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Natural Resources Conservation Services

Engineering Technical Note No. 3

Rainfall-Frequency and Design Rainfall Distribution for Selected Pacific Islands

Issued September 2008

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Cover Photo: Aasu village and watershed, Island of Tutuila, American Samoa, courtesy of NRCS.

Acknowledgements

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Abstract

Updated rainfall-frequency values for the Territory of Guam, Saipan and Rota (Commonwealth of Northern Mariana Islands), Yap, Chuuk, Pohnpei, and Kosrae (Federated States of Micronesia), Koror (Republic of Palau), Majuro (Marshall Islands), Tutuila (American Samoa), and Wake Island are included in this report (see Figure 1). Durations from 15-minutes to 72-hours and return periods from 1-year to 500-years were estimated based upon data recorded by the U.S. National Weather Service over a period of 10 to 48 years. The rainfall records are from recent years with the measurements extending from as early as 1954 up to and including 2006. Most stations have data between the years 1980 to 2005. A rainfall distribution which distributes the rainfall over a 24-hour design storm period was also developed in order to use these rainfall values for hydrologic analysis and design.

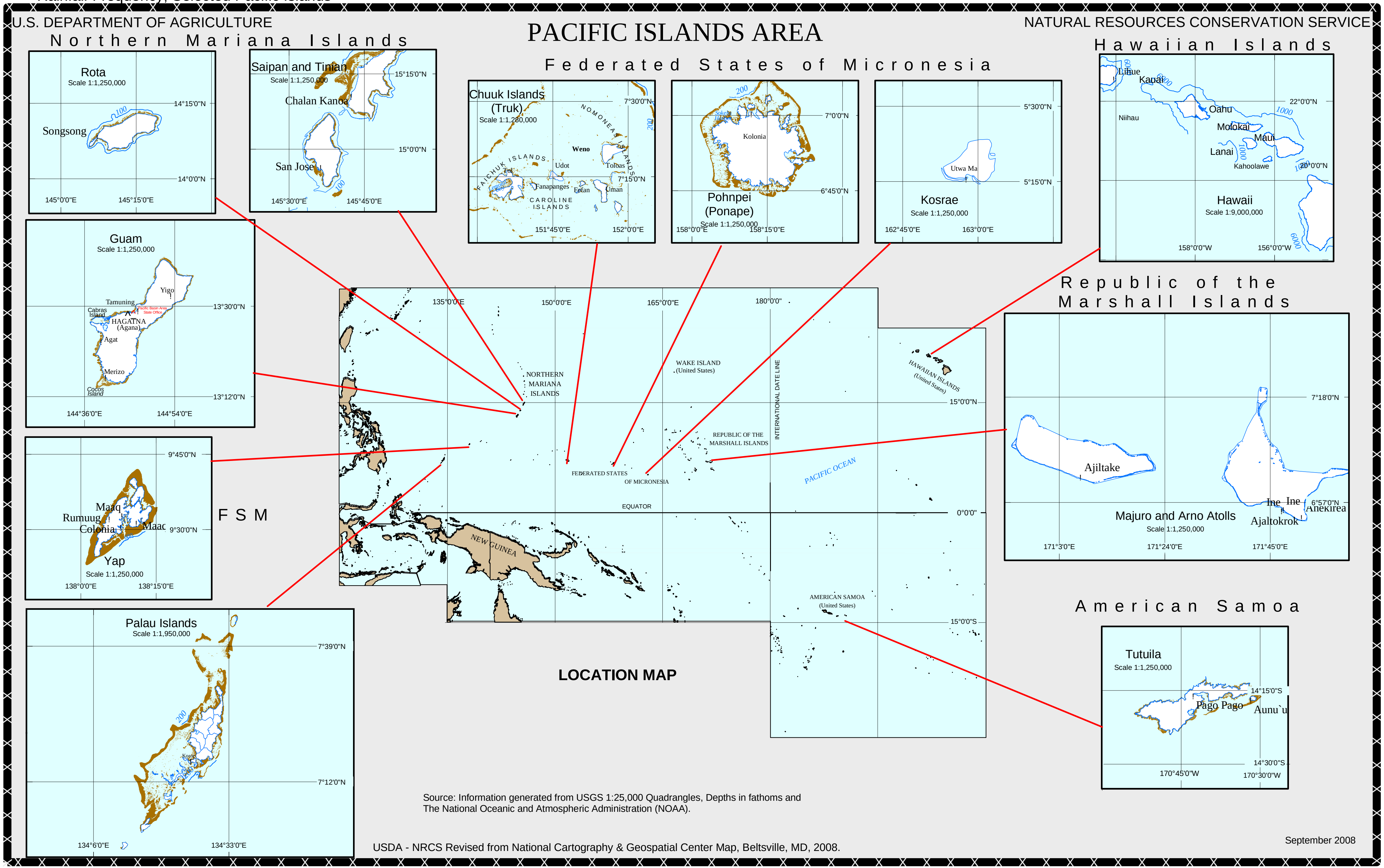
Introduction / Background

Rainfall-frequency information is needed for design of soil conservation practices for erosion control, streambank protection projects, stormwater management facilities, stream crossings such as bridges and culverts, and flood plain management studies.

There is a need for updated rainfall-frequency information because some of the islands have reports which are many years old and some islands have no report at all.

NRCS has developed hydrologic analysis methods and software to estimate volume of runoff and peak discharge for small watersheds. The technical references are within the NRCS National Engineering Handbook Part 630 – Hydrology (2004). The chapters of this handbook are available over the internet. The principal software tools which have been developed are EFH-2 (NRCS, 2003), WinTR-55 (NRCS, 2004), and WinTR-20 (NRCS, 2004). These software tools are available for download at no cost over the internet.

Figure 1 shows the general location of the islands included in this report. Territory of Guam, Saipan and Rota (Commonwealth of Northern Mariana Islands), Yap, Chuuk, Pohnpei, and Kosrae (Federated States of Micronesia), Koror (Republic of Palau), Majuro (Marshall Islands), and Tutuila (American Samoa) are shown. Wake Island is labeled on Figure 1. Wake Island is located north of the Marshall Islands at approximately 168 degrees East longitude and 20 degrees North latitude.


U.S. DEPARTMENT OF AGRICULTURE
PACIFIC ISLANDS AREA
NATURAL RESOURCES CONSERVATION SERVICE
Northern Mariana Islands
Rota
Scale 1:1,250,000
Songsong
Saipan and Tinian
Scale 1:1,250,000
Chalan Kanoa
San Jose
Federated States of Micronesia
Chuuk Islands (Truk)
Scale 1:1,280,000
Weno
Pohnpei (Ponape)
Scale 1:1,250,000
Kolonia
Kosrae
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Hawaiian Islands
Lihue
Kauai
Niihau
Oahu
Molokai
Maui
Lanai
Kahoolawe
Hawaii
Scale 1:9,000,000
Guam
Scale 1:1,250,000
HAGATNA (Agana)
Yigo
Tamuning
Agat
Merizo
Yap
Scale 1:1,250,000
Colonia
F S M
Palau Islands
Scale 1:1,950,000
Republic of the Marshall Islands
Majuro and Arno Atolls
Scale 1:1,250,000
Ajiltake
Ajaltokrok
American Samoa
Tutuila
Scale 1:1,250,000
Pago Pago
Aunu`u
NORTHERN MARIANA ISLANDS
WAKE ISLAND (United States)
HAWAIIAN ISLANDS (United States)
REPUBLIC OF THE MARSHALL ISLANDS
FEDERATED STATES OF MICRONESIA
INTERNATIONAL DATE LINE
PACIFIC OCEAN
EQUATOR
NEW GUINEA
AMERICAN SAMOA (United States)
LOCATION MAP
Source: Information generated from USGS 1:25,000 Quadrangles, Depths in fathoms and The National Oceanic and Atmospheric Administration (NOAA).
USDA - NRCS Revised from National Cartography & Geospatial Center Map, Beltsville, MD, 2008.
September 2008

NRCS (formerly the Soil Conservation Service, SCS) has a long history in design of engineering measures in small watersheds (SCS, 1973). The basis of the NRCS procedure involves the rainfall-runoff process. Data related to rainfall consists of rainfall magnitude and time distribution. Data related to the watershed are drainage area, runoff curve number (CN), time of concentration (Tc), and dimensionless unit hydrograph. If the watershed is somewhat larger and not homogeneous in land use, soil, land slope, or other characteristics, basic data on the stream network is generally required (NRCS, National Engineering Handbook Part 630, 2004).

Rainfall-frequency is generally derived from a series of measurements at rainfall gaging stations. To develop rainfall-frequency values is a principal purpose of this report. The second principal purpose concerns the distribution of rainfall over a design storm period. The selection of the 24-hour duration as the design storm period goes back many years to the 1950's, when good quality and quantity measurements were available only for daily time periods. Short term records for limited locations were available for durations less than 24 hours. The distribution of rainfall over the 24-hour period is critical in estimating the peak discharge for a small watershed. One of the basic assumptions of the NRCS hydrologic design procedure is that the frequency of the rainfall event produces an equal frequency of runoff event. For example, the 10-year rainfall produces the 10-year flood. Since the peak discharge is directly related to a rainfall duration equal to the watershed time of concentration (Tc), the time distribution contains an intense center portion and gradually lessens in intensity for times approaching the tails of the distribution at zero and 24 hours. The following figure from SCS TP-149 shows standard design rainfall distributions for the Type I and Type II storms. These distributions are based on rainfall-frequency analyses. More information on the technical development of rainfall distributions is included in TP-149 (SCS, 1973).

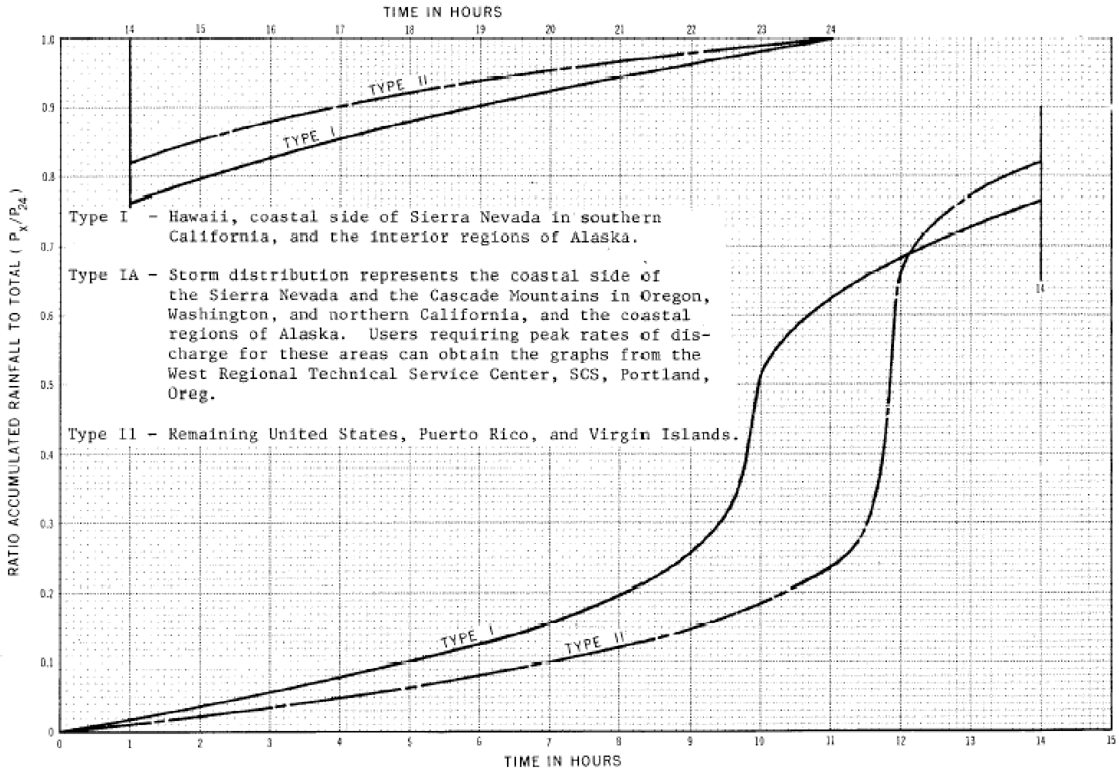

Figure 2. Type I and Type II rainfall distributions from TP-149.

Developing a rainfall distribution based on rainfall-frequency information from the Pacific Islands is a critical need in order to successfully apply NRCS hydrologic procedures.

A detailed description of the meteorology and climatology of Saipan and Guam are included in Lander (2004). There are distinct wet and dry seasons in Saipan and Guam. For example, at the Saipan International Airport, the mean dry-season (January through June) rainfall was 20.26 inches and the mean wet-season (July through December) rainfall was 53.21 inches (Lander (2004). The wet season in Guam typically occurs from August to October and the dry season occurs from December to June. July and November are transition months. In northern Guam, the average rainfall during the wet season is about 12 inches per month and during the dry season about 5 inches per month (CNMI and Guam Stormwater Management Manual, 2006). Various meteorological conditions produce heavy rainfalls for small geographic areas up to large regions. During the wet season, isolated thunderstorm cells can provide heavy rainfall on small areas. Larger scale convective systems, monsoons, tropical cyclones, and typhoons cover increasingly larger geographic scales. In the dry season, off-season tropical cyclones occur periodically. Another weather system called a “shear line” occurs with passing cold fronts and can provide moderate to heavy rainfall. Considering the complex meteorology of the Pacific Islands, there is much variation from Palau to American Samoa which can only be measured at several climatic data stations.

Oceanic systems such as El Nino impact the rainfall patterns as well. These stations have fairly short measurement records. Naturally, there are limitations as to how well a short period of record can represent the complex weather systems and associated rainfall. Treatment and analysis of data will be discussed in following sections of the report. Several rainfall-frequency studies have been completed in the past for individual islands with varying years of records. Lander (2004) analyzed Saipan International Airport and Capitol Hill in Saipan. The U.S. Army Corps of Engineers completed rainfall-frequency analyses for Guam (1980) and Saipan (2003). Comparisons of results with previous studies will be addressed later in this report.

Rainfall Data

Significant amounts of rainfall data were obtained and analyzed from a variety of sources including the National Weather Service and local governments. Some data extend back to the early 1900's (Lander and Guard, 2003 and Morrissey, Shafer, Postawko, and Gibson, 1993). Data were measured at several different time intervals. Rainfall at some gages was recorded on a daily basis, some at hourly intervals, and some at 15 minute intervals. Some rainfall records are stored in a computer database and many past records are not. Available data for the 17 stations listed in Table 1 were extracted from the National Climatic Data Center database. In addition to the digital data, hand-written records for Majuro (Marshall Islands) contained in U. S. Department of Commerce (1971) were analyzed. Data for maximum rainfall recorded at 5, 10, 15, and 30 minutes, and 1, 2, 3, and 24 hours were extracted for the years 1958-70.

Even though significant amounts of data have been collected, there are limitations in that there are missing days or months, gages starting and stopping, and relatively few gages which have measurements at hourly or shorter intervals. The principal focus of this study was to gather data for durations of 24-hours or less. There are not many hourly and 15-minute gages within the study area.

Rainfall Data Screening and Analysis

Data quality is a major concern. In some cases, due to high winds, the gage does not measure the rainfall accurately (Khosrowpanah, 1996), as gages generally do not catch the full amount of rainfall. Complete years of data at a gage were considered optimal, yet many gages had missing days, months and/or years which detract from an accurate rainfall-frequency analysis.

It was decided that only the data of highest quality would be analyzed. This includes the following list of 17 locations with the respective periods of record. Nine of the stations had both 15 minute and 60 minute observations. Seven stations had 60 minute observations. One station had daily records.

Table 1. List of 17 stations analyzed in this report.

Station Name	Station Number	Observation Interval, minutes	Years of record	Latitude Degrees Minutes	Longitude Degrees Minutes	Elevation Feet
Fena Lake, Guam	914200	15, 60	26	13° 22' N	144° 42'E	60
Inarajan, Guam	914278	15,60	27	13° 18' N	144° 44'E	85
Piti, Guam	914670	15,60	27	13° 28' N	144° 41'E	10
Taguac, Guam	914229	60	14	13° 32' N	144° 50'E	110
Capitol Hill, Saipan, Northern Marianas	914080	15, 60	19	15° 13' N	145° 45'E	827
Rota, Northern Marianas	914801	15, 60	23	14° 07' N	145° 08'E	14
Saipan IA, Saipan, Northern Marianas	914855	15, 60	25	15° 06' N	145° 42'E	65
Yap WSO, FSM	914951	60	15	9° 28' N	138° 05'E	13
Chuuk, FSM	914851	60	10	7° 28' N	151° 50'E	2
Pohnpei Hospital, FSM	914745	15, 60	26	6° 57' N	158° 13'E	30
Pohnpei WSO, FSM	914751	60	10	6° 57' N	158° 13'E	37
Kosrae, FSM	914385	Daily	48	5° 19' N	163° 02'E	2
Koror, Palau	914351	60	22	7° 19' N	134° 28'E	29
Majuro, Marshall Islands	914460	5, 60	5-min, 13 years 60-min, 22 years	7° 05' N	171° 22'E	3
Atu'u, Tutuila, Am. Samoa	914060	15, 60	20	14° 15' S	170°41'W	81
Malaeloa, Tutuila, Am. Samoa	914594	15, 60	26	14° 19' S	170°46'W	42
Wake Island	914901	60	12	19° 17' N	166° 38'E	4

Since there are two or more rain gages on the islands of Guam, Saipan, Pohnpei, and Tutuila, locations of these gages are included in Appendix 8. All data used in these analyses are included in Appendix 1 to this report. The main purpose for including the data is to provide a starting point for anyone updating the rainfall-frequency analyses in the future when more years of data are available.

The frequency analysis for each station was completed for both the Generalized Extreme Value (GEV) and Gumbel probability distributions. These analyses used highest values at each location during each year in the period of record (one value per year) which is referred to as the annual series. The annual maximum values were analyzed as a single group and not divided based on the several categories of storms which occur throughout the year. The final results were obtained using concepts of L-moments to calculate mean and standard deviation and the Gumbel, Extreme Value Type I, frequency distribution to derive the estimates of 2-year to 500-year rainfall for durations of 15-minutes, 30-minutes, 1-hour, 3-hour, 6-hour, 12-hour, 24-hour, 48-hour, and 72-hour. The primary reason the Gumbel was chosen over the GEV was that the Gumbel has a fixed value of skew. Of the three moments calculated from the data, mean, standard deviation, and skew, progressively longer periods of record are required to derive a reasonable estimate. For example, it takes a relatively short record to estimate the mean, a longer period of record to estimate the standard deviation, and an even longer period of record to estimate the skew. With the short periods of record, the GEV provided a wide range of skew values. The skew can be influenced by high rainfall or lack of high rainfall measured at individual stations. Different skews were computed for different rainfall durations. This did not seem logical. For reasons of uniformity and consistency, the Gumbel probability distribution was chosen.

The L-Moment procedure was applied to each station individually. There is an option in the L-Moment procedure to consider a group of stations when determining the moments for individual stations. This grouping procedure was not used due to the wide geographic extent of the stations involved.

For stations with 15-minute and 60-minute observations, statistical analyses for the annual series were completed for both and compared. Since the results were reasonably close, the analyses of 15-minute data were used in the remainder of this report to develop rainfall-frequency values and rainfall distributions. The results are included in Appendix 2. The 15 minute data may be used to develop rainfall-frequency information at durations down to 15 minutes which will be useful in designing stormwater management facilities for small watersheds.

As shown in Table 1, Majuro, Marshall Islands had 60-minute data for 22 years. These data were used to estimate the rainfall-frequency for 1, 3, 6, 12, 24, 48, and 72-hours. The thirteen years of additional data at Majuro were not used to determine the rainfall-frequency values published in this report. Data for different durations were available. Using the additional data would have provided 35 years of data for only the 1, 3, and 24-

hour durations. For statistical consistency, only the 22 years of record were analyzed for rainfall-frequency. However, since this was the only station with records for 5 and 10 minutes, these data were analyzed and used to develop ratios of 5-minute / 15-minute and 10-minute / 15-minute rainfall and used in development of the design rainfall distributions which are discussed later in this report.

Since daily rainfall records were available at Kosrae, its statistical treatment was somewhat different. The maximum one-day, two-day, and three-day rainfalls for each year of record were extracted. Rain gages that are measured on a daily basis are generally recorded at a specific hour of the day, for example 8:00 AM. This opens up the possibility that the highest 24-hour period may include more rainfall than was measured for the day. For example, if the rain for a particular storm began at 4:00 AM and ended at 4:00 PM, the rainfall during that storm would be separated into two daily measurements when the storm actually happened within a 24-hour period. To adjust the daily data for this possibility, the one-day rainfall was converted to 24-hour rainfall by multiplying by the factor 1.13 (Hershfield, 1961). Two-day rainfall was converted to 48-hour rainfall by multiplying by the factor 1.05. Three-day rainfall was converted to 72-hour rainfall by multiplying by the factor 1.02. The Gumbel probability distribution parameters for the 24, 48, and 72-hour data series were determined using the method of moments to compute the mean and standard deviation.

The annual series values were then converted to partial duration series values. The partial duration series is somewhat different than the annual series. The annual series includes the highest rainfall for each year, and therefore has only one value per year. The partial duration series includes all values above a specified base value so that some years can have multiple values and some years may have no value included. One common practice in selecting partial duration series values is to select the highest N values from a period of N years. In designing stormwater management or other practices, it is generally considered preferable to use the partial duration series because when something is designed it is more relevant to consider all possible storms (multiple storms per year) instead of just the highest each calendar year. The partial duration analysis generally results in slightly higher 2-year and 5-year rainfall values. Values from 10-year to 500-year are almost identical between the annual and partial duration series. The reason why the annual series is analyzed first is that standard statistical procedures are derived from the theory of annual series. Standard statistical analysis methods for the partial duration series are not available. The partial duration series may be plotted on probability paper and a curve fit to the data by visual means. However, an equation based on statistical analysis may not be developed for a partial duration series.

By determining partial duration values, the 1-year rainfall at each location could be estimated. The 1-year rainfall is one of the storms analyzed for the design of stormwater management facilities (CNMI and Guam, 2006). The 2, 5, 10, 25, 50, 100, 200, and 500-year return periods were also estimated.

Rainfall – Partial Duration Frequency Results

Detailed results of rainfall-frequency for partial duration series are included in Appendix 3. The equation used to convert from annual series to partial duration is also included in Appendix 3.

Since the period of record for all but one station was short by statistical standards, being anywhere from 10 to 27 years, a standard error was computed (Kite, 1977). Standard error of the partial duration series was computed for durations of 15-minutes where available, 30 minutes where available, and for the 1-hour, 3-hour, 6-hour, 12-hour, and 24-hour durations. Standard errors for the 24-hour, 48-hour, and 72-hour durations at Kosrae were computed. This represents the uncertainty in estimating the value of, for example, the 100-year 24-hour rainfall. Using the partial duration values as base values, there is a 68% probability that the true value will fall between the base value plus or minus one standard error. There is a 95% probability that the true value will fall between the base value plus or minus two standard errors. The values of standard error and how they were computed are described in Appendix 4.

Partial duration results for the Capitol Hill (914080) station are included in this report. However, the results are not used for the development of the 24-hour design rainfall distribution, as there are reservations about the results. The area around Capitol Hill has some of the highest average annual rainfall on the island of Saipan, yet the rainfall-frequency values derived from the 19 years of data are significantly lower than those derived for the Saipan International Airport (914855) and the next-closest station Rota (914801). Figure 3, below, shows the annual maximum 24-hour rainfall for the three stations as recorded for each year of record. There are 18 years where the period of record overlaps and the values may be compared.

Of the 18 years of overlap, measurements at the Capitol Hill station are lower than both Saipan IA and Rota for 10 of the years. For years where the record does not overlap, measurements at Saipan IA and Rota are generally higher. There are four years when the annual maximum value at Saipan IA is greater than the largest value at Capitol Hill. There are five years when the annual maximum value at Rota is greater than the largest value at Capitol Hill. The combination of these factors causes the rainfall-frequency results to be significantly higher at Saipan IA and Rota. Typhoon Steve in 1993 was recorded at Saipan IA (16.5 inches) but is missing from the records at Capitol Hill.

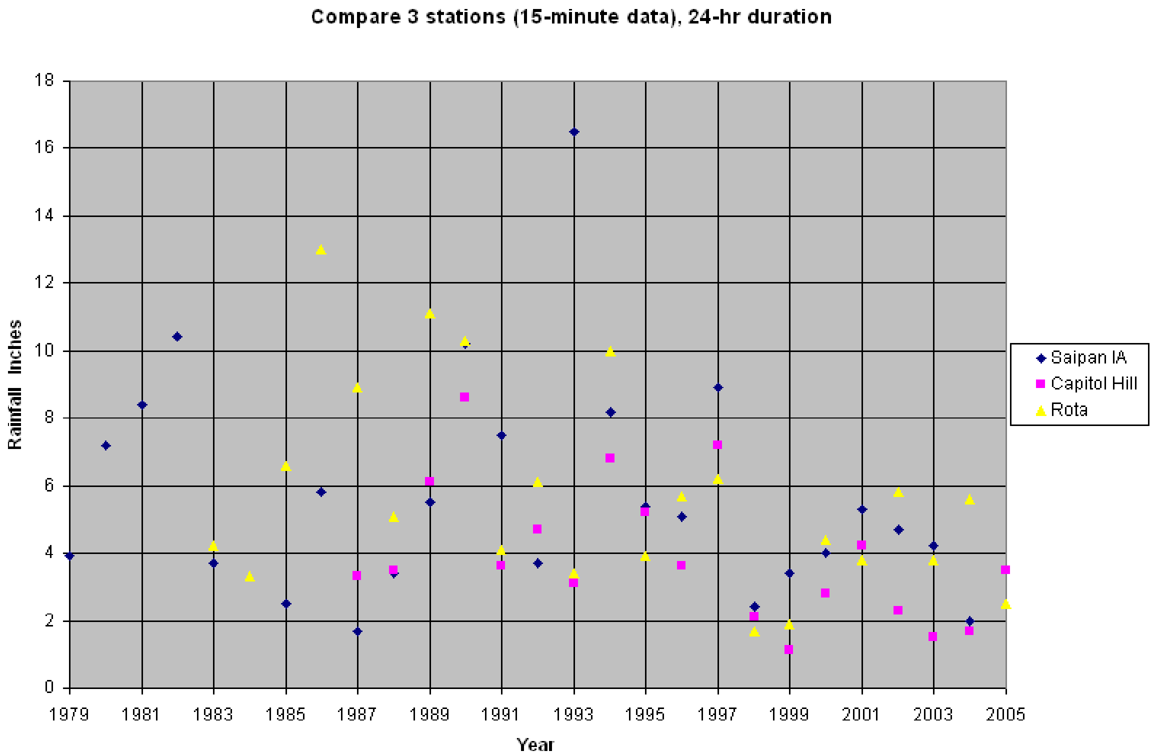

Figure 3. Annual maximum 24-hour rainfall measured at Saipan IA, Capitol Hill, and Rota.

Comparison of Rainfall –Frequency Results to those of previous reports

Rainfall-frequency values have been developed for several of the islands in previous reports. Barrett Consulting Group (1987) prepared a design standards report for the State of Kosrae. A probability plot of 24-hour rainfall was included for the islands of Yap, Chuuk, Pohnpei, and Guam. Annual maximum values were plotted according to plotting position. Table 2 below summarizes the comparison of results.

Table 2. Comparison of rainfall-frequency from Barrett (1987) to results of this report.

Return Period	Range of rainfall (Barrett, 1987)	Range of rainfall (this report)
2-year	5.5 to 6.5 inches	4.9 to 7.1 inches
5-year	6.9 to 8.6 inches	6.9 to 10 inches
10-year	8.8 to 10.5 inches	7.8 to 11.8 inches
25-year	11 to 14 inches	8.8 to 14.2 inches

The range of 24-hour values in Barrett (1987) is narrower than the results of this report, however the ranges overlap.

The U.S. Army Corps of Engineers (1980) completed a rainfall-frequency study including isohyetal maps for the island of Guam. The period of record for the 10 stations analyzed was generally from 1948-80. Nine stations were daily recording gages and only one of the 10 stations had any data on an hourly or less measurement interval.

Table 3. Comparison of US ACE (1980) and results of this report.

Return Period	Range of rainfall USACE (1980)	Range of rainfall (this report)
2-year 1-hour	1.0 to 2.5 inches	1.5 to 2.0 inches
5-year 1-hour	1.5 to 3.0	1.9 to 2.7
10-year 1-hour	2.0 to 3.5	2.2 to 3.1
50-year 1-hour	2.5 to 4.5	2.7 to 4.2
100-year 1-hour	2.5 to 5.5	3.0 to 4.7
2-year 6-hour	2.5 to 4.5 inches	3.1 to 3.8 inches
5-year 6-hour	3.0 to 5.5	4.2 to 5.3
10-year 6-hour	3.5 to 6.5	4.9 to 6.2
50-year 6-hour	5.0 to 10.0	6.5 to 8.3
100-year 6-hour	5.0 to 11.0	7.2 to 9.2
2-year 24-hour	4.0 to 8.0 inches	4.9 to 6.2 inches
5-year 24-hour	6.0 to 12.0	7.0 to 8.8
10-year 24-hour	7.0 to 14.0	8.3 to 10.6
50-year 24-hour	9.0 to 23.0	11.3 to 14.4
100-year 24-hour	12.0 to 26.0	12.6 to 16.0

The range of rainfall in US ACE (1980) is consistently larger than the range of rainfall in this report. However, the results of this report are included within the ranges of US ACE (1980) for all the return periods and durations in Table 3.

Recent research by Lander (2004) has indicated on Guam and Saipan that extreme rain events are not dependent upon elevation. Also, typhoons may cross the islands at virtually any location, thus indicating that the range of extreme rainfall events should be relatively uniform across the island.

The US ACE (1980) report includes frequency-intensity-duration curves for the Taguac NWS station in Guam. The comparison of US ACE (1980) and results of this report are included in Table 4, below.

Table 4. Comparison of rainfall frequency-intensity-duration results for Taguac, Guam.

Duration	Range of intensity USACE (1980)	Range of intensity (this report)
5-minutes	6.05 – 7.45 inches/hour	4.4 – 11.5 inches/hour
15-minutes	4.15 – 5.9	3.4 – 8.8
1-hour	2.25 – 3.85	1.8 – 4.7
24-hour	0.3 – 0.9	0.26 – 0.67

The range in Table 4 represents the 2-year through 100-year intensity. For the 5-minute, 15-minute, and 1-hour durations, the US ACE (1980) results fall within the range of the results of this report. In support of the higher short duration intensities estimated in this report, a recent study of short duration intensities was conducted by Guard (2008) of the National Weather Service. Based on 1-minute rainfall records for Guam, he found the range of 5-minute intensity to range from 5.4 to 11.4 inches/hour and the 15-minute intensity to range from 5.4 to 10.2 inches/hour. These bounds represent the range of the 2-year through 100-year return periods.

The Northern Islands Company (1989) prepared a Storm Water Control Handbook for the Northern Mariana Islands. The 24-hour 2-year to 100-year return period maps are included. Results are compared in Table 5, below.

Table 5. Comparison of 24-hour rainfall at Saipan International Airport.
* A more definitive value could not be read from the maps.

Return Period - years	24-hour rainfall, Storm Water Control Handbook (1989)	24-hour rainfall results from this report
2	4.4 inches	5.22 inches
5	7.1	8.13
10	8.0	10.06
25	10.0*	12.49
50	10.0*	14.3
100	10.0*	16.09

Isohyetal maps of Saipan for the 2-year to 100-year 24-hour rainfall were modeled after the average annual rainfall map of Saipan. There were distinct topographic effects. The values from this report included in Table 5 are near an average value for the whole island for each return period of the Storm Water Control Handbook (1989). It was already mentioned that extreme rain events are not dependent upon elevation in Saipan (Lander, 2004).

Lander (2004) includes a comparison of rainfall-frequency for the Saipan International Airport showing 5-year to 100-year return periods and 15-minute to 24-hour durations. The table includes estimates from the US Army Corps of Engineers (2003) and results of a study by the University of Guam. The 5-year and 10-year values are reasonably close to each other and to the results of this report. The Corps of Engineers values diverge with an increasing trend for the 25-year through 100-year compared to the results of this report. However, the Corps of Engineers 16.8 inches for the 100-year 24-hour is not much larger than the 16.1 inches in this report. The University of Guam results diverged in a greatly increasing trend for the 25-year to 100-year with an estimated 100-year 24-hour rainfall of 26.4 inches. The larger values are due to analyzing the rainfall frequency data as a mixed distribution. This treats the rainfall-frequency curve as two parts with the lower return periods (10-year and below) as one line segment and the return periods higher than 10-years as another line segment. For this report, the annual maximum data were treated as a single distribution which is explained more in the Assumptions and Limitations section of this report. The National Weather Service rainfall records include the 16.5 inch 24-hour rainfall from Typhoon Steve in 1993. Two other 24-hour totals of more than 10 inches were also included. The annual maximum values were analyzed as a single distribution due partially to the difficulty of assigning probabilities to the extreme rainfall events. For example, the 16.5 inch rainfall was the largest within the 25 years of available data. Without more years of data, it cannot be judged with a high degree of confidence what probability to assign to Typhoon Steve. Plots of the annual maximum data versus probability are included in Appendix 7.

The final comparison of results with a past study concerns that of Guard (2008). Guard analyzed 1-minute rainfall measurements and developed tables for 1-minute to 15-minute durations and 2-year to 100-year return periods for the island of Guam. Large storms were divided into two categories: Typhoon Eye-Wall and all other storms (including thunderstorms). The eye of the typhoon is at the center and the eye-wall, around the circumference of the eye, has the highest wind speeds and highest rainfall intensity. All other storms (including thunderstorms) occur throughout the year. The point of overlap between this report and the study of Guard is the determination of 15-minute rainfall-frequency. Results of Guard showed a 15-minute rainfall of 1.35 inches for the 2-year event for both storm types. The 100-year 15-minute rainfall for the Typhoon Eye-Wall and all other storms (including thunderstorms) are 2.4 and 2.35 inches respectively. Three 15-minute rainfall gages on Guam were analyzed in this report and the range of 15-minute rainfall was from 0.74 (2-year) to 2.32 inches (100-year). The 100-year comparison is reasonable but the 2-year rainfalls are lower in this report. Different data sources and periods of record were used as well as different measurement interval periods. There could be complications in measurement accuracy and equipment operation/failure that could make these two datasets incompatible. There is a possibility that the maximum 15-minute rainfall overlaps two adjacent 15-minute periods such that the maximum 15-minute rainfall for a particular year is underestimated. Since the three rain gages on Guam had 26 or 27 years of 15-minute measurements, a reasonable amount of confidence can be placed in the statistical analysis by the L-Moment procedures. In the Recommendations for Further Research section of this report, more study of 1-minute rainfall data is recommended.

As a summary of these comparisons with prior studies, it may be concluded that these prior studies have been limited in geographic extent, often limited in available data, and have not included the scope or type of results provided in this report. There are studies for some of the islands but no consistent study of all the islands which are included in this report. Therefore, values included in this report should supersede these previous studies.

Design Rainfall Distribution Analysis

To begin the rainfall distribution analysis, the partial duration values were used to develop ratios of shorter durations to the 24-hour rainfall. For example, the ratios of

15-minute to 24-hour, 30-minute to 24-hour, 1-hour to 24-hour, etc were calculated for all stations. Eight stations included 15-minute to 24-hour data and seven stations included data from 1-hour to 24-hours.

The purpose of the design rainfall distribution is to provide the maximum rainfall intensity for all durations from 6 minutes (0.1 hour) to 24 hours. Earlier, it was stated that frequency of rainfall is assumed to be equal to frequency of peak discharge. In order to insure this assumption for small watersheds with a range of response times (Tc), the design rainfall distribution is constructed so that the most intense part of the distribution is contained in the next most intense part of the distribution. The placement of the most intense part of the 24-hour storm controls to some extent the peak discharge estimated from the watershed. The later the intense part is, the higher the estimated peak discharge. Having the most intense part centered at 12 hours is a balance between front and back end loaded storms. For example, the most intense hour of the distribution is from 11.5 to 12.5 hours of the 24-hour distribution. The most intense 3-hours of the distribution are from 10.5 to 13.5 hours. The most intense 6-hours are from 9.0 to 15.0 hours. This concept is used to build the distribution from the most intense part at 12.0 hours outward towards 24 hours. In the historical development of the standard NRCS design rainfall distributions, the few rain gages with measurements at 5-minutes to 15-minutes were used to construct a rainfall distribution. A region with similar ratios of shorter duration to the 24-hour rainfall was identified. The concept that non-dimensional ratios are similar across larger regions was a reasonable assumption and a single distribution could be developed.

Design Rainfall Distribution Results

A design rainfall distribution was developed for all return periods from 1-year to 500-year at each of 15 stations. Capitol Hill was not included (see discussion on page 9). A distribution for Kosrae was not possible because data were not available for durations less than 24 hours. Rainfall distribution plots for each rain gage are included in Appendix 5. Ratios of shorter durations to the 24-hour duration were used to develop the two design rainfall distributions are included in Table 6-3 of Appendix 6.

Development of standard design rainfall distributions was partly driven by need to develop graphical procedures to estimate peak discharge (SCS, 1973). With the general availability of high-speed computers, there is much more flexibility. At one extreme, standard design rainfall distributions may be eliminated in favor of a custom-made distribution at a specific location based on the rainfall-frequency data, such as 15-minute to 24-hour rainfall values for return periods of 1 year to 500 years. Each return period could have its own distribution recognizing that a 1-year storm has a different duration versus intensity relationship than a 500-year storm. On the other hand, developing a distribution or set of distributions for each station assumes the intensity-duration relationship is relatively accurate at each station. This may not be the case, as the periods of record are rather short. Developing an average distribution which represents a group of stations could smooth out stations where the results of statistical analysis may not represent the natural rainfall pattern.

The first attempt was to develop a single distribution based on the average of 15 stations. The second attempt was to separate the two stations on Tutuila, American Samoa from the 13 stations north of the equator. Rainfall distributions for Tutuila were significantly different from those at stations north of the equator. For this reason, one distribution was developed for islands north of the equator and one developed for the American Samoa Island of Tutuila. They were developed by averaging the ratios at the durations of 5, 10, 15, 30, and 60-minutes, 2, 3, 6, and 12 hours.

Since maximum 5-minute data were available for 13 years at Majuro, these data were used to determine ratios for the 5-minute and 10-minute durations which were used in both the Northern Pacific and American Samoa design rainfall distributions. The L-Moment procedure was used to derive the Gumbel moments and an annual series rainfall-frequency relation was computed for the available durations at Majuro (5, 10, 15, 30 minute, and 1, 2, 3, and 24 hours). The 1-year through 500-year partial duration values were then computed. The ratio of 15-minute to 10-minute and ratio of 10-minute to 5-minute rainfall were computed and compared to Guard (2008). For Guam, Guard derived two sets of ratios, one for Typhoon Eye-Wall and the other for all other storms (including thunderstorms).

Table 6. Comparison of short duration rainfalls of Guard (2008) to those of this report.

Ratio	10-minute / 5-minute	15-minute / 10-minute
Majuro ratios	1.68	1.36
Guard, Typhoon	2	1.5
Guard, All other storms	1.75 – 1.8	1.4

The ratios for Majuro are somewhat less than those of Guard. The data at Majuro was not divided into the two storm types. The ratios for Majuro were used to estimate the 5-minute and 10-minute rainfall for the 8 stations with 15-minute data (Capitol Hill, CNMI was excluded). The remaining duration used to develop the design rainfall distributions was the 2-hour. The 2-hour duration was interpolated between the 1-hour and 3-hour duration values based on log-log interpolation.

Data for four significant storms have been analyzed with respect to distribution of the rainfall during the storm. These are Typhoon Chaba (Rota Resort & Country Club, 8/22/2004), Typhoon Paka (Talofofo Golf Course, Guam, 12/16/1997), Typhoon Chata'an (Mt. Jumullong, Guam, 7/5/2002), and the storm of January 28, 1961 in Majuro. Time series plots for Typhoons Chaba and Paka are shown in Figures 4 and 5 below. These were derived based on information from Lander (2008).

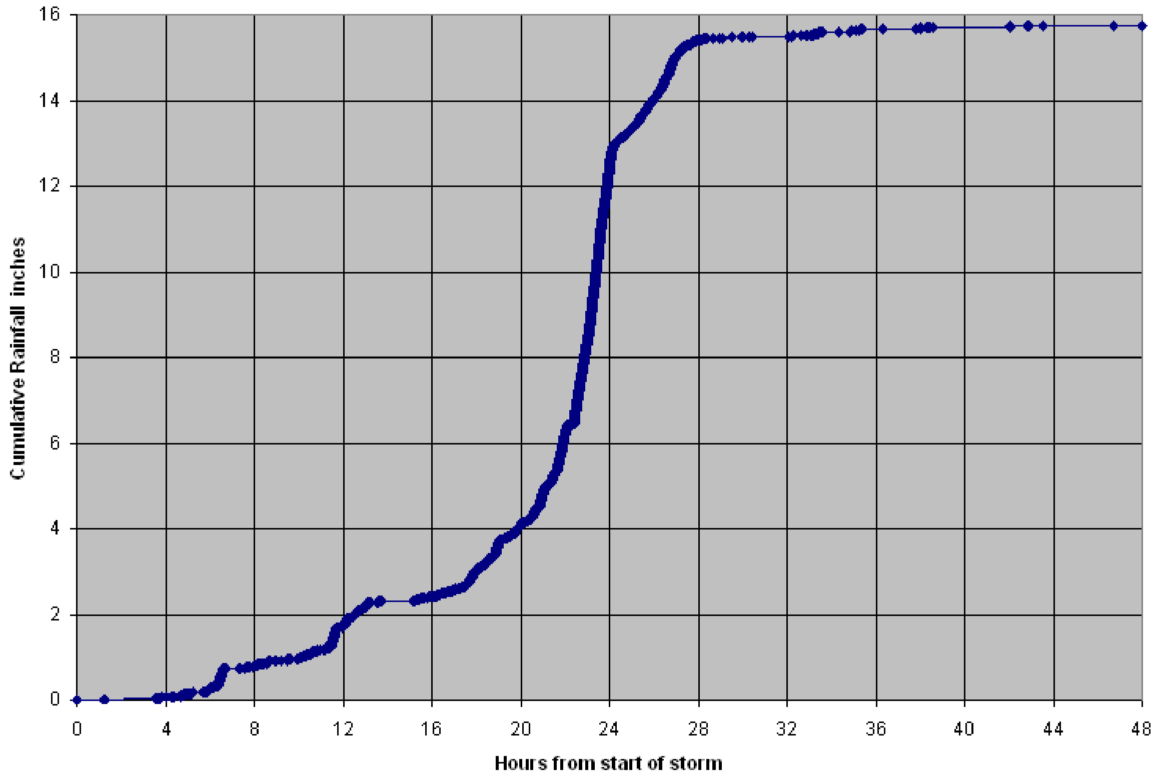

Figure 4. Typhoon Chaba (Rota Resort & Country Club, 8/22/2004)

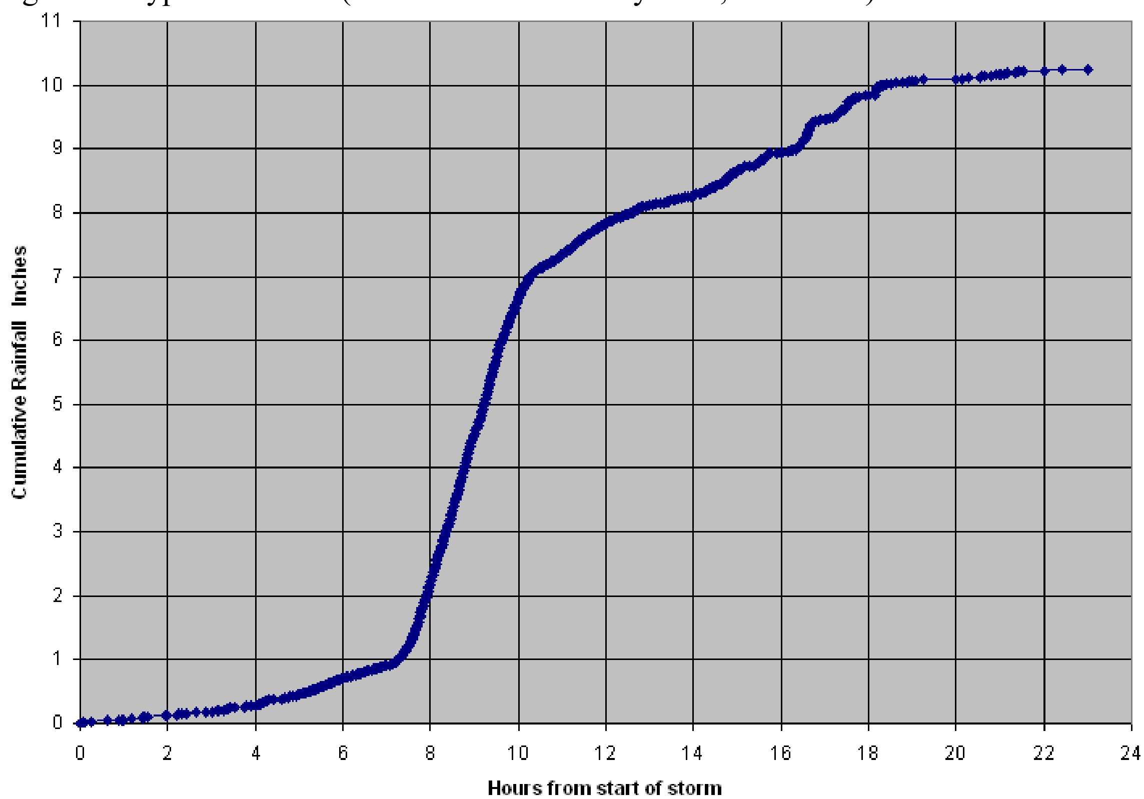

Figure 5. Typhoon Paka (Talofofo Golf Course, Guam, 12/16/1997)

For the purposes of developing a design rainfall distribution, the most important information derived from these actual rainfall distributions is the maximum rainfall for a range of durations and the ratio of these rainfalls to the total storm rainfall. This information is contained in Tables 7 and 8, below. Data for Typhoon Chata'an were taken from USGS (2002). Data for Majuro were taken from U. S. Department of Commerce (1971).

Table 7. Maximum rainfall (inches) for durations of 5-minutes to 24-hours. (* denotes storm total, not necessarily the 24-hour amount). N/A: not available.

Name/Date	Place	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Chaba	Rota	0.48	0.94	1.31	2.43	4.32	7.49	9.08	11.5	14.07	16.5
Paka	Guam	0.23	0.46	0.67	1.25	2.41	4.6	6	7.21	9.23	10.24
Chata'an	Guam	N/A	N/A	N/A	N/A	5.9	N/A	10.8	13.7	N/A	19.6*
1/28/1961	Majuro	0.27	0.51	0.7	1.22	2.18	3.98	5.41	N/A	N/A	9.57

Table 8. Rainfall ratios for four typhoons compared to three design rainfall distributions. N/A: not available.

Name/Date	Place	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Chaba	Rota	0.03	0.06	0.08	0.15	0.26	0.45	0.55	0.70	0.85	1.0
Paka	Guam	0.02	0.05	0.07	0.12	0.24	0.45	0.59	0.70	0.90	1.0
Chata'an	Guam	N/A	N/A	N/A	N/A	0.30	N/A	0.55	0.70	N/A	1.0
1/28/1961	Majuro	0.03	0.05	0.07	0.13	0.23	0.42	0.57	N/A	N/A	1.0
Northern Pacific		0.06	0.10	0.14	0.21	0.30	0.41	0.49	0.63	0.82	1.0
American Samoa		0.07	0.12	0.17	0.23	0.33	0.45	0.54	0.67	0.81	1.0
Type I		0.06	0.11	0.14	0.23	0.28	0.37	0.43	0.57	0.76	1.0

The ratios for 5-minutes to 12-hours are reasonably similar for the four storms. However, large short duration rainfalls most often occur in thunderstorms. For example, Typhoon Chaba had a 24-hour rainfall of approximately 100-year return period. However, the maximum 15-minute rainfall is only equivalent to a 10-year return period. Instead of developing peak discharges for several different rainfall distributions, a single maximized rainfall distribution may be used which includes the maximum rainfall for all durations. This is why the duration ratios less than 2 hours are higher for the Northern Pacific and American Samoa distributions developed for this report. The opposite trend is evident for durations of 3-hours to 12-hours; the typhoons have larger ratios than the Northern Pacific and American Samoa design distributions. The design rainfall distributions were based on the ratios of the 3-hour /24-hour, 6-hour / 24-hour, and 12-hour / 24-hour for each return period such as 100-year. This emphasizes the fundamental difference between actual storms and design storms.

Using rainfall-frequency and rainfall distribution with EFH-2

Engineering Field Handbook Chapter 2 (EFH-2) was originally a hand computation method involving use of charts, graphs, and tables to estimate peak discharge and volume of runoff for design of engineering practices on small watersheds. The procedure is now automated in the EFH-2 computer program. EFH-2 accepts rainfall distribution tables other than the four standard NRCS storm types Type I, Type IA, Type II, and Type III. Tables for the Northern Pacific distribution (N_PAC) and American Samoa (AM_SAM) which operate with EFH-2 have been prepared. The file named **type.rf** is available with this report and should be copied into the directory **Program Files\USDA\EFH2**. A database for the Pacific Islands now has 24-hour duration rainfall for 1-year to 100-year return periods, extracted from Appendix 3, for 16 stations studied in this report (Capitol Hill not included). The file named **COUNTY.PB** should be copied into the directory **Program Files\USDA\EFH2**. Upon opening EFH-2, the user need only select the location, design rainfall distribution, enter the watershed data (drainage area, curve number, watershed slope, and watershed length), and then execute the program. Figures 6, 7, and 8 illustrate the process.

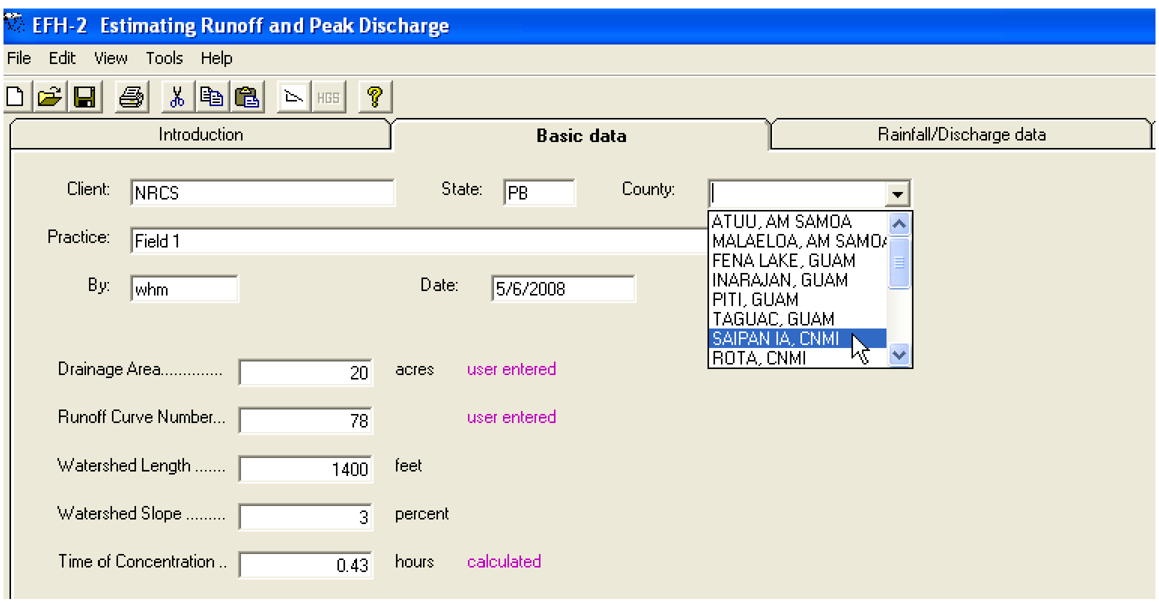

Figure 6. "Basic data tab" window for EFH-2.

The user enters the "State" as **PB** (Pacific Basin). The "County" pull-down menu has the list of 16 locations. For this example, **Saipan IA, CNMI** (Saipan International Airport) is selected. The user then needs to enter the remaining data such as drainage area, Runoff Curve Number, etc.

Procedures to derive watershed data such as Runoff Curve Number, Watershed Length, etc are contained in TP-149 (SCS, 1973) or from Engineering Field Handbook Chapter 2 (NRCS, 2003). The next step is to select the tab "Rainfall/Discharge data".

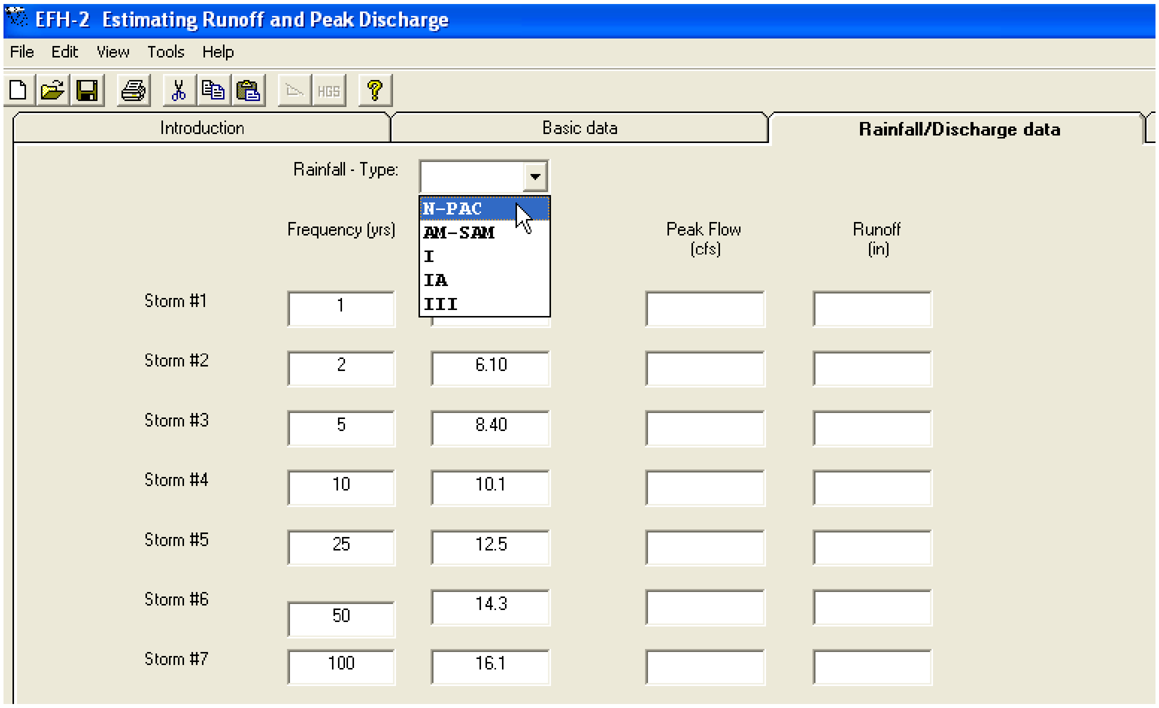

Figure 7. “Rainfall/Discharge data tab” window for EFH-2.

The only remaining selection is the “Rainfall – Type” from the pull-down list. Two of the options are **N-PAC** (Northern Pacific) and **AM-SAM** (American Samoa). After selecting a “Rainfall – Type:”, the Peak Flow (cfs) and Runoff (inches) are displayed as shown in Figure 8, below. The data and results may be saved in a file and/or printed.

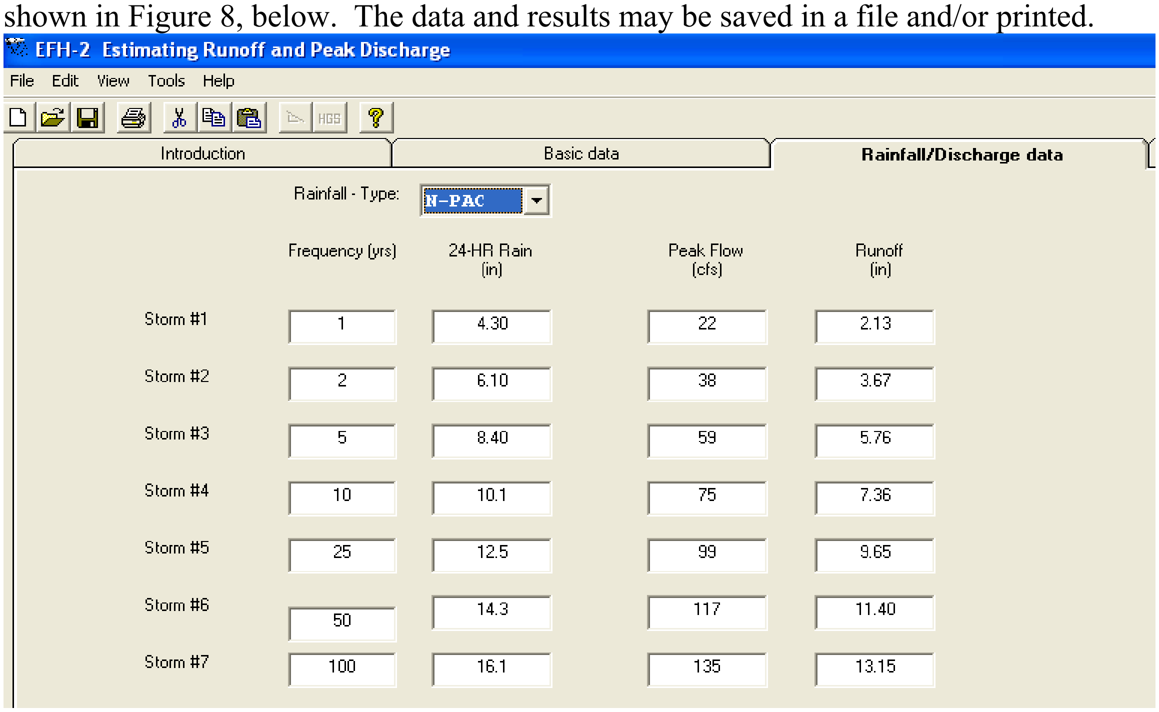

Figure 8. Peak discharge and runoff volume results for EFH-2.

Using rainfall-frequency and rainfall distribution with WinTR-55

WinTR-55 is a storm event hydrologic model used to estimate peak discharge and volume of runoff for small watersheds with more capabilities than EFH-2. The principal advantage is to be able to analyze a complex watershed by dividing the watershed into sub-areas. Rainfall amount and time distribution are inputs to the model. Other input includes drainage area, time of concentration (Tc), and runoff curve number (CN). Reach lengths and cross section rating tables are required if the watershed is divided into sub-areas and reaches. WinTR-55 is somewhat simpler than WinTR-20 in that the user interface is more user-friendly. There are several operational limitations as well such as no added or diverted water and uniform rainfall is assumed over the entire watershed.

When WinTR-55 is installed, 24-hour rainfall-frequency tables are included in a file named **NRCS_Storm_Data.** This file is installed in the directory Documents and Settings\All Users\Application Data\USDA\Shared Engineering Data\. Whenever WinTR-55 is opened, these rainfall data tables may be used for any project. The WinTR-55 rainfall database includes 16 stations in this report. They may be selected easily by the user.

The WinTR-55 rainfall distribution files are named **North_Pac.tbl** and **Am_Samoa.tbl**. These two rainfall distribution files should be copied into a directory similar to the one shown in Figure 9, below.

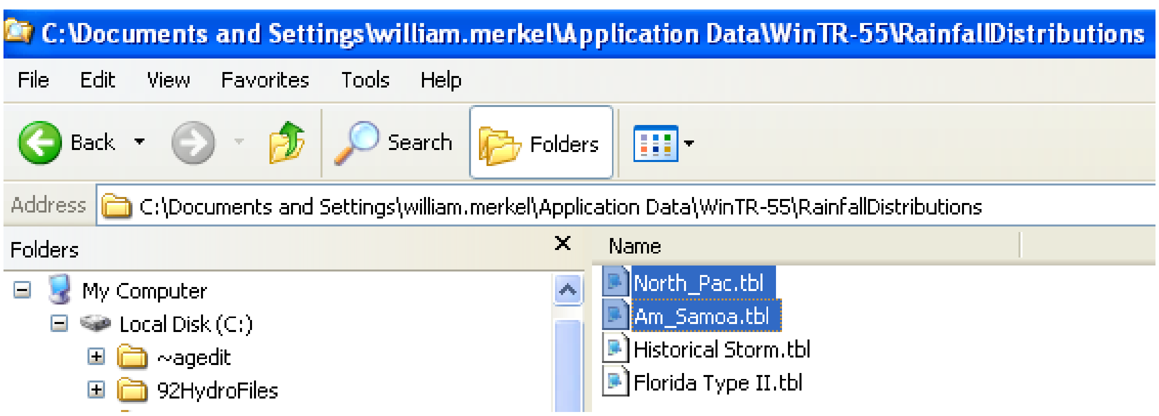

Figure 9. Directory where WinTR-55 rainfall distribution tables are saved.

The steps of opening and starting an application in WinTR-55 are included next.

Open WinTR-55. Figure 10 below shows the blank main input window.

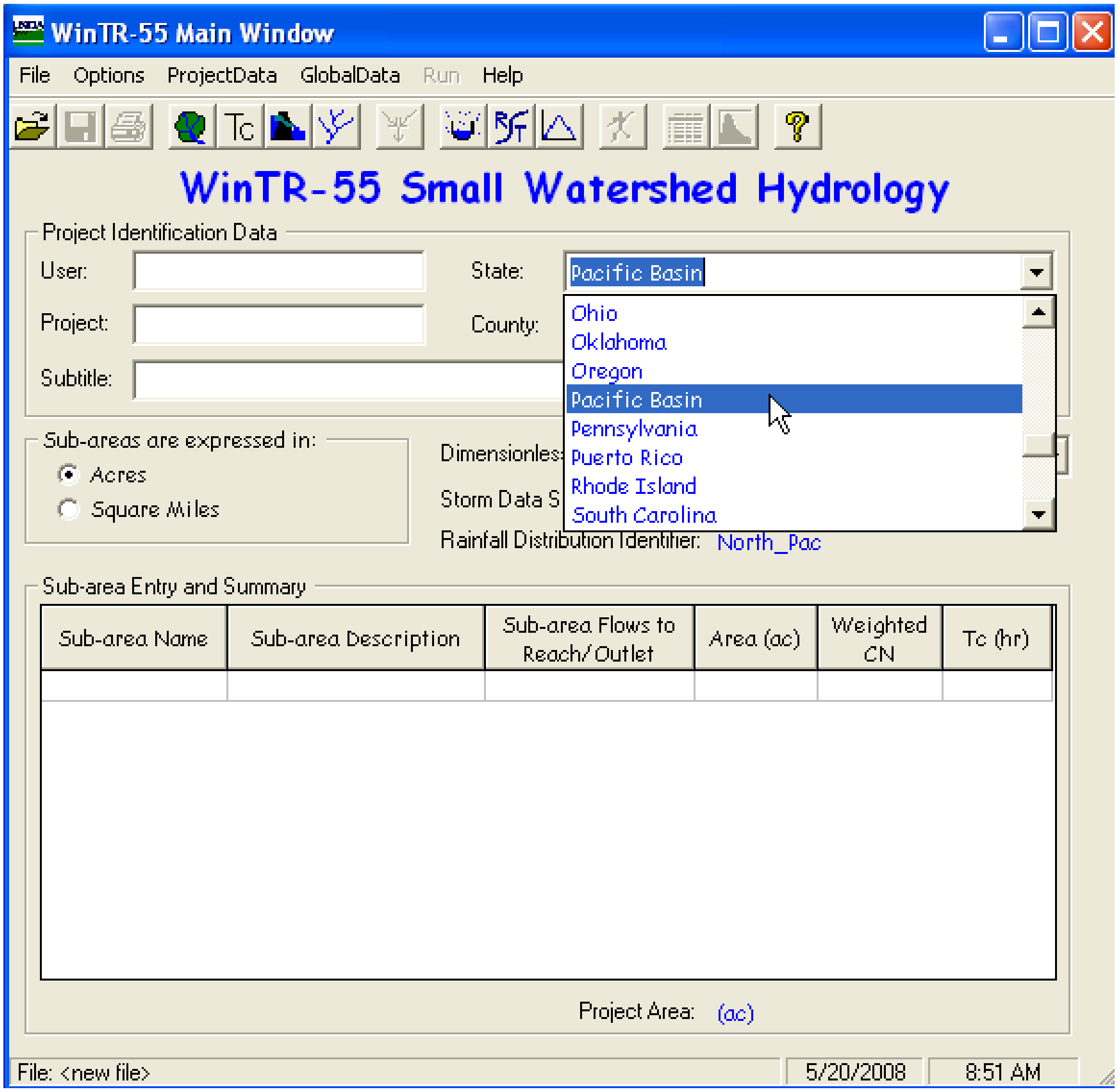

Figure 10. WinTR-55 main input window with “State” selected.

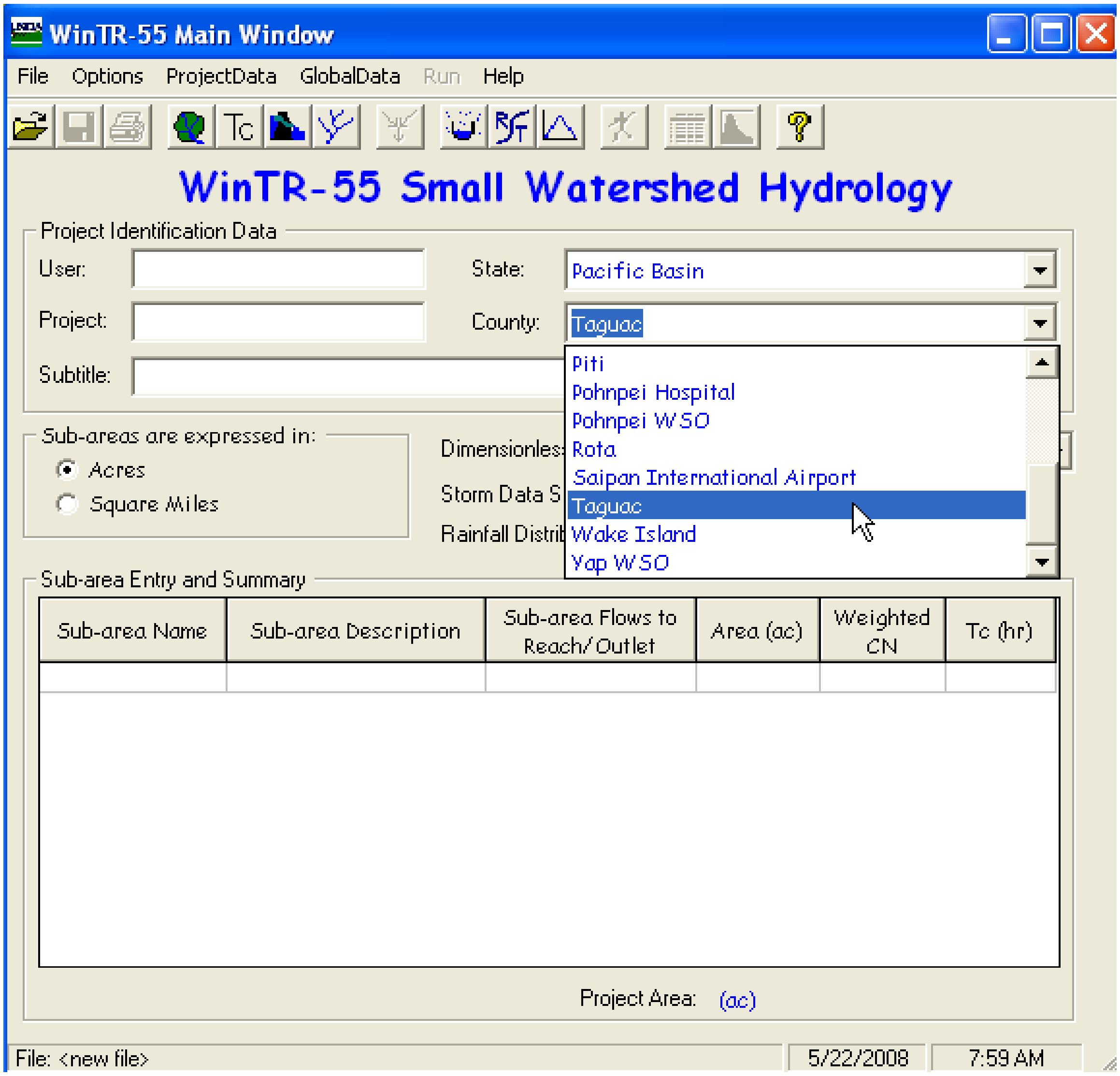

Figure 11. WinTR-55 main input window with "County" selected.

Select "County" as the rainfall station, Taguac, Guam in this example.

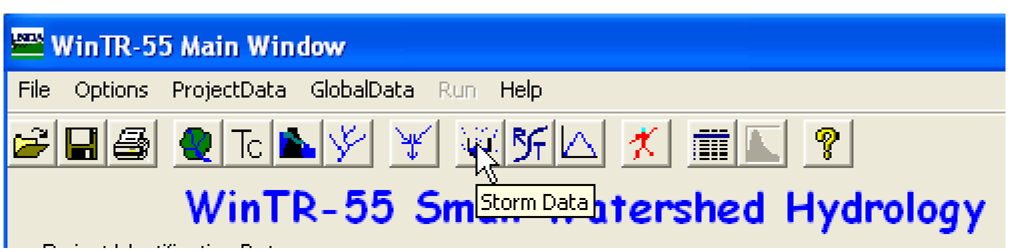

Figure 12. WinTR-55 Storm Data icon.

Select the Storm Data icon in the top menu bar.

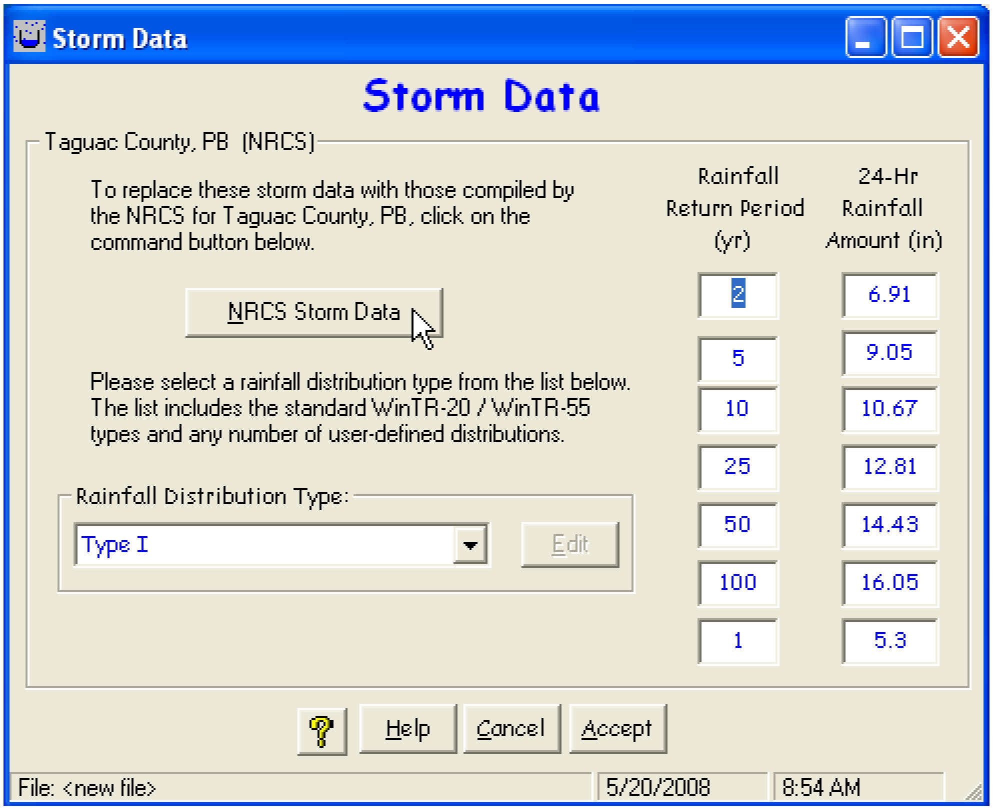

Figure 13. WinTR-55 Storm Data window.

Click the **NRCS Storm Data** button. The rainfall data (return periods and 24-hour amounts) for Taguac will then be brought into the window. The **Rainfall Distribution Type** appears as **Type I**, which represents the standard Type I rainfall distribution.

WinTR-55 carries over the rainfall data and rainfall distribution from the previous application. Update the location and/or rainfall distribution if they are different from the previous application of WinTR-55.

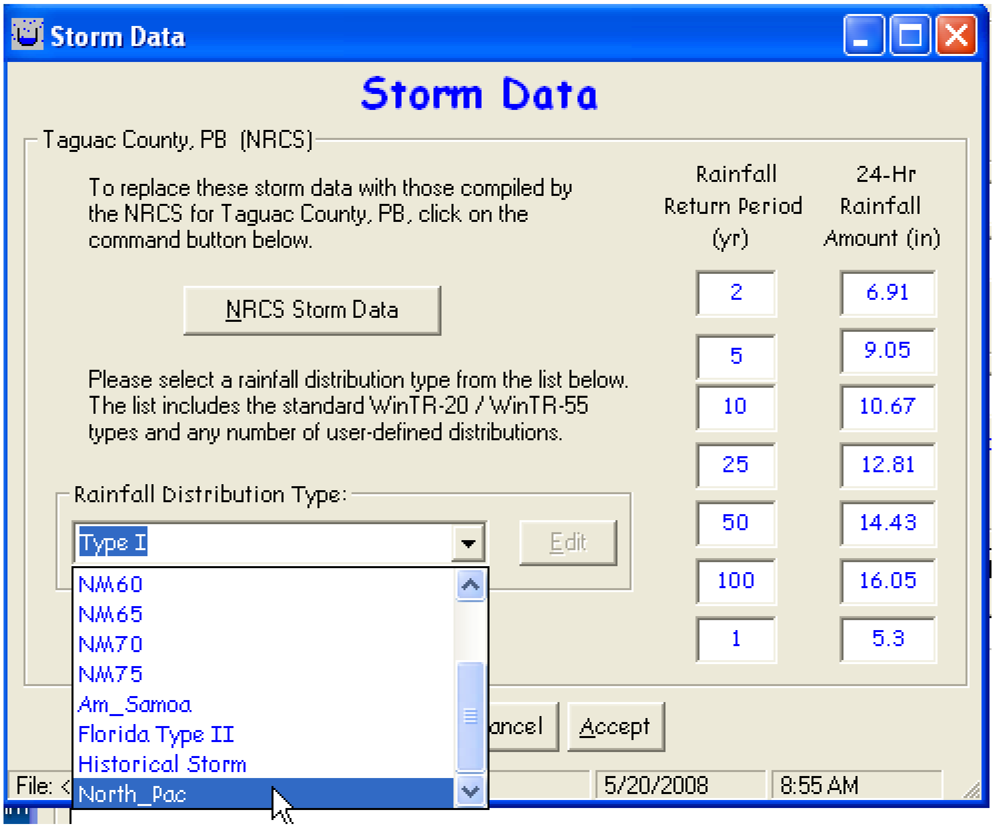

Figure 14. WinTR-55 Storm Data window and select Rainfall Distribution Type.

Use the pull-down list to select either **North_Pac** or **Am_Sam** (depending which rainfall station has been selected). For Taguac, select **North_Pac** distribution.

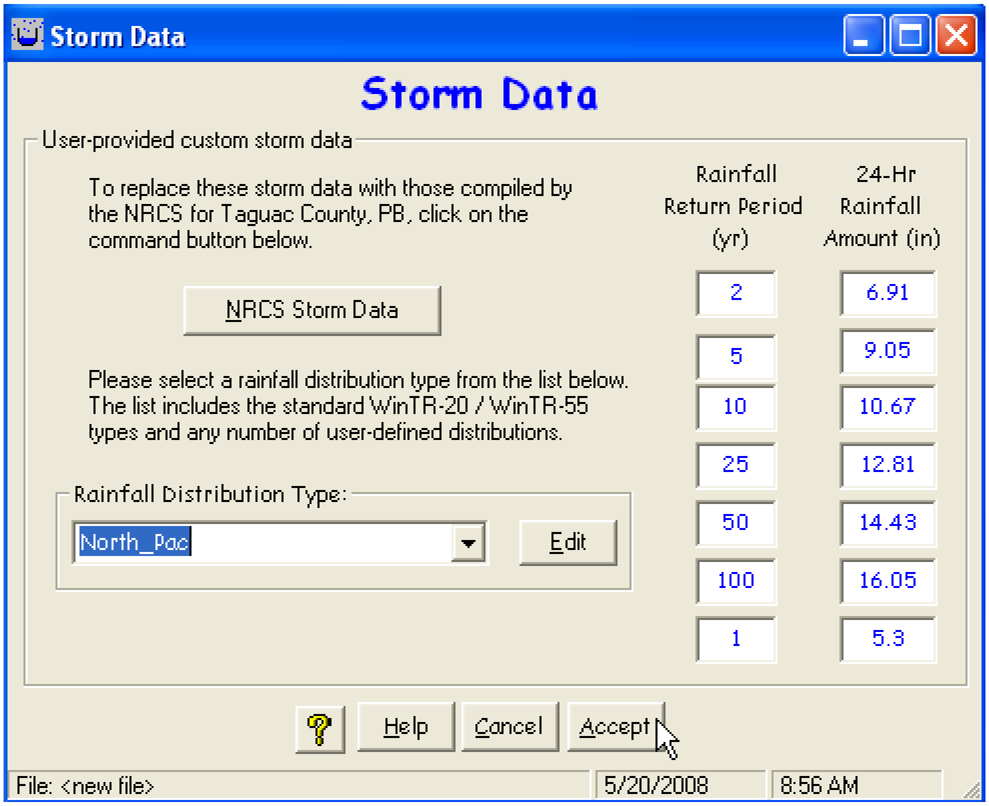

Figure 15. Completed WinTR-55 Storm Data window.

Click the **Accept** button to return to the main input window.

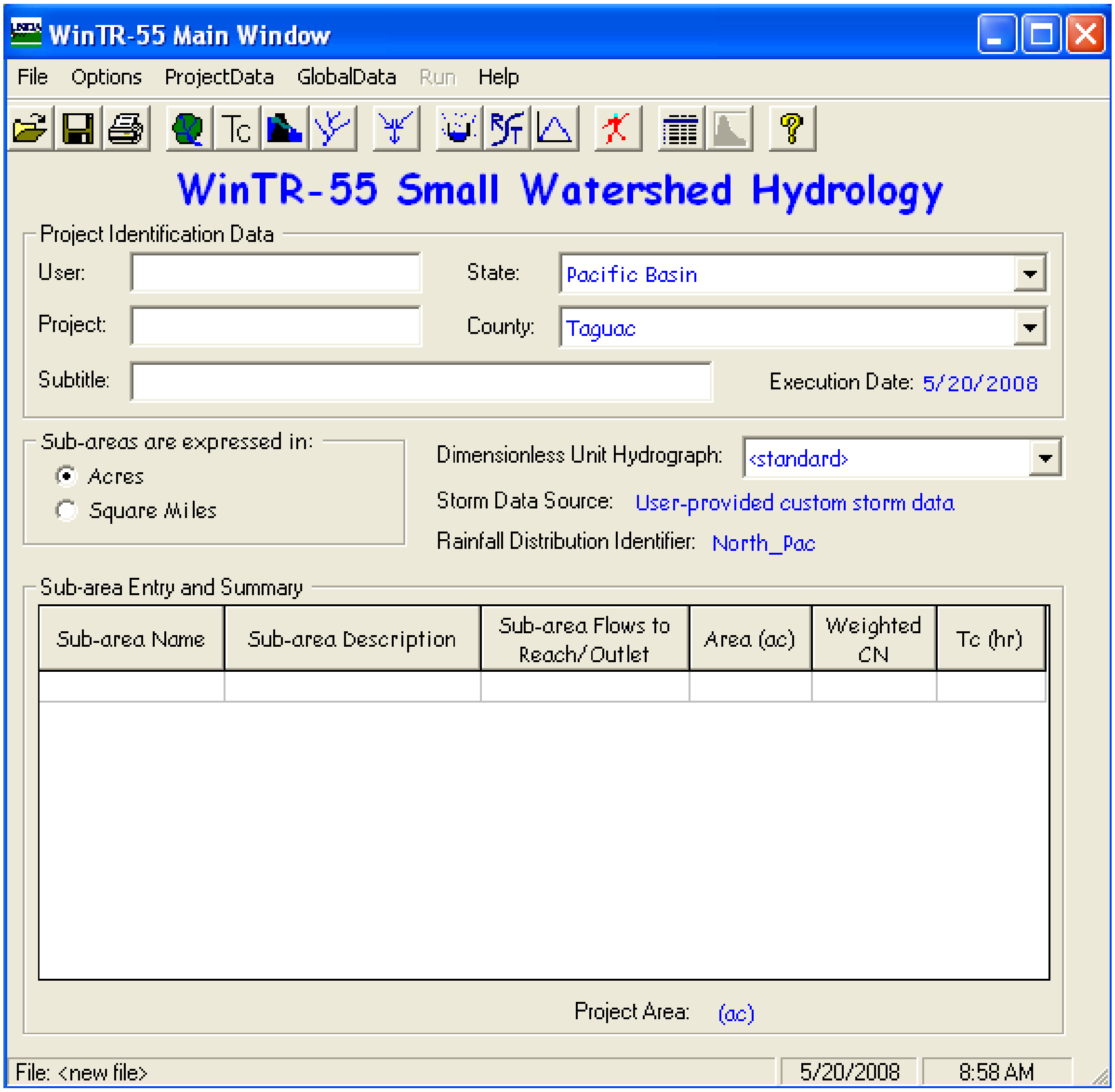

Figure 16. WinTR-55 main input window with completed rainfall data.

Enter a project description and the remaining watershed data such as sub-area name, drainage area, curve number, time of concentration, etc. Save the file and execute WinTR-55. WinTR-55 has a detailed user guide, examples, and training material available.

Note: A version of WinTR-55 is being developed which will include the Northern Pacific and American Samoa distributions as standard selectable rainfall distributions instead of being treated as historical or custom rainfall distributions. The revised rainfall database will include the rainfall distribution type as either North_Pac or Am_Sam which will be automatically entered instead of having to select the rainfall distribution from the storm data pull-down list. This will simplify the application of WinTR-55 in the Pacific Area.

When completed, the revised WinTR-55 will be posted on a web site (see **Downloading NRCS software over the Internet**, below**).**

Using rainfall-frequency and rainfall distribution with WinTR-20

WinTR-20 is a storm event hydrologic model used to estimate peak discharge and volume of runoff for small watersheds. It will perform a hydrologic analysis for watersheds ranging from simple to complex characteristics. Rainfall amount and time distribution are inputs to the model. Other input includes drainage area, time of concentration (Tc), and runoff curve number (CN). Reach lengths and cross section rating tables are required if the watershed is divided into sub-areas. Rating tables which include elevation, discharge, and storage for ponds or lakes must be entered in order to complete a flood routing.

Appendix 6 includes rainfall distribution tables developed through this study.

Sample WinTR-20 input files which may be used to start a hydrologic analysis on any of the islands are included in the distribution package for this report. The input files contain rainfall amounts and rainfall distributions. These files are named **WinTR20_sample_input_North_Pacific.inp** and **WinTR20_sample_input_Am_Samoa.inp**. To use these files for a certain project, copy the appropriate file, rename the file, open WinTR-20, and select "open existing file". Browse and select the file just copied and renamed. The input file will contain data for Storm Analysis and Rainfall Tables.

The user needs to enter the 24-hour rainfall amounts and add data for the watershed such as drainage area, CN, Tc, reach, and cross sections (if any) before running the software.

Note: A version of WinTR-20 is being developed which will include the Northern Pacific and American Samoa distributions as standard rainfall distributions instead of being treated as user input distributions. The user will be able to select the North_Pac or Am_Sam rainfall distribution from the rainfall distribution pull-down list. This will simplify the application of WinTR-20 in the Pacific Area. When completed, it will be posted on a web site (see **Downloading NRCS software over the Internet**, below**).**

Downloading NRCS software over the Internet

EFH-2, WinTR-55, and WinTR-20 are several of the NRCS software products which may be downloaded from the Internet. The web site for those individuals outside the NRCS is:

http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/tool_mod.html

Employees of NRCS may request the software be installed by Information Technology staff.

Assumptions and Limitations

Rainfall events are caused by several categories of storm including tropical cyclones and thunderstorms. In a report of Lander (2004), study of the gage at Saipan International Airport, using a relatively long period of record, revealed what appears to be a mixed distribution. Smaller more frequent storms generated smaller rainfalls whereas large rainfall amounts were generated by less frequent tropical cyclones.

Rainfall from Typhoon Chata'an of July 5, 2002 and Typhoon Pongsona of December 8, 2002 were not included in the record of three Guam rain gages used in this report: Fena Lake, Inarajan, and Piti. The period of record used for Taguac (1984-99) did not include the year 2002. The US Geological Survey (2002) reported rainfall totals for Chata'an at 5 locations on Guam. Values ranged from 13.8 to 21.4 inches. Significant rainfalls for one, three, and six hour durations were also reported. Lander (2004) reports twenty-four hour total rainfall for Pongsona ranging from 4 to 23 inches. Since these typhoons and possibly others, were not included for Guam and the other islands, rainfall for large storms (greater than a 10-year return period) may be higher than results of this report. Statistical analysis, often used in the engineering profession, attempts to derive useful information from a series of measurements, in this case rainfall. It does not attempt to understand the physical laws of the situation which in this case are extremely complex, random in both location and date of occurrence, and possibly changing over time. Statistical analysis attempts to represent a large population of storm events with a sample consisting of a relatively short period of record.

Data were analyzed in this study as if they were from a single population as there are not enough years of data to analyze separate populations. Plots of the original annual series based on the Weibull plotting position versus rainfall were generated. The Gumbel annual series frequency distribution was also plotted. Plots for the 1-hour, 6-hour, and 24-hour rainfall at each of 16 stations were generated and the 24-hour, 48-hour, and 72-hour plots were generated for Kosrae. A total of 51 plots are included in Appendix 7. Of these 51 plots, eight showed a strong indication there could be a mixed distribution. Twelve plots showed a moderate indication towards a mixed distribution and the remaining 31 showed a weak indication for a mixed distribution. The criteria used to lead to this conclusion was that if the large storm event rainfall values were more than 2 standard errors above the Gumbel value, it was considered a strong indication of a mixed distribution. If the large storm event rainfall values were between 1 and 2 standard errors above the Gumbel value, it was considered a moderate indication. If the large storm event rainfall values were between plus and minus 1 standard error of the Gumbel value, it was considered a weak indication. Even if there were mixed distributions, there is not enough data to analyze them as such. Also, consistent records of tropical storms were not available. Certain islands have good records of these large storms and other islands do not.

The 5/10 and 10/15 minute ratios for Majuro were used in development of both design rainfall distributions. Since 15 minute rainfall data were the shortest duration available at 8 stations, the ratios in Table 6 were used to estimate these shorter durations.

Recommendations for further research

More analysis of rainfall gages with daily records should be completed. It might be sufficient to accept the rainfall distribution developed based on 15-minute and hourly gages and use it on islands where there are only daily gage records. The 24-hour rainfall at return periods of 1-year to 500-years would be all that is needed on those islands. In some cases, the daily recording gages have a much longer period of record than the 15-minute or hourly recording gages. Analysis of the longer daily records could provide a better estimate of the 24-hour rainfall-frequency than that derived from the 15-minute or hourly recording gages.

More rainfall gages on the larger islands of Guam, Saipan, Pohnpei, Palau, and Kosrae should be analyzed to develop isohyetal maps showing the variation of rainfall across the island. There could be orographic, typical storm path, or prevailing wind impacts on the rainfall for various return periods. Effects of large scale storms such as monsoons and typhoons on the rainfall magnitude and rainfall distribution should be analyzed. A mixed population statistical analysis could improve both the definition of frequent storm and infrequent storm amounts for design purposes.

If there are more 5-minute or 10-minute data, it would be useful to compute ratios of these shorter durations to the 15-minute or 60-minute rainfall. It would refine the rainfall distribution for these shorter durations. In a future update to this rainfall-frequency study, include older hard-copy rainfall records to maximize the years of record. There are additional rainfall records that have not been added to the National Climatic Data Center (NCDC) computer databases. Additional climatological records for 5-minute measurements are available for several stations from 1982-87 and hourly measurements from 1968-87. More and more 1-minute rainfall data are being collected, especially on Guam. As more years are collected, better definition of short duration rainfall intensities and rainfall distributions will be possible.

Hydrologic response to extreme rainfall should be analyzed by utilizing stream gage data where available. This would improve application of hydrologic modeling for stormwater management and flood plain management. Whereas, rainfall magnitude and distribution are essential inputs to a hydrologic model, watershed characteristics are equally important to quantify. Some of these are time of concentration, runoff curve number, and dimensionless unit hydrograph. By analyzing rainfall and runoff data, better estimates of the watershed characteristics can be obtained. These may then be used to improve estimates of physical characteristics of ungaged watersheds.

Summary and Conclusions

Rainfall-frequency and rainfall distributions were analyzed at 17 locations in the Pacific Islands. Annual and partial duration rainfall-frequency values were developed for durations of 15 minutes to 72 hours and from the 1-year to 500-year return periods.

Since periods of record for the stations were fairly short, 10 to 27 years with only one station with 48 years, extending the frequency curve to events as large as the 100-year and 500-year events is rather tenuous. However, with those short records, good estimates of the 1-year to 25-year storms are reasonable. These are storms generally used for design of soil conservation practices and stormwater management projects. For hydrologic analysis of large events or significant projects, sensitivity study using the plus and minus standard error values for these rainfalls could provide an upper or lower limit to impacts of those extreme rainfall amounts.

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Appendix 1 Annual Maximum Series Rainfall Data

The results in Table 1-1 (A through R) were extracted from National Weather Service rainfall records. Rainfall data are in units of inches. Durations in the tables range from 15-minutes (15m) to 72 hours (72h). Some of the stations have missing years in the following table. These years are omitted due to missing data records evidenced by very low annual maximum values or possible measurement and/or reporting errors with very high values or inconsistent values when comparing annual maximum values for all durations in a given year.

Table 1-1A. Annual maximum series rainfall data for Fena Lake (914200), Guam

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1980	0.9	1.7	2.2	3.4	3.9	6.4	9.3	10.9	12.6
1981	1	1.5	2	3.3	3.5	4.8	6.6	8.6	9.8
1982	0.7	0.8	1.1	1.9	3.2	4.8	5.8	6.7	7
1983	0.8	1	1.4	2	2.2	2.8	3.2	4.4	5.2
1984	1	1.8	2.5	4	4.4	5.4	5.8	6.3	7
1985	0.9	1.3	1.8	2.6	2.6	2.9	3.7	4.7	5.1
1986	0.9	1.5	1.8	3.7	5.6	8	9.2	10.7	11.1
1987	0.6	1.1	1.8	2.1	2.2	2.4	3.6	4.3	5
1988	0.7	1.1	1.8	2.8	4.2	5.4	6	6.3	6.3
1989	0.8	1.1	1.7	3.1	3.5	4.7	7	7.6	8.3
1990	0.6	1	1.6	2.2	3.8	5.1	7.6	8.6	9
1991	0.9	1.5	2	2.4	3.1	4.3	6	6.4	8
1992	1.1	1.9	2.3	3.9	6.1	7.7	11.4	12.4	14.1
1993	0.9	1.3	2	3.2	5.2	5.5	7.5	8.7	9.2
1994	1	1.4	1.8	2.3	2.6	2.9	4.4	5.9	7.8
1995	0.9	1.7	3.1	4.3	4.4	4.5	4.5	5.2	7.2
1996	0.9	1.7	2.4	2.9	3.1	3.6	5.2	6.9	7.1
1997	1.1	2	3.7	8.8	10.1	13.1	14.6	15.5	15.5
1998	0.9	1.2	1.4	1.8	2.3	2.6	3.1	4.2	4.4
1999	0.8	1.4	2	2.8	2.8	4	4.7	5	7.5
2000	0.7	1	1.4	3	3.3	4.5	8.5	10.1	11.7
2001	0.9	1.4	2.3	3.2	3.3	3.6	4.5	6.2	7.4
2002	0.8	1.5	1.5	2.3	2.9	4.5	6.7	7.6	7.8
2003	0.7	1	1.4	1.8	1.8	2.6	3	3.6	4.5
2004	1.2	1.3	2.1	3.4	5	7.5	8.2	9.3	9.7
2005	1.5	2	2.3	2.4	3.7	5	6.1	6.8	7.1

Table 1-1B. Annual maximum series rainfall data for Inarajan (914278), Guam

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1979	0.3	0.5	0.6	0.9	1.1	1.4	1.7	2.8	2.9
1980	0.9	1.5	2.3	4.7	6.8	10	12.9	14.9	17.4
1981	0.6	0.8	1.1	2.6	3.7	5	6.3	8.3	8.8
1982	0.7	1.1	1.9	2.1	2.9	4.3	5.2	5.8	6.2
1983	0.6	0.8	1	1.7	2.2	2.7	2.7	3	3.7
1984	0.7	1.1	1.5	2.3	3.4	3.9	4.1	4.5	5.3
1985	0.9	1.1	1.5	2.4	3.3	4	4.9	5.7	6
1986	0.7	1.1	1.4	3.2	4.3	6.2	7.4	9.1	9.8
1987	1	1.4	1.5	2.6	3	3.1	3.9	5.3	6.1

1988	0.7	1	1.6	2.6	4.2	5.6	5.8	5.9	6
1989	0.9	1.6	1.9	3.5	3.9	5.2	7.2	7.6	8.3
1990	0.4	0.7	0.7	1.1	1.9	3	3.7	4.2	4.3
1991	0.7	1.1	1.6	2.4	3.3	4.2	4.7	5.9	6.5
1992	0.7	1.2	1.9	3.4	5.4	6.9	8	8.2	8.7
1993	0.7	1.2	1.5	2.8	3.5	4.2	6.6	8	8.2
1994	1	1.6	1.8	2.2	2.3	3.1	4.5	4.9	5.5
1995	0.7	0.9	1.6	2.3	2.5	3.4	3.8	4.7	4.8
1996	1	1.5	2.2	3	3.2	3.2	4	5.5	7.3
1997	0.9	1.3	1.9	3	5.2	6.7	8.1	8.7	8.8
1998	0.6	1	1.4	1.9	2.1	2.4	2.4	3.2	3.5
1999	1.4	1.4	1.6	2	3	3.9	4.7	4.8	8.3
2000	0.8	1.4	2	3.5	3.8	4	7.4	9.2	10.3
2001	0.8	1.4	2	2.9	3	3.1	4.5	7.6	8.1
2002	0.7	1	1.4	2.1	2.6	3.6	4.5	5.6	5.7
2003	0.8	1.3	1.8	2	2.4	2.6	3	3.7	4.5
2004	0.9	1.4	1.9	2.8	4.2	5.9	7.1	8.5	9.9
2005	0.7	1.2	1.7	2	2.7	3.5	3.8	4.9	5.4

Table 1-1C. Annual maximum series rainfall data for Piti (914670), Guam

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1979	0.7	1.2	2.3	4	6.7	8.1	8.5	11.6	12.4
1980	0.7	1.4	2.6	6.7	8.5	9.6	10.4	11.6	12.9
1981	0.9	1.6	2.9	4.9	5.9	6.1	7.1	7.4	8.1
1982	0.6	1	1.3	2	2.6	3.6	4.1	5.1	6
1983	0.6	0.8	1.2	1.8	2.8	2.8	2.9	3.1	3.2
1984	1.1	1.3	1.9	3.9	5	6.5	6.7	7	7.2
1985	1.2	2.1	2.9	3.6	3.7	3.9	4.5	5.5	6
1986	2	2	2	3.4	3.7	5	5.1	6.8	7.1
1987	0.7	1	1.6	2.1	2.6	3	4.7	6.7	7.9
1988	1.8	2.4	3.7	4.5	4.8	5.4	6	6.1	6.1
1989	0.9	1.1	1.3	2.8	3.4	4.2	4.6	5.4	5.5
1990	0.7	1.4	1.6	1.9	2.7	4.6	6.7	7.5	7.8
1991	0.7	1.2	1.8	2.9	3.6	6.1	7.6	8.1	8.1
1992	1.3	2.5	3.1	4	6.9	8	8	9.2	9.2
1993	1.5	2.4	2.5	4.1	5	5.2	5.4	6.8	6.9
1994	0.9	1.1	1.5	2.9	3.5	3.9	4.1	4.9	5.9
1995	1	1.5	1.8	3	4	4.1	4.5	7.4	10.2
1996	1.1	1.4	2.1	2.7	3.4	4.4	5.1	9.7	10.3
1997	1.8	3.6	3.6	4.5	6.1	8.4	9.6	10.5	10.5
1998	0.8	1.1	1.3	1.7	2.8	4.1	4.4	4.8	5.3
1999	0.7	1.3	1.8	2.4	2.4	3.9	4.8	5.1	7.6
2000	0.9	1.5	2	3.2	3.8	5.4	9.7	10.7	11.7
2001	1	1.5	1.8	2.2	2.6	2.8	3.2	4.5	5.8
2002	1.4	1.7	2.6	3	3.2	4.1	4.6	6.7	7.7
2003	0.7	1.2	1.8	2.7	3.5	6	6.8	7.4	8.5
2004	0.5	0.8	1.1	1.4	2.3	2.3	2.4	3.3	3.6
2005	1.3	2.3	2.8	3.8	5	5.7	6.6	8.6	9.1

Table 1-1D. Annual maximum series rainfall data for Taguac (914229), Guam

Year	1h	3h	6h	12h	24h	48h	72h
1984	2	3.62	4.96	6.93	8.26	11.27	12.36
1985	1.25	1.81	2.69	3.21	4.08	5.29	6.64
1986	1.49	3.01	5.67	8.84	12.07	12.55	12.76
1987	1.96	2.23	2.78	3.93	5.08	5.81	6.39
1988	1.3	2.47	4.35	5.78	6.45	6.84	6.91
1989	1.2	2.77	3.34	3.7	4.93	6.1	7.35
1990	2.24	2.95	4.14	7.2	11.09	12.5	12.93
1991	1.45	2.06	3.12	4.49	6.5	7.25	7.38
1992	2.41	3.9	5.5	7.61	10.89	12.61	14.95
1993	0.92	1.87	2.67	3.01	4.62	6.01	6.16
1994	1.44	2.64	3.42	4.06	4.26	5.4	6.26
1996	2.61	2.61	2.61	3.64	3.84	4.85	6.71
1998	1.7	1.7	1.7	2.35	4.17	4.67	5.3
1999	4.68	4.68	4.68	6	6.75	7.09	9.38

Table 1-1E. Annual maximum series rainfall data for Capitol Hill (914080), Saipan, CNMI.

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1987	0.7	0.8	1	1.1	1.4	1.9	3.3	3.6	3.8
1988	0.5	0.7	1	1.7	1.8	2	3.5	4	4
1989	1	1.5	1.9	3.6	4.9	5.3	6.1	10.5	11.5
1990	1	1.8	2.6	4.4	6.4	7.3	8.6	10	11.5
1991	0.7	1.2	1.7	2.8	3	3.1	3.6	3.9	4.8
1992	0.7	1.2	2	4.2	4.5	4.6	4.7	5	7
1993	0.7	1	1.5	1.7	1.8	2.9	3.1	3.6	4.4
1994	1.4	2	2.6	3.3	3.8	4.8	6.8	8.3	8.5
1995	0.8	1.4	2	3.1	4.1	5.1	5.2	8	8.3
1996	0.9	1.5	2.2	2.9	3.3	3.5	3.6	3.6	4
1997	0.6	1.1	1.3	3.3	4.4	5.7	7.2	8.2	9.1
1998	1	1.4	1.4	1.4	1.5	1.8	2.1	3.3	3.4
1999	0.4	0.5	0.5	0.7	0.8	0.8	1.1	1.5	2.1
2000	0.6	0.8	0.9	1.7	2.1	2.5	2.8	3.2	3.7
2001	1.1	1.7	1.7	1.8	2.3	3.6	4.2	5.1	5.1
2002	0.8	1	1.1	1.6	1.9	2.1	2.3	3.6	3.9
2003	0.5	0.7	0.7	1.2	1.5	1.5	1.5	2.1	2.5
2004	0.5	0.7	0.8	0.9	0.9	1.2	1.7	2.5	2.5
2005	1.2	1.9	2.7	2.9	3.1	3.1	3.5	5.8	7.6

Table 1-1F. Annual maximum series rainfall data for Rota (914801), CNMI

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1983	0.7	1.3	1.6	2.7	3.5	3.8	4.2	4.3	4.5
1984	1.5	1.5	1.5	1.8	2.1	2.6	3.3	5	5.7
1985	0.9	1.7	2.6	3.4	3.7	5	6.6	11	11.2
1986	1	1.9	3.7	6.4	9.6	12.1	13	13.3	13.3
1987	1.2	2.2	3.2	5.3	6.1	8.2	8.9	9.1	9.1
1988	0.6	1	1.7	3	4.1	4.9	5.1	5.2	5.2
1989	0.8	1.1	1.8	3.7	5.2	7.3	11.1	14.1	14.5
1990	0.6	1.1	2	3.7	5.7	8.4	10.3	11.2	11.3
1991	0.7	0.8	1.3	2.3	2.8	4	4.1	4.1	4.8
1992	1.1	1.7	2.7	3.2	3.5	4.6	6.1	7.9	9.6
1993	0.5	0.8	1.1	1.2	2.1	3.1	3.4	4	4.7
1994	1.2	2.3	4	6	7.8	9.9	10	10.5	10.7
1995	0.7	1.3	1.5	2.1	2.6	2.8	3.9	5.4	6.7
1996	0.9	1.5	1.8	3.8	4.3	4.8	5.7	6.9	7.5
1997	0.8	1.4	1.9	3.5	4.7	5	6.2	8.4	9.2
1998	0.4	0.5	0.5	0.9	1.1	1.7	1.7	1.8	2.6
1999	0.6	0.7	1	1.5	1.7	1.7	1.9	2.8	3.7
2000	0.6	1	1.3	2.3	3.1	3.7	4.4	5.6	7.1
2001	1.2	2	2.4	2.4	2.8	3.4	3.8	6	7.4
2002	1.4	1.9	2.1	4.4	4.6	4.9	5.8	9.3	11.3
2003	1.1	1.6	2.2	2.2	2.9	3.7	3.8	4.5	5.7
2004	0.9	1.5	1.8	3.5	4.1	4.8	5.6	9.2	10.5
2005	0.8	1.3	2	2.2	2.3	2.3	2.5	3.5	3.7

Table 1-1G. Annual maximum series rainfall data for Saipan International Airport (914855), CNMI

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1979	0.9	1.7	2.2	2.6	3.6	3.8	3.9	4	5.4
1980	1.8	2.2	2.5	3.2	4	6.4	7.2	8	9.6
1981	0.9	1.6	2.3	3.5	4.6	6.9	8.4	11.2	12.7
1982	0.6	1	1.4	3.1	4.1	7.7	10.4	13.7	14.9
1983	0.9	1.4	2.2	3	3.1	3.2	3.7	5.4	5.9
1985	0.5	0.7	1.1	2.3	2.5	2.5	2.5	2.5	2.7
1986	0.9	1.2	1.7	1.9	2.7	3.7	5.8	6.9	7.6
1987	0.7	0.9	1.2	1.4	1.4	1.7	1.7	2	2.4
1988	0.8	1	1.3	1.4	2.1	2.3	3.4	4.4	5.4
1989	0.8	1.1	1.4	2.5	3.1	5	5.5	8.5	8.7
1990	2.4	2.6	3	4.1	6.6	7.4	10.2	11	12.1
1991	0.7	1.1	1.7	2.9	4.2	6	7.5	8.2	8.2
1992	0.7	1.3	2	2.7	3.1	3.6	3.7	4.7	7.1
1993	1.6	2.8	4.4	8.1	12	15.3	16.5	16.7	16.7
1994	1	1.8	2.9	4.6	4.7	4.8	8.2	9.1	9.2
1995	0.8	1.1	1.3	2.4	3.5	4.4	5.4	7.2	7.8
1996	0.8	1.3	2	2.5	3.5	4.5	5.1	5.6	6.1
1997	1	1.3	2	3.3	4.3	7	8.9	10.1	10.3
1998	0.6	1.1	1.4	1.4	1.4	2.1	2.4	3	3.1
1999	0.9	1.2	1.5	1.8	1.8	2.6	3.4	4.3	5.2
2000	1.2	1.9	2.3	2.8	3.1	3.1	4	6	8.4
2001	0.9	1.2	2.3	3.4	3.5	4.8	5.3	6.3	6.3
2002	1	1.6	2.2	3.5	4.1	4.2	4.7	7.5	8.2
2003	0.7	1.2	1.6	2.9	3.4	3.8	4.2	6.2	6.8
2004	0.5	0.9	1.1	1.5	1.5	1.5	2	2.4	2.8

Table 1-1H. Annual maximum series rainfall data for Yap WSO (914951), FSM

Year	1h	3h	6h	12h	24h	48h	72h
1986	1.52	2.82	3.19	3.53	4.24	4.24	4.24
1989	1.07	2.15	3.16	3.98	3.98	3.98	3.98
1993	2.56	4.24	4.59	5.45	6.51	6.87	7.48
1994	1.29	2.32	2.81	4.12	5.34	5.81	6.05
1995	1.91	2.9	3.15	3.16	3.83	5.09	6.34
1996	2.38	3.35	3.93	4.77	7.46	12.08	12.25
1997	1.68	2.14	2.62	3.1	3.36	5.05	5.52
1998	1.73	3.03	3.17	3.3	4.64	4.96	5.27
1999	2.79	3.25	3.48	5.9	7.56	7.87	8.97
2000	2.42	4.09	4.43	5.3	5.67	6.08	6.71
2001	2.58	3.84	4.02	4.08	5.72	6.2	7.31
2002	2.63	4.93	5.77	5.98	6.12	8.62	8.93
2003	2.15	3.85	5.33	7.61	11.79	14.2	15.09
2004	2.26	4.04	4.24	5.94	7.44	7.91	8.18

Table 1-1I. Annual maximum series rainfall data for Chuuk (914851), FSM

Year	1h	3h	6h	12h	24h	48h	72h
1984	1.81	2.34	3.69	5.23	6.17	7.39	8.19
1985	2.83	4.1	5.08	6.24	6.78	7.17	7.39
1986	1.72	3.33	3.68	5.01	5.13	7.57	8.82
1987	2.13	3.76	4.22	4.74	4.94	5.42	7.42
1988	2.02	2.59	3.31	4.78	4.92	4.95	6.92
1989	1.89	2.41	3.24	4.12	7.16	12.37	13.79
1990	1.88	4.5	4.86	5.46	6.06	8.12	9.01
1991	1.96	3.42	4.81	5.24	5.75	7.07	8.15
1992	1.78	2.64	3.19	3.28	4.81	6.73	8.24
1993	2	3.27	4.71	6.86	7.89	7.89	8

Table 1-1J. Annual maximum series rainfall data for Pohnpei Hospital (914745), FSM

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1980	1.1	1.5	2.1	2.5	3.2	4.6	6.1	6.5	7.8
1981	0.8	1.3	1.7	2.2	3.1	4.1	5.2	7.4	9.3
1982	1.3	1.9	2.5	3.8	4.6	5	6.5	6.5	6.7
1983	1	1.5	2.5	3.8	4.4	5.5	6.1	6.7	7
1984	1	1.8	2.6	2.6	2.7	3.3	4.5	4.8	5.1
1985	1.3	2.2	3.7	5.5	6.3	6.5	7.6	8.3	8.6
1986	1.6	2	2.6	3.5	4.4	5.8	8.1	9.7	9.7
1987	1.3	1.6	2.4	4.3	6	6.9	7.3	8.4	9.6
1988	0.8	1.3	1.5	2.6	3.5	4.7	5.3	7.4	8.1
1989	1.4	2.6	3.9	5.4	5.6	5.8	6.6	7.1	7.6
1990	0.9	1.7	2.6	3.1	5.3	7.8	11	12.8	13.5
1991	1.5	1.8	2.4	4.2	6.4	9.5	10.3	10.3	10.9
1992	1.4	2.4	3	4.8	8.4	13.6	16.1	16.2	16.2
1993	0.7	1	1.4	2.6	3	3.7	4.1	6.7	6.9
1994	0.9	1.4	2.3	3.9	5.9	8.1	8.2	8.4	8.9
1995	1.3	2	2.7	3.4	4	5.9	9.4	10.8	10.9
1996	1.1	1.4	1.8	2.3	3.3	4.6	7.6	8.4	9
1997	1.1	1.9	3	5.5	6.8	10.3	11.1	13.1	13.2
1998	0.9	1.6	2.3	3.4	3.6	4.8	5.3	7.7	8.5
1999	0.8	1.1	1.6	2.5	3.6	4	5.1	7	9.5
2000	0.7	1.3	1.9	3.7	4.7	5	5.7	6.3	8.2
2001	1	1.8	2.5	4	5.2	6.1	6.3	10.2	10.9
2002	1.1	1.6	2.2	4.3	6.4	7.3	9	9.2	9.7
2003	1.4	2.7	4.3	5.6	6.3	10.6	12.9	13.6	16.6
2004	0.9	1.4	2.1	3	4.1	4.1	4.1	6.3	7.6
2005	1	1.3	1.9	3.3	3.6	3.9	6.9	9	9.5

Table 1-1K. Annual maximum series rainfall data for Pohnpei WSO (914751), FSM

Year	1h	3h	6h	12h	24h	48h	72h
1984	1.66	2.1	2.84	3.1	3.68	4.38	4.62
1985	3	4.87	5.54	5.72	6.55	7.03	7.38
1986	2.15	3.28	4.49	5.7	6.31	10.6	11.45
1987	2.27	4.31	6.33	8.61	9.15	9.71	10.11
1988	2.06	2.53	3.73	5.12	5.65	6.86	7.48
1989	2.26	3.75	4.52	5.68	5.99	10.17	10.7
1990	2.14	3.22	5.78	7.49	11.11	12.59	12.87
1991	3.12	6.7	8.29	8.75	8.97	12.21	14.42
1992	2.55	3.83	6.92	10.8	13.16	13.41	13.42
1993	1.36	2.66	3.08	3.73	5.56	6.41	7.14

Table 1-1L. Annual maximum series rainfall data for Kosrae (914395), FSM. For Kosrae, FSM, the 1-day precipitation was converted to the 24-hour precipitation by multiplying by 1.13. The 2-day was converted to 48-hour by the ratio 1.05. The 3-day was converted to the 72-hour by the ratio 1.02.

Year	1-day	24-hour	2-day	48-hour	3-day	72-hour
1954	3.83	4.33	5.89	6.18	6.21	6.33
1955	9.58	10.83	9.99	10.49	11.3	11.53
1956	4.88	5.51	6.13	6.44	7.2	7.34
1957	9.94	11.23	11.57	12.15	14.85	15.15
1958	11.02	12.45	14.26	14.97	18.88	19.26
1959	10.77	12.17	12.74	13.38	14.16	14.44
1960	8.81	9.96	13.29	13.95	15.02	15.32
1961	5.66	6.40	6.94	7.29	8.55	8.72
1962	7.16	8.09	11.57	12.15	13.66	13.93
1963	6.67	7.54	11.15	11.71	15.3	15.61
1964	3.27	3.70	5.21	5.47	6.11	6.23
1965	6.15	6.95	9.83	10.32	9.94	10.14
1966	4.14	4.68	5.94	6.24	7.21	7.35
1967	8.74	9.88	9.26	9.72	9.26	9.45
1968	4.31	4.87	5.29	5.55	5.95	6.07
1969	5.58	6.31	9.3	9.77	9.52	9.71
1970	4.52	5.11	5.42	5.69	5.88	6.00
1971	6.07	6.86	7.3	7.67	7.91	8.07
1972	5.33	6.02	5.73	6.02	6.58	6.71
1973	4.58	5.18	5.17	5.43	5.35	5.46
1974	6.12	6.92	7.67	8.05	9.53	9.72
1975	5.42	6.12	6.65	6.98	8.2	8.36
1976	6.46	7.30	6.46	6.78	6.46	6.59
1977	6.41	7.24	6.86	7.20	7.13	7.27
1978	3.87	4.37	6.18	6.49	8.16	8.32
1979	3.34	3.77	4.61	4.84	4.87	4.97
1985	2.43	2.75	4.2	4.41	5.9	6.02
1986	3.64	4.11	4.74	4.98	5.64	5.75
1987	4.22	4.77	6.55	6.88	6.93	7.07
1988	3.83	4.33	5.08	5.33	5.62	5.73
1989	6.96	7.86	9.22	9.68	9.24	9.42
1990	3.5	3.96	5.42	5.69	5.59	5.70
1991	5.41	6.11	9.29	9.75	9.43	9.62
1992	6.1	6.89	7.77	8.16	7.98	8.14
1993	7.73	8.73	9.13	9.59	9.79	9.99
1994	4.21	4.76	6.78	7.12	7.51	7.66
1995	4.42	4.99	5.41	5.68	5.8	5.92
1996	6.22	7.03	9.79	10.28	11.87	12.11
1997	6.25	7.06	10.39	10.91	12.06	12.30
1998	4.29	4.85	5.43	5.70	6.49	6.62
1999	4.38	4.95	6.35	6.67	7.5	7.65
2000	4.83	5.46	6.05	6.35	6.78	6.92
2001	11.92	13.47	16.06	16.86	20.05	20.45
2002	6.62	7.48	10.13	10.64	15.9	16.22
2003	7.13	8.06	10.19	10.70	12.41	12.66
2004	3.89	4.40	5.66	5.94	8.86	9.04
2005	6.82	7.71	7.44	7.81	8.18	8.34
2006	9.53	10.77	9.95	10.45	10.97	11.19

Table 1-1M. Annual maximum series rainfall data for Koror (914351), Palau

Year	1h	3h	6h	12h	24h	48h	72h
1984	1.63	2.58	2.75	3.62	3.62	4.4	4.96
1985	2.3	4.75	4.97	5.38	6.09	7.11	7.91
1986	2.29	3.82	5	6.75	8.55	9.23	9.66
1987	1.85	3.35	4.84	5.74	6.19	7.78	8.36
1988	1.84	3.41	4.71	5.99	6.35	8.46	8.46
1989	2.11	4.09	5.11	5.26	5.29	7.01	9.99
1990	3.23	5.46	6.47	8.45	13.83	16.54	16.69
1991	2.28	4.89	6.7	12.2	13.78	14.15	14.81
1992	1.32	1.85	2.98	3.04	4.74	5.76	6.26
1993	1.82	3.27	4.64	5.28	5.54	6.67	7.81
1994	2.05	2.94	4.3	4.63	4.69	4.78	6.08
1995	2.06	2.75	4.51	6.6	6.72	7.72	7.86
1996	1.47	2.44	3.41	4.86	7.43	8.4	8.5
1997	2.69	3.85	4.39	4.44	5.06	6.94	7.71
1998	3.8	4.42	4.51	4.52	4.53	5.58	5.86
1999	2.03	3.48	4.38	6.4	7.14	8.78	8.97
2000	1.75	4.24	5.05	5.61	5.76	6.49	7.47
2001	1.97	2.92	4.12	6.85	10.18	14.36	15.51
2002	2.78	5.58	5.73	5.74	6.43	6.91	7.99
2003	2.07	3.23	3.69	4.53	5.83	9.09	9.73
2004	2.58	5.39	6.31	7.86	8.01	8.12	10.72
2005	1.84	3.5	4.76	7.43	7.75	8.13	8.42

Table 1-1N. Annual maximum series rainfall data for Majuro (914460), Marshall Islands (1955-70).

Year	5m	10m	15m	30m	60m	2h	3h	24h
1955								7.19
1956								5.39
1957								10.01
1958	0.4	0.78	0.78	1.82	2.02	2.56	3	4.64
1959	0.43	0.66	0.85	1.33	2.17	3.29	3.46	5.73
1960	0.42	0.78	1.12	1.71	2.22	3.28	3.35	3.72
1961	0.41	0.7	0.99	1.22	2.18	3.98	5.41	9.57
1962	0.47	0.75	0.95	1.52	2.41	3.9	4.04	5.86
1963	0.39	0.67	0.85	1.43	2.13	3.03	3.47	3.92
1964	0.42	0.75	1.02	1.64	2.68	4.85	5.08	5.56
1965	0.46	0.84	1.1	1.43	1.93	2.96	3	3.67
1966	0.7	1.12	1.56	2.22	2.77	2.8	2.8	4.32
1967	0.5	0.78	1.03	1.43	2.29	2.73	2.9	4.46
1968	0.43	0.73	1.01	1.72	2.07	3.1	3.55	5.18
1969	0.38	0.57	0.79	1.22	1.76	2.25	2.79	6.63
1970	0.29	0.53	0.73	1.44	1.59	1.82	2.09	4.01

Table 1-1O. Annual maximum series rainfall data for Majuro (914460), Marshall Islands (1984-2005).

Year	1h	3h	6h	12h	24h	48h	72h
1984	1.59	2.02	2.98	4.13	5.15	6.28	6.32
1985	2.01	3.03	3.52	4.46	5.05	5.42	5.45
1986	2.27	3.02	4.93	5.26	5.29	6.54	6.54
1987	1.79	2.81	3.58	4.45	5.86	5.9	6.01
1988	1.46	2.1	3.43	5.31	7.71	9.97	11.51
1989	2.07	3.7	4.25	4.34	5.2	5.46	6.45
1990	2.59	3.37	3.73	4.5	5.09	5.18	5.37
1991	2.35	4.81	8	12.45	15.26	15.55	16.35
1992	2.37	4.21	5.3	6.16	6.26	6.87	9.01
1993	2.26	3.03	3.75	5.06	6.39	6.73	9.61
1994	1.96	3.69	4.32	5.43	5.8	6.73	6.86
1995	1.28	1.98	2.4	3.08	5.22	6.38	7.34
1996	2.05	2.95	4.42	4.83	4.83	5.19	6.35
1997	1.82	2.99	4.58	5.52	5.53	5.83	6.86
1998	1.84	3.51	5.21	5.9	6.02	6.31	6.31
1999	2.18	3.28	3.57	3.81	4.4	4.84	5.86
2000	1.98	3.72	6.37	9.44	10.04	10.14	10.92
2001	2.41	4.13	4.88	5.31	5.5	5.72	5.96
2002	2.1	3.99	4.19	4.2	6.42	6.89	7.25
2003	2.41	3.01	3.63	3.75	4.69	4.95	6.39
2004	1.52	1.91	2.4	3.44	4.14	4.89	5.28
2005	2.05	3.81	3.93	3.97	4.56	7.6	9.48

Table 1-1P. Annual maximum series rainfall data for Atu'u (914060), Tutuila, American Samoa

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1979	1	1.1	2	3.6	4.4	4.5	5.1	8.8	10.1
1980	1.1	1.9	2.7	4.9	5.9	7.2	7.8	7.8	8.4
1981	1.3	1.9	2.8	4.7	6.1	6.7	11	12.9	13.8
1982	0.8	1.2	2.2	3.2	6	7	7.9	12.2	15.7
1983	1.2	1.9	3.6	4.9	5.4	6	7.1	8.4	10
1984	2.5	2.5	2.7	4.7	5.2	5.7	6.5	8.5	13.5
1985	2.1	2.1	3.4	4.8	6.3	7.5	8.9	9.4	10.8
1986	1.3	2.3	3.5	5.5	5.7	6.9	8.1	9	10.2
1987	1.1	1.7	2.4	4.5	5.7	5.9	7	7.7	9.7
1988	1.2	1.8	2.4	4.3	5.2	5.4	6.3	9.9	11.3
1989	1.1	1.6	2.3	4.7	5.3	5.9	7.8	12.1	12.2
1990	0.9	1.3	1.9	2.9	3.1	3.6	4.6	5.6	6.4
1991	1.1	1.9	3.1	5.3	7.3	7.8	8.6	9	9.9
1992	0.9	1.4	1.8	2.6	4	6	7.6	8.2	10.3
1993	1.2	1.7	2.6	3.9	4.1	4.6	5.6	5.7	6.1
1994	1	1.7	2.3	3.7	5.9	6.1	6.1	6.5	7.8
1996	1	1.5	2.6	3.9	4.8	5.1	5.3	8.3	9.7
1997	1.1	1.3	2.1	4.3	7.4	11.4	16.1	19.1	19.4
1998	0.7	1.3	2.2	3.1	3.8	4.5	4.9	7.6	8.2
2000	0.8	1.3	1.8	3	3.9	4.6	5.9	8	8.7

Table 1-1Q. Annual maximum series rainfall data for Malaeloa (914594), Tutuila, American Samoa

Year	15m	30m	1h	3h	6h	12h	24h	48h	72h
1980	1.1	2.1	3.4	4.2	4.6	5.5	5.6	6.2	7
1981	1.1	1.8	3	5.5	7.5	8.9	9.3	10.3	11.4
1982	1	1.8	2.5	2.9	3.2	5.8	7.6	11.5	14.9
1983	0.8	1.3	2.1	3.5	4.3	4.7	5.4	6.8	7.8
1984	1.6	1.9	3.8	6.7	7.4	7.8	8.7	9.1	10.9
1985	1.2	2	2.7	5.3	5.8	7.9	9	9.8	11.5
1986	3.1	3.2	3.2	3.4	6	7.3	8.7	13.5	14.3
1987	0.9	1.2	1.6	2.7	3.9	6.3	7.5	8.7	8.8
1988	0.9	1.7	2	2.5	2.8	3.1	3.7	6.3	6.7
1989	1	1.6	2.1	2.7	4	6.5	7.9	9.3	10
1990	1.1	1.3	1.6	2.5	3	3.8	5.9	10.7	12.7
1991	1.1	2.1	3.5	6.2	6.4	6.4	8.5	13.2	15.5
1992	1.3	2.3	2.6	2.6	3.3	5.4	7.3	7.5	8.3
1993	1.1	2.1	2.6	3.7	4.4	6	7.1	8.1	8.2
1994	1.8	1.9	3.1	4.7	6.7	8	8.6	9.9	10.4
1995	1	1.5	2.7	4	4.2	5.2	5.4	7.5	8.4
1996	1.7	2	2.6	3.1	4.8	6.6	6.6	7.8	10
1997	1.7	2.6	2.6	2.6	3.7	5.1	6.6	9.9	12.6
1998	1	1.7	2.6	4.7	5	5.7	6.3	10.7	12
1999	1	1.9	2.9	3.8	5	6.5	11.6	12.5	15.2
2000	1	1.5	2.1	3.9	4.8	5	6	7.2	7.4
2001	0.9	1.7	2.6	3.3	4.2	4.4	5.1	6.7	8.7
2002	0.9	1.4	2.6	3.7	3.9	5.9	6.6	7.5	9.9
2003	0.9	1.4	2.3	4.1	5.9	7.1	8.2	10.9	13.6
2004	0.9	1.7	2.5	3.1	3.2	4	4.9	6.2	7.2
2005	1	1.7	2.8	3.5	4.5	5.3	7	7.1	7.4

Table 1-1R. Annual maximum series rainfall data for Wake Island (914901)

Year	1h	3h	6h	12h	24h	48h	72h
1986	1.23	2.29	2.53	3	3.94	6.62	6.97
1987	1.18	1.59	1.66	1.99	3.19	3.38	3.63
1988	1.26	1.71	2.13	2.13	2.14	2.2	2.2
1989	1.17	1.5	1.55	1.85	1.97	3.23	3.37
1990	1.68	3.47	3.93	4.06	5.89	6.01	6.04
1991	1.35	2.41	2.51	2.53	2.76	3.48	4.31
1992	2.27	4.04	5.27	6.36	7.21	9.64	10.36
1993	1.31	1.33	1.33	1.87	2.46	2.5	2.57
1994	0.9	1.16	1.31	1.44	1.62	2.67	2.82
1995	1.31	1.71	2.43	3.38	3.49	4.19	5.21
1996	1.05	2.61	4.31	6.26	6.81	8.81	8.97
1997	0.75	1.69	1.77	1.92	2.13	2.27	3.05

Appendix 2 Annual Series Results

The results in Table 2-1 (A through R) were derived from the Gumbel probability distribution. It is described in many standard textbooks such as Chow (1988). The Gumbel parameters were solved separately for each rainfall duration using L-Moment procedures (Maidment, 1993). Rainfalls are in units of inches.

Table 2-1A. Annual series rainfall for Fena Lake (914200), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	0.86	1.33	1.88	2.87	3.54	4.59	5.94	6.94	7.79
5	1.04	1.66	2.39	3.89	4.93	6.49	8.39	9.53	10.43
10	1.16	1.88	2.72	4.57	5.84	7.75	10.01	11.25	12.18
25	1.31	2.16	3.15	5.43	7.00	9.34	12.06	13.42	14.39
50	1.42	2.36	3.46	6.06	7.86	10.52	13.58	15.03	16.03
100	1.53	2.56	3.77	6.69	8.71	11.69	15.09	16.63	17.65
200	1.64	2.77	4.09	7.32	9.56	12.86	16.60	18.22	19.27
500	1.78	3.03	4.50	8.15	10.68	14.40	18.58	20.32	21.41

Table 2-1B. Annual series rainfall for Inarajan (914278), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	0.74	1.12	1.53	2.38	3.13	3.97	4.91	5.89	6.58
5	0.92	1.39	1.92	3.11	4.22	5.53	6.97	8.18	9.12
10	1.05	1.57	2.17	3.59	4.94	6.56	8.33	9.71	10.80
25	1.20	1.80	2.49	4.19	5.85	7.86	10.05	11.63	12.93
50	1.32	1.97	2.73	4.64	6.52	8.83	11.33	13.05	14.51
100	1.44	2.14	2.96	5.09	7.19	9.79	12.60	14.47	16.08
200	1.55	2.30	3.20	5.53	7.86	10.74	13.86	15.88	17.64
500	1.70	2.52	3.51	6.12	8.74	12.01	15.53	17.74	19.70

Table 2-1C. Annual series rainfall for Piti (914670), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	0.95	1.47	1.98	2.99	3.83	4.76	5.49	6.68	7.37
5	1.32	2.03	2.66	4.08	5.26	6.48	7.48	8.92	9.70
10	1.56	2.40	3.11	4.80	6.21	7.61	8.79	10.40	11.25
25	1.87	2.87	3.68	5.71	7.41	9.05	10.46	12.28	13.21
50	2.10	3.21	4.10	6.39	8.31	10.11	11.69	13.67	14.66
100	2.32	3.56	4.52	7.06	9.19	11.17	12.92	15.05	16.10
200	2.55	3.90	4.94	7.73	10.07	12.22	14.14	16.42	17.53
500	2.85	4.36	5.49	8.61	11.24	13.61	15.75	18.24	19.42

Table 2-1D. Annual series rainfall for Taguac (914229), Guam

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.76	2.58	3.46	4.69	6.15	7.21	8.13
5	2.54	3.42	4.67	6.63	8.80	10.02	11.07
10	3.06	3.97	5.47	7.92	10.55	11.89	13.02
25	3.72	4.67	6.47	9.54	12.76	14.24	15.48
50	4.20	5.19	7.22	10.75	14.40	15.99	17.31
100	4.69	5.70	7.96	11.94	16.04	17.73	19.12
200	5.17	6.22	8.70	13.13	17.66	19.46	20.93
500	5.80	6.89	9.68	14.70	19.80	21.74	23.31

Table 2-1E. Annual series rainfall for Capitol Hill (914080), Saipan, CNMI.

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	0.75	1.12	1.44	2.13	2.55	3.00	3.59	4.59	5.16
5	1.01	1.56	2.09	3.21	3.98	4.65	5.49	7.03	7.88
10	1.18	1.86	2.53	3.92	4.93	5.74	6.75	8.64	9.68
25	1.39	2.22	3.07	4.83	6.13	7.12	8.34	10.68	11.96
50	1.55	2.50	3.48	5.50	7.02	8.14	9.53	12.19	13.64
100	1.71	2.77	3.88	6.16	7.91	9.15	10.70	13.70	15.32
200	1.87	3.04	4.29	6.82	8.79	10.17	11.87	15.19	16.98
500	2.08	3.40	4.82	7.69	9.95	11.50	13.41	17.17	19.19

Table 2-1F. Annual series rainfall for Rota (914801), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	0.83	1.31	1.84	2.86	3.60	4.47	5.20	6.49	7.23
5	1.11	1.78	2.61	4.18	5.37	6.79	7.95	9.71	10.42
10	1.29	2.09	3.12	5.06	6.55	8.32	9.78	11.84	12.53
25	1.53	2.48	3.76	6.16	8.03	10.26	12.08	14.54	15.20
50	1.71	2.77	4.23	6.98	9.13	11.70	13.79	16.53	17.17
100	1.88	3.06	4.70	7.79	10.22	13.13	15.48	18.52	19.14
200	2.05	3.35	5.17	8.60	11.31	14.55	17.17	20.49	21.09
500	2.28	3.73	5.79	9.67	12.74	16.43	19.40	23.10	23.67

Table 2-1G. Annual series rainfall for Saipan International Airport (914855), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	0.88	1.32	1.84	2.71	3.38	4.30	5.22	6.38	7.12
5	1.22	1.78	2.49	3.81	4.97	6.62	8.13	9.68	10.47
10	1.44	2.09	2.92	4.54	6.03	8.15	10.06	11.86	12.69
25	1.72	2.48	3.47	5.46	7.36	10.09	12.49	14.62	15.49
50	1.93	2.76	3.88	6.14	8.35	11.53	14.30	16.66	17.57
100	2.14	3.05	4.28	6.82	9.33	12.96	16.09	18.69	19.63
200	2.35	3.33	4.68	7.49	10.30	14.38	17.88	20.71	21.69
500	2.62	3.70	5.21	8.38	11.59	16.26	20.23	23.38	24.40

Table 2-1H. Annual series rainfall for Yap WSO (914951), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.99	3.12	3.58	4.50	5.61	6.59	7.07
5	2.52	4.00	4.56	5.80	7.54	9.15	9.75
10	2.88	4.58	5.20	6.67	8.81	10.84	11.52
25	3.32	5.32	6.01	7.75	10.42	12.98	13.76
50	3.65	5.86	6.62	8.56	11.61	14.57	15.43
100	3.98	6.40	7.22	9.36	12.80	16.14	17.08
200	4.31	6.94	7.81	10.16	13.98	17.71	18.72
500	4.74	7.66	8.60	11.22	15.54	19.78	20.89

Table 2-1I. Annual series rainfall for Chuuk (914851), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.94	3.09	3.92	4.89	5.74	7.12	8.27
5	2.27	3.89	4.77	6.00	6.94	9.01	10.01
10	2.48	4.42	5.33	6.73	7.75	10.26	11.17
25	2.76	5.10	6.03	7.65	8.76	11.84	12.63
50	2.96	5.60	6.56	8.34	9.51	13.01	13.71
100	3.16	6.09	7.08	9.02	10.25	14.18	14.79
200	3.36	6.59	7.60	9.69	10.99	15.34	15.86
500	3.62	7.24	8.28	10.59	11.97	16.87	17.27

Table 2-1J. Annual series rainfall for Pohnpei Hospital (914745), FSM

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.04	1.62	2.32	3.50	4.52	5.80	7.07	8.34	9.13
5	1.29	2.04	2.98	4.51	5.93	8.02	9.67	10.82	11.62
10	1.46	2.31	3.41	5.18	6.86	9.50	11.39	12.46	13.27
25	1.67	2.66	3.96	6.03	8.03	11.36	13.56	14.53	15.35
50	1.83	2.92	4.36	6.66	8.90	12.74	15.17	16.06	16.89
100	1.98	3.18	4.77	7.28	9.77	14.11	16.77	17.59	18.43
200	2.14	3.43	5.17	7.91	10.63	15.48	18.36	19.11	19.95
500	2.34	3.77	5.70	8.73	11.77	17.28	20.47	21.11	21.97

Table 2-1K. Annual series rainfall for Pohnpei WSO (914751), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	2.15	3.48	4.82	6.02	7.09	8.76	9.35
5	2.72	4.78	6.61	8.42	9.93	11.87	12.65
10	3.10	5.64	7.79	10.01	11.81	13.93	14.83
25	3.58	6.73	9.28	12.02	14.18	16.54	17.60
50	3.93	7.54	10.39	13.51	15.94	18.47	19.65
100	4.28	8.34	11.49	14.99	17.69	20.39	21.68
200	4.64	9.14	12.59	16.46	19.44	22.30	23.71
500	5.10	10.19	14.04	18.40	21.74	24.82	26.38

Table 2-1L. Annual series rainfall for Kosrae (914395), FSM

Return Period	24-hour	48-hour	72-hour
2	7.15	8.55	9.61
5	9.06	10.74	12.37
10	10.25	12.42	14.47
25	12.08	14.54	17.10
50	13.50	16.20	19.15
100	14.92	17.85	21.20
200	16.33	19.50	23.23
500	18.20	21.66	25.92

Table 2-1M. Annual series rainfall for Koror (914351), Palau

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	2.07	3.55	4.51	5.64	6.55	7.80	8.58
5	2.60	4.56	5.50	7.36	8.86	10.43	11.25
10	2.95	5.23	6.16	8.49	10.39	12.18	13.01
25	3.39	6.07	6.99	9.93	12.33	14.38	15.24
50	3.72	6.70	7.60	10.99	13.76	16.01	16.90
100	4.05	7.32	8.21	12.04	15.18	17.64	18.54
200	4.37	7.94	8.82	13.10	16.60	19.25	20.17
500	4.80	8.76	9.63	14.48	18.48	21.38	22.33

Table 2-1N. Annual series rainfall for Majuro (914460), Marshall Islands (1958-70)

Return Period	5-min	10-min	15-min	30-min	60-min
2	0.42	0.72	0.95	1.50	2.11
5	0.50	0.84	1.13	1.75	2.42
10	0.55	0.93	1.26	1.92	2.63
25	0.61	1.03	1.41	2.13	2.89
50	0.66	1.10	1.53	2.28	3.08
100	0.71	1.18	1.64	2.43	3.27
200	0.75	1.26	1.76	2.59	3.46
500	0.81	1.36	1.91	2.79	3.71

Table 2-1O. Annual series rainfall for Majuro (914460), Marshall Islands (1984-2005)

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.95	3.09	4.03	4.92	5.79	6.44	7.21
5	2.30	3.85	5.18	6.52	7.52	8.31	9.39
10	2.54	4.35	5.94	7.59	8.66	9.55	10.84
25	2.83	4.99	6.89	8.93	10.11	11.11	12.67
50	3.05	5.46	7.61	9.92	11.18	12.27	14.03
100	3.26	5.93	8.31	10.91	12.24	13.42	15.37
200	3.48	6.40	9.01	11.90	13.30	14.56	16.72
500	3.76	7.01	9.94	13.20	14.70	16.08	18.49

Table 2-1P. Annual series rainfall for Atu'u (914060), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.11	1.60	2.42	3.96	5.06	5.84	7.00	8.76	10.07
5	1.45	1.98	2.96	4.83	6.21	7.36	9.19	11.33	12.97
10	1.67	2.23	3.32	5.41	6.98	8.38	10.64	13.03	14.90
25	1.95	2.54	3.78	6.14	7.94	9.66	12.47	15.19	17.33
50	2.17	2.78	4.12	6.68	8.66	10.60	13.82	16.78	19.13
100	2.37	3.01	4.45	7.21	9.37	11.55	15.17	18.37	20.92
200	2.58	3.24	4.79	7.75	10.08	12.48	16.51	19.95	22.70
500	2.86	3.55	5.23	8.45	11.01	13.72	18.28	22.03	25.05

Table 2-1Q. Annual series rainfall for Malaeloa (914594), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.13	1.75	2.52	3.61	4.48	5.68	6.81	8.64	9.91
5	1.48	2.15	3.04	4.67	5.74	7.05	8.47	10.78	12.62
10	1.71	2.41	3.38	5.37	6.58	7.95	9.57	12.20	14.41
25	2.01	2.75	3.81	6.26	7.64	9.10	10.96	14.00	16.67
50	2.22	2.99	4.13	6.92	8.42	9.95	11.99	15.33	18.35
100	2.44	3.24	4.45	7.57	9.20	10.80	13.01	16.66	20.02
200	2.65	3.48	4.77	8.22	9.97	11.64	14.03	17.97	21.68
500	2.94	3.81	5.19	9.08	11.00	12.75	15.37	19.71	23.87

Table 2-1R. Annual series rainfall for Wake Island (914901)

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
2	1.22	1.97	2.34	2.79	3.30	4.15	4.50
5	1.58	2.79	3.51	4.28	5.09	6.49	6.95
10	1.82	3.34	4.29	5.26	6.27	8.03	8.57
25	2.12	4.02	5.27	6.50	7.76	9.99	10.62
50	2.34	4.53	6.00	7.43	8.86	11.44	12.13
100	2.56	5.04	6.72	8.34	9.96	12.87	13.64
200	2.78	5.54	7.44	9.25	11.05	14.31	15.14
500	3.07	6.21	8.38	10.46	12.50	16.20	17.12

Appendix 3 Partial Duration Series Results

Table 3-1 was used to convert rainfall values from annual series to partial duration series.

Table 3-1. Conversion from Annual Series to Partial Duration Series Return Period

Return Period in years Partial Duration Series	Return Period in years Annual Series
1	1.58
2	2.54
5	5.52
10	10.51
25	25.5
50	50.5
100	100.5
200	200.5
500	500.5

Table 3-1 is based on an equation from Chow (1988).

Tpd = 1 / (Ln (Tas / (Tas – 1)))

Where: Tpd = return period for partial duration series, years
Tas = return period for annual series, years
Ln = natural logarithm

The Gumbel equation for each station and set of durations was solved for the annual series return periods in Table 1. The results are contained in Tables 3-2A to 3-2R.

The 2-year and 5-year partial duration series return period rainfall values are significantly different from the annual series. The 10-year to 500-year return periods are nearly the same for partial duration and annual series.

Table 3-2A. Partial duration rainfall for Fena Lake (914200), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.80	1.22	1.72	2.54	3.10	3.97	5.15	6.10	6.94
2	0.91	1.43	2.03	3.16	3.94	5.14	6.65	7.69	8.55
5	1.06	1.69	2.44	3.99	5.06	6.67	8.63	9.78	10.69
10	1.17	1.89	2.75	4.62	5.91	7.84	10.12	11.37	12.30
25	1.31	2.16	3.16	5.44	7.02	9.37	12.11	13.47	14.44
50	1.42	2.36	3.47	6.07	7.87	10.54	13.60	15.05	16.05
100	1.53	2.56	3.78	6.70	8.72	11.70	15.10	16.64	17.66
200	1.64	2.77	4.09	7.32	9.56	12.86	16.60	18.23	19.28
500	1.78	3.03	4.50	8.15	10.68	14.40	18.58	20.32	21.41

Table 3-2B. Partial duration rainfall for Inarajan (914278), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.68	1.03	1.41	2.15	2.78	3.47	4.25	5.15	5.75
2	0.79	1.20	1.64	2.59	3.45	4.42	5.50	6.55	7.31
5	0.94	1.42	1.95	3.18	4.32	5.68	7.17	8.41	9.37
10	1.06	1.58	2.19	3.62	4.99	6.63	8.43	9.81	10.92
25	1.21	1.80	2.50	4.21	5.87	7.89	10.09	11.67	12.98
50	1.32	1.97	2.73	4.65	6.53	8.84	11.35	13.07	14.53
100	1.44	2.14	2.97	5.09	7.20	9.80	12.61	14.48	16.09
200	1.55	2.30	3.20	5.53	7.86	10.75	13.87	15.88	17.64
500	1.70	2.52	3.51	6.12	8.74	12.01	15.53	17.74	19.70

Table 3-2C. Partial duration rainfall for Piti (914670), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.83	1.29	1.76	2.64	3.36	4.21	4.85	5.96	6.61
2	1.06	1.63	2.18	3.30	4.24	5.26	6.06	7.33	8.04
5	1.35	2.08	2.73	4.18	5.40	6.64	7.67	9.14	9.93
10	1.58	2.43	3.14	4.85	6.28	7.69	8.89	10.51	11.36
25	1.88	2.88	3.69	5.73	7.44	9.08	10.49	12.32	13.25
50	2.10	3.22	4.11	6.40	8.32	10.13	11.71	13.69	14.68
100	2.33	3.56	4.52	7.06	9.20	11.18	12.93	15.06	16.11
200	2.55	3.90	4.94	7.73	10.08	12.22	14.14	16.43	17.54
500	2.85	4.36	5.49	8.61	11.24	13.61	15.75	18.24	19.42

Table 3-2D. Partial duration rainfall for Taguac (914229), Guam

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.50	2.31	3.07	4.06	5.30	6.29	7.18
2	1.98	2.82	3.81	5.25	6.91	8.02	8.98
5	2.62	3.50	4.78	6.82	9.05	10.30	11.36
10	3.10	4.01	5.52	8.01	10.67	12.02	13.16
25	3.73	4.68	6.49	9.58	12.81	14.30	15.53
50	4.21	5.20	7.23	10.76	14.43	16.02	17.33
100	4.69	5.71	7.97	11.95	16.05	17.74	19.13
200	5.17	6.22	8.70	13.14	17.66	19.46	20.93
500	5.80	6.89	9.68	14.70	19.80	21.74	23.31

Table 3-2E. Partial duration rainfall for Capitol Hill (914080), Saipan, CNMI.

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.67	0.98	1.23	1.78	2.08	2.47	2.97	3.80	4.28
2	0.82	1.25	1.63	2.44	2.96	3.48	4.14	5.29	5.95
5	1.03	1.60	2.16	3.31	4.12	4.81	5.68	7.26	8.14
10	1.19	1.87	2.56	3.97	5.00	5.82	6.84	8.75	9.81
25	1.40	2.23	3.09	4.85	6.16	7.15	8.38	10.73	12.00
50	1.56	2.50	3.49	5.50	7.04	8.16	9.54	12.22	13.67
100	1.71	2.77	3.89	6.16	7.91	9.16	10.71	13.71	15.33
200	1.87	3.04	4.29	6.82	8.79	10.17	11.87	15.20	16.99
500	2.08	3.40	4.82	7.69	9.95	11.50	13.41	17.17	19.19

Table 3-2F. Partial duration rainfall for Rota (914801), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.74	1.16	1.60	2.44	3.03	3.72	4.31	5.45	6.20
2	0.91	1.45	2.07	3.24	4.11	5.14	5.99	7.42	8.15
5	1.14	1.82	2.68	4.31	5.55	7.01	8.22	10.02	10.73
10	1.31	2.11	3.15	5.12	6.63	8.43	9.90	11.99	12.68
25	1.54	2.49	3.77	6.18	8.06	10.30	12.13	14.59	15.25
50	1.71	2.78	4.24	6.99	9.14	11.72	13.81	16.56	17.20
100	1.88	3.06	4.71	7.80	10.23	13.14	15.49	18.53	19.15
200	2.05	3.35	5.17	8.60	11.31	14.56	17.18	20.50	21.10
500	2.28	3.73	5.79	9.67	12.74	16.43	19.40	23.10	23.67

Table 3-2G. Partial duration rainfall for Saipan International Airport (914855), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.77	1.17	1.63	2.36	2.87	3.55	4.28	5.32	6.04
2	0.98	1.45	2.03	3.03	3.84	4.97	6.06	7.33	8.09
5	1.25	1.83	2.55	3.92	5.13	6.84	8.41	10.00	10.80
10	1.46	2.11	2.95	4.59	6.10	8.26	10.19	12.01	12.84
25	1.73	2.48	3.48	5.48	7.39	10.13	12.54	14.68	15.55
50	1.94	2.77	3.88	6.15	8.36	11.55	14.32	16.69	17.60
100	2.14	3.05	4.28	6.82	9.33	12.97	16.10	18.70	19.65
200	2.35	3.33	4.68	7.49	10.31	14.39	17.88	20.72	21.70
500	2.62	3.70	5.21	8.38	11.59	16.26	20.24	23.38	24.40

Table 3-2H. Partial duration rainfall for Yap WSO (914951), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.82	2.84	3.27	4.08	4.99	5.77	6.20
2	2.14	3.37	3.86	4.88	6.17	7.33	7.84
5	2.57	4.08	4.65	5.93	7.72	9.40	10.01
10	2.90	4.62	5.24	6.72	8.90	10.96	11.65
25	3.33	5.33	6.03	7.78	10.45	13.03	13.81
50	3.66	5.87	6.63	8.57	11.63	14.59	15.45
100	3.98	6.41	7.22	9.37	12.81	16.15	17.09
200	4.31	6.95	7.82	10.16	13.98	17.72	18.73
500	4.74	7.66	8.60	11.22	15.54	19.78	20.89

Table 3-2I. Partial duration rainfall for Chuuk (914851), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.84	2.83	3.65	4.54	5.35	6.51	7.70
2	2.04	3.32	4.17	5.21	6.09	7.66	8.77
5	2.30	3.97	4.85	6.10	7.06	9.19	10.18
10	2.50	4.46	5.37	6.78	7.80	10.35	11.25
25	2.76	5.11	6.05	7.67	8.78	11.88	12.66
50	2.96	5.60	6.57	8.35	9.52	13.03	13.73
100	3.16	6.10	7.08	9.02	10.26	14.19	14.80
200	3.36	6.59	7.60	9.70	10.99	15.34	15.86
500	3.62	7.24	8.28	10.59	11.97	16.87	17.27

Table 3-2J. Partial duration rainfall for Pohnpei Hospital (914745), FSM

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	0.96	1.49	2.11	3.17	4.07	5.08	6.23	7.54	8.33
2	1.11	1.74	2.51	3.79	4.93	6.44	7.82	9.06	9.85
5	1.32	2.08	3.04	4.61	6.06	8.24	9.92	11.06	11.86
10	1.47	2.33	3.44	5.23	6.92	9.60	11.51	12.57	13.38
25	1.67	2.67	3.97	6.05	8.06	11.40	13.61	14.57	15.39
50	1.83	2.92	4.37	6.67	8.92	12.76	15.19	16.09	16.92
100	1.98	3.18	4.77	7.29	9.78	14.12	16.78	17.60	18.44
200	2.14	3.43	5.17	7.91	10.63	15.48	18.37	19.11	19.96
500	2.34	3.77	5.70	8.73	11.77	17.28	20.47	21.11	21.97

Table 3-2K. Partial duration rainfall for Pohnpei WSO (914751), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.96	3.06	4.24	5.25	6.17	7.75	8.28
2	2.31	3.85	5.34	6.71	7.91	9.66	10.30
5	2.78	4.91	6.78	8.65	10.20	12.17	12.97
10	3.13	5.70	7.87	10.12	11.94	14.08	14.99
25	3.59	6.75	9.32	12.06	14.23	16.59	17.66
50	3.94	7.55	10.41	13.53	15.97	18.50	19.68
100	4.29	8.35	11.50	15.00	17.71	20.40	21.70
200	4.64	9.14	12.59	16.47	19.44	22.31	23.71
500	5.10	10.19	14.04	18.41	21.74	24.82	26.38

Table 3-2L. Partial duration rainfall for Kosrae (914395), FSM

Return Period	24-hour	48-hour	72-hour
1	5.62	7.03	7.75
2	6.98	8.61	9.77
5	8.79	10.70	12.44
10	10.15	12.28	14.45
25	11.95	14.38	17.12
50	13.32	15.96	19.14
100	14.68	17.54	21.16
200	16.04	19.12	23.18
500	17.85	21.22	25.85

Table 3-2M. Partial duration rainfall for Koror (914351), Palau

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.90	3.22	4.19	5.09	5.80	6.95	7.72
2	2.22	3.84	4.80	6.14	7.22	8.56	9.35
5	2.65	4.66	5.60	7.52	9.08	10.69	11.51
10	2.97	5.27	6.20	8.57	10.50	12.30	13.14
25	3.40	6.09	7.01	9.96	12.37	14.43	15.29
50	3.73	6.71	7.61	11.00	13.78	16.04	16.92
100	4.05	7.33	8.22	12.05	15.19	17.65	18.55
200	4.37	7.94	8.82	13.10	16.61	19.26	20.18
500	4.80	8.76	9.63	14.48	18.48	21.38	22.33

Table 3-2N. Partial duration rainfall for Majuro (914460), Marshall Islands (1958-70)

Return Period	5-min	10-min	15-min	30-min	60-min
1	0.40	0.68	0.89	1.42	2.01
2	0.44	0.75	1.00	1.57	2.20
5	0.51	0.86	1.15	1.78	2.45
10	0.55	0.93	1.27	1.93	2.64
25	0.61	1.03	1.42	2.13	2.89
50	0.66	1.11	1.53	2.28	3.08
100	0.71	1.18	1.64	2.44	3.27
200	0.75	1.26	1.76	2.59	3.46
500	0.81	1.36	1.91	2.79	3.71

Table 3-2O. Partial duration rainfall for Majuro (914460), Marshall Islands (1984-2005)

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.84	2.84	3.66	4.40	5.23	5.84	6.50
2	2.05	3.31	4.36	5.38	6.29	6.98	7.84
5	2.34	3.92	5.29	6.68	7.69	8.49	9.61
10	2.55	4.39	5.99	7.66	8.74	9.63	10.94
25	2.84	5.00	6.91	8.96	10.14	11.14	12.71
50	3.05	5.47	7.62	9.94	11.19	12.29	14.05
100	3.26	5.93	8.32	10.92	12.25	13.43	15.38
200	3.48	6.40	9.02	11.90	13.31	14.57	16.72
500	3.76	7.01	9.94	13.20	14.70	16.08	18.49

Table 3-2P. Partial duration rainfall for Atu'u (914060), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.00	1.48	2.24	3.68	4.69	5.34	6.30	7.93	9.13
2	1.21	1.71	2.57	4.21	5.39	6.28	7.63	9.50	10.91
5	1.48	2.01	3.01	4.92	6.33	7.51	9.40	11.58	13.26
10	1.69	2.25	3.35	5.45	7.03	8.45	10.74	13.15	15.03
25	1.96	2.55	3.79	6.15	7.96	9.68	12.51	15.23	17.38
50	2.17	2.78	4.12	6.68	8.67	10.62	13.84	16.81	19.16
100	2.38	3.01	4.46	7.22	9.37	11.55	15.18	18.38	20.93
200	2.58	3.24	4.79	7.75	10.08	12.49	16.52	19.95	22.71
500	2.86	3.55	5.23	8.45	11.01	13.72	18.28	22.03	25.05

Table 3-2Q. Partial duration rainfall for Malaeloa (914594), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.02	1.62	2.35	3.27	4.07	5.23	6.28	7.94	9.04
2	1.23	1.86	2.67	3.92	4.84	6.07	7.29	9.25	10.69
5	1.51	2.19	3.09	4.77	5.87	7.18	8.63	10.99	12.88
10	1.73	2.43	3.40	5.42	6.64	8.02	9.65	12.30	14.53
25	2.01	2.75	3.82	6.28	7.66	9.13	10.99	14.04	16.72
50	2.23	3.00	4.14	6.93	8.43	9.97	12.00	15.35	18.38
100	2.44	3.24	4.45	7.58	9.20	10.80	13.02	16.66	20.03
200	2.65	3.48	4.77	8.22	9.98	11.64	14.03	17.98	21.69
500	2.94	3.81	5.19	9.08	11.00	12.75	15.37	19.71	23.87

Table 3-2R. Partial duration rainfall for Wake Island (914901)

Return Period	60-min	3-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	1.11	1.70	1.96	2.31	2.73	3.40	3.71
2	1.33	2.21	2.68	3.22	3.82	4.83	5.21
5	1.62	2.87	3.63	4.42	5.26	6.71	7.19
10	1.83	3.37	4.34	5.33	6.35	8.14	8.68
25	2.12	4.04	5.29	6.53	7.79	10.03	10.66
50	2.34	4.54	6.01	7.44	8.88	11.46	12.15
100	2.56	5.04	6.72	8.35	9.97	12.89	13.65
200	2.78	5.54	7.44	9.26	11.06	14.31	15.15
500	3.07	6.21	8.39	10.46	12.50	16.20	17.12

Appendix 4 Partial Duration Series Standard Error Results

Table 4-1 was used as the basis for computing standard error of partial duration rainfall values.

Table 4-1. Partial Duration, Annual Series Return Period, and Reduced Variable

Return Period in years Partial Duration Series	Return Period in years Annual Series	Reduced Variable, Y_T
1	1.58	0.00003
2	2.54	0.69289
5	5.52	1.60951
10	10.51	2.30255
25	25.5	3.21886
50	50.5	3.91203
100	100.5	4.60517
200	200.5	5.29832
500	500.5	6.21461

Table 4-1 is based on equations from Chow (1988) and Kite (1977).

$T_{pd} = 1 / (\text{Ln} (T_{as} / (T_{as} - 1)))$

Where: T_{pd} = return period for partial duration series, years
T_{as} = return period for annual series, years
Ln = natural logarithm

$Y_T = - \text{Ln} (- \text{Ln} ((T_{as} - 1) / T_{as}))$

Where: Y_T = reduced variable for Gumbel probability distribution.
The practical interpretation of Y_T is that it is a plotting position. If the values of rainfall frequency calculated from the Gumbel distribution are plotted against the value of Y_T on log-probability paper, the result will be a straight line.

The equation for standard error (S_x) from Kite (1977) is:

$S_x = [(1.1086 + 0.514*Y_T + 0.6079*Y_T^2) / (N / \sigma^2)]^{0.5}$

Where: N = years of record
σ = standard deviation

The equation for standard error was solved for each station and set of durations for the reduced variables (Y_T) in Table 4-1. Tables 4-2A to 4-2Q contain rainfall values (inches) for plus and minus one standard error from the partial duration rainfalls of Appendix 3.

Table 4-2A-1. Partial duration rainfall plus one standard error for Fena Lake (914200), Guam.

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.84	1.28	1.81	2.72	3.35	4.32	5.59
2	0.95	1.50	2.14	3.40	4.26	5.57	7.21
5	1.12	1.80	2.60	4.32	5.51	7.29	9.42
10	1.24	2.03	2.95	5.03	6.47	8.61	11.12
25	1.40	2.33	3.42	5.98	7.75	10.37	13.38
50	1.53	2.56	3.78	6.69	8.71	11.70	15.10
100	1.65	2.80	4.13	7.41	9.69	13.03	16.82
200	1.78	3.03	4.49	8.13	10.66	14.37	18.54
500	1.95	3.33	4.96	9.08	11.94	16.13	20.82

Table 4-2A-2. Partial duration rainfall minus one standard error for Fena Lake (914200), Guam.

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.77	1.16	1.62	2.35	2.84	3.63	4.70
2	0.87	1.35	1.91	2.93	3.62	4.70	6.08
5	1.00	1.59	2.27	3.66	4.61	6.06	7.83
10	1.09	1.76	2.54	4.20	5.34	7.06	9.13
25	1.22	1.99	2.89	4.91	6.30	8.38	10.83
50	1.31	2.16	3.16	5.45	7.03	9.38	12.11
100	1.40	2.33	3.42	5.98	7.75	10.37	13.39
200	1.50	2.51	3.69	6.51	8.47	11.36	14.66
500	1.62	2.73	4.04	7.22	9.42	12.67	16.35

Table 4-2B-1. Partial duration rainfall plus one standard error for Inarajan (914278), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.71	1.08	1.48	2.28	2.98	3.75	4.61
2	0.83	1.26	1.73	2.75	3.69	4.77	5.97
5	1.00	1.50	2.08	3.41	4.67	6.17	7.82
10	1.13	1.69	2.34	3.91	5.42	7.25	9.25
25	1.30	1.94	2.69	4.58	6.42	8.69	11.14
50	1.43	2.13	2.96	5.08	7.18	9.78	12.58
100	1.56	2.32	3.23	5.59	7.94	10.87	14.02
200	1.70	2.51	3.50	6.10	8.71	11.96	15.46
500	1.87	2.77	3.85	6.77	9.71	13.40	17.37

Table 4-2B-2. Partial duration rainfall minus one standard error for Inarajan (914278), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.64	0.98	1.34	2.02	2.59	3.19	3.88
2	0.75	1.14	1.56	2.43	3.20	4.07	5.04
5	0.88	1.33	1.83	2.95	3.98	5.18	6.51
10	0.98	1.48	2.03	3.33	4.56	6.01	7.61
25	1.11	1.67	2.30	3.84	5.31	7.09	9.04
50	1.21	1.81	2.50	4.21	5.88	7.91	10.12
100	1.31	1.95	2.70	4.59	6.45	8.73	11.19
200	1.41	2.09	2.90	4.97	7.02	9.54	12.27
500	1.53	2.28	3.17	5.47	7.77	10.61	13.69

Table 4-2C-1. Partial duration rainfall plus one standard error for Piti (914670), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.90	1.39	1.88	2.83	3.62	4.51	5.20
2	1.14	1.76	2.33	3.55	4.56	5.64	6.51
5	1.47	2.26	2.94	4.53	5.86	7.19	8.30
10	1.73	2.65	3.41	5.29	6.85	8.38	9.68
25	2.06	3.16	4.04	6.29	8.17	9.95	11.51
50	2.32	3.55	4.52	7.05	9.18	11.15	12.90
100	2.58	3.95	4.99	7.81	10.18	12.35	14.29
200	2.84	4.34	5.47	8.58	11.19	13.56	15.69
500	3.18	4.86	6.10	9.59	12.52	15.15	17.53

Table 4-2C-2. Partial duration rainfall minus one standard error for Piti (914670), Guam

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.77	1.19	1.64	2.44	3.10	3.90	4.49
2	0.97	1.51	2.02	3.06	3.92	4.87	5.61
5	1.24	1.91	2.51	3.84	4.94	6.10	7.04
10	1.43	2.20	2.87	4.42	5.71	7.01	8.09
25	1.69	2.59	3.34	5.18	6.71	8.20	9.48
50	1.88	2.89	3.70	5.75	7.46	9.10	10.52
100	2.07	3.18	4.06	6.32	8.21	10.00	11.56
200	2.27	3.47	4.41	6.89	8.96	10.89	12.60
500	2.52	3.86	4.88	7.64	9.95	12.08	13.97

Table 4-2D-1. Partial duration rainfall plus one standard error for Taguac (914229), Guam

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.70	2.52	3.37	4.55	5.95
2	2.23	3.08	4.19	5.86	7.74
5	2.96	3.87	5.32	7.68	10.22
10	3.53	4.47	6.19	9.08	12.14
25	4.29	5.28	7.35	10.95	14.69
50	4.86	5.89	8.23	12.37	16.63
100	5.44	6.50	9.12	13.80	18.57
200	6.01	7.12	10.00	15.23	20.52
500	6.78	7.93	11.18	17.12	23.09

Table 4-2D-2. Partial duration rainfall minus one standard error for Taguac (914229), Guam.

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.31	2.10	2.77	3.58	4.64
2	1.74	2.56	3.43	4.64	6.09
5	2.27	3.13	4.25	5.96	7.88
10	2.66	3.55	4.85	6.93	9.21
25	3.17	4.09	5.64	8.20	10.93
50	3.56	4.50	6.23	9.15	12.23
100	3.94	4.91	6.82	10.10	13.52
200	4.32	5.32	7.41	11.04	14.81
500	4.83	5.85	8.18	12.29	16.52

Table 4-2E-1. Partial duration rainfall plus one standard error for Capitol Hill (914080), Saipan, CNMI.

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.72	1.07	1.37	2.01	2.39	2.82	3.38
2	0.89	1.37	1.80	2.73	3.35	3.92	4.65
5	1.13	1.77	2.40	3.72	4.66	5.43	6.40
10	1.31	2.08	2.87	4.49	5.68	6.60	7.75
25	1.55	2.50	3.49	5.50	7.03	8.15	9.54
50	1.74	2.82	3.95	6.27	8.06	9.33	10.90
100	1.92	3.13	4.42	7.05	9.09	10.51	12.27
200	2.11	3.45	4.89	7.82	10.12	11.69	13.63
500	2.35	3.87	5.52	8.84	11.48	13.26	15.44

Table 4-2E-2. Partial duration rainfall minus one standard error for Capitol Hill (914080), Saipan, CNMI.

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.61	0.88	1.09	1.55	1.78	2.12	2.57
2	0.76	1.13	1.45	2.15	2.58	3.03	3.63
5	0.93	1.44	1.91	2.91	3.58	4.18	4.95
10	1.07	1.67	2.25	3.46	4.32	5.03	5.93
25	1.24	1.96	2.69	4.19	5.28	6.14	7.22
50	1.37	2.19	3.02	4.74	6.01	6.98	8.19
100	1.50	2.41	3.35	5.28	6.74	7.81	9.15
200	1.63	2.63	3.68	5.83	7.46	8.65	10.11
500	1.80	2.93	4.12	6.54	8.42	9.74	11.38

Table 4-2F-1. Partial duration rainfall plus one standard error for Rota (914801), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.79	1.25	1.75	2.69	3.37	4.17	4.85
2	0.98	1.56	2.25	3.56	4.54	5.70	6.67
5	1.23	1.99	2.95	4.76	6.16	7.81	9.17
10	1.43	2.31	3.48	5.69	7.39	9.43	11.09
25	1.69	2.75	4.19	6.91	9.04	11.59	13.65
50	1.89	3.08	4.73	7.85	10.29	13.22	15.60
100	2.09	3.41	5.27	8.78	11.55	14.86	17.54
200	2.29	3.74	5.82	9.71	12.80	16.51	19.49
500	2.55	4.18	6.53	10.95	14.46	18.68	22.07

Table 4-2F-2. Partial duration rainfall minus one standard error for Rota (914801), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.68	1.07	1.45	2.18	2.69	3.27	3.78
2	0.84	1.33	1.88	2.92	3.68	4.57	5.32
5	1.04	1.66	2.42	3.85	4.93	6.21	7.27
10	1.19	1.91	2.82	4.55	5.86	7.43	8.71
25	1.38	2.23	3.35	5.45	7.08	9.02	10.60
50	1.53	2.47	3.74	6.13	8.00	10.22	12.03
100	1.67	2.71	4.14	6.82	8.91	11.41	13.45
200	1.82	2.96	4.53	7.49	9.82	12.61	14.86
500	2.01	3.27	5.05	8.39	11.03	14.18	16.73

Table 4-2G-1. Partial duration rainfall plus one standard error for Saipan International Airport (914855), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.83	1.26	1.75	2.56	3.16	3.98	4.82
2	1.06	1.56	2.18	3.29	4.21	5.51	6.74
5	1.36	1.98	2.77	4.28	5.65	7.61	9.38
10	1.60	2.30	3.23	5.04	6.76	9.22	11.40
25	1.91	2.73	3.83	6.06	8.23	11.36	14.09
50	2.14	3.05	4.29	6.83	9.35	12.99	16.13
100	2.38	3.38	4.75	7.61	10.47	14.62	18.18
200	2.62	3.70	5.21	8.38	11.59	16.26	20.23
500	2.93	4.13	5.82	9.40	13.07	18.42	22.94

Table 4-2G-2. Partial duration rainfall minus one standard error for Saipan International Airport (914855), CNMI

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.71	1.09	1.50	2.15	2.57	3.12	3.74
2	0.90	1.35	1.87	2.77	3.47	4.43	5.38
5	1.14	1.68	2.34	3.55	4.60	6.08	7.45
10	1.32	1.92	2.68	4.13	5.44	7.30	8.99
25	1.55	2.24	3.14	4.89	6.54	8.90	11.00
50	1.73	2.48	3.48	5.47	7.37	10.11	12.51
100	1.90	2.72	3.82	6.04	8.20	11.31	14.03
200	2.08	2.96	4.15	6.61	9.02	12.52	15.54
500	2.31	3.27	4.60	7.36	10.11	14.10	17.53

Table 4-2H-1. Partial duration rainfall plus one standard error for Yap WSO (914951), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.95	3.05	3.50	4.39	5.45
2	2.30	3.64	4.16	5.27	6.75
5	2.80	4.46	5.07	6.48	8.54
10	3.19	5.09	5.77	7.42	9.93
25	3.70	5.94	6.70	8.67	11.77
50	4.09	6.58	7.41	9.62	13.18
100	4.47	7.22	8.12	10.57	14.58
200	4.86	7.86	8.83	11.52	15.99
500	5.38	8.71	9.77	12.78	17.85

Table 4-2H-2. Partial duration rainfall minus one standard error for Yap WSO (914951), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.69	2.63	3.04	3.77	4.53
2	1.98	3.11	3.57	4.48	5.59
5	2.35	3.71	4.24	5.37	6.90
10	2.61	4.15	4.72	6.03	7.87
25	2.97	4.73	5.36	6.88	9.14
50	3.23	5.16	5.85	7.53	10.09
100	3.49	5.60	6.32	8.17	11.03
200	3.75	6.03	6.80	8.81	11.98
500	4.10	6.60	7.43	9.65	13.23

Table 4-2I-1. Partial duration rainfall plus one standard error for Chuuk (914851), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.93	3.06	3.90	4.86	5.70
2	2.16	3.62	4.48	5.62	6.53
5	2.47	4.39	5.29	6.68	7.70
10	2.71	4.99	5.92	7.50	8.59
25	3.04	5.79	6.76	8.60	9.79
50	3.28	6.40	7.40	9.43	10.71
100	3.53	7.01	8.04	10.27	11.62
200	3.78	7.62	8.68	11.11	12.54
500	4.10	8.42	9.53	12.21	13.75

Table 4-2I-2. Partial duration rainfall minus one standard error for Chuuk (914851), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.74	2.59	3.40	4.21	4.99
2	1.92	3.02	3.85	4.80	5.64
5	2.13	3.55	4.41	5.53	6.43
10	2.29	3.93	4.81	6.06	7.01
25	2.49	4.44	5.34	6.74	7.76
50	2.64	4.81	5.74	7.26	8.33
100	2.79	5.19	6.13	7.78	8.89
200	2.94	5.56	6.52	8.29	9.45
500	3.14	6.06	7.04	8.97	10.20

Table 4-2J-1. Partial duration rainfall plus one standard error for Pohnpei Hospital (914745), FSM

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	1.00	1.56	2.23	3.35	4.32	5.49	6.71
2	1.17	1.84	2.66	4.02	5.25	6.95	8.42
5	1.40	2.21	3.25	4.94	6.52	8.96	10.76
10	1.57	2.50	3.71	5.64	7.49	10.50	12.56
25	1.81	2.89	4.31	6.58	8.79	12.56	14.96
50	1.98	3.18	4.77	7.29	9.77	14.12	16.78
100	2.16	3.47	5.23	8.00	10.76	15.68	18.60
200	2.34	3.76	5.69	8.71	11.74	17.24	20.42
500	2.57	4.15	6.30	9.65	13.05	19.31	22.84

Table 4-2J-2. Partial duration rainfall minus one standard error for Pohnpei Hospital (914745), FSM

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.91	1.41	1.99	2.98	3.81	4.67	5.76
2	1.05	1.64	2.36	3.56	4.61	5.93	7.23
5	1.23	1.94	2.83	4.28	5.61	7.52	9.08
10	1.37	2.16	3.17	4.82	6.35	8.70	10.45
25	1.54	2.45	3.63	5.52	7.33	10.24	12.25
50	1.68	2.67	3.97	6.05	8.06	11.40	13.61
100	1.81	2.89	4.31	6.58	8.79	12.56	14.96
200	1.94	3.10	4.65	7.11	9.52	13.72	16.32
500	2.11	3.39	5.10	7.80	10.49	15.25	18.10

Table 4-2K-1. Partial duration rainfall plus one standard error for Pohnpei WSO (914751), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	2.13	3.44	4.77	5.95	7.01
2	2.53	4.34	6.00	7.60	8.96
5	3.08	5.59	7.71	9.91	11.69
10	3.50	6.55	9.04	11.69	13.80
25	4.07	7.85	10.82	14.08	16.62
50	4.50	8.83	12.17	15.89	18.76
100	4.93	9.81	13.52	17.71	20.91
200	5.37	10.80	14.87	19.53	23.06
500	5.94	12.11	16.66	21.93	25.91

Table 4-2K-2. Partial duration rainfall minus one standard error for Pohnpei WSO (914751), FSM

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.80	2.68	3.72	4.54	5.34
2	2.10	3.37	4.67	5.83	6.86
5	2.48	4.23	5.85	7.40	8.72
10	2.75	4.85	6.70	8.55	10.08
25	3.11	5.66	7.82	10.05	11.85
50	3.38	6.27	8.65	11.17	13.18
100	3.64	6.88	9.48	12.29	14.50
200	3.91	7.48	10.32	13.40	15.82
500	4.26	8.28	11.41	14.88	17.56

Table 4-2L-1. Partial duration rainfall plus one standard error for Kosrae (914395), FSM

Return Period	24-hour	48-hour	72-hour
1	6.47	7.79	8.70
2	7.87	9.45	10.76
5	9.76	11.71	13.56
10	11.21	13.43	15.70
25	13.14	15.72	18.55
50	14.60	17.46	20.71
100	16.06	19.20	22.87
200	17.53	20.94	25.03
500	19.46	23.24	27.90

Table 4-2L-2. Partial duration rainfall minus one standard error for Kosrae (914395), FSM

Return Period	24-hour	48-hour	72-hour
1	5.89	7.10	7.84
2	7.14	8.58	9.68
5	8.73	10.48	12.04
10	9.92	11.89	13.80
25	11.48	13.75	16.11
50	12.66	15.15	17.85
100	13.84	16.55	19.58
200	15.01	17.95	21.32
500	16.57	19.80	23.61

Table 4-2M-1. Partial duration rainfall plus one standard error for Koror (914351), Palau

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	2.00	3.42	4.39	5.43	6.26
2	2.35	4.09	5.04	6.56	7.79
5	2.84	5.01	5.95	8.13	9.90
10	3.21	5.72	6.64	9.33	11.52
25	3.70	6.66	7.57	10.93	13.68
50	4.08	7.38	8.27	12.14	15.31
100	4.45	8.09	8.97	13.36	16.95
200	4.83	8.81	9.68	14.57	18.60
500	5.32	9.76	10.61	16.18	20.77

Table 4-2M-2. Partial duration rainfall minus one standard error for Koror (914351), Palau

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.79	3.02	3.99	4.75	5.34
2	2.09	3.59	4.55	5.71	6.64
5	2.46	4.30	5.25	6.92	8.27
10	2.74	4.83	5.77	7.81	9.48
25	3.10	5.52	6.44	8.99	11.06
50	3.37	6.04	6.95	9.87	12.25
100	3.65	6.56	7.46	10.75	13.44
200	3.92	7.07	7.97	11.63	14.62
500	4.28	7.76	8.64	12.79	16.19

Table 4-2N-1. Partial duration rainfall plus one standard error for Majuro (914460), Marshall Islands (1984-2005).

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.91	2.99	3.89	4.72	5.58
2	2.14	3.50	4.65	5.78	6.72
5	2.46	4.19	5.69	7.24	8.29
10	2.71	4.72	6.50	8.37	9.50
25	3.03	5.43	7.56	9.87	11.12
50	3.28	5.97	8.37	11.00	12.34
100	3.53	6.51	9.19	12.14	13.56
200	3.78	7.05	10.00	13.28	14.79
500	4.11	7.77	11.08	14.79	16.41

Table 4-2N-2. Partial duration rainfall minus one standard error for Majuro (914460), Marshall Islands (1984-2005).

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.77	2.69	3.44	4.08	4.89
2	1.97	3.12	4.08	4.98	5.86
5	2.21	3.66	4.89	6.11	7.08
10	2.40	4.05	5.48	6.95	7.98
25	2.64	4.57	6.27	8.05	9.16
50	2.82	4.96	6.86	8.88	10.05
100	3.00	5.35	7.44	9.70	10.94
200	3.18	5.74	8.03	10.52	11.82
500	3.41	6.26	8.81	11.61	12.99

Table 4-2O-1. Partial duration rainfall plus one standard error for Atu'u (914060), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	1.07	1.56	2.35	3.86	4.93	5.66	6.75
2	1.29	1.81	2.72	4.44	5.69	6.68	8.21
5	1.61	2.15	3.22	5.24	6.75	8.08	10.21
10	1.84	2.42	3.60	5.85	7.57	9.16	11.75
25	2.16	2.77	4.11	6.67	8.65	10.59	13.80
50	2.40	3.04	4.50	7.29	9.47	11.68	15.36
100	2.65	3.31	4.89	7.91	10.30	12.77	16.92
200	2.89	3.58	5.28	8.53	11.12	13.86	18.49
500	3.21	3.94	5.80	9.36	12.21	15.31	20.56

Table 4-2O-2. Partial duration rainfall minus one standard error for Atu'u (914060), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.93	1.40	2.13	3.50	4.45	5.03	5.84
2	1.12	1.61	2.43	3.98	5.09	5.88	7.06
5	1.36	1.88	2.81	4.59	5.90	6.95	8.59
10	1.53	2.07	3.10	5.05	6.50	7.74	9.73
25	1.76	2.33	3.47	5.64	7.28	8.78	11.21
50	1.93	2.52	3.74	6.08	7.87	9.56	12.32
100	2.11	2.71	4.02	6.52	8.45	10.33	13.43
200	2.28	2.90	4.30	6.96	9.04	11.11	14.54
500	2.50	3.16	4.66	7.55	9.81	12.13	16.01

Table 4-2P-1. Partial duration rainfall plus one standard error for Malaeloa (914594), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	1.08	1.69	2.45	3.46	4.30	5.48	6.58
2	1.31	1.96	2.79	4.16	5.13	6.39	7.67
5	1.63	2.32	3.25	5.12	6.27	7.63	9.17
10	1.87	2.59	3.61	5.85	7.15	8.58	10.32
25	2.19	2.96	4.09	6.83	8.32	9.84	11.85
50	2.44	3.24	4.45	7.57	9.20	10.80	13.01
100	2.69	3.52	4.82	8.32	10.09	11.76	14.18
200	2.93	3.80	5.18	9.06	10.98	12.73	15.35
500	3.26	4.17	5.66	10.05	12.15	14.00	16.89

Table 4-2P-2. Partial duration rainfall minus one standard error for Malaeloa (914594), Tutuila, American Samoa

Return Period	15-min	30-min	60-min	3-hour	6-hour	12-hour	24-hour
1	0.95	1.55	2.26	3.07	3.84	4.98	5.97
2	1.15	1.77	2.55	3.67	4.55	5.76	6.91
5	1.40	2.06	2.92	4.43	5.46	6.74	8.09
10	1.59	2.27	3.19	4.99	6.12	7.46	8.97
25	1.83	2.55	3.55	5.73	7.00	8.41	10.12
50	2.01	2.75	3.82	6.28	7.66	9.13	10.99
100	2.19	2.96	4.09	6.83	8.32	9.84	11.86
200	2.38	3.17	4.36	7.38	8.98	10.56	12.72
500	2.62	3.44	4.72	8.11	9.85	11.50	13.86

Table 4-2Q-1. Partial duration rainfall plus one standard error for Wake Island (914901)

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.20	1.92	2.28	2.71	3.21
2	1.45	2.48	3.07	3.72	4.42
5	1.79	3.26	4.19	5.13	6.11
10	2.05	3.86	5.04	6.22	7.41
25	2.40	4.67	6.19	7.67	9.16
50	2.66	5.28	7.06	8.77	10.48
100	2.93	5.89	7.93	9.88	11.80
200	3.20	6.50	8.80	10.99	13.13
500	3.55	7.31	9.96	12.45	14.89

Table 4-2Q-2. Partial duration rainfall minus one standard error for Wake Island (914901)

Return Period	60-min	3-hour	6-hour	12-hour	24-hour
1	1.01	1.48	1.65	1.91	2.25
2	1.20	1.93	2.28	2.72	3.22
5	1.44	2.48	3.07	3.71	4.41
10	1.62	2.88	3.64	4.44	5.28
25	1.85	3.41	4.39	5.39	6.42
50	2.02	3.80	4.96	6.11	7.28
100	2.19	4.20	5.52	6.82	8.13
200	2.36	4.59	6.08	7.53	8.98
500	2.59	5.11	6.81	8.46	10.11

Appendix 5 Design Rainfall Distributions for Individual Stations

The results in Figure 5-1 (A through P) were derived from partial duration analyses contained in Appendix 3. Kosrae is not included because durations less than 24 hours were not available.

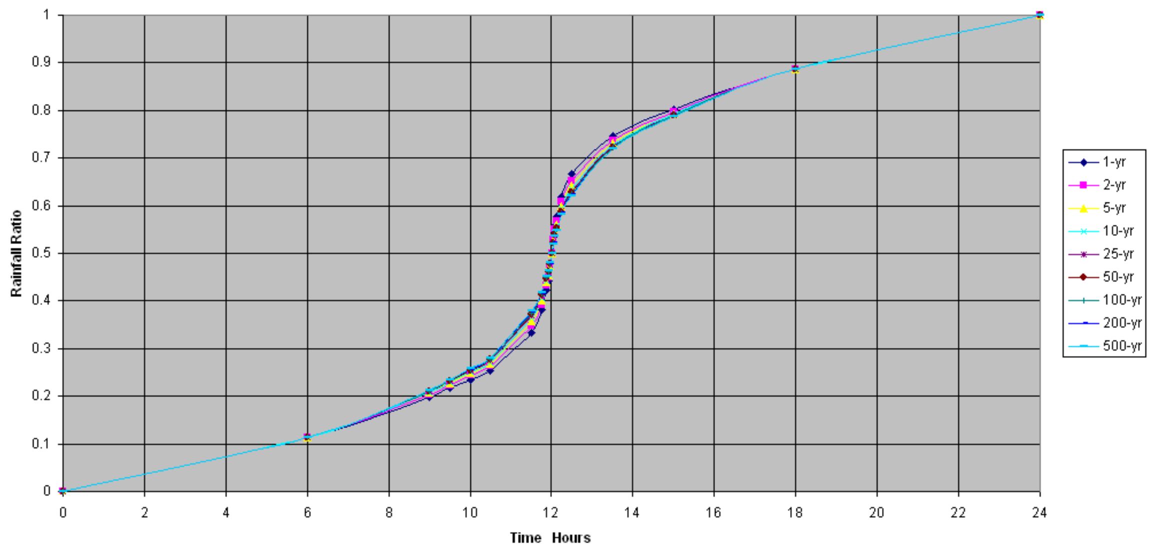

Figure 5-1A. Design rainfall distribution for 1-year to 500-year for Fena Lake (914200), Guam

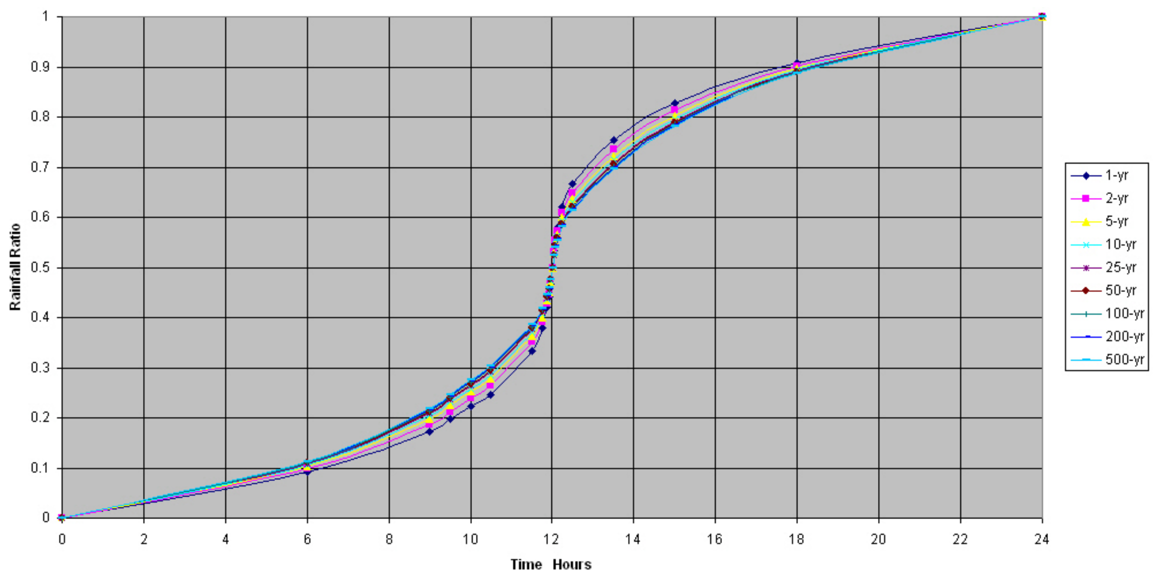

Figure 5-1B. Design rainfall distribution for 1-year to 500-year for Inarajan (914278), Guam

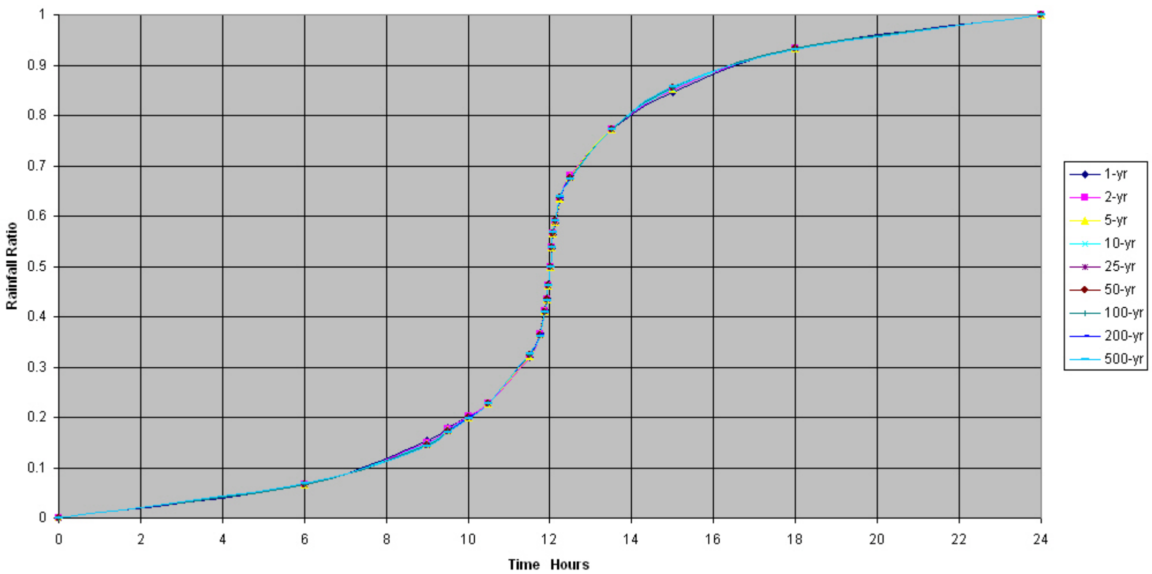

Figure 5-1C. Design rainfall distribution for 1-year to 500-year for Piti (914670), Guam

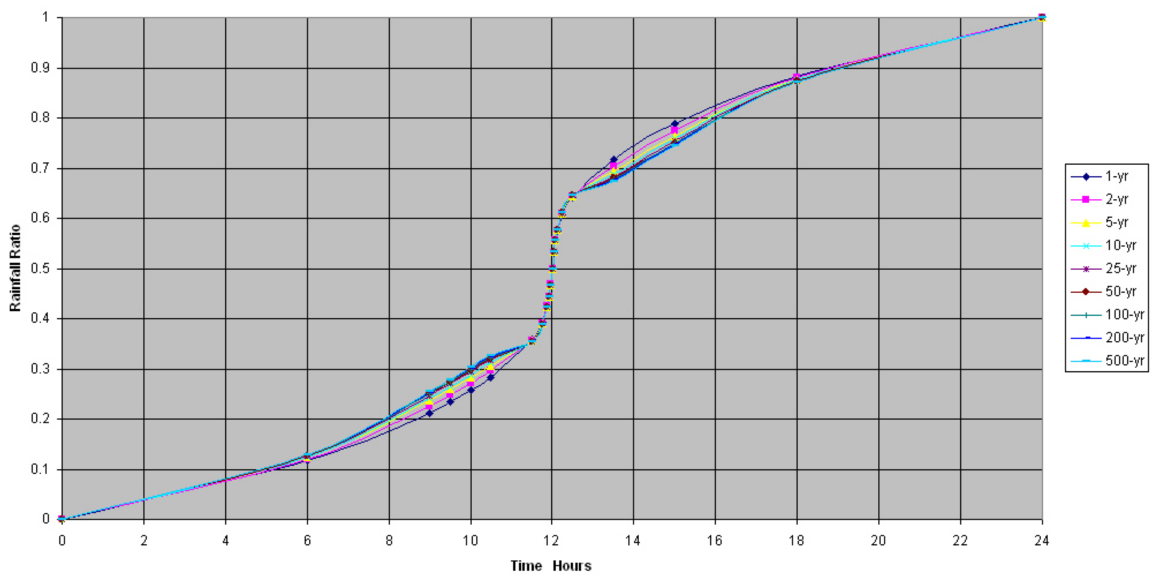

Figure 5-1D. Design rainfall distribution for 1-year to 500-year for Taguac (914229), Guam

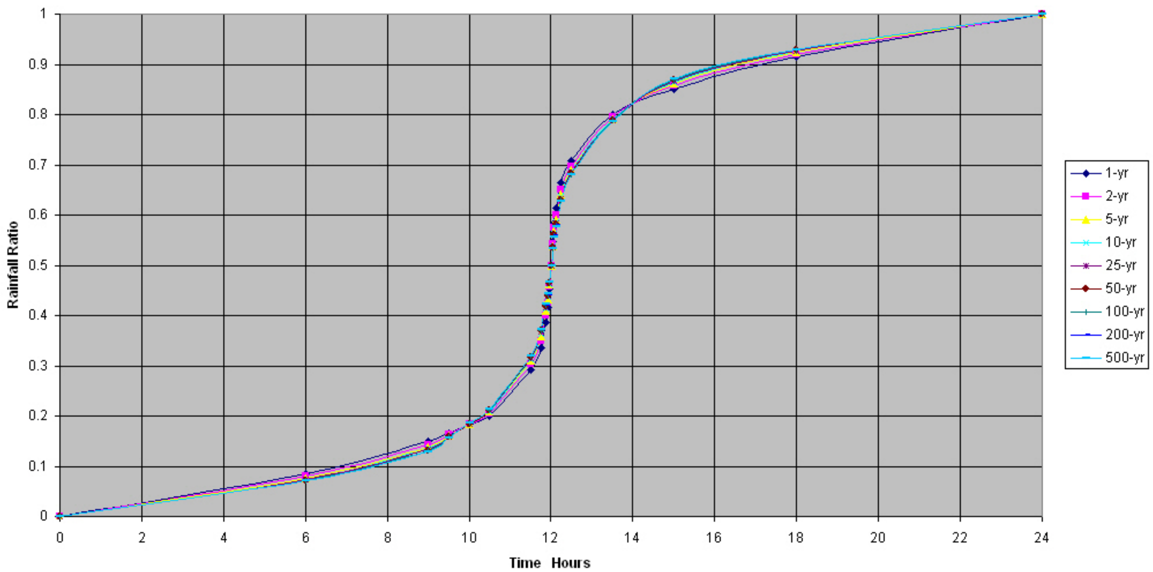

Figure 5-1E. Design rainfall distribution for 1-year to 500-year for Capitol Hill (914080), Saipan, CNMI.

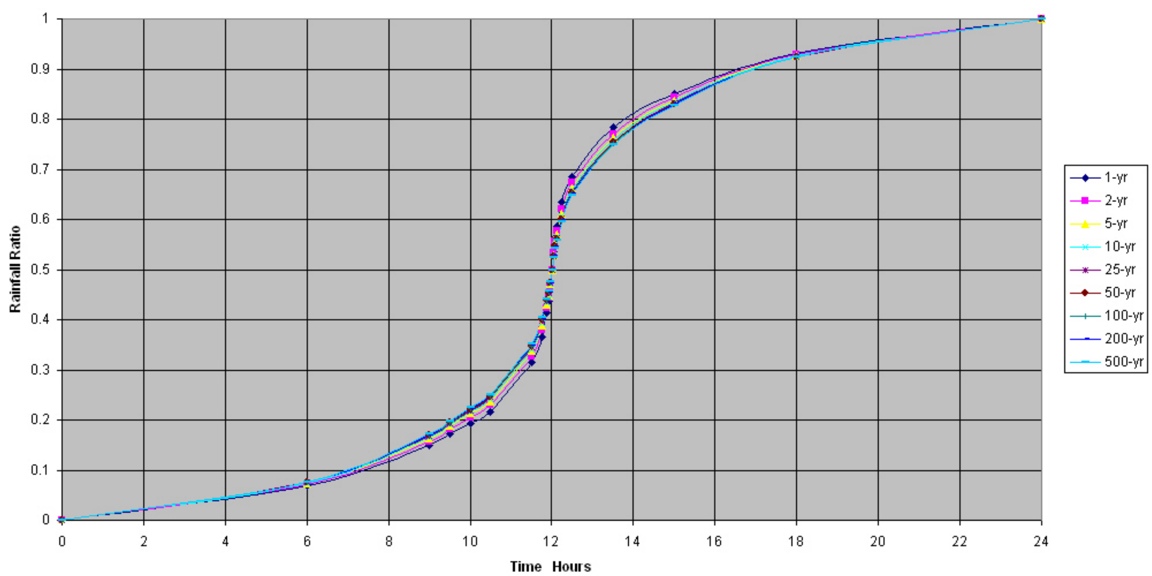

Figure 5-1F. Design rainfall distribution for 1-year to 500-year for Rota (914801), CNMI

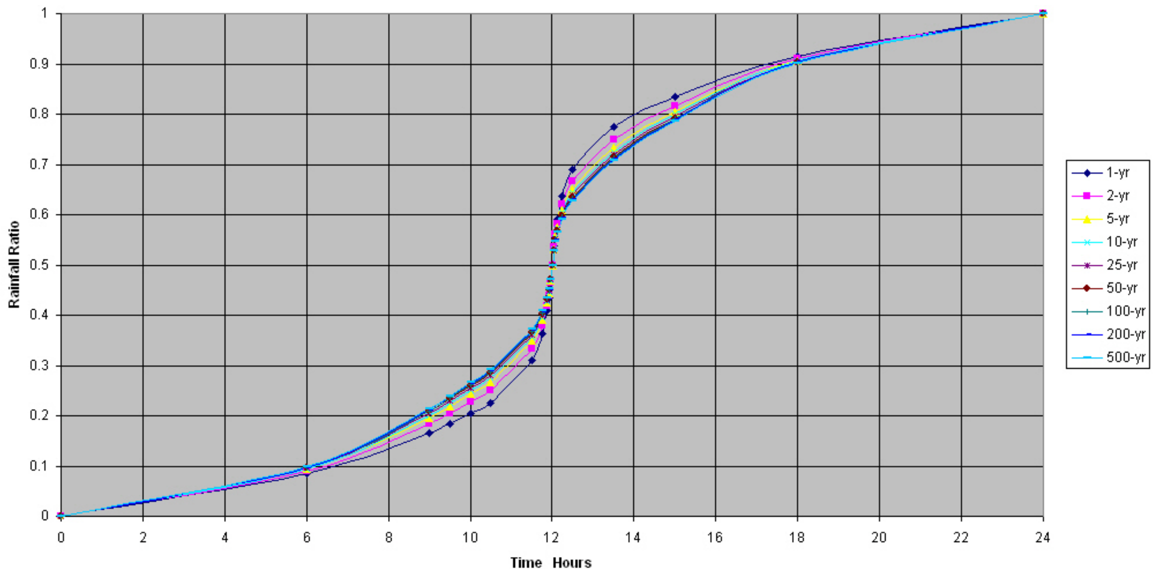

Figure 5-1G. Design rainfall distribution for 1-year to 500-year for Saipan International Airport (914855), CNMI

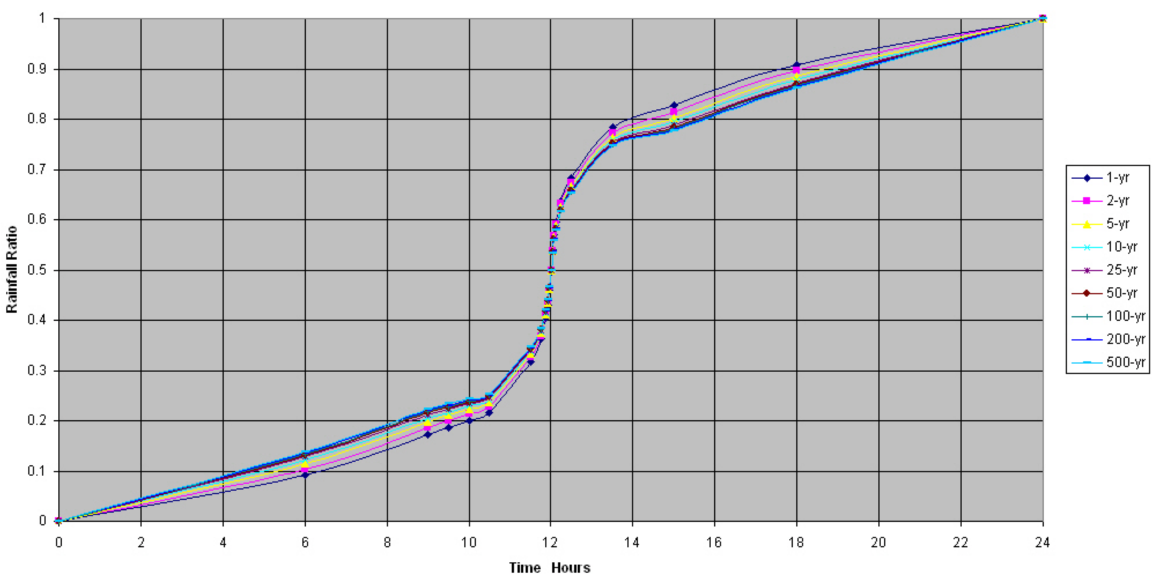

Figure 5-1H. Design rainfall distribution for 1-year to 500-year for Yap WSO (914951), FSM

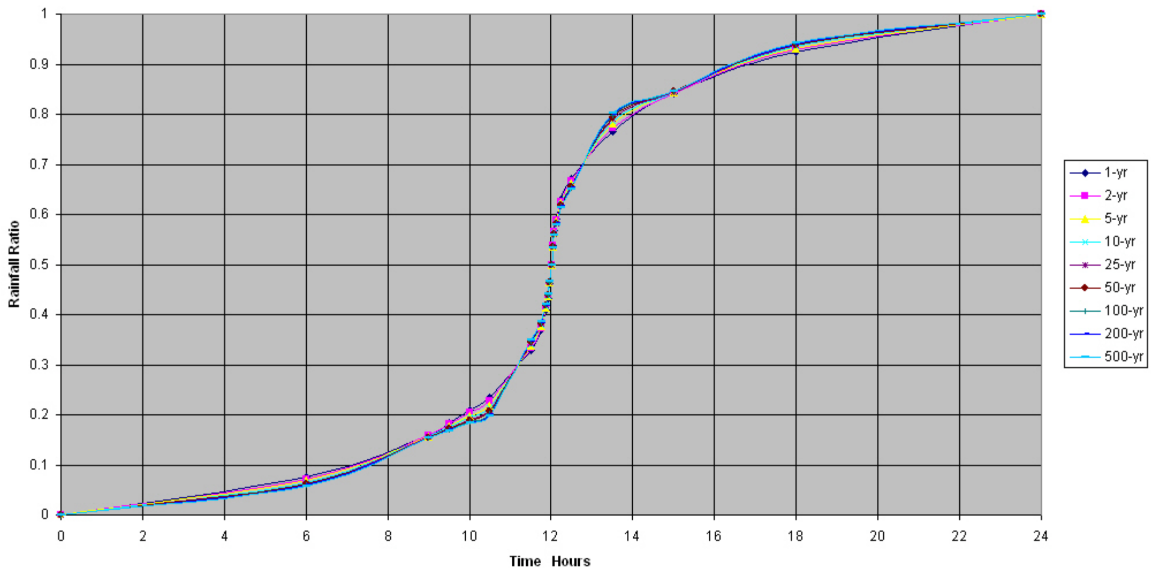

Figure 5-1I. Design rainfall distribution for 1-year to 500-year for Chuuk (914851), FSM

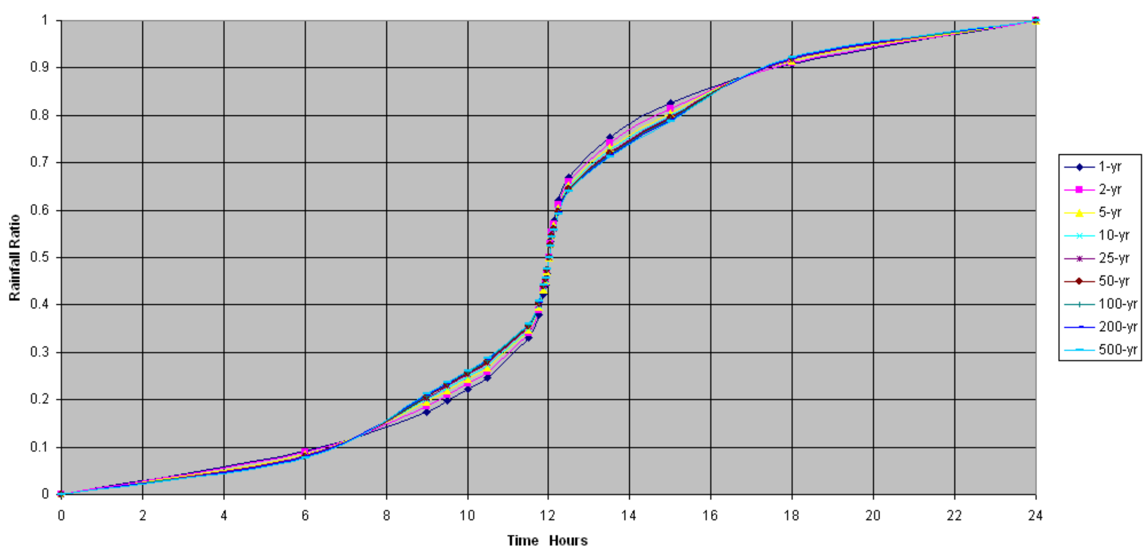

Figure 5-1J. Design rainfall distribution for 1-year to 500-year for Pohnpei Hospital (914745), FSM

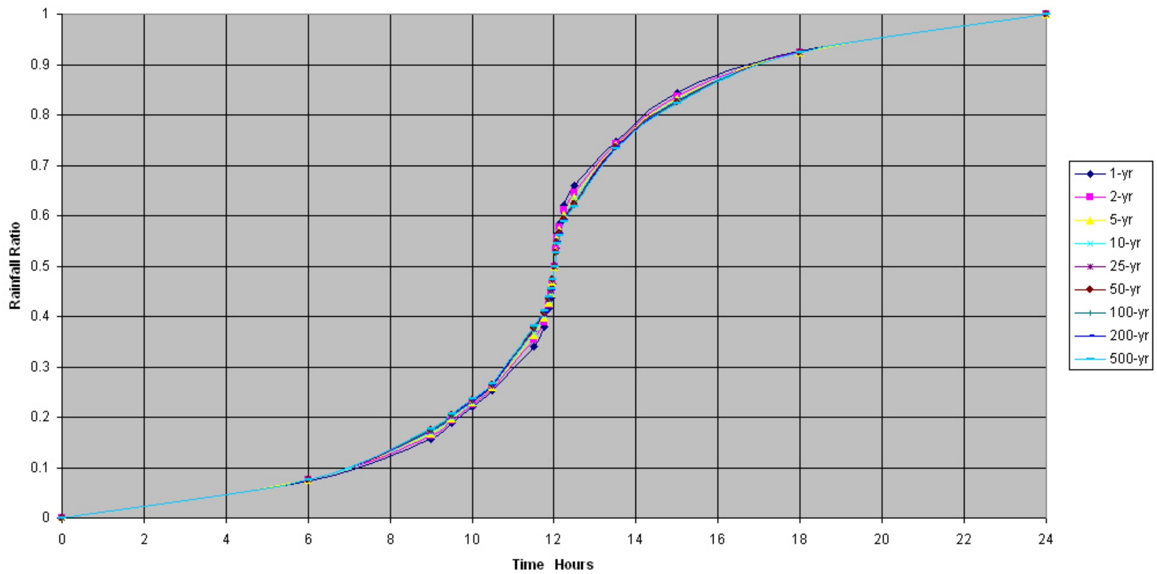

Figure 5-1K. Design rainfall distribution for 1-year to 500-year for Pohnpei WSO (914751), FSM

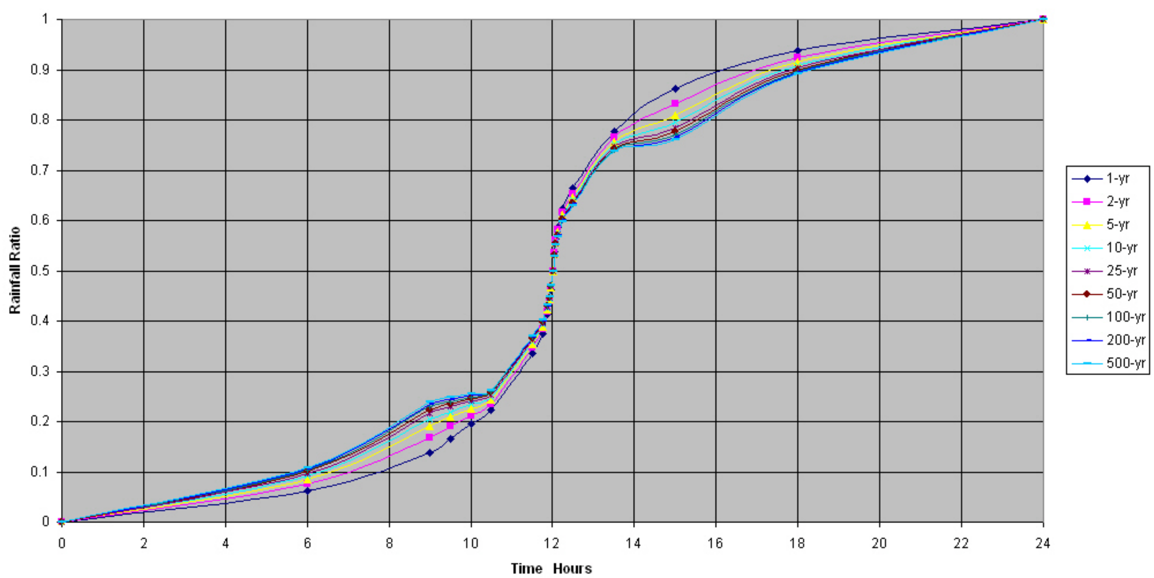

Figure 5-1L. Design rainfall distribution for 1-year to 500-year for Koror (914351), Palau

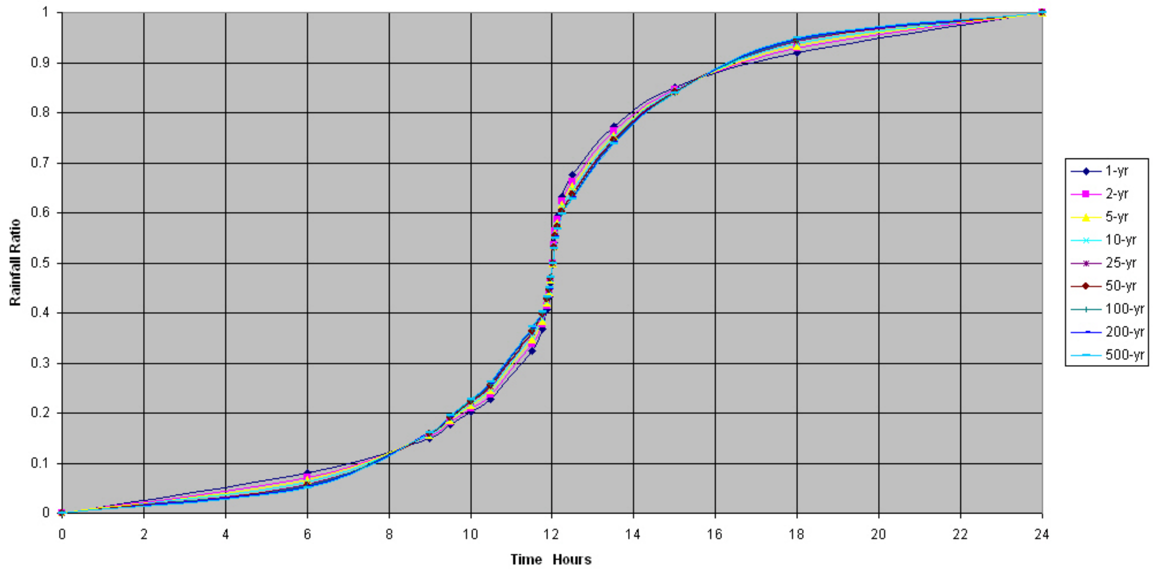

Figure 5-1M. Design rainfall distribution for 1-year to 500-year for Majuro (914460), Marshall Islands based on data from 1984-2005.

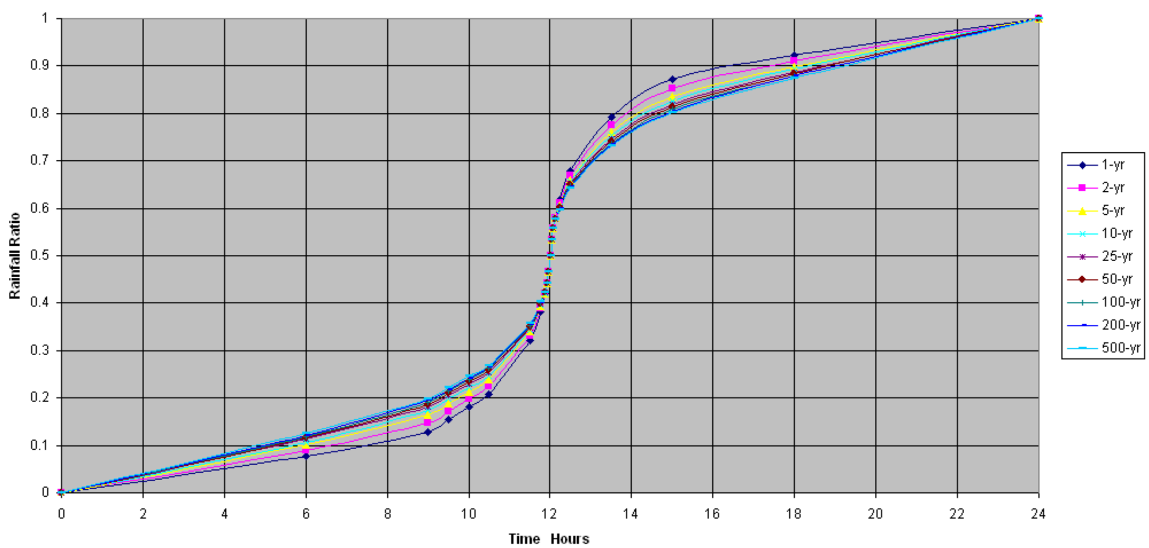

Figure 5-1N. Design rainfall distribution for 1-year to 500-year for Atu'u (914060), Tutuila, American Samoa.

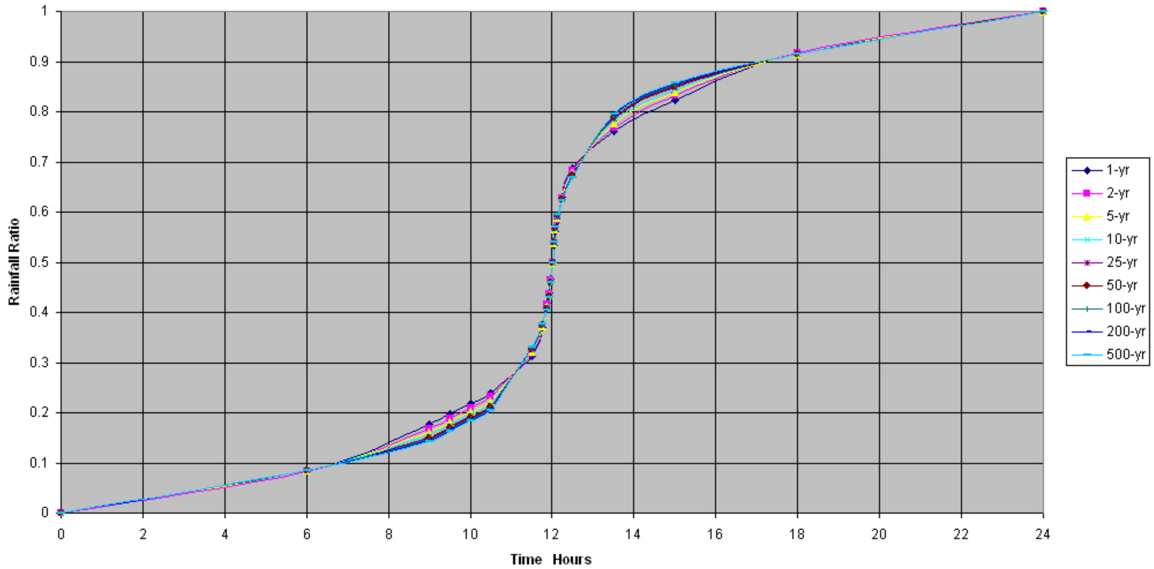

Figure 5-1O. Design rainfall distribution for 1-year to 500-year for Malaeloa (914594), Tutuila, American Samoa.

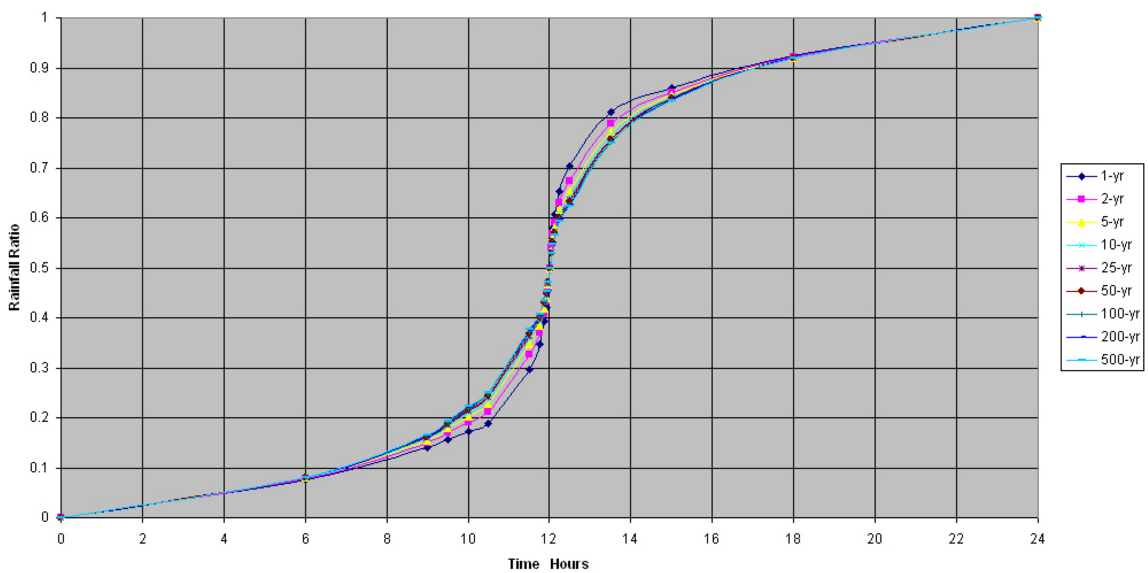

Figure 5-1P. Design rainfall distribution for 1-year to 500-year for Wake Island (914901).

Appendix 6 Design Rainfall Distributions for General Use

The results in Figures 6-1 and 6-2 were derived from design rainfall distributions in Appendix 5. These represent the average distribution of return periods from 1-year to 500-year. Tables 6-1 and 6-2 represent the respective 24 hour rainfall distribution table at an interval of 0.1 hour. Table 6-3 includes the ratios of shorter duration to the 24 hour duration which were used to develop the two design rainfall distributions. The ratios for the NRCS Type I design rainfall distribution are included for comparison purposes only.

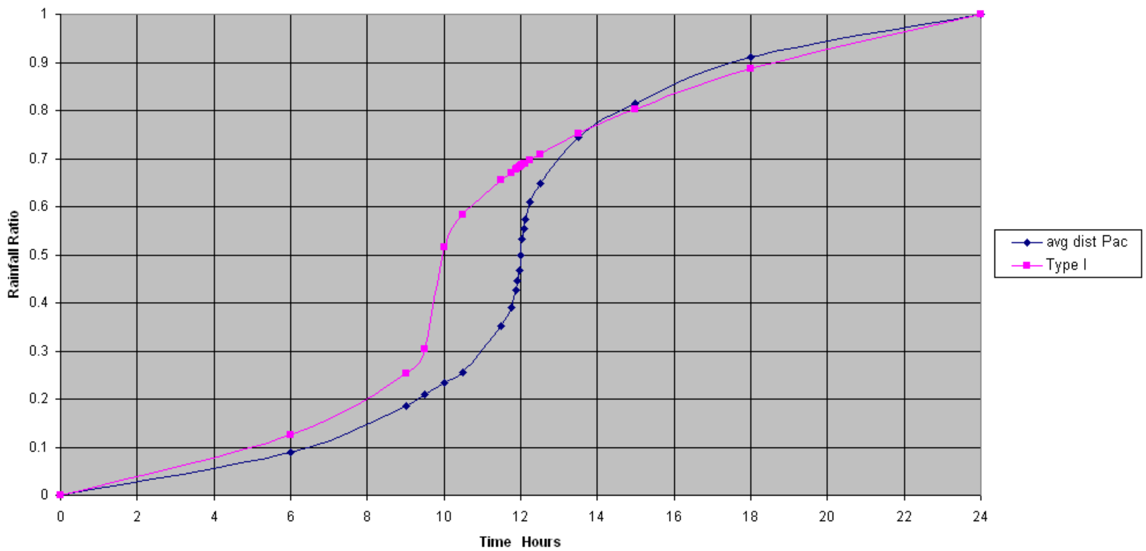

Figure 6-1. Design Rainfall Distribution for Guam, CNMI, Marshall Islands, Wake Island, Federated States of Micronesia.

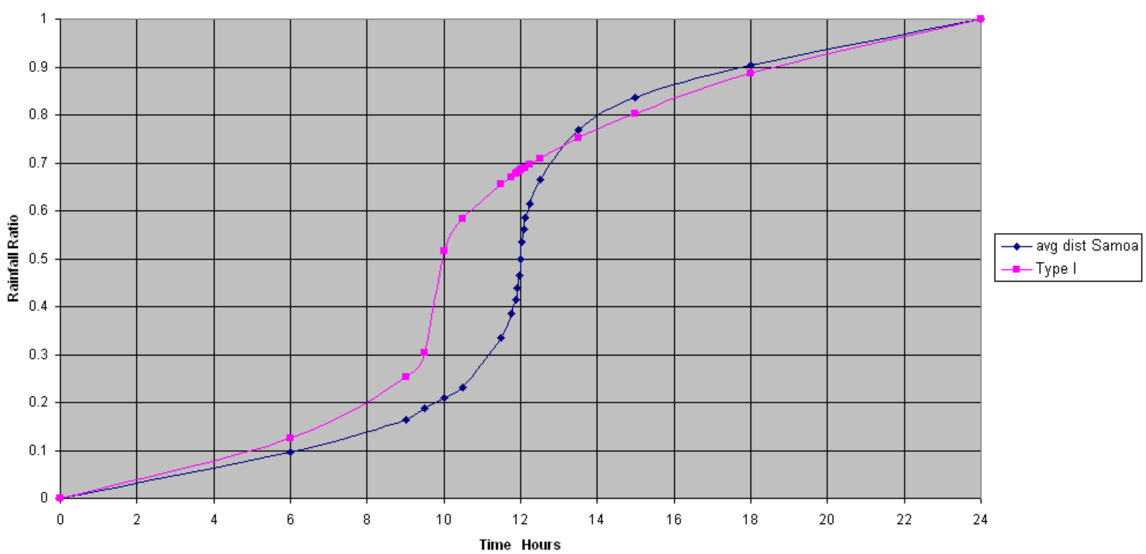

Figure 6-2. Design Rainfall Distribution for Tutuila, American Samoa.

Table 6-1. Design Rainfall Distribution Table for Guam, Palau, CNMI, Marshall Islands, Wake Island, Federated States of Micronesia.

Start Time (hours)	Start Time plus 0.0	Start Time plus 0.1	Start Time plus 0.2	Start Time plus 0.3	Start Time plus 0.4
0.0	0.0	0.000336	0.000711	0.0011	0.0016
0.5	0.0021	0.0026	0.0032	0.0038	0.0044
1.0	0.0051	0.0058	0.0066	0.0074	0.0082
1.5	0.0091	0.01	0.011	0.012	0.013
2.0	0.0141	0.0152	0.0164	0.0176	0.0188
2.5	0.0201	0.0214	0.0227	0.0241	0.0255
3.0	0.027	0.0285	0.03	0.0316	0.0332
3.5	0.0349	0.0366	0.0383	0.0401	0.0419
4.0	0.0438	0.0457	0.0476	0.0496	0.0516
4.5	0.0536	0.0557	0.0578	0.06	0.0622
5.0	0.0644	0.0667	0.069	0.0714	0.0738
5.5	0.0762	0.0787	0.0812	0.0838	0.0864
6.0	0.089	0.0917	0.0944	0.0971	0.0999
6.5	0.1027	0.1056	0.1085	0.1114	0.1144
7.0	0.1174	0.1205	0.1236	0.1267	0.1299
7.5	0.1331	0.1364	0.1397	0.143	0.1464
8.0	0.1498	0.1532	0.1567	0.1602	0.1638
8.5	0.1674	0.171	0.1747	0.1784	0.1822
9.0	0.186	0.1903	0.1947	0.1991	0.2036
9.5	0.2081	0.2127	0.2173	0.2219	0.2267
10.0	0.2314	0.2362	0.2411	0.246	0.251
10.5	0.256	0.2642	0.2724	0.2806	0.2888
11.0	0.297	0.3079	0.3188	0.3297	0.3406
11.5	0.3515	0.3683	0.3851	0.4087	0.4423
12.0	0.4895	0.5577	0.5913	0.6149	0.6317
12.5	0.6485	0.6594	0.6703	0.6812	0.6921
13.0	0.703	0.7112	0.7194	0.7276	0.7358
13.5	0.744	0.749	0.754	0.7589	0.7638
14.0	0.7686	0.7733	0.7781	0.7827	0.7873
14.5	0.7919	0.7964	0.8009	0.8053	0.8097
15.0	0.814	0.8178	0.8216	0.8253	0.829
15.5	0.8326	0.8362	0.8398	0.8433	0.8468
16.0	0.8502	0.8536	0.857	0.8603	0.8636
16.5	0.8669	0.8701	0.8733	0.8764	0.8795
17.0	0.8826	0.8856	0.8886	0.8915	0.8944
17.5	0.8973	0.9001	0.9029	0.9056	0.9083
18.0	0.911	0.9136	0.9162	0.9188	0.9213
18.5	0.9238	0.9262	0.9286	0.931	0.9333
19.0	0.9356	0.9378	0.94	0.9422	0.9443
19.5	0.9464	0.9484	0.9504	0.9524	0.9543

20.0	0.9562	0.9581	0.9599	0.9617	0.9634
20.5	0.9651	0.9668	0.9684	0.97	0.9715
21.0	0.973	0.9745	0.9759	0.9773	0.9786
21.5	0.9799	0.9812	0.9824	0.9836	0.9848
22.0	0.9859	0.987	0.988	0.989	0.99
22.5	0.9909	0.9918	0.9926	0.9934	0.9942
23.0	0.9949	0.9956	0.9962	0.9968	0.9974
23.5	0.9979	0.9984	0.9989	0.999289	0.999664
24.0	1.0				

Table 6-2. Design Rainfall Distribution Table for Tutuila, American Samoa.

Start Time (hours)	Start Time plus 0.0	Start Time plus 0.1	Start Time plus 0.2	Start Time plus 0.3	Start Time plus 0.4
0.0	0.0	0.0012	0.0023	0.0035	0.0047
0.5	0.0059	0.0071	0.0084	0.0096	0.0109
1.0	0.0122	0.0135	0.0148	0.0162	0.0175
1.5	0.0189	0.0203	0.0216	0.0231	0.0245
2.0	0.0259	0.0274	0.0289	0.0303	0.0318
2.5	0.0334	0.0349	0.0364	0.038	0.0396
3.0	0.0412	0.0428	0.0444	0.046	0.0477
3.5	0.0494	0.051	0.0527	0.0545	0.0562
4.0	0.0579	0.0597	0.0615	0.0632	0.0651
4.5	0.0669	0.0687	0.0706	0.0724	0.0743
5.0	0.0762	0.0781	0.08	0.082	0.0839
5.5	0.0859	0.0879	0.0899	0.0919	0.094
6.0	0.096	0.0981	0.1001	0.1022	0.1043
6.5	0.1065	0.1086	0.1108	0.1129	0.1151
7.0	0.1173	0.1195	0.1218	0.124	0.1263
7.5	0.1285	0.1308	0.1331	0.1355	0.1378
8.0	0.1401	0.1425	0.1449	0.1473	0.1497
8.5	0.1521	0.1546	0.157	0.1595	0.162
9.0	0.1645	0.1687	0.1729	0.1772	0.1815
9.5	0.1859	0.1903	0.1948	0.1993	0.2039
10.0	0.2085	0.2132	0.218	0.2228	0.2276
10.5	0.2325	0.2412	0.2499	0.2586	0.2673
11.0	0.276	0.2877	0.2994	0.3111	0.3228
11.5	0.3345	0.3547	0.3749	0.3972	0.429
12.0	0.487	0.571	0.6028	0.6251	0.6453
12.5	0.6655	0.6772	0.6889	0.7006	0.7123
13.0	0.724	0.7327	0.7414	0.7501	0.7588
13.5	0.7675	0.7724	0.7772	0.782	0.7868
14.0	0.7915	0.7961	0.8007	0.8052	0.8097
14.5	0.8141	0.8185	0.8228	0.8271	0.8313

15.0	0.8355	0.838	0.8405	0.843	0.8454
15.5	0.8479	0.8503	0.8527	0.8551	0.8575
16.0	0.8599	0.8622	0.8645	0.8669	0.8692
16.5	0.8715	0.8737	0.876	0.8782	0.8805
17.0	0.8827	0.8849	0.8871	0.8892	0.8914
17.5	0.8935	0.8957	0.8978	0.8999	0.9019
18.0	0.904	0.906	0.9081	0.9101	0.9121
18.5	0.9141	0.9161	0.918	0.92	0.9219
19.0	0.9238	0.9257	0.9276	0.9294	0.9313
19.5	0.9331	0.9349	0.9368	0.9385	0.9403
20.0	0.9421	0.9438	0.9455	0.9473	0.949
20.5	0.9506	0.9523	0.954	0.9556	0.9572
21.0	0.9588	0.9604	0.962	0.9636	0.9651
21.5	0.9666	0.9682	0.9697	0.9711	0.9726
22.0	0.9741	0.9755	0.9769	0.9784	0.9797
22.5	0.9811	0.9825	0.9838	0.9852	0.9865
23.0	0.9878	0.9891	0.9904	0.9916	0.9929
23.5	0.9941	0.9953	0.9965	0.9977	0.9988
24.0	1.0				

Table 6-3. Ratios used to develop the design rainfall distributions for Northern Pacific and American Samoa.

Duration	5 min	10 min	15 min	30 min	1 hour	2 hour	3 hour	6 hour	12 hour	24 hour
Northern Pacific	0.060	0.101	0.137	0.213	0.297	0.406	0.488	0.628	0.822	1.000
American Samoa	0.074	0.124	0.169	0.230	0.331	0.448	0.535	0.671	0.808	1.000
Type I	0.063	0.110	0.148	0.213	0.281	0.370	0.437	0.578	0.761	1.000

Appendix 7 Probability Plots for Selected Pacific Island Stations

The results in Figure 7 (A through Q) were plotted from data contained in Appendices 1, 2, and 4. Rainfall data are in units of inches.

To derive the plots in this Appendix, the annual maximum rainfall values were ranked from highest to lowest, with the highest value given rank number 1 and the lowest value given rank number N, with N being the number of years of record. The probability for each value was then computed using the Weibull equation:

$$P = 1 - (m / (N + 1))$$

Where: P = probability, m = rank, and N = number of years.

The probability was converted to the Gumbel plotting position using the equation:

$$Y = - LN (- LN (P))$$

Where: Y = Gumbel plotting position, LN = natural logarithm, and P = probability.

Using this plotting scheme, the rainfall values computed using the Gumbel probability distribution plot as a straight line. There is a plotted data point representing the maximum rainfall for each year of record. The plots in this Appendix show how well the Gumbel distribution fits the recorded annual maximum rainfalls for the 17 stations (Capitol Hill, Island of Saipan is included). Of the 51 plots, eight show a strong indication there could be a mixed distribution as the maximum value of rainfall plots over 2 standard errors above the Gumbel distribution line. Twelve plots show a moderate indication towards a mixed distribution as the maximum value of rainfall plots between 1 and 2 standard errors above the Gumbel distribution line. The remaining 31 show a weak indication for a mixed distribution as the maximum value of rainfall plots between -1 and +1 standard error with respect to the Gumbel distribution line.

Table 7-1. Relationship of Return Period, Probability, and Gumbel Plotting Position.

Return Period, Years	Probability	Gumbel Plotting Position
2	0.5	0.37
5	0.8	1.50
10	0.9	2.25
25	0.96	3.20
50	0.98	3.90
100	0.99	4.60
200	0.995	5.30
500	0.998	6.21

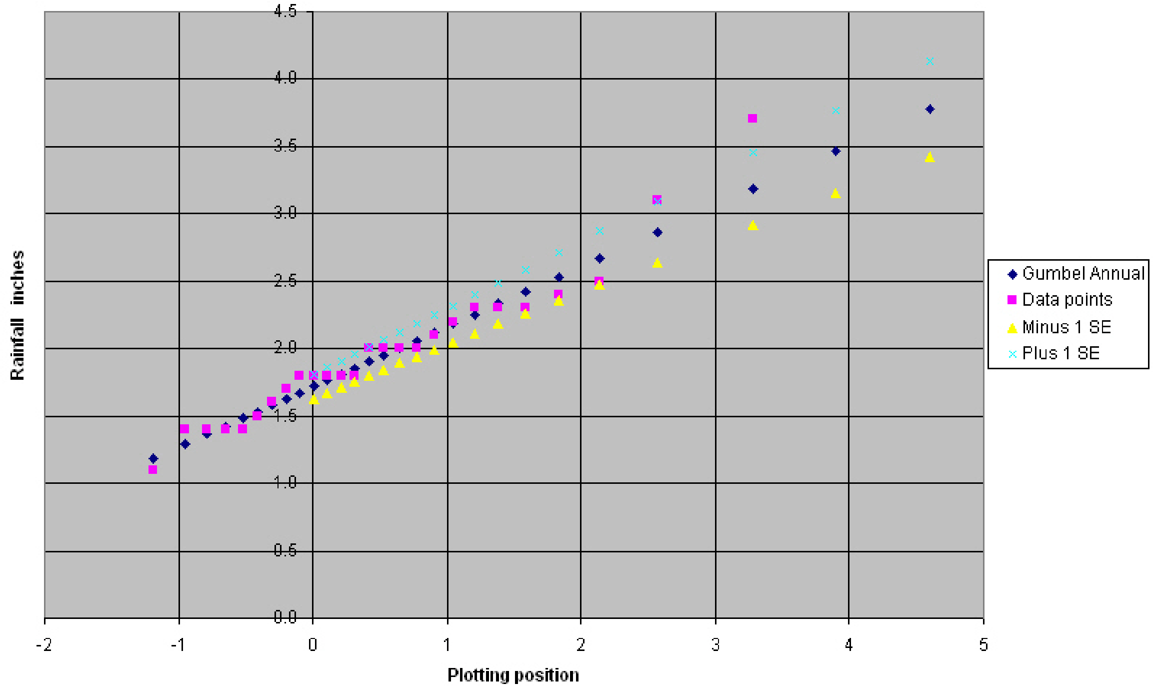

Figure 7-A1. Plot of 1-hour data points versus Gumbel analysis for Fena Lake, Guam.

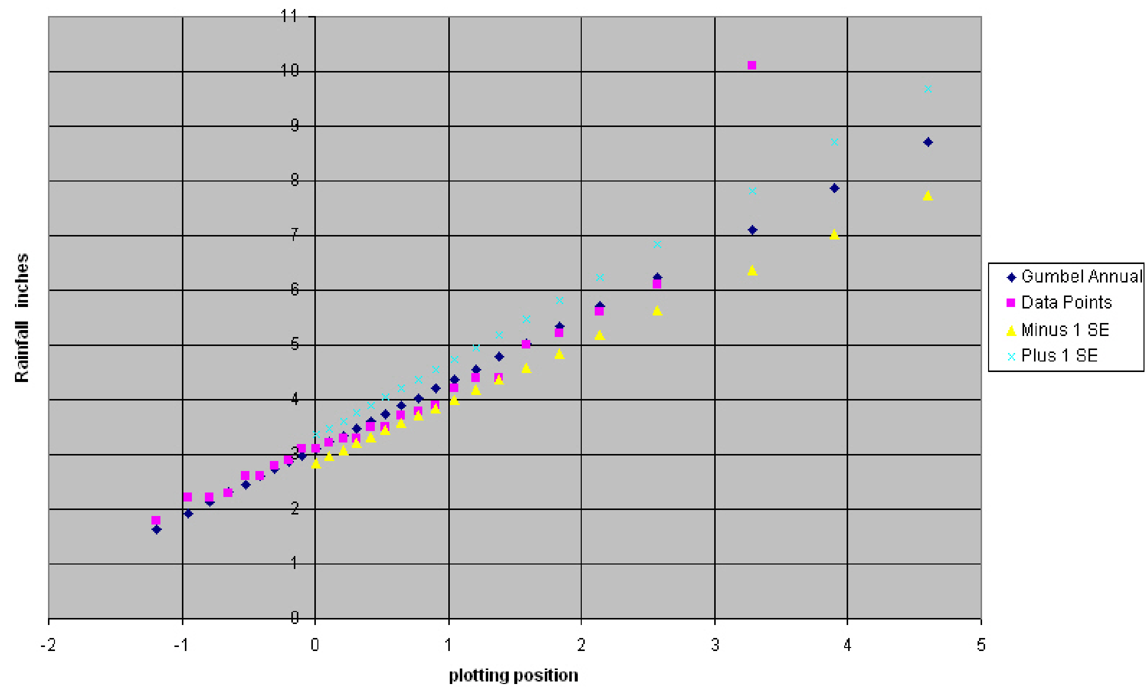

Figure 7-A2. Plot of 6-hour data points versus Gumbel analysis for Fena Lake, Guam.

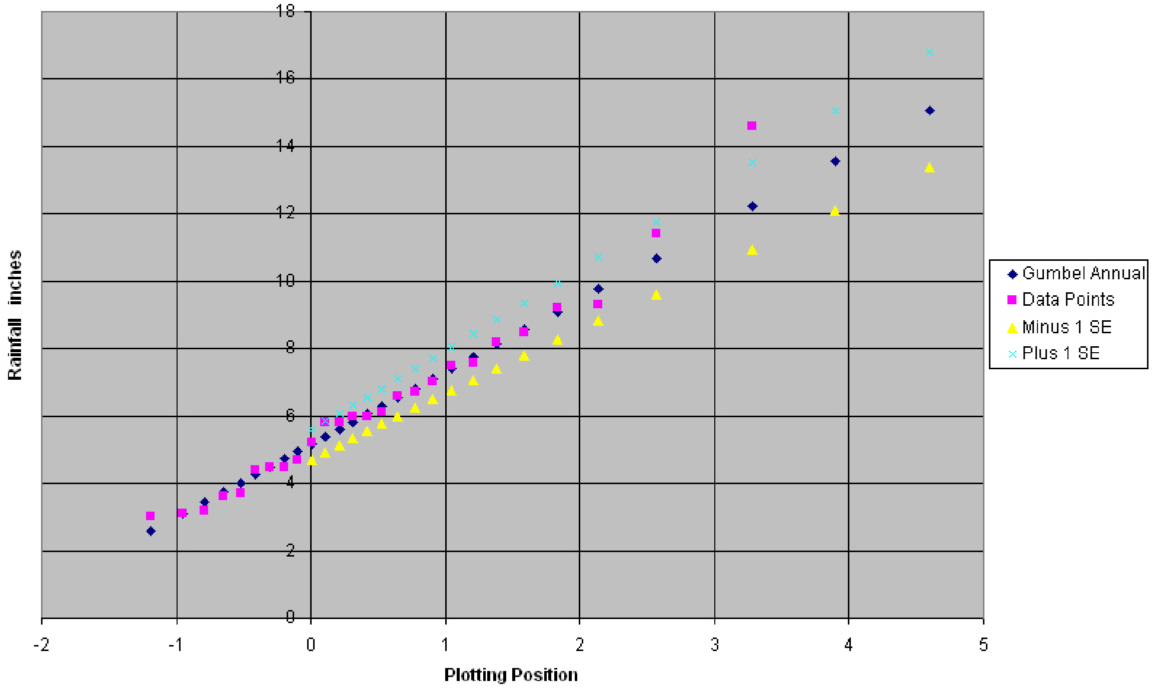

Figure 7-A3. Plot of 24-hour data points versus Gumbel analysis for Fena Lake, Guam.

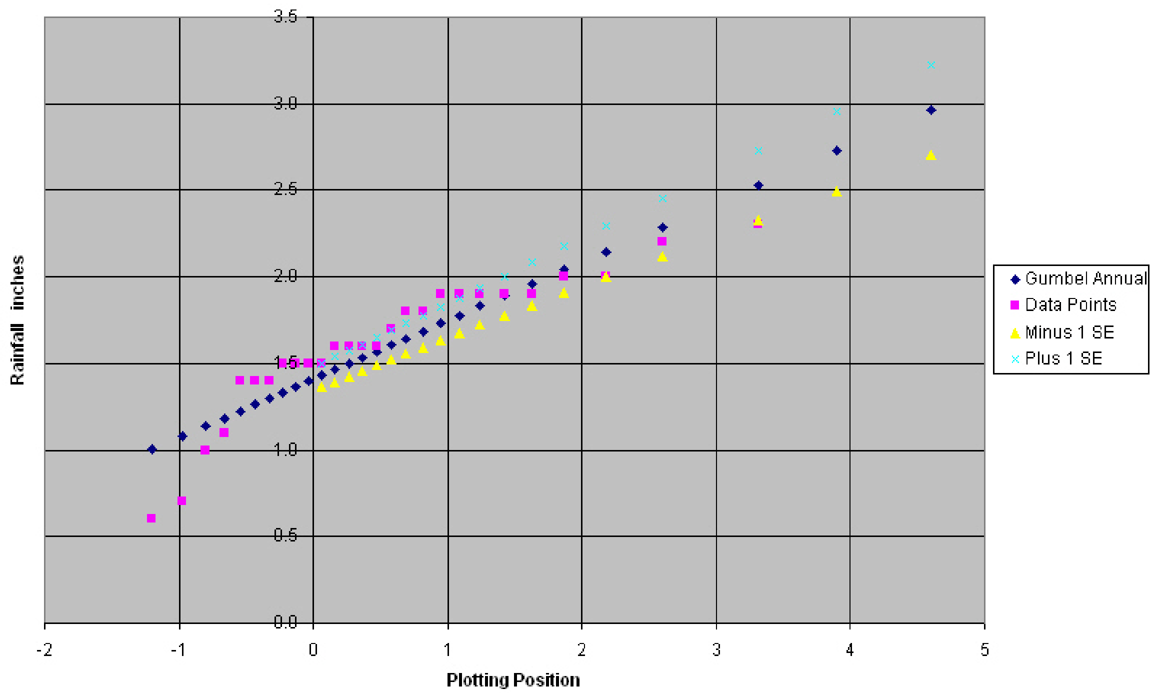

Figure 7-B1. Plot of 1-hour data points versus Gumbel analysis for Inarajan, Guam.

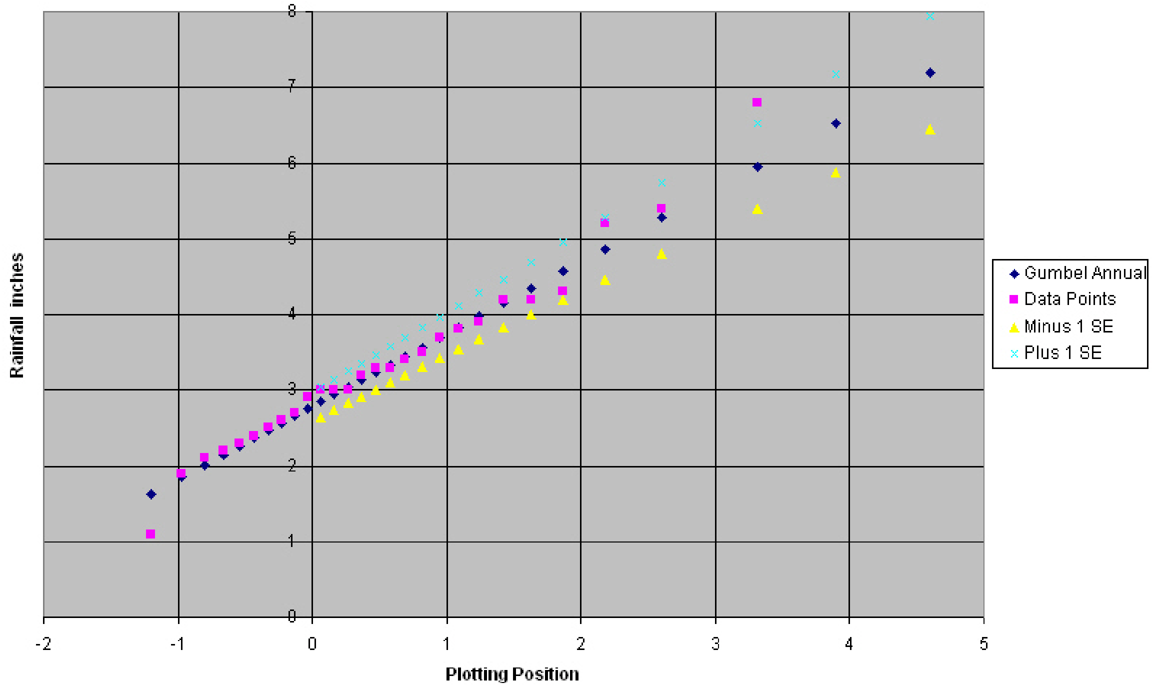

Figure 7-B2. Plot of 6-hour data points versus Gumbel analysis for Inarajan, Guam.

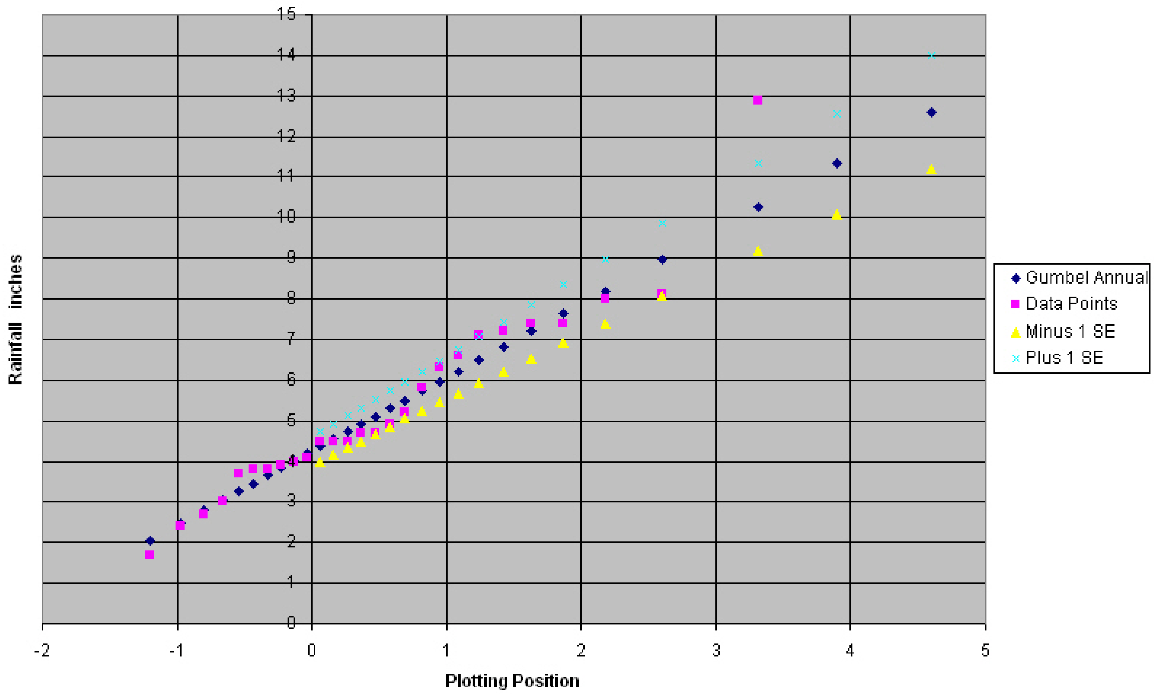

Figure 7-B3. Plot of 24-hour data points versus Gumbel analysis for Inarajan, Guam.

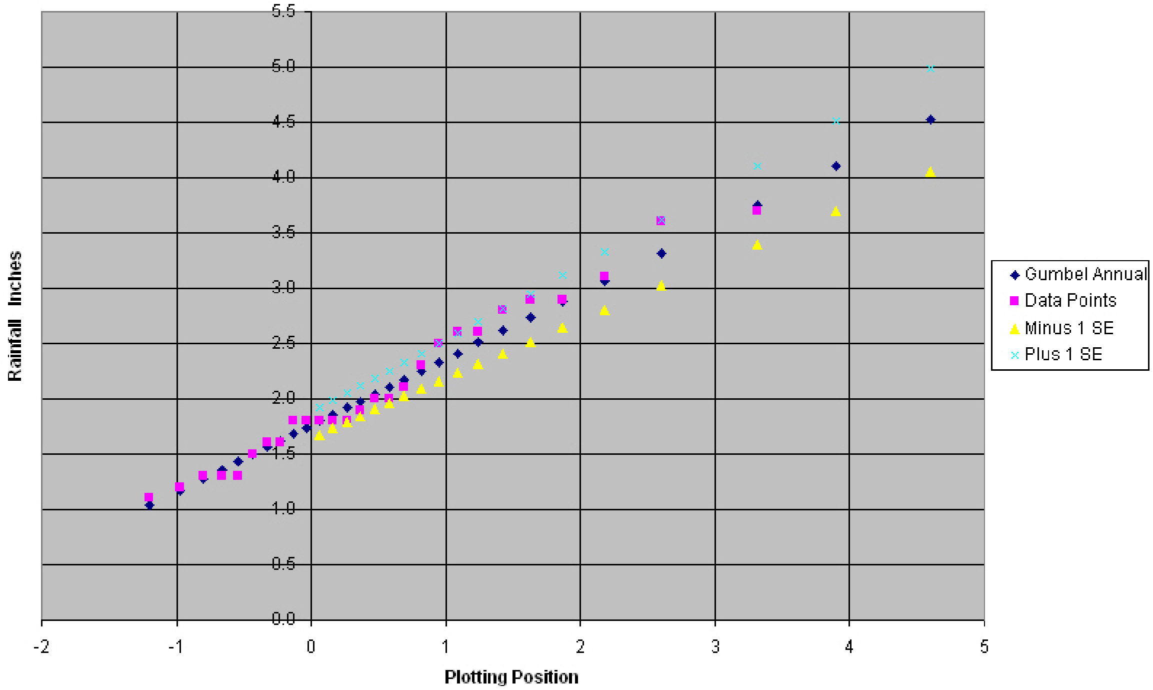

Figure 7-C1. Plot of 1-hour data points versus Gumbel analysis for Piti, Guam.

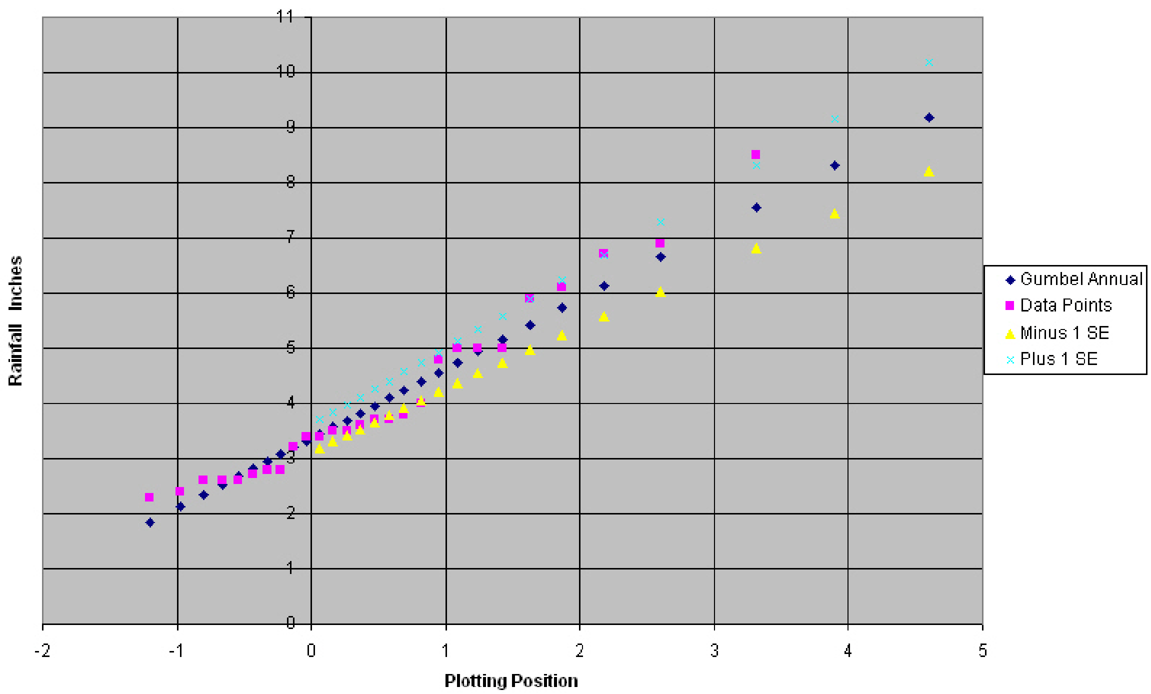

Figure 7-C2. Plot of 6-hour data points versus Gumbel analysis for Piti, Guam.

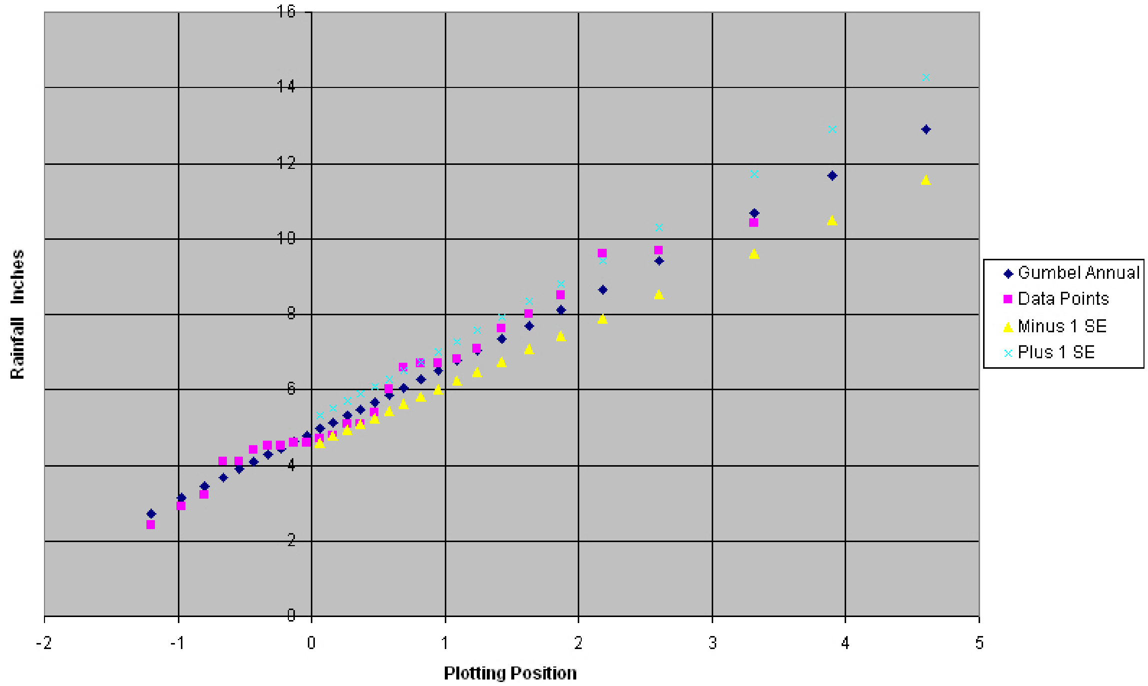

Figure 7-C3. Plot of 24-hour data points versus Gumbel analysis for Piti, Guam.

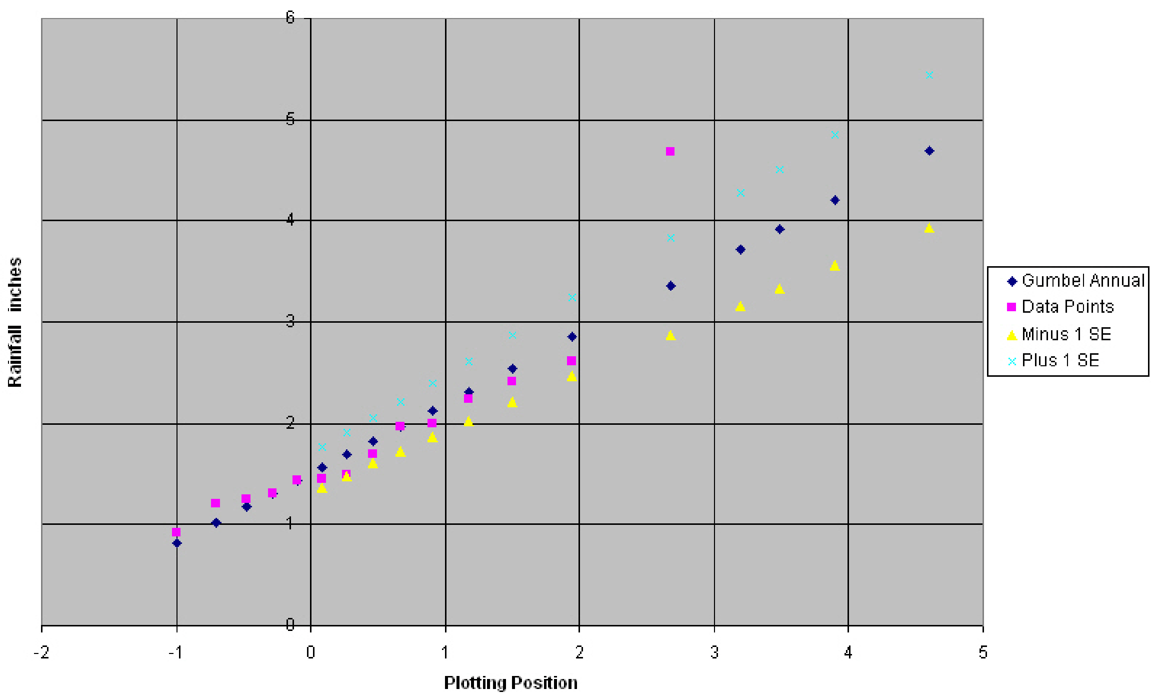

Figure 7-D1. Plot of 1-hour data points versus Gumbel analysis for Taguac, Guam.

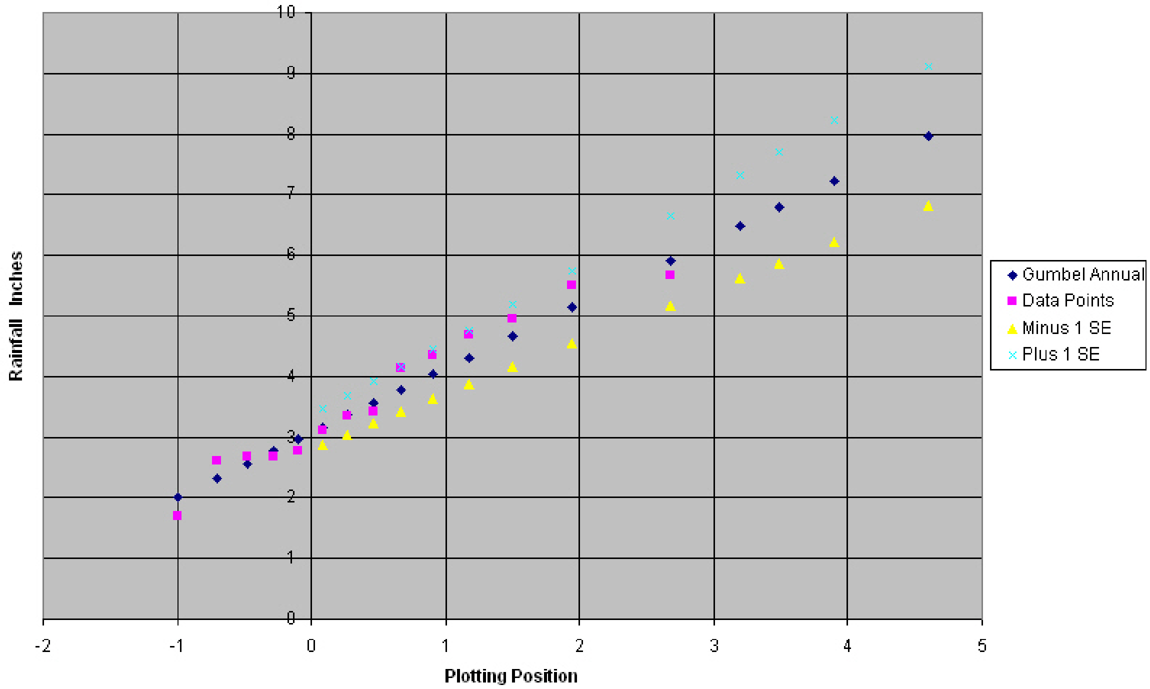

Figure 7-D2. Plot of 6-hour data points versus Gumbel analysis for Taguac, Guam.

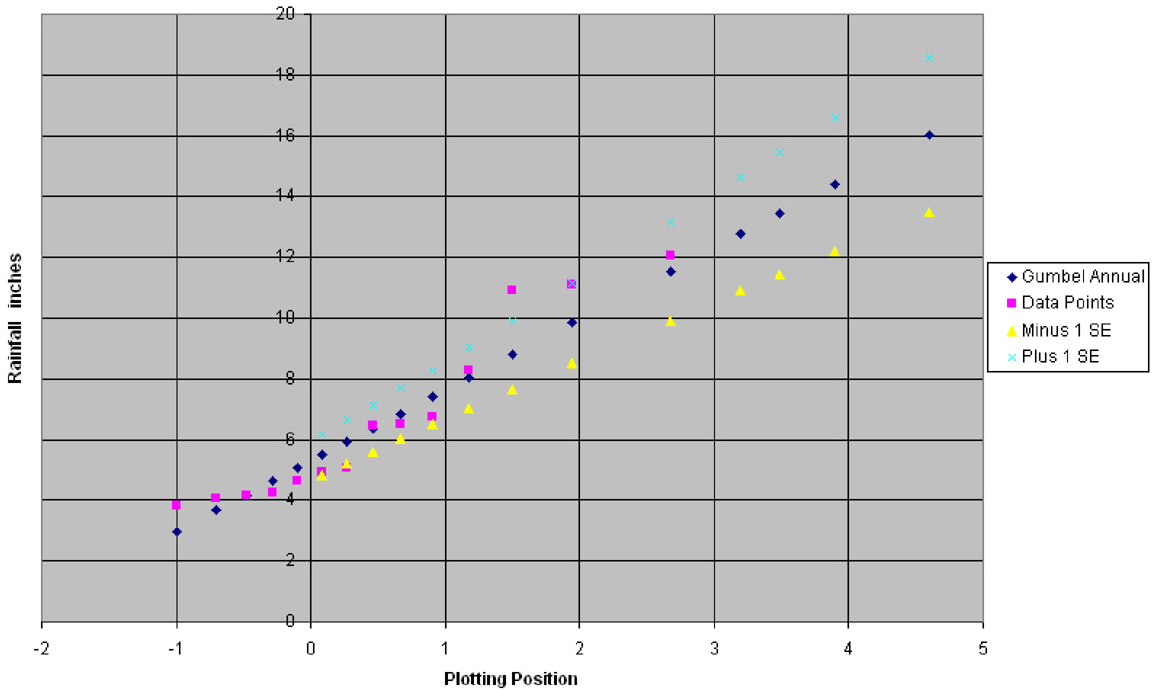

Figure 7-D3. Plot of 24-hour data points versus Gumbel analysis for Taguac, Guam.

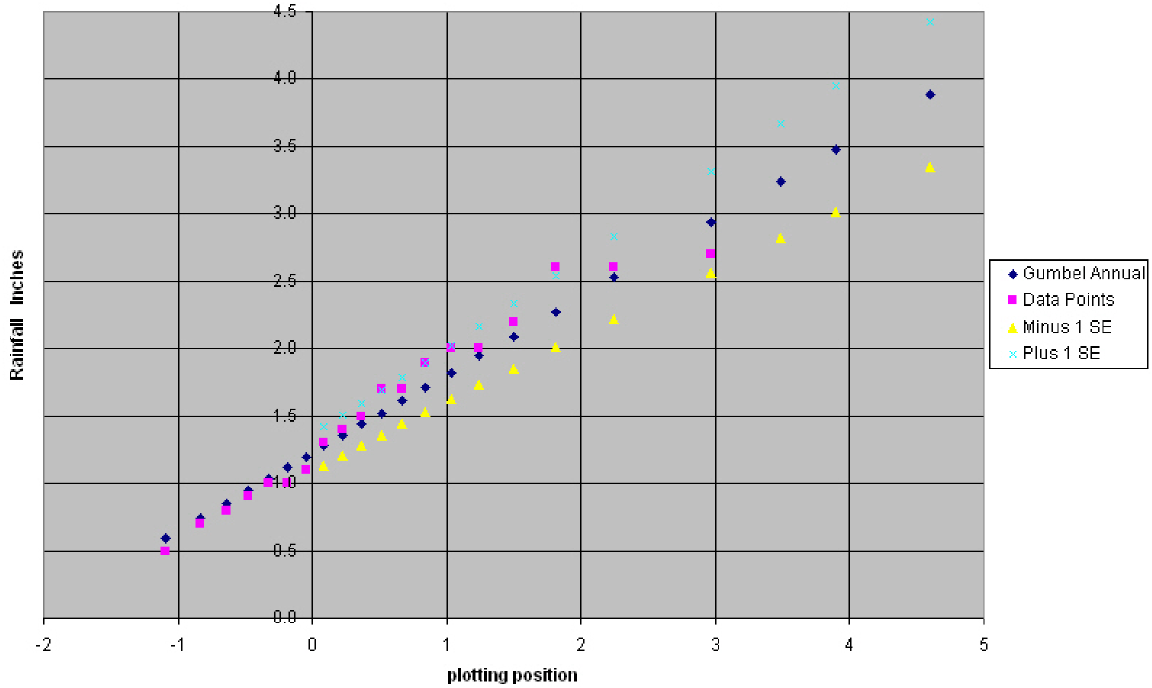

Figure 7-E1. Plot of 1-hour data points versus Gumbel analysis for Capitol Hill, CNMI.

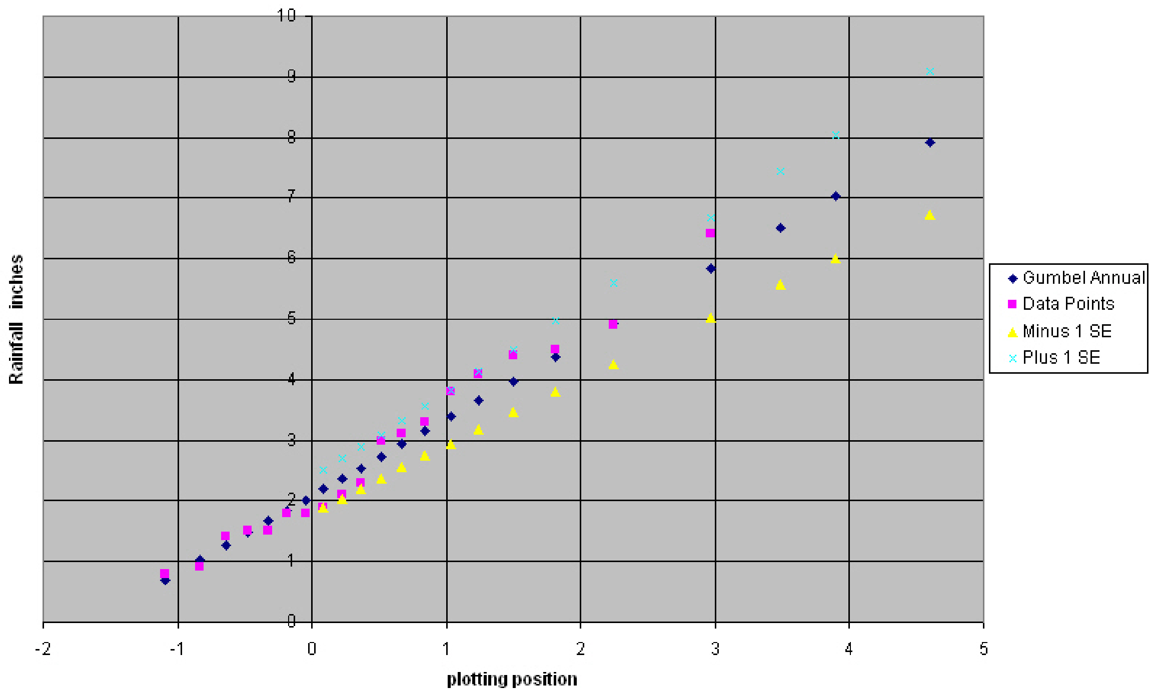

Figure 7-E2. Plot of 6-hour data points versus Gumbel analysis for Capitol Hill, CNMI.

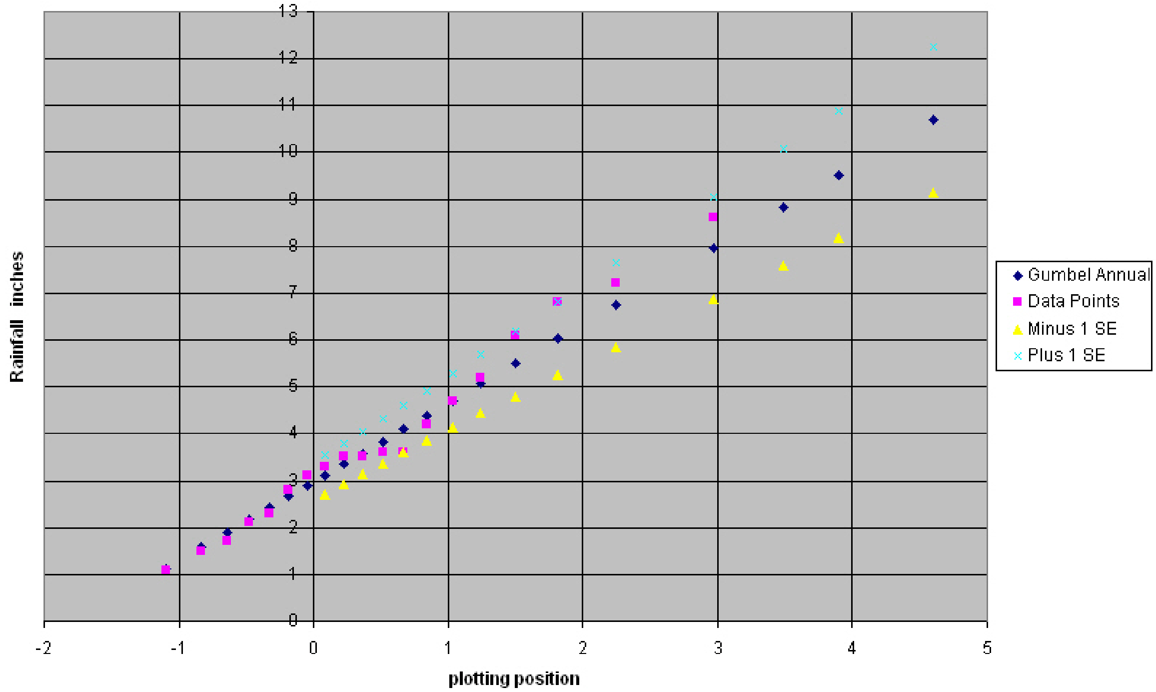

Figure 7-E3. Plot of 24-hour data points versus Gumbel analysis for Capitol Hill, CNMI.

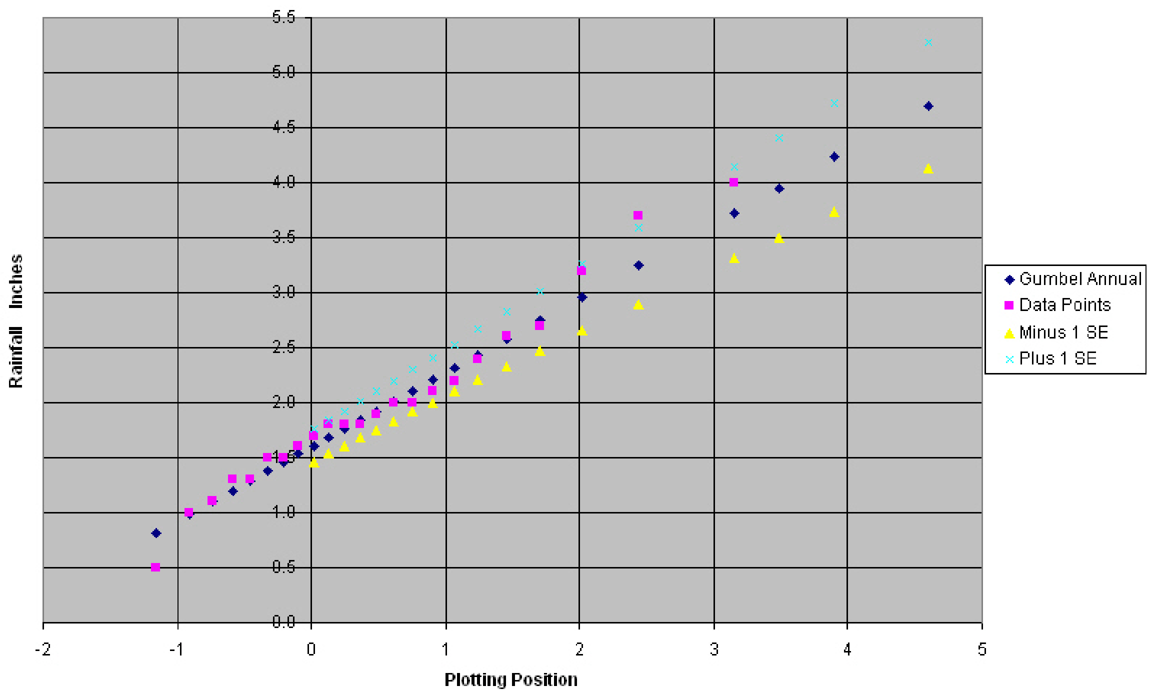

Figure 7-F1. Plot of 1-hour data points versus Gumbel analysis for Rota, CNMI.

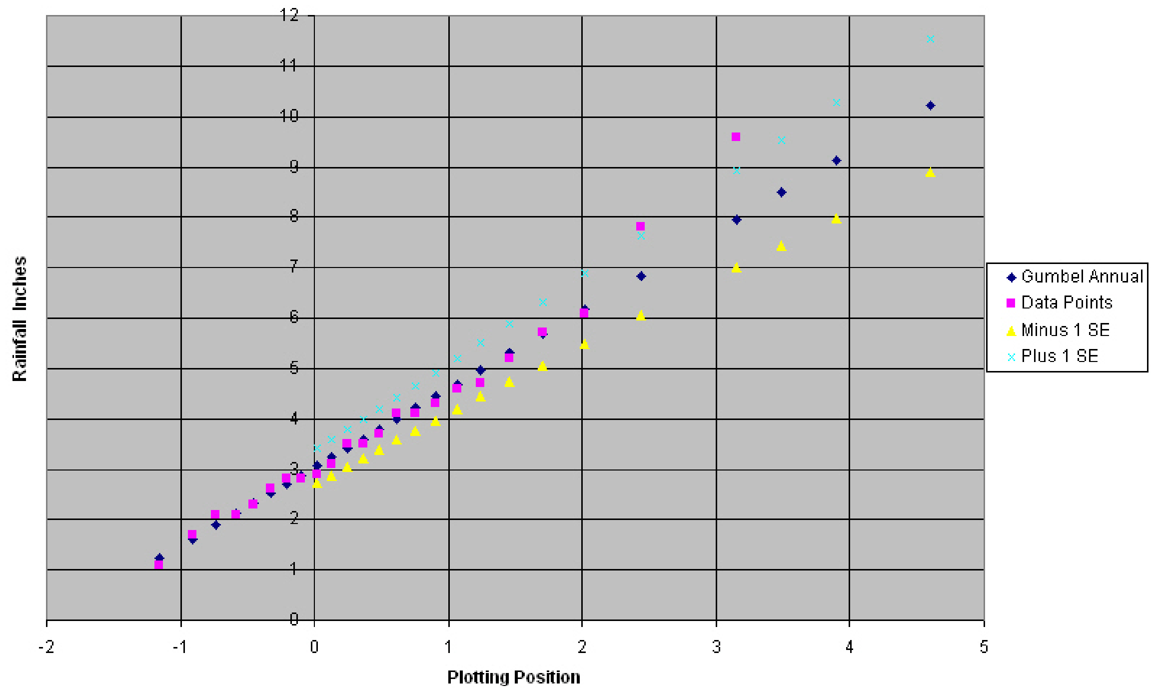

Figure 7-F2. Plot of 6-hour data points versus Gumbel analysis for Rota, CNMI.

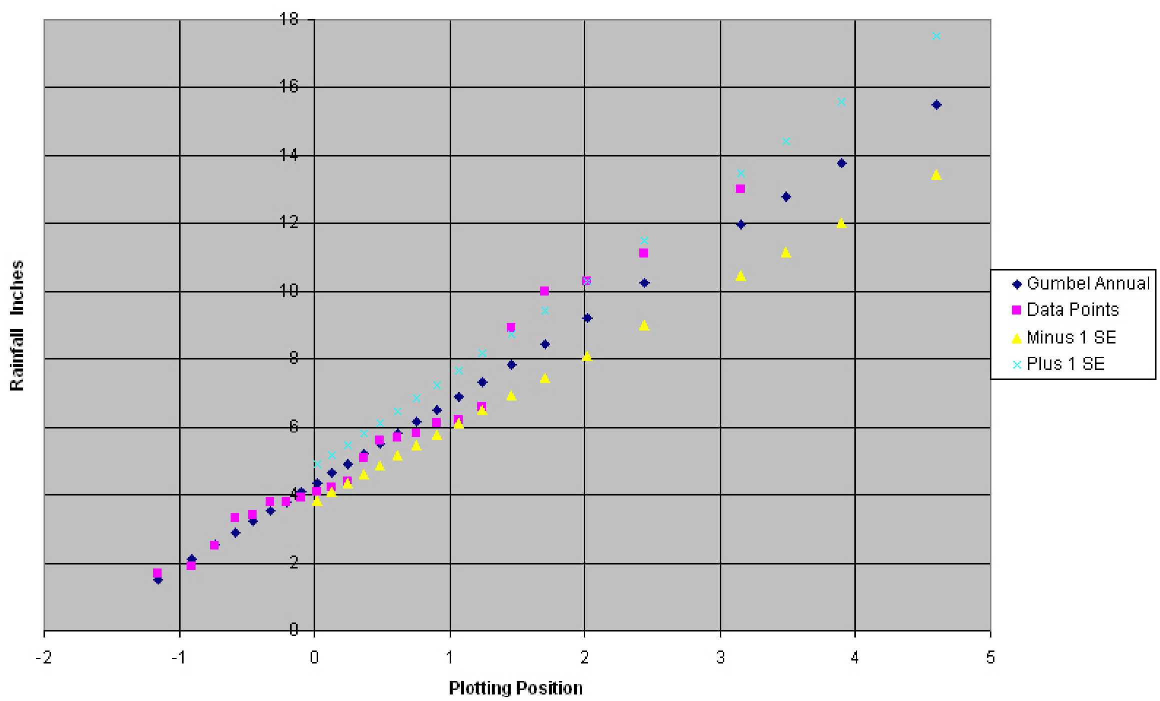

Figure 7-F3. Plot of 24-hour data points versus Gumbel analysis for Rota, CNMI.

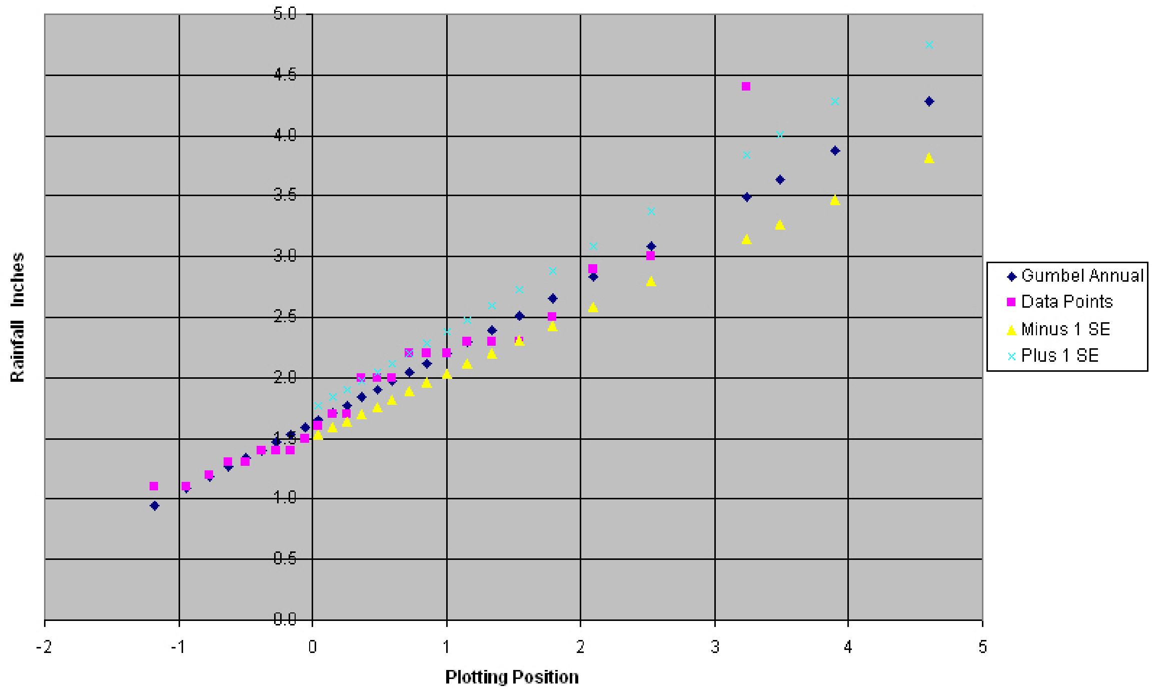

Figure 7-G1. Plot of 1-hour data points versus Gumbel analysis for Saipan IA, CNMI.

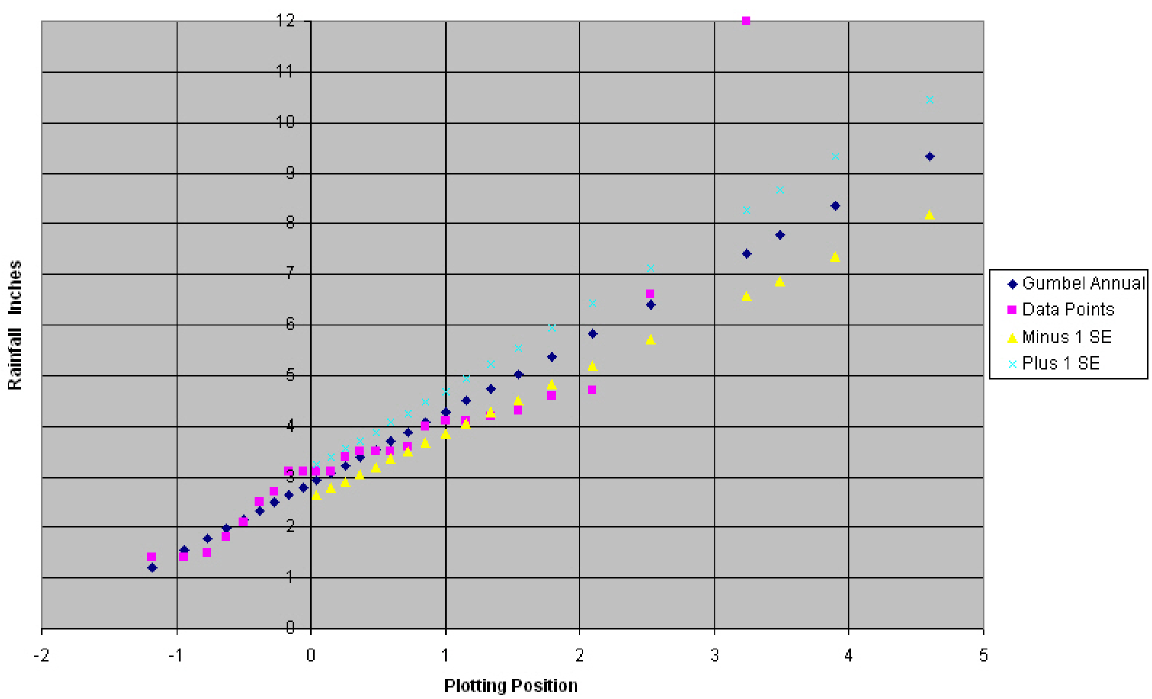

Figure 7-G2. Plot of 6-hour data points versus Gumbel analysis for Saipan IA, CNMI.

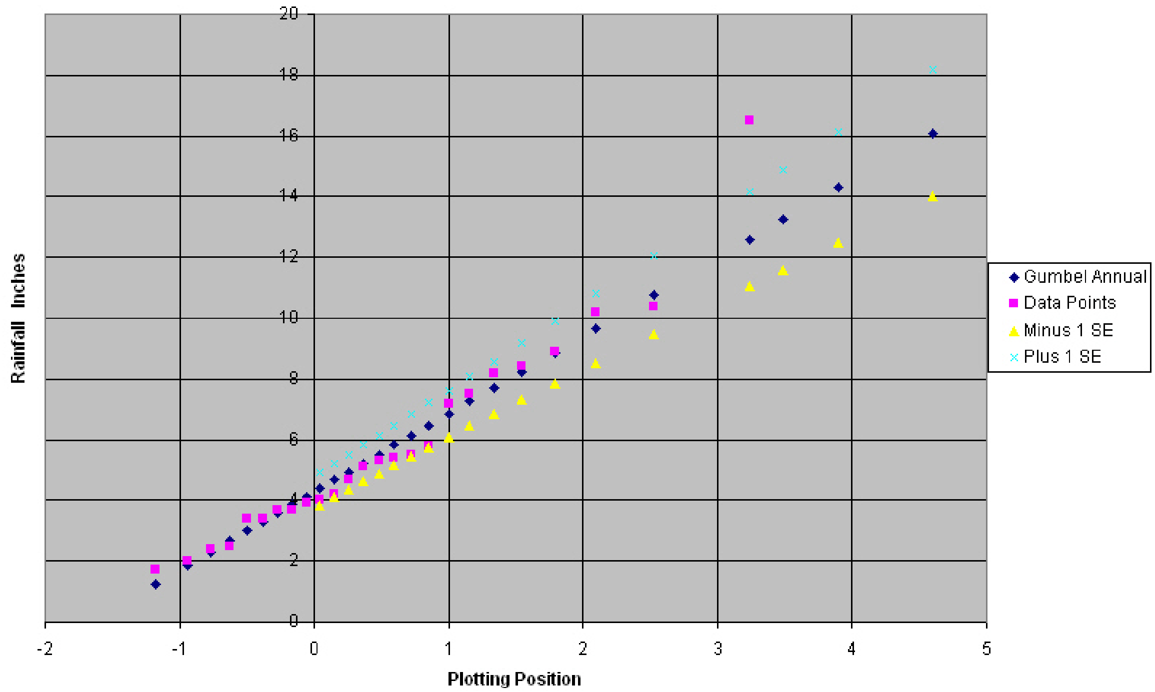

Figure 7-G3. Plot of 24-hour data points versus Gumbel analysis for Saipan IA, CNMI.

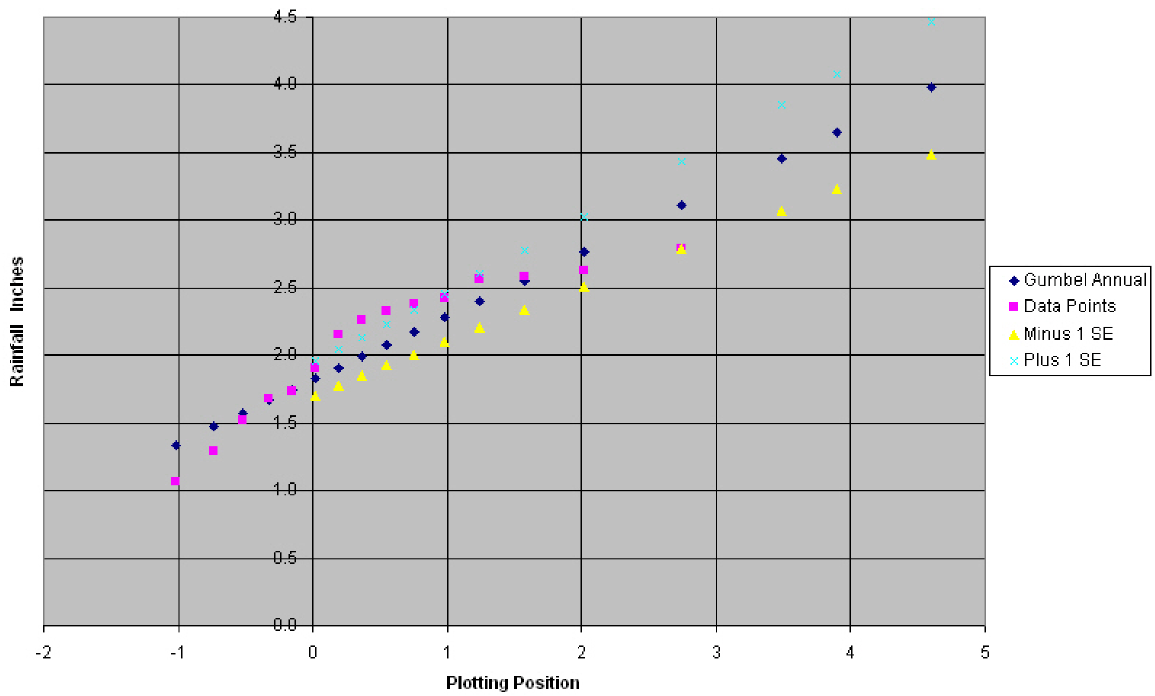

Figure 7-H1. Plot of 1-hour data points versus Gumbel analysis for Yap, FSM.

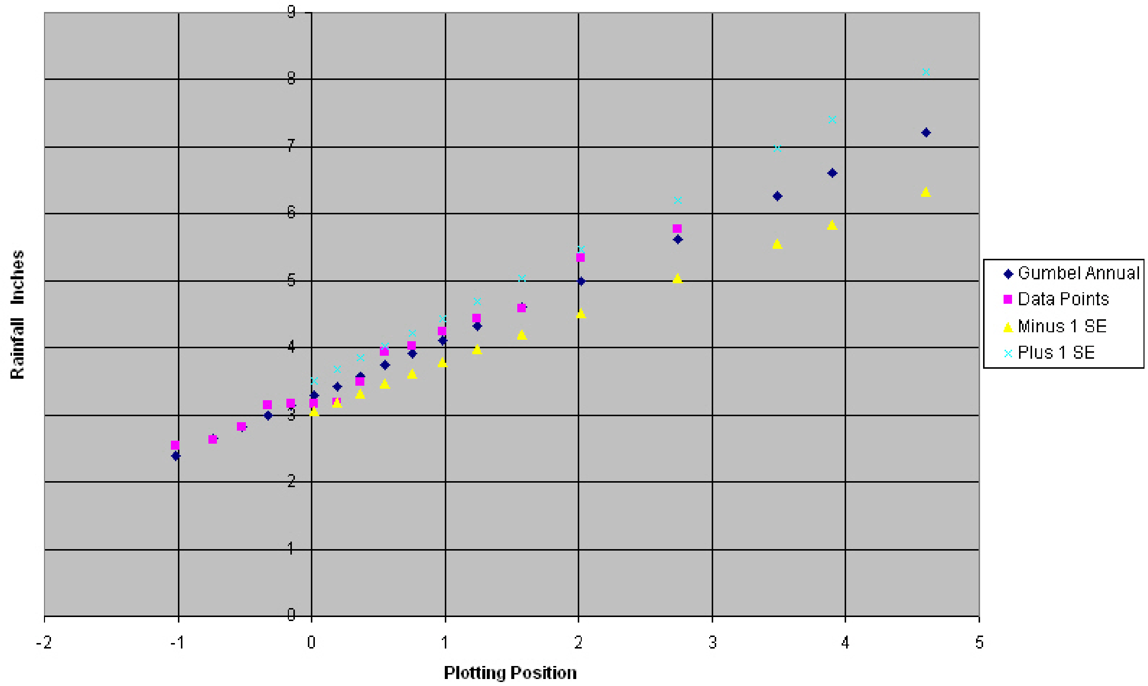

Figure 7-H2. Plot of 6-hour data points versus Gumbel analysis for Yap, FSM.

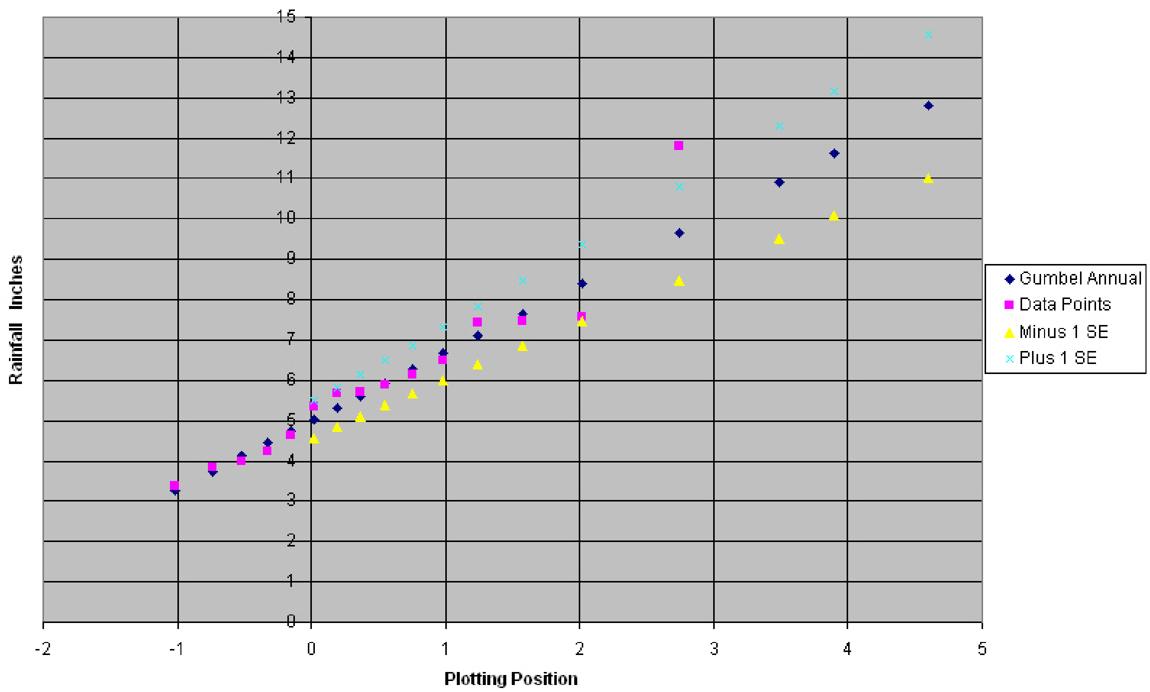

Figure 7-H3. Plot of 24-hour data points versus Gumbel analysis for Yap, FSM.

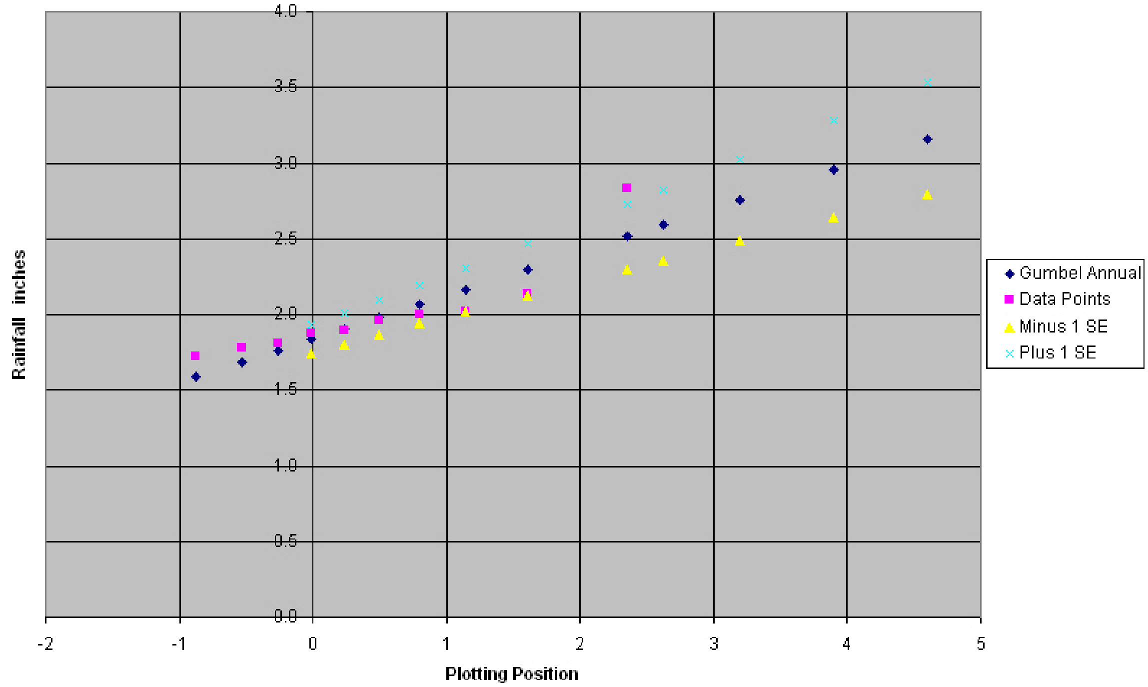

Figure 7-I1. Plot of 1-hour data points versus Gumbel analysis for Chuuk, FSM.

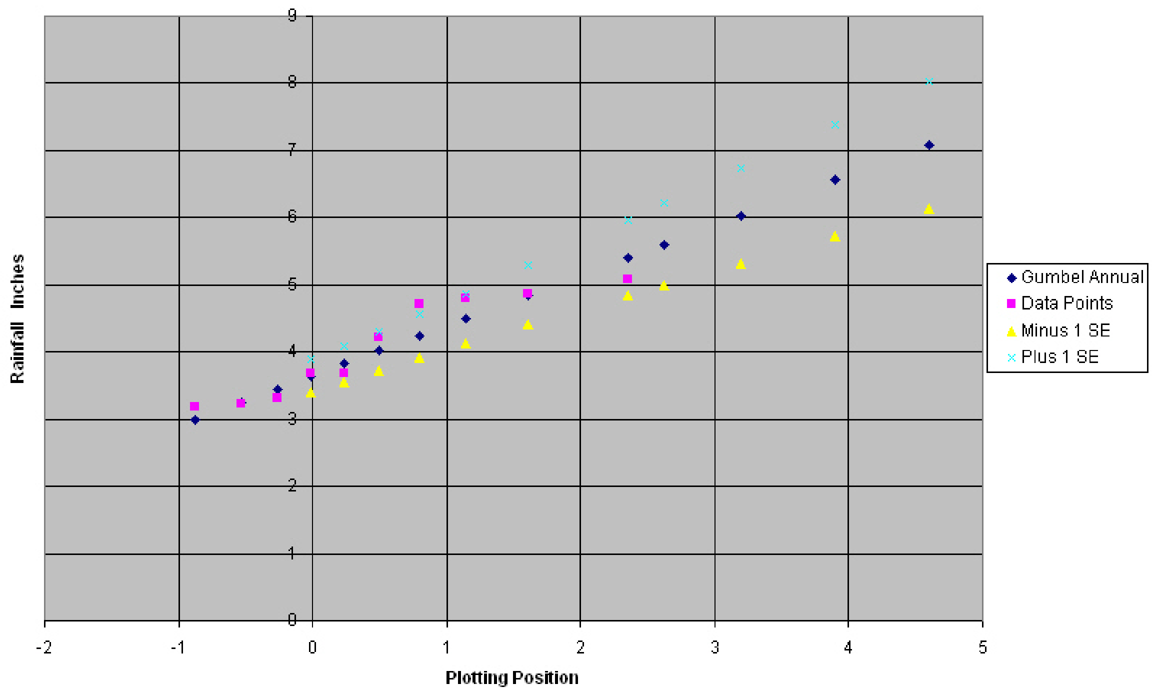

Figure 7-I2. Plot of 6-hour data points versus Gumbel analysis for Chuuk, FSM.

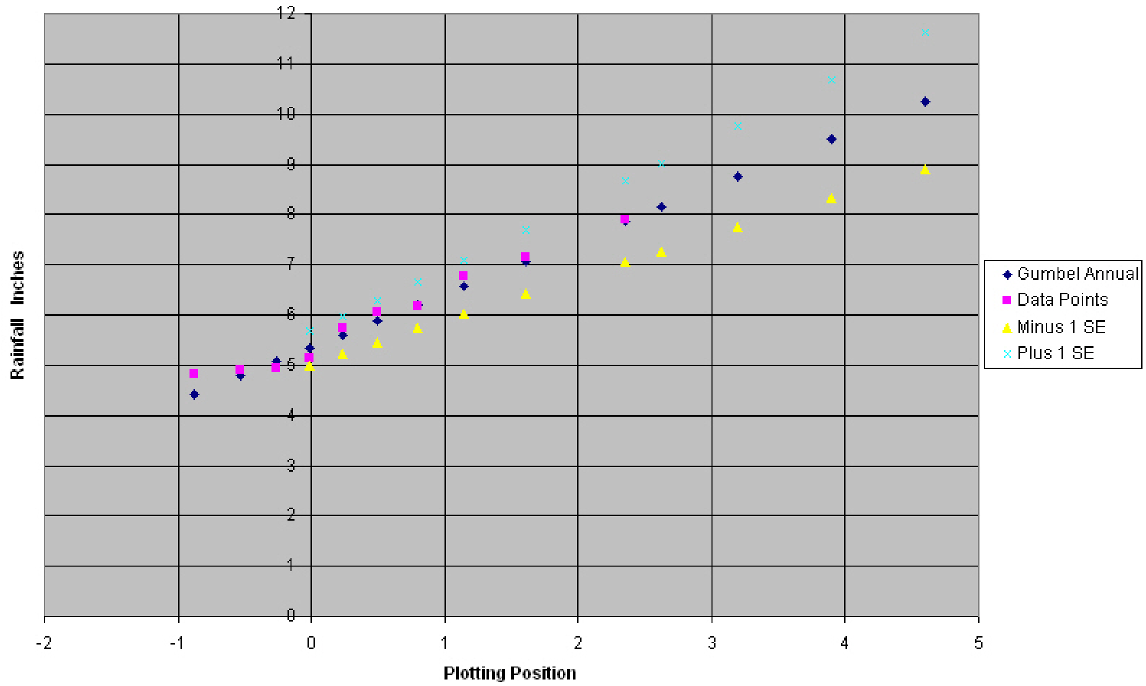

Figure 7-I3. Plot of 24-hour data points versus Gumbel analysis for Chuuk, FSM.

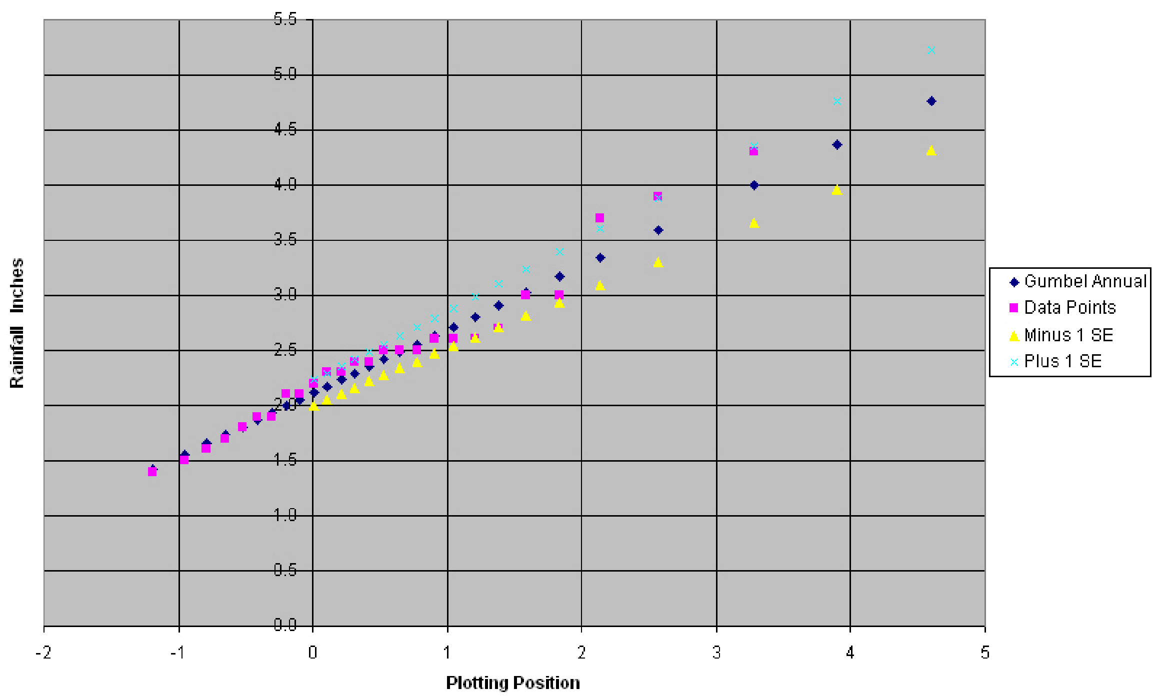

Figure 7-J1. Plot of 1-hour data points versus Gumbel analysis for Pohnpei Hospital, FSM.

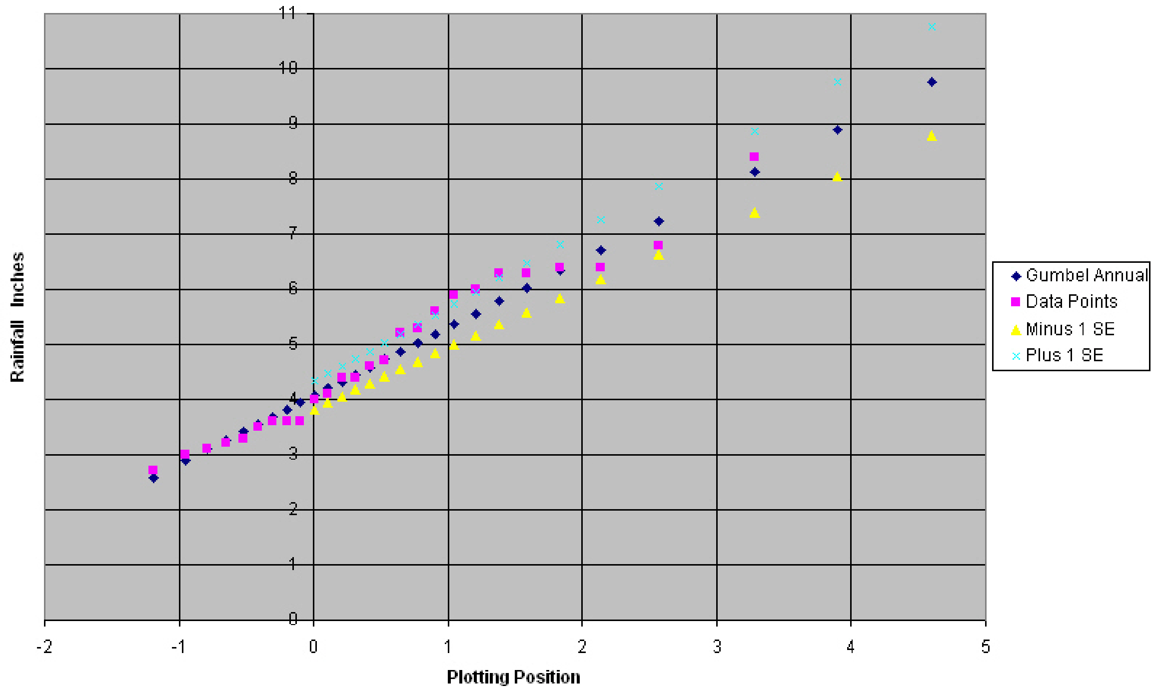

Figure 7-J2. Plot of 6-hour data points versus Gumbel analysis for Pohnpei Hospital, FSM.

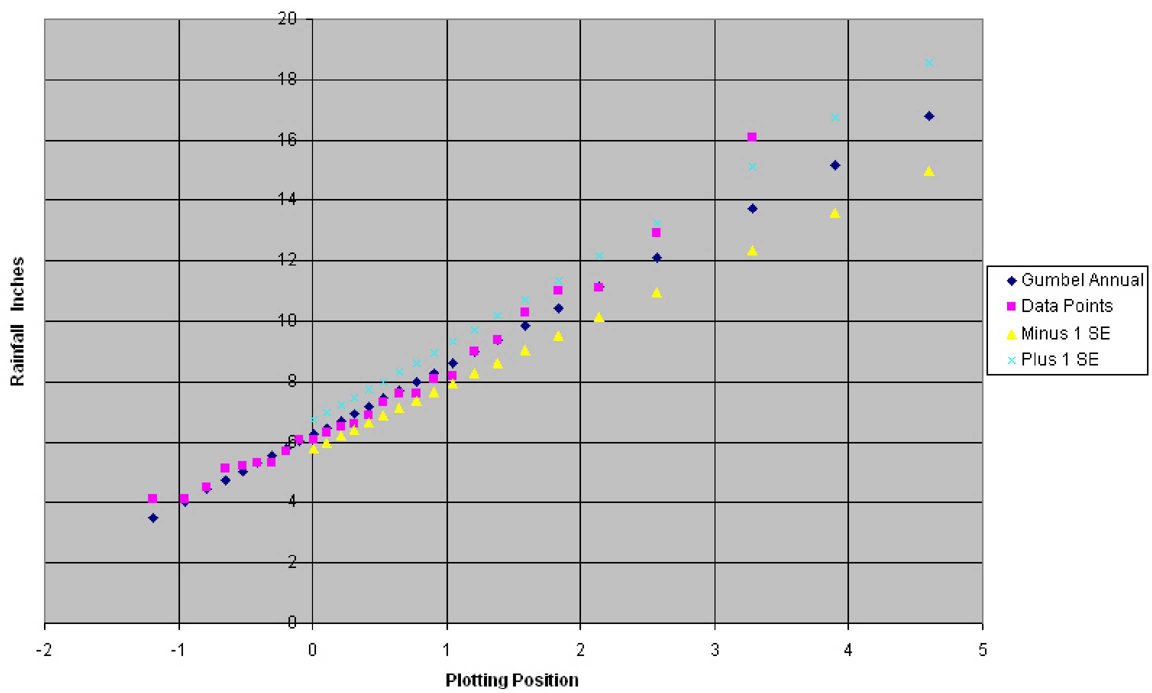

Figure 7-J3. Plot of 24-hour data points versus Gumbel analysis for Pohnpei Hospital, FSM.

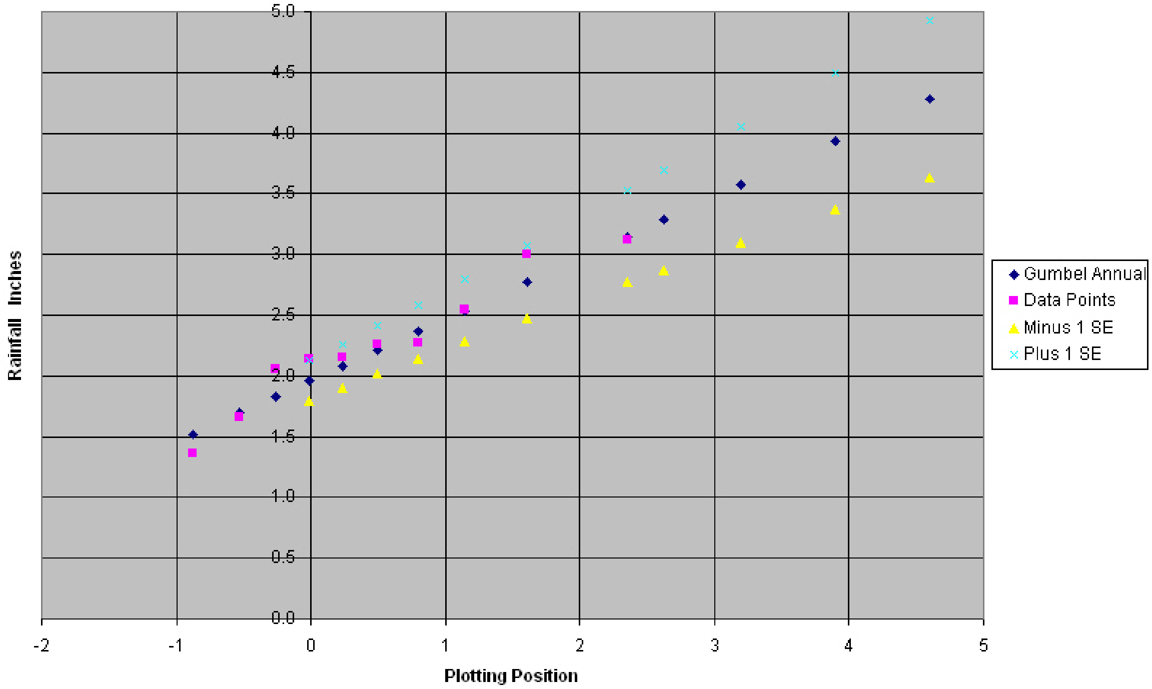

Figure 7-K1. Plot of 1-hour data points versus Gumbel analysis for Pohnpei WSO, FSM.

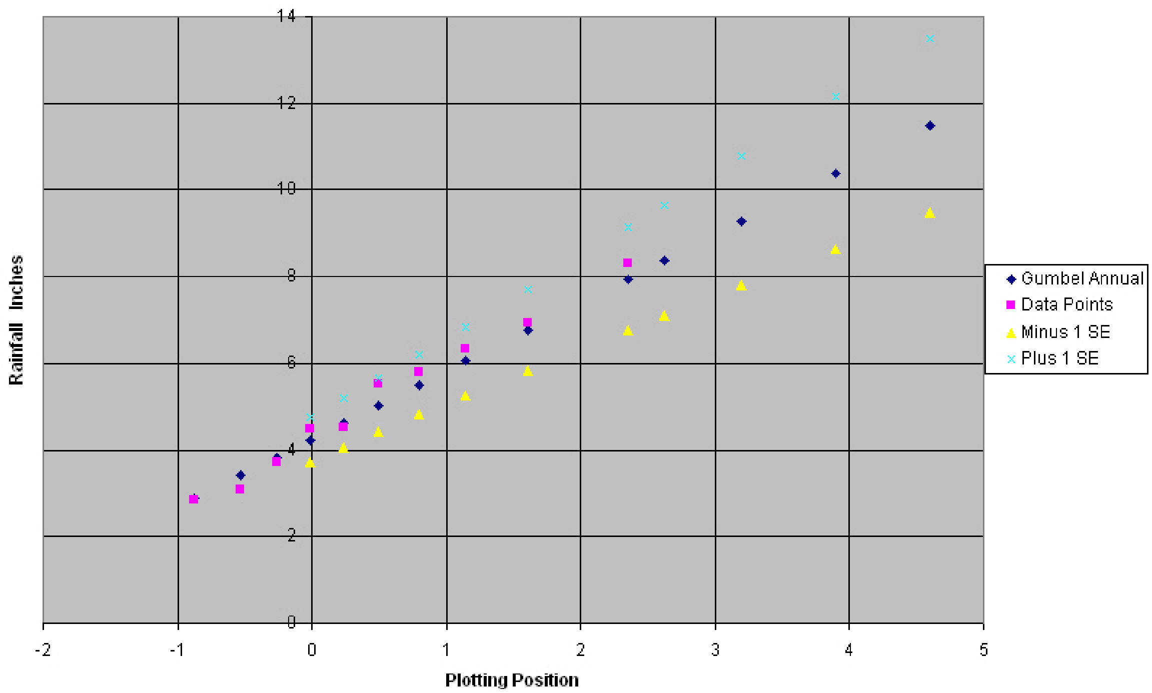

Figure 7-K2. Plot of 6-hour data points versus Gumbel analysis for Pohnpei WSO, FSM.

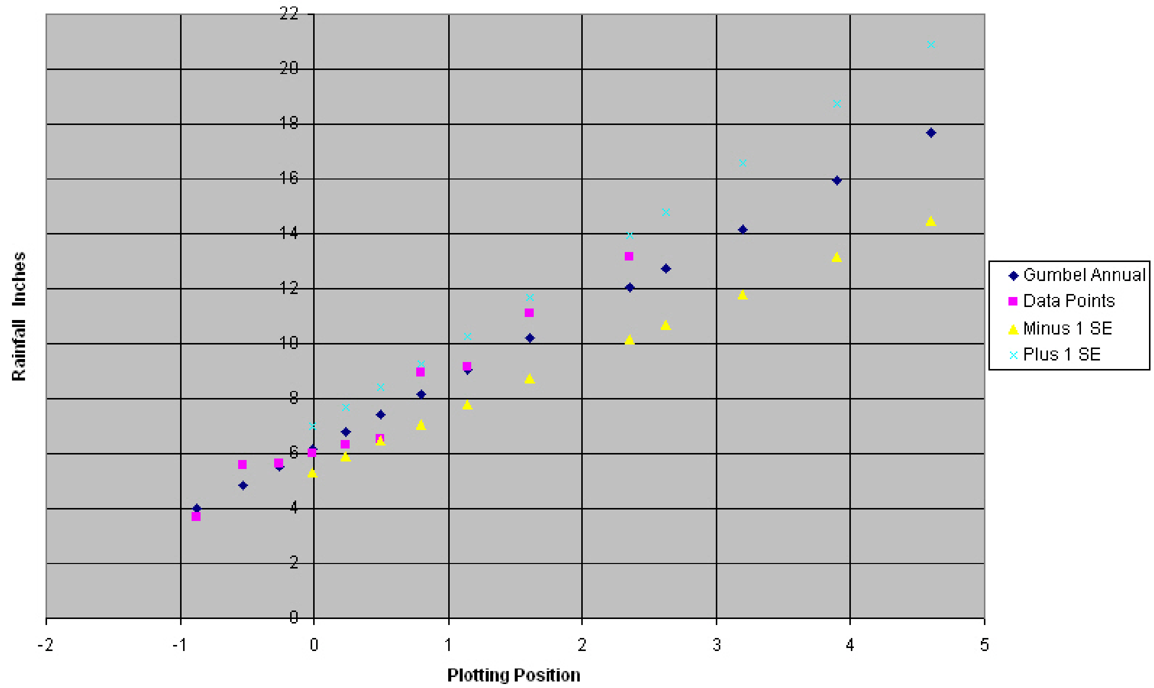

Figure 7-K3. Plot of 24-hour data points versus Gumbel analysis for Pohnpei WSO, FSM.

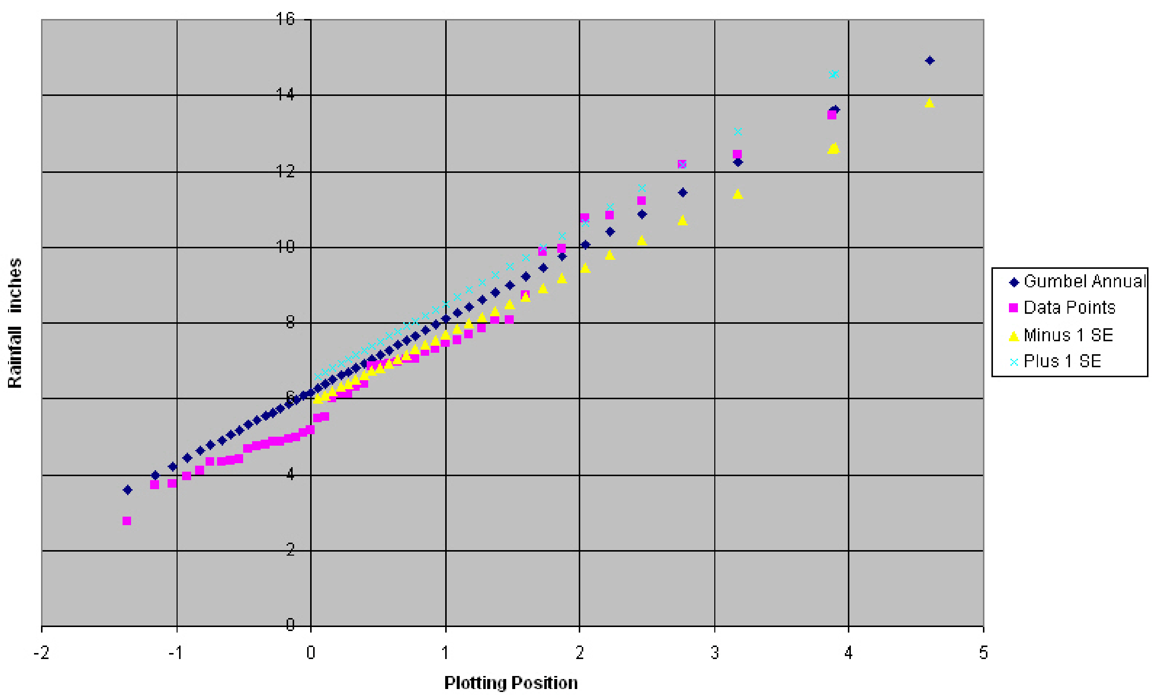

Figure 7-L1. Plot of 24-hour data points versus Gumbel analysis for Kosrae, FSM.

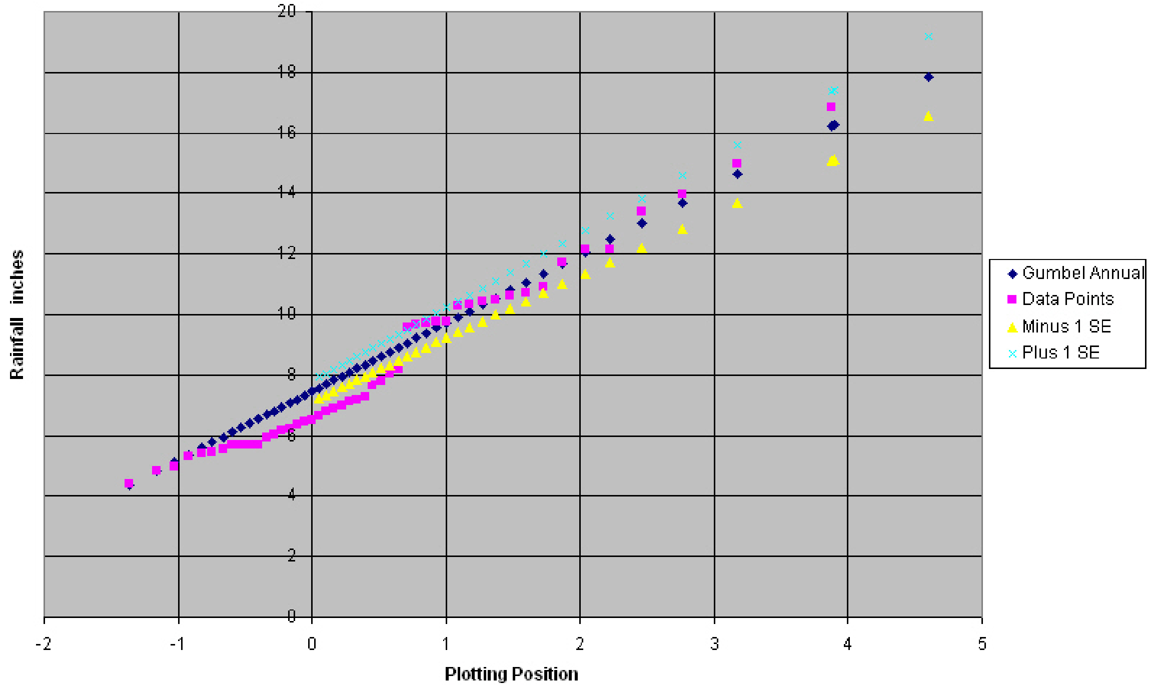

Figure 7-L2. Plot of 48-hour data points versus Gumbel analysis for Kosrae, FSM.

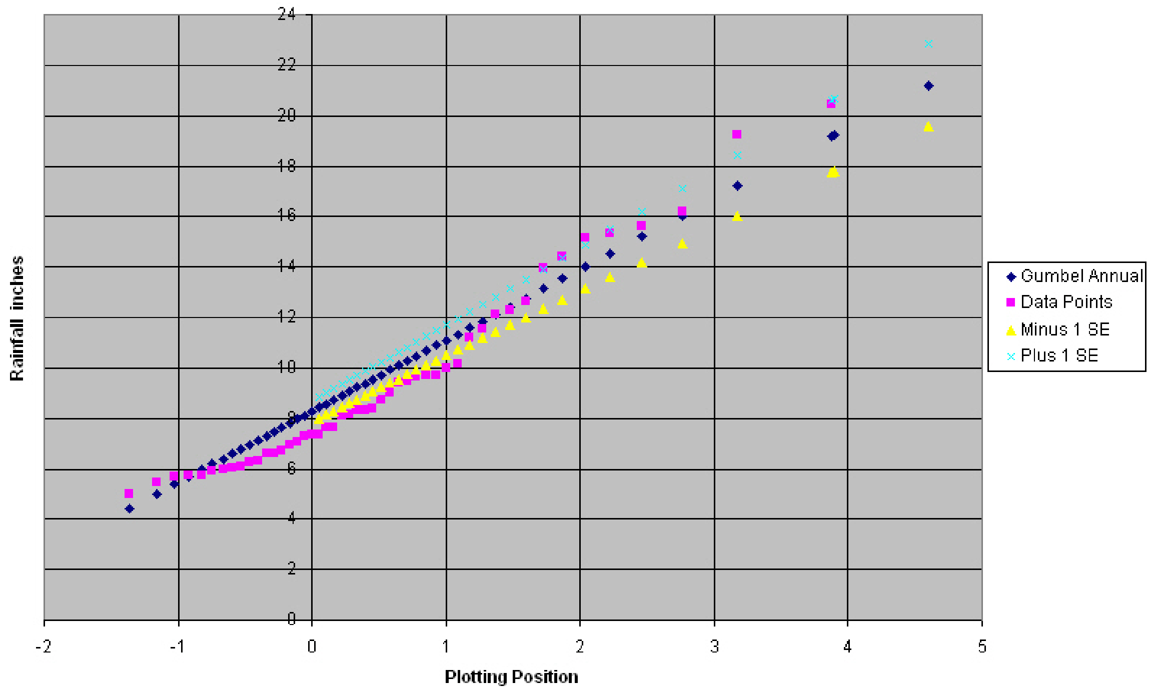

Figure 7-L3. Plot of 72-hour data points versus Gumbel analysis for Kosrae, FSM.

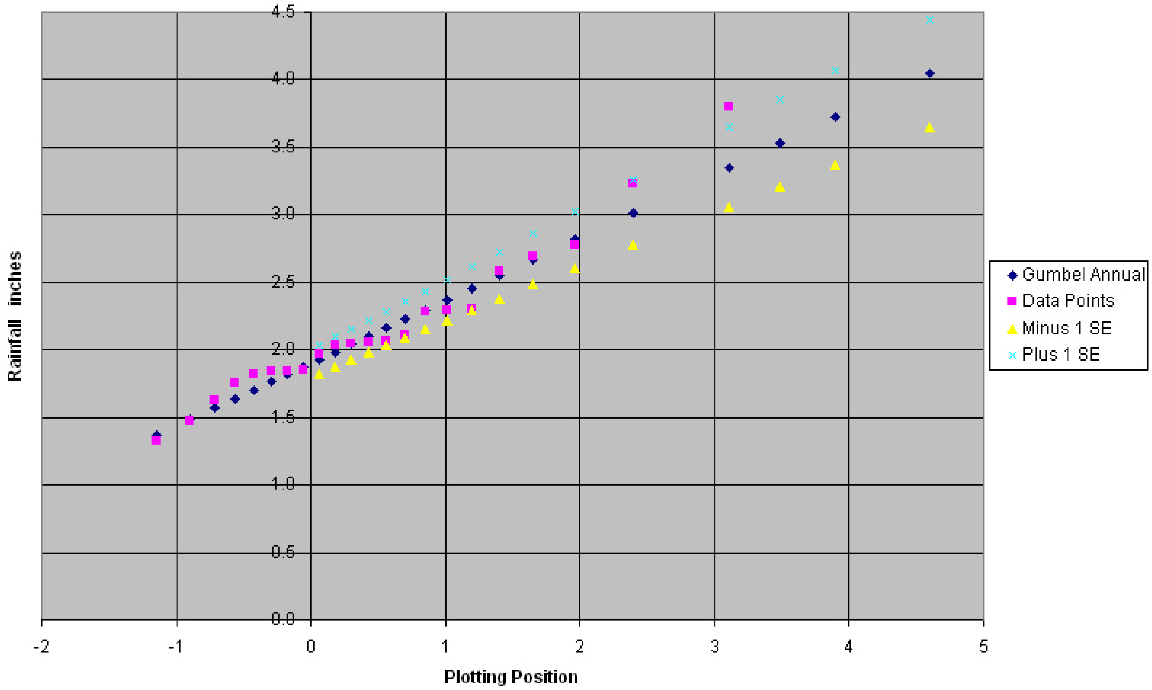

Figure 7-M1. Plot of 1-hour data points versus Gumbel analysis for Koror, Palau.

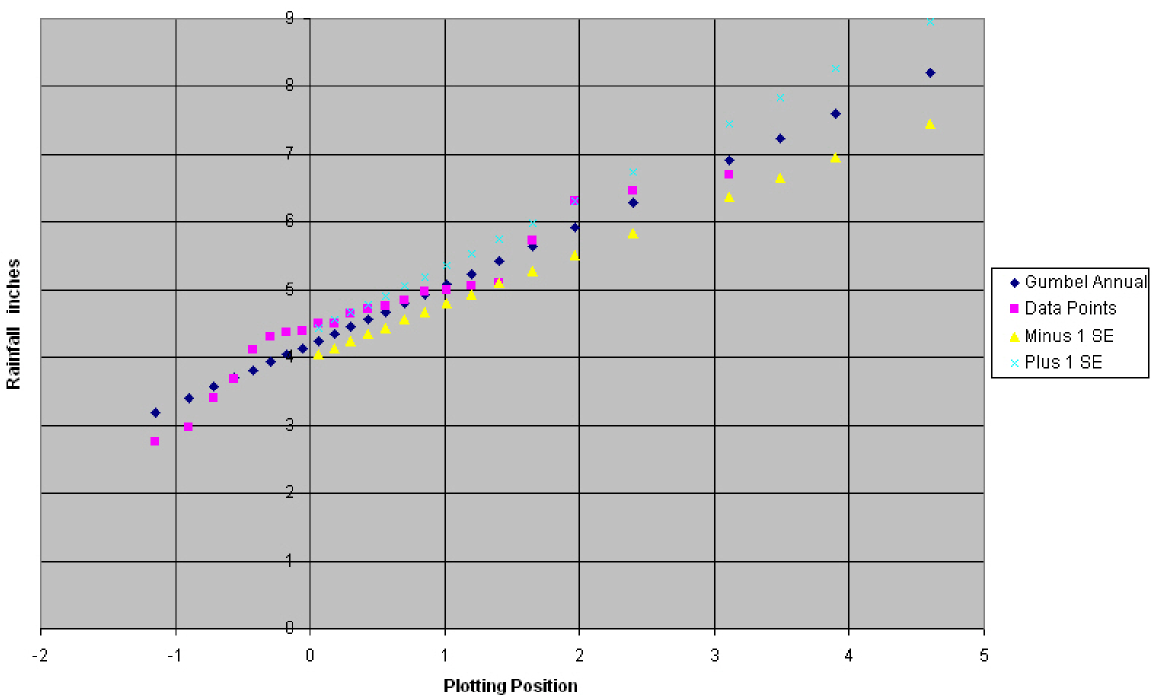

Figure 7-M2. Plot of 6-hour data points versus Gumbel analysis for Koror, Palau.

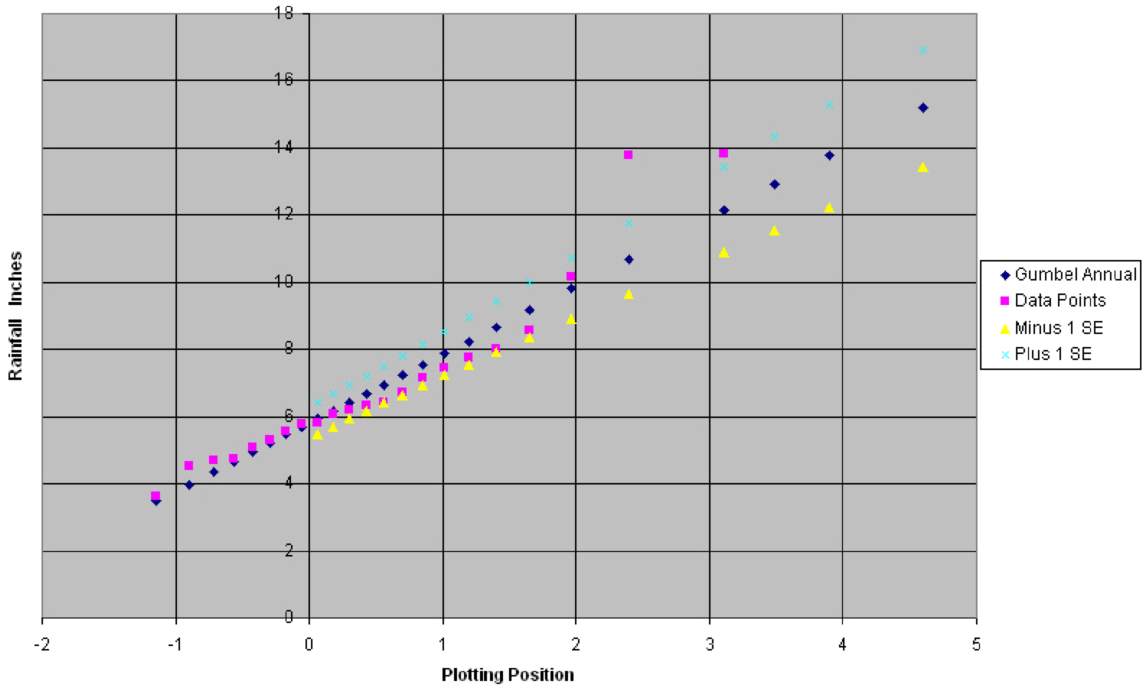

Figure 7-M3. Plot of 24-hour data points versus Gumbel analysis for Koror, Palau.

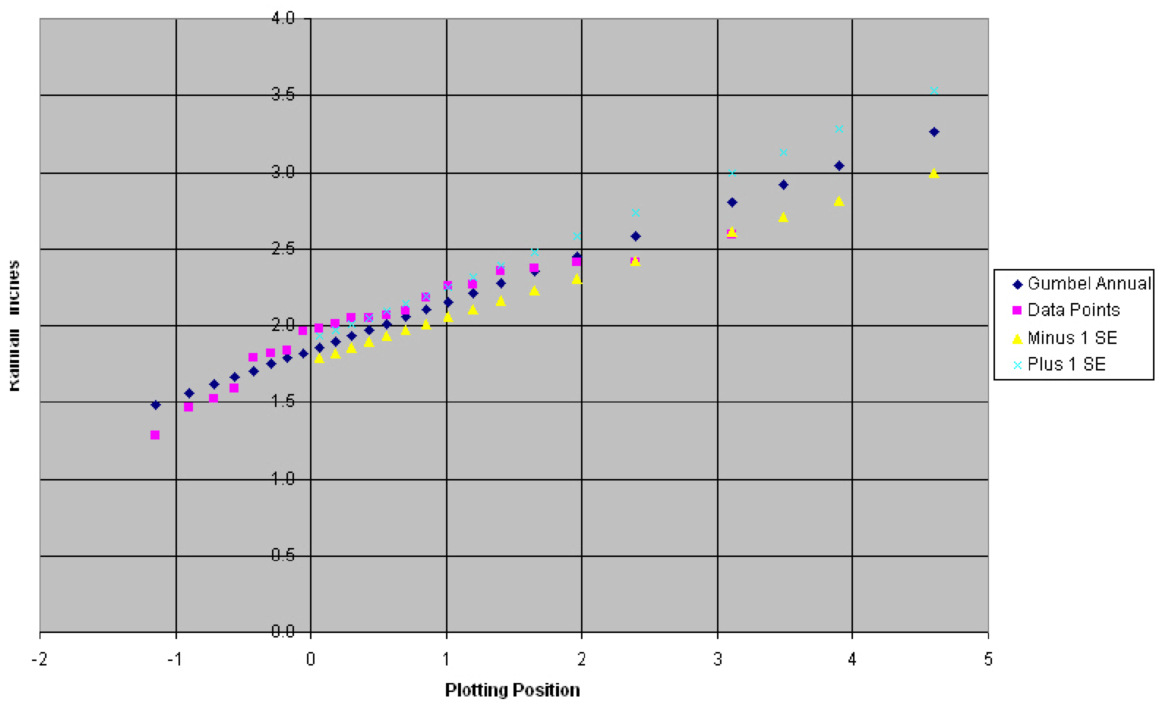

Figure 7-N1. Plot of 1-hour data points versus Gumbel analysis for Majuro, Marshall Islands (1984-2005).

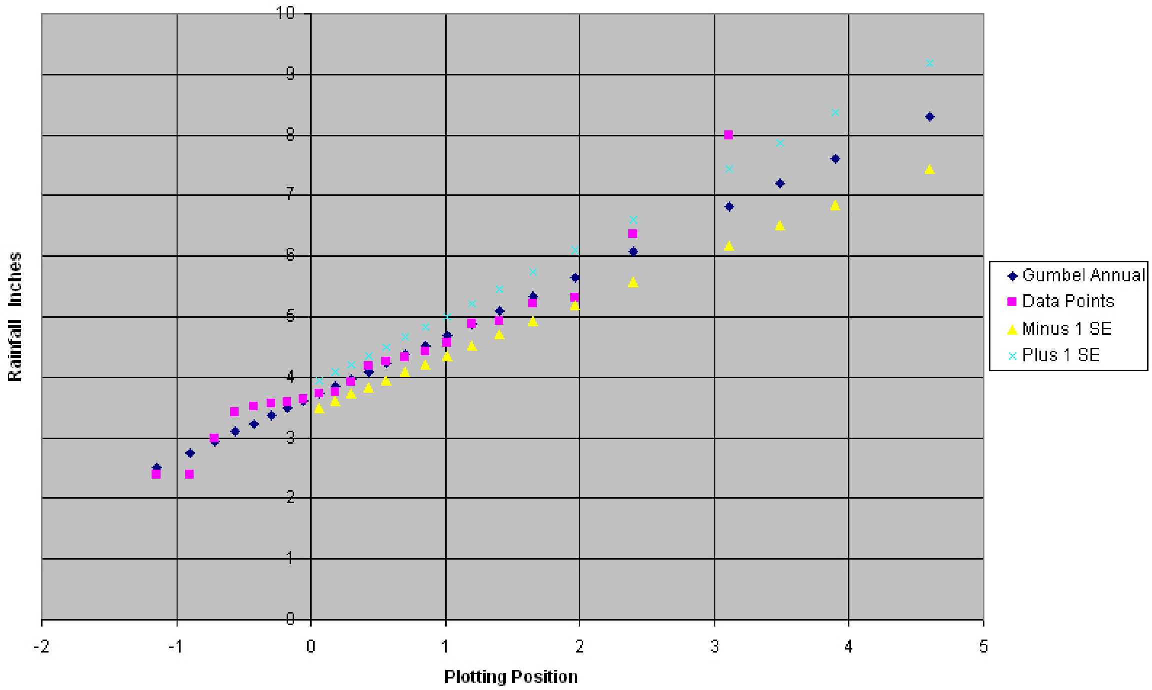

Figure 7-N2. Plot of 6-hour data points versus Gumbel analysis for Majuro, Marshall Islands (1984-2005).

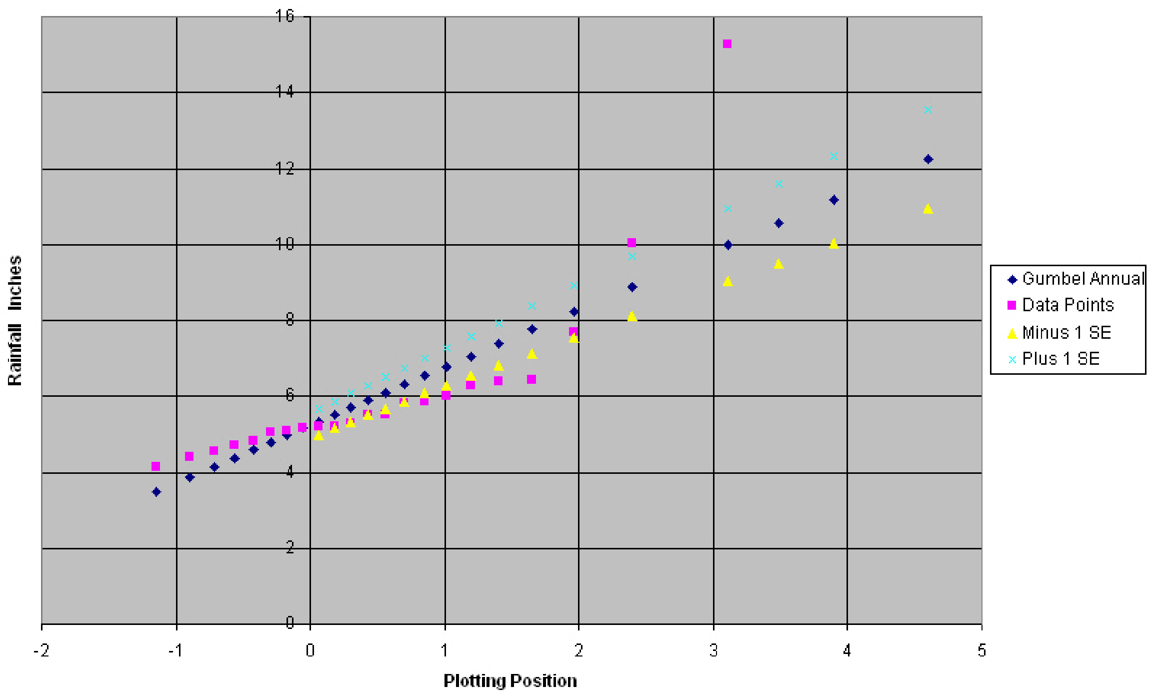

Figure 7-N3. Plot of 24-hour data points versus Gumbel analysis for Majuro, Marshall Islands (1984-2005).

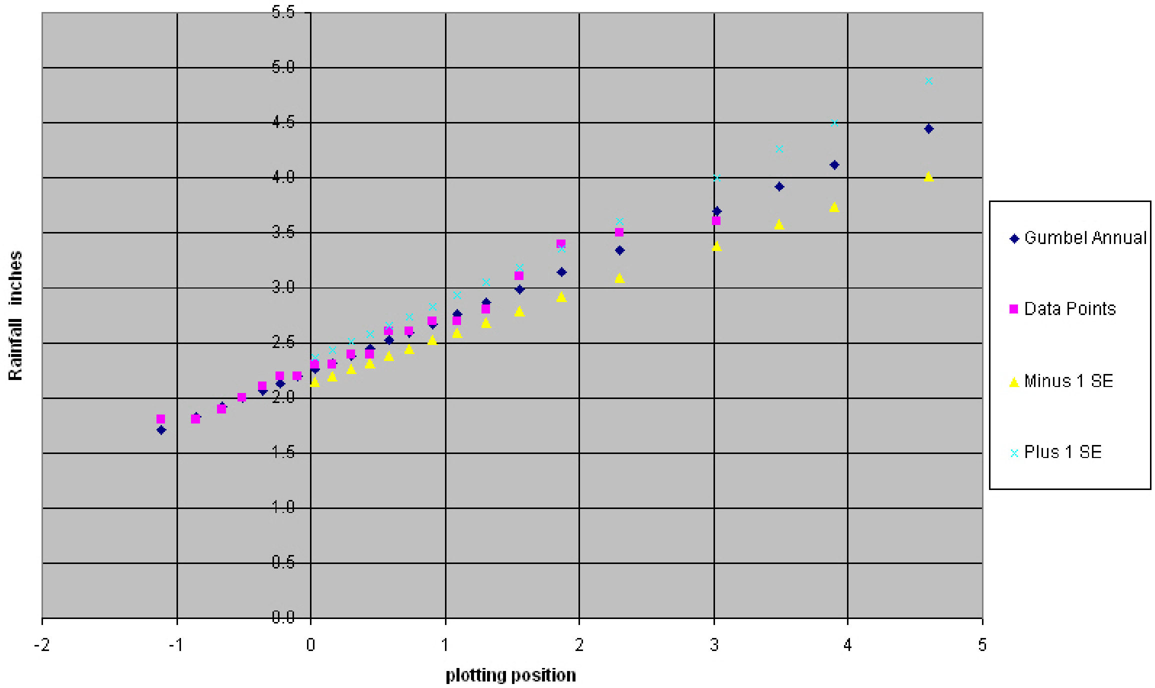

Figure 7-O1. Plot of 1-hour data points versus Gumbel analysis for Atuu, Tutuila, American Samoa.

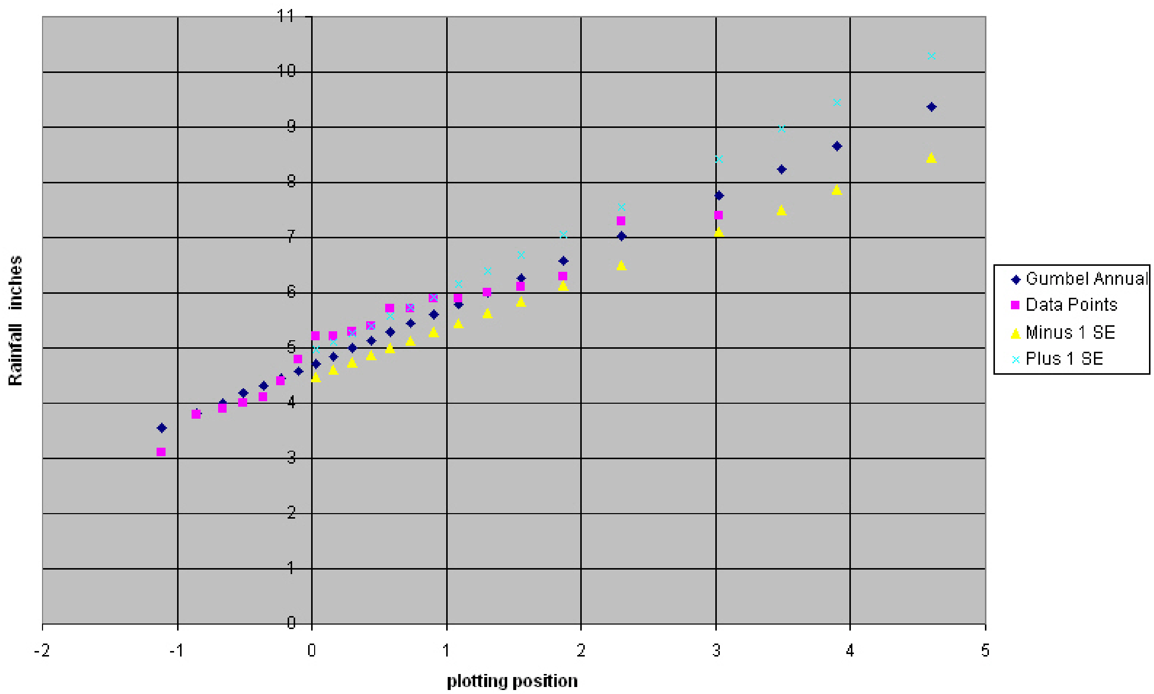

Figure 7-O2. Plot of 6-hour data points versus Gumbel analysis for Atuu, Tutuila, American Samoa.

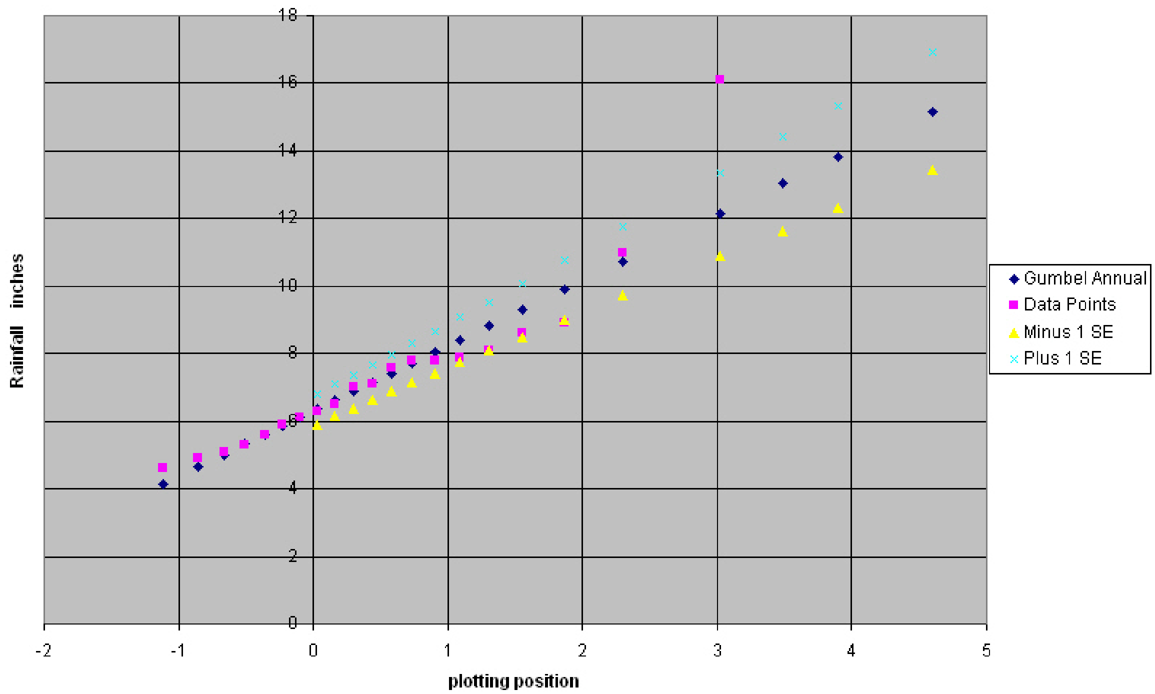

Figure 7-O3. Plot of 24-hour data points versus Gumbel analysis for Atuu, Tutuila, American Samoa.

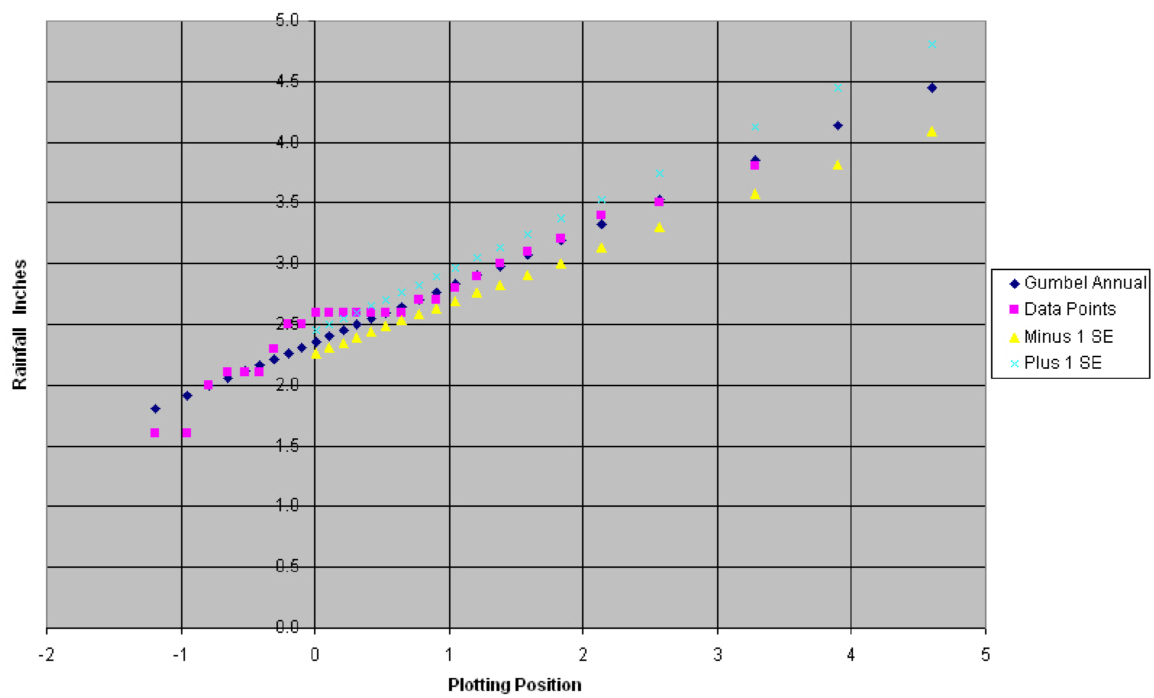

Figure 7-P1. Plot of 1-hour data points versus Gumbel analysis for Malaeloa, Tutuila, American Samoa.

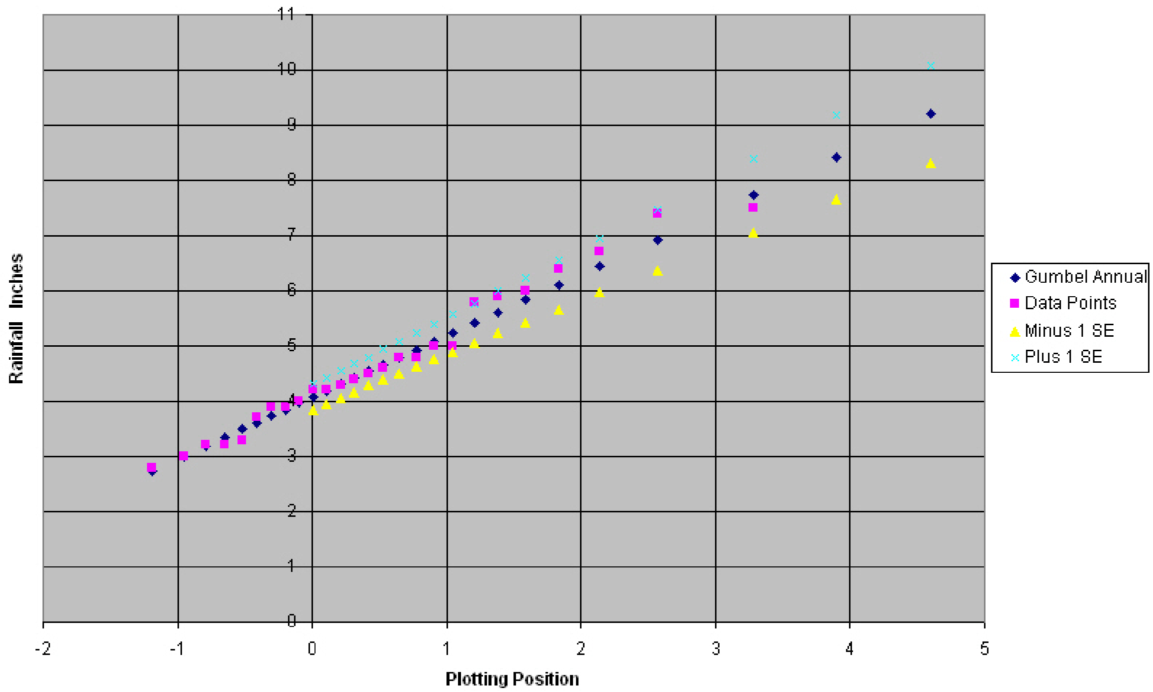

Figure 7-P2. Plot of 6-hour data points versus Gumbel analysis for Malaeloa, Tutuila, American Samoa.

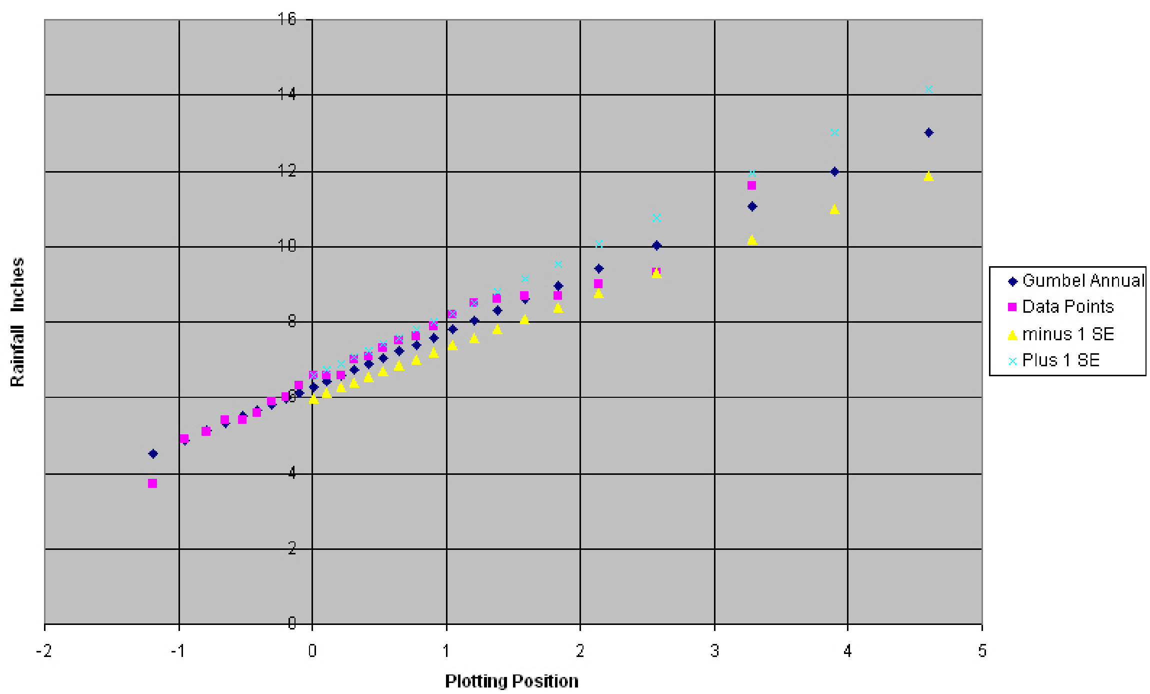

Figure 7-P3. Plot of 24-hour data points versus Gumbel analysis for Malaeloa, Tutuila, American Samoa.

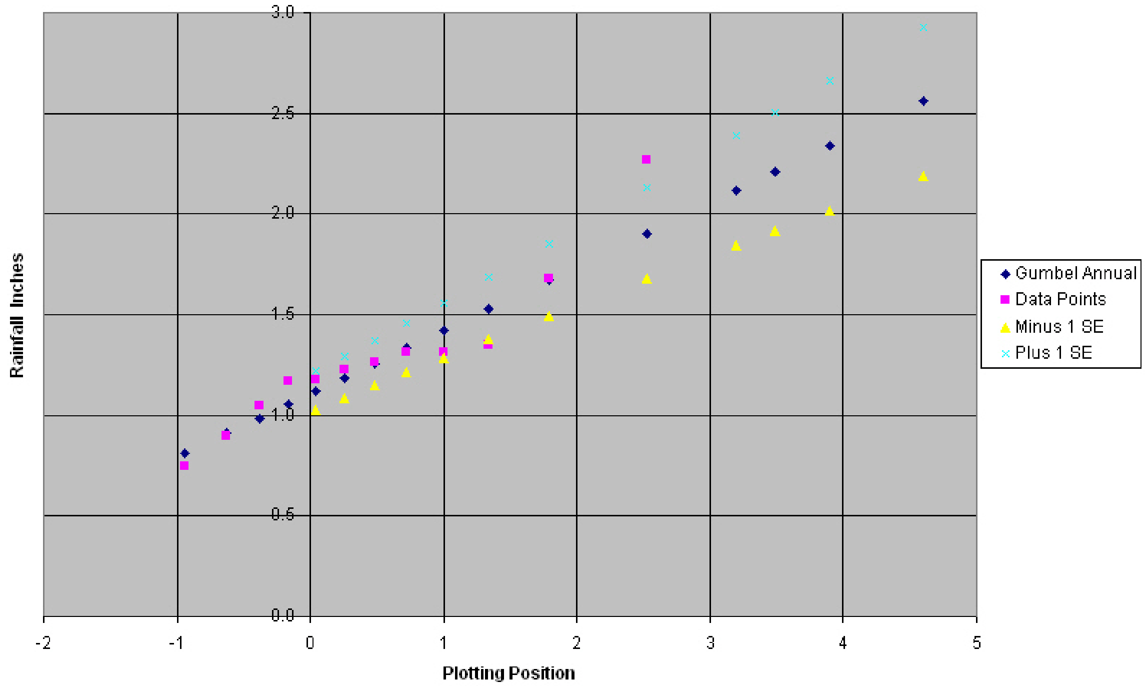

Figure 7-Q1. Plot of 1-hour data points versus Gumbel analysis for Wake Island.

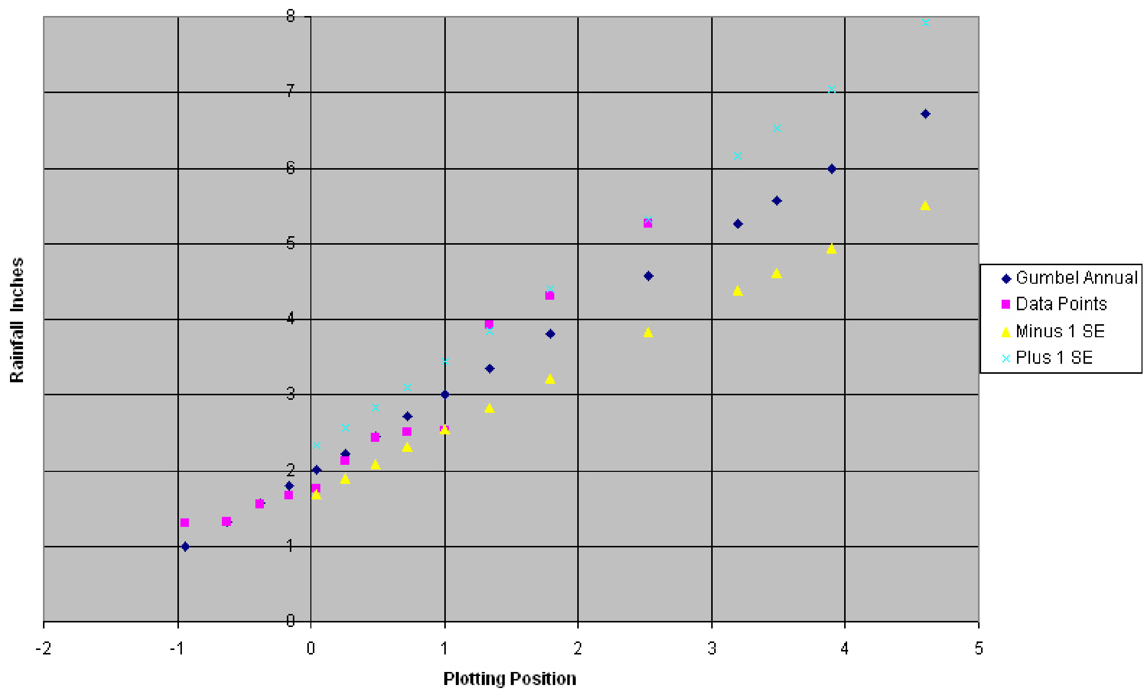

Figure 7-Q2. Plot of 6-hour data points versus Gumbel analysis for Wake Island.

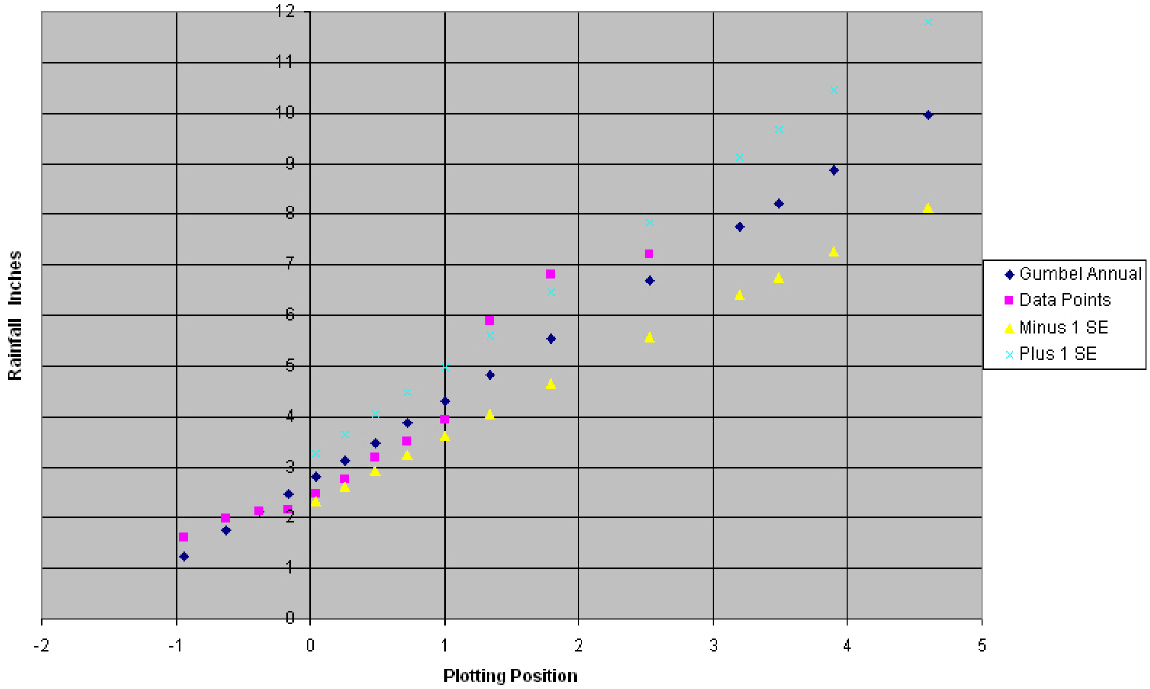

Figure 7-Q3. Plot of 24-hour data points versus Gumbel analysis for Wake Island.

Appendix 8 Locations of rain gages on Guam, Saipan, Pohnpei, and Tutuila

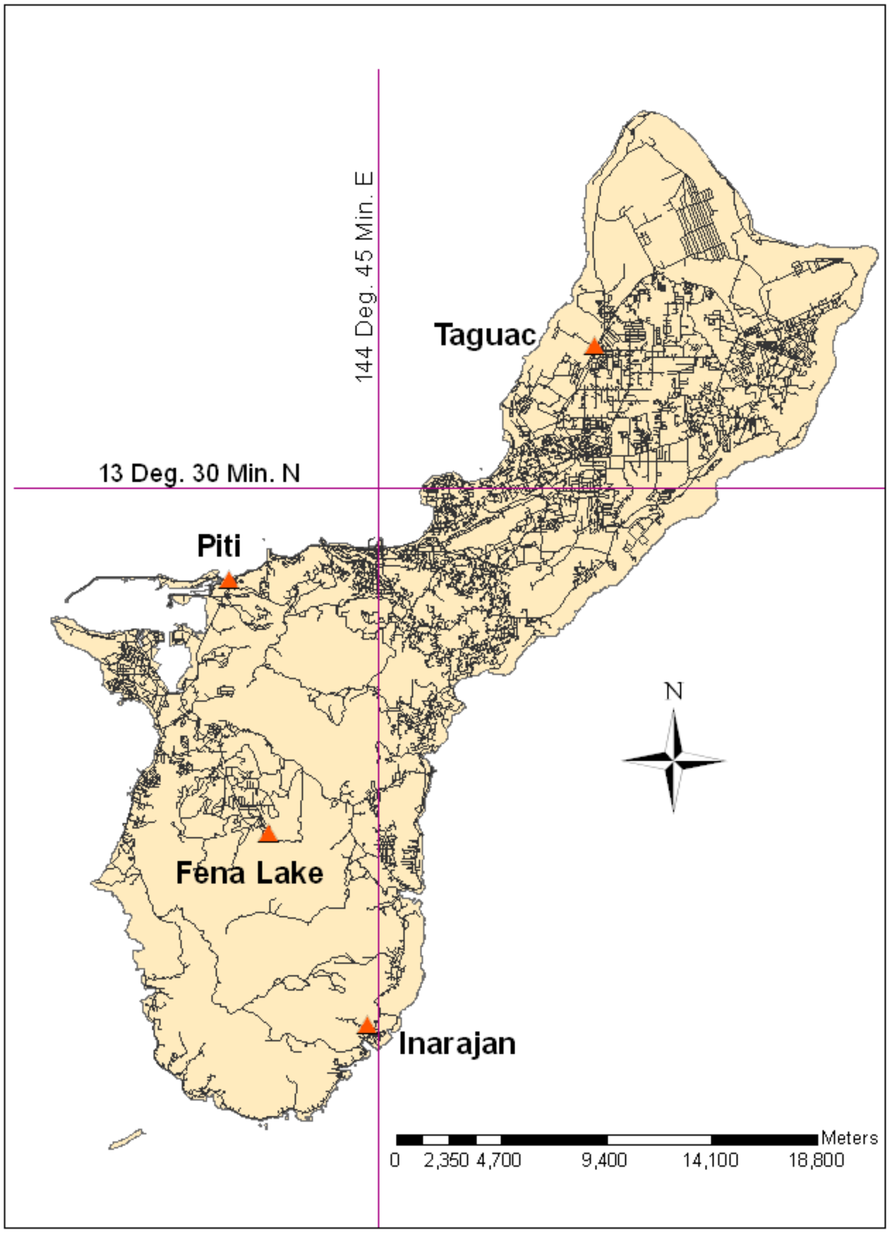

Figure 8-1. Map of the Territory of Guam with location of four rain gages.

Figure 8-2. Map of the island of Saipan, Commonwealth of the Northern Mariana Islands with location of two rain gages.

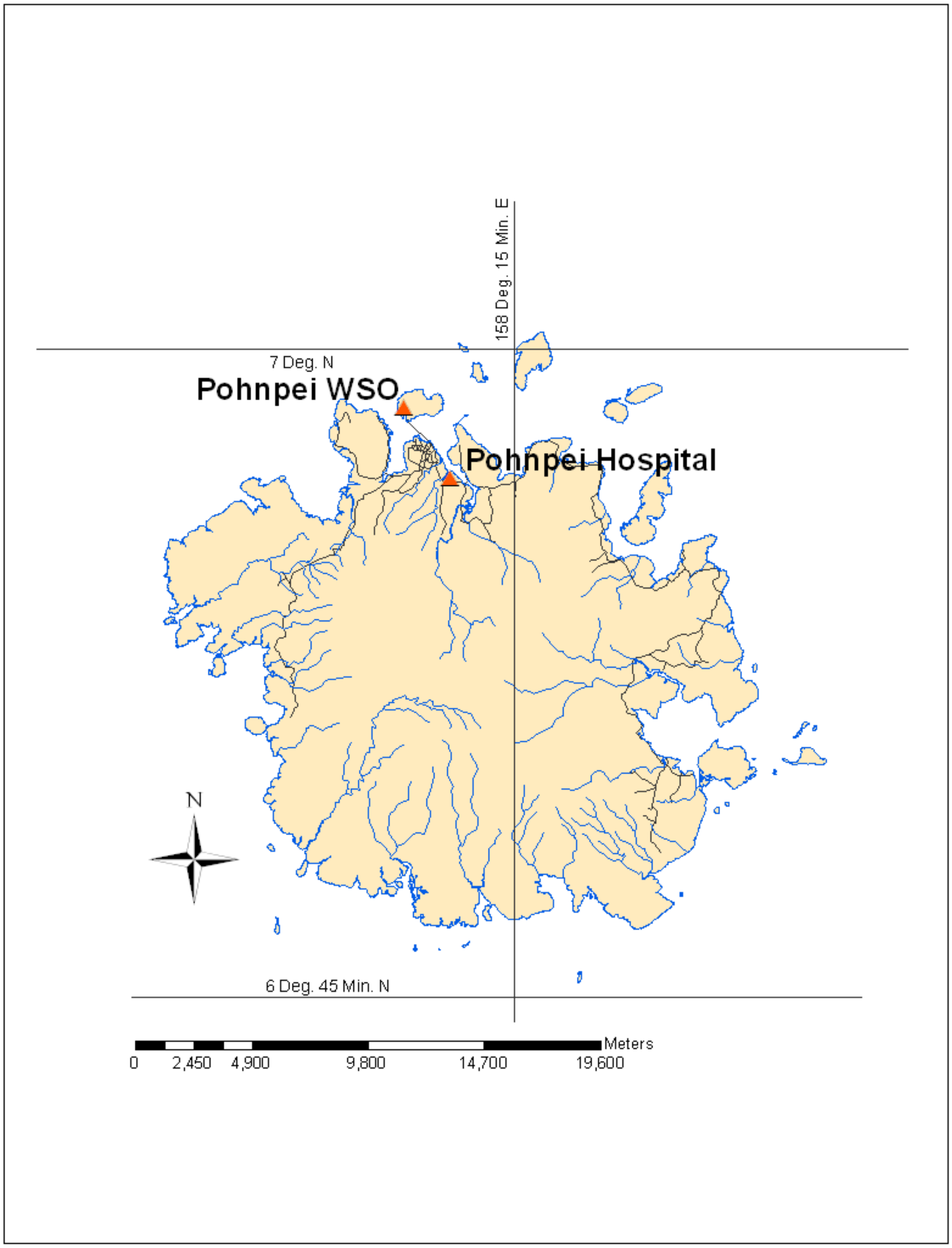

Figure 8-3. Map of the island of Pohnpei, Federated States of Micronesia with location of two rain gages.

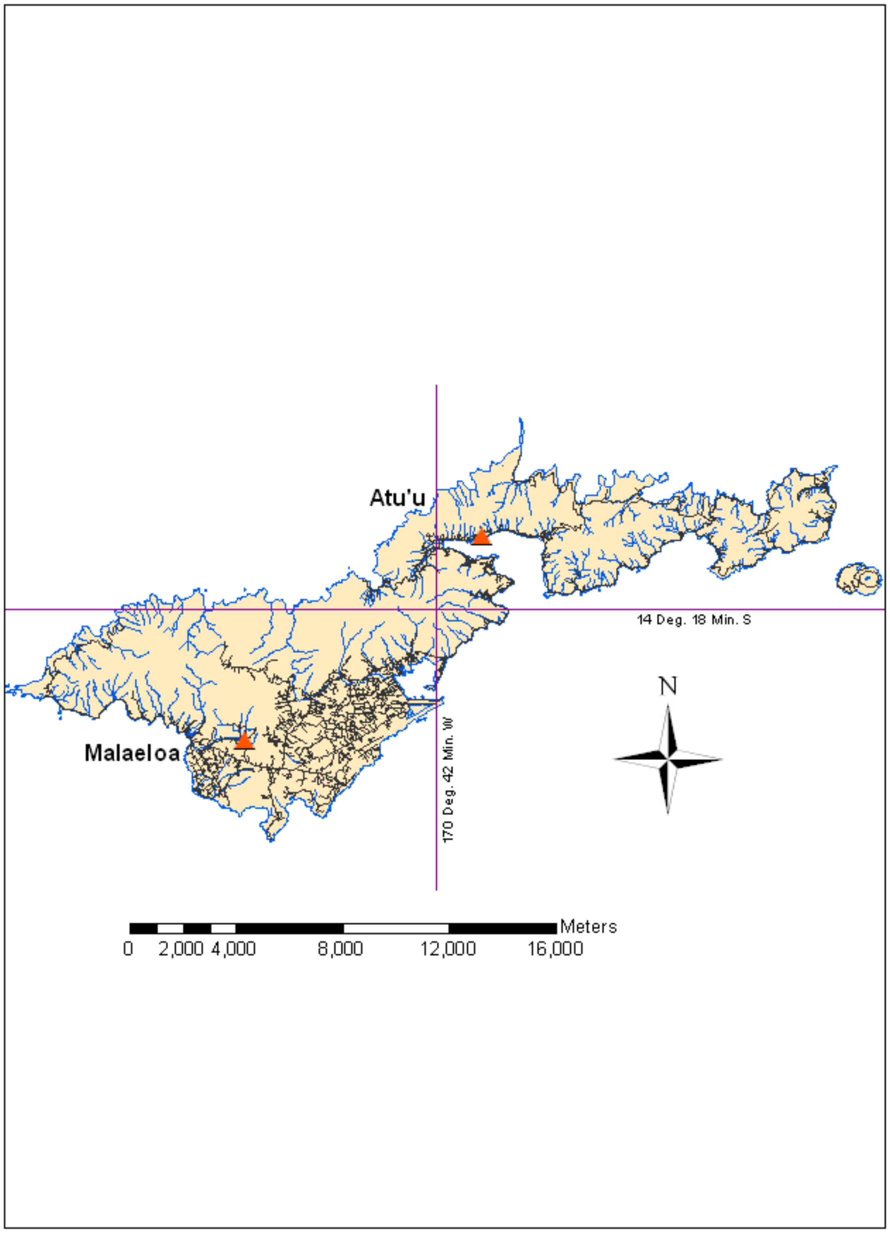

Figure 8-4. Map of the island of Tutuila, American Samoa with location of two rain gages.