

A PROPOSAL FOR  
UPDATING  
PRECIPITATION FREQUENCY ESTIMATES  
FOR THE NORTHWESTERN STATES

Prepared by

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## INTRODUCTION

NOAA’s National Weather Service (NWS) proposes updating precipitation frequency estimates for the states of Washington, Oregon, Idaho, Montana and Wyoming. The update will be published as a Volume of NOAA Atlas 14 “Precipitation-Frequency Atlas of the United States” on the web at “[www.nws.noaa.gov/ohd/hdsc](http://www.nws.noaa.gov/ohd/hdsc)”.

The AASHTO Technical Committee on Hydrology and Hydraulics rated this study as a high priority for funding and it has been endorsed by the Transportation Research Board’s Technical Committee on Hydrology, Hydraulics and Water Quality (AFB60) and the Federal Advisory Committee on Water Information’s Subcommittee on Hydrology.

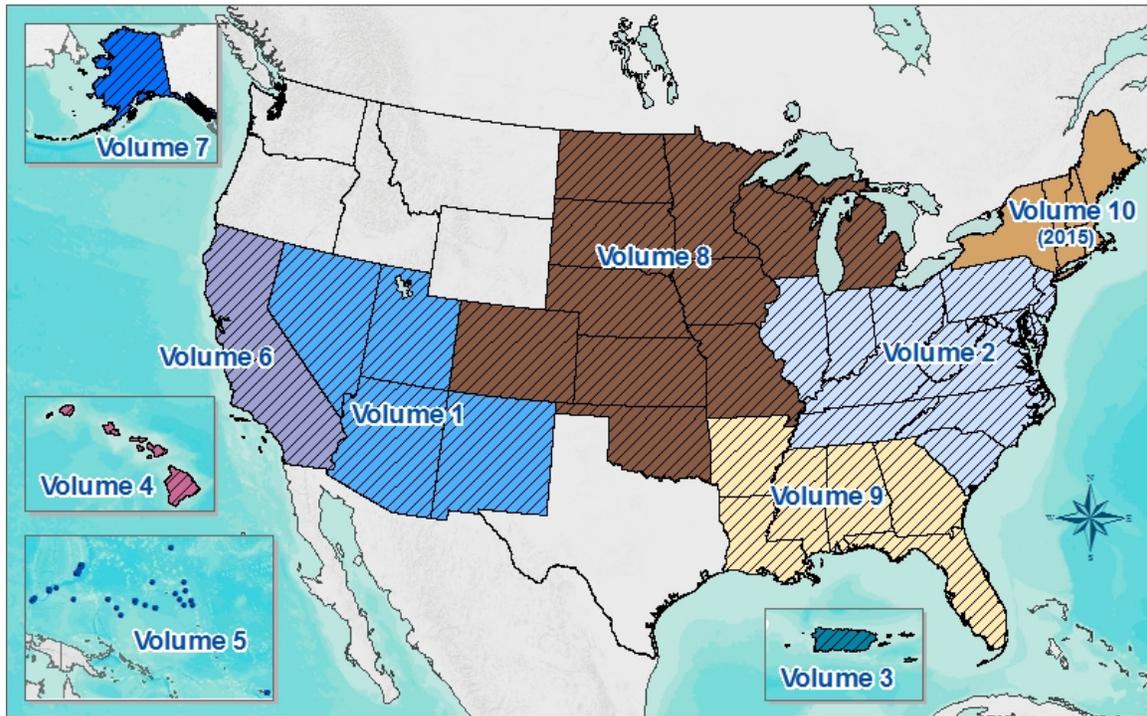


Figure 1. Updates will be done in groups of states

Figure 1 above shows states that have already been updated by marking them with diagonal lines. A project to prepare a volume for the northeastern states of ME, VT, NH, NY, MA, CT, and RI is underway and due for completion in 2015. The new NOAA Atlas 14 estimates are greatly improved in terms of accuracy, reliability and resolution. They are derived using improved data in terms of both period of record and station density, state of the art statistical techniques, and a new approach to spatial interpolation that accounts for variation in terrain. The technologies used so far in NOAA Atlas 14 have been recognized as state of the art. Those technologies with potential improvements will be applied to the development of this volume.

It is proposed that the northwestern states be updated as a group to reduce costs as discussed in Section 5 Budget.

## **OBJECTIVE**

The purpose of this study is to determine annual exceedance probabilities (AEP) and average recurrence intervals (ARI) for durations ranging from 5 minutes to 60 days and for ARIs from 1 to 1,000 years. The point estimates will be spatially interpolated to a spatial resolution of approximately 4km x 4 km. The study results will be published as a volume of NOAA Atlas 14, a wholly web based publication available at [www.nws.noaa.gov/ohd/hdsc](http://www.nws.noaa.gov/ohd/hdsc). The publication will include the artifacts provided in previous Volumes, including access through the Precipitation Frequency Data Server, base grids in standard formats, electronic copies of maps, results of trend analyses, charts of seasonal distributions and probabilistic temporal distributions, and detailed documentation. Updated areal reduction factors are being developed as a separate appendix to NOAA Atlas 14 for the entire U.S.

The project will review and process all reasonably available rainfall data. It is recognized that the rainfall data archived by NOAA's National Climatic Data Center (NCDC) may not be sufficient to accomplish the objectives of this project. Therefore, other data available from sources such as State Climatologists and other Federal, State and local agencies will be examined and included where appropriate.

The state of the art techniques and processes developed and applied for previous NOAA Atlas 14 Volumes will be applied with updates as appropriate. They include regional frequency analysis based on L-moments using a region of influence approach, including error estimates, PRISM based techniques for spatial interpolation, techniques for the analysis of climatic trend, temporal distribution and seasonality, internal consistency checks and variety of automated processes designed to enhance productivity.

Intermediate results in the form of hourly and daily estimates at several ARIs will be distributed for peer review.

## WORK PLAN

### **Task 1 - Data Collection and Quality Control**

#### A. Background

Many years of data have accumulated since the completion of the current estimates. In addition many new stations have been installed. Furthermore, unknown quantities of additional data exist as a result of networks and stations maintained by Federal, State, local and private agencies, and not archived by NCDC. These data must be obtained in digital form and quality controlled both to determine their suitability for use in this project and to ensure the quality of the resulting estimates.

While quality control of data is the subject of this task specifically, it is an ongoing byproduct of later tasks. For example, the L-moment statistics provide an opportunity to examine the data for “discordant” stations. As do the results of spatial interpolation if questionable spatial patterns appear. The specific analyses and products of this task focus only on the initial quality control processes whereas ongoing quality control is included as part of later tasks of it is a byproduct.

#### B. Analyses

Both daily and hourly data will be used, and where available 15-minute data and other data of 1 hour or less will be collected for use in short-duration relations. The data will be assembled in digital form in a manner that is amenable to manipulation and collation in a variety of different ways. The specific form of the storage will follow the techniques and formats refined during the development of previous NOAA Atlas 14 Volumes.

Data which may contribute to annual or monthly maximums, partial duration series, or temporal distributions will be reviewed for quality, period of record, completeness and independence. Questionable data will be investigated using original historical records and newspaper accounts. Data whose quality is not satisfactory will be removed from the database and will not be used in subsequent analyses. In cases where data are changed, the change will be maintained in a log for future reference. Data will not be generated synthetically except in cases where adjustment factors are applied such as in the case of adjusting between constrained daily measurements and unconstrained 24 hour measurements.

The data will be analyzed to determine the seasonality of heavy rainfall. Seasonality will be used as a measure of quality control by excluding years in which there are insufficient observations during the heavy rainfall months.

The data records will also be examined to ensure a minimum number of data years at each station. Stations with an insufficient number of data years will be excluded. The minimum number of data years will be determined as a trade off between a sufficient number of data years and a sufficient density of stations included in the analysis. Stations with large gaps in the period of record will be examined to ensure that there is no change

in statistics across the gap. Nearby stations with complementary periods of record that would otherwise have an insufficient number of data years will be examined as candidates for merging.

The data will also be examined to determine if temporal trends or shifts exist in the statistics relevant to precipitation frequency estimation. Analysis during the development of previous NOAA Atlas Volumes demonstrated that such trends and shifts were relatively small. This finding led to the conclusion that the entire period of record was suitable for analysis as opposed to attempting to select a smaller and specific period of record that might be representative of some future climate.

### C. Product

This task will result in a database of observations and extracted time series that will be used in subsequent analyses. Observations found lacking in quality in subsequent analyses, will be excluded from the database at that time and any time series such data contributes to will be re-extracted.

## **Task 2 – Regionalization**

### A. Background

The statistical approach to be used relies on the development of regions (or sets of observing locations) which are homogeneous according to certain specific statistical criteria. However in order to avoid artificial development of these regions, they must make sense from a climatological point of view.

### B. Analysis

The regions will be defined using a region of influence approach developed in preceding NOAA Atlas 14 volumes. In this approach, a new region of influence is defined and refined for each observing location across the study area domain. The advice of local experts such as the State Climatologist will be sought in cases where unusual non-homogeneity and/or heterogeneity apply.

### C. Product

This step will result in the definition of regions which satisfy the specific homogeneity criteria of the analysis technique as well as make sense from a climatological point of view.

## **Task 3 - Frequency Distribution Selection and Fitting Studies**

### A. Background

The statistical techniques being used for this project do not rely in pre-selection of a single probability distribution function. Rather a range of candidate functions are examined and the function that best represents the distribution of the population

represented by the sample data is initially selected. Implicit in the selection process is also the process of determining parameters for the distribution so that it best represents the underlying population.

#### B. Analysis

L-Moments statistics will be computed for each region and both hourly and daily durations. Based on the statistics, and a variety of tests, an initial distribution will be selected for each region. The spatial distribution of selections will then be examined and sensitivity testing will be performed to ensure that there is a smooth transition between selected distributions across regions. The same approach will then be applied to the longer durations however weight will be given to the distributions selected at shorter durations.

#### C. Product

The outcome of this task will be the selection of a fitted frequency distribution for each region and each duration. The parameters of the selected distributions will have been computed.

### **Task 4 - Frequency Calculations**

#### A. Background

Once the probability distributions for each region and duration have been selected and parameterized it is a simple matter to compute the precipitation frequency estimates at each observing location.

#### B. Analysis

Precipitation frequency values for durations between 60 minutes and 60 days at average recurrence intervals from 1 to 1,000 years will be computed. The equations for the distribution functions will be applied at each location using the mean of the time series at the specific site and the regional values for the higher order parameters.

#### C. Product

The product from this task will be a set of precipitation frequency values for durations from 60 minutes to 60 days at each observing location.

### **Task 5 - Short Duration Estimates**

#### A. Background

Due to the scarcity of data with duration of less than 1 hour, precipitation frequency estimates for those durations will be computed as a ratio of hourly duration estimates. The ratio will be computed as an average for those sites where both hourly and sub-hourly duration observations exist.

## B. Analysis

Locations with both hourly, and either 5, 10, 15 or 30 minute data will be identified. At those locations, the selected hourly distribution function will be fitted to each of the sub-hourly durations. Quantiles for each of the sub-hourly durations will be computed and then ratios of each or these quantiles to the hourly quantiles will be computed. The ratios will be examined for consistency across the project area and with other studies and will then be averaged over the study area. The final ratios for each duration will then be applied to the hourly quantiles computed for each hourly station in the study area to compute quantiles for the sub-hourly durations.

## C. Product

The final products of this task will be sub-hourly precipitation frequency estimates at each hourly station in the project area.

### **Task 6 – Internal Consistency at Observing Locations**

#### A. Background

The estimates must satisfy a series of internal consistency constraints. For example, a 24 hour estimate of depth must not be higher than a 48 hour estimate of depth at a particular average recurrence interval. Similarly at a particular duration an estimate for a 50 year average recurrence interval cannot be higher than the estimate for the 100 year average recurrence interval.

#### B. Analysis

Algorithms for testing internal consistency at observing locations and making adjustments when necessary were developed and demonstrated during the production of previous NOAA Atlas 14 Volumes. These same algorithms will be tested, revised if necessary, and applied in this task. The results will be examined to ensure that the adjustment techniques developed earlier are successful.

#### C. Product

The product from this task will be a set of precipitation frequency values for each duration at each observing location that satisfy at-site internal consistency.

### **Task 7 – Spatial Interpolation and Consistency**

#### A. Background

Precipitation frequency estimates computed at observing locations will be spatially interpolated to grids with a spacing of approximately 30 arc-sec. The spatial interpolation process will account for variations in terrain and will produce grids which are consistent from one grid to the next. The spatial interpolation process, developed

during the preparation of previous NOAA Atlas 14 Volumes will be examined along with alternate techniques.

## B. Analysis

NWS has worked with the Oregon State University PRISM Group to produce a modified version of PRISM suitable for spatial interpolation of precipitation frequency estimates over varying terrain. This process will be verified and modified as necessary during this task for this specific domain. The process is applied to spatial interpolation of the distribution means at each duration. A subsequent process developed by NWS and used in previous volumes is then used with the spatially interpolated grids of distribution mean to produce spatially interpolated grids for all average recurrence intervals. These processes include a variety of internal consistency checks and noise filters. Other spatial interpolation techniques may be examined and applied if appropriate.

## C. Products

Spatially interpolated high resolution grids of precipitation frequency estimates for each combination of average recurrence interval and duration across the project area domain.

### **Task 8 – Mapping and other Spatial Artifacts**

#### A. Background

A variety of spatial artifacts will be developed to assist users in interpreting and using the precipitation frequency estimates. The primary artifacts will be digital versions of the spatially interpolated grids and high quality cartographic maps in pdf format. Each of these artifacts will be made available via the web through the Precipitation Frequency Data Server. Such availability will allow users to incorporate digital versions of the estimates directly in their applications without having to go through an expensive and error prone digitizing step as in past publications.

#### B. Analysis

The grids of precipitation frequency estimates developed in Task 7 are the preferred source. In order to enhance the use of the data in this form, the grids will be converted to a standard ASCII format. The format consists of a header that specifies the geographic domain and resolution, followed by the actual grid cell values. The grid files will be accompanied by Federal Geographic Data Committee-compliant metadata.



## B. Analysis

The NWS uses a modified version of a technique developed at the Illinois Water Survey (Huff, 1990) that provides a temporal curve as proportion of total duration and total volume. There are curves provided for each cumulative probability based on an analysis of historical data. Curves will be developed for 6-, 12-, 24-, and 96-hour durations. The data from which the curves are drawn will be made available as ASCII files on the web through the Precipitation Frequency Data Server to allow users to incorporate the curves in their applications.

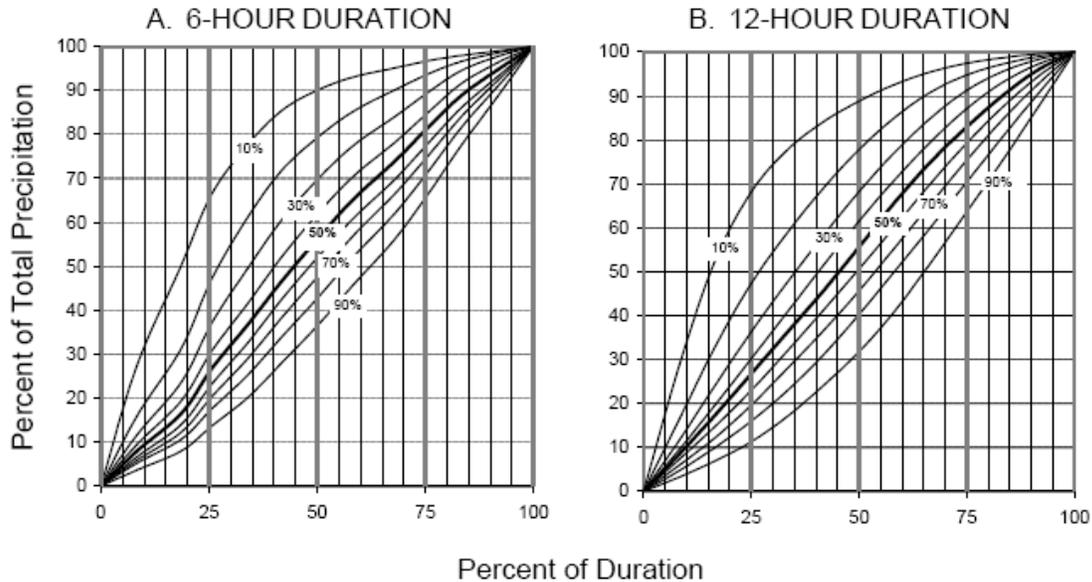


Figure 3. Probabilistic temporal distributions

## C. Products

Probabilistic temporal distributions as charts for 6-, 12-, 24-, and 96-hour durations. ASCII files of data from which the curves are drawn.

### Task 10 - Peer Reviews

#### A. Background

The development of precipitation frequency estimates benefits greatly by incorporating local knowledge. In order to incorporate this knowledge the initial spatial distribution of 1- and 24-hour daily estimates at 100 year ARI as well as the mean of the annual maximum series which represents an ARI of approximately 2.3 years will be made available for review. The full range of estimates at observing locations will also be included in this review. Following the review period, a document will be prepared and distributed that lists all comments and documents the action taken in response to each comment.

The invitation to review will be distributed widely to a list developed from suggestions made by funding sources as well as a list maintained by NWS which includes interested parties, recognized academics specializing in the field, and State Climatologists.

#### B. Analysis

Information will be distributed for review. After an appropriate period, NWS will analyze each comment received and will determine what action to take in response to the comments. Documentation of the comments and actions will be prepared and published.

#### C. Products

Improved estimates based on local knowledge, improved documentation, documentation of the review itself.

### **Task 11 - Documentation**

#### A. Background

Precipitation frequency estimates are published with a target audience of knowledgeable users. These users require documentation in order to understand the basis of the estimates and their scope and applicability. The documentation will not attempt to be an academic text that replaces or reproduces published scientific work, rather it will reference such sources as appropriate. Similarly, the documentation will not attempt to provide basic education and so will not replace or reproduce basic academic texts developed for that purpose.

#### B. Analysis

All aspects of the development of each artifact will be described in sufficient depth to allow the knowledgeable user to understand the basis of the estimates and their scope and applicability. The documentation developed for previous NOAA Atlas 14 Volumes was approximately 250-300 pages for each volume, significantly more than has been provided in the past. Documentation for this volume will be similar in layout, coverage and depth.

#### C. Products

Documentation of the basis of development of each of the NOAA Atlas 14 artifacts with a unique set of documentation for this volume.

### **Task 12 - Final Deliverables**

#### A. Products

- Web based Precipitation Frequency Data Server for accessing each artifact
- Precipitation frequency estimates with upper and lower 90% confidence intervals at durations of 5, 15, 30, 60, and 120 minutes, 3, 6, 12, 24 hours, and 2, 4, 7, 10, 20, 30, 45, and 60 days, and ARIs of 1, 2, 5, 10, 25, 50, 100, 200, 500, and 1,000 years

- High resolution grids of precipitation frequency estimates and upper and lower 90% confidence intervals with one grid for each combination of frequency and duration for the expected value and upper and lower 90% confidence intervals
- Meta information in Federal Geographic Data Transfer Standard format
- Either cartographic maps of the estimates with one map for selected combinations of frequency and duration for the expected value and upper and lower 90% confidence intervals or equivalent information delivered through an Internet map server.
- Probabilistic temporal distributions for 6, 12, 24 and 96 hour durations in both chart and digital form
- Peer reviews of initial spatial distributions of estimates at 1 and 24 hour durations for 100 and approximately 2.3 year ARIs.
- Charts of the seasonal distribution of annual maxima.
- Documentation
- Status Reports

### **Task 13 – Status Reporting**

#### A. Background

Progress for this volume will be reported each quarter in a Quarterly Status Report.

#### B. Analysis

Reports will be made available via the web and notification of their availability will be distributed by email to a list of addresses maintained by NWS and provided by funding sources. Reports will document progress in the preceding quarter, status of the entire project, issues, activities expected in the coming quarter and expected completion schedule.

#### C. Products

Quarterly Status Reports for each Volume delivered within 10 days of the conclusion of each quarter.

## **PROGRAM MANAGEMENT**

Mr. Geoffrey Bonnin, Chief of the Hydrologic Science and Modeling Branch (HSMB), Office of Hydrologic Development, NOAA's National Weather Service, will be the primary point of contact and responsible manager for this task. Dr. Sanja Perica, Director of the Hydrometeorological Design Studies Center within HSMB will be the program and technical manager for the development of the Volume prepared under this proposal.

## BUDGET

The following budget table shows the estimated total three year project cost of \$1,683,272 as well as the prorated share of the cost for each state. The cost per year is one third of the costs shown in the table.

	State	Daily	Hourly	Total	Area sqmi	Project Cost	State Cost
<b>Northwest</b>	ID	274	110	384	83,574		\$234,019
	OR	481	193	674	98,386		\$374,558
	WA	395	173	568	71,303		\$306,952
	MT	592	187	779	147,046		\$457,885
	WY	399	131	530	97,818	\$1,683,272	\$309,858

The estimates are based on the costs incurred for production of prior NOAA Atlas 14 Volumes. The estimation metric is based on the number of daily and hourly stations in the NCDC archives and the area of the state. The costs do not include travel.

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## **LIST OF ACRONYMS**

AASHTO	American Association of State Highway and Transportation Officials
AEP	Annual Exceedance Probabilities
ARI	Average Recurrence Interval
CRAB	Cascade Residual Add-Back
GIS	Geographic Information System
HDSC	Hydrometeorological Design Studies Center
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SCAS	Spatial Climate Analysis Service (University of Oregon)