HYDROMETEOROLOGICAL DESIGN STUDIES CENTER QUARTERLY PROGRESS REPORT

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Office of Hydrologic Development

National Weather Service

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DISCLAIMER

The data and information presented in this report are provided only to demonstrate current progress on the various tasks associated with these projects. 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 other purpose does so at their own risk.

TABLE OF CONTENTS

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. The Atlas is divided into volumes based on geographic sections of the country and affiliated territories. NOAA Atlas 14 is a web-based document available through the Precipitation Frequency Data Server (PFDS; http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).

HDSC released updated estimates for 17 U.S. states on April 19th, 2013 as part of NOAA Atlas 14 in Volumes 8 and 9. Volume 8 includes the following midwestern states: Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin; and Volume 9 includes the following southeastern states: Alabama, Arkansas, Georgia, Florida, Louisiana and Mississippi. Estimates for the following northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont will be published in 2015 as Volume 10. Figure 1 shows the northeast project area as well as the published Volumes 1 to 9 of NOAA Atlas 14.

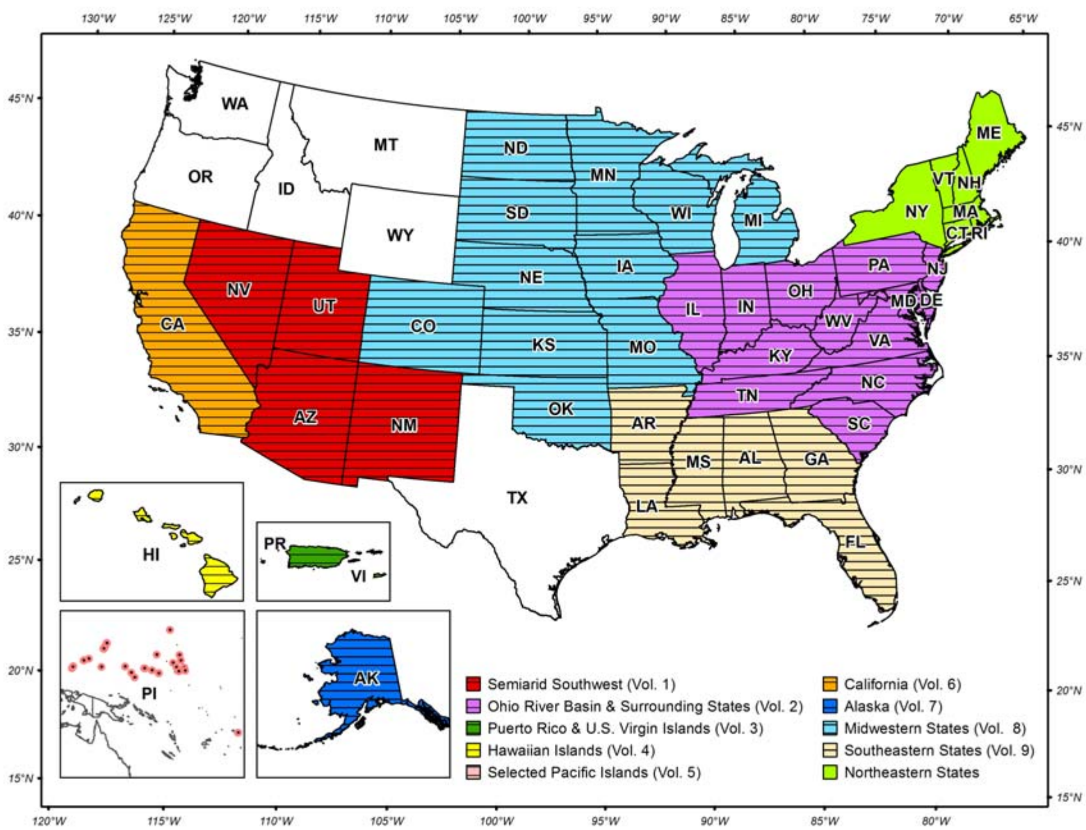

Figure 1. Project area for the northeastern states and project areas published in NOAA Atlas 14, Volumes 1-9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECTS FOR THE MIDWESTERN AND SOUTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Apr 2013)

To facilitate a more efficient process, the Midwestern and Southeastern precipitation frequency projects were done simultaneously. Because of that, the results shown in this section apply for both projects.

1.1.1. Publication announcement

Precipitation frequency estimates for the Midwestern States and Southeastern States were published on April 19th, 2013 as NOAA Atlas 14 Volumes 8 and 9, respectively. The estimates were published through our Precipitation Frequency Data Server at http://hdsc.nws.noaa.gov/hdsc/pfds/. Volume 8 covers the states of Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin. Volume 9 covers the states of Alabama, Arkansas, Florida, Georgia, Louisiana and Mississippi. These Volumes supersede information in Arkell and Richards (1986), Technical Memorandum HYDRO-35 (1977), Technical Paper 40 (1961), Technical Paper 49 (1964), and NOAA Atlas 2 Volume III (1973) for the states covered.

The publications include:

- High resolution grids of precipitation frequency estimates with corresponding bounds of 90% confidence intervals for average recurrence intervals (ARIs) of 1-year through 1,000-years for selected durations from 5-minutes through 60-days
- Cartographic maps of precipitation frequency estimates for selected ARIs and durations
- Seasonality analysis for annual maximum series
- Temporal distributions of heavy precipitation for 6-hour, 12-hour, 24-hour, and 96-hour durations
- Annual maximum series data used in the analysis
- Rainfall frequency estimates for higher elevations stations (only in Volume 8).

Documentation describing the station metadata, data, and project methodology will be released in June 2013.

1.1.2. Peer review

During the peer review of preliminary precipitation frequency estimates for the project areas, interested parties evaluated the accuracy of station metadata and the reasonableness of point precipitation frequency estimates in addition to their spatial patterns. After the close of the peer review, HDSC received a few additional comments.

In late February, members of the Colorado Department of Transportation, the Denver Urban Drainage and Flood Control District, and the Colorado Climate Center met to further evaluate the preliminary estimates and to discuss their review with HDSC. They provided valuable feedback regarding shorter duration estimates in Denver and other estimates throughout Colorado.

HDSC reviewed all comments received from the peer review and addressed any concerns as we finalized estimates. Comments from peer reviewers will be consolidated and included in our final documentation with our responses.

1.1.3. Revision of station data and estimates in response to peer review

a. Station metadata and data

15-minute data from the Oakland County Water Resources Commissioner in Michigan received during the peer review process were evaluated to extend nearby Southeast Michigan Council of Governments (SEMCOG) and NCDC station data. As a result, we extended the data at nine hourly and/or daily stations. Because of this, two daily stations previously deleted because they did not have long enough records were added back to the analysis.

Based on feedback received during the peer review, five previously deleted stations in Colorado were added back to the analysis and merged to produce longer records at nearby stations.

Lastly, we changed the station names for stations from the Minnesota Department of Natural Resources, State Climatology Office so that it will be easier for those familiar with the dataset to find a station of interest.

b. At-station mean annual maximum estimates

We estimated 15-minute mean annual maxima (MAMs) and/or revised MAMs for other durations at 12 locations to anchor and improve spatial interpolation at higher elevations in Colorado and South Dakota.

Station-dense areas in Florida were revisited. Many stations there sampled the same period or had shorter records and could be biasing the results. This review resulted in the deletion of nine stations.

c. At-station precipitation frequency estimates

Regions used to compute precipitation frequency estimates at stations were revisited in areas where, based on the reviewers' comments, 2-year or 100-year estimates did not conform to expected regional patterns and to reduce station-driven bulls' eyes showing on cartographic maps. For this project, regions were developed using a radius-of-influence approach for each station. (Until documentation for Volumes 8 and 9 are published, more details on the regionalization approach can be found in documentation for Volume 7, Section 4.6.2; http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume7.pdf.) Hourly data included in regions were also checked to ensure a sufficient number of data years and consistency with nearby stations, particularly in flat terrain. Lastly, coastal areas were carefully evaluated and re-regionalized as needed to produce consistent patterns along the coast. The result of this re-regionalization was more consistent with peer reviewers' expectations and better reflected the spatial smoothness of the expected climatology of the estimates.

Lastly, a Monte Carlo simulation procedure, as described in Hosking and Wallis (1997), was used to construct 90% confidence intervals (i.e., 5% and 95% confidence limits) on precipitation frequency curves. A station dependence analysis indicated that AMS data from different stations in a region were frequently highly correlated (especially for longer durations), so the algorithm was adjusted to account for inter-station correlation. Since estimates and confidence intervals for each duration were calculated independently, confidence intervals were adjusted for consistency across durations.

d. Interpolation of mean annual maxima and precipitation frequency estimates

Point mean annual maximum (MAM) data were spatially interpolated to grids by Oregon State University's PRISM Climate Group. Those grids serve as the basis for deriving gridded precipitation frequency estimates at the different durations and frequencies. The PRISM Climate Group performed three additional iterations based on HDSC's review and edits to produce the final MAM grids for each duration.

Development of the precipitation frequency grids for each frequency utilizes the inherently strong linear relationship that exists between mean annual maxima and precipitation frequency estimates for the 2-year average recurrence interval (ARI), as well as between precipitation frequency estimates for consecutive ARIs. The 2-year and 100-year grids were carefully reviewed with respect to comments from the peer review and to reduce questionable station-driven patterns. Minor adjustments were made to estimates to improve patterns. The resulting patterns were then carried through to other recurrence intervals in an iterative process.

To achieve smoother spatial results, HDSC applied a dynamic filter to precipitation frequency grids calculated from MAM grids. Parameters of the filter, which control the amount of smoothing, are a function of elevation gradients and proximity to the coastline. Parameters were selected such that maximum smoothing was applied in flat terrain, no smoothing was applied in the mountains, and the transition from one to the other was gradual. Minor adjustments were made to the parameters of the filter during the last quarter. The filter was applied to grids for all recurrence intervals.

1.1.4. Precipitation frequency estimates for longer durations in Missouri

HDSC developed precipitation frequency estimates for the 10% annual exceedance probability for the state of Missouri for 90-day, 180-day, and 365-day durations. Since no mean annual maximum grids exist for durations over 60 days, relationships between the 90-, 180-, and 365-day estimates and the 60-day estimates were developed and used to derive these grids.

1.1.5. Precipitation frequency estimates for n-minute durations

15-minute and 30-minute MAM grids were developed by the PRISM Climate Group. Precipitation frequency grids for those durations were derived by assuming that relationships used to derive grids of 60-minute precipitation frequency estimates are applicable for the 15-minute (and 30-minute) estimates. The assumption was tested on stations that had data at sub-hourly durations and was found to be acceptable. Therefore, the ratio grids based on the 60-minute duration developed between mean annual maxima (MAMs) and precipitation frequency estimates for the 2-year average recurrence interval (ARI), as well as between precipitation frequency estimates for consecutive ARIs, were applied in the same cascading fashion to the 15-minute and 30-minute grids.

The 15-minute precipitation frequency grids were then multiplied by previously computed scaling factors 0.82 and 0.56 to develop precipitation frequency grids for the 10-minute and 5-minute durations, respectively.

1.1.6. Temporal distributions of heavy precipitation

HDSC computed temporal distributions of precipitation amounts for 6-, 12-, 24-, and 96-hour durations exceeding corresponding magnitudes for 2-year average recurrence interval. The temporal distributions are expressed in probability terms as cumulative percentages of precipitation totals at various time steps. To provide detailed information on the varying temporal distributions, separate temporal distributions were also derived for four precipitation cases defined by the duration quartile in which the greatest percentage of the total precipitation occurred. Stations were grouped into five climate regions and separate temporal distributions were derived for each climate region. The climate regions were delineated based on extreme precipitation characteristics expressed through 24-hour mean annual maximum (MAM) estimates, mean annual precipitation (MAP) and elevation.

When a location is selected through the Precipitation Frequency Data Server (PFDS), the temporal distribution files for the appropriate climate region are accessible under the 'Supplementary information' tab.

1.1.7. Seasonality of annual maxima

To portray the seasonality of extreme precipitation throughout the project area, annual maxima that exceeded precipitation frequency estimates (quantiles) with selected annual exceedance probabilities (AEPs) for specific durations were examined for each climate region. Graphs showing the monthly variation of the exceedances for a region are provided for each location in the project area via the PFDS. They show the percentage of annual maxima for a given duration from all stations in a region that exceeded corresponding precipitation frequency estimates at selected AEP levels in each month. We provide results for 60-minute, 24-hour, 2-day, and 10-day durations and for annual exceedance probabilities of 1/2, 1/5, 1/10, 1/25, 1/50, and 1/100.

1.1.8. Rainfall frequency analysis

Precipitation frequency estimates represent precipitation magnitudes regardless of the type of precipitation. For some applications it may be important to differentiate total precipitation (which may include snow) frequency estimates from liquid precipitation (i.e., rainfall) only. To explore differences in total and liquid-only precipitation frequency estimates, concurrent rainfall and precipitation AMS were extracted. We conducted the rainfall frequency analysis for durations up to 24 hours, which are of most interest to design projects relying on peak flows.

Concurrent daily precipitation and snowfall measurements were available from NCDC's daily dataset. Recorded snowfall amounts were first converted to snow water equivalent using the 10 to 1 rule, which assumes that the density of water is 10 times the density of snowfall. Rainfall amounts were then calculated as a difference between precipitation and snow water equivalent.

Since snow and temperature measurements were not available for hourly durations, we used daily maximum and minimum temperature measurements from co-located daily stations to classify precipitation amounts as solid or liquid. Precipitation that occurred when the daily maximum temperature was above 34^0 F was considered rainfall. Precipitation that occurred when the temperature was equal to or below that threshold was considered snowfall.

Frequency analysis was done on at-station rainfall-only AMS and on total precipitation AMS. A comparison between precipitation and rainfall frequency estimates revealed that differences between precipitation and rainfall frequency estimates were noteworthy only for Colorado and South Dakota stations above approximately 4,000 feet in elevation. Regression equations relating rainfall frequency estimates with precipitation frequency estimates were developed for those stations and applied to produce rainfall frequency estimates with corresponding confidence intervals for locations in Colorado and South Dakota for durations between 60-minutes and 24-hours.

1.1.9. Comparison with previous NWS studies

With each volume of NOAA Atlas 14, we provide comparisons of the estimates against the previous NWS studies. We prepared preliminary difference maps between NOAA Atlas 14 100-year estimates and previous publications - Technical Paper 40 maps of 24-hour estimates and Technical Memorandum HYDRO-35 map of 60-minute estimates. For Colorado, comparisons were made with NOAA Atlas 2 Volume III estimates.

1.1.10. Development of PFDS web pages for Volumes 8 and 9

Web pages were updated for the new project areas of Volumes 8 and 9 and all related products were created.

Federal Geographic Data Committee (FGDC) compliant metadata was prepared for the Volumes 8 and 9 grids, separately. Templates for cartographic maps of each state (or group of states) were developed and maps for selected durations and recurrence intervals were created. Files with annual maximum series data used in analysis were created. Corresponding documentation pages were edited to reflect changes in currently valid documents.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - Jun 2013)

In the next reporting period, HDSC will complete the documentation to accompany Volume 8 and Volume 9 precipitation frequency estimates. It will be published via the Precipitation Frequency Data Server.

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, trend analysis, 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 [Complete]

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

Web publication of estimates [Complete]

Web publication of documentation [June 2013]

2. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

2.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2013)

The project area includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont and an approximately 1-degree buffer around these states (Figure 3).

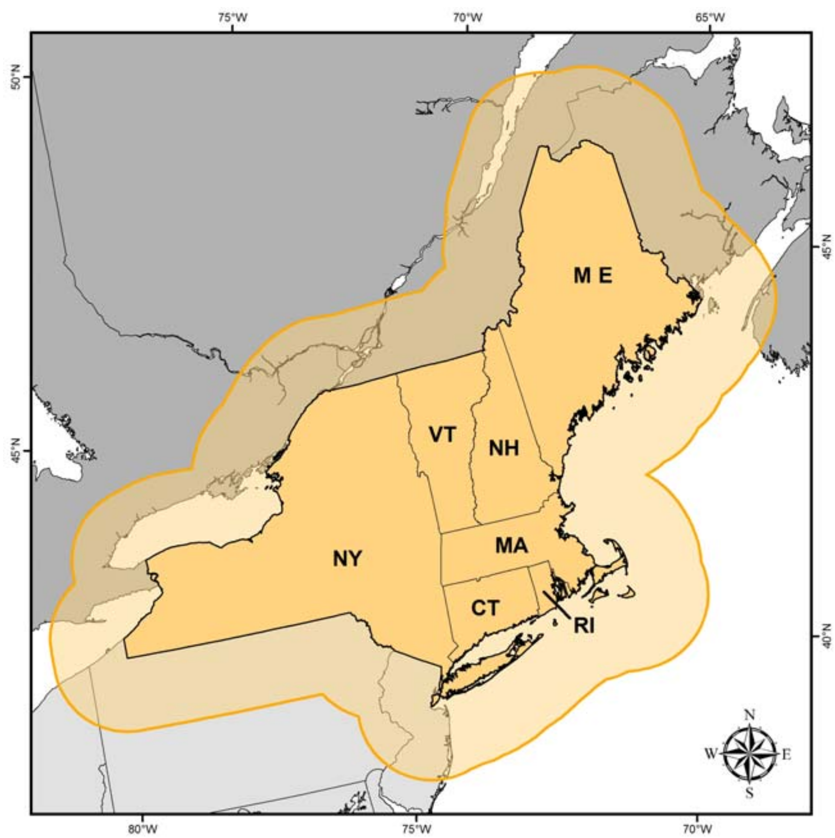

Figure 3. Northeastern precipitation frequency project area (shown in orange).

2.1.1. Data collection and formatting

Nine of the collected datasets were formatted during this quarter. Table 1 shows the status of the data collected thus far. If you know about other data we could use, please contact us at HDSC.Questions@noaa.gov.

Table 1. Sources of data for the precipitation frequency analysis for the Northeast states. Datasets in grey were investigated but will not be used for various reasons.

Source	**Reporting interval**	**Preliminary number of stations**	**Status**
Automated Surface Observing Systems (ASOS)	1-minute	42	Formatted.
Colorado Climate Center: Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)	1-day	2,637	Formatted (however, many only have a few years).
Environment Canada	1-day 1-hour	2,980 536	Formatted.
Illinois State Water Survey: National Atmospheric Deposition Program (NADP) dataset	1-day	57	In process of being formatted.
Massachusetts Department of Conservation and Recreation (DCR)	1-day	176	Received on CD.
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	varies	TBD	Received on DVD.
Midwestern Region Climate Center (MRCC): 19th Century Forts and Voluntary Observers Database	1-day	63	Formatted.
National Climatic Data Center (NCDC)	1-day 1-hour 15-minute n-minute	3,001 593 517 43	Formatted.
National Environmental Satellite, Data, and Information Service (NESDIS): U.S. Climate Reference Network (USCRN)	1-day 1-hour	11 11	Formatted.
National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	1-hour 1-day	6 6	Downloaded from website.
Rhode Island Department of Environmental Management, Office of Water Resources	1-hour	1	Received via email.
U.S. Department of Agriculture: Agricultural Research Service (ARS)	variable	23	Downloaded from website; working to ascertain station metadata.
U.S. Forest Service: Remote Automated Weather Stations (RAWS) dataset	1-hour	TBD	Currently downloading from FTP site.
U.S. Geological Survey (USGS) Connecticut Water Science Center	1-day; 15-minute	TBD	No progress.
USGS Maine Water Science Center	1-day 15-minute	16 n/a	Formatted.
USGS Massachusetts-Rhode Island Water Science Center	1-day hourly 15-minute	5 1 16	Formatted.
USGS New Hampshire-Vermont Water Science Center	1-day 15-minute	6 n/a	Formatted.
USGS New York Water Science Center	1-day	1	Formatted.
Global Summary of the Day (NCDC)	1-day	n/a	Data are duplicate of NCDC and Environment Canada data.
Northeast Regional Climate Center (NRCC): CLimate Information for Management and Operational Decisions (CLIMOD)	1-day	n/a	Data are duplicate of NCDC.
U.S. Army Corps of Engineers	1-hour	n/a	No suitable dataset available.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - Jun 2013)

Data collection and formatting will be completed. Quality control of the station metadata will begin.

2.3. PROJECT SCHEDULE

Data collection, formatting, and initial quality control [June 2013]

Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, trend analysis, independence, consistency across durations, duplicate stations, candidates for merging) [December 2013]

Regionalization and frequency analysis [July 2014]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [December 2014]

Peer review [December 2014]

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]

3. AREAL REDUCTION FACTORS

3.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2013)

Areal reduction factors (ARFs) are needed to convert average point precipitation frequency estimates to areal estimates with the same recurrence interval for an area of interest. After an extensive literature review, HDSC has selected three diverse fixed-area ARF methods for further evaluation. Selection was done primarily from the perspective of their potential application to NOAA Atlas 14 precipitation frequency estimates. These methods are described in earlier Quarterly Progress Reports (e.g., see http://www.nws.noaa.gov/oh/hdsc/current-projects/progress/201301_HDSC_PR.pdf).

Due to limited resources and higher priority precipitation frequency projects, during this reporting period, no progress was made on this task.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - Jun 2013)

With the recent completion of the precipitation frequency projects for the midwestern and southeastern states, we expect to progress on this task in the next reporting period.

3.3. PROJECT SCHEDULE

It is expected that this project will be completed by the end of 2013.

III. OTHER

1. RECENT MEETINGS AND CONFERENCES

On January 14, Geoff Bonnin, Chief of the Hydrologic Science and Modeling Branch of the NWS Office of Hydrologic Development made a presentation entitled *Changes to Extreme Precipitation Events: What the Historical Record Shows and What It Means for Engineers* at the annual meeting of the Transportation Research Board in Washington, D.C.

Geoff Bonnin and Sanja Perica, Director of HDSC, attended the Workshop on Probabilistic Flood Hazard Assessment (PFHA) hosted by the United States Nuclear Regulatory Commission (NRC) in Rockville, MD on January 29th – 31st. The purpose of the workshop was to assess, discuss, and inform the participants on the state-of-the-practice for extreme flood assessments within a risk context. Mr Bonnin gave a presentation entitled *Precipitation Frequency Estimates For The Nation And Extremes – A Perspective* and served as a panelist for one of the sessions.

HDSC attended, via teleconference and webinar, the Annual Meeting of the City Engineers Association of Minnesota on January 30th. Sanja Perica presented *Updated Precipitation Frequency Estimates for Minnesota* which covered the approach used to develop the estimates and preliminary estimates for Minnesota. Barr Engineering presented their review of the preliminary results released during the peer review.

On February 19th, Sanja Perica participated in the workshop organized by the NOAA Regional Climate Services and North Atlantic Regional Team at the University of Massachusetts, Amherst. Workshop participants included representatives from several federal and state agencies and academia. Participants discussed HDSC’s update of precipitation frequency estimates in the northeastern states, differences in the methodologies used by HDSC in NOAA Atlas 14 volumes from those used in the Northeast Regional Climate Center’s 2012 project for New York and New England, and updates’ consequences on infrastructure design.

Sandra Pavlovic, a civil engineer with HDSC, attended the Iowa Section of the American Society of Civil Engineers (ASCE), Water Resource Conference on March 21st in Cedar Rapids, Iowa. She presented *Updated Precipitation Frequency Estimates for Iowa* which covered the approach used to develop the estimates and preliminary estimates for Iowa.