HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 July to 30 September 2016

Office of Water Prediction
National Weather Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Silver Spring, Maryland

October 2016

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.

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I. INTRODUCTION

The Hydrometeorological Design Studies Center (HDSC) within the Office of Water Prediction (OWP; formerly, Office of Hydrologic Development and National Water Center)[1] of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) has been 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. Figure 1 shows the states or territories associated with each of the Volumes of the Atlas. To date, we have updated precipitation frequency estimates 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), 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), and Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (Volume 10, 2015). Since May 2015, HDSC has been working on updating precipitation frequency estimates for the state of Texas. We expect to publish them in mid-2018 in NOAA Atlas 14, Volume 11.

Funding for HDSC work comes from external sources. For recent volumes, most of the funds have come from the U.S. Army Corps of Engineers (USACE), Federal Highway Administration (FHWA) and State Departments of Transportation. These funds flow through the Transportation Pooled Fund (TPF) Program, which is set up to allow interested federal, state, and local agencies and other organizations to combine resources to support transportation relevant research studies. This requires only a single agreement between NWS and FHWA rather than many agreements with each entity providing funds. OWP has been working with FHWA and several Northwestern state agencies on securing funding to extend NOAA Atlas 14 coverage to the remaining five northwestern states: Idaho, Montana, Oregon, Washington, and Wyoming in Volume 12. An updated solicitation for this project will be listed on the TPF web page in the near future. For any inquiries regarding the status of this effort, please send an email to HDSC.questions@noaa.gov.

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[1] *The Office of Hydrologic Development reorganized into the National Water Center in May 2015 which was recently renamed as the Office of Water Prediction (OWP) with locations in Silver Spring, MD, Tuscaloosa, AL, and Chanhassen, MN.*

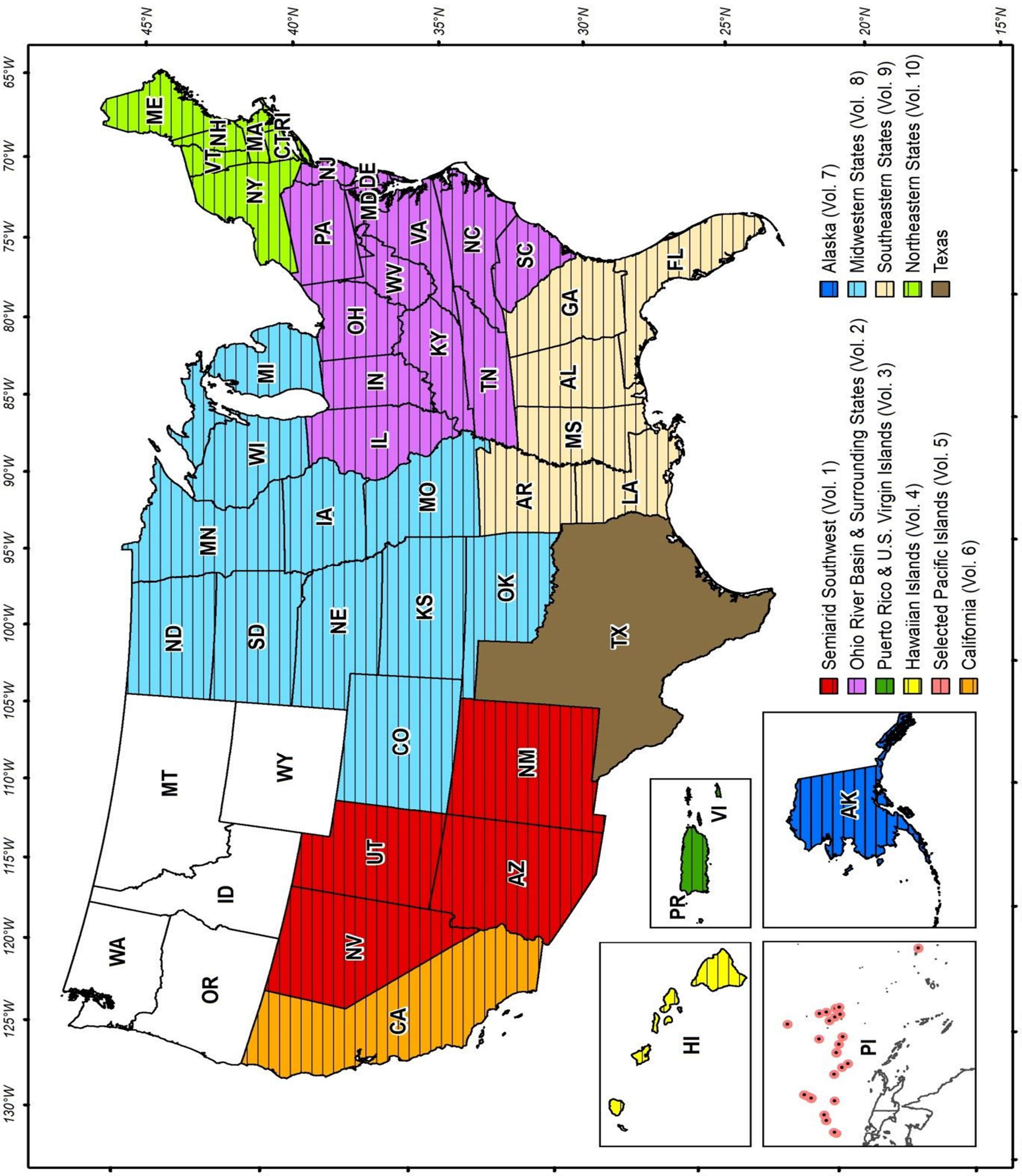

Figure 1. Current project area for Volume 11 (Texas) and project areas included in published Volumes 1 to 10.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2016)

Precipitation frequency estimates for the following seven northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont were published on September 30, 2015, as NOAA Atlas 14, Volume 10. The estimates for any location in the project area, along with all related products except documentation, are available for download in a variety of formats through the Precipitation Frequency Data Server (PFDS).

Work on documentation describing the station metadata, data, and project methodology has been put on hold as of October 2015 due to funding issues. Those issues have just been resolved and we restarted the work.

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2016)

Work on documentation will resume. We expect to release the NOAA Atlas 14 Volume 10 document by the end of this reporting period. We will publish the document here: http://www.nws.noaa.gov/oh/hdsc/currentpf.htm.

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 [Complete]

Remaining tasks (e.g., development of gridded precipitation frequency estimates, confidence intervals, development of PFDS web pages) [Complete]

Web publication of estimates [Complete]

Web publication of Volume 10 document [December 30, 2016]

2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS

2.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2016)

The extended project area for the NOAA Atlas 14 Volume 11 precipitation frequency project includes the state of Texas and approximately a 1-degree buffer around the state (Figure 2). We began this project in May 2015 and expect to complete it in mid-2018.

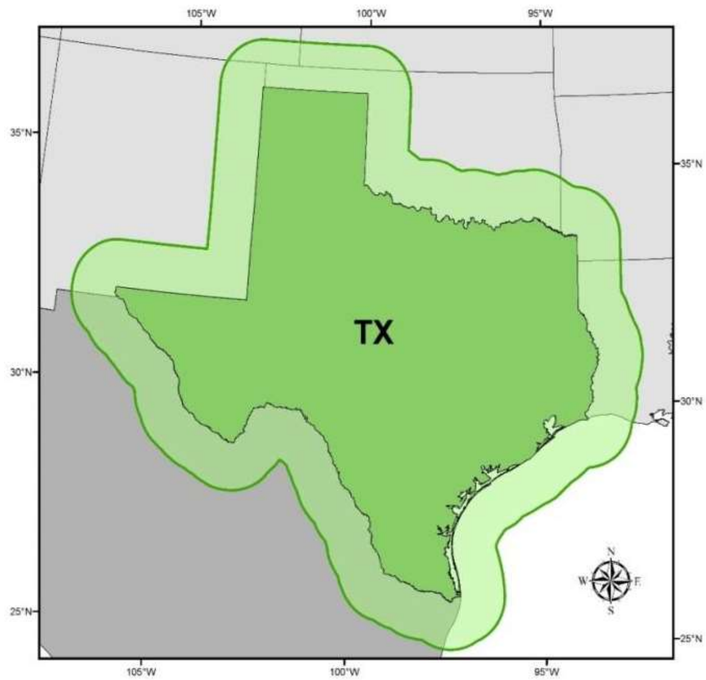

Figure 2. NOAA Atlas 14, Volume 11 extended project area (shown in green).

During this reporting period, we continued data collection, digitization and formatting. We made significant progress with annual maximum series extraction and quality control tasks. Below, we describe in more detail the major tasks performed during this reporting period.

2.1.1. Data collection and formatting

The primary source of data for NOAA Atlas 14 Volumes is the NOAA's National Centers for Environmental Information (NCEI), but we recognize that the NCEI's precipitation data may not be sufficient to accomplish the objectives of NOAA Atlas 14. Therefore, for each project area, we also collect data from other Federal, State and local agencies.

For this project area we are trying to assemble all reliable precipitation data for stations in Texas, as well as in adjacent portions of neighboring states (Arkansas, Louisiana, New Mexico, and Oklahoma) and also in Mexico. Since we started this project, we have contacted numerous agencies for assistance with the data. During this reporting period, we continued reviewing the information provided to us and contacting other agencies which were indicated as additional sources of potentially useful data.

We format all data to a common format at one of three base durations (1-day, 1-hour, 15-minute) that correspond to the original reporting period. Data recorded at variable time steps are formatted at 15-minute increments. So far, we have formatted data for 9,319 stations from 30 datasets; they are listed in Table 1. Locations of daily stations formatted and processed as of this time are shown in Figure 3. Only stations with at least 30 years of AMS data (shown as red circles) will be considered for frequency analysis, although allowances may be made for isolated stations. Stations with less than 30 years of data, shown as black dots in the figure, will still be used in various quality control tasks; some of those stations may end up being used in the analysis through merging their data with data from nearby stations and from datasets not formatted yet. Similarly, Figures 4 and 5 show locations of stations recording at 1-hour and at sub-hourly durations, respectively, where stations with less than 20 years of AMS data are shown as black dots. Datasets with an asterisk in Table 1 are formatted but not processed yet, so stations from those datasets that pass the minimum number of data-years requirement are not plotted on the maps.

Table 2 contains information on the status of collection and formatting tasks for additional datasets. Datasets indicated as “not used” generally contain information already included in other datasets, data assessed as not reliable for this specific purpose, or stations with very short periods of record deemed unsuitable for merging with any nearby station.

We would like to thank all of those who responded to our inquiry and/or provided the data. We still welcome any information on the data for this project area and ask for help with collecting the data from datasets indicated as “need contact information”. If you know about any datasets in addition to those listed in Tables 1 and 2, particularly in areas of low station density (see Figures 3 to 5), please contact us at HDSC.Questions@noaa.gov.

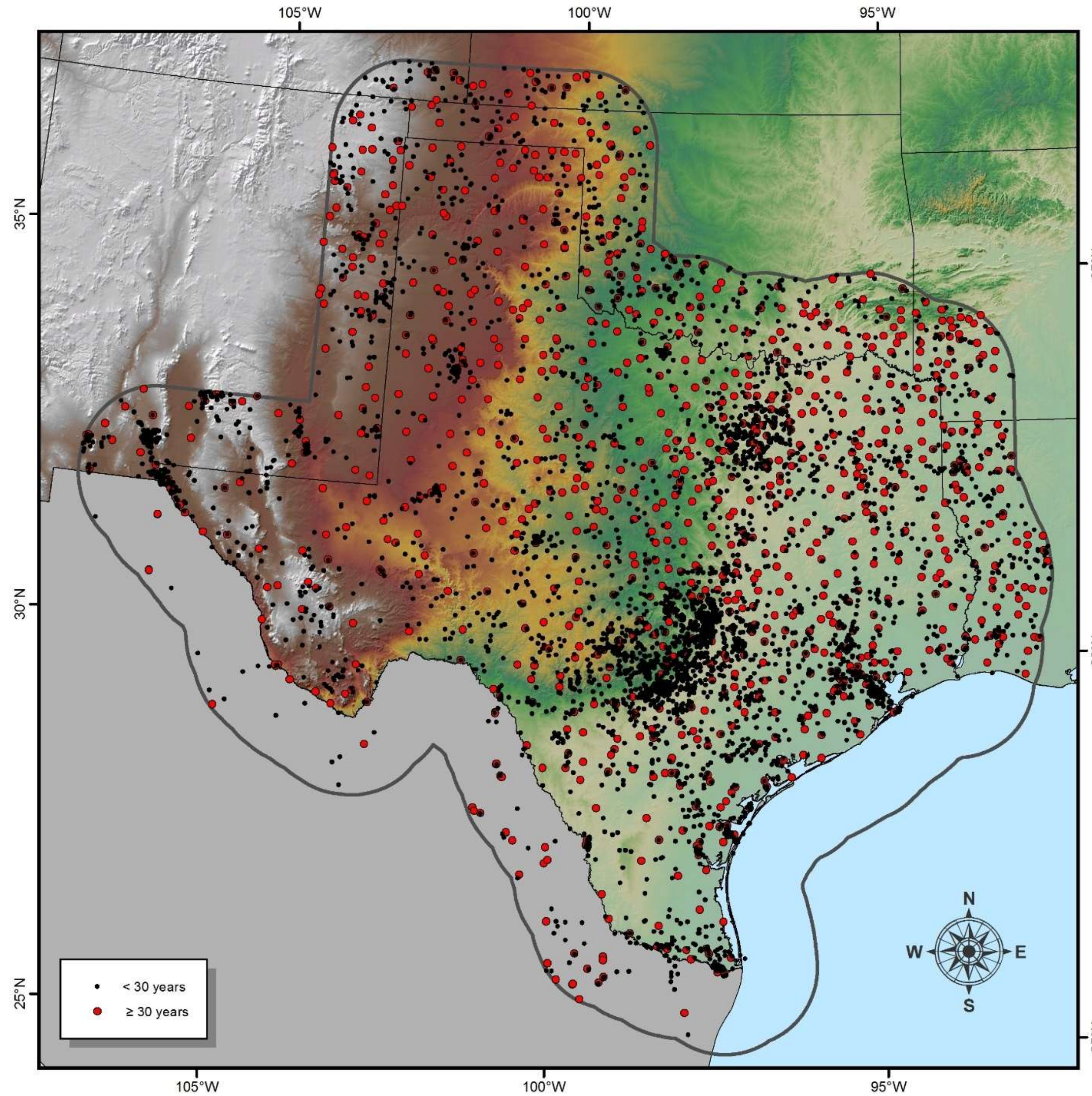

Figure 3. Map of stations recording at 1-day intervals formatted as of this time. Only stations shown as red circles (995 of 5,432 stations) will be considered in frequency analysis for durations between 1 day and 60 days.

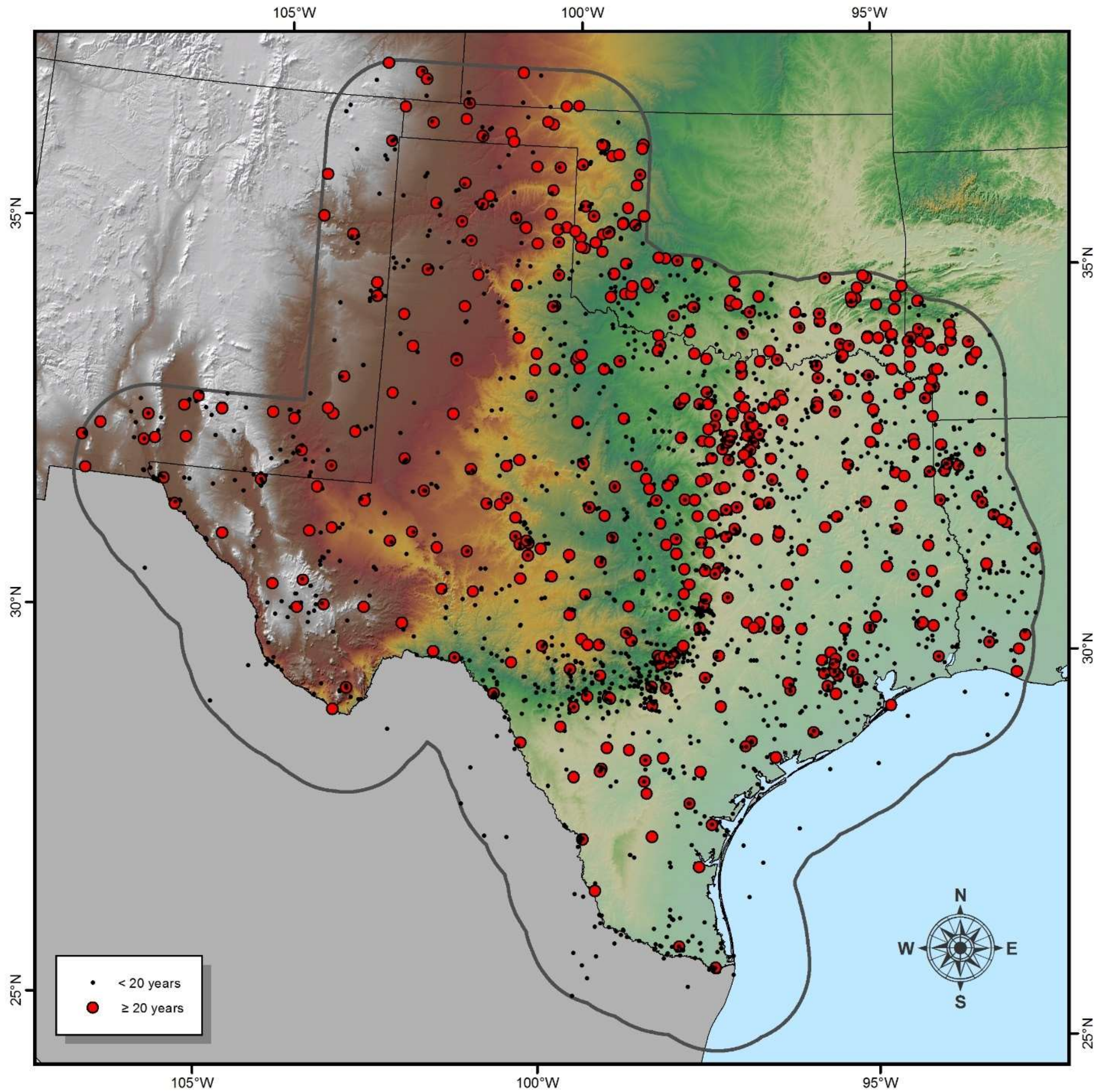

Figure 4. Map of stations recording at 1-hour interval formatted as if this time. Only stations shown as red circles (497 of 2,458 stations) will be considered in frequency analysis for durations between 1 hour and 60 days.

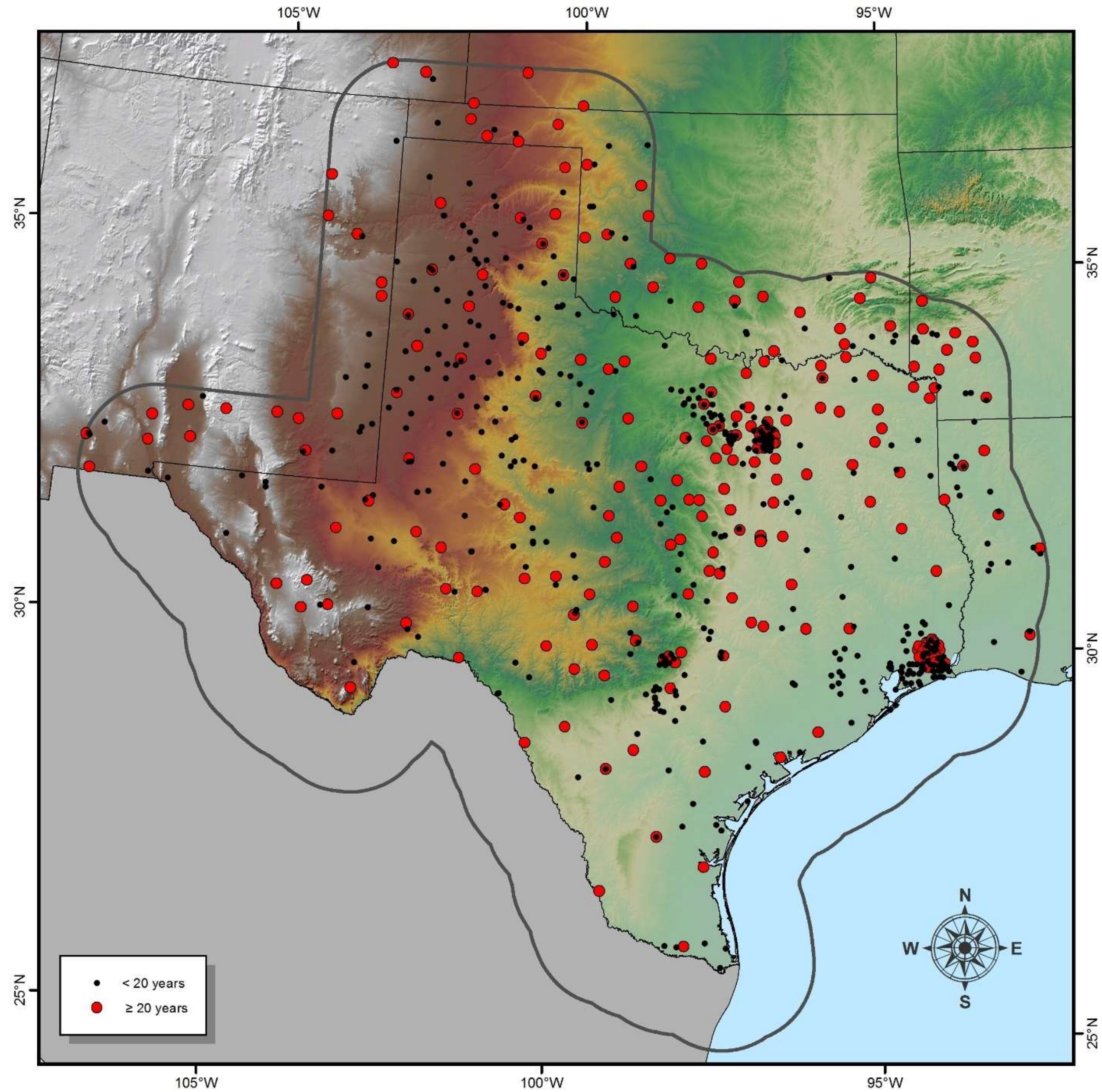

Figure 5. Map of stations recording at sub-hourly intervals formatted as of this time. Only stations shown as red circles (283 of 757 stations) will be considered in frequency analysis for durations between 15 minutes and 60 days.

Table 1. Datasets formatted as of this time.

Source of data and dataset/network name (formatted and plotted on the map)	**Recording period**	**Number of stations**
NCEI: Automated Surface Observing System (ASOS)	1-min	81
NCEI: DSI 3260	15-min	352
NCEI: DSI 3240	1-hr	806
NCEI: Global Historical Climatology Network (GHCN)	1-day	5,237
NCEI: Quality Controlled Local Climatological Data (QCLCD)	1-hr	277
NCEI: Unedited Local Climatological Data (ULCD)	1-hr	176
City of Dallas ALERT Network	varying	62
Edwards Aquifer Authority	1-hr	141
Guadalupe-Blanco River Authority*	6-min	50
Harris County Flood Control District's Flood Warning System*	varying	142
Jefferson County Drainage District 6 ALERT Precipitation and Stream Level Network	varying	95
Midwestern Regional Climate Center: CDMP 19th Century Forts and Voluntary Observers Database	1-day	26
National Atmospheric Deposition Program (NADP)	1-day	32
National Estuarine Research Reserve System (NERRS)*	15-min, 1-hr	2
National Weather Service Hydrometeorological Automated Data System	1-hr	908
Oklahoma Mesonet Observation Network*	5-min 1-day	140 140
Sabine River Authority Precipitation Dataset	1-day	4
Servicio Meteorologico Nacional, Mexico	1-day	99
Tarrant Regional Water District (Greater Fort Worth area)/ Tarrant County Urban Flood Control Network	15-min, 1-hr	35
Texas Commission on Environmental Quality: Air Quality Network*	1-hr	21
Texas Evapotranspiration Network*	1-hr,1-day	122
Texas Water Development Board*	1-hr,1-day	18
Titus County Fresh Water Supply District No. 1*	1-day	1
U.S. Bureau of Reclamation: HydroMet	1-hr, 1-day	94
US Dept. of Agriculture (USDA): Agricultural Research Service (ARS)	varying	18
USDA, Forest Service: Remote Automated Weather Station (RAWS) Network	1-hr	108
USDA , National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)*	1-hr	17
USGS Nation Water Information System (NWIS)	15-min	20
West Texas Mesonet	1-min, 15-min	95
TOTAL		**9,319**

Table 2. Status of data collection and formatting for additional datasets.

Source of data and dataset/network name (when available)	Status
Lower Colorado River Authority Regional Meteorological Network	waiting for data
International Boundary and Water Commission Lavaca/Navidad River Authority Gage Network	contacted with data request
San Antonio River Authority	need contact information
Bexar County Urban Flood Control Network City of Austin ALERT Network Meteorological Assimilation Data Ingest System (MADIS) NCEI: Automated Weather Observing System (AWOS) NCEI: U.S. Climate Reference Network (USCRN) Northeast Texas Municipal Water District (NETMWD) PivoTrac Monitoring, LLC Road Weather Information System (RWIS) Union Pacific Railroad Weather Station Network	not used

2.1.2. Annual maximum series (AMS) extraction

The precipitation frequency analysis approach we used in this project is based on AMS analysis across a range of durations. AMS for each station whose data were formatted were obtained by extracting the highest precipitation amount for a particular duration in each successive calendar year. Calendar year was used in this project area, rather than a standard water year (October - September), based on the distribution of heavy precipitation events so that a year begins and ends during a relatively dry season. AMS at stations were extracted for all durations equal to or longer than the base duration (or reporting interval) up to 60 days. The criteria for extraction were designed to exclude maxima if there were too many missing or accumulated data during the year, especially during critical months when precipitation maxima were most likely to occur. All annual maxima that resulted from accumulated data were flagged screened to ensure that the incomplete data did not result in erroneously low maxima (see Section 2.1.5).

2.1.3. Data digitization

In this reporting period, with the help of students/interns working with the U.S. Army Corps of Engineers - Fort Worth District, we continued to digitize additional precipitation data from the NCEI's Climate Database Modernization Program (CDMP). The focus up until this point has been mostly on extending records for hourly stations in urban areas, but this work will also apply to stations in data scarce areas and stations with significant periods of record missing. A summary of the work completed and in progress thus far with the stations' names, recording intervals and periods of record digitized is shown in Table 3.

Table 3. Status of digitization work (indicates digitization in progress)*

Station name	Recording interval	Period digitized
Abilene	1-hr	1906-1940
Brackettville/Fort Clark	1-day	1853-1899
Corpus Christi	1-hr	1902-1940
Dallas	1-hr	1914-1940*
Galveston	1-hr	1892-1940*
Fort Worth	1-hr	1903-1940
Houston	1-hr	1910-1940*
San Antonio	1-hr	1903-1940
Taylor	1-hr	1903-1932

Figure 6 shows, as an example, the effect of newly digitized hourly data on 1-day AMS for NCEI's daily station Taylor (station ID 41-8861; also merged with nearby NCEI's station 41-8862). For this station, the daily record was extended for an additional 27 years (1903-1929). As is evident from the figure, several of the largest values in the AM series, including the AM from the September 7-11, 1921 extreme event, come from the newly digitized data.

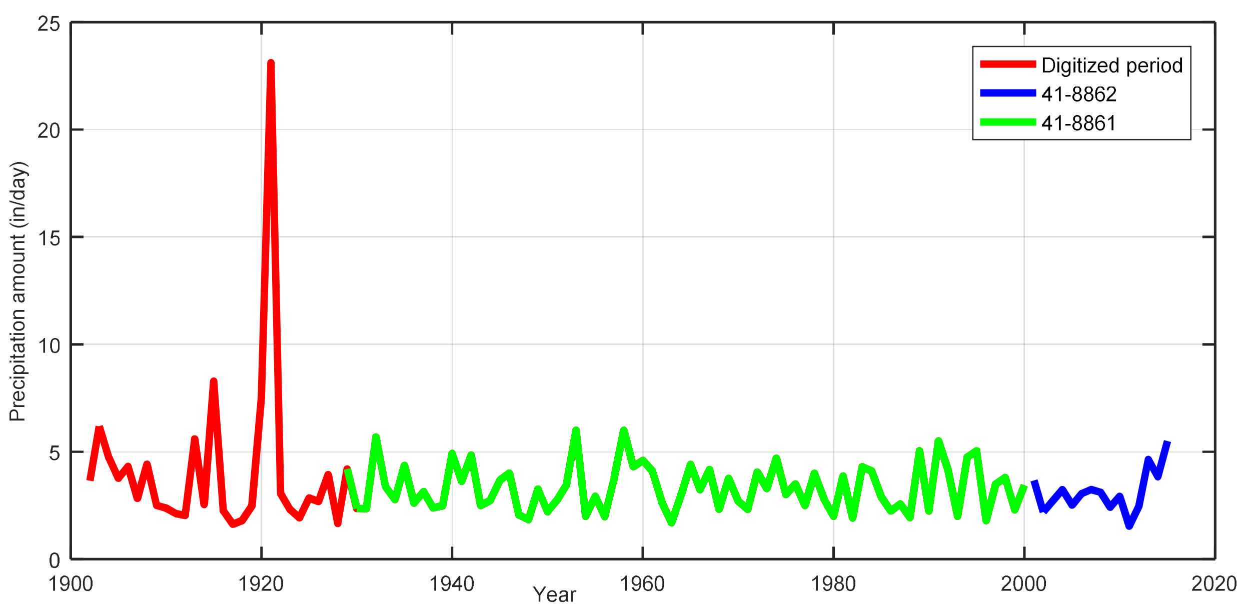

Figure 6. 1-day annual maximum series for Taylor station (41-8861 in green and 41-8862 in blue). AM from the newly digitized hourly data are shown in red.

2.1.4. Metadata quality control

We finished screening the basic metadata (latitude, longitude and elevation) for stations formatted so far and made corrections where appropriate. Specifically, we screened stations that plotted in the ocean or in the wrong state, or had no elevation recorded in the original dataset. Stations that had no elevation were assigned elevations from a 30-second resolution digital elevation model (DEM). We also checked station locations if their provided elevation was more than 100 feet different than the elevation extracted from the DEM. Such stations were re-located as necessary based on inspection of satellite images, maps and records of the station's history. We will provide original and revised coordinates for all stations used in the analysis in Appendix 1 of the NOAA Atlas 14, Volume 11 document.

2.1.5. AMS quality control

Since AMS data at both high and low extremities can considerably affect precipitation frequency estimates, they have to be carefully investigated and either corrected or removed from the AMS if due to measurement errors.

We use different statistical tests to identify high and low outliers in the distribution of at-station precipitation AMS. All identified outliers and other questionable maxima at base durations (15-minute, 1-hour and 1-day) are now being verified. First, they are mapped with concurrent measurements at nearby stations. If they cannot be confirmed, they are investigated further using information from climatological observation forms, monthly storm data reports and other historical weather event publications obtained primarily from the NCEI's Environmental Document Access and Display System (EDADS).

Figure 7 shows the distribution of the daily AMS data for NCEI's 79-0049 station where statistical tests identified the 11/04/1978 amount of 20 inches/day as a high outlier. This event was flagged as suspicious after reviewing nearby stations that did not observe any rainfall within a few days of this event. After reviewing the original observer's form, the event was confirmed to be zero and is most likely a typo. We have corrected this value in our raw data files and extracted a new AM for that year.

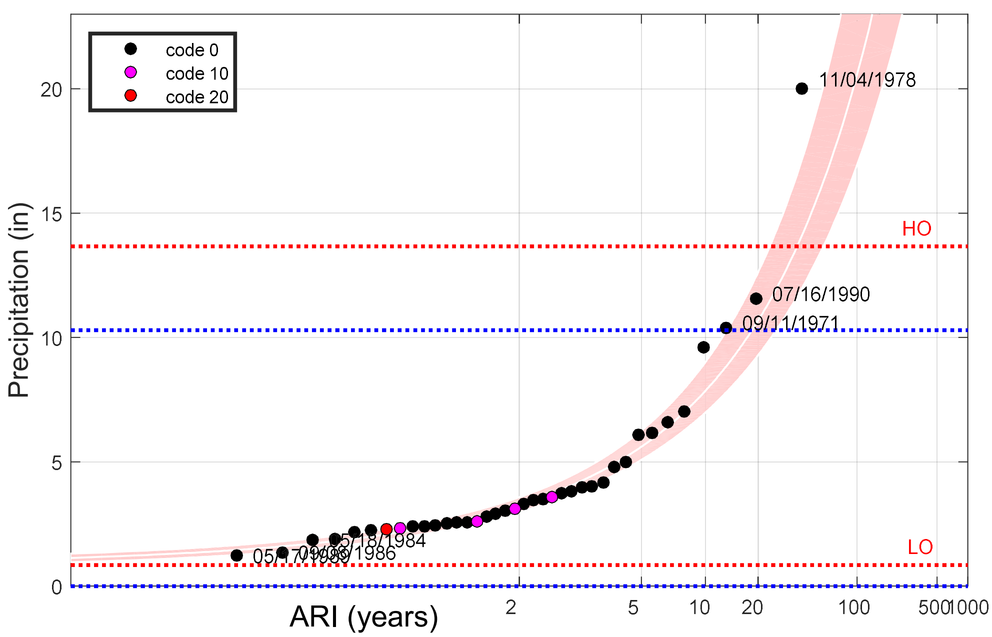

Figure 7. Quality control for 1-day AMS for station 79-0049. 1978 AM value of 20 inches was flagged as a high outlier by statistical tests. Further review established there was no rain on that day.

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2016)

We will continue work on digitization tasks and on various quality control and data reliability tests.

2.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [In progress; still collecting additional datasets]

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) [In progress; due January 2017]

Regionalization and frequency analysis [March 2017]

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

Peer review [August 2017]

Revision of PF estimates [January 2018]

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

Web publication [April 2018]

III. OTHER

1. PRECIPITATION FREQUENCY DATA SERVER (PFDS) ENHANCEMENTS

1.1. FILE NAME FOR DOWNLOADS

The precipitation frequency estimates for a selected location can be downloaded as a .csv file from the drop-down menu at the bottom of the PFDS page with the precipitation frequency estimates table. The .csv downloadable file name has been changed to reflect the information within the file. The file name follows the format below:

Estimate-type_Data-type_Units_Time-series-type.csv,

where estimate type is further classified as precipitation frequency estimates (PF), upper confidence limits (UCL), lower confidence limits (LCL), precipitation frequency estimates with upper and lower confidence limits (All); data type as depth or intensity; units in English or Metric unit system; and time series type as annual maxima series (AMS) or partial duration series (PDS). For example, PF_Depth_English_PDS.csv file name shows that the file contains the precipitation frequency (PF) estimates based on frequency analysis of partial duration series (PDS) shown as precipitation depths in inches (English units' system).

1.2. ADDING PHYSICAL ADDRESS

The street address search bar under the manual location selection option was added to the PFDS web based location look-up functionality. This new search allows users to search for a city name, street name, landmark, zip code, physical address, etc. To get started, type the physical address in the search box and click enter. Figure 8 shows the image of the PFDS webpage for the state of Maryland with the added street address search bar marked in red.

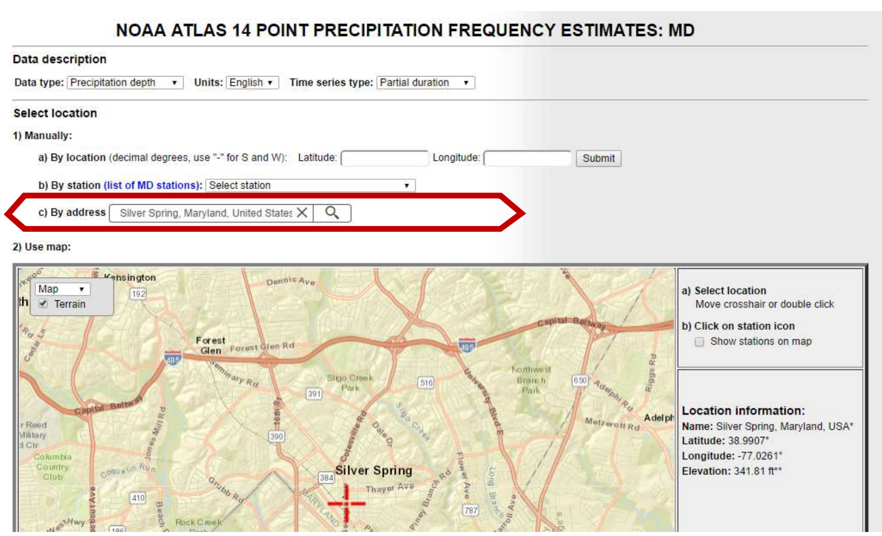

Figure 8. The added physical address search bar for manually selecting the desired location under the PFDS location look-up functionality. The example on the Figure shows the Silver Spring, MD town search.

1.3. TRANSITION FROM GOOGLE TO ESRI MAPS API

Two years ago, Google changed their cost model for NOAA to have access to their Google Map products and NOAA no longer had unlimited usage of the Google Maps API. All NOAA teams were asked to fully transition from Google Maps API by the end of September 2016, when the current contract expired. As a result, all PFDS web based maps and location look-up functionality were migrated to ESRI maps API on September 28.

2. EXCEEDANCE PROBABILITY ANALYSIS FOR SELECTED STORM EVENTS

HDSC creates maps of annual exceedance probabilities (AEPs) for selected significant storm events for which observed precipitation amounts for at least one duration have AEP of 1/500 or less over a large area. AEP is the probability of exceeding a given amount of rainfall for a given duration at least once in any given year at a given location. It is an indicator of the rarity of rainfall amounts and is used as the basis of hydrologic design. For the AEP analysis, we look at a range of durations and select one or two critical durations which show the lowest exceedance probabilities for the largest area, i.e., the “worst case(s).” Since, for a given event, the beginning and end of the worst case period are not necessarily the same for all locations, the AEP maps do not represent isohyets at any particular point in time, but rather within the whole event. The maps, usually accompanied with extra information about the storm, are available for download from the following page: http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/. During this reporting period we analyzed annual exceedance probabilities (AEPs) of the worst case rainfall for three storm events: 30 July 2016 Ellicott City, Maryland event; 11-13 August 2016 Louisiana event; and 11 July 2016 Northern Wisconsin event.

The underlying data for the AEP analyses are rainfall observations and point rainfall frequency estimates at 30-arc second resolution for a range of durations and AEPs. Whenever feasible, gridded rainfall observations are developed from rainfall data collected from all available reporting rain gauges at the time when the map is created (such as rain gauges from the National Centers for Environmental Information's - NCEI’s: Climate Data Online). Alternatively, we rely on the National Centers for Environmental Prediction’s multi-sensor precipitation Stage IV analysis product and the NCEI’s Next Generation Weather Radar (NEXRAD) product. Rainfall frequency estimates typically come from the NOAA Atlas 14 Volumes.

2.1 MERGED NOAA ATLAS 14 PRODUCT FOR THE CONTIGUOUS UNITED STATES

During this reporting period we developed a merged NOAA ATLAS 14 product for the contiguous United States by integrating 30-arc second gridded precipitation frequency estimates from NOAA Atlas 14 Volumes 1, 2, and 6 to 10. It covers every contiguous U.S. state except ID, MT, OR, TX, WA and WY, for which no NOAA Atlas 14 estimates are available. The estimates from different volumes have been merged and blended along the volumes’ boundaries for use in AEP analyses. Merged products are available for durations between 1-hour and 7-day and for the following average recurrence intervals (years): 2, 5, 10, 25, 50, 100, 200, 500, and 1000. We will make the merged product accessible in the near future from the AEP web page through the OPeNDAP access standard. Since we altered estimates along the volumes’ boundaries, we do not recommend the use of this product for engineering design. For precipitation frequency estimates used in design please see the [Precipitation Frequency Data Server.]

2.2 ELLICOTT CITY, MARYLAND, 30 JULY 2016

On 30 July 2016, the three-hour rainfall totals exceeding 6-inches of rain caused devastating flash flooding in Ellicott City, Maryland, that claimed two lives and the destruction of the historic Old Town (http://www.weather.gov/lwx/EllicottCityFlood2016). The rarity of this event is illustrated in the figures below. Figure 9 shows how the maximum observed rainfall amounts compared to corresponding rainfall frequency estimates for AEPs up to 1/1000 (0.1%) for durations from 5 minutes to 6 hours for a rain gauge in Maryland - ELYM2 Ellicott City (39.27333°N, 76.80444°W). The rain gauge is part of the Hydrometeorological Automated Data System (HADS). The AEPs are estimates from NOAA Atlas 14 Volume 2. As can be seen from Figure 9, observed rainfall amounts have probabilities of less than or equal to 1/1000 for durations up to 3 hours.

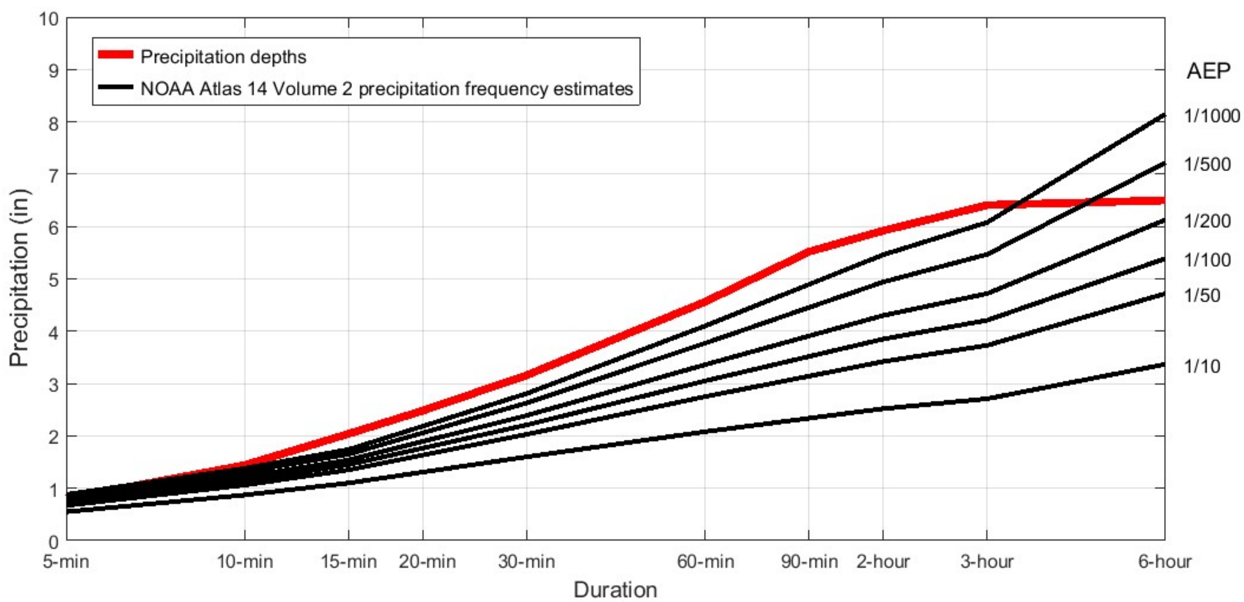

Figure 9. Maximum observed rainfall amounts in relationship to the corresponding rainfall frequency estimates for the ELYM2 gauge.

The map in Figure 10 shows the areas that experienced 3-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%). Rainfall frequency estimates are from NOAA Atlas 14 Volume 2. Rainfall amounts were derived from the National Centers for Environmental Prediction, Environmental Modeling Center's Stage IV analysis. The resolution of the Stage IV estimates (~4km) is unable to capture the rarest localized precipitation values, such as seen from the ELYM2 gauge in Figure 9. The Stage IV pixel that includes the ELYM2 gauge has a 3-hour rainfall amount of approximately 5.3 inches in contrast to the gauge measurement of 6.41 inches. To account for the local underestimation of the Stage IV product, Stage IV rainfall values in the area were scaled by the 6.41/5.3 ratio. The resulting AEP map is shown in Figure 10 and available for download from the following page:
http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/AEP_Ellicott_City_July2016.pdf

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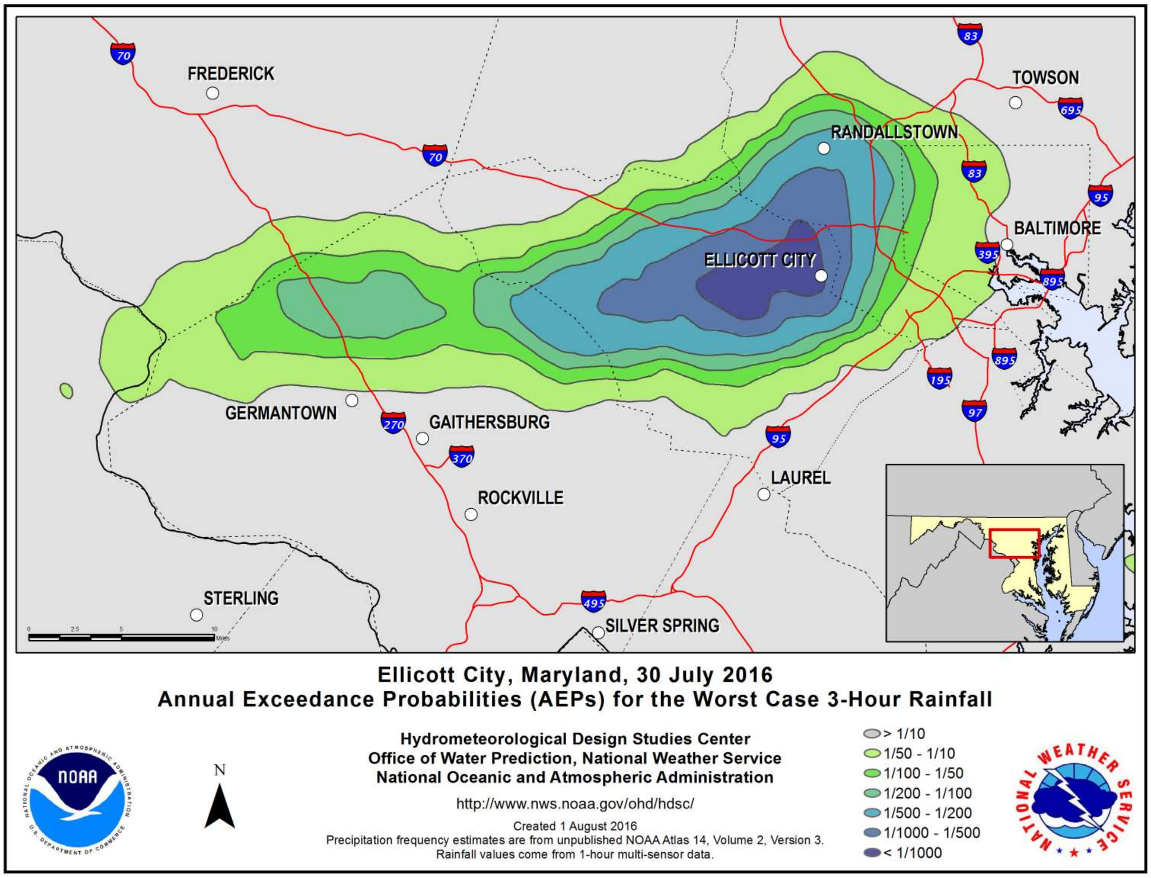

Figure 10. Annual exceedance probability for the worst case 3-hour rainfall for the 30 July, 2016, Ellicott City, Maryland event.

2.3 LOUISIANA, 11-13 AUGUST 2016

The August 2016 storm event in the southern part of the state of Louisiana caused devastating flooding that took at least thirteen lives and caused destruction to public and private properties (https://www.climate.gov/news-features/event-tracker/august-2016-extreme-rain-and-floods-along-gulf-coast). As a result, the state of Louisiana declared a state of emergency.

The HDSC analyzed annual exceedance probabilities (AEPs) for this storm. Figures 11 and 12 show the rarity of this event. Figure 11 shows how the maximum observed rainfall amounts at a station compare to corresponding rainfall (precipitation) frequency estimates for AEPs up to 1/1000 (0.1%) for durations from 1 hour to 60 days. The station data was recorded at the Hydrometeorological Automated Data System’s rain gauge in Louisiana: WBHL1, White Bayou at Highway 64 Near Zachary 2SE (30.6361°N, 91.1272°W). The upper confidence limit for the 1/1000 AEP is also shown in the figure to illustrate the uncertainty associated with the AEP calculation. As can be seen from Figure 11, observed rainfall amounts at this location have probabilities less than or equal to 1/1000 for daily durations up to 20 days.

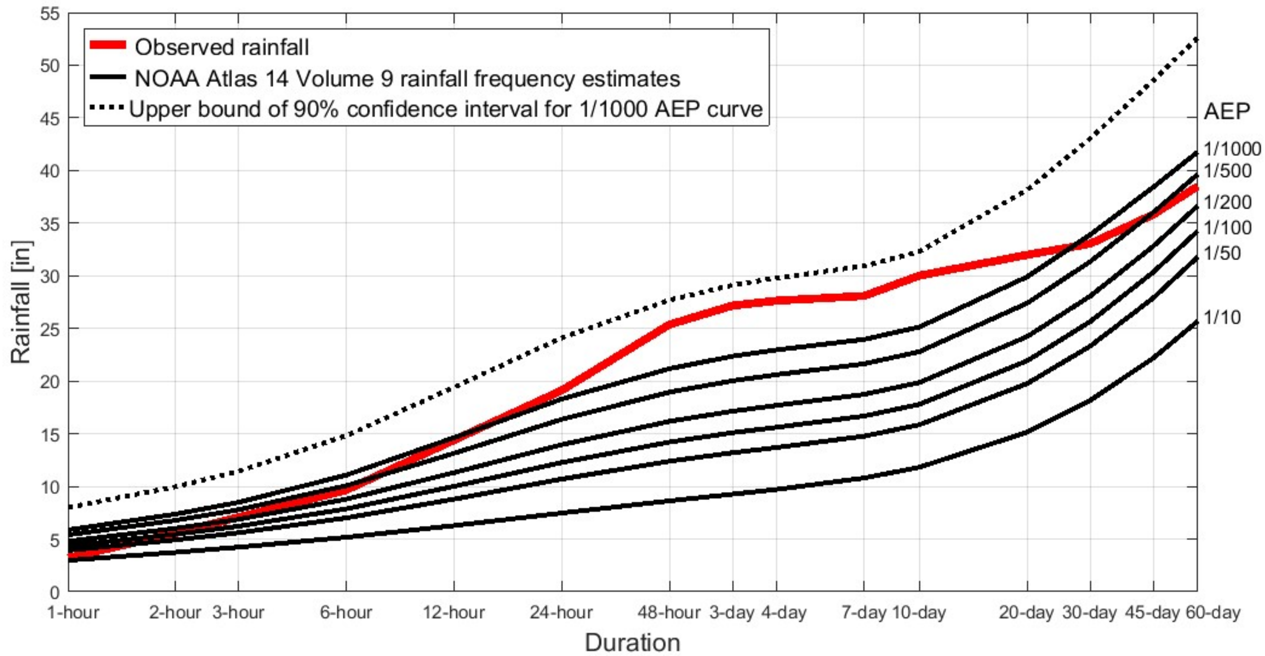

Figure 11. Maximum observed rainfall amounts in relation to the corresponding rainfall frequency estimates for the WBHL1 gauge

The map in Figure 12 shows the worst case 48-hour rainfall in inches. The map in Figure 13 shows the areas that experienced the maximum 48-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%). The maximum 48-hour rainfall amounts were derived from the National Centers for Environmental Prediction, Environmental Modeling Center's Stage IV analysis dataset. Stage IV data is a mosaicked product of regional hourly and 6-hourly multi-sensor (radar + gauges) precipitation estimates produced by the National Weather Service's River Forecast Centers. 6-hourly rainfall grids were aggregated to overlapping 48-hour periods, and the maximum amount of rainfall was extracted for each grid cell inside the area of interest. The maximum 48-hour rainfall grid was then converted to an AEP map by comparing the values to 30 arc-seconds gridded NOAA Atlas 14 Volume 9 rainfall frequency estimates. This analysis is also available for download from the following page: http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/AEP_Louisiana_August2016.pdf

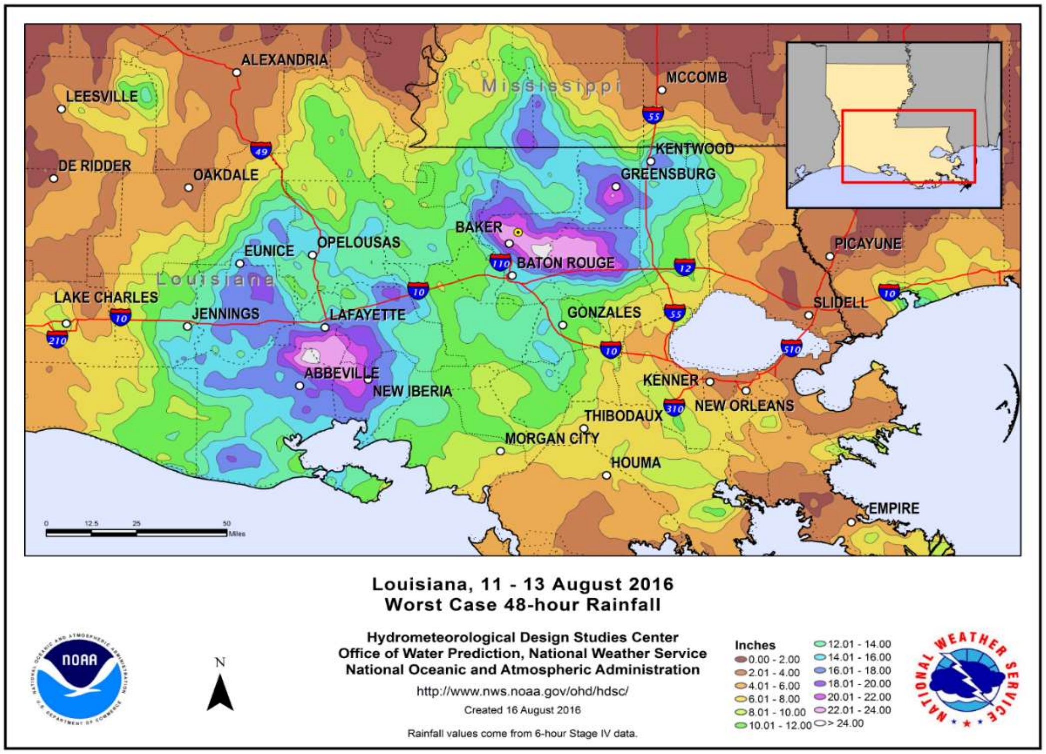

Figure 12. The worst case 48-hour rainfall in units of inches for the 11-13 August 2016, Louisiana event.

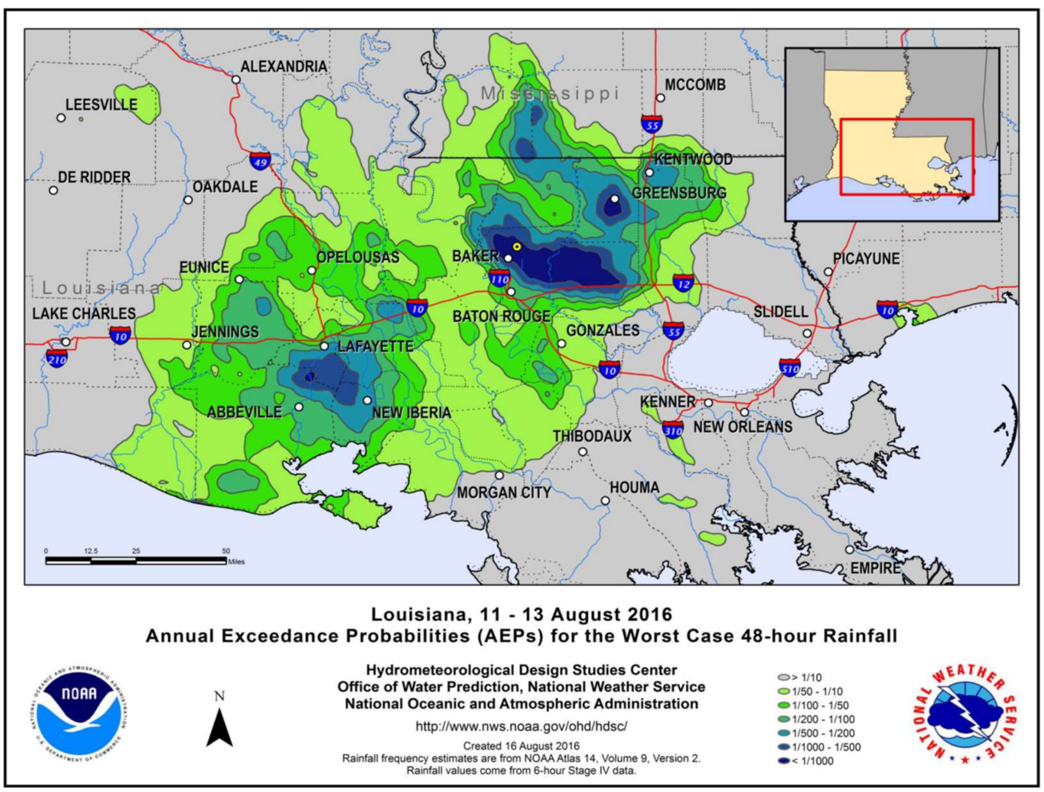

Figure 13. Annual exceedance probabilities for the worst case 48-hour rainfall for the 11-13 August 2016, Louisiana event.

2.4 NORTHERN WISCONSIN, 11 JULY 2016

On July 11, 2016, the 6-hour rainfall totals exceeded 7 inches of rain in Northern Wisconsin, causing devastating flooding that resulted in the loss of human life and devastation of private and public property, and infrastructure. A state of emergency was declared as a result of this storm event (http://www.nbcnews.com/news/us-news/emergency-declared-after-storms-cause-deadly-wisconsin-floods-n608291). HDSC analyzed annual exceedance probabilities (AEPs) for this storm and concluded that the 6-hour period showed the lowest exceedance probabilities for the largest area. The map in Figure 14 shows the areas that experienced the maximum 6-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%).

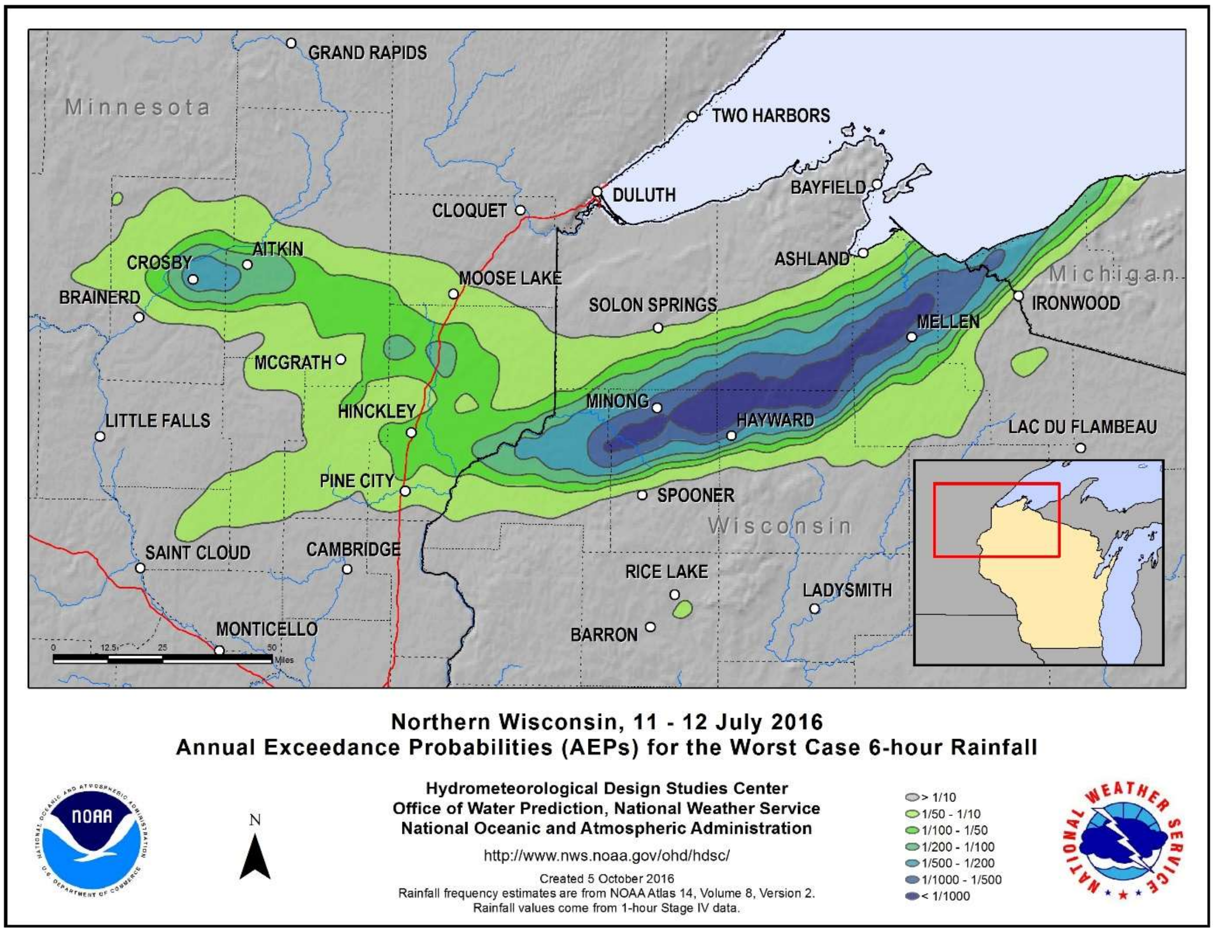

Figure 14. Annual exceedance probabilities for the worst case 6-hour rainfall for the 11-12 July, 2016, Northern Wisconsin event.