HYDROMETEOROLOGICAL DESIGN STUDIES CENTER

QUARTERLY PROGRESS REPORT

1 October to 31 December 2014

Office of Hydrologic Development

National Weather Service

National Oceanic and Atmospheric Administration

U.S, Department of Commerce

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DISCLAIMER

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I. INTRODUCTION

The Hydrometeorological Design Studies Center (HDSC) within the Office of Hydrologic Development of National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) is updating precipitation frequency estimates for various parts of the United States and affiliated territories. Updated precipitation frequency estimates for durations from 5 minutes to 60 days and average recurrence intervals between 1- and 1,000-years, accompanied by additional relevant information (e.g., 95% confidence limits, temporal distributions, seasonality) are published in NOAA Atlas 14. All NOAA Atlas 14 products and documents are available for download from the Precipitation Frequency Data Server (PFDS).

NOAA Atlas 14 is divided into volumes based on geographic sections of the country and affiliated territories. To date, precipitation frequency estimates have been updated for Arizona, Nevada, New Mexico and Utah (Volume 1, 2004), Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia and West Virginia (Volume 2, 2004), Puerto Rico and U.S. Virgin Islands (Volume 3, 2006), Hawaiian Islands (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), California (Volume 6, 2011), Alaska (Volume 7, 2011), and Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin (Volume 8, 2013), Alabama, Arkansas, Florida, Georgia, Louisiana and Mississippi (Volume 9, 2013). We are currently updating estimates for seven northeastern states that will be published in September 2015 as Volume 10. Those states are Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Work on updating precipitation frequency estimates for the state of Texas is expected to start in early 2015 and due for completion in February 2018. We have been working with the Federal Highway Administration (FHWA) using their "pooled funding" mechanism (FHWA Pooled Fund) to secure funding to extend NOAA Atlas 14 to the remaining five northwestern states (Idaho, Montana, Oregon, Washington, Wyoming). Figure 1 shows the states or territories associated with each of the Volumes of the Atlas. States that have already been updated in Volumes 1 to 9 are indicated by marking them with horizontal lines.

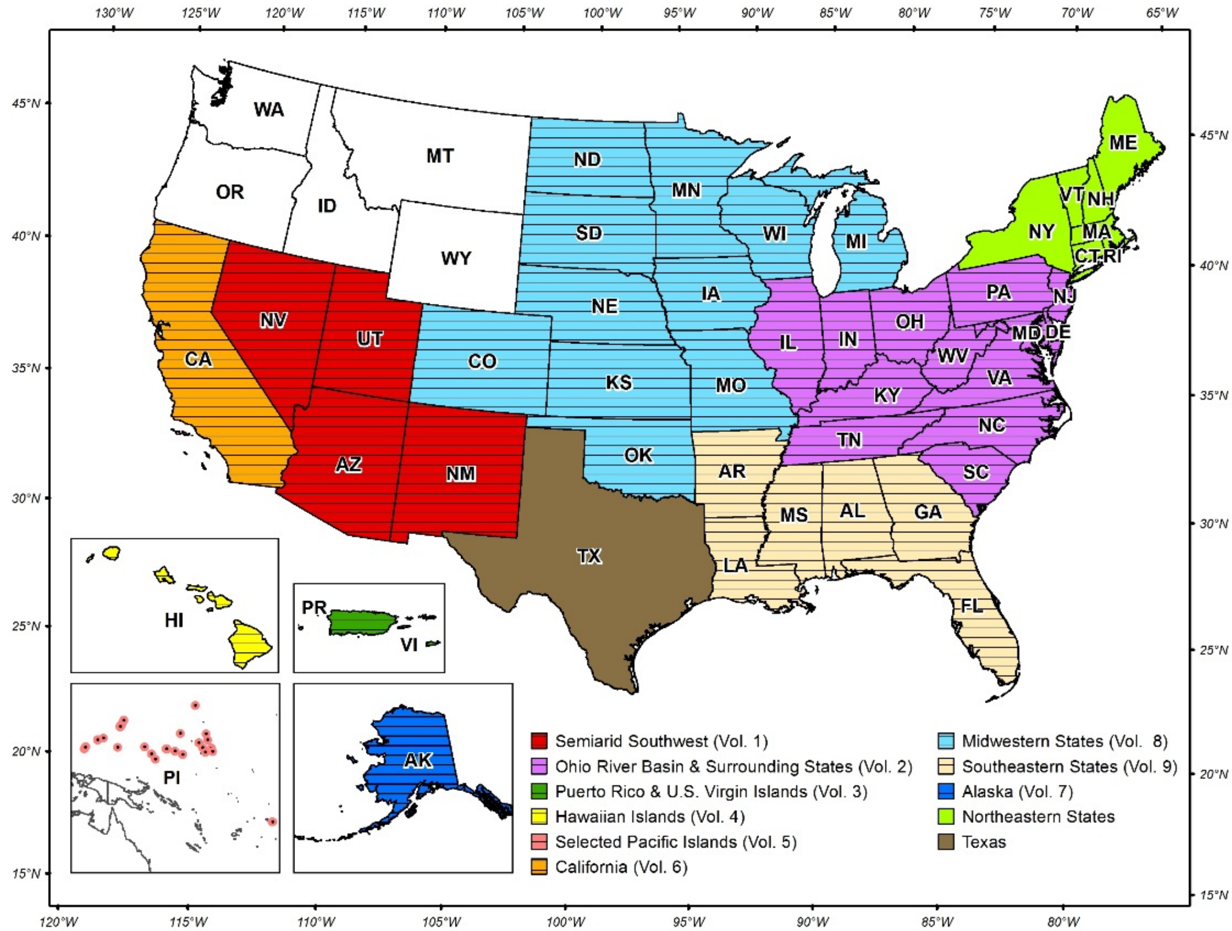

Figure 1. Current project areas for Volumes 10 (Northeastern states) and 11 (Texas) and project areas included in published Volumes 1 to 9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1 PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2014)

The project area for the Northeastern precipitation frequency project includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont, and approximately a 1-degree buffer around these states (Figure 2).

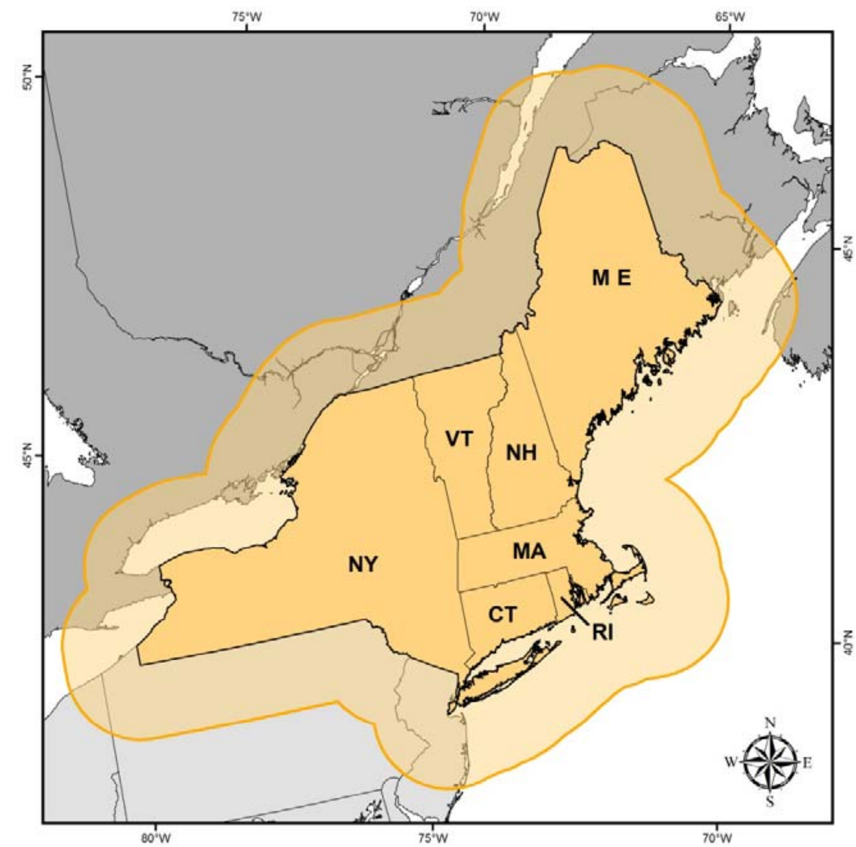

Figure 2. Northeastern precipitation frequency project area (shown in orange).

On September 30th, we sent an invitation to review our preliminary estimates to potential reviewers suggested by funding agencies as well as a list maintained by NWS which includes interested parties, recognized academics specializing in the field, and State Climatologists. During this reporting period, we consolidated and reviewed comments received so far, and started to address them accordingly. We also updated our database, revised mean annual maxima maps, developed temporal distribution charts and performed seasonality analysis. The individual sections below describe in more detail major tasks performed during this reporting period.

1.1.1 Peer review

The peer review process started on October 1st, 2014 and concluded on November 16th, 2014. The following information was prepared and distributed for the review:

- metadata for stations whose data were used to prepare mean annual maximum precipitation maps and/or in precipitation frequency analysis;
- metadata for stations whose data were collected, but not used in the analysis;
- at-station depth-duration-frequency (DDF) curves for 60-minute to 10-day durations and for 2-year to 100-year average recurrence intervals (ARIs);
- maps of spatially-interpolated precipitation frequency estimates for 60-minute, 24-hour and 10-day durations and for 2-year and 100-year ARIs.

The reviewers were asked to provide feedback on the reasonableness of point precipitation frequency estimates, their spatial patterns, and station metadata. More details on the review process and products are available from Jul - Sep 2014 progress report.

Comments were received from the U.S. Army Corps of Engineers, various state agencies and NWS Weather Forecast Offices. During this reporting period, we consolidated all comments, reviewed them and we started to address them accordingly. The (anonymous) reviewers' comments with our responses and resulting actions will be published as an Appendix 4 in the Volume 10 document.

1.1.2 Data collection and data screening

In this reporting period, we have received and formatted precipitation data from the Narragansett Bay Commission. We digitized and formatted additional data for selected observing locations from the Massachusetts Department of Conservation and Recreation dataset. We also extracted and quality controlled corresponding AMS data.

1.1.3 Spatial analysis of mean annual maxima grids

In NOAA Atlas 14, grids of precipitation frequency estimates and corresponding 90% confidence intervals at 30 arc-sec resolution are developed based on related grids of mean annual maximum (MAM) values and at-station precipitation frequency estimates. The MAM grids are developed from at-station MAM values by the Oregon State University's PRISM Climate Group using their hybrid statistical-geographic approach for mapping climate data named Parameter-elevation Regressions on Independent Slopes Model (PRISM).

Based on comments received during the peer review, during this reporting period, we have re-examined at-station MAMs and revised spatial patterns in MAM grids for base durations used in the peer review: 1-hour, 1-day and 10-day. Some at-station MAM estimates were adjusted or added back to the dataset to better anchor the spatial interpolation in areas of varied terrain and/or where the lack of stations or short records unduly influenced expected spatial patterns, particularly at hourly durations.

We also started spatial analysis of MAM estimates interpolated to a 30-arc grid for remaining durations: 15-min, 30-min, 2-hr, 3-hr, 6-hr, 12-hr, 2-day, 4-day, 7-day, 20-day, 30-day and 45-day. Several iterations with the PRISM Climate Group will be required to ensure consistency of interpolated MAMs across all durations.

1.1.4 Temporal distributions

The Natural Resources Conservation Service has developed curves that are commonly used to describe the temporal distribution of rainfall. For NOAA Atlas 14, NWS has adopted a technique for describing the many potential temporal distributions of natural rainfall in probabilistic terms; the technique is described in more detail in Appendix 5 of Volume 9 document.

Temporal distributions of precipitation amounts exceeding precipitation frequency estimates for the 2-year ARI have been calculated for 6-hour, 12-hour, 24-hour, and 96-hour durations for two climate regions delineated for this project area based on characteristics of heavy precipitation (shown in Figure 3). They will be expressed in probability terms as cumulative percentages of precipitation totals and will be provided as charts and in tabular format

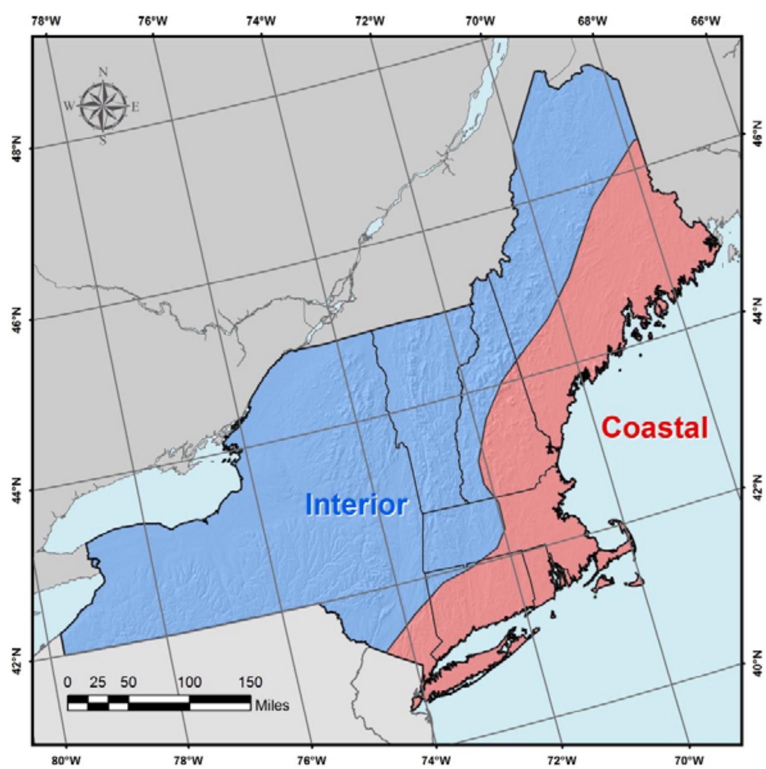

Figure 3. Delineated climate regions.

1.1.5 Seasonality analysis

The seasonality of the extreme precipitation shows the monthly variation of annual maxima that exceeded precipitation frequency estimates for selected exceedances and given durations. This analysis is described in more details in Appendix 6 of Volume 9 document. During this reporting period, we completed seasonality analysis.

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2015)

During the next reporting period, we will update National Climatic Data Center's 15-minute, 1-hour, 1-day data for the most recent rainfall record in order to extract AMS for 2013 and 2014, where possible. We will finish addressing the peer review comments, recalculate at-site precipitation frequency estimates and derive 5-min and 10-min estimates by scaling 15-minute precipitation frequency estimates. We'll also check internal consistency of estimates at observing locations and smooth estimates across frequencies and durations, as needed. We'll develop final grids of mean annual maxima for all durations.

1.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [Complete]

Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, independence, consistency across durations, duplicate stations, candidates for merging) [Complete]

Regionalization and frequency analysis [Complete]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Complete]

Peer review [Complete]

Revision of PF estimates [June 2015]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [July 2015]

Web publication [September 2015]

2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS

NOAA Atlas 14, Volume 11 precipitation frequency project includes the state of Texas and approximately a 1-degree buffer around this state (Figure 4). This project is expected to start in February/March 2015 and should be completed by February 2018.

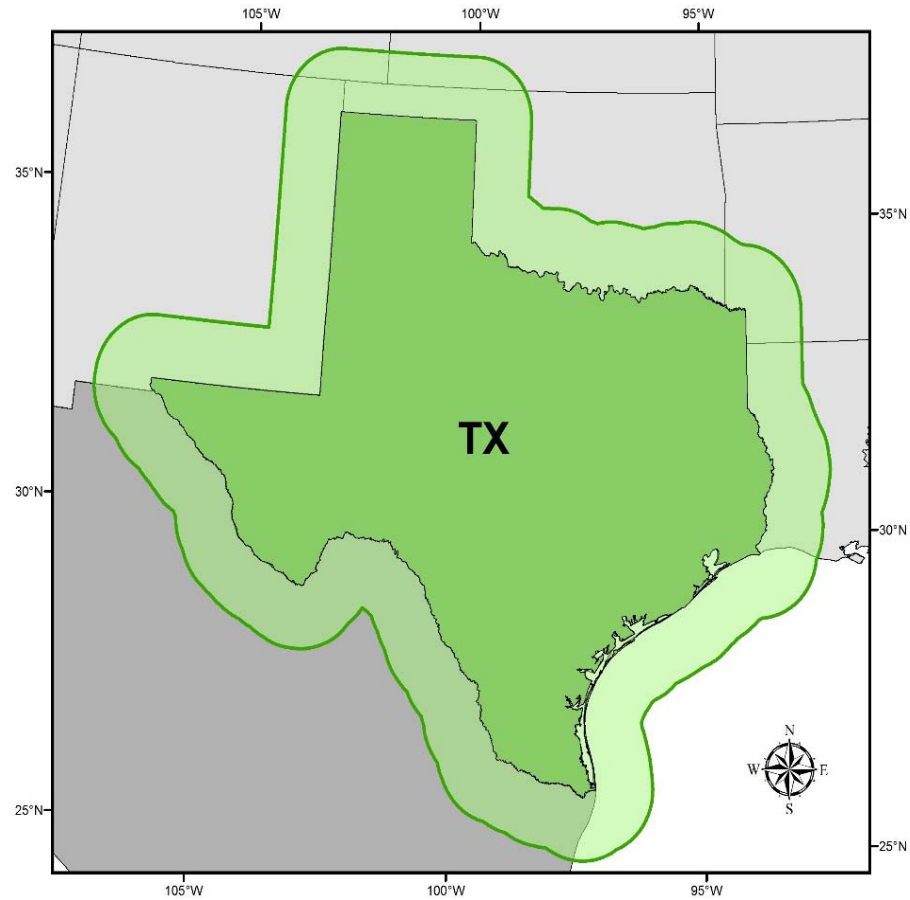

Figure 4. NOAA Atlas 14, Volume 11 project area (shown in green).

2.1 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2015)

In the next reporting period, we will start data collection process. It is recognized that the precipitation data archived by the National Climatic Data Center (NCDC) may not be sufficient to accomplish the objectives of this project. Therefore, we will solicit precipitation data available from other Federal, State and local agencies. All data will be examined and formatted in a common format, where appropriate.

2.2 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [December 2015]

Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, independence, consistency across durations, duplicate stations, candidates for merging) [November 2016]

Regionalization and frequency analysis [January 2017]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [April 2017]

Peer review [June 2017]

Revision of PF estimates [October 2017]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [January 2018]

3. AREAL REDUCTION FACTORS PROJECT

Areal reduction factors (ARFs) are needed to transform average point precipitation frequency estimates for an area of interest to corresponding areal estimates that have the same probability of exceedance. Among the different ARF derivation methods, the "geographically-fixed" method is the established method for use with precipitation frequency studies.

Based on an extensive review of geographically-fixed ARF derivation methods, HDSC selected two methods for further evaluation. Methods were selected primarily from the perspective of their potential application to NOAA Atlas 14 precipitation frequency estimates. The first method combines the notions of dynamic scaling and statistical self-similarity to find a general form for rainfall intensity as a function of duration and area. For the second method, point and areal depth-duration-frequency curves are characterized using the Generalized Extreme Value (GEV) distribution, where the distribution parameters are determined as a function of both, the area and duration. For more details on methodologies, please see Section 2 of Jan - Mar 2014 progress report.

3.1 PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2014)

This project has been put on hold in June 2014 until the reorganization of the NWS headquarters is complete (expected by mid-2015). For more information on the tasks accomplished to date, please see Section 2 of Apr - Jun 2014 progress report.

3.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2015)

No activities are planned for the next reporting period.

3.3 PROJECT SCHEDULE

The ARF project is on hold during the reorganization of the NWS Headquarters.

4. ANALYSIS OF IMPACTS OF CLIMATE CHANGE ON PRECIPITATION FREQUENCY ESTIMATES

Precipitation magnitude-frequency relationships in NOAA Atlas 14 Volumes have been computed using a regional frequency analysis approach on the Annual Maximum Series (AMS) data based on L-moment statistics, where typically the 3-parameter Generalized Extreme Value (GEV) distribution was a distribution of choice. This approach assumes stationarity in the AMS data for frequency distribution selection and fitting, and as such, may not be suitable for frequency analysis in the presence of non-stationary climate conditions.

The Federal Highway Administration (FHWA) has an interest in better understanding the potential impact of climate change on the intensity-duration-frequency (IDF) curves at local scales so that designers of future infrastructure will use appropriate design standards. As part of that effort, FHWA tasked HDSC to survey the state of the art methodologies in this area, to conduct a pilot project to analyze trends in historical rainfall exceedances and impacts of climate change on precipitation magnitudes from NOAA Atlas 14 and to determine how HDSC findings compare to corresponding results obtained in the climate community.

For the pilot project, relevant literature has been reviewed, methodologies appropriate for distribution fitting under non-stationary conditions have been identified and related codes have been prepared. A flexible, nonlinear modeling framework for non-stationary GEV analysis developed by Cannon (2010)[1] was selected for further evaluation. In this model, a generalized maximum likelihood (MLE) approach is used instead of the current NOAA Atlas 14 L-moment approach to calculate GEV parameters, as it allows a time dependency to be introduced in the calculation. Due to the flexibility of its architecture, the model can be used to perform stationary analysis or, when distribution parameters are dependent on time, it can be used to perform non-stationary extreme value analysis. The model is capable of representing a wide range of non-stationary relationships, including those due to inter-decadal climatic variability.

One limitation of AMS-based frequency analysis is that only the highest precipitation amount for a given duration for a year is included in the analysis. This means that other significant events from the same year, although potentially larger than the highest rainfall events of other years, are not considered. Consequently, in order to detect any changes in frequency of extreme events, frequency analysis has to be done on the partial duration series (PDS) data. For the PDS model, we applied a generalized Pareto (GP) distribution as it has been shown that the assumptions of, respectively, GP distributed exceedance magnitudes and a Poisson distributed number of threshold exceedances in the PDS imply the corresponding AMS to follow the generalized extreme value (GEV) distribution with the same shape parameter as in the GP distribution.

4.1 PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2014)

Limited progress has been made on this project during this reporting period. We continued literature review and the evaluation of IDFs from various types of non-stationary models against the current NOAA Atlas 14 stationary model. A range of non-stationary models, from the simplest one with a single distribution parameter linearly varying with time to complex models with different types of non-linear trends in all distribution parameters have been investigated.

4.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2015)

Evaluation of IDFs from various types of PDS-based and AMS-based non-stationary models against the current NOAA Atlas 14 stationary model will continue. A summary report, which highlights main findings, will be prepared.

4.3 PROJECT SCHEDULE

Expected completion date for this pilot project is March 2015.

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[1] *A. J. Cannon, 2010. A flexible nonlinear modelling framework for nonstationary generalized extreme value analysis in hydroclimatology. Hydrological Processes, 24, 673-685. DOI: 10.1002/hyp.7506.*

III. OTHER

1. MEETINGS AND CONFERENCES

On October 2, Dr. Sanja Perica (by invitation of the Nuclear Regulatory Commission) gave a presentation on parameter estimation and sources of uncertainties in NOAA Atlas 14 estimates to the Interagency Steering Committee on Multimedia Environmental Modeling Working Group 2, which focuses on the development and application of software systems and techniques to assess model uncertainty and parameter estimation.

On November 18, Michael St Laurent, a University Corporation for Atmospheric Research (UCAR) employee supporting HDSC, gave an invited, web based presentation entitled: “Preliminary Appraisal of Statistical Probable Maximum Precipitation Estimates Based on Hershfield Method” to the Advisory Committee on Water Information (ACWI)’s Extreme Storm Events Work Group.