OHIO RIVER BASIN PRECIPITATION FREQUENCY PROJECT

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

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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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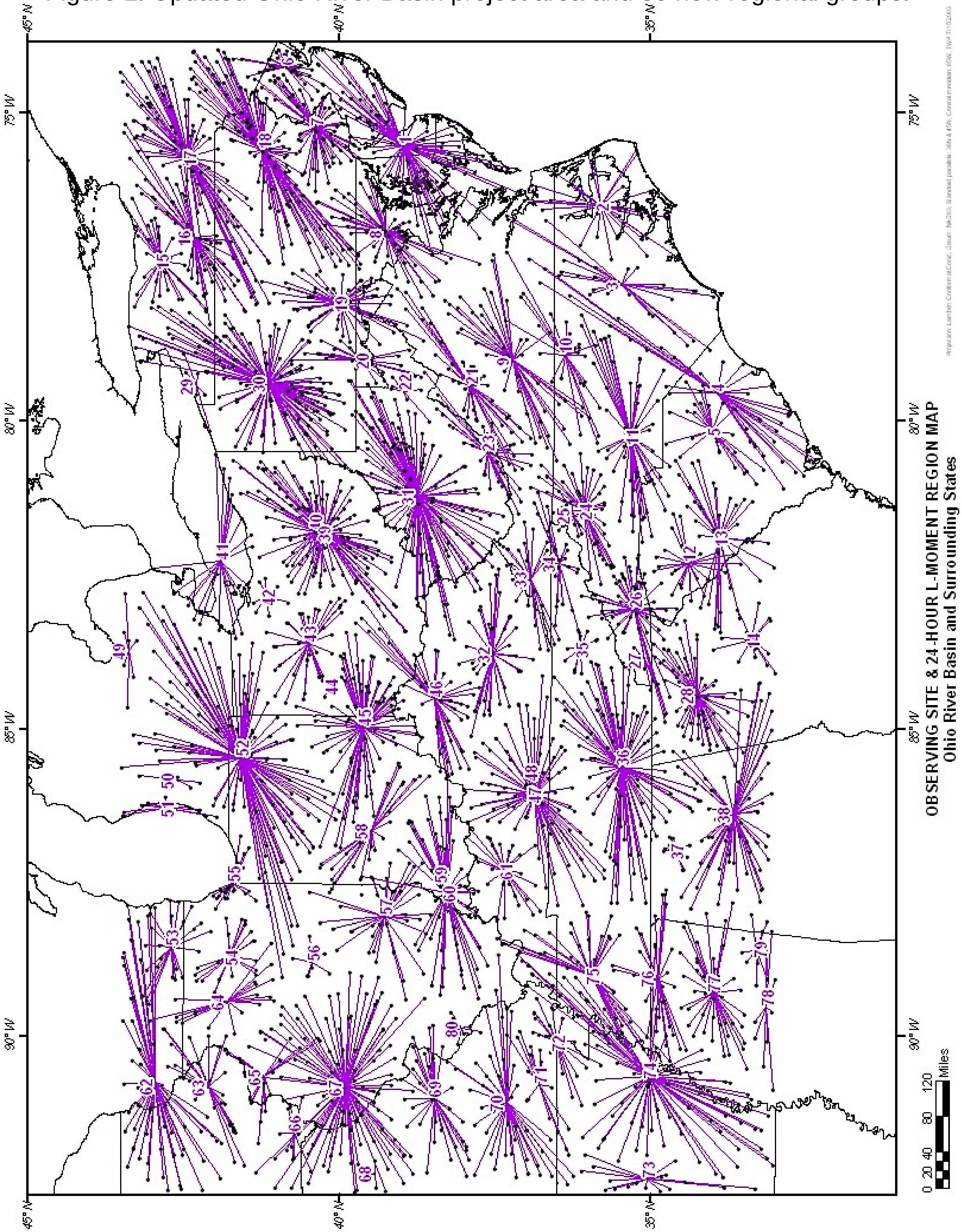
1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for the Ohio River Basin and surrounding states. Current precipitation frequency estimates for this area are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *NWS HYDRO-35* "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al 1977) and *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964). The new project 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 all-season precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The project will review and process all appropriate 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 with the additional ability to download digital files.

The project will produce estimates for 13 states. Parts of nine additional bordering states are included to ensure continuity across state borders. The Susquehanna River and Delaware River Basins are included in the project area. The core and border areas, as well as tentative regions now used in the analysis, are shown in Figure 1.

Figure 1. Updated Ohio River Basin project area and 80 new regional groups.



2. Highlights

Inconsistencies in the 24-hour annual maximum time series at co-located daily and hourly stations were corrected at some stations. Erroneous repeating values of 0.99" were observed and corrected in the daily dataset during a preliminary check of longer duration results. Additional information is provided in Section 3.1, Data Quality Control.

The 52 daily regions were carefully examined and subdivided based on 24-hour results. 80 regions and 3 at-sites were formed by considering climatology, topography and L-Coefficient-of-Variation along with L-Skewness (using the 1000yr real-data-check as a tool) for homogeneity. GEV is the best fit overall for the new daily regions. Updated longer duration (2-day to 60-day) annual maximum series were extracted and L-moments run for the 80 regions. The results are being checked for heterogeneity. Through a preliminary examination, it was decided not to use the daily regions for the hourly data, but to subdivide the original 16 Ohio regions (Figure 2) based on the 60-minute duration. The 60-minute subdivision process is complete yielding 24 hourly regions which will be checked for heterogeneity in the other shorter durations (2-hour to 12-hour). Additional information is provided in Section 3.2, L-moment Analysis.

Thirteen new n-minute stations were added to produce a total of 96 n-minute stations. N-minute ratios converting hourly 60-minute precipitation frequency estimates to n-minute estimates were calculated. Observed variations over return frequencies, 2-year to 1000-year, were preserved in the final n-minute ratios. Observed spatial variation was also preserved by using 2 large regions (northern and southern). Additional information is provided in Section 3.3, N-minute Ratios.

Software was written to accommodate different numbers of stations at different multi-day durations to retain as much data as possible. Work has begun on software to examine stations that are near each other that may be correlated. Additional information is provided in Section 3.4, Software Updates.

In preparation for the upcoming peer review, an updated 100-year 24-hour grid and a preliminary 100-year 60-minute grid were created and are being evaluated. Additional information is provided in Section 3.5, Spatial Interpolation.

A web-page template to provide access to huge volumes of data, including spatial (GIS) data, was developed. The PFDS was populated with preliminary Ohio data to ensure the PFDS is ready for the peer review once it is populated with the complete set of draft precipitation frequency estimates. Additional information is provided in Section 3.6, Precipitation Frequency Data Server.

Temporal distributions are complete. Additional information is provided in Section 3.7, Temporal Distributions.

Progress continues in the development of the geographically-fixed depth-area-reduction (DAR) relationships for area sizes of 10 to 400 square miles in the United States. The name of this project has been officially changed to the DAR project (formerly was depth-area-duration, DAD). Testing and evaluation of pre-processing statistical results are nearly complete. Testing of the semi-objective grouping procedure used in NOAA Technical Report NWS 24 (TR-24) was conducted. Work began on the actual determination of depth area ratios. Additional information is provided in Section 3.8, Spatial Relations (Depth Area Reduction Project).

3. Progress in this Reporting Period

3.1 Data Quality Control

Quality control is a continuous process throughout the different phases of the project. During the careful examination of the 24-hour annual maxima, inconsistencies at co-located daily and hourly stations were observed and corrected. If the 24-hour *hourly* annual maximum for a given year at a co-located station was greater than the 24-hour *daily* annual maximum due to missing or unreliable data in the daily dataset, the daily observations were manually corrected by inserting 24-hour accumulations from the hourly observations as the daily value on the appropriate day (and vice versa). Data were replaced at co-located stations with only real values temporally derived or accumulated from their co-located counter-part on a case by case basis, and only in cases where regionalization was greatly impacted.

During a preliminary check of longer duration (2-day to 60-day) results, erroneous data was found in the daily dataset and corrected. Specifically, repeated values of 0.99" (expressed as 99 in our dataset) occurred in some station data. When accumulated over many days these erroneous values impacted L-moment results. Occurrences of this error were investigated at several stations and found that most 99's were actually missing data (flagged in our data set as -999). Therefore, the occurrences of 2 or more consecutive 99's were replaced with -999.

3.2 L-moment Analysis

The 52 daily regions were examined paying particular attention to a real data check for maximum observed 1-day events that exceed the 1000-year estimate at a station. 31 regions of the 52 were subdivided on a case by case basis using 24-hour data to ultimately reduce the standard error of the quantile estimates by considering climatology, topography and L-Coefficient of Variation along with L-Skewness (using 1000yr real-data-check issues as a tool) for homogeneity. This resulted in subdividing the 52 regions into 80 regions and 3 at-sites (see Figure 1 and Table 1). The draft 24-hour precipitation frequency estimates and confidence limits were computed and the draft 100-year 24-hour precipitation frequency map was generated. These are complete and ready for the peer review.

Table 1. Number of stations in new regions.

region	# daily	# hourly	total
1	76	12	88
2	28	9	37
3	26	8	34
4	34	9	43
5	24	2	26
6	31	12	43
7	62	15	77
8	57	20	77
9	44	14	58
10	24	6	30
11	51	12	63
12	22	6	28
13	35	8	43
14	12	4	16
15	31	8	39
16	46	17	63
17	78	29	107
18	96	41	137
19	46	22	68
20	22	13	35
21	34	10	44
22	7	3	10
23	30	9	39
24	39	10	49
25	11	0	11
26	51	15	66
27	6	1	7
28	52	21	73
29	6	2	8
30	122	48	170
31	126	39	165
32	33	12	45
33	23	10	33
34	19	6	25
35	9	2	11
36	88	20	108
37	10	2	12
38	58	13	71
39	67	32	99
40	37	16	53
41	19	7	26
42	7	2	9
43	34	15	49
44	4	1	5
45	78	34	112
46	41	20	61
47	62	22	84
48	6	3	9
49	6	1	7
50	4	2	6
51	10	5	15
52	104	48	152
53	25	5	30
54	18	5	23
55	17	16	33
56	6	2	8
57	32	13	45
58	21	10	31
59	3	2	5
60	46	19	65
61	25	9	34
62	53	16	69
63	25	15	40
64	18	4	22
65	20	6	26
66	12	2	14
67	89	31	120
68	3	0	3
69	31	15	46
70	42	16	58
71	15	5	20
72	20	2	22
73	16	3	19
74	70	23	93
75	35	14	49
76	28	13	41
77	40	13	53
78	9	3	12
79	10	2	12
80	5	4	9
A1	1	2	3
A2	1	0	1
A3	1	0	1
totals	2785	968	3753

Note: Daily stations must have at least 30 years of data.
Note: Hourly stations must have at least 20 years of data.

The best-fitting distributions were tabulated for all 80 regions for the 24-hour duration. GEV is the best fit overall. Specifically, GEV is best fit for 34 regions, GNO for 24 regions, GLO for 15 regions, PE3 for 3 regions, GEV-GNO tied for 1 region, 3 regions are not definitive. We will conduct sensitivity tests to examine whether or not a single best-fitting distribution may be applied to consistent geographic areas.

Before the longer duration (2-day through 60-day) L-moment analyses could be run, software had to be written to accommodate different numbers of stations for different durations. (See Section 3.4, Software Updates). During the preliminary check of longer duration results, a data quality issue was observed and corrected (see Section 3.1, Data Quality Control). Updated longer duration annual maximum series were extracted and L-moments run for the new 80 daily regions. We are currently checking these updated results for heterogeneity.

Shorter durations (60-minute through 12-hour) are currently being examined. Through a preliminary examination, it was decided not to use the daily regions for the hourly data, but to subdivide the original 16 Ohio project regions (Figure 2) based on the 60-minute duration for the following reasons:

1. Different climatological mechanisms may cause 24-hour maxima and 60-minute maxima in Ohio project area.
2. The 60-minute duration is highly critical to design and requires additional scrutiny.
3. There are only 968 hourly stations whereas there are 2789 daily stations resulting in relatively few hourly stations in each daily region (some of the 80 regions had < 3 hourly stations).
4. Hourly stations often have shorter records.
5. Confidence levels are low when there are fewer stations and shorter records in a region.

The 60-minute subdivision process is complete, pending a final check, for all 16 regions yielding 24 hourly regions (Table 2). These new regions will be renumbered and the remaining shorter durations of these regions will be checked for heterogeneity.

Figure 2. Original 16 regions in the Ohio Project area.

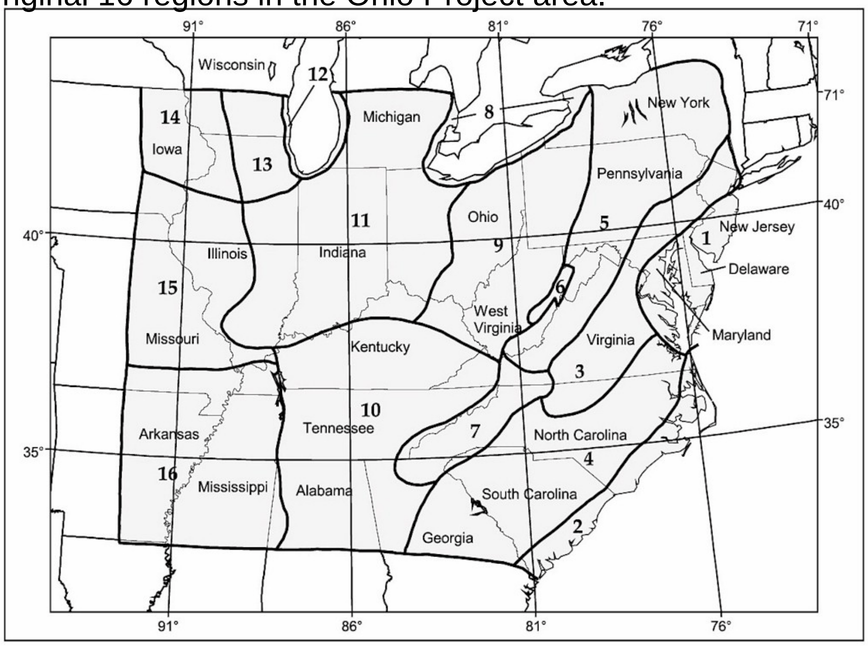


Table 2: Subdivision of original 16 regions based on 60-minute data.

region	subdivision process
1	minor changes
2	expanded to include stns from reg4
3	no change
4	2 subregions
5	3 subregions
6	no longer exists; combined into other regions
7	2 subregions
8	no change
9	no change
10	3 subregions
11	3 subregions
12	no longer exists; combined into other regions
13	some stns moved to reg14
14	2 subregions
15	expanded to include stns from reg16
16	2 subregions
total # of new regions	24 new regions

3.3 N-minute Ratios

Thirteen new n-minute stations, that had previously been set aside, were added to produce a total of 96 n-minute stations with at least 14 years of data each. Tests showed that using ratios of n-minute (5-minute through 30-minute) to 60-minute precipitation frequency estimates to convert the 60-minute estimates from hourly stations to n-minute estimates is more reasonable and reliable than using n-minute estimates directly computed from n-minute data. N-minute data have a lower reliability than hourly data. There are also many fewer n-minute stations than hourly stations, which may lead to underestimation. N-minute ratios were calculated at each n-minute station and evaluated at different return frequencies and throughout the project area. Observed variations in n-minute ratios over return frequencies, 2-year to 1000-year, were preserved in the final n-minute ratios. The final ratios were then averaged in 2 large regions, a northern region and a southern region, for the Ohio project area to preserve observed spatial variation. The northern region has 53 stations (Table 3) and includes original regions 5, 8, 9, 11, 12, 13, 14, and 15 from Figure 2. The southern region has 43 stations (Table 4) and includes original regions 1, 2, 3, 4, 7, 10, and 16.

Table 3. Regional average ratios of n-minute vs 60-minute in Ohio River Basin project for the northern region.

Frequencies	5-min	10-min	15-min	30-min
2-year	0.319	0.498	0.609	0.815
5-year	0.305	0.474	0.582	0.797
10-year	0.298	0.460	0.566	0.786
25-year	0.289	0.442	0.546	0.771
50-year	0.283	0.429	0.531	0.759
100-year	0.277	0.417	0.518	0.748
200-year	0.272	0.406	0.505	0.737
500-year	0.266	0.391	0.488	0.723
1000-year	0.261	0.380	0.475	0.712

Table 4. Regional average ratios of n-minute vs 60-minute in Ohio River Basin project for the southern region.

Frequencies	5-min	10-min	15-min	30-min
2-year	0.287	0.459	0.577	0.797
5-year	0.271	0.434	0.549	0.780
10-year	0.262	0.419	0.530	0.768
25-year	0.251	0.400	0.507	0.751
50-year	0.243	0.387	0.490	0.738
100-year	0.236	0.375	0.474	0.726
200-year	0.229	0.363	0.458	0.713
500-year	0.220	0.348	0.438	0.697
1000-year	0.214	0.337	0.423	0.685

3.4 Software Updates

Software was written to accommodate different number of stations at different longer durations during the L-moment calculations for a region. Different numbers of stations at a longer duration may occur when a station does not have the minimum amount of data necessary in a given year to extract an annual maximum. If the station no longer has at least 30 years of annual maximums, it is not included in the analysis and causes a discrepancy.

Work has begun on examining stations that are near to each other that may be correlated. Software to compare station annual maxima series and tally concurrent years and annual maxima that coincide has been written.

3.5 Spatial Interpolation

In preparation for the upcoming peer review, an updated 100-year 24-hour grid and a preliminary 100-year 60-minute grid were created using the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure. We are currently evaluating the 100-year grids before converting them to cartographic-quality maps for the peer-review.

3.6 Precipitation Frequency Data Server (PFDS)

Other than minor bug fixes, the Precipitation Frequency Data Server underwent few changes. Most notably, however, was the development of a GIS/Data download web-page template. The template is designed to provide access to huge volumes of data, including spatial (GIS) data, in a clear and organized manner. The template, which will be used for each individual state, will be first used in the next few weeks for the delivery of the final Semiarid Southwestern United States data.

In preparation for the upcoming peer review, the PFDS was populated with preliminary precipitation frequency data to ensure everything is working properly. The PFDS is ready for the peer review once it is populated with the complete set of draft precipitation frequency estimates.

3.7 Temporal Distributions

Temporal Distributions are complete. The 6-hour and 4-day durations were completed during the quarter. A weighted average smoothing was applied to all the graphs. During the next quarter documentation will be written and a peer review initiated.

3.8 Spatial Relations (Depth-Area-Reduction Project)

Progress continues in the development of the geographically-fixed depth-area-reduction (DAR) relationships for area sizes of 10 to 400 square miles in the United States. Since depth-area-duration (DAD) relates more to probable maximum precipitation applications and storm-centered analyses, the name of this project has been officially changed to the DAR project. Testing and evaluation of pre-processing statistical results using the Chicago, IL and Walnut Gulch, AZ networks are nearly complete. Several tests of a 5-station grouping process were conducted to determine the sensitivity of the semi-objective grouping procedure used in NOAA Technical Report NWS 24 (TR-24), which is also being used in this study. After careful inspection of the text and graphics in TR-24, we were able to reproduce the pre-processed results using the Chicago, IL data, despite the fact that the TR-24 description of 5-station relative means was somewhat ambiguous. Near the end of this quarter, work began on duplicating the procedures discussed in TR-24 chapter 6, the actual determination of depth area ratios.

A total of 13 different geographic areas throughout the United States have been quality controlled and will be used in the project. The set of curves developed for each area will be tested for differences to determine if a single set of DAR curves is applicable to the entire U.S. Otherwise, separate curves for different regions of the country will be developed.

4. Issues

4.1 USACE Meeting

Geoff Bonnin, representing HDSC, presented a paper at the "World Water and Environmental Resources Congress 2003 and Related Symposia" sponsored by the Environmental and Water Resources Institute (EWRI) of the American Society of Civil Engineers (ASCE) in June. The paper, *Recent Updates to NOAA/NWS Rainfall Frequency Atlases,* was well-received and generated significant interest and anticipation of final publication.

5. Projected Schedule and Remaining Tasks

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.

Data Collection and Quality Control [Complete]
Temporal Distributions of Extreme Rainfall [Complete]
L-Moment Analysis/Frequency Distribution [July 2003]
Peer Review of Spatially Distributed Point Estimates [August 2003]
Spatial Interpolation [September 2003]
Precipitation Frequency Maps [October 2003]
Web Publication [October 2003]
Spatial Relations (Depth Area Reduction Studies) [September 2003]

5.1 L-Moment Analysis

Hourly regions will be finalized during the next quarter. The L-moment statistical analysis will be completed for all datasets and durations. Specifically, the tasks that remain before the peer review are to finish the long duration heterogeneity check and to run the short duration precipitation frequency estimates and confidence limits for the new hourly regions and check heterogeneity of all shorter durations.

5.2 Spatial Interpolation

During the next quarter, HDSC will derive the draft 100-year 60-minute precipitation frequency map for the peer review. The draft 100-year 24-hour and 60-minute grids will be peer reviewed in the upcoming weeks. After addressing reviewer comments, HDSC will produce and send final mean annual maxima for all durations to be interpolated by PRISM.

5.3 Peer Review

The peer review is scheduled to begin in the first week of August. The review will include the point precipitation frequency estimates and associated confidence intervals for all durations (5-minute to 60-day) and all return frequencies (2-year to 1000-year). The review will cover all stations, even those outside the core area of the project. The purpose for including the non-core area is to provide continuous data across the exterior project area border. Comments pertaining to data in non-core areas will be addressed according to their influence to the core project area . The review will also include the spatially interpolated grids for the following:

1. 1-hour mean annual maximum maps ("index flood" maps)
2. 1-hour 100-year precipitation frequency maps
3. 24-hour mean annual maximum maps ("index flood" maps)
4. 24-hour 100-year precipitation frequency maps

5.4 Temporal Distributions of Extreme Rainfall

Documentation for the temporal distributions will be completed during the next quarter and a peer review of the results initiated.

5.5 Spatial Relations (Depth-Area-Reduction Project)

Software for the DAR computations will be completed in the next quarter and the computations will be performed for 13 areas, and the resulting curves will be tested for differences to determine if a single set of DAR curves is applicable to the entire U.S. or whether curves vary by region.

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