HAWAII PRECIPITATION FREQUENCY PROJECT

Update of *Technical Paper No. 43*

Twentieth Progress Report
1 January 2006 to 31 March 2006

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
National Oceanic and Atmospheric Administration
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DISCLAIMER

The data and information presented in this report 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 of NOAA's National Weather Service plans to update 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) and *Technical Paper No. 51*, "Two- to Ten-Day Rainfall for Return Periods of 2 to 100 Years in the Hawaiian Islands" (U.S. Weather Bureau, 1965). 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 Project will determine annual precipitation frequencies for durations from 5 minutes to 60 days, for average recurrence intervals from 1 to 1,000 years. The Project will review and process rainfall data for the Project area and use accepted statistical methods. The Project results will be published as a Volume of NOAA Atlas 14 on the internet (http://www.nws.noaa.gov/ohd/hdsc) using web pages with the ability to download digital files.

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

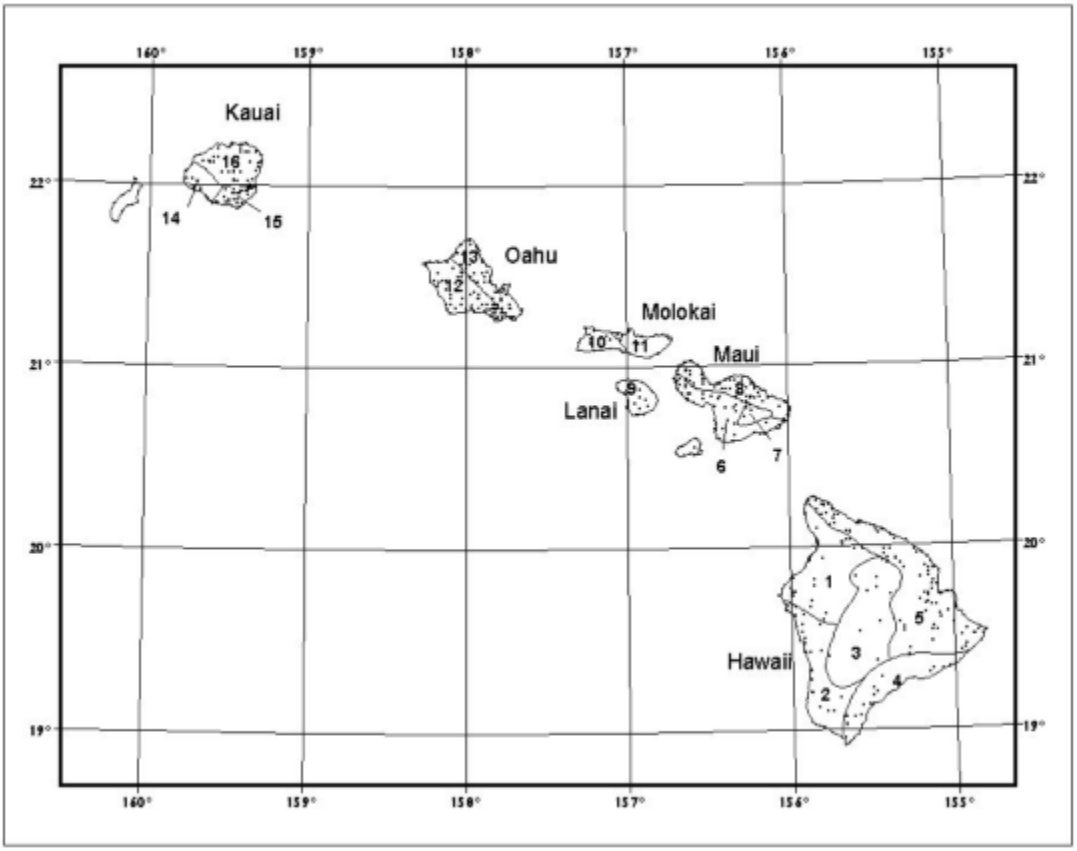

Figure 1. Hawaii Precipitation Frequency Project area, regional divisions and daily station locations.

2. Highlights

An over threshold quality control of the daily rainfall data (TD3200 and TD3206) is complete. Many cases where accumulated values had been entered as missing were found to have been observed and corrected. Hourly data are being quality controlled. Additional information is provided in Section 3.1, Data Collection and Quality Control.

Modifications are being made to the annual maximum series and partial duration series extraction software to accommodate the large amounts of accumulated data but still extract meaningful maximums. Additional information is provided in Section 3.2, Data Series Extraction.

HDSC is investigating a potential Internet Map Server to replace the need for cartographic maps. Additional information is provided in Section 3.3, Internet Map Server.

HDSC continuously monitors the hits, integrity and performance of the Precipitation Frequency Data Server (PFDS), the on-line portal for all NOAA Atlas 14 deliverables and information. Additional information is provided in Section 3.4, PFDS.

Six additional dense rain gauge networks have either been added or are being considered to the growing list of ARF study areas across the United States. Although ARF software development has been slow, several milestones have been reached. Additional information is provided in Section 3.5, Areal Reduction Factors.

3. Progress in this Reporting Period

3.1 Data Collection and Quality Control

HDSC distributed an email to relevant parties to solicit any additional rainfall data available to add to the dataset. Responses were received pointing out a number of additional datasets. Three Remote Automated Weather Stations (RAWS) on the Hawaiian Islands with sufficient period of record and data quality have been added to the hourly dataset. These stations are located in locations that previously had a spatial gap in the data. They are:

ID	Name	Latitude	Longitude	Elevation (feet)
498007	Kaupo Gap Hawaii NPS	20.684166	156.15194	4030
498010	Makapulapai NPS	21.20333	156.96611	75
496006	Keamoku Lava Flow Hawaii NPS	19.04222	155.36278	5600

Two Climate Reference Network (CRN) stations were discovered in Hawaii but short period of record eliminated them from consideration. Additional hourly rainfall data from gages maintained by the United States Geological Survey (USGS) will be obtained during the next quarter.

Daily Data.
An initial maximum over threshold quality control of the daily rainfall data (TD3200 and TD3206) is complete. Forty-one stations were found in the TD3206 dataset that had no metadata, such as latitude, longitude and elevation. Efforts were made to retrieve the metadata from NCDC and other sources, such as the state climatologist and regional hydrologist as well as the internet, but metadata was found for only 13 of these stations. The remaining stations will be removed from the database unless metadata can be found. The NCDC station identifiers are:

51-	0545
51-	2458
51-	2766
51-	2774
51-	2884
51-	2956
51-	2983
51-	3039
51-	3423
51-	3821
51-	3822

51-	4397
51-	4563
51-	4683
51-	4763
51-	4771
51-	5009
51-	5032
51-	5549
51-	5645
51-	6084
51-	6231
51-	6271
51-	6393
51-	6741
51-	7315
51-	7373
51-	7681

Accumulated Data Corrections. 7,453 cases from 280 unique stations in which accumulated values were entered as missing were found in the daily TD3200 dataset and corrected. Older versions of this dataset retained by HDSC have an accumulated flag "A" associated with the high values after the strings of missing values. These data were selectively replaced in the newer version since there may have been QC done on the remainder of the dataset that we do not want to overwrite. 447 additional cases from 58 unique stations where accumulated values were entered as missing, but were not associated with an "A" flag in the previous dataset have also been discovered and corrected. All of these corrections have been forwarded to NCDC.

The corrected daily data were combined with daily monthly maximums hand-entered previously by HDSC. Then this dataset was combined with another dataset of additional daily stations containing daily monthly maximums previously hand-entered at the Hawaii Climate Office.

Hourly Data. 1-hour extreme values-over-threshold quality control was begun during this quarter. Annual maximum series (AMS) and partial duration series (PDS) for all hourly durations (1-hour through 24-hour) will be quality controlled using *QCseries*, a technique which performs a statistical evaluation against nearby stations.

3.2 Data Series Extraction

Data that are accumulated over a period (for example, 30-days) may not be suitable for precipitation frequency analysis of shorter durations because the distribution among the accumulated days is unknown. Therefore, HDSC has modified the AMS and PDS extraction software to consider all accumulated data as "non-data" for certain shorter durations. In this way, maxima for the certain shorter durations will not be selected from these accumulated periods and maximums will not be extracted for years that have too much accumulated data.

The rule for the extraction software to accommodate accumulated data for the extraction of reasonable maximums is:

- If the total sum of precipitation in a duration is coming from an accumulation series which is greater than 150% of that duration then reject the sum for that duration (200% if a 1-day duration).
    - Example: a 4-day duration can be extracted from a 5-day or 6-day accumulation series but not from a 7-day or longer
    - Example: a 1-day duration can be extracted from a 2-day accumulation but not from a 3-day or longer

Additional rules for combined missing, accumulated and "real" data are being considered.

3.3 Internet Map Server

HDSC is investigating potential Internet Map Servers (IMS) to replace the need for cartographic maps. An IMS would allow a user to create a map of the desired average recurrence interval and duration and zoom in on an area of interest. Cartographic maps of key durations and frequencies will still be produced but the entire suite of all possible duration and frequency combinations (as many as 540 maps) may not be produced. It remains to be determined if or when the IMS would be implemented as part of the final deliverables.

3.4 PFDS

HDSC continuously monitors the hits, integrity and performance of the PFDS, which continues to receive a steady number of hits per month. The graph in Figure 2 below summarizes the number of individual data inquires made since October 2004, while the map in Figure 2 indicates the locations of inquires during the past quarter.

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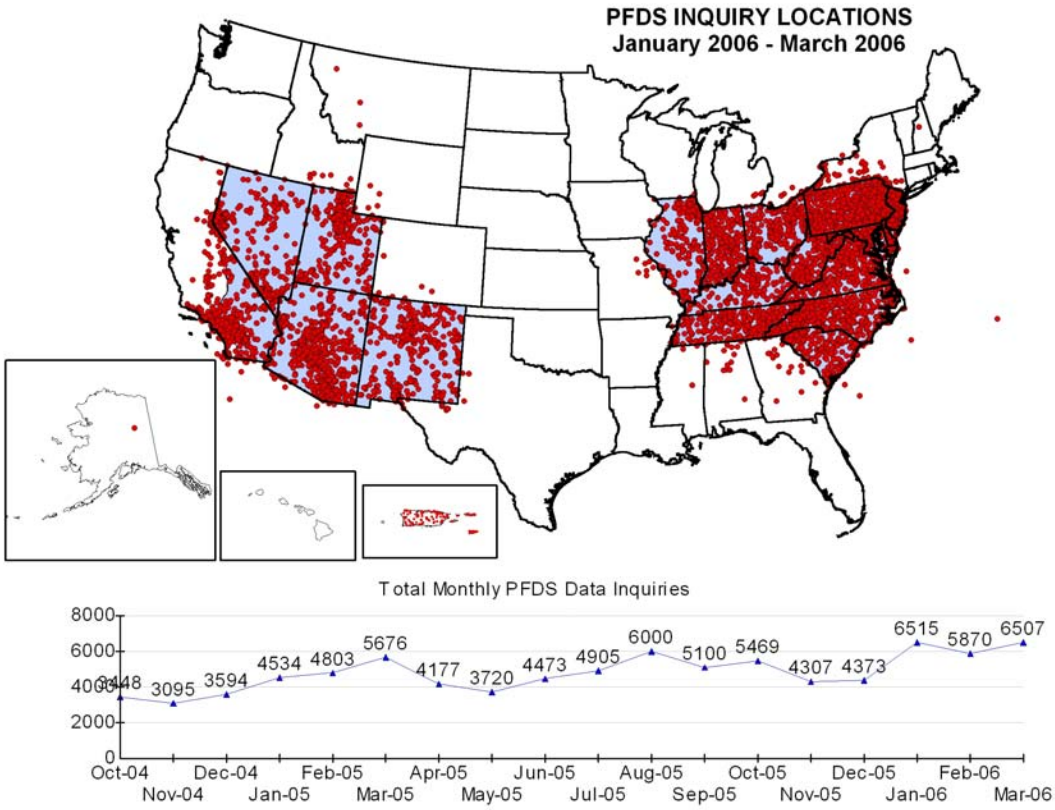

Figure 2: Map of 18,892 PFDS data inquiry locations during the period January-March 2006.

3.5 Areal Reduction Factors

Work continues in the development of geographically-fixed Areal Reduction Factors (ARFs) for area sizes of 10 to 500 square miles and durations of 30-minutes to 48-hours for the United States. The results of this supplementary study will be applicable to all volumes of NOAA Atlas 14.

Although ARF software development has been slow, several milestones have been reached. The continuing goal is to develop ARF software based on the NOAA Technical Report NWS 24 (Myers and Zehr, 1980) methodology and obtain the same results published in TR-24 for the Chicago rain gauge network, then apply the methodology to the new study areas we have assembled. The ARF computations are a function of six variables that vary in time and space. Fitting functions (curves) to these six variables so that the results reproduce those in TR-24 has been difficult. Five of the six variables have been successfully coded and produce values very similar to those published in TR-24. The ARF software is expected to be completed during the next quarter.

Six additional rain gauge networks either have been added to or are being considered for the growing list of ARF study areas across the United States. They are located in/near:

- Los Alamos, NM
- Harris County, TX
- Melbourne, FL
- South-central Washington State
- Louisville, KY
- Portland, OR

Figure 3 shows the locations of all rain gauge networks to be used, those rejected as unsuitable and those still under consideration. Meanwhile, Table 1 provides additional details of the preliminary study areas. HDSC will no longer actively seek additional networks. However, efforts to find adequate networks in Alaska, Puerto Rico and Hawaii continue.

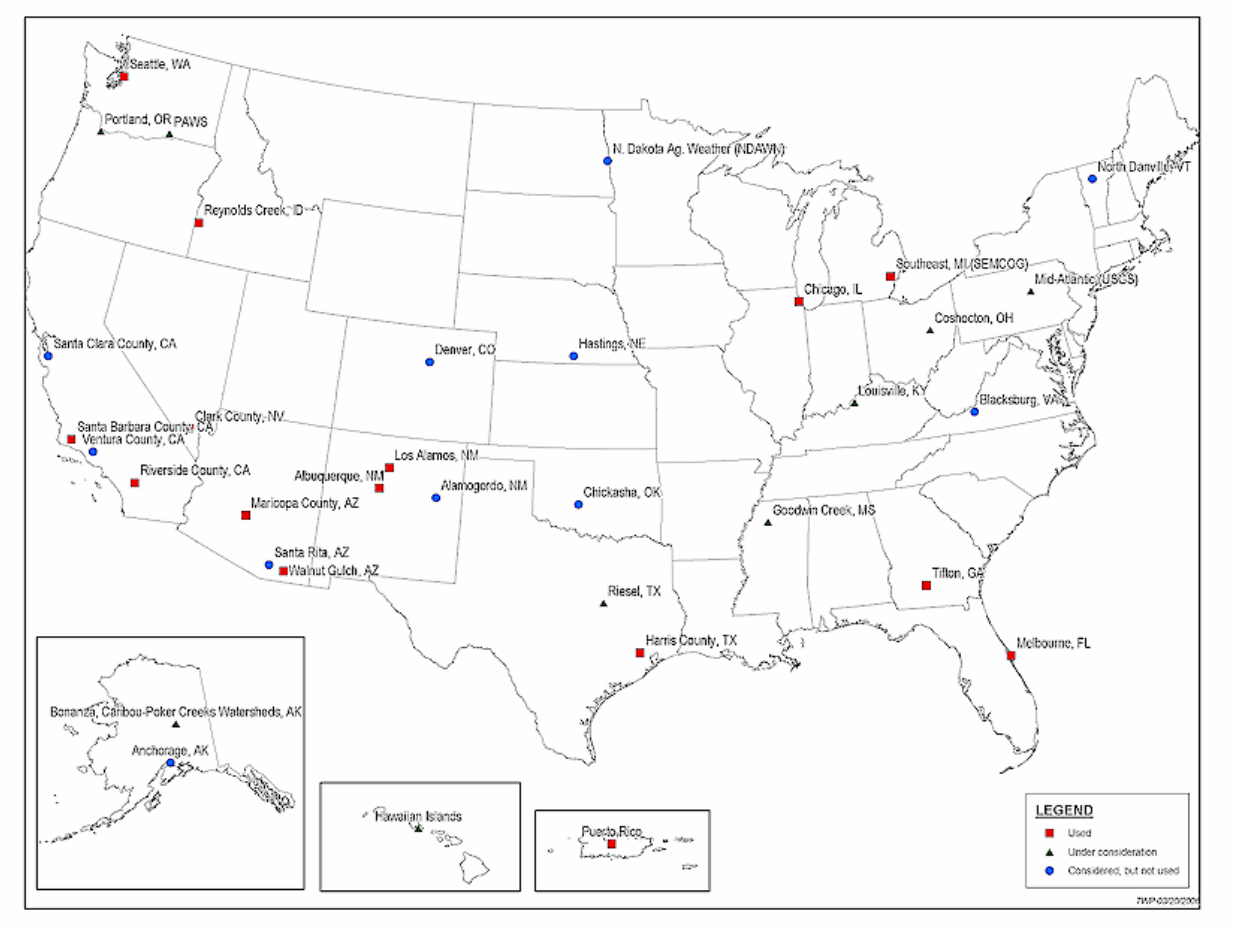

Figure 3. Map of ARF study areas.

Table 1. Preliminary ARF study areas.

Study area location	Included	Date range	~Size (sq-mi)	Stations	Lat*	Lon*	Elev.* (ft)
Albuquerque, NM	Yes	1978-1992	400	13	35.161	-106.566	5311
Chicago, IL	Yes	1949-1980	n/a	18	41.830	-87.692	618
Clark County, NV	Yes	1990-2004	n/a	48	36.290	-114.978	940
Los Alamos, NM	Yes	1990-2005	150	9	35.858	-106.282	7011
Maricopa county, AZ	Yes	1980-2001	n/a	31	33.789	-112.303	2572
Reynolds Creek, ID	Yes	1962-1996	n/a	44	43.169	-116.769	5342
Riverside county, CA	Yes	1961-2001	n/a	45	33.793	-116.995	1987
Santa Barbara, CA	Yes	1968-2003	n/a	38	34.590	-119.957	1203
Seattle, WA	Yes	1978-2003	216	23	47.553	-122.333	152
South-central Washington state (PAWS)	Yes	1989-2005	700	15	46.071	-119.306	765
Southeast Michigan (SEMCOG)	Yes	1988-2002	n/a	50	42.518	-83.286	730
Melbourne, FL	Yes	1997-2005	450	35	28.545	-80.634	0
Harris County, TX	Yes	1997-2005	3800	165	29.779	-95.405	n/a
Walnut Gulch, AZ	Yes	1954-1996	n/a	107	31.728	-110.024	4656
Chickasha (Micronet), OK	Maybe	1994-2005	1130	44	34.885	-98.075	398
Coshocton, OH	Maybe	1940-2001	n/a	22	40.435	-81.799	1044
Goodwin, MS	Maybe	1981-1996	n/a	32	34.232	-89.914	333
Jefferson County, KY	Maybe	1991-2005	n/a	18	38.190	-85.670	n/a
Portland, OR	Maybe	1976-2005	200	45	45.537	-122.662	n/a
Tifton, GA	Maybe	1968-1981	n/a	55	31.439	-83.590	n/a
Ventura, CA	Maybe	n/a	n/a	134	34.370	-119.067	n/a
Bonanza, Caribou-Poker Creeks Watershed(s), AK	Maybe	n/a	50	n/a	64.750	-148.230	1641
Puerto Rico (eastern)	Maybe	1973-2003	500	10-18	18.260	-65.910	800
Hawaii	Maybe	~1948-2005	n/a	n/a	n/a	n/a	n/a
Alamogordo Creek, NM	No	1955-1962	67	64	34.920	-104.143	4898
Blacksburg, VA	No	n/a	n/a	<10	37.250	-80.417	n/a
Denver, CO	No	n/a	n/a	n/a	39.750	-105.000	n/a
Ft. Collins, CO	No	1999-2005	12		40.567	-105.093	5099
Riesel, TX	No	n/a	10	39	31.482	-96.880	544
Hastings, NE	No	1938-1967	n/a	19	40.255	-98.376	n/a
North Danville, VT	No	1958-1975	n/a	27	49.678	-74.724	2118

*Denotes average central location of study area

4. Issues

4.1 Funding for Hawaii Project

The U.S. Army Corps of Engineers (USACE) has asked NWS to proceed with the Hawaii project following completion of precipitation frequency updates for Puerto Rico. We have begun work on the project as resources become available without affecting the schedule of the Puerto Rico project.

4.2 Past and Upcoming Meetings

On February 2nd HDSC met with Dan Cooley (Colorado State University (CSU), National Center for Atmospheric Research), Richard Davis (CSU), and Richard Smith (University of North Carolina) to discuss research on a Bayesian approach to precipitation frequency analysis and possible collaborative research.

On March 30th the Office of Hydrologic Development hosted a half-day workshop for Chinese delegates from Hohai University in Nanjing, China. HDSC participated and initiated a discussion on precipitation frequency analysis and practical consistency adjustment techniques in hopes of fostering collaborative research.

4.3 Update to NOAA Atlas 14 Volumes 1 and 2

The precipitation frequency estimates for the semiarid southwest United States published as Volume 1 of NOAA Atlas 14 and for the Ohio River basin and surrounding states published as Volume 2 of NOAA Atlas 14 will be updated in the near future to incorporate technical enhancements and minor data/analysis corrections. 1-year precipitation frequency estimates will also be released at that time. Careful evaluation of each possible enhancement and correction is underway. The enhancements result from peer reviews and lessons learned in Volumes 2 and 3. They include improved spatial interpolation when using the inverse-distance-weighting function, improved consistency adjustments for co-located daily and hourly stations and for hourly-only stations, and an improvement to the 24-hour confidence limits. Difference maps of the previous versions and the updated versions will be provided. An Addendum will be made available to provide additional details.

4.4 California Precipitation Frequency Project

The state of California and others have verbally committed to funding a project to update the precipitation frequency estimates for the remaining portion of California. Agencies involved include CA Department of Transportation, CA Department of Water Resources, NOAA Coastal Storms Program, and U.S. Army Corps of Engineers. A Memorandum of Understanding is being written. Geoffrey Bonnin, Director of HDSC, attended a fruitful meeting in Sacramento California on March 23rd, 2006 to discuss the details with the State and other interested parties.

5. Projected Schedule and Remaining Tasks

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks that will be worked on during the next few quarters are also included in this section.

Data Collection and Quality Control [June 2006]
L-Moment Analysis/Frequency Distribution [August 2006]
Trend Analysis [August 2006]
Temporal Distributions of Extreme Rainfall [September 2006]
Peer Review of Spatially Distributed Estimates [October 2006]
Spatial Interpolation [January 2007]
Precipitation Frequency Maps [March 2007]
Web Publication [February 2007]
Documentation [March 2007]

Areal Reduction Factors [October 2006]

5.1 Data Collection and Quality Control.

During the next quarter, issues concerning stations with significant amounts of accumulated data will be resolved and new series extracted. Quality control of the daily and hourly data sets will continue using the objective, spatially-based tool, *QCseries*. Stations that meet certain criteria will be considered for merging. Records will be checked for statistical consistency if large gaps in time exist. Testing of the regionalization will begin to develop homogeneous regions for the L-moment analysis.

5.2 Areal Reduction Factors (ARF)

Computations for the ARF curves will be completed in the next quarter for 14 areas. The resulting curves will be tested for differences to determine if a single set of ARF curves is applicable to the entire U.S. or whether curves vary by region.

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