**Design Storm Rainfall Depths - An Overview of the Research Methods**

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**WHY DO THE STUDY?**

Simply stated the depth of water associated with rain events may be more accurately defined in light of new methods for analyses and additional data. The five water management districts (WMDs) in Florida – Northwest Florida, St. Johns River, South Florida, Southwest Florida, and Suwannee River – have worked with the Federal Emergency Management Agency (FEMA) to improve and formalize their relationships with a federal agency that shares flood protection responsibilities. The WMDs have each executed a Cooperating Technical Partners (CTP) Memorandum of Agreement with FEMA. Staff from the five WMDs and other partners coordinates on a regular basis to discuss the unique issues facing Florida in implementing FEMA’s Flood Insurance Rate Map (FIRM) Modernization program. As CTPs, the WMDs see the necessity of a coordinated approach to implementing and managing Map Modernization and the advantages of dealing with issues as a united front. As a product of this coordination, the WMDs identified the need to develop consistent rainfall depth criteria across the state for hydrologic analysis.

Regionally specific rain depths have been developed by most of the WMDs to produce design criteria within their area boundaries. Along the boundaries between WMDs, the rainfall depths often do not match and in fact differ by several inches in some locations. In addition, Isopluval maps generated by each WMD differ from the national standards: National Weather Service Technical Paper 40 (TP-40), published in 1961; National Weather Service Technical Paper (TP-49), published in 1964; and the National Oceanic and Atmospheric Administration Technical Memorandum NWS HYDRO-35, published in 1977. Differences in the maps are a result of using local data, different periods of record, different best-fit distributions, and different approaches to filling in data gaps both spatially and temporally.

Because the boundaries of the WMDs are based largely on watershed boundaries rather than political boundaries, many counties within the state are split between WMDs. One issue that has been raised during several Map Modernization projects is the difference among the WMDs in the total rainfall depth for a given duration. For split counties, determining which design storm criteria to apply for a countywide Map Modernization project must be determined. The WMDs have suggested that developing Isopluval rainfall depth curves for the entire state is the best alternative to manage the design rainfall depth inconsistencies across the state. Developing updated, statewide Isopluval rainfall depth curves provides the WMDs a consistent approach based on defendable techniques, local data, and a longer period of record than existing maps.

**PAST STATE WIDE DATA ANANLYSES**

The last state-wide update using the then current rainfall data was completed in 1995. Since then there have been various other studies for specific areas that in some ways have resulting in discontinuous estimates of rainfall depths for different return periods at the boundaries of the Water Management Districts in the State of Florida.

The 1995 update preformed by the UCF research team resulting in the development of equal precipitation lines for the State of Florida and used rainfall data acquired from NOAA and the Water Management Districts in digital format. The data were obtained in both 15-minute and hourly recorded rainfall for stations in Florida, 5 stations in southern Georgia, and one file containing only 15-minute data from southeast Georgia. The information was then parsed into annual and partial series records containing the required durations for the study. An extensive visual quality control check of all data resulted in the acceptance of a total of 107 rainfall (76 hourly and 31 fifteen-minute) stations.

A sample of 25 stations was selected based on their spatial location and amount of data available for analysis. Distribution analysis of these 25 stations and comparison to results obtained in reviewed research resulted in the selection of the Log Pearson Type III distribution. The predicted rainfall volumes for the desired return periods of 2-, 3-, 5, 10-, 25-, 50-, 100-, 200-, and 500-years were generated and then converted to intensities. These intensities were then used to determine the best equation to fit the intensity versus duration data to the standard forms associated with IDF curves.

Since rainfall data collected and analyzed represented a single location, spatial analysis was used to estimate the values for unrecorded areas within the boundaries of the study. Kriging was used as the interpolation estimator for the special analysis to obtain the best possible local averages coinciding with actual obtained values of recorded rainfall stations. All 107 sites were used in the kriging analysis incorporating the location of the stations and the predicted rainfall intensities at those stations. The estimates at 625 coordinate points in the Florida grid resulting from the kriging process provided the curve fit parameters for the selected best fit equation.

**WHAT WAS DONE TO UPDATE THE DEPTH CURVES?**

The proposed plan for updating the precipitation frequency estimates for the State of Florida includes all of the steps taken in the above described analysis and was divided into four tasks.

1. The first task was a review of the literature to determine the extent of work being completed for similar analyses. An annotated bibliography and summary report resulted.

2. In the second task, the national data used was from three major sources, namely the National Climatic Data Center (NCDC), a digital format of the available NOAA rainfall stations for the state of Florida, and additional quality controlled digital data from the Water Management Districts. To ensure the best possible accuracy of this project, additional visual QC checking was performed on all data. The rainfall stations used in southern Georgia and southeast Alabama were again used. This helped in obtaining consistency across the north Florida borders. A DVD or other suitable storage device with all the rainfall data that was deemed acceptable was submitted along with a report statistically summarizing the data for each station. The proposed method for parsing the data, performing the frequency analysis, and the spatial interpolation was also presented in a draft technical report. The report was submitted to a WMD committee for approval prior to starting task three.

3. The third task involved parsing of the data and frequency analysis. The revised data set was submitted along with a draft report documenting the data used, methodology for parsing the data, the process for inspecting the accuracy of the data, the methodologies for determining the sample of stations for the frequency analysis, the range of functions used in the frequency analysis and the result thereof. Summary tables and figures were included. Any abnormalities in the data were documented with recommended solutions. This technical report was presented to a committee of WMD members as a draft and revision made based upon the committee input.

4. The final report was composed of technical reports and posted for ease of use on a computer site known as Wiki (an online database depository of information). The site called the UCF Rainfall Analysis, and it currently gets on the average over 300 hits per month.

**DETAILS OF THE METHODOLOGIES USED IN TASKS 2 and 3**

**Step 1 – Determination of Rainfall Maxima**

There is a significant quantity of rain depth data, but for some periods of time the records are not complete. To select the data for analysis, at least eleven years must be available. For each year of the eleven, there should be no more than 28 consecutive days of missing data and no more than 60 intermittent days of missing data. Also accumulations should not total more than 122 in a year. We also had available NOAA data and the selection of each year already included the rule of no more than 30 consecutive days of missing data. The majority of the data available is in hourly depths. From these rain depths, the annual maximum is determined for all durations under study. A computer program was written that parses through the data for each site determining the maximum rainfall for all durations. This program is available at the computer site named “ucf-rainfall.pbworks.com”. The program simply starts at a given time accumulating rainfall forward for the duration being accumulated. If this volume is greater than the current maximum, it replaces that maximum. The process is repeated for every starting value (rainfall value in the data set) in the data for each year. These values were also verified by hand checking their values against the actual data for the site. The following table shows the annual maximum volume for each year of available data and analyzed duration for the rainfall site at Orlando International Airport.



**Annual Maximum Volumes (inches) for Site 6628 (Orlando IAP)**

**Step 2 – Distribution Fit for the Rainfall Data**

The maximum data for a given duration is now fit to a probability distribution. The selected distribution for all data analysis was the GEV distribution. This determination was made by visual comparison of fit comparing Normal, 2 Parameter Log Normal, 3 Parameter Log Normal, Pearson, Log Pearson, Gumbel, and GEV distributions. The Weiss factor was applied to the data before analysis to account for the possibility of missing actual maxima for durations close to the time increment of the data. The results of the Distribution Fit are the GEV Parameters (Mean, 2nd Moment, Skew, L-Moments) and a prediction of the maximum based distribution fit. The fit value (Rainfall Volume) is a function of return period and duration. The following table shows the results of the GEV Distribution fit for the Orlando International Airport.



**GEV Volume Predictions (inches) with Weiss factors for Site 6628 (Orlando IAP)**

**Step 3 – Curve Fit to Final Equation Form**

The final step of the analysis for a single site is to fit the distribution data to a single curve fit form. The form of the equation selected was



Where D = Duration (in hours) and a, b, and n are curve fit parameters. An example of the curve fit parameters for the Orlando International Airport site is shown.



**Curve Fit Parameters with Weiss for Site 6628 (Orlando IAP)**

These parameters are then used to calculate the final volume prediction for each duration and return period. These values are calculated for every site.



**GEV Volume Predictions (inches) Curve Fit for Site 6628 (Orlando IAP)**

**Actual Maximum Volumes with Weiss**

**Step 4 – Spatial Analysis**

Each site now has 81 rainfall volume predictions for the 9 return periods and the 9 rainfall volumes that were part of the analysis. The final step is to develop a set of rainfall volume isohyetes representing all the stations that were part of the analysis. The first step was to choose a spatial analysis methodology that adequately represents the data. A standard spatial kriging analysis was selected as the best methodology. Methods compared were inverse distance to a power, standard kriging, minimum curvature, modified Shepards method, natural neighbor, nearest neighbor, polynomial regression, radial basis functions, triangulation with linear interpolation, moving average, and local polynomial. These were applied to fifteen sites and selection was made based on the reproduction of actual rainfall volumes from the sites. The krig analysis was performed on all data and the results were published for each duration and return period.



5 Year Return Period 1 Hour Duration Rainfall Volume in Inches Annual Maximum Series