# HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
# QUARTERLY PROGRESS REPORT

1 January to 31 March 2017

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

April 2017

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) 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, accompanied by additional relevant information 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 AZ, NV, NM, UT (Volume 1, 2004), DC, DE, IL, IN, KY, MD, NC, NJ, OH, PA, SC, TN, VA, WV (Volume 2, 2004), PR and U.S. Virgin Islands (Volume 3, 2006), HI (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), CA (Volume 6, 2011), AK (Volume 7, 2011), CO, IA, KS, MI, MN, MO, ND, NE, OK, SD, WI (Volume 8, 2013), AL, AR, FL, GA, LA, MS (Volume 9, 2013), and CT, MA, ME, NH, NY, RI, VT (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. 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: ID, MT, OR, WA, WY in Volume 12. For any inquiries regarding the status of this effort, please send an email to HDSC.questions@noaa.gov.

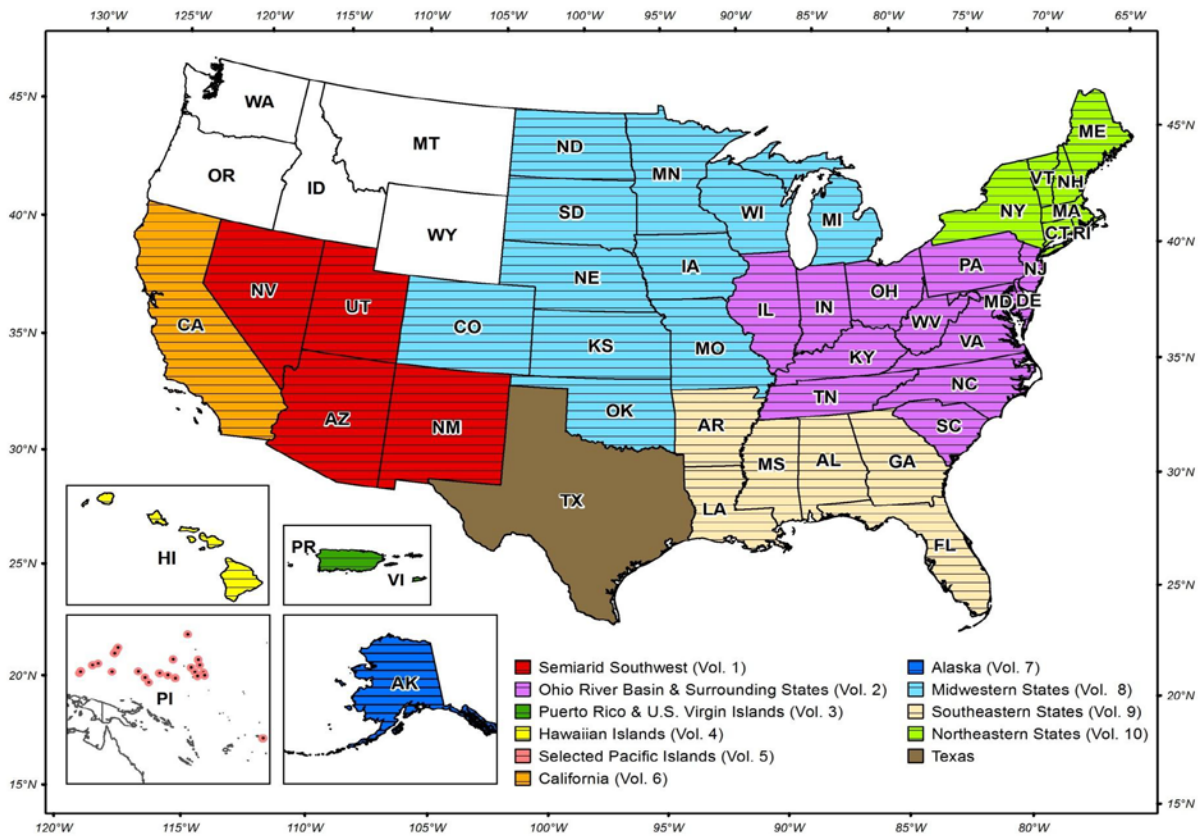



*Figure 1. Current project area for Volume 11 (TX) and project areas included in published Volumes 1 to 10.*

# II. CURRENT PROJECTS

## 1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

### 1.1 PROGRESS IN THIS REPORTING PERIOD (Jan - March 2017)

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).

During this reporting period, we worked on the documentation describing station metadata, data, and project methodology. Work has been put on hold temporarily while some funding issues are resolved.

### 1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (April - Jun 2017)

We expect that the work on documentation will resume soon and that we will release the NOAA Atlas 14 Volume 10 document by the end of the next reporting period. We will publish the document on the PF Documents page.

### 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, and development of PFDS web pages) [Complete]

Web publication of estimates [Complete]

Web publication of Volume 10 document [June 2017]

# 2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS

## 2.1 PROGRESS IN THIS REPORTING PERIOD (Jan - March 2017)

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).

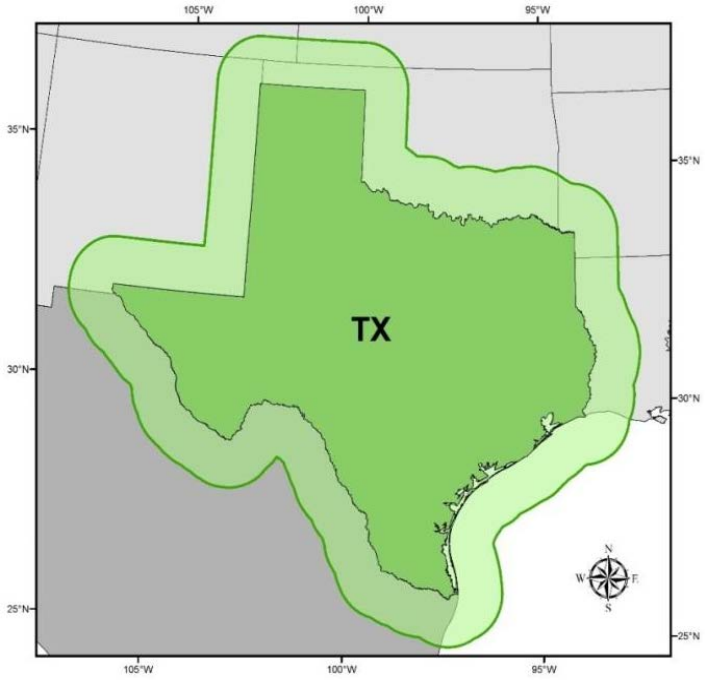



*Figure 2. NOAA Atlas 14, Volume 11 extended project area.*

During this reporting period we collected and re-formatted additional datasets and completed related station screening and quality control tasks. We also continued with data digitization and started work on the following tasks: conversion of constrained observations (e.g., 1-day) to unconstrained values (e.g., 24-hour), spatial analysis of 1-day mean annual maxima and regionalization. The individual sections below 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). In addition to the NCEI's data, we gathered precipitation data collected by other Federal, State and local agencies 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 and would like to thank all of those who responded to our inquiry and/or provided the data.

During this reporting period, we finished reviewing and re-formatting all the information provided to us. All data was formatted to a common format at one of three base durations (1-day,

1-hour, and 15-minute) that corresponds to the original reporting period. Data recorded at n-minute or at variable time steps were formatted at 15-minute increments. Each formatted station was assigned a unique 6-digit identification number (ID), where the first 2 digits of the ID indicate the dataset. We have formatted and retained data for 10,310 stations from 34 datasets listed in Table 1. The total number of formatted stations per recording period is listed in Table 2.

*Table 1. List of formatted datasets.*

| Source of data: dataset/network name | ID (first 2 digits) | Recording period |
|---|---|---|
| NCEI: Automated Surface Observing System (ASOS) | 78 | 1-min |
| NCEI: DSI 3260 | 03,05,14,16, 29,34,41 | 15-min |
| NCEI: DSI 3240 | 03,05,14,16, 29,34,41 | 1-hr |
| NCEI: Global Historical Climatology Network (GHCN) | 03,05,14,16,29, 34,41,69,79,90 | 1-day |
| NCEI: Integrated Surface Data (Lite) | 64 | 1-hr, 1-day |
| NCEI: Quality Controlled Local Climatological Data (QCLCD) | 56 | 1-hr |
| NCEI: Unedited Local Climatological Data (ULCD) | 55 | 1-hr |
| City of Austin ALERT Network | 65 | varying |
| City of Dallas ALERT Network | 81 | varying |
| Edwards Aquifer Authority | 62 | 1-hr |
| Guadalupe-Blanco River Authority | 77 | 6-min |
| Harris County Flood Control District's Flood Warning System | 60 | varying |
| Jefferson County Drainage District 6 ALERT Precipitation and Stream Level Network | 82 | varying |
| Lower Colorado River Authority Regional Meteorological Network | 63 | varying |
| Midwestern Regional Climate Center: CDMP 19th Century Forts and Voluntary Observers Database | 52 | 1-day |
| National Atmospheric Deposition Program (NADP) | 54 | 1-day |
| National Estuarine Research Reserve System (NERRS) | 57 | 15-min, 1-hr |
| NWS Hydrometeorological Automated Data System | 85 | 1-hr |
| Oklahoma Mesonet Observation Network | 86 | 5-min, 1-day |
| San Antonio River Authority | 91 | varying |
| Sabine River Authority Precipitation Dataset | 58 | 1-day |
| Servicio Meteorologico Nacional, Mexico | 61 | 1-day |
| Tarrant Regional Water District (Greater Fort Worth area)/ Tarrant County Urban Flood Control Network | 83 | 15-min, 1-hr |
| Texas Commission on Env. Quality: Air Quality Network | 75 | 1-hr |
| Texas Evapotranspiration Network | 89 | 1-hr, 1-day |
| Texas Water Development Board (TWDB) | 84 | 1-hr, 1-day |
| Titus County Fresh Water Supply District No. 1 | 53 | 1-day |
| U.S. Bureau of Reclamation: HydroMet | 87 | 1-hr, 1-day |
| US Dept. of Agriculture (USDA): Agricultural Research Service (ARS) | 94 | varying |
| USDA, Forest Service: Remote Automated Weather Station (RAWS) Network | 76 | 1-hr |
| USDA , National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN) | 88 | 1-hr |
| USGS Nation Water Information System (NWIS) | 59 | 15-min |
| USGS Hydrologic Data for Urban Studies in Texas | 66 | 1-day |
| West Texas Mesonet | 80 | 1-min, 15-min |

*Table 2. Number of stations retained for further analysis per recording period.*

| Recording period | Number of stations |
|---|---|
| 1-day | 5,873 |
| 1-hr | 3,067 |
| 15-min, n-min, varying | 1,370 |
| **TOTAL** | **10,310** |

Table 3 contains information on additional datasets that will not be used in the analysis. They largely contain information already included in other datasets, or data assessed as not reliable for this specific purpose, or they contain only stations with short records unsuitable for merging with nearby stations.

*Table 3. Additional datasets investigated.*

| Source of data and dataset/network name (if available) |
|---|
| Bexar County Urban Flood Control Network |
| Meteorological Assimilation Data Ingest System (MADIS) |
| Mexico Hourly Data downloaded from Iowa IEM |
| 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 |

Locations of formatted daily stations are shown in Figure 3. Only stations with at least 30 years of useful 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, were used in various quality control tasks. Similarly, Figures 4 and 5 show locations of formatted stations recording at 1-hour and at sub-hourly durations, respectively, where stations with less than 20 years of useful data are shown as black dots.

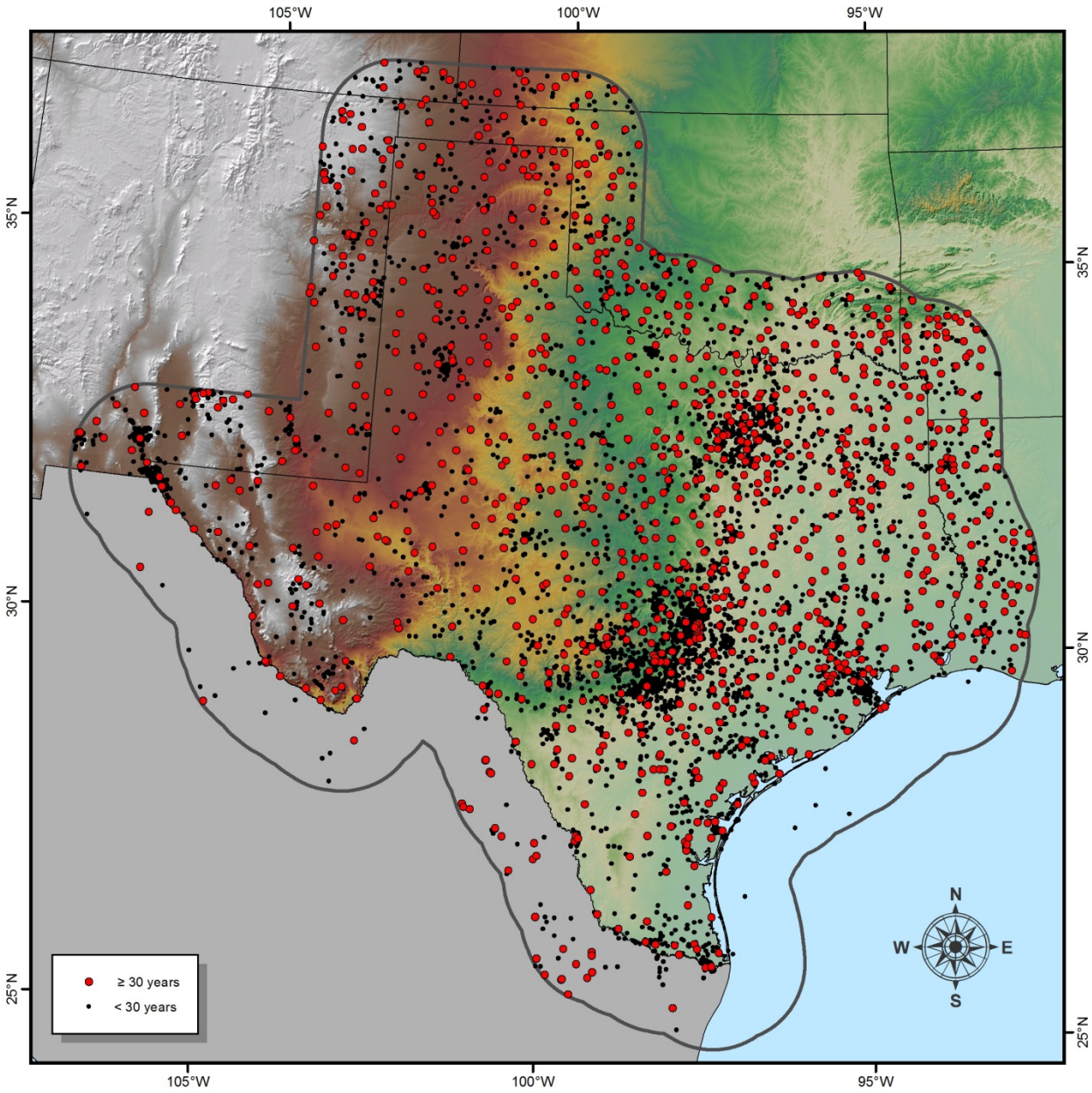



*Figure 3. Map showing 5,873 formatted stations recording at 1-day interval. Only 1,074 of those stations (shown as red circles) will be considered in frequency analysis for durations between 1 day and 60 days.*

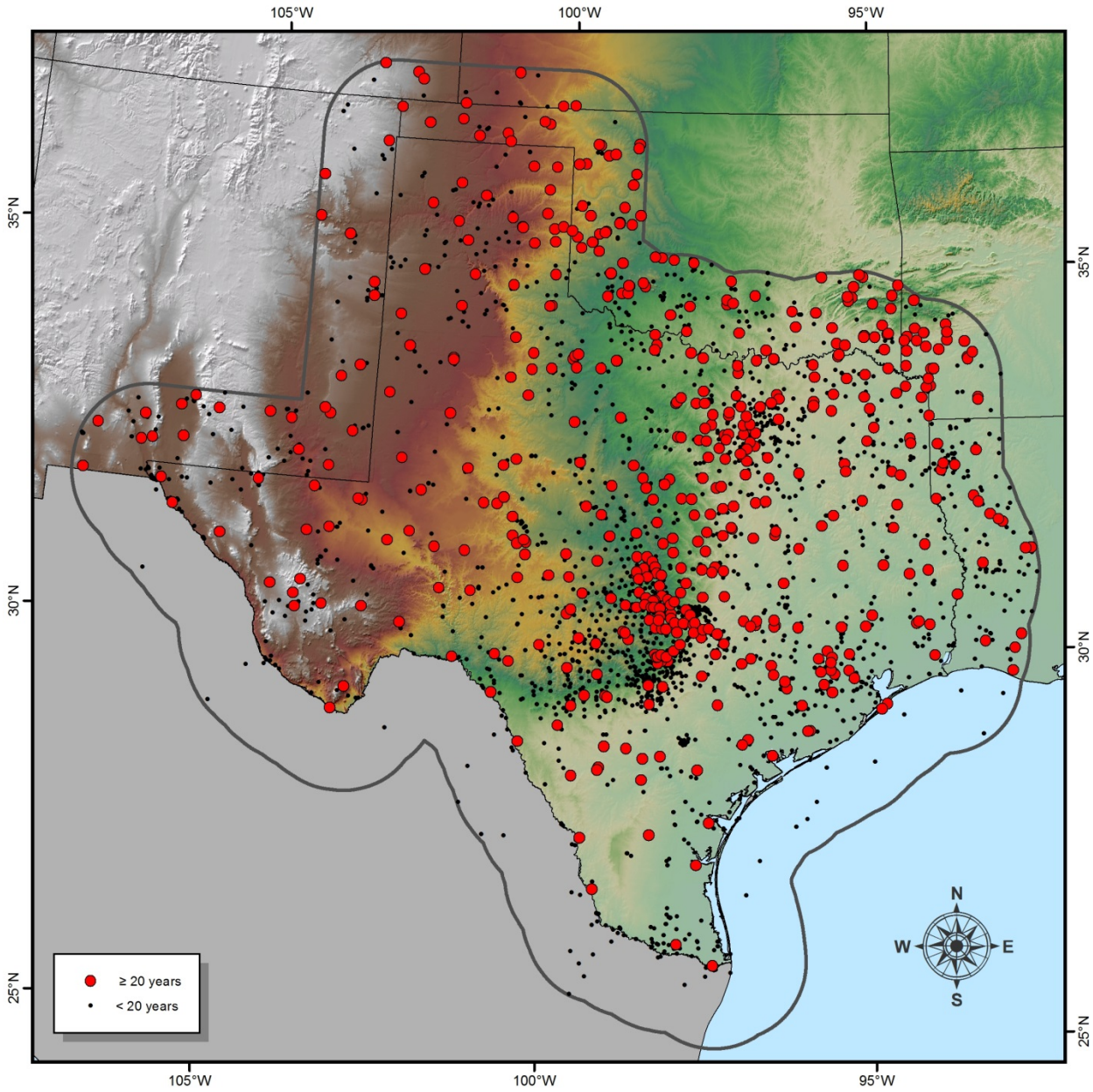



*Figure 4. 3,067 formatted stations recording at 1-hour interval. Only 541 stations shown as red circles will be considered in frequency analysis for durations between 1 hour and 60 days.*

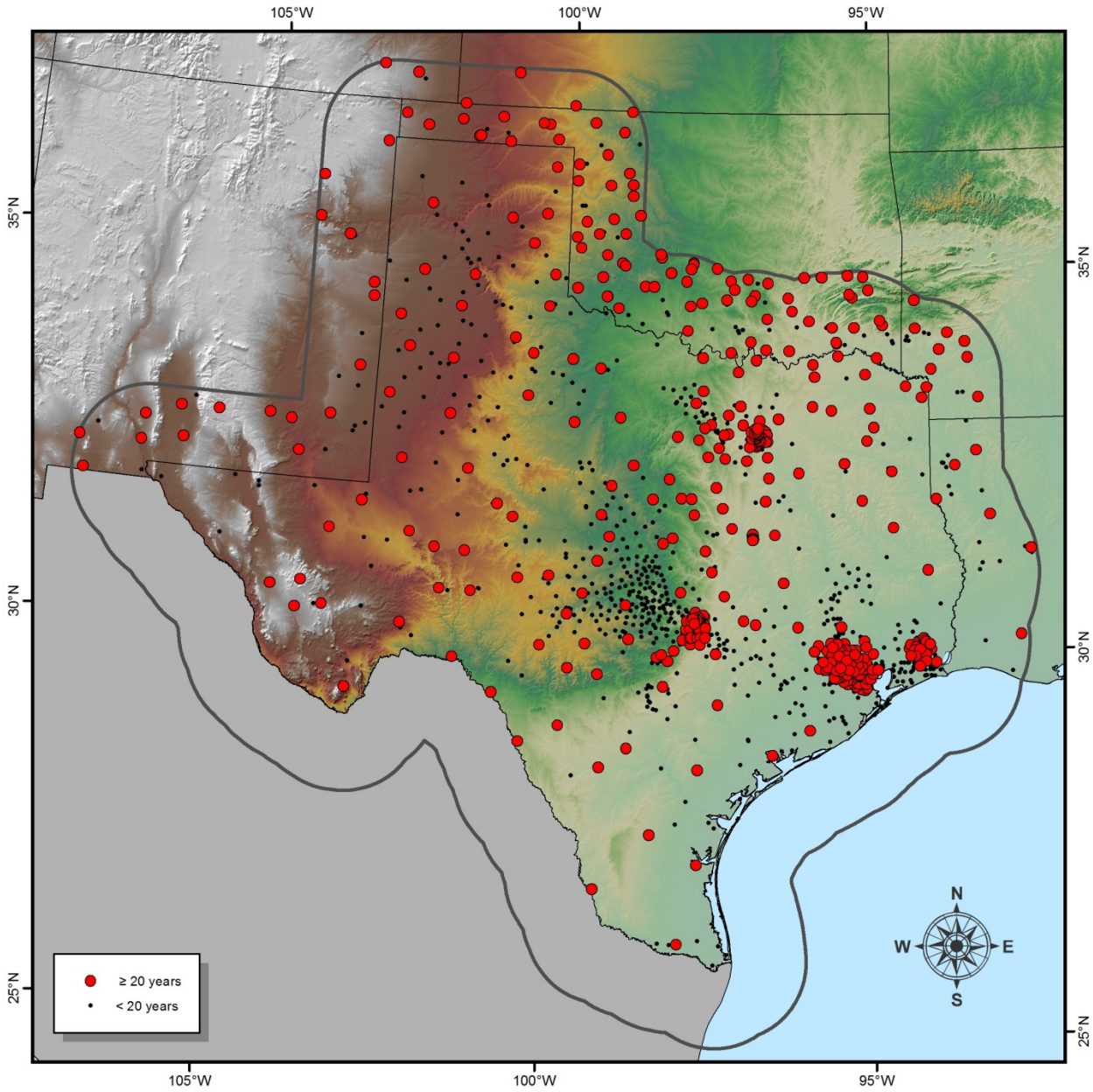



*Figure 5. 1,370 formatted stations recording at sub-hourly intervals. Only 491 of those stations (shown as red circles) will be considered in frequency analysis for durations between 15 minutes and 60 days.*

### 2.1.2. Data digitization

In this reporting period, we continued to digitize precipitation data from the NCEI's Climate Database Modernization Program archive. We have focused mostly on extending records for hourly stations in urban areas and for hourly and daily stations in data scarce areas, as well as adding missing information for essential locations. A summary of the work completed so far with the stations' names, recording intervals and periods of record digitized is shown in Table 4.

*Table 4. Status of digitization work.*

| Station name | Recording interval | Period digitized |
|---|---|---|
| Abilene | 1-hour | 1906-1940 |
| Amarillo | 1-hour | 1904 -1940 |
| Brackettville/Fort Clark | 1-day | 1853-1899 |
| Corpus Christi | 1-hour | 1902-1940 |
| Cotulla | 1-day | 1902-2002 |
| El Paso | 1-hour | 1906-1940 |
| Fort Brown/Brownsville | 1-day | 1849-1900 |
| Fort Worth | 1-hour | 1903-1940 |
| Galveston | 1-hour | 1892-1940 |
| Hearne/Valley Junction | 1-day | 1888-1946 |
| Houston | 1-hour | 1910-1940 |
| Houston | 1-day | 1888-1909 |
| San Antonio | 1-hour | 1903-1940 |
| Taylor | 1-hour | 1903-1932 |

### 2.1.3. Quality control of metadata and station cleanup

We screened the basic metadata (latitude, longitude and elevation) for stations formatted in this period and made corrections where appropriate. The original and revised coordinates and elevations will be provided in Appendix 1 of the NOAA Atlas 14, Volume 11 document.

The station cleanup and merges were re-evaluated for all formatted stations. During this task we performed the following:

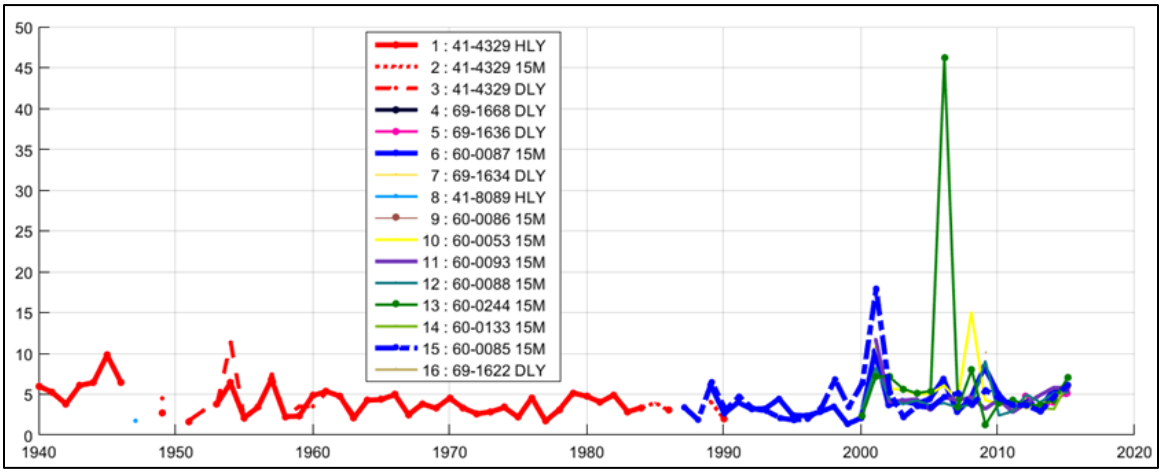
- screening for duplicate records at collocated stations,
- extending records at longer-duration stations using data from collocated stations,
- screening for duplicate stations from different datasets,
- screening nearby stations for potential merging to increase record lengths,
- removing shorter, less reliable records in station-dense areas.

Figure 6 shows an example of a station cleanup task done for the NCEI's station 41-4329 that has 3 collocated gauges: 15-min, hourly, and daily. 13 nearby stations from different datasets located within a 3.5-mile radius were also considered for this task (see table at the bottom of the figure). During this cleanup, we deleted all nearby stations except the two long record 15-min gauges from the Harris County Flood Control District's Flood Warning System (60-0085 and 60-0087). Deleted stations had short records in the station-dense area, were not candidates for merging, or had data quality issues.

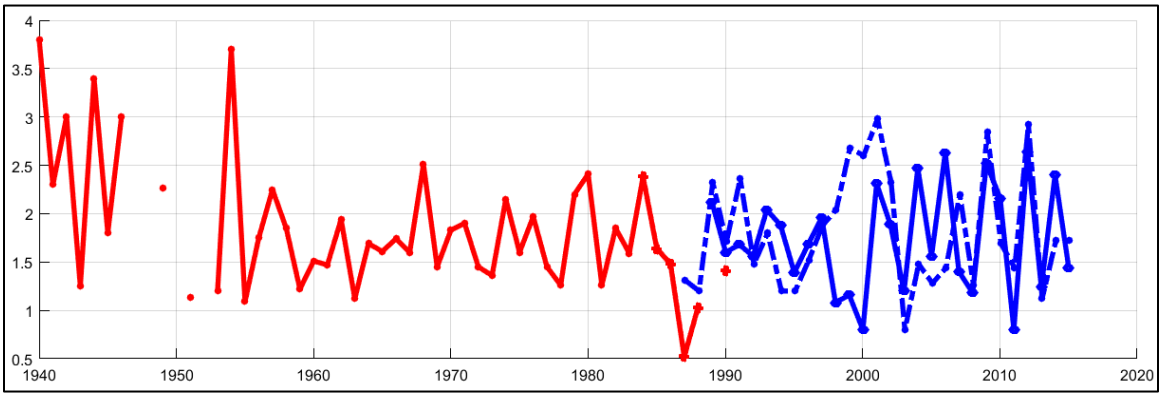
1992-2016 data from 15-minute station 60-0087 (at a distance of 1.96 miles) was used to extend records of all three collocated gauges 41-4329. The 1987 low annual maximum value for hourly station 41-4329 (Figure 6 in the middle) prompted further investigation that showed numerous multi-hour accumulations during 1987-1990. As a result, data from 60-0087 were used for that period as well. Further inspection of merged time series at longer durations indicated that records for station 60-0087 during 1998-2000 may be too low. For example, the station recorded only 2.75 inches during the Tropical Storm Frances in September 1998, when 7-12 inches occurred over a large area of Houston and was adequately measured by 60-0085. To account

for this deficiency, data from station 60-0085 were used for those 3 years. At the end, station 41-4329 had 31 years of data at sub-hourly durations and 70 years for longer durations.

a) 1-day AMS




b) 1-hour AMS




c) Basic information on nearby stations

| i | Station ID | Type | Station name | POR | Distance (mi) | Elev (ft) | Diff (ft) | 1-day MAM (in) | Diff (in) | nyr |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **41-4329** | **HLY** | **HOUSTON SATSUMA** | **1940-1991** | **0.00** | **122** | **( 0)** | **4.04** | **( +0.00)** | **43** |
| **2** | **41-4329** | **15M** | **HOUSTON SATSUMA** | **1984-1990** | **0.00** | **122** | **( 0)** | **3.31** | **( -0.73)** | **5** |
| **3** | **41-4329** | **DLY** | **HOUSTON SATSUMA** | **1940-1991** | **0.00** | **121** | **( -1)** | **4.18** | **( +0.14)** | **44** |
| 4 | 69-1668 | DLY | JERSEY VILLAGE 4.6 NW | 2013-2016 | 0.45 | 131 | ( 9) | 5.13 | ( +1.09) | 1 |
| 5 | 69-1636 | DLY | CYPRESS 3.2 ESE | 2010-2016 | 1.78 | 138 | ( 16) | 4.30 | ( +0.26) | 4 |
| **6** | **60-0087** | **15M** | **CYPRESS CK AT HUFFMEISTER RD** | **1988-2016** | **1.96** | **128** | **( 6)** | **4.22** | **( +0.18)** | **27** |
| 7 | 69-1634 | DLY | CYPRESS 3.4 E | 2010-2013 | 2.29 | 141 | ( 19) | 3.89 | ( -0.14) | 2 |
| 8 | 41-8089 | HLY | SATSUMA | 1947-1948 | 2.51 | 112 | ( -10) | 1.75 | ( -2.29) | 1 |
| 9 | 60-0086 | 15M | CYPRESS CK AT ELDRIDGE PKWY N | 2014-2016 | 2.89 | 132 | ( 10) | 5.96 | ( +1.92) | 1 |
| 10 | 60-0053 | 15M | WHITE OAK BYU AT JONES RD | 2001-2016 | 3.11 | 115 | ( -7) | 5.83 | ( +1.79) | 15 |
| 11 | 60-0093 | 15M | LITTLE CYPRESS CK AT KLUGE RD | 2001-2016 | 3.14 | 132 | ( 10) | 4.79 | ( +0.75) | 15 |
| 12 | 60-0088 | 15M | CYPRESS CK AT US 290 | 1999-2016 | 3.14 | 134 | ( 12) | 4.51 | ( +0.47) | 16 |
| 13 | 60-0244 | 15M | US 290 @ W RD HOV PARK & RIDE | 2000-2016 | 3.27 | 116 | ( -6) | 7.41 | ( +3.37) | 16 |
| 14 | 60-0133 | 15M | HORSEPEN CK AT TRAILSIDE DR | 2012-2016 | 3.42 | 104 | ( -18) | 4.29 | ( +0.25) | 3 |
| **15** | **60-0085** | **15M** | **CYPRESS CK AT GRANT RD** | **1986-2016** | **3.47** | **116** | **( -6)** | **4.43** | **( +0.39)** | **29** |
| 16 | 69-1622 | DLY | JERSEY VILLAGE 6.2 W | 2009-2012 | 3.58 | 138 | ( -16) | 10.13 | ( +6.09) | 1 |

*Figure 6. Station cleanup and merge task for collocated NCEI's station 41-4329.*

### 2.1.4. Annual maximum series (AMS) extraction and quality control

We extracted the AMS for stations formatted in this reporting period. The AMS were extracted for all durations equal to or longer than the base duration (or reporting interval) up to 60 days. AMS data identified as questionable were carefully investigated and either corrected or removed from the AMS if due to measurement errors. For more information on the AMS extraction and quality control, see for example Section 4.5 of NOAA Atlas 14 Volume 9 document.

### 2.1.5. Correction for constrained observations

We began developing factors to convert constrained observations (e.g., 1-day) to unconstrained values (e.g., 24-hour). Quality-controlled, concurrent constrained and unconstrained annual maxima from hourly stations will be used in a zero-intercept regression model to develop correction factors for daily durations, while collocated hourly (constrained) and n-minute/15-minute (unconstrained) concurrent annual maxima will be used to develop correction factors for hourly durations.

### 2.1.6. Spatial analysis of mean annual maximum (MAM) data

During this reporting period, we began spatial analysis of at-station MAM estimates for 1-day duration. MAM for each station is reviewed for inconsistencies relative to MAMs at nearby stations. The goal is to identify locations where MAMs are affected by short periods of record or missed extreme amounts. Flagged MAMs will be investigated and either adjusted or removed from the analysis.

### 2.1.7. Regionalization

Regional approaches to frequency analysis use data from stations that are expected to have similar frequency distributions to yield more accurate estimates of extreme quantiles than approaches that use only data from a single station. The region of influence approach used in this volume defines regions such that each station has its own region with a potentially unique combination of nearby stations.

During this reporting period, we began work on the regionalization task. Initial regions for each station are formed by grouping the closest 20 stations. Each region is then revised based on examination of stations' distances from a target station, elevation differences, inspection of their locations with respect to mountain ridges, and assessment of similarities/dissimilarities in the progression of relevant L-moment statistics across durations. During this process, some inconsistent stations will be removed from the analysis, particularly in dense network areas where nearby stations have much longer records.

## 2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (April - June 2017)

In the next reporting period we will complete analysis of spatial patterns in mean annual maxima. We will send 15-minute, 1-hour, 1-day and 10-day MAMs estimated at gaged locations to Oregon State University's PRISM Climate Group for high-resolution spatial interpolation using their hybrid statistical-geographical approach for mapping climate data. This task typically requires several iterations. Also, we will continue work on regionalization and derivation of depth-duration-frequency curves at gauged locations. We will continue work on digitization tasks and finish various quality control and data reliability tests as needed.

## 2.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [Done, but 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; April 2017]

Regionalization and frequency analysis [In progress; June 2017]

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

Peer review [September 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 of data [May 2018]

Web publication of documentation [May 2018]

# III. OTHER

## 1. PRECIPITATION FREQUENCY DATA SERVER ENHANCEMENTS

We continue to make enhancements to all Precipitation Frequency Data Server (PFDS) pages. During this period, major revision was done for the Storm Analysis page.

We developed the NOAA Atlas 14 CONUS product that combines NOAA Atlas 14 precipitation frequency estimates for durations between 60 minutes and 7 days and annual exceedance probabilities down to 1/1000 (or average recurrence intervals up to 1000 years) for every contiguous U.S. state except ID, MT, OR, TX, WA and WY, for which no NOAA Atlas 14 estimates are available. The NOAA Atlas 14 CONUS product is in a NetCDF format and is available for download from the Unidata Program Center's THREDDS Data Server using the following link: NOAA_Atlas_14_CONUS.nc. Additional information on how to read, extract and manipulate this data using remote data access protocols such as the Open-source Project for a Network Data Access Protocol (OPeNDAP) is available from the Storm analysis page.

We recommend that this merged product is not used in design as we adjusted estimates along the volumes' boundaries to reduce discrepancies (discrepancies are unavoidable as each volume was completed independently and at a different time; for more information see Section 5 of the NOAA Atlas 14 documents).

## 2. NOAA ATLAS 14 DOCUMENTS

Section 5 of each volume of NOAA Atlas 14 explains in detail how to navigate the PFDS and extract needed information. Since 2004, when the first volume of NOAA Atlas 14 was released, we completely redesigned PFDS pages two times and have been continuously making changes to improve the usability and readability of the PFDS website's content, to increase data download speeds and to provide additional information. In order to keep the PFDS section for all NOAA Atlas 14 documents up-to-date, this section is now offered for download as a separate file: NA14_Sec5_PFDS.pdf.