HAWAII PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 43*

Sixth Progress Report
1 July 2002 through 30 September 2002

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for Hawaii. Current precipitation frequency estimates for Hawaii are contained in *Technical Paper No. 43,* "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years" (U.S. Weather Bureau 1962). The update includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14 on the internet using web pages with the ability to download digital files.

The study area covers the Hawaiian islands including Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. The study area including preliminary regions is shown in Figure 1.

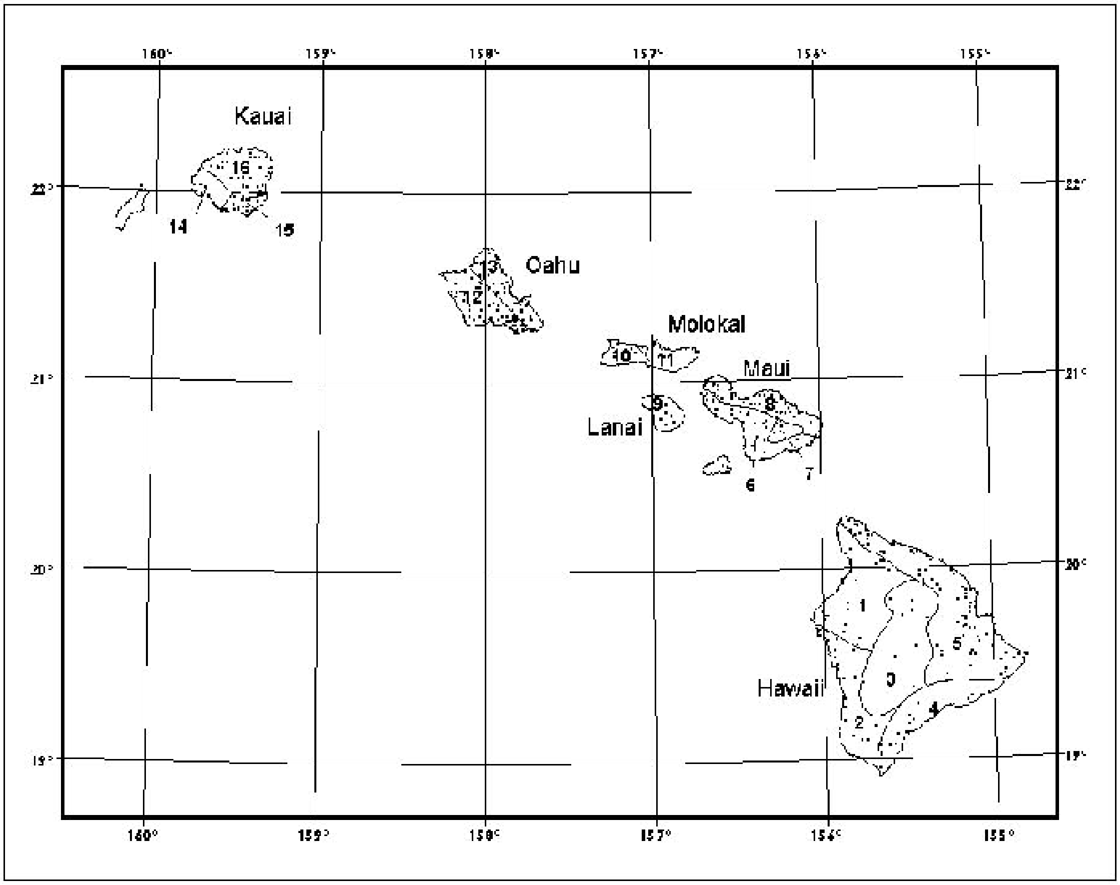

Figure 1. Hawaii Precipitation Frequency study area, regional divisions and daily station locations.

2. Highlights

Issues associated with funding this project have been resolved. See Section 5; Issues.

Data entry of monthly maximums from daily gages maintained by the State continues by the University of Hawaii. HDSC received data from the University for the Big Island during the reporting period. Entry continues by the University with Maui County. Additional information on this subject is available in Section 4.1, Data Collection and Quality Control.

The Semiarid Precipitation Frequency Study observing site review allowed users to not only review the Semiarid precipitation frequency estimates, but the Precipitation Frequency Data Server (PFDS) as well. The PFDS held up well during its first debut, and a tremendous amount of valuable input was received and quickly incorporated into the PFDS. Additional information is provided in Section 4.2, Precipitation Frequency Data Server.

Internal consistency software was revised to adjust quantiles through the 24-hour duration for hourly-only stations. Software was developed to adjust quantiles for co-located hourly and daily data, particularly across the 12-hour to 24-hour durations. Software was also written to calculate conversion factors from annual maximum series to partial duration series which will be part of the final deliverable. Additional information is provided in Section 4.3, Software Development.

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. The progress includes identification of four additional study areas, completion of quality control on the existing eight study areas, and testing of the initial computer programming. Additional Information is provided in Section 4.4, Spatial Relations (Depth Area Duration Study).

Temporal distributions will be produced for the 4-day duration in addition to the 12 and 24 hour durations. Additional information on this subject is available in Section 4.5, Temporal Distribution.

The PRISM technique for spatial interpolation appears to be providing excellent results. Additional information is provided in Section 4.6, Spatial Interpolation

3. Status

3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percentage completed per task. Past status reports should also be referenced for additional information.

Hawaii study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [25%]:
- Multi-Day
- Daily
- Hourly
- 15-minute
- N-minute

The University of Hawaii will continue digitizing daily data from a network of state operated gages. Once this data is added to our data set the number of daily stations will greatly increase. The University will enter monthly maximums of daily data.

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [0%]:
- Multi-Day
- Daily
- Hourly
- 15-minute
- N-minute

Temporal Distributions of Extreme Rainfall [0%]
- Assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- Sort, average and plot time distributions of hourly maximum and median events by storm area, quartile and duration

Spatial Interpolation [0%]
- Create mean annual maximum (a.k.a. "index flood") grids with PRISM for all durations from 60-minute to 60-days.
- Apply a precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure to create a total of 162 grids. The same

procedure will be used to create 162 upper and 162 lower bound precipitation frequency grids. (See 4.6, Spatial Interpolation for more details.)
- Apply study-wide conversion factor to the 1-hour precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids.

Peer Reviews [0%]:
- Lead review of point precipitation frequency estimates
- Lead review of spatial interpolation grids

Data Trend Analysis [0%]
- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Deliverables [20%]
- Prepare data and documentation for web delivery

Spatial Relations (Depth Area Duration Study) [40%]
- Obtain data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations from each network
- Compute ratio of maximum to average depth for all durations and networks and plot
- Prepare curves of best fit (depth area curves) for each duration and network

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in separate volume of NOAA Atlas 14.

4. Progress in this Reporting Period

4.1 Data Collection and Quality Control.

HDSC received the hand entered digital rainfall data from the University of Hawaii for the Big Island. The University began to hand enter state rainfall data for Maui County as well.

4.2 Precipitation Frequency Data Server.

The Semiarid Precipitation Frequency study observing site review allowed users to not only review the Semiarid precipitation frequency estimates, but the Precipitation Frequency Data Server (PFDS) as well. The PFDS held up well during its first debut, and a tremendous amount of valuable input was received and quickly incorporated into the PFDS.

Changes and bug fixes include, but are not limited to:

- Fixed data truncation at 100 inches problem
- Fixed the “Download table as text” function
- Added new Depth-Duration Frequency (DDF) graph (see below)
- Changed the titling of the x- and y-axis
- Added more “Submit” buttons to alleviate the confusion on how to get to the output page
- Modified the screen layout such that it fits comfortably on one screen (width-wise).
- Limited the list of stations in the pull-down menu to only those stations in the selected state

In order to provide users a complete perspective of precipitation frequency estimates, a new graph is now part of the precipitation frequency output page. An example of the popular new graph is shown in Figure 2.

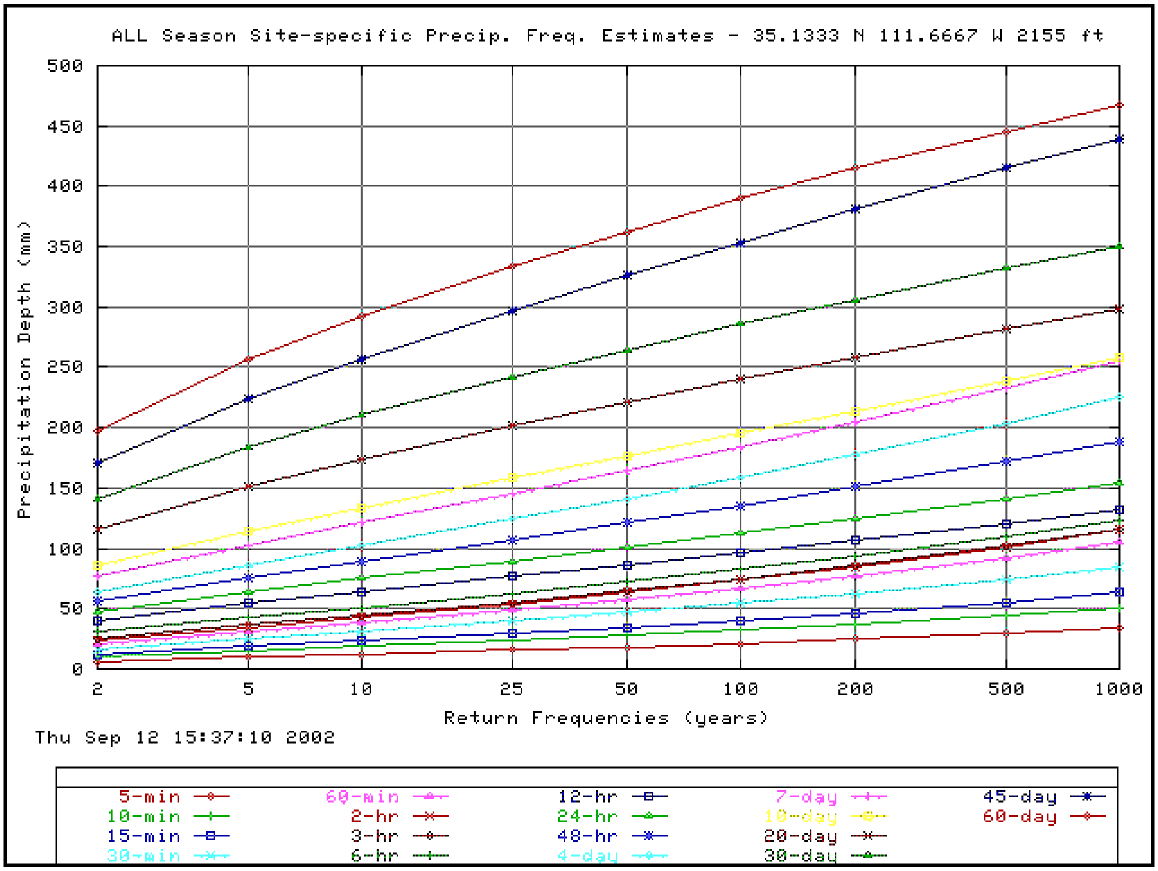

Figure 2. Sample Depth-Duration Frequency Graph

Additionally, a paper was written about the PFDS to be included in the proceedings of the American Meteorological Society's (AMS) 9th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology conference. The paper will be presented as part of the AMS Annual Meeting in Long Beach, California in February 2003. For a pre-print, please contact Tye Parzybok at tye.Parzybok@noaa.gov

4.3 Software Development.

Internal consistency software was revised to adjust quantiles through the 24-hour duration for hourly-only stations. Cases where a shorter duration has an estimate that is higher than the next longer duration (e.g., 2-hr = 1.9 and 3-hr = 1.5) are mitigated by adjusting using ratios based on the 1-hour duration.

Software was developed to adjust quantiles of co-located hourly and daily stations, particularly across the 12-hour to 24-hour durations. This adjustment assumes that the daily 24-hour quantiles are true because they are based on our most consistent values and generally have longer record lengths. The method preserves the hourly distribution for 60-minute through 12-hour quantiles at a given hourly station. It then adjusts the quantiles using ratios based on means and regional growth factors (RGFs) since these are the primary parameters in calculating quantile estimates and thus are the major contributors to any observed disconnect between the hourly 12-hour and 24-hour estimates. The software was modified to run on all co-located stations on a region-by-region basis.

Software has also been written to calculate conversion factors from annual maximum series (AMS) to partial duration series (PDS). This software will be tested and run for all durations and return frequencies. The AMS to PDS ratios will be averaged for each region and reported in the final deliverable.

4.4 Spatial Relations (Depth Area Duration Study).

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. Four additional study areas (three in California and one in Arizona) have been identified and will likely be included in the D-A-D study. Quality control on the existing eight study areas has been completed. A study area in the Middle Atlantic area may also be used. The initial computer programming has been written and successfully tested on two study areas. The secondary D-A-D programming continues and will be completed sometime early in the next quarter.

Upon completion, the final D-A-D reduction relationships will be available for use in basins throughout the continental United States. We have not yet been able to find data networks in the Hawaiian Islands suitable for this type of analysis. As a consequence, we have no basis for recommending these relationships will be suitable for the Hawaiian Islands. During the next quarter we will discuss this issue further with local experts to ensure we have not overlooked possible sources of data.

Data has been collected and prepared as shown in Table 1. Also, if additional dense-area-networks are identified, they will be added after the current software development phase of the projected is completed.

Table 1. Dense Area Rain Gauge Networks in DAD Study.

Depth Area Duration Study Areas	**Data Extraction and Re-Formatting**
Walnut Gulch, AZ	X
Reynolds Creek, ID	X
Tifton, GA	X
Hastings, NE	X
Alamogordo Creek, NM	X
Safford, AZ	X
Santa Rita, AZ	X
Cochocton, OH	X
Danville, VT	X
Chicago, IL (NCDC stations)	X
Riverside, CA	X
Maricopa County, AZ	X
Ventura County, CA	
Santa Clara County, CA	
Santa Barbara County, CA	

4.5 Temporal Distribution.

To better correspond with precipitation frequency durations that will be presented, a 4-day temporal distribution will be developed instead of a 3-day. Temporal distributions for 12 and 24 hour storms will also be computed.

4.6 Spatial Interpolation

On July 30, 2002 Geoff Bonnin and Tye Parzybok traveled to the Spatial Climate Analysis Service (SCAS) at Oregon State University, Corvallis, Oregon to discuss and obtain the first draft PRISM-interpolated Semiarid mean annual maxima (a.k.a. “index flood”) grids for 1-hour and 24-hour. The successful all-day meeting covered the following items:

- To better understand how PRISM (Parameter-elevation Regressions on Independent Slopes Model) performed in spatially interpolating the mean annual maxima values to grids
- Assessment of hard-copy maps (contoured) of the draft grids (1-hour and 24-hour "index flood")
- The evaluation of suspect data points and their influence on the grid results
- Inspection of model performance in difficult areas (e.g. transition between orographically-forced extreme regime in central New Mexico to a regime of more synoptically-forced events in eastern New Mexico)
- Differences between the NOAA Atlas 2 2-year 1-hour and 24-hour maps

It was concluded at the meeting that PRISM was doing an excellent job and was properly parameterized to accurately spatially interpolate point index flood values.

The draft "index flood" grids allowed HDSC to fully test the precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure. CRAB is a derivation process that utilizes the strong, linear relationship between a particular duration and frequency (e.g. 50-year 24-hour) and the next higher frequency (e.g. 100-year 24-hour). In fact, this relationship within a region is a constant obtainable from the regional growth factors. With the CRAB procedure however, a global (all-region) relationship is developed based on actual observing-site data, then the linear relationship is applied to the preceding grid (i.e. 50-year 24-hour) to establish a first guess 100-year 24-hour grid. Knowing regional differences occur, residuals (actual minus observed) are calculated for each observing-site and then normalized (divided by) by the preceding estimate (50-year 24-hour). These (point) normalized residuals are then spatially interpolated to a grid. The resultant grid is then de-normalized by multiplying it by the preceding grid to obtain a grid of actual residuals. The last step is to simply add the residual grid to the first guess grid to arrive at the final 100-year 24-hour grid. The process, as the term cascade implies, utilizes a previously derived grid to derive the next grid. So the same process is followed for deriving the 200-year 24-hour grid, but instead of the 50-year 24-hour grid being used as the predictor, the new 100-year 24-hour grid is used.

5. Issues

5.1 Funding

The National Weather Service provides precipitation frequency estimates at the request of, and with funds provided by, a variety of Federal, state and local agencies. While there appears to be general informal agreement that the precipitation frequency estimates for the Hawaiian Islands should be updated, we have found no formal document detailing the work to be performed. In the first week of September, Dave Wingerd of the U. S. Army Corps of Engineers and Gary Carter of the National Weather Service agreed that it has been, and would continue to be, the intent of both organizations that the National Weather Service would perform the work with funding provided by the Corps. During the next quarter a document will be prepared to formalize the agreement and provide details of the work to be performed.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section. The University of Hawaii Digitizing completion date is indicated as Month Zero (M_0).

Data Collection and Quality Control [M_0 + 3 months]
Trend Analysis [M_0 + 4 months]
L-Moment Analysis/Frequency Distribution [M_0 + 5 months]
Peer Review of Point Estimates [M_0 + 7 months]
Temporal Distributions of Extreme Rainfall [M_0 + 8 months]
Spatial Interpolation [M_0 + 10 months]
Precipitation Frequency Maps [M_0 + 11 months]
Web Publication [M_0 + 11 months]
Spatial Relations (Depth Area Duration Studies) [January 2003]

During the next quarter a more detailed schedule will be developed. We expect to be able to obtain NCDC data through 2002 early in 2003 and then start the quality control and testing of the regionalization on an island by island basis as complete data sets are assembled. The estimation of the appropriate probability distribution functions and the parameterization of these functions as well as the spatial interpolation steps will be done for all islands as a group to ensure consistency in this part of the process.

6.1 Data Collection and Quality Control.

During the next quarter the University of Hawaii will continue to hand enter data into a digital format for Maui County and begin data entry for Oahu. The projected schedule is summarized in Table 2.

Table 2. Projected Schedule of Hand Entry of State Daily Gage Monthly Maximums.

Island	**Projected Completion Date**
Maui County (Maui, Lanai, Molokai)	10/25/02
Oahu	01/15/03
Kauai	05/15/03

6.2 Spatial Relations (Depth Area Duration Study)

The method to be used for computing the DAD curves has been selected. Software to decode and format the data files and the DAD computations will be developed and executed. If additional dense-area-networks are available, they will be added to the analysis.

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