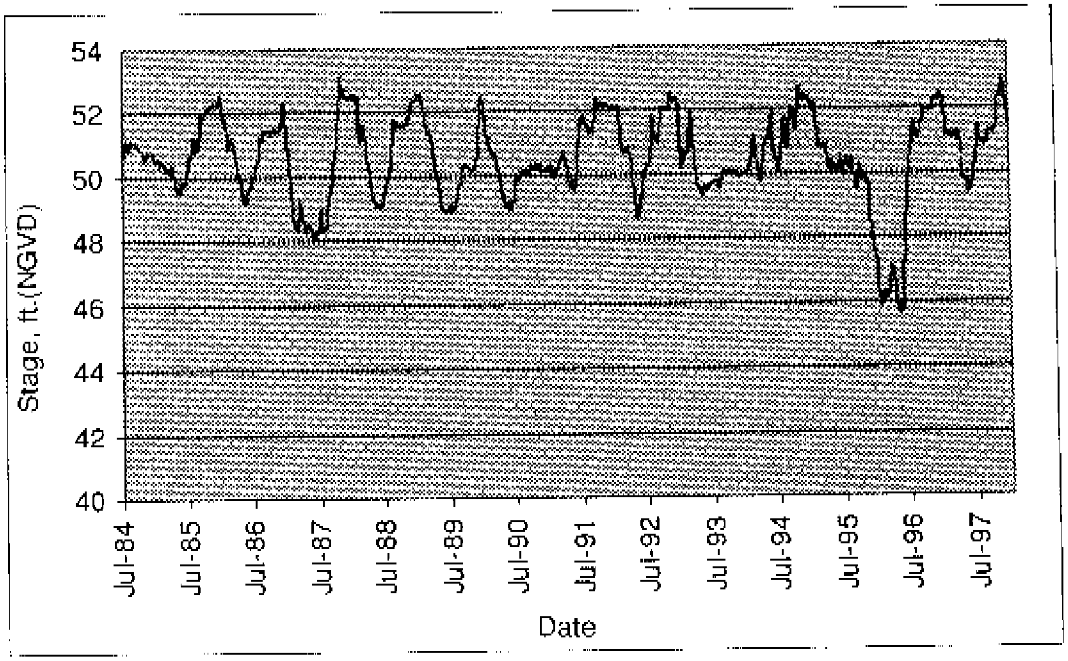



Figure 14a. Historical average stage at Lake Kissimmee.

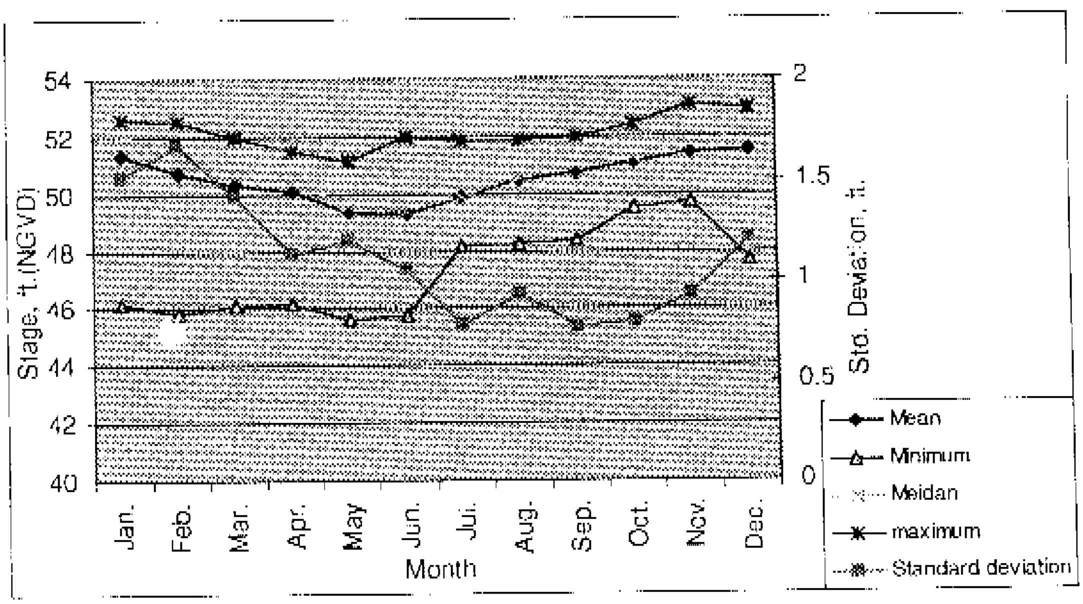



Figure 14b. Monthly statistics for average stage at Lake Kissimmee.

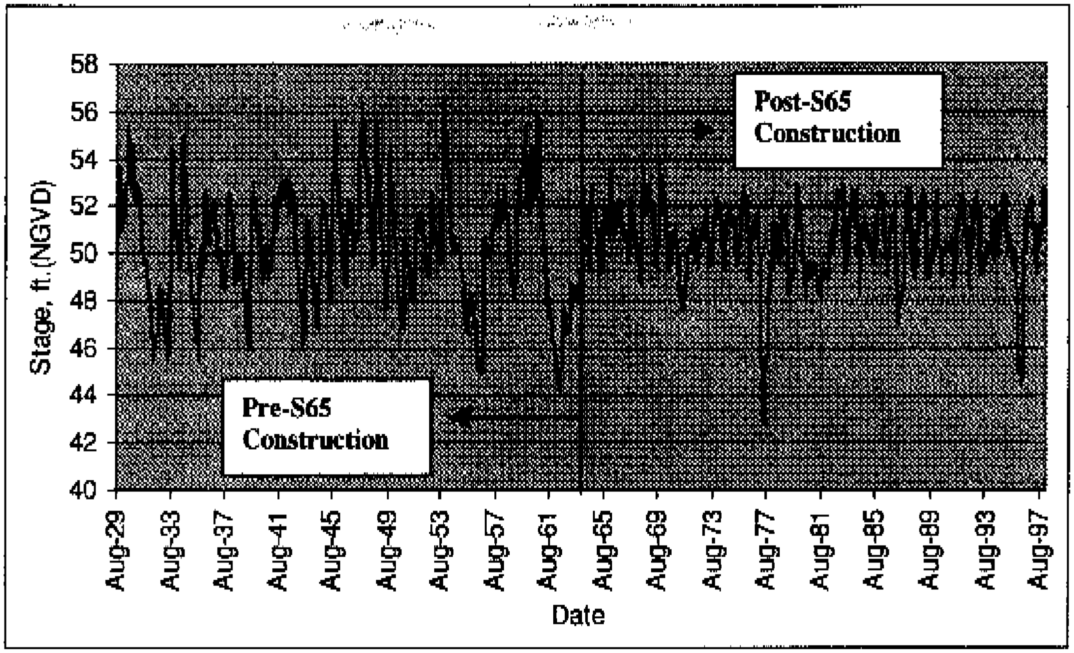



Figure 15a. Historical headwater average stage at S65.

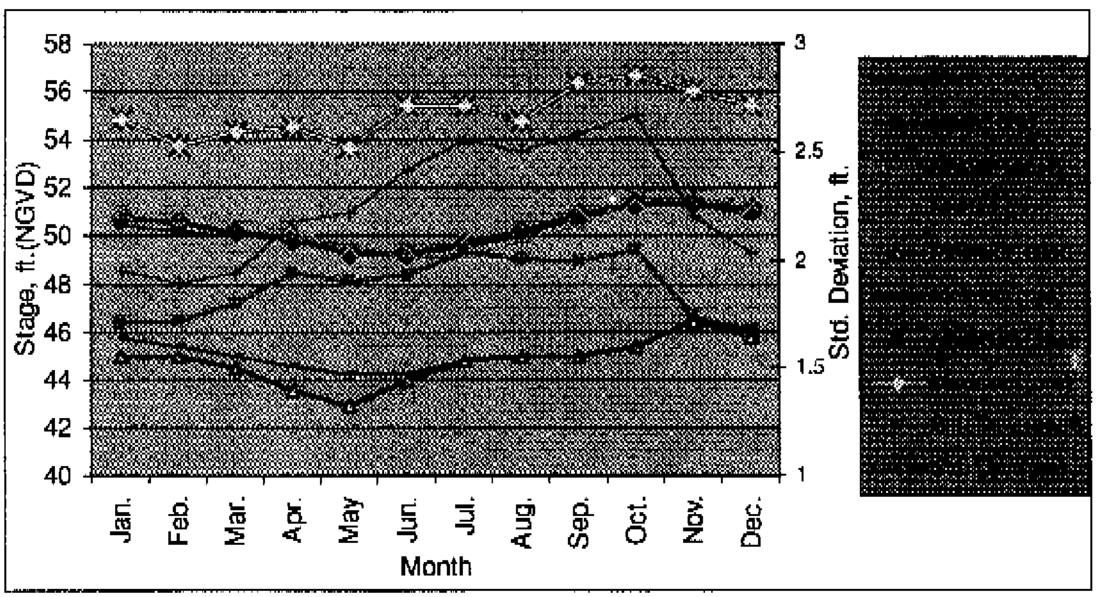



Figure 15b. Monthly statistics for headwater average stage at S65 before S65 construction "pre", and after S65 construction "post".

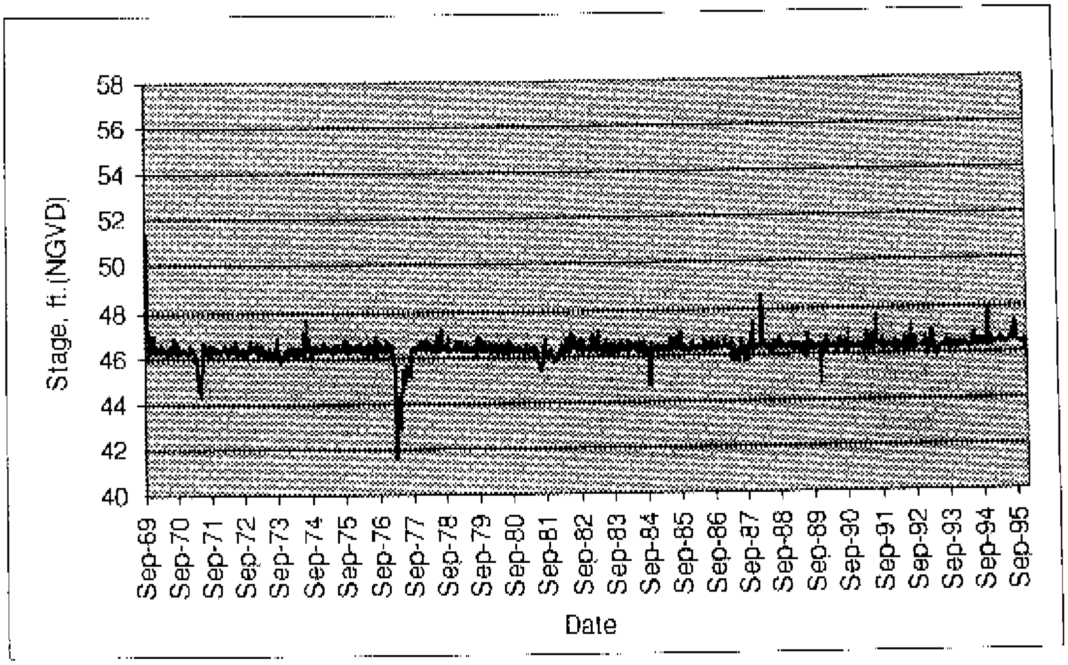



Figure 16a. Historical tailwater average stage at S65.

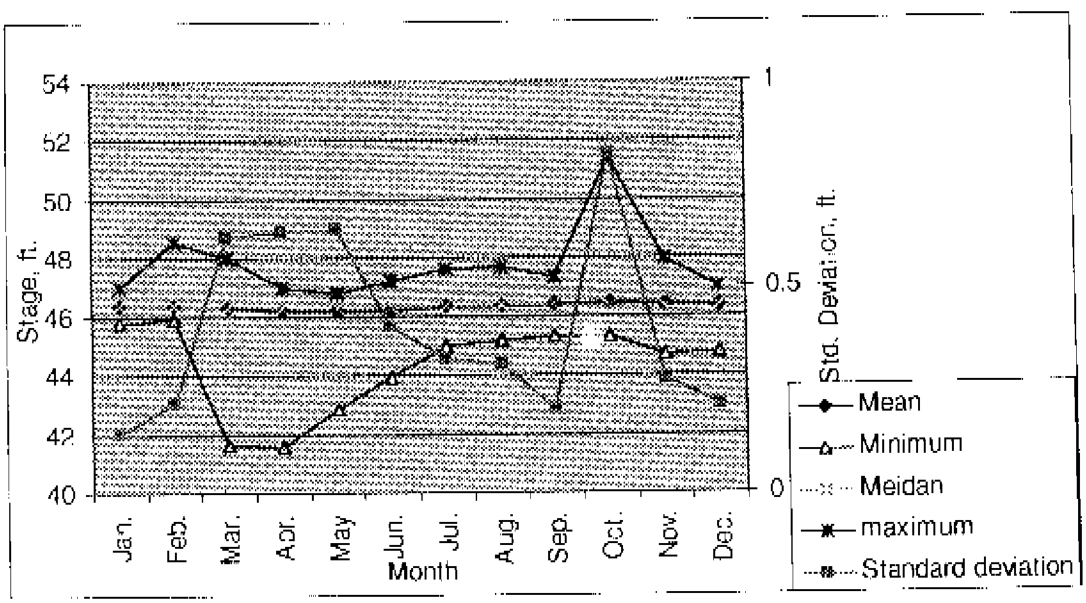



Figure 16b. Monthly statistics for tailwater average stage at S65.

## Data Estimation and Summary

Lake Alfred pan evaporation data maintain the expected seasonal variation for the entire period of record. However, Lake Alfred average annual pan evaporation data were found to be too high compared to the estimates obtained by Wylen and Zorn (1998) for annual lake evaporation (47 inches) within the study area. Jones et. al. (1984) reported an estimated annual potential evapotranspiration of 47 inches for a nearby location (Lakeland, Latitude 28 01 00). Visher and Hughes (1975) estimated maximum potential evaporation for the general area as 48 inches.

The estimation of the annual maximum potential evaporation from Lake Alfred pan evaporation data was performed in two steps:

1) Estimating the missing daily records using linear interpolation, and limiting the maximum daily records to the estimated maximum for this area (0.35 inches).
2) Reducing the annual pan evaporation data by a factor (K) of 0.67. This factor maintains an annual potential evaporation of 47 inches.

The estimated annual potential evaporation at Lake Alfred is presented in Figure 18. Figure 19 shows the associated monthly statistics.

Table 4. Information about stations with pan evaporation records within, or close to, the LKB.

| Station | Dbkey | Method | Starting date | Ending date | Latitude | Longitude |
|---|---|---|---|---|---|---|
| S-65 | 06336 | Daily sum | Oct/83 | Oct/97 | 274813 | 811154 |
| Alfred | 06355 | Daily sum | May/65 | Jul/97 | 280600 | 814300 |
| Kissimmee | 06378 | Daily sum | Feb/67 | Dec./93 | 281725 | 812655 |

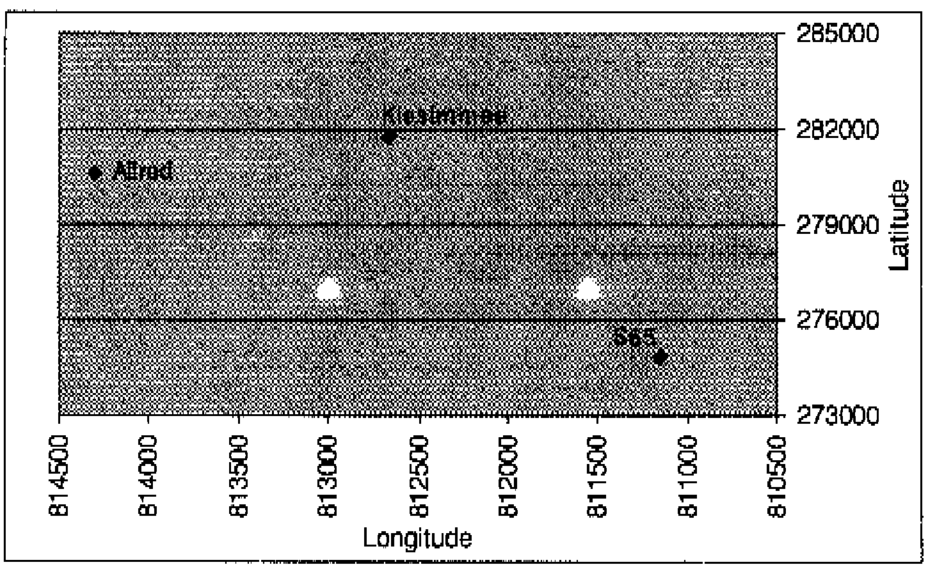



Figure 17. Locations of pan evaporation stations within or close to the LKB.

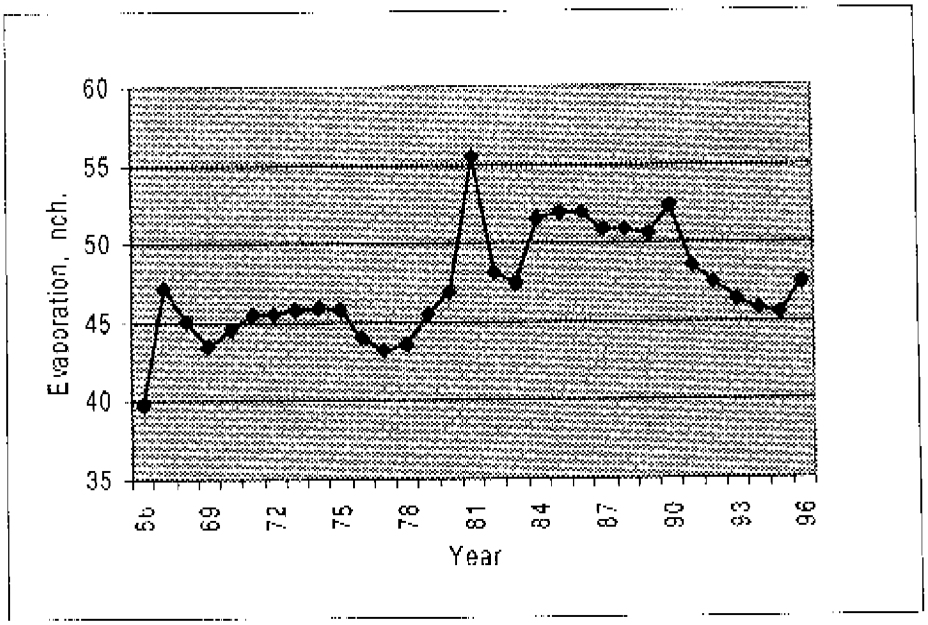



Figure 18. Estimated annual potential evaporation at Lake Alfred.

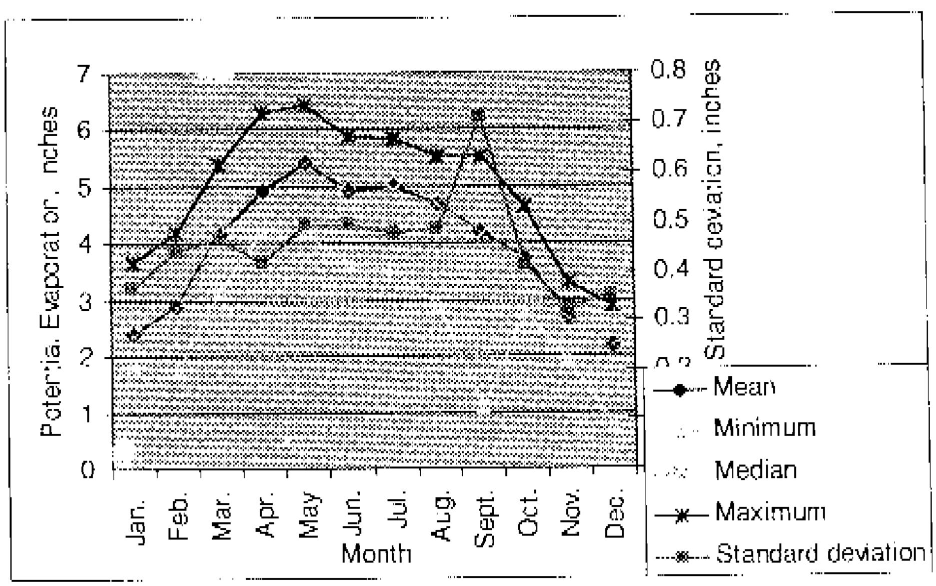



Figure 19. Monthly statistics for estimated potential evaporation at Lake Alfred.

## SUMMARY

Data summaries and preferred key development for the hydrologic data pertaining to the LKB, were presented. The hydrologic components of interest are Flow, Rainfall, Stage, and Evaporation. Statistical approaches coupled with previous experience and hydrologic concepts were effective tools in this study. Missing and "unrealistic" flow data were estimated using auto-correlation analysis, previous hydrologic concepts, and data visualization. Monthly rainfall data were summarized in tables for the entire periods of record at all stations. Rainfall annual averages and monthly statistics were presented. Average stages for all lakes within LKB and downstream from Lake Kissimmee were presented and summarized into monthly statistics. Pan evaporation data were used to estimate potential evaporation. A correction factor based on previous studies was incorporated in the estimation. In general, the results of this study were consistent with the expected seasonal variations and with the Lake Kissimmee regulation schedule. Due to the unavailability of much of the inflow data component, a water budget computation was not possible.

## REFERENCES

Fan, A. 1986. A Routing Model for the Upper Kissimmee Chain of Lakes. Technical Publication, South Florida Water Management District, West Palm Beach, Florida.

Fan, A., and S. Lin. 1984. Water budget for Upper Kissimmee Chain of Lakes. Technical Publication, South Florida Water management District, West Palm Beach, Florida.

Jones, J. W., L. H. Allen, S. F. Shih, J. S. Rogers, L. C. Hammond, A. G. Smajstrala, and J. D. Martsolf. 1984. Estimated and Measured Evaporation for Florida Climate, Crops, and Soils. Technical Bulletin 840, Agricultural Experiment Station, IFAS, University of Florida.

Guardo, M. 1992. An Atlas of the Upper Kissimmee Surface Water Management Basins. Technical Memorandum, Water Resources Engineering Division, Department of Research and Evaluation, South Florida Water Management District, West Palm Beach, Florida.

Visher, F. N., and G. H. Hughes. 1975. The difference between rainfall and potential evaporation in Florida: Florida Bureau of Geology, Map Series 32, Tallahassee, Florida.

Wylen, P.R. and M.R. Zorn. Prediction of Mean Annual Flows in North and Central Florida. Journal of the American Water Resources Association. Vol. 34. No. 1.pp. 149-157.

APPENDIX A

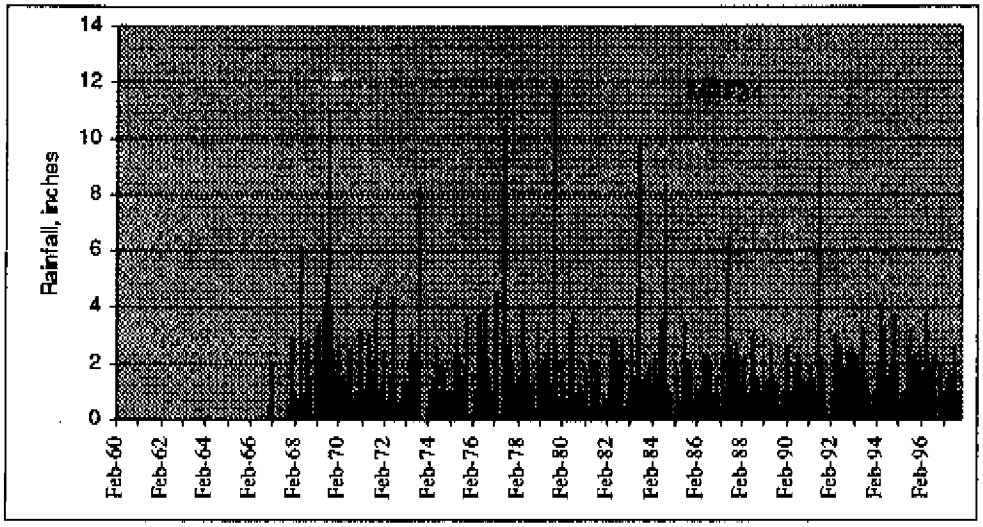



Figure A1. Historical daily rainfall data at station MRF24 (few records are cumulative values of more than one day).

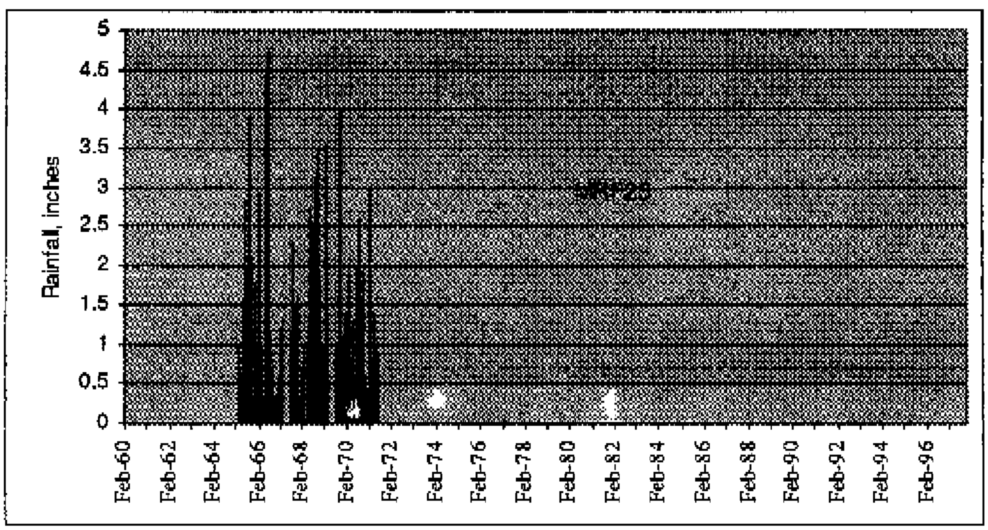



Figure A2. Historical daily rainfall data at station MRF25 (few records are cumulative values of more than one day).

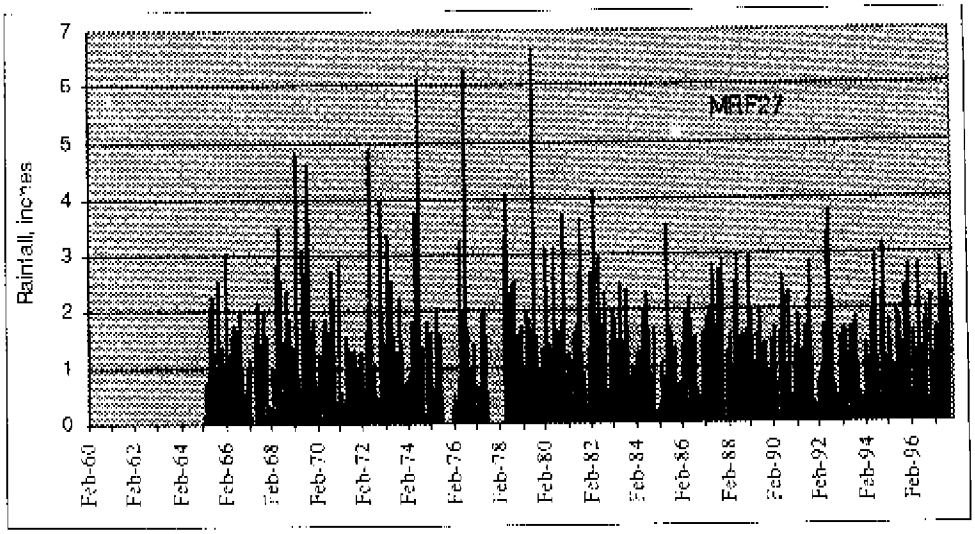



Figure A3. Historical daily rainfall data at station MRF27 (few records are cumulative values of more than one day).

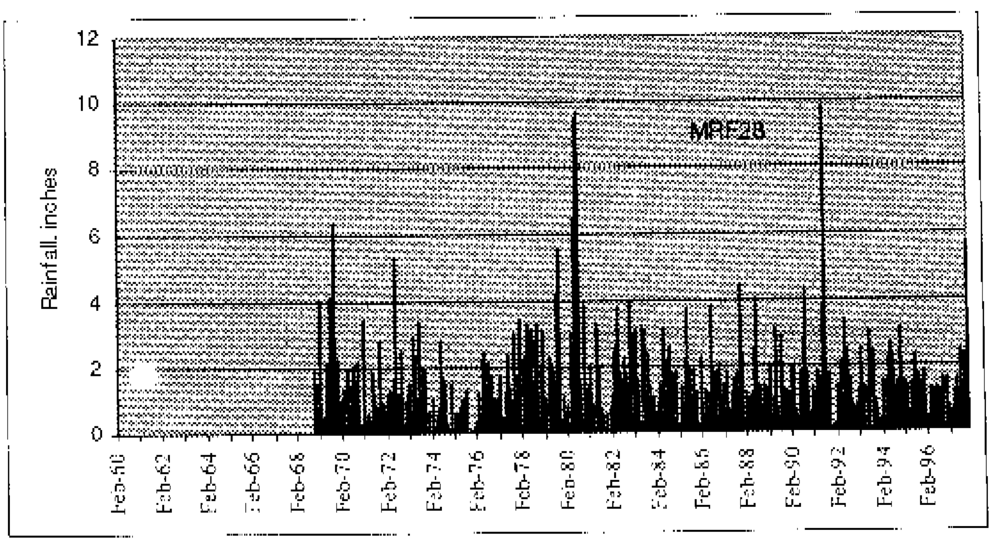



Figure A4. Historical daily rainfall data at station MRF28 (few records are cumulative values of more than one day).

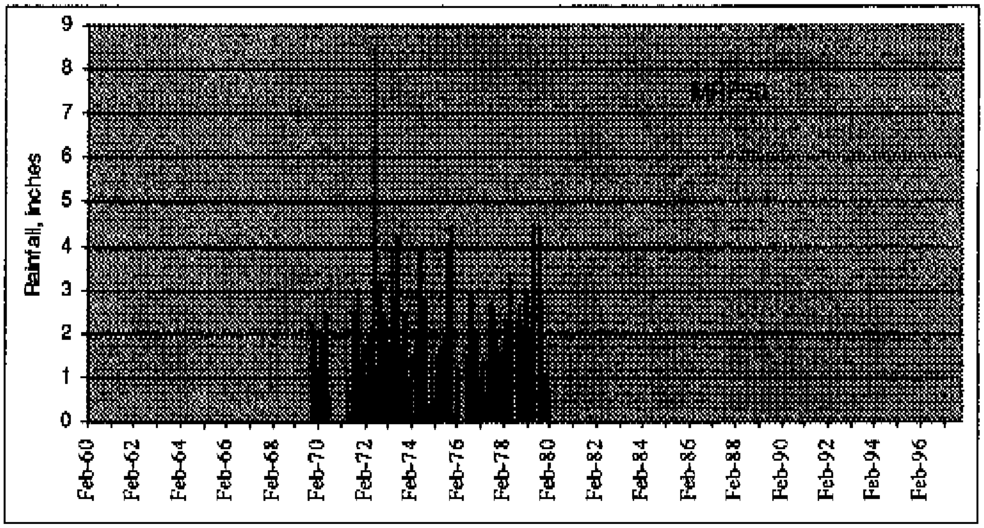



Figure A5. Historical daily rainfall data at station MRF50 (few records are cumulative values of more than one day).

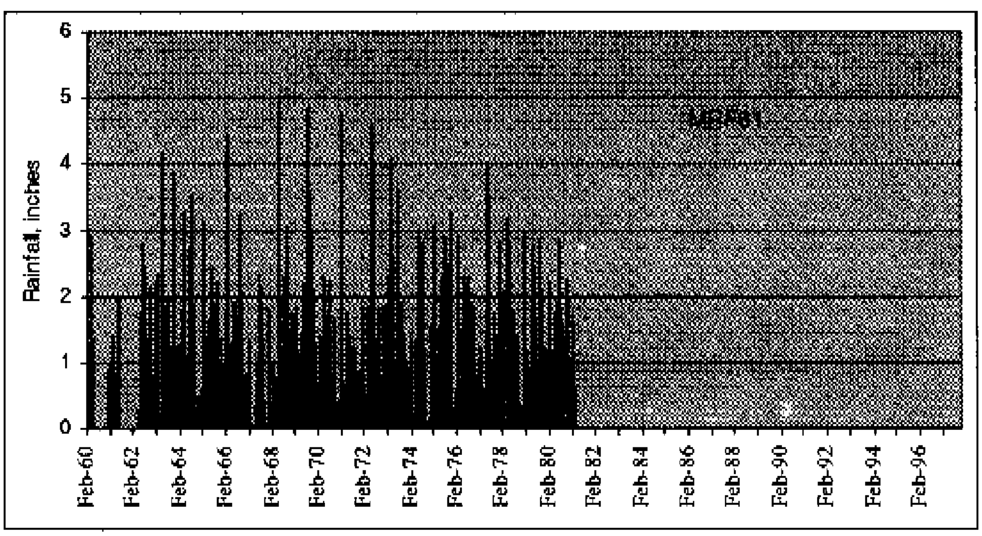



Figure A6. Historical daily rainfall data at station MRF61 (few records are cumulative values of more than one day).

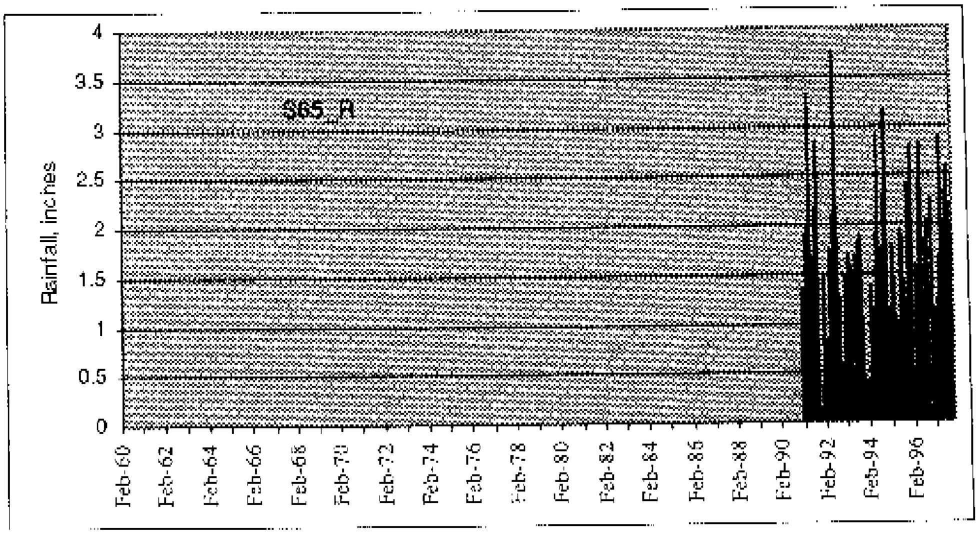



Figure A7. Historical daily rainfall data at station S65_R (few records are cumulative values of more than one day).

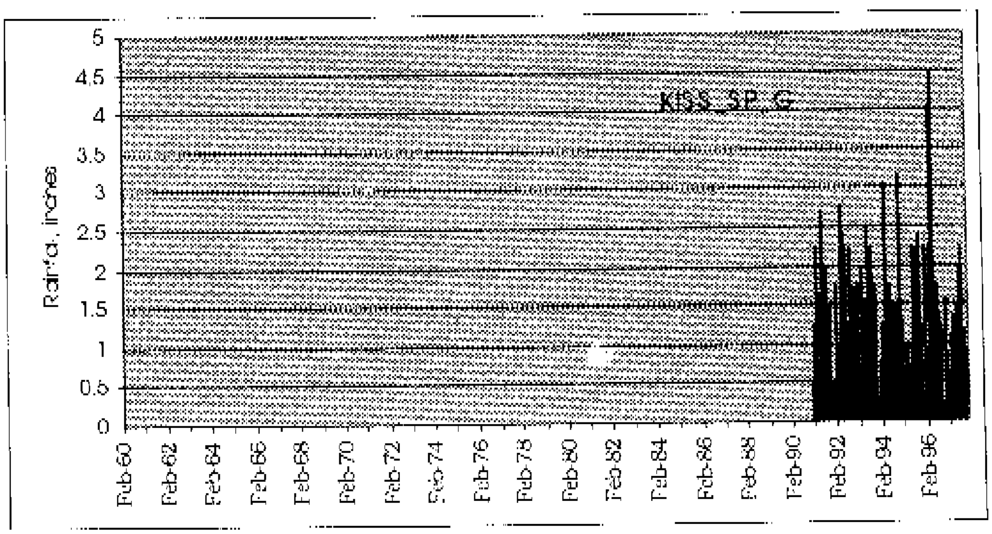



Figure A8. Historical daily rainfall data at station KISS_SP_G (few records are cumulative values of more than one day).

APPENDIX B

Table B1_1. Monthly and Annual Sums for Station MRF24, dbkey 5912

| year | Jan. | Feb. | Mar. | Apr. | May | June | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 66 | ---- | ---- | ---- | ---- | ---- | ---- | --- | ---- | --- | ---- | 0 | 1.25 | 1.25 * |
| 67 | 2.04 | ---- | ---- | --- | ---- | ---- | ---- | ---- | ---- | 0.82 | 0.19 | 2.93 | 5.98 * |
| 68 | 0.45 | 1.77 | 0.72 | 0.34 | 4.39 | 11.5 | 2.4 | 4.17 | 4.92 | 2.33 | 2.38 | 0 | 35.37 |
| 69 | 3.45 | 1.55 | 8.5 | 0.42 | 2.83 | 9.11 | 10.9 | --- | 11.75 | --- | 3.51 | 4.85 | 56.87 * |
| 70 | 2.68 | 4.13 | 6.83 | 1.28 | 2.84 | 3.84 | 7.28 | 4.52 | 2.67 | 1.66 | 1.29 | 1.2 | 40.22 |
| 71 | 0.28 | 6.5 | 2.78 | 0.71 | 4.49 | 10.03 | 9.9 | 4.31 | 3.31 | 9.42 | 1.65 | 1.66 | 55.04 |
| 72 | 1.17 | 4.41 | 2.03 | 1.07 | 3.98 | 7.1 | 9.58 | 2.5 | 0 | 0.81 | 2.19 | 2.21 | 37.05 |
| 73 | 4.46 | 2.12 | 4.21 | 4.53 | 4.62 | --- | ---- | ---- | ---- | ---- | ---- | ---- | 19.94 * |
| 74 | ---- | 1.07 | 0.25 | 1.05 | 3.26 | 9.69 | 5.8 | 3.4 | 10.28 | 0.11 | 0.24 | 1.74 | 36.89 * |
| 75 | 0.41 | 2.7 | 1 | 3.31 | 12.5 | 5.17 | 7.82 | 7.56 | 7.87 | 5.58 | 0.78 | 0.33 | 55.03 |
| 76 | 0.15 | 0.68 | 0.98 | 1.58 | 10.37 | 11.36 | 7.42 | 9.2 | 9.44 | 0.58 | 2.98 | 2.24 | 56.98 |
| 77 | ---- | 2.12 | 1.22 | 0.01 | 0 | 11.28 | 11.52 | 5.03 | 5.38 | 1.81 | 5.4 | 3.74 | 47.51 * |
| 78 | 2.05 | 3.33 | 2.25 | 1.03 | 5.31 | 11.45 | 12.56 | 5.02 | 3.02 | 0.65 | 0.44 | 3.11 | 50.22 |
| 79 | 5.68 | 1.34 | 3.03 | 3.64 | 6.68 | 5.7 | 3.29 | 0.45 | 16.55 | 0.16 | 2.92 | 1.39 | 50.83 |
| 80 | 6.09 | 2.5 | 2.22 | 2.58 | 5.84 | 2.97 | 4.73 | 9.67 | 2.02 | 1.15 | 4.84 | 0.73 | 45.34 |
| 81 | 0.67 | 3.26 | 0.81 | 0 | 4.88 | 6.34 | 4.74 | 7.78 | 4.14 | 1.13 | 1.18 | 1.51 | 36.44 |
| 82 | 1.19 | 0.88 | 6.12 | 5.85 | 4.09 | 11.5 | 8.63 | 3.11 | 7.84 | 2.13 | 0.39 | 1.25 | 52.98 |
| 83 | 2.18 | 5.53 | 3.37 | 2.23 | 0.76 | 10.4 | 10.64 | 4.33 | 4.68 | 4.38 | 3.2 | 7 | 58.7 |
| 84 | 0.6 | 2.72 | 1.44 | 3.91 | 3.42 | 6.25 | 4.05 | 6.35 | 4.64 | 0.56 | 2.78 | 0.28 | 37 |
| 85 | 0.36 | 0.71 | 2.26 | 1.36 | 1.36 | 5.58 | 8.63 | 3.56 | 3.66 | 1.6 | 2.26 | 0.96 | 32.3 |
| 86 | 2.36 | 2.15 | 3.29 | 0.33 | 0.17 | 7.96 | 10.84 | 7.51 | 4.75 | 2.29 | 0.49 | 4.9 | 47.04 |
| 87 | 1.49 | 1.15 | 8.56 | 0.22 | 1.57 | 7.79 | 4.06 | 6.9 | 6.12 | 7.85 | 6.22 | 0.14 | 52.07 |
| 88 | 2.31 | 1.69 | 5.79 | 1.29 | 0.78 | 1.51 | 8.66 | 7.78 | 4.86 | 0.7 | 3.83 | 0.91 | 40.11 |
| 89 | 4.65 | 0.06 | 3.09 | 3.23 | 3.98 | 7.77 | 4.1 | 2.99 | 5.17 | 0.86 | 1.95 | 3.71 | 41.56 |
| 90 | 1.01 | 4.27 | 0.48 | 1.17 | 0.37 | 5.44 | 6.34 | 7.05 | 2.36 | 3.74 | 0.76 | 1.61 | 34.6 |
| 91 | 2.16 | 0.79 | 4.94 | 4.34 | 3.77 | 1.65 | 9.48 | 6.26 | 3.58 | 3.34 | 0.1 | 0.43 | 40.84 |
| 92 | 1.42 | 1.88 | 0.55 | 7.1 | 2.55 | 12.62 | 3.87 | 11.48 | 3.17 | 4.69 | 3.71 | 0.46 | 53.5 |
| 93 | 7.3 | 2.36 | 3.33 | 4.84 | 2.34 | 6.41 | 4.49 | 4.27 | 4.48 | 2.05 | 0.85 | 0.64 | 43.36 |
| 94 | 3.61 | 2.63 | 1.73 | 6.69 | 2.85 | 10.95 | 3.44 | 4.01 | 7.31 | 3.29 | 4.77 | 3.47 | 54.74 |
| 95 | 2.04 | 2.48 | 1.78 | 2.41 | 1.89 | 8.92 | 9.06 | 9.69 | 6.09 | 5.95 | 1.86 | 0.33 | 52.5 |
| 96 | 4.14 | 0.64 | 6.49 | 4.24 | 5.36 | 9.07 | 3.07 | 11.79 | -- | 3.47 | 0.91 | 3.5 | 52.68 * |
| 97 | 1.53 | 0.8 | 2.64 | 5.37 | 3.28 | 4.76 | 11.8 | 4.79 | 2.42 | 0.95 | --- | ---- | 38.34 * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B1_2. Statistics of the Monthly Sums for Station MRF24, dbkey 5912

| #yrs | month | Mean | Stdv | Min | Med | Max |
|---|---|---|---|---|---|---|
| 30 | 1 | 2.242 | 3.712 | ---- | 2.035 | 7.3 |
| 30 | 2 | 2.274 | 2.309 | 0.06 | 2.119 | 6.5 |
| 30 | 3 | 3.089 | 5.531 | 0.25 | 2.26 | 8.56 |
| 30 | 4 | 2.537 | 4.359 | 0 | 1.58 | 7.1 |
| 30 | 5 | 3.684 | 7.515 | 0 | 3.28 | 12.5 |
| 29 | 6 | 7.728 | 9.743 | 1.51 | 7.77 | 12.62 |
| 29 | 7 | 7.21 | 9.565 | 2.4 | 7.28 | 12.56 |
| 29 | 8 | 5.683 | 8.934 | ----- | 4.79 | 11.79 |
| 28 | 9 | 5.446 | 11.609 | 0 | 4.68 | 16.55 |
| 29 | 10 | 2.554 | 5.433 | 0.11 | 1.659 | 9.42 |
| 30 | 11 | 2.136 | 2.943 | 0 | 1.86 | 6.22 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | 12 | 1.949 | 2.873 | 0 | 1.39 | 7 |

Table B2_1. Monthly and Annual Sums for Station MRF25, dbkey

| year | Jan. | Feb. | Mar. | Apr. | May | June | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | ---- | ---- | 1.67 | 1.52 | 0.58 | 6.27 | 12.45 | 6.4 | 8.17 | 4.61 | 0.6 | 2.8 | 45.07 * |
| 66 | 6.27 | 6.36 | 1.93 | 1.14 | 8.12 | 6.76 | 11.95 | 7.3 | 3.4 | 2.79 | 0.32 | 0.8 | 57.14 |
| 67 | 1.3 | 2.92 | 1.32 | ---- | ---- | ---- | ---- | 6.43 | 6.01 | 0.88 | 0.1 | 1.98 | 20.94 * |
| 68 | 0.54 | 1.55 | 1.67 | 0.9 | 5.3 | 15.35 | 8.12 | 2.83 | 7.88 | 6.4 | 2.4 | 0 | 52.94 |
| 69 | 1.78 | 1.21 | 7.47 | ---- | ---- | ---- | ---- | ---- | 4.17 | 10.85 | ---- | ---- | 25.48 * |
| 70 | 2.3 | 1.9 | 3.8 | 0 | 3.3 | 0.6 | 5.2 | 6.7 | 0 | 4 | 0 | 1.2 | 29 |
| 71 | 0.4 | 5.66 | 0.6 | 1.55 | 2.08 | 2.95 | ---- | ---- | ---- | ---- | ---- | ---- | 13.24 * |
| 72 | ---- | ---- | 0.1 | ---- | 13.28 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 13.38 * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B2_2. Statistics of the Monthly Sums for Station MRF25, dbkey 5921

| #yrs | month | Mean | Stdv | Min | Med | Max |
|---|---|---|---|---|---|---|
| 6 | 1 | 2.098 | 4.699 | 0.4 | 1.3 | 6.27 |
| 6 | 2 | 3.267 | 4.892 | 1.21 | 1.9 | 6.36 |
| 8 | 3 | 2.32 | 5.514 | 0.1 | 1.67 | 7.47 |
| 5 | 4 | 1.022 | 0.4 | 0 | 0.9 | 1.55 |
| 6 | 5 | 5.443 | 21.631 | 0.58 | 3.3 | 13.28 |
| 5 | 6 | 6.386 | 31.448 | 0.6 | 2.95 | 15.35 |
| 4 | 7 | 9.43 | 11.693 | 5.2 | 8.12 | 12.45 |
| 5 | 8 | 5.932 | 3.138 | 2.83 | 6.4 | 7.3 |
| 6 | 9 | 4.938 | 9.518 | 0 | 4.17 | 8.17 |
| 6 | 10 | 4.922 | 11.831 | 0.88 | 4 | 10.85 |
| 5 | 11 | 0.684 | 0.973 | 0 | 0.1 | 2.4 |
| 5 | 12 | 1.356 | 1.162 | 0 | 0.8 | 2.8 |

Table B3_1. Monthly and Annual Sums for Station MRF27, dbkey

| year | Jan. | Feb. | Mar. | Apr. | May | June | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | ---- | ---- | 1.21 | 2.05 | 1.28 | 8.14 | 12.11 | 4.95 | 5.97 | 4.81 | 0.91 | 2.46 | 43.89 * |
| 66 | 5.56 | 5.82 | 1.69 | 1.49 | 4.58 | 5.29 | 6.87 | 4.86 | 4.67 | 3.14 | 0.08 | 0.89 | 44.94 |
| 67 | 1.33 | 2.7 | 0.22 | 0 | 0.38 | 6.61 | 7 | 7.25 | 6.65 | 0.46 | 0.13 | 1.89 | 34.62 |
| 68 | 0.6 | 2.03 | 1.31 | 0.33 | 9.16 | 14.64 | 5.3 | 2.98 | 5.71 | 7.45 | 2.39 | 0.2 | 52.1 |
| 69 | 1.85 | 1.34 | 7.81 | 1.89 | 1.89 | 6.92 | 8.32 | 6.67 | 9.64 | 10.17 | 3.17 | 3.66 | 63.33 |
| 70 | 2.34 | 2.2 | 5.41 | 0.79 | 3.58 | 5.6 | 8.79 | 3.79 | 2.48 | 6.05 | 0.34 | 1 | 42.37 |
| 71 | 0 | 4.77 | 1.15 | 0.38 | 1.07 | 8.34 | 8.24 | 5.41 | 2.31 | 5.79 | 0.41 | 1.39 | 39.26 |
| 72 | 2.99 | 4.21 | 2.79 | 2.47 | 5.52 | 8.02 | 2.74 | 4.46 | 0.66 | 1.37 | 5.58 | 3.16 | 43.97 |
| 73 | 5.23 | 1.58 | 2.58 | 7.26 | 5.22 | 4.42 | 7.98 | 6.44 | 7.05 | 3.86 | 0.08 | 1.69 | 53.39 |
| 74 | 0.4 | 1.86 | 0.08 | 3.4 | 8.17 | 13.98 | 20.28 | 10.97 | 6.84 | 0.47 | 0.32 | 4.69 | 71.46 |
| 75 | 1.08 | 2.71 | 2.1 | 2.38 | 10.18 | 5.65 | 9 | ---- | ---- | ---- | ---- | ---- | 33.1 * |
| 76 | 0.57 | 0.33 | 0.94 | 1.4 | 5.67 | 11.65 | 5.08 | 13.22 | 7.13 | 2.7 | 1.3 | 2.99 | 52.98 |
| 77 | 2.78 | 1.48 | 1.42 | 0.82 | 10.18 | 5.65 | 9 | ---- | ---- | ---- | ---- | ---- | 31.33 * |
| 78 | ---- | ---- | ---- | ---- | 6.74 | 13.41 | 10.14 | 7.89 | 6.98 | 4.9 | ---- | 3.36 | 53.42 * |
| 79 | 5.45 | 1.47 | 1.52 | 2.26 | 10.57 | 3.33 | 2.5 | 6.83 | 19.52 | 0.52 | 1.21 | 1.33 | 56.51 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 2.75 | 5.29 | 2.6 | 3.24 | 5.02 | 10.32 | 6.54 | 10.41 | 3.88 | 1.59 | 7.96 | ---- | 59.6 | * |
| 81 | 0.49 | 3.51 | 1.47 | 0.3 | 2.61 | 6.26 | 6.66 | 10.13 | 11.2 | 1.16 | 1.58 | 0.29 | 45.66 | |
| 82 | 2.15 | 3.23 | 6.43 | 7.47 | 7.06 | 8.68 | 8.05 | 2.6 | 7.97 | 4.6 | 0.95 | 1.49 | 60.68 | |
| 83 | 4.47 | 8.08 | 4.77 | 2.36 | 1.96 | 9.52 | 3.74 | 3.74 | 4.79 | 4.51 | 1.9 | 4.15 | 53.99 | |
| 84 | 0.77 | 2.52 | 2.15 | 2.35 | 6.36 | 4.51 | 8.88 | 5.64 | 2.91 | 1.1 | 3.99 | 0.56 | 41.74 | |
| 85 | 0.69 | 0.69 | 1.45 | 1.92 | 3.45 | 7.21 | 6.72 | 5.89 | 4.16 | 1.26 | 3 | 1.69 | 38.13 | |
| 86 | 2.46 | 1.52 | 5.15 | 0.3 | 0.97 | 8.93 | 6.55 | 5.92 | 5.57 | 1.59 | 1.46 | 2.32 | 42.74 | |
| 87 | 2.8 | 1.92 | 8.34 | 0.26 | 1.38 | 7.41 | 5.72 | 1.81 | 8.74 | 6.7 | 10.39 | 0.12 | 55.59 | |
| 88 | 2.16 | 2.96 | 6.31 | 0.44 | 1.85 | 5.36 | 13.09 | 8.88 | 4.76 | 1.07 | 2.92 | 1.82 | 51.62 | |
| 89 | 3.39 | 0.6 | 4.47 | 2.08 | 4.68 | 7.28 | 5.06 | 3.46 | 7.81 | 1.66 | 2.04 | 3.39 | 45.92 | |
| 90 | 0.38 | 5.14 | 0.38 | 1.13 | 1.18 | 7.31 | 9.55 | 9 | 4.75 | 2.66 | 0.88 | 0.72 | 43.08 | |
| 91 | 2.63 | 1.23 | 5.68 | 4.16 | 6.61 | 4.71 | 7.15 | 7.24 | 4.25 | 8.26 | 0.27 | 0.82 | 53.01 | |
| 92 | 0.22 | 2.8 | 1.35 | 4.05 | 2.06 | 12.87 | 8.58 | 12 | 2.85 | 2.01 | 0.75 | 0.53 | 50.07 | |
| 93 | 4.15 | 2.44 | 4.17 | 3.39 | 2.97 | 0.72 | 3.17 | 8.01 | 5.96 | 4 | 1.17 | 0.71 | 40.86 | |
| 94 | 1.44 | 3.05 | 1.48 | 3.17 | 1.54 | 13.34 | 11.68 | 4.54 | ---- | 4.75 | 4.46 | 2.63 | 52.08 | * |
| 95 | 1.71 | 3.61 | 4.47 | 3.97 | 2.18 | 8.93 | 4.23 | 9.6 | 5.41 | 5.57 | 2.88 | 0.26 | 52.82 | |
| 96 | 4.67 | 0.67 | 5.29 | 0.97 | 7.47 | 7.93 | 1.59 | 5.67 | 3.46 | 4.38 | 0.37 | 2.82 | 45.29 | |
| 97 | 2.08 | 1.12 | 3.48 | 5.01 | 5.35 | 5.05 | 11.49 | 9.23 | 5.99 | 0 | ---- | ---- | 48.8 | * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B3_2. Statistics of the Monthly Sums for Station MRF27, dbkey

| #yrs | month | Mean | Stdv | Min | Med | Max |
|---|---|---|---|---|---|---|
| 31 | 1 | 2.245 | 2.67 | 0 | 2.08 | 5.56 |
| 31 | 2 | 2.674 | 3.077 | 0.33 | 2.2 | 8.08 |
| 32 | 3 | 3.115 | 5.187 | 0.08 | 2.15 | 8.34 |
| 32 | 4 | 2.297 | 3.55 | 0 | 2.05 | 7.47 |
| 33 | 5 | 4.512 | 9.043 | 0.38 | 3.58 | 10.57 |
| 33 | 6 | 7.818 | 10.692 | 0.72 | 7.28 | 14.64 |
| 33 | 7 | 7.63 | 13.147 | 1.59 | 7 | 20.28 |
| 31 | 8 | 6.758 | 8.215 | 1.81 | 5.92 | 13.22 |
| 30 | 9 | 6.002 | 11.743 | 0.66 | 5.57 | 19.52 |
| 31 | 10 | 3.502 | 6.609 | 0 | 2.7 | 10.17 |
| 29 | 11 | 2.169 | 5.86 | 0.08 | 1.21 | 10.39 |
| 29 | 12 | 1.829 | 1.659 | 0.12 | 1.49 | 4.69 |

Table B4_1. Monthly and Annual Sums for Station MRF28, dbkey

| year | Jan. | Feb. | Mar. | Apr. | May | June | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | SUM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 2.64 | 0.15 | 2.79 | * |
| 69 | 2.32 | 1.55 | ---- | 1.84 | 1.6 | 6.99 | 9.96 | 10.26 | 15.21 | 7.91 | 4.28 | 4.73 | 66.65 | * |
| 70 | 3.25 | 1.87 | 5.35 | 0.31 | 5.47 | 2.74 | 8.25 | 6.18 | 4.27 | 3.44 | 0.42 | 0.96 | 42.51 | |
| 71 | 0.21 | 5.31 | 1.29 | 1.08 | 0.96 | 9.29 | 10.25 | 4.04 | 2.97 | 5.97 | 0.67 | 1.16 | 43.2 | |
| 72 | 2.41 | 0.38 | 2.61 | ---- | 4.95 | 12.18 | 3.95 | 6.2 | 1.19 | 3.82 | 3.33 | 2.44 | 43.46 | * |
| 73 | 4.69 | 1.93 | 3.87 | ---- | 4.6 | 4.38 | 7.12 | 6.08 | 5.59 | 4.07 | 0.05 | 1.7 | 44.08 | * |
| 74 | 0.22 | 1.81 | 0.06 | 0.78 | 2.53 | 8.91 | 12.83 | ---- | 2.92 | 0.14 | 0.28 | 2.11 | 32.59 | * |
| 75 | 0.45 | 1.23 | 1.28 | 0.81 | 3.61 | 6.42 | 5.17 | ---- | ---- | ---- | ---- | 0.42 | 19.39 | * |
| 76 | 0.59 | 2.13 | 0.4 | 0.97 | 7.04 | 7.66 | 5.87 | 7.09 | 9.34 | 1.48 | 2.55 | 2.07 | 47.19 | |
| 77 | 1.9 | 2.15 | 0.75 | 0.13 | 2.22 | 4.9 | 9.37 | 5.94 | 9.19 | 1.23 | 5.5 | ---- | 43.28 | * |
| 78 | -- | ---- | ---- | 0.08 | 6.15 | 10.51 | 18.17 | 0.09 | 4.04 | 3.98 | 0.52 | 3.53 | 47.07 | * |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 79 | 7.78 | 1.28 | 1.82 | 3.31 | 9.5 | 4.24 | 7 | 6.63 | 9.24 | 8.99 | 0.92 | 1.5 | 62.21 | |
| 80 | 2.63 | 0.48 | 1.16 | 5.8 | 5.31 | 7.98 | 11.74 | 7.01 | 4.95 | 0.73 | 9.58 | 2.02 | 59.38 | |
| 81 | 0.45 | 3.8 | 1.11 | 0.05 | 3.81 | 4.17 | 4.76 | 3.6 | 1.25 | 0.78 | 0.29 | 0.18 | 24.25 | |
| 82 | 0.94 | 1.64 | 6.59 | 7.05 | 10.09 | 5.31 | 6.79 | 6.24 | 7.63 | 3.89 | 5.13 | 2.3 | 63.6 | |
| 83 | 4.36 | 10.88 | 5.61 | 2.59 | 2.16 | 13.24 | 6.95 | 4.04 | 9.27 | 4.48 | 2.51 | 4.02 | 70.11 | |
| 84 | 1.34 | 2.7 | 2.72 | 1.19 | 10.49 | 3.88 | 7.03 | 6.18 | 5.62 | 0.86 | 5.53 | 0.37 | 47.91 | |
| 85 | 0.54 | 0.72 | 2.67 | 1.74 | 2.89 | 10.92 | 5.83 | 6.13 | 4.2 | 2.84 | 1.7 | 1.95 | 42.13 | |
| 86 | 1.21 | 1.49 | 4.2 | 0.25 | 0.87 | 8.17 | 6.32 | 7.06 | 2.29 | 1.89 | 1.08 | 3.48 | 38.31 | |
| 87 | 1.6 | 1.46 | 7.03 | 0.74 | 1.12 | 4.81 | 6.49 | 4.49 | 6.09 | 7.29 | 8.57 | 0.26 | 49.95 | |
| 88 | 2.04 | 2.31 | 5.02 | 0.22 | 3.21 | 4.36 | 9.7 | 7.1 | 3.86 | 1.59 | 3.26 | 1.5 | 44.17 | |
| 89 | 2.7 | 0.29 | 3.13 | 2.85 | 5.11 | 4.22 | 1.89 | 5.5 | 7.78 | 0.76 | 2.33 | 3.37 | 39.92 | |
| 90 | 0.97 | 5.08 | 1.5 | 0.98 | 1.02 | 7.5 | 6.78 | 11.16 | 4.84 | 4.52 | 0.85 | 0.67 | 45.86 | |
| 91 | 2.5 | 1.33 | 5.32 | 3.05 | 7.08 | 10.48 | ---- | 7.07 | 5.15 | 5.12 | 0.1 | 0.28 | 47.48 | * |
| 92 | 0.27 | 2.61 | 1.23 | 4.69 | 1.61 | 9.23 | 3.93 | 16.61 | 3.29 | 2.23 | 1.19 | 0.6 | 47.49 | |
| 93 | 4.94 | 2.21 | 4.83 | ---- | ---- | 1.12 | ---- | ---- | 4.5 | 3.69 | 0.29 | 0.72 | 22.3 | * |
| 94 | 1.49 | 2.35 | 2.22 | 4.27 | 1.99 | 11.12 | 9.43 | 7.9 | 8.35 | 2.49 | 3.89 | 3.22 | 58.72 | |
| 95 | 1.72 | 2.04 | 3.81 | 3.54 | 2.27 | 6.87 | 8.02 | 8.64 | 3.34 | 4.56 | 1.82 | 0.52 | 47.15 | |
| 96 | 4.17 | 0.59 | 4.64 | 1.3 | 3.8 | 7.21 | 4.72 | 6.46 | 3.09 | 3.37 | 0.31 | 2.18 | 41.84 | |
| 97 | 2.03 | 0.79 | 2.45 | 4.18 | 3.59 | 2.45 | 10.3 | 2.93 | 5.62 | 1.51 | 8.53 | ---- | 44.38 | * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B4_2. Statistics of the Monthly Sums for Station MRF28, dbkey 5946

| *#yrs* | *month* | *Mean* | *Stdv* | *Min* | *Med* | *Max* |
|---|---|---|---|---|---|---|
| 28 | 1 | 2.133 | 3.114 | 0.21 | 1.72 | 7.78 |
| 28 | 2 | 2.229 | 4.359 | 0.29 | 1.81 | 10.88 |
| 27 | 3 | 3.062 | 3.887 | 0.06 | 2.61 | 7.03 |
| 26 | 4 | 2.069 | 3.678 | 0.05 | 1.19 | 7.05 |
| 28 | 5 | 4.109 | 7.575 | 0.87 | 3.591 | 10.49 |
| 29 | 6 | 6.94 | 9.719 | 1.12 | 6.87 | 13.24 |
| 28 | 7 | 7.427 | 12.899 | ----- | 6.95 | 18.17 |
| 26 | 8 | 6.562 | 9.06 | 0.09 | 6.2 | 16.61 |
| 28 | 9 | 5.539 | 9.418 | 1.19 | 4.838 | 15.21 |
| 28 | 10 | 3.344 | 5.16 | 0.14 | 3.37 | 8.99 |
| 29 | 11 | 2.694 | 7.382 | 0.05 | 1.7 | 9.58 |
| 28 | 12 | 1.729 | 1.685 | 0.15 | 1.5 | 4.73 |

Table B5_1. Monthly and Annual Sums for Station MRF50, dbkey

| *year* | *Jan.* | *Feb.* | *Mar.* | *Apr.* | *May* | *June* | *Jul.* | *Aug.* | *Sep.* | *Oct.* | *Nov.* | *Dec.* | *SUM* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 69 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 0 | 6 | 4.7 | 10.7 | * |
| 70 | 4.1 | 2.3 | 7.6 | 0.9 | 7.2 | 3.2 | ---- | ---- | ---- | ---- | ---- | ---- | 25.3 | * |
| 71 | ---- | ---- | ---- | ---- | 2.2 | ---- | ---- | 3.2 | ---- | 7.6 | 1.3 | 1.7 | 16 | * |
| 72 | 3.86 | ---- | ---- | 3.4 | 7.5 | 14.86 | 5.9 | 9.5 | 2.5 | 5.7 | 6.4 | 4.1 | 63.72 | * |
| 73 | 7 | 2.8 | 5.6 | 9.1 | 5.4 | 8.4 | 10.3 | 12.4 | 9.9 | 6 | 0.2 | 3.8 | 80.9 | |
| 74 | 0.2 | 3.4 | 0.4 | 2.9 | 4.7 | 15.3 | 16.1 | 6 | 5.8 | 0.6 | 0.5 | 1.82 | 57.72 | |
| 75 | 0.75 | 2.1 | 2.9 | 4.2 | 12.2 | 8.1 | ---- | 12.6 | 16.3 | 7.1 | 0.2 | 0.2 | 66.65 | * |
| 76 | 0 | 2.7 | ---- | ---- | ---- | ---- | 7.8 | 9.5 | 9 | 1.8 | 3.61 | 3.6 | 38.01 | * |
| 77 | 3.6 | 4.12 | 1.52 | 0 | 4.24 | 3.9 | 10.8 | 1.3 | 7.45 | 2 | 4.5 | 2.9 | 46.33 | |
| 78 | 3.5 | 4.8 | 5.2 | 0.6 | 5.9 | 7.25 | ---- | ---- | 7.6 | 3.9 | 0.5 | ---- | 39.25 | * |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 79 | 10.16 | 1.7 | 4.4 | 3.4 | 14.8 | ---- | ---- | ---- | 12.5 | 1.1 | 1 | 2 | 51.06 * |
| 80 | 3.7 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 3.7 * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B5_2. Statistics of the Monthly Sums for Station MRF50, dbkey 6112

| *#yrs* | *month* | *Mean* | *Stdv* | *Min* | *Med* | *Max* |
|---|---|---|---|---|---|---|
| 11 | 1 | 3.282 | 10.556 | ----- | 3.5 | 10.16 |
| 10 | 2 | 2.238 | 3.377 | ----- | 2.3 | 4.8 |
| 10 | 3 | 2.531 | 9.347 | ----- | 1.52 | 7.6 |
| 10 | 4 | 2.296 | 9.069 | ----- | 0.9 | 9.1 |
| 10 | 5 | 6.337 | 20.429 | ----- | 5.4 | 14.8 |
| 10 | 6 | 5.87 | 36.256 | ----- | 3.9 | 15.3 |
| 10 | 7 | 4.705 | 39.909 | ----- | ----- | 16.1 |
| 10 | 8 | 5.219 | 30.039 | ----- | 3.2 | 12.6 |
| 10 | 9 | 6.951 | 30.236 | ----- | 7.45 | 16.3 |
| 11 | 10 | 3.185 | 8.972 | ----- | 1.8 | 7.6 |
| 11 | 11 | 2.131 | 6.416 | ----- | 0.5 | 6.4 |
| 11 | 12 | 2.116 | 3.687 | ----- | 1.82 | 4.7 |

Table B6_1. Monthly and Annual Sums for Station MRF61, dbkey 6200

| *year* | *Jan.* | *Feb.* | *Mar.* | *Apr.* | *May* | *June* | *Jul.* | *Aug.* | *Sep.* | *Oct.* | *Nov.* | *Dec.* | *SUM* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | ---- | 2.39 | 5.08 | 4.24 | 4.26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15.97 * |
| 61 | 1.58 | 1.67 | 2.4 | ---- | 2 | 5.35 | ---- | ---- | ---- | ---- | ---- | ---- | 13 * |
| 62 | ---- | ---- | ---- | ---- | 1.42 | 11.65 | 6.89 | 8.86 | 5.5 | 1.1 | 3.68 | 1.02 | 40.12 * |
| 63 | 1.79 | 6.33 | 1.38 | 0.32 | 13.61 | 5.34 | 3.57 | 5.48 | 3.72 | 0.85 | 5.12 | 2.61 | 50.12 |
| 64 | 3.65 | 4.59 | 2.79 | 2.07 | 4.31 | 3.94 | 7.63 | 14.68 | 6.53 | 0.78 | 0.84 | 0.55 | 52.36 |
| 65 | 1.02 | 4.99 | 3.36 | 3.18 | 4.56 | 10.74 | 9.81 | 10.99 | 7.72 | 7.24 | 1.42 | 2.34 | 67.37 |
| 66 | 5.8 | 8.13 | 1.49 | 1.83 | 3.72 | 9.38 | 5.77 | 4.82 | 6.39 | 1.71 | 0.12 | 1.25 | 50.41 |
| 67 | 0.72 | 3.81 | 0.07 | 0 | 0.15 | 5.76 | 12.14 | 13.28 | 5.38 | 1.29 | 0.16 | 2.72 | 45.48 |
| 68 | 0.46 | 1.87 | 1.18 | 0.34 | 4 | 14.72 | 6.47 | 2.77 | 8.63 | 5.3 | 2.22 | 0.57 | 48.53 |
| 69 | 2.39 | 1.36 | 6.71 | 2.64 | 2.46 | 5.02 | 7.95 | 12.27 | 10.25 | 9.84 | 3.44 | 4 | 68.33 |
| 70 | 2.54 | 1.3 | 5.22 | 0.26 | 4.56 | 3.1 | 7.66 | 5.46 | 3.3 | 3.07 | 0.39 | 1.11 | 37.97 |
| 71 | 0.17 | 6.02 | 1.55 | 1.03 | 2.1 | 8.97 | 8.19 | 5.19 | 1.79 | 4.83 | 0.49 | 0.96 | 41.29 |
| 72 | 1.76 | 4.65 | 3.08 | 2.36 | 4.03 | 11.22 | 3.12 | 7.56 | 0.64 | 2.74 | 4.31 | 3.16 | 48.63 |
| 73 | 5.82 | 1.63 | 4.54 | 7.28 | 5.46 | 4.59 | 11.42 | 9.5 | 7.25 | 2.34 | 1.56 | 2.36 | 63.75 |
| 74 | 1 | 2.13 | 0.24 | 1.59 | 5.7 | 12 | 12.64 | 10.9 | 4.2 | 0.3 | 0.38 | 2.36 | 53.44 |
| 75 | 0.94 | 4.56 | 1.37 | 0.7 | 7.72 | 8.38 | 11.99 | 10.58 | 11.33 | 6.4 | 0.34 | 0.68 | 64.99 |
| 76 | 0.68 | 0.78 | 3.64 | 1.34 | 6.46 | 9.66 | 9.56 | 10.16 | 9.8 | 1.72 | 3.38 | 2.96 | 60.14 |
| 77 | 2.08 | 1.82 | 0.93 | 0.39 | 3.64 | 2.78 | 9.19 | 5 | 6.82 | 2.3 | 4.35 | 6.26 | 45.56 |
| 78 | 2.98 | 3.32 | 3.94 | 0.3 | 5.58 | 7.62 | 13.45 | 1.55 | 2.35 | 2.58 | 0.48 | 3.58 | 47.73 |
| 79 | 6.72 | 0.88 | 2 | 2.7 | 9.14 | 6.47 | 7.63 | 4.64 | 16.31 | 0.25 | 1.09 | 1.52 | 59.35 |
| 80 | 2.88 | 4.32 | 1.82 | 3.96 | 6.18 | 6.7 | 7.38 | 7.54 | 3.55 | 0.61 | 5.47 | 1.35 | 51.76 |
| 81 | 0.46 | 3.16 | 0.87 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 4.49 * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B6_2. Statistics of the Monthly Sums for Station MRF61, dbkey 6200

| #yrs | month | Mean | Stdv | Min | Med | Max |
|---|---|---|---|---|---|---|
| 21 | 1 | 2.127 | 3.919 | ----- | 1.58 | 6.72 |
| 22 | 2 | 3.134 | 4.617 | ----- | 2.39 | 8.13 |
| 22 | 3 | 2.404 | 3.525 | ----- | 1.82 | 6.71 |
| 21 | 4 | 1.666 | 3.676 | ----- | 1.03 | 7.28 |
| 21 | 5 | 4.812 | 8.477 | 0.15 | 4.26 | 13.61 |
| 21 | 6 | 7.304 | 13.174 | 0 | 6.47 | 14.72 |
| 21 | 7 | 7.7 | 14.746 | ----- | 7.63 | 13.45 |
| 21 | 8 | 7.165 | 18.456 | ----- | 5.48 | 14.68 |
| 21 | 9 | 5.747 | 17.119 | ----- | 5.38 | 16.31 |
| 21 | 10 | 2.594 | 7.292 | ----- | 1.71 | 9.84 |
| 21 | 11 | 1.832 | 3.637 | ----- | 0.84 | 5.47 |
| 21 | 12 | 1.933 | 2.485 | ----- | 1.35 | 6.26 |

Table B7_1. Monthly and Annual Sums for Station S65_R, dbkey

| year | Jan. | Feb. | Mar. | Apr. | May | June | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 2.43 | 1.51 | 6.65 | 3.17 | 8.66 | 5.31 | 7.18 | 6.54 | 4.25 | 7.36 | 0.27 | 0.82 | 54.15 |
| 92 | ---- | ---- | ---- | ---- | ---- | 12.88 | ---- | 12.01 | ---- | ---- | ---- | 0.53 | 25.42 * |
| 93 | 4.15 | 2.44 | 4.17 | 3.39 | 2.97 | 0.72 | 3.17 | 8.01 | 5.96 | 4 | 1.16 | 0.68 | 40.82 |
| 94 | 1.44 | 3.05 | 1.52 | 3.17 | 1.54 | 12.89 | 11.68 | 4.54 | 8.24 | 4.67 | 4.41 | 2.63 | 59.78 |
| 95 | 1.67 | 3.61 | 4.49 | 3.97 | 2.12 | 9.65 | 4.27 | 9.6 | 5.41 | 5.57 | 2.81 | 0.26 | 53.43 |
| 96 | 4.75 | 0.67 | 5.29 | 0.97 | 7.47 | 7.93 | 1.49 | 5.67 | 3.46 | 4.38 | 0.37 | 2.82 | 45.27 |
| 97 | 2.08 | 1.09 | 3.49 | 5.01 | 5.35 | 5.22 | 11.93 | 9.23 | 5.99 | 1.81 | 2.15 | ---- | 53.35 * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B7_2. Statistics of the Monthly Sums for Station S65_R, dbkey

| #yrs | month | Mean | Stdv | Min | Med | Max |
|---|---|---|---|---|---|---|
| 6 | 1 | 2.753 | 1.879 | 1.44 | 2.08 | 4.75 |
| 6 | 2 | 2.062 | 1.34 | 0.67 | 1.51 | 3.61 |
| 6 | 3 | 4.268 | 2.987 | 1.52 | 4.17 | 6.65 |
| 6 | 4 | 3.28 | 1.768 | 0.97 | 3.17 | 5.01 |
| 6 | 5 | 4.685 | 8.682 | 1.54 | 2.97 | 8.66 |
| 7 | 6 | 7.8 | 19.689 | 0.72 | 5.31 | 12.89 |
| 6 | 7 | 6.62 | 19.571 | 1.49 | 4.27 | 11.93 |
| 7 | 8 | 7.943 | 6.61 | 4.54 | 6.54 | 12.01 |
| 6 | 9 | 5.552 | 2.735 | 3.46 | 5.41 | 8.24 |
| 6 | 10 | 4.632 | 3.35 | 1.81 | 4.38 | 7.36 |
| 6 | 11 | 1.862 | 2.545 | 0.27 | 1.16 | 4.41 |
| 6 | 12 | 1.29 | 1.274 | 0.26 | 0.68 | 2.82 |

Table B8_1. Monthly and Annual Sums for Station KISS_SP_G, dbkey

| year | Jan. | Feb. | Mar. | Apr. | May | June | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 2.17 | 1.68 | 6.53 | 3.36 | 6.15 | 3.84 | 9.81 | 7.03 | 2.8 | 4.03 | 0.12 | 0.7 | 48.22 |
| 92 | ---- | ---- | ---- | ---- | ---- | 13.74 | ---- | 13.34 | ---- | ---- | ---- | 0.6 | 27.68 * |
| 93 | 7.92 | 1.45 | 4.76 | 4.5 | 2.47 | 4.43 | 4.09 | 5.65 | 4.98 | 3.75 | 0.5 | 1.52 | 46.02 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 94 | 3.5 | 2.85 | 2.9 | 5.8 | 1.95 | 10.41 | 5.18 | 5.63 | 6.76 | 3.71 | 4.51 | 3.35 | 56.55 |
| 95 | 1.94 | 1.2 | 3.15 | 3.5 | 2.4 | 10.9 | 8.01 | 7.8 | 6.33 | 6.37 | 1.85 | 0.9 | 54.35 |
| 96 | 4.65 | 0.5 | 7.42 | 0.55 | 13.29 | 7.58 | 3.26 | 10.66 | 5.75 | 4.13 | 0.8 | 2.98 | 61.57 |
| 97 | 2.38 | 1.1 | 2.95 | 4.23 | 3.75 | 6.65 | 8.38 | 6.18 | 3.52 | 1.97 | 1.34 | ---- | 42.45 * |

* Partial: Annual sum based on cumulative rainfall in less than 12 months

Table B8 2. Statistics of the Monthly Sums for Station KISS_SP_G, dbkey 16590

| #yrs | month | Mean | Stdv | Min | Med | Max |
|---|---|---|---|---|---|---|
| 6 | 1 | 3.76 | 5.182 | 1.94 | 2.38 | 7.92 |
| 6 | 2 | 1.463 | 0.62 | 0.5 | 1.2 | 2.85 |
| 6 | 3 | 4.619 | 3.886 | 2.9 | 3.15 | 7.42 |
| 6 | 4 | 3.656 | 3.08 | 0.55 | 3.5 | 5.8 |
| 6 | 5 | 5.002 | 18.814 | 1.95 | 2.47 | 13.29 |
| 7 | 6 | 8.221 | 13.145 | 3.84 | 6.65 | 13.74 |
| 6 | 7 | 6.455 | 6.961 | 3.26 | 5.18 | 9.81 |
| 7 | 8 | 8.041 | 8.502 | 5.63 | 6.18 | 13.34 |
| 6 | 9 | 5.023 | 2.491 | 2.8 | 4.98 | 6.76 |
| 6 | 10 | 3.993 | 1.98 | 1.97 | 3.75 | 6.37 |
| 6 | 11 | 1.52 | 2.52 | 0.12 | 0.8 | 4.51 |
| 6 | 12 | 1.675 | 1.448 | 0.6 | 0.9 | 3.35 |