Maryland Department of the Environment

Introduction to Maryland PMP Update

Scott Bass, P.E.

MDE Dam Safety

Hydrology and Hydraulics

Outline

- PMP Definition
- Computation Methods
- Examples
- State and Basin Specific PMP Studies
- PMP and Maryland

Probable Maximum Precipitation (PMP)

- What is the Probable Maximum Precipitation?

HMR-51, page 2

1.3 Definition of PMP

PMP is defined as "the the
for a given duration that is
area at a certain time of ye
In consideration of our limi
interrelationships in storms

Another definition of PMP
by hydrometeorologists in ar
hydrological design purposes
deemed adequate by competent
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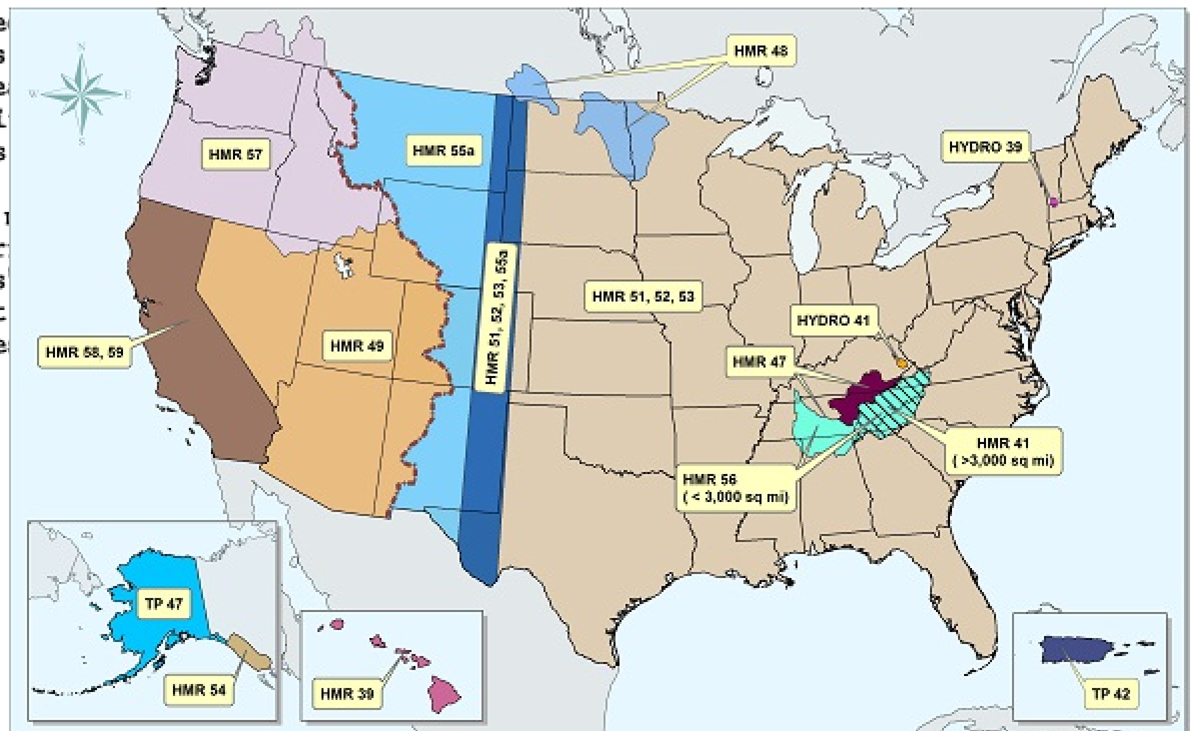


<u>Probable Maximum Precipitation (PMP).</u> Theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of the year.

Design Storms and Hazard Classifications

- Low Hazard
  - 100-year storm
- Significant Hazard
  - ½ Probable Maximum Flood (1/2 PMF)
- High Hazard
  - Probable Maximum Flood (PMF)

PMP vs. PMF

- Probable Maximum Precipitation
  - "Theoretically, the greatest depth of precipitation for a given duration that is physically possible for a given size storm area at a particular geographic location at a certain time of year"
- Probable Maximum Flood
  - The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the drainage basin under study

Hydrometeorological Report No. 51 (HMR-51)

- Depths for various
  - Drainage Area sizes
    - <10 mi²
    - <200 mi²
    - <1,000 mi²
    - < 5,000 mi²
    - < 10,000 mi²
  - Storm Durations
    - 6 hr
    - 12 hr
    - 24 hr
    - 48 hr
    - 72 hr

~27.5" in 6 hours!

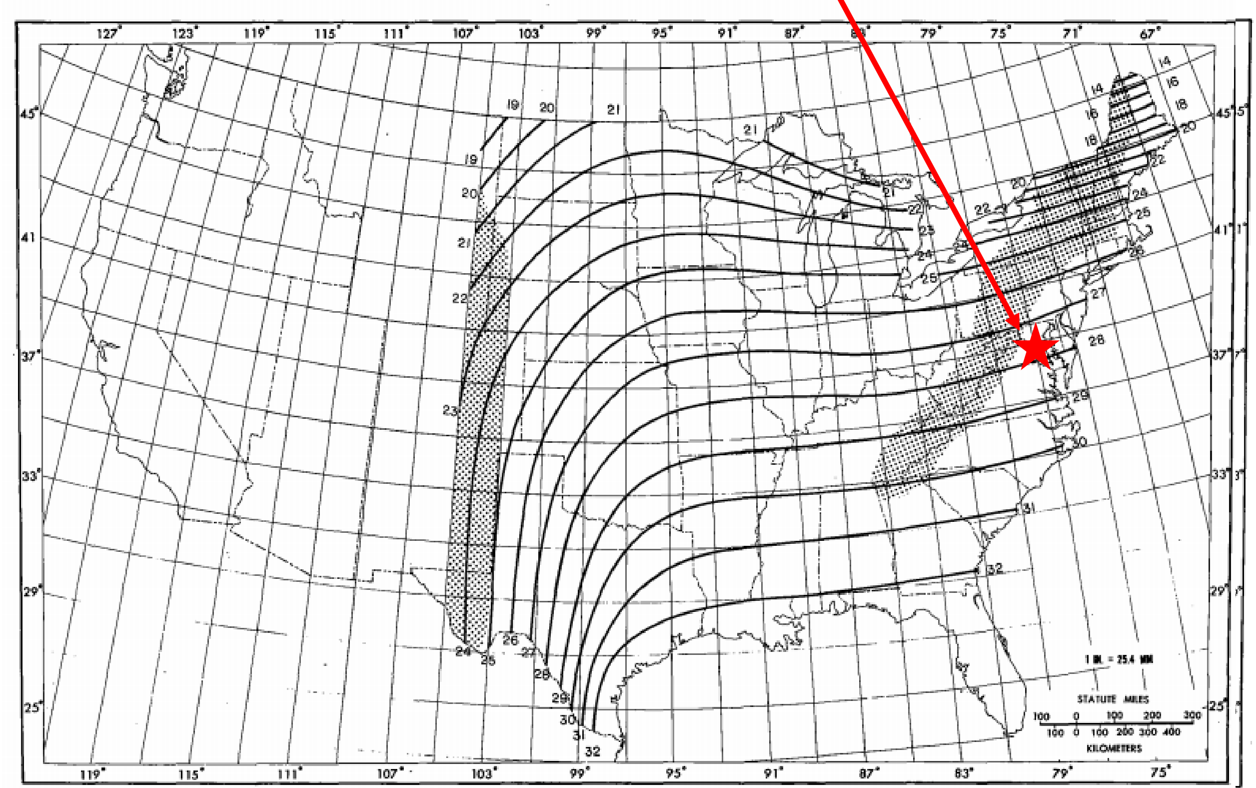
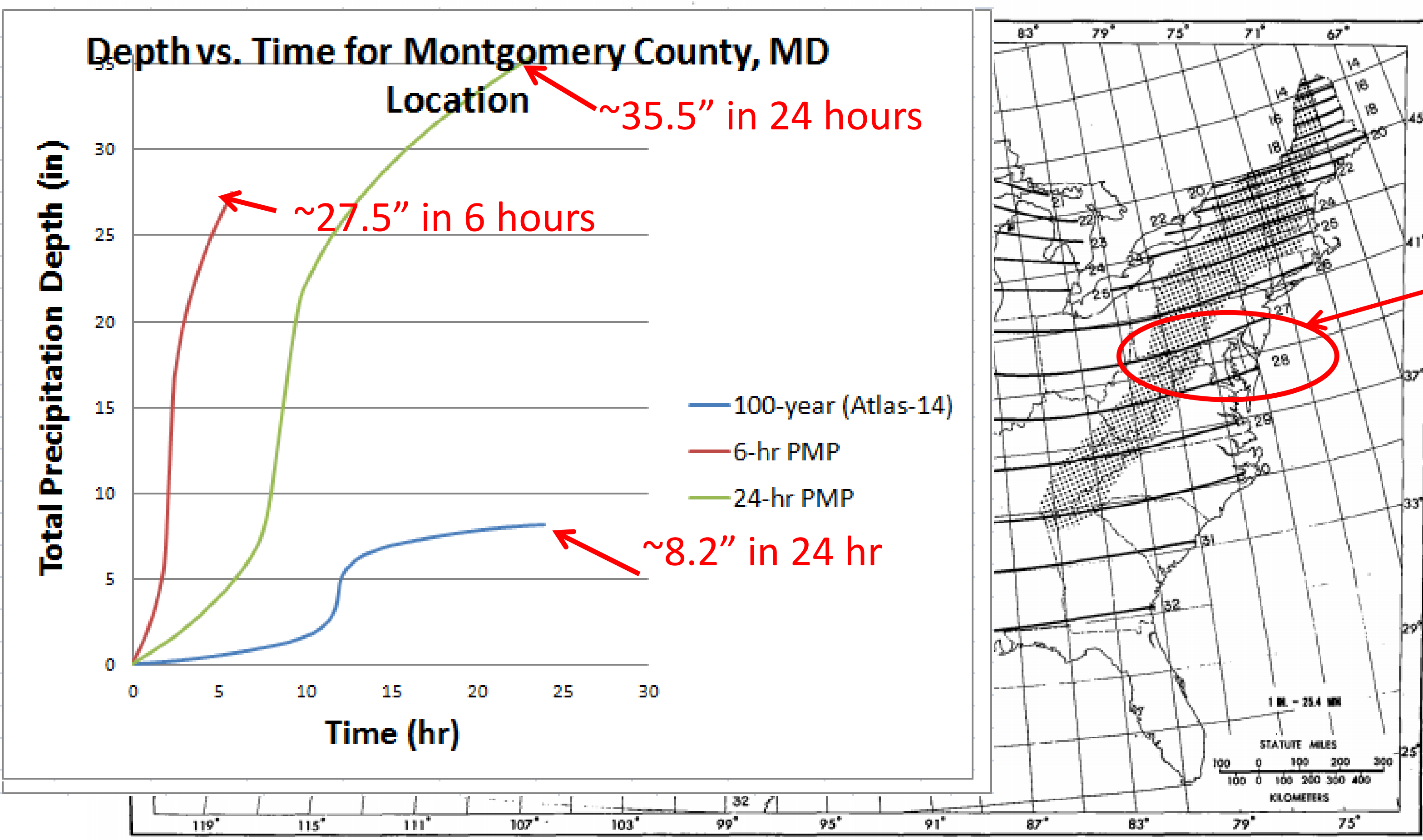


Figure 18.--All-season PMP (in.) for 6 hr 10 mi² (26 km²).

The PMP, continued



Maryland
~27-28.5”
in 6 hours
DA < 10 mi^2

Figure 18.--All-season PMP (in.) for 6 hr 10 mi^2 (26 km^2).

Storms – HMR-51

Storm Index No.	Storm Assignment No.	Date
1	OR 9-19	9/10-13/1878
2	SA 1-1	5/30-6/1/1889
3	MR 4-3	6/4-7/1896
4	UMV 1-2	7/18-22/1897
6	NA 1-7B	7/26-29/1897
7	GM 3-4	6/27-7/1/1899
8	LMV 2-5	4/15-18/1900
11	GL 4-9	10/7-11/1903
13	GL 2-12	6/3-8/1905
14	UMV 2-5	6/9-10/1905
16	MR 5-13	6/6-8/1906
17	GM 3-14	8/4-8/1906
20	SW 1-11	10/19-24/1908
22	UMV 1-11A	7/18-23/1909
26	LMV 3-19	3/24-28/1914
29	GL 2-16	8/31-9/1/1914
31	SA 2-9	7/13-17/1916
33	GM 5-15B	9/15-17/1919
36	MR 4-21	6/17-21/1921
37	GM 4-12	9/8-10/1921
38	MR 4-23	9/27-10/1/1923
42	MR 4-24	9/17-19/1926
44	NA 1-17	11/2-4/1927
47	LMV 2-20	3/11-16/1929
49	SW 5-1	6/30-7/2/1932
50	NA 1-20A	9/16-17/1932
51	NA 1-20B	9/16-17/1932
53	SW 2-11	4/3-4/1934
54	LMV 4-21	5/16-20/1935
55	MR 3-28A	5/30-31/1935
56	- -	5/30-31/1935
57	GM 5-20	5/31/1935
59	NA 1-27	7/6-10/1935
65	- -	6/19-20/1939
67	MR 4-5	6/3-4/1940
68	NA 2-4	9/1/1940
69	SW 2-18	9/2-6/1940
71	UMV 1-22	8/28-31/1941
74	OR 9-23	7/17-18/1942
76	SA 1-28A	10/11-17/1942
77	SW 2-20	5/6-12/1943
78	MR 6-15	6/10-13/1944
80	MR 7-2B	8/12-16/1946
82	- -	6/23-24/1948
85	SA 5-8	9/3-7/1950
86	MR 10-2	7/9-13/1951
87	MR 10-8	6/7/1953
88	SW 3-22	6/23-28/1954
90	OMT 10-54	10/14-15/1954
91	NA 2-22A	8/17-20/1955
93	QUE 8-57	8/3-4/1957
96	SW 3-23	6/13-20/1965
97	SW 3-24	9/19-24/1967
99	NA 2-23	8/19-20/1969
100	NA 2-24A	6/19-23/1972

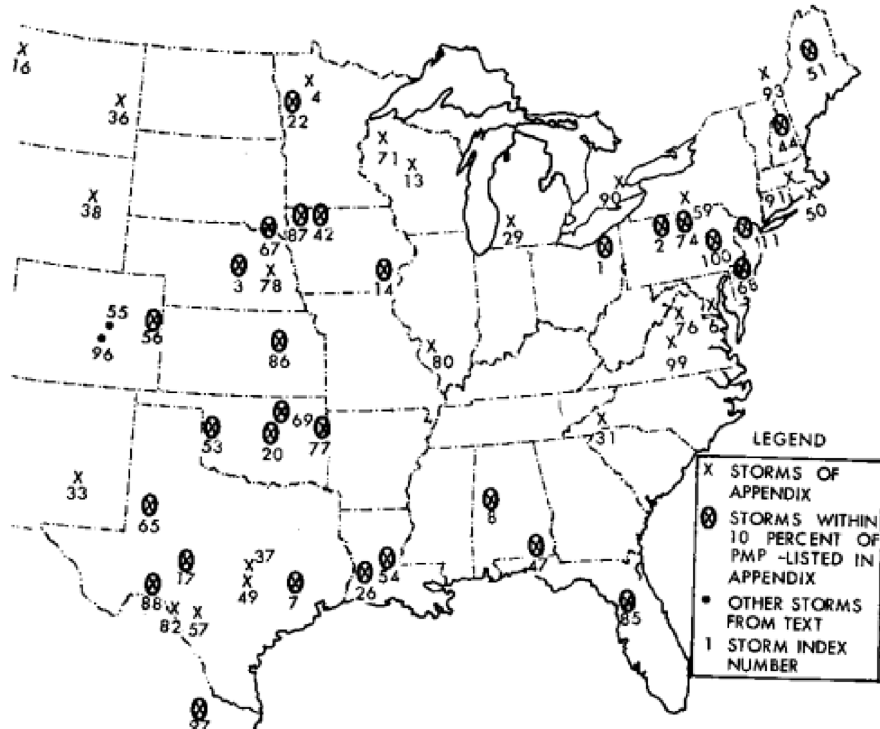


Figure 1.--Location of storms. [Storms of appendix (section 2.2.1), others mentioned in text (sections 2.4.5 and 3.2.3), and those within 10 percent of PMP (section 4.1)]

The “stippled” area

1.4.2 Stippled Regions on PMP Maps

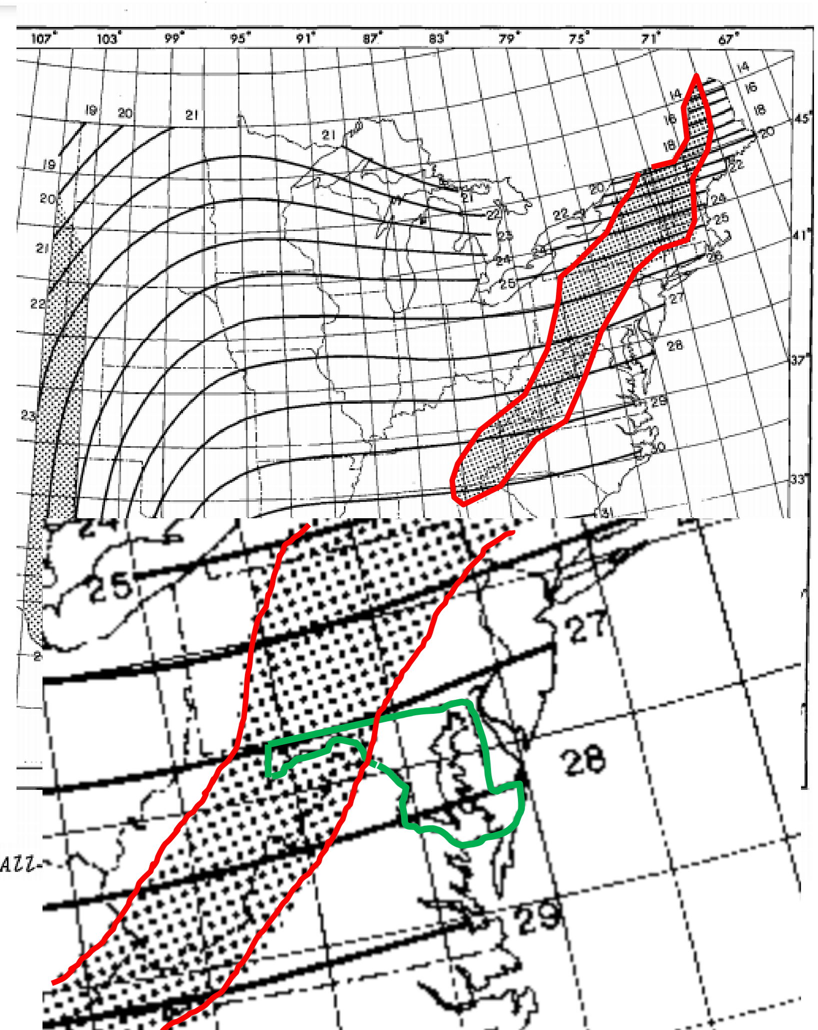
The generalized PMP maps (figs. 18-47) are stippled in two regions, (a) the Appalachian Mountains extending from Georgia to Maine and (b) a strip between the 103rd and 105th meridian. This stippling outlines areas within which the generalized PMP estimates might be deficient because detailed terrain effects have not been evaluated.

In developing the maps of PMP, it was sometimes necessary to transpose storms to and from higher terrain. Determination of storm transposition limits (section 2.4.2) took into account topography homogeneity in a general sense, thereby avoiding major topographic considerations. However, regional analysis required definition across mountains such as the Appalachians. For such regions, the assumption was made that the reduced height of the column of moisture available for processing (section 2.3.2) at higher elevations is compensated by intensification from steeper terrain slopes.

In contrast to the use of these simplifying assumptions, studies of PMP covering portions of the Western States (U.S. Weather Bureau 1961, 1966, and Hansen et al. 1977) and the Tennessee River drainage (Schwarz and Helfert 1969) do take into account detailed terrain effects. A laminar flow orographic precipitation computation model, useful in some regions where cool-season precipitation is of greatest concern, gives detailed definition for some of the Western States. For the Tennessee River drainage, nonorographic PMP was adjusted for terrain effects by consideration of numerous different rainfall criteria, taking into account meteorological aspects of critical storms of record.

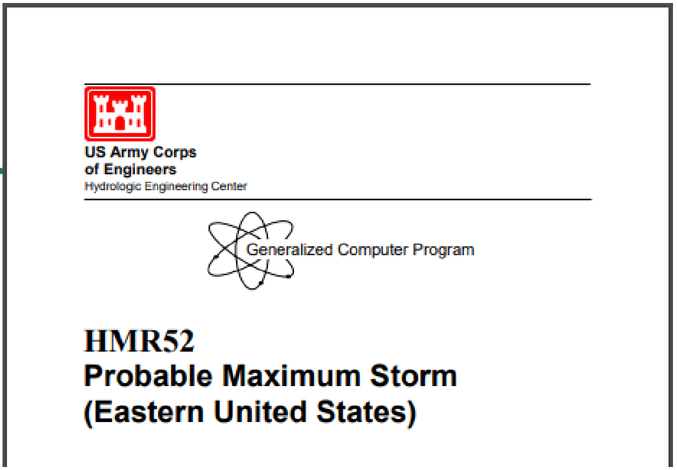
We expect future studies of the Hydrometeorological Branch will involve detailed generalized studies covering the stippled regions. Until these studies are completed, we suggest that major projects within the stippled regions be considered on a case-by-case basis as the need arises.

Figure 18.--All-



PMF – Modeling

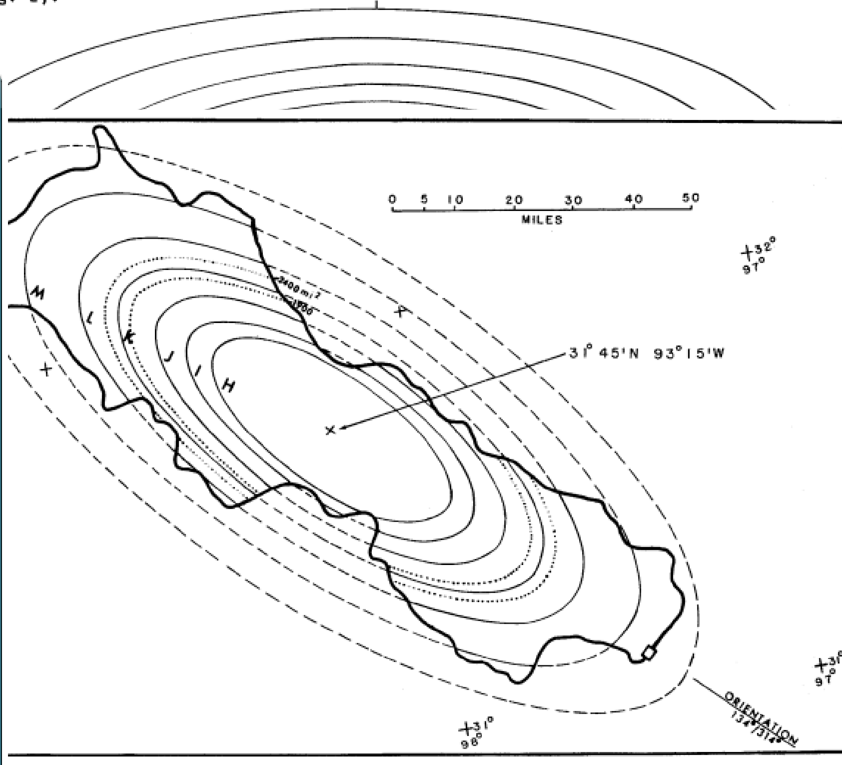
- Small dams, very small drainage areas
  - 6-hr Depth from HMR-51
  - Emergency Spillway Freeboard Hydrograph (ESFB)(TR-60)
    - Sometimes referred to as “Type-B” (HydroCAD)
- Large Dams, Large Drainage Areas
  - HMR-52
  - MetVUE
    - June 2019

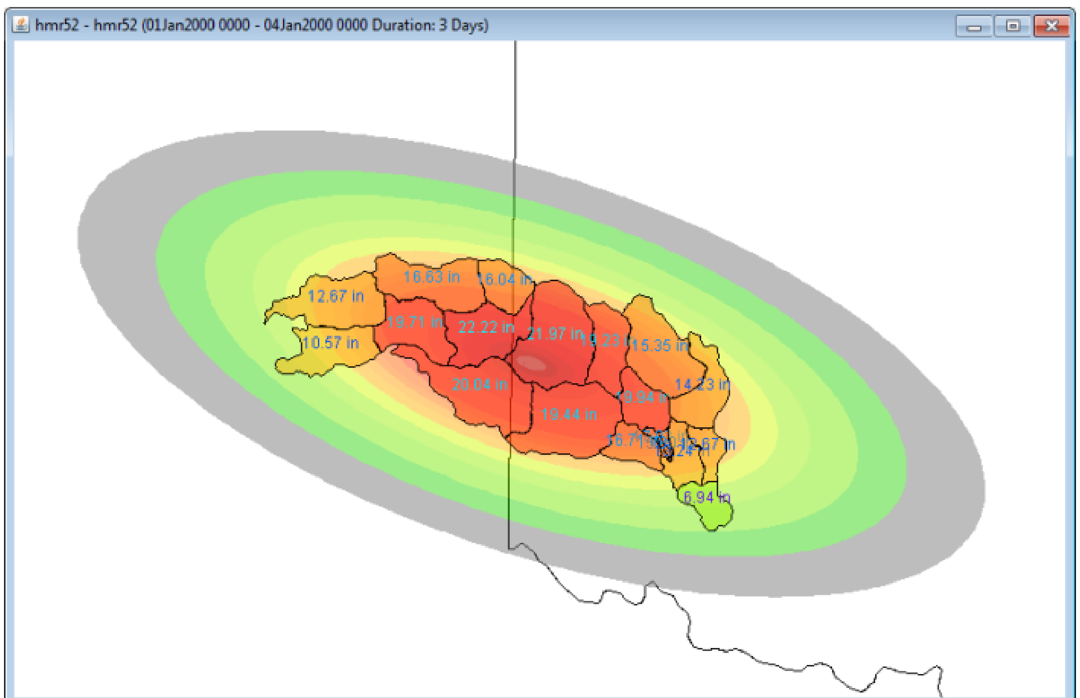

US Army Corps of Engineers
Hydrologic Engineering Center

Generalized Computer Program

HMR52
Probable Maximum Storm (Eastern United States)

(1) Isohyetal shape. The PMS is represented by elliptical isohyets, each of which has a ratio of major axis to minor axis of 2.5 to 1. Standard ellipses have been established containing areas from 10 to 60,000 mi² (Fig. 2).





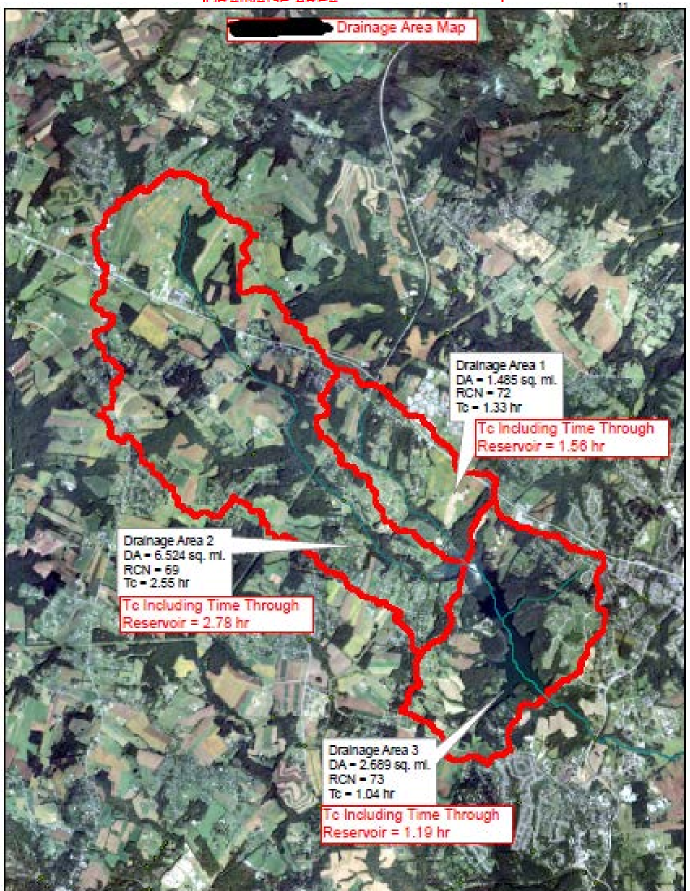
PMF Modeling – HMR-52

HMR

PROBABLE MAXIMUM STORM (HMR52)
NOVEMBER 1982
REVISED APRIL 91
RUN DATE 11/16/2015 TIME 15:30:25

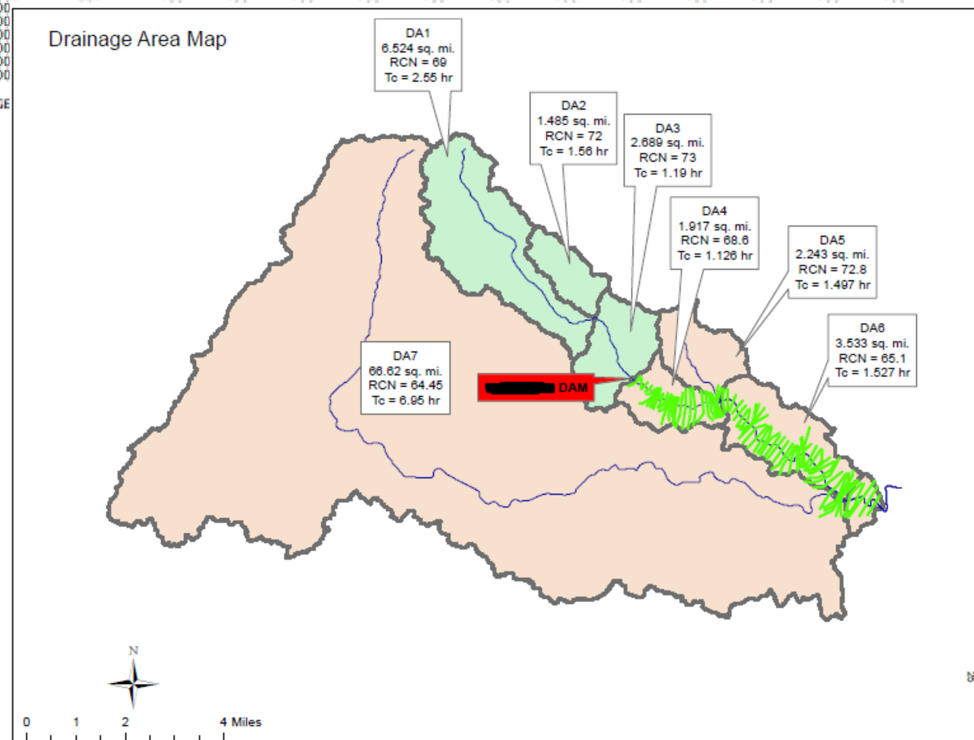
U.S. ARMY CORPS OF ENGINEER
THE HYDROLOGIC ENGINEERING CE
609 SECOND STREET
DAVIS, CALIFORNIA 95616
(916) 551-1748 OR (FTS) 460-1

HMR-52 OVER [redacted] DAM
DRAINAGE AREA



PROBABLE MAXIMUM STORM FOR A
STORM AREA = 10. SQ. MI., ORIENTATION = 310., PREFERRED ORIENTATION = 350.
STORM CENTER COORDINATES, X = 247.8, Y = 120.9

	ISOHYET AREA (SQ.MI.)	AREA WITHIN BASIN (SQ.MI.)	1	2	3	4	5	6	7	8	9	10	11	12
			DEPTHS (INCHES) FOR 6-HOUR INCREMENTS OF PMS											
A	10.	8.	27.19	4.42	2.26	1.53	1.16	.93	.78	.67	.59	.52	.47	.43
B	25.	11.	17.40	2.83	1.47	.99	.75	.61	.51	.44	.38	.34	.31	.28
C	50.	11.	13.05	2.12	1.08	.73	.56	.45	.37	.32	.28	.25	.23	.21
D	100.	11.	10.33	1.72	.88	.60	.45	.36	.30	.26	.23	.20	.18	.17
E	175.	11.	8.16	1.33	.68	.46	.35	.28	.23	.20	.18	.16	.14	.13
F	300.	11.	6.53	1.06	.54	.37	.28	.22	.19	.16	.14	.13	.11	.10
G	450.	11.	5.17	.88	.45	.31	.23	.19	.16	.13	.12	.10	.09	.09
H	700.	11.	3.81	.62	.32	.21	.16	.13	.11	.09	.08	.07	.07	.06
I	1000.	11.	2.72	.44	.23	.15	.12	.09	.08	.07	.06	.05	.05	.04
J	1500.	11.	1.63	.31	.15	.10	.08	.06	.05	.04	.04	.03	.03	.03
K	2150.	11.	.54	.13	.07	.05	.03	.03	.02	.02	.02	.02	.01	.01
L	3000.	11.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
M	4500.	11.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	6500													
O	10000													
P	15000													
Q	25000													
R	40000													
S	60000													
AVERAGE														



PMF Modeling – HEC-MetVue

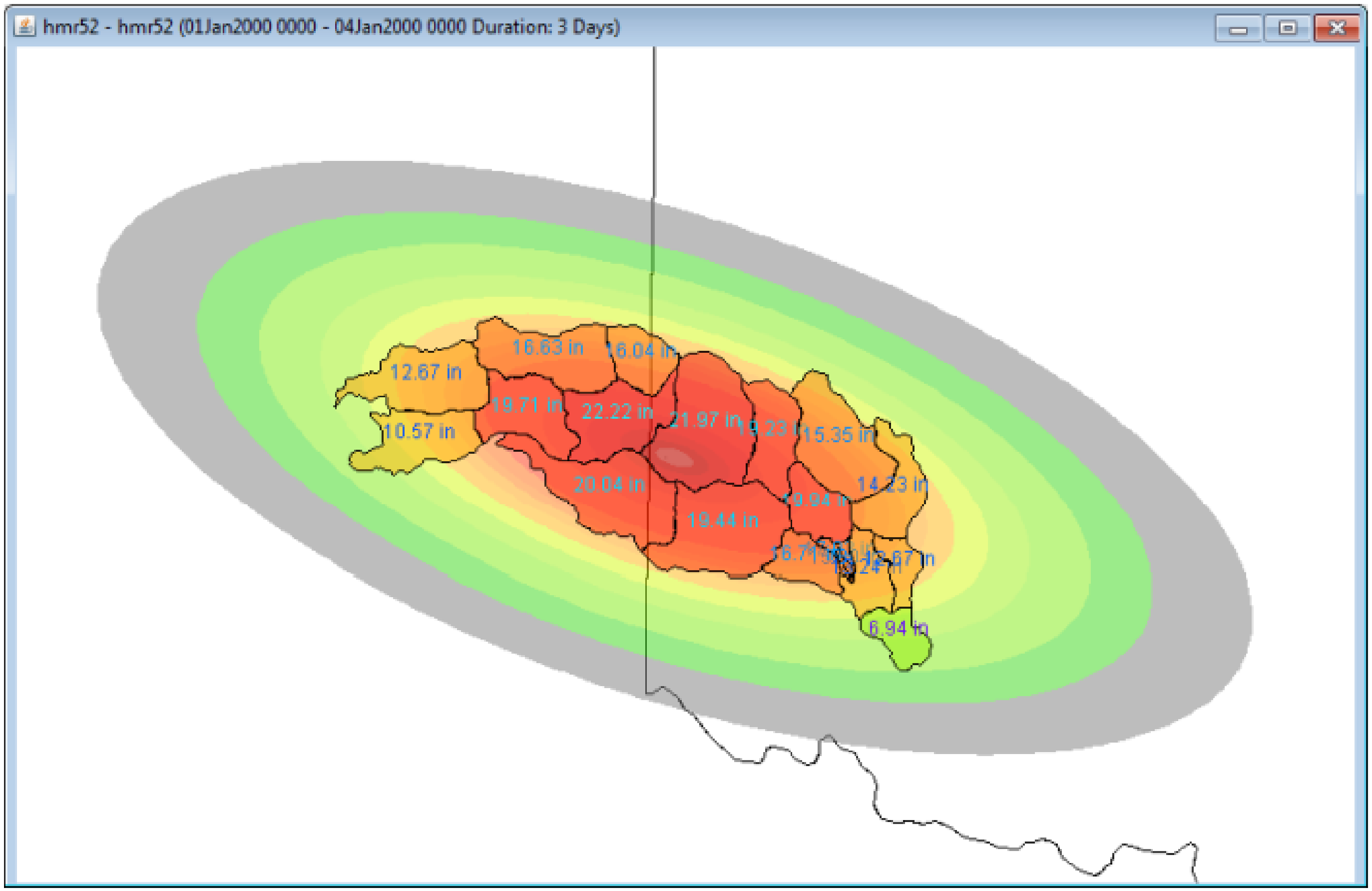
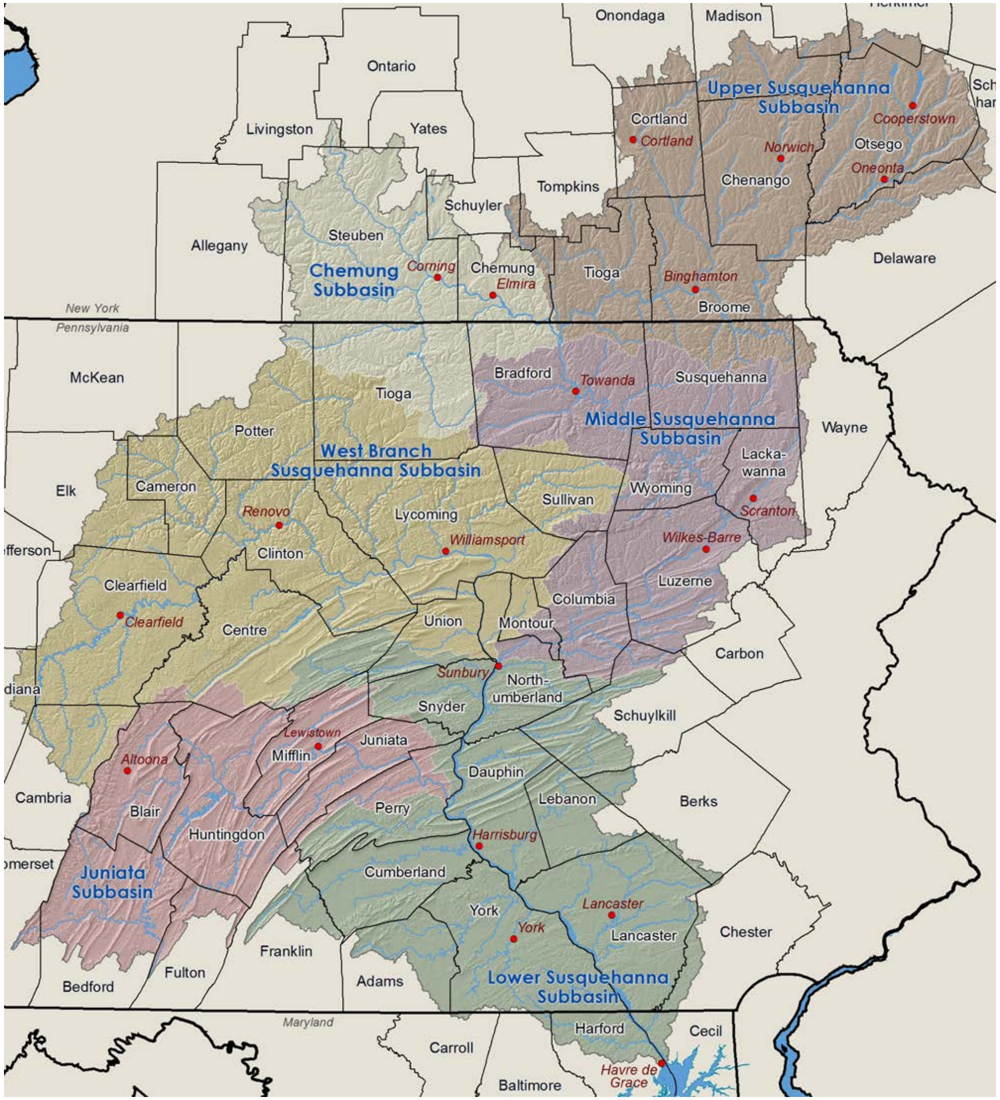


Figure 168 - Sample HMR52 design storm in default position.

Basin Specific Probable Maximum Flood Studies



Harvey and the PMP


Sections
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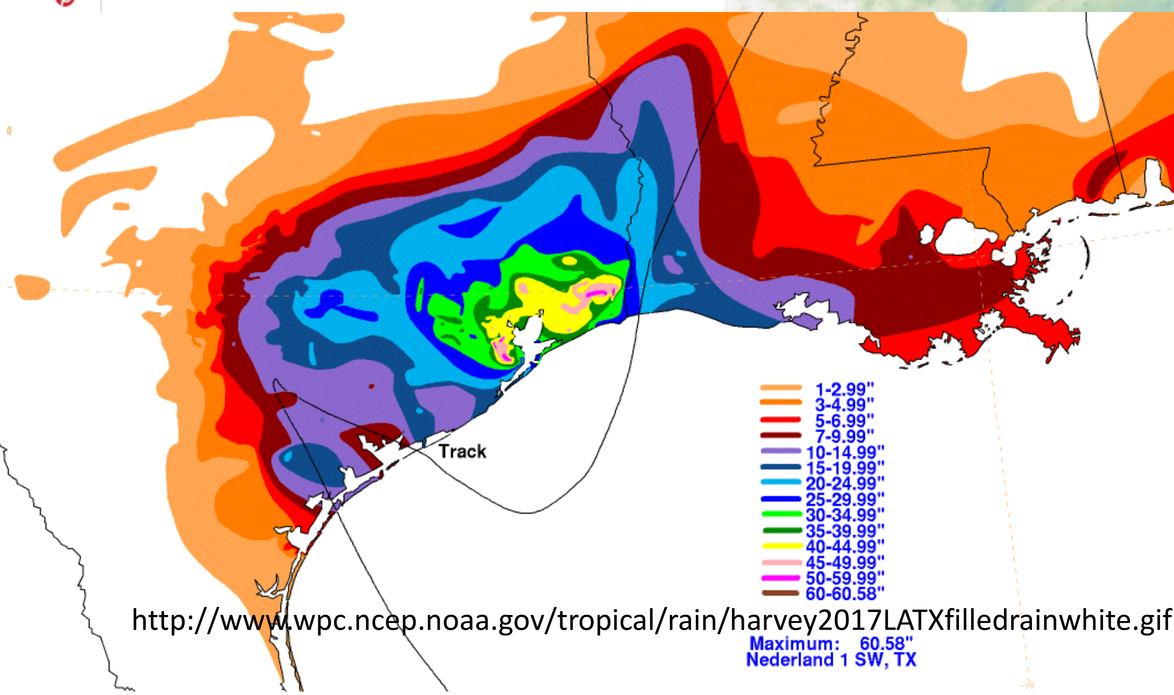
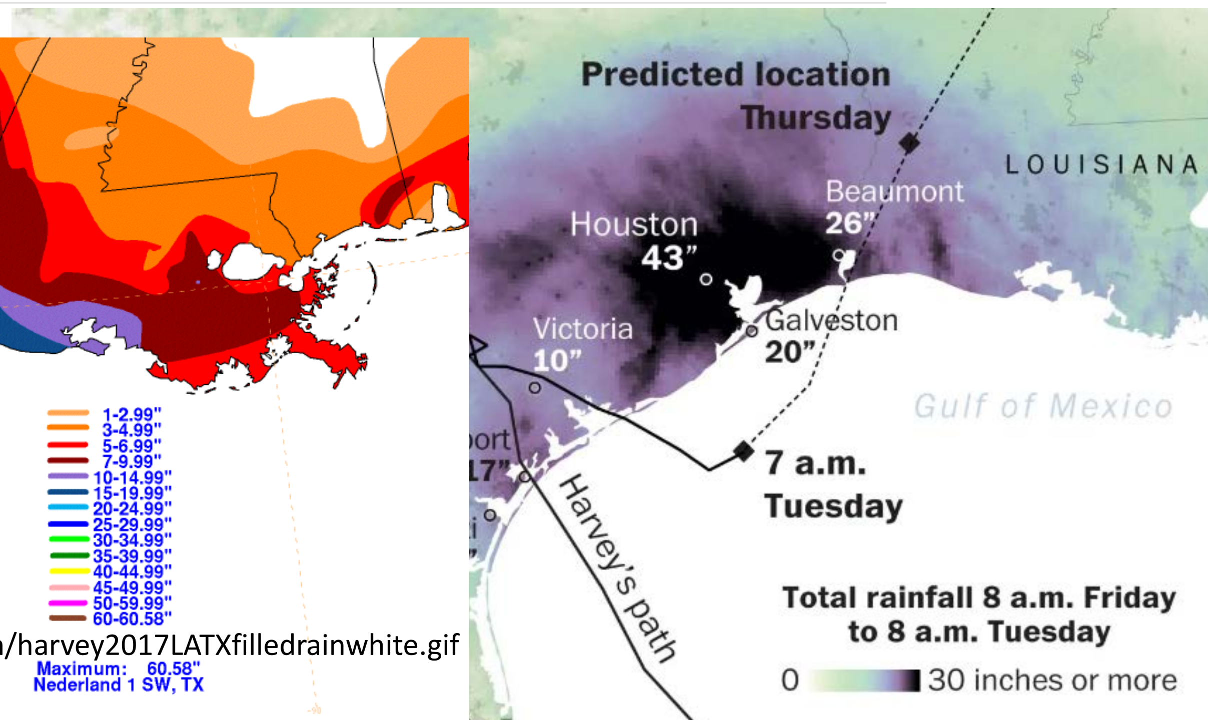
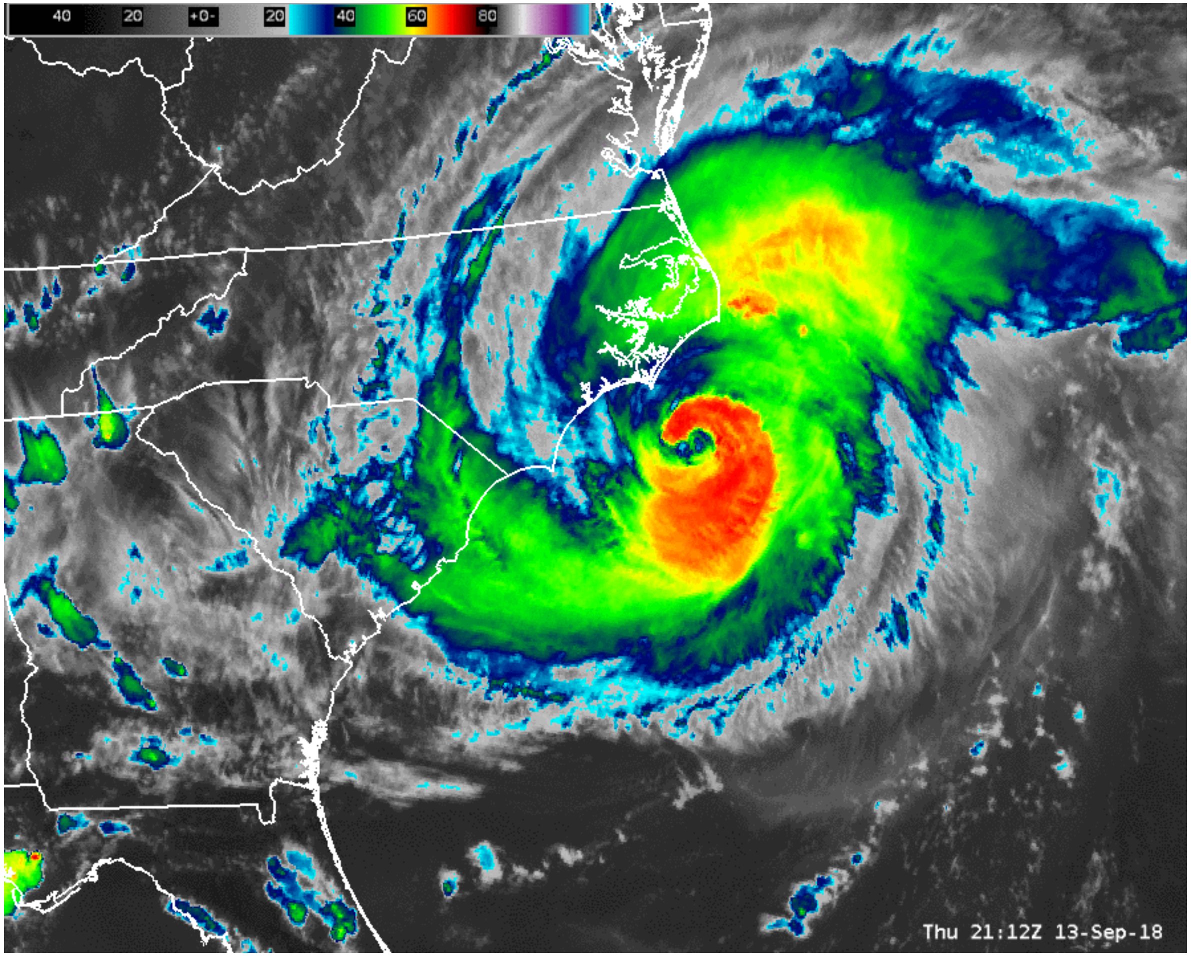
Analysis
September is the most energetic month for hurricanes ever recorded in the Atlantic
Harvey. Irma. Maria. Why is this hurricane season so bad?
Perspective
Hurricanes are menacing our economy. We have to invest in better prediction.
As flooded Houston neighborhoods dry out, residents wonder: Are they worth the risk?
Capital Weather Gang
60 inches of rain fell from Hurricane Harvey in Texas, shattering U.S. storm record



http://www.wpc.ncep.noaa.gov/tropical/rain/harvey2017LATXfilledrainwhite.gif



Hurricane Florence



Florence and the PMP

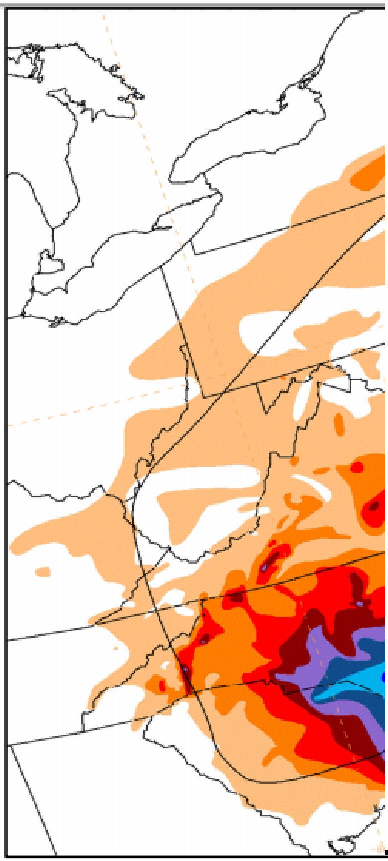
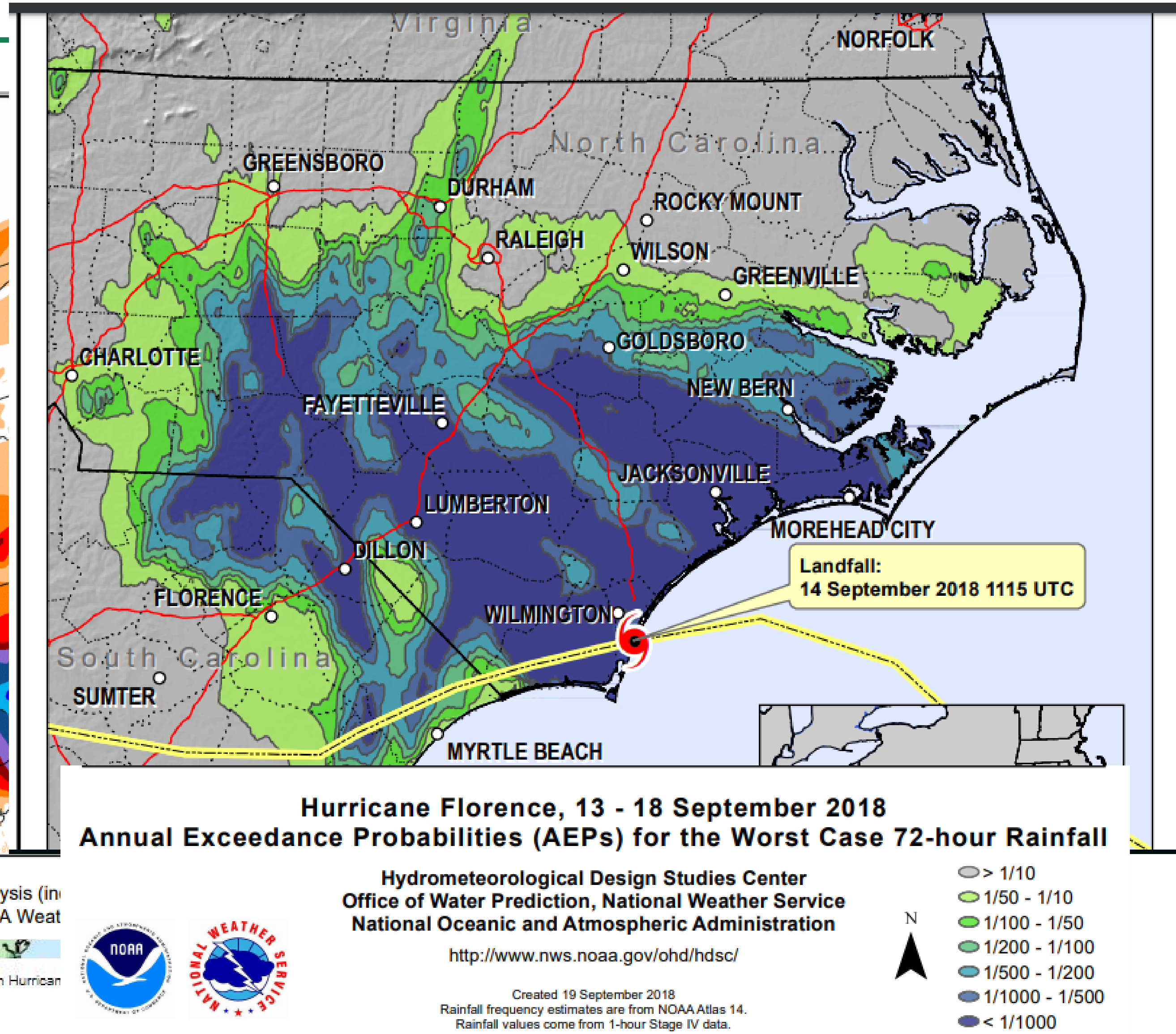


Figure 12. Hurricane Florence U.S. rainfall analysis (in
phase. Graphic courtesy of the NOAA Weat

Multi-sensor rainfall estimates from Hurrican



State Specific PMP Studies and Tools

Maryland Adjacent

DCR | **Virginia Department of Conservation and Recreation**
CONSERVE. PROTECT. ENJOY.

The Virginia Soil and Water Conservation Board adopted the Probable Maximum Precipitation Study for Virginia and the Associated PMP Evaluation Tool and Database on Dec. 9, 2015. Here are **the Impounding Structure Regulations (4VAC50-20)** (PDF) that made the Probable Maximum Precipitation values effective on March 23, 2016 (Section 4VAC50-20-50 was amended). The board's **Guidance Document on New Probable Maximum Precipitation Implementation** (PDF) became effective on that date and was revised on March 29, 2018..

Deliverables from the PMP study are available for download below.

- PMP Final Report and Appendices
  - **Executive Summary** (PDF)
  - **Final Report** (PDF)
  - **Appendices A-E, G-K (67Mb)** (PDF)
  - **Appendix F (76Mb)** (PDF)
- Pre-run PMPs
  - **Virginia PMPs Pre-run For 900+ High and Significant Hazard Dams (Zipped - 218Mb)**. ***Note***: This file may take several hours to unzip because of the volume of data.
- PMP Evaluation GIS Tool and Implementation and Certification Guidance
  - **PMP Tool** (Zipped - 67Mb) Tool works in ArcMap and ArcPro platforms.
  - **PMP Tool Description and Usage** (PDF)
  - **PMP Evaluation Tool Training Document** (PDF) (February 2016)
  - **Virginia PMP 2015 Watershed Calculation Spreadsheet** (Excel) (revised September 2016)
  - **Guidance Document on New Probable Maximum Precipitation (PMP) Implementation** (PDF)
  - **Certification Form: Review of New Probable Maximum Precipitation Values** (PDF) (effective March 23, 2016) using the PMP Evaluation Tool

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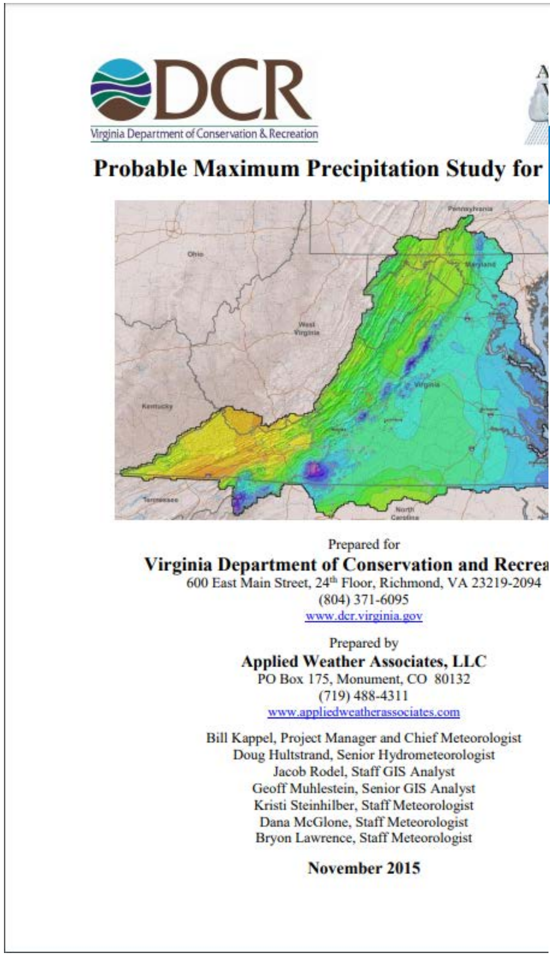
Deliverables from the PMP Study

- PMP Final Report and Appendices
  - Final Report (13MB) (PDF)
  - Appendices A-E, G-L (62MB) (PDF)
  - Appendix F (94MB) (PDF)
- PMP Evaluation GIS Tool, Instructions, and Temporal Distribution Spreadsheet
  - PMP Tool (451 MB) (ZIP)
  - Instructions – Using the PA PMP Tool in ArcGIS (PDF)
  - PMP Distribution Spreadsheet (Excel)
  - Instructions – Using the PMP Spreadsheet for Temporal Distribution (PDF)
  - Example PMP-PMF Analysis – Lake Nessmuk (ZIP)

- https://www.dcr.virginia.gov/dam-safety-and-floodplains/pmp-tool
- https://www.dep.pa.gov/Business/Water/Waterways/DamSafety/Pages/Probable-Maximum-Precipitation-Study-.aspx

State Specific PMP Studies – Maryland Adjacent - Virginia


DCR
Virginia Department of Conservation & Recreation

Probable Maximum Precipitation Study for

Prepared for
Virginia Department of Conservation and Recrea
600 East Main Street, 24th Floor, Richmond, VA 23219-2094
(804) 371-6095
www.dcr.virginia.gov

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(719) 488-4311
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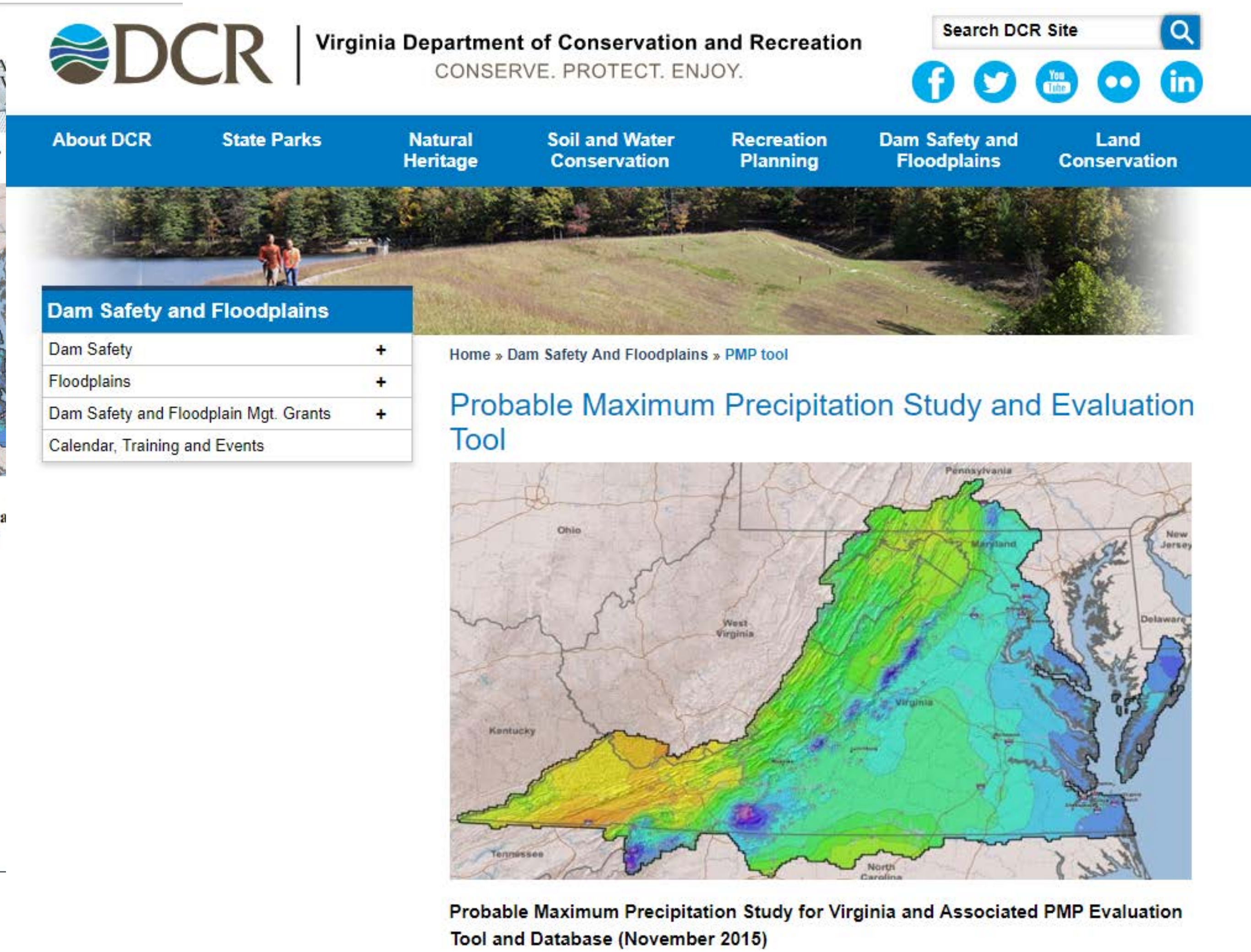
November 2015



State Specific PMP Studies – Maryland Adjacent – Pennsylvania

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Applied Weather Associates

Probable Maximum Precipitation Study for Pennsylvania

Prepared for
Pennsylvania Department of Environmental Protection
400 Market Street, Harrisburg, PA 17105-8460
(717) 787-8568
https://www.dep.pa.gov/Business/Water/Waterways/DamSafety/Pages/default.aspx

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Bryon Lawrence, Staff Meteorologist

March 2019

Comparison to HMR Studies

13.1 Comparison of PMP Values to HMR Studies

This study employs a variety of improved methods when compared to previous HMR studies. These methods include:

- A far more robust storm analysis system with a higher temporal and spatial resolution
- Improved dew point/SST and precipitation climatologies that provide an increased ability to maximize and transpose storms
- Gridded PMP calculations which result in higher spatial and temporal resolutions
- A greatly expanded storm record

Stippled Region Topographic Effects Accounted For

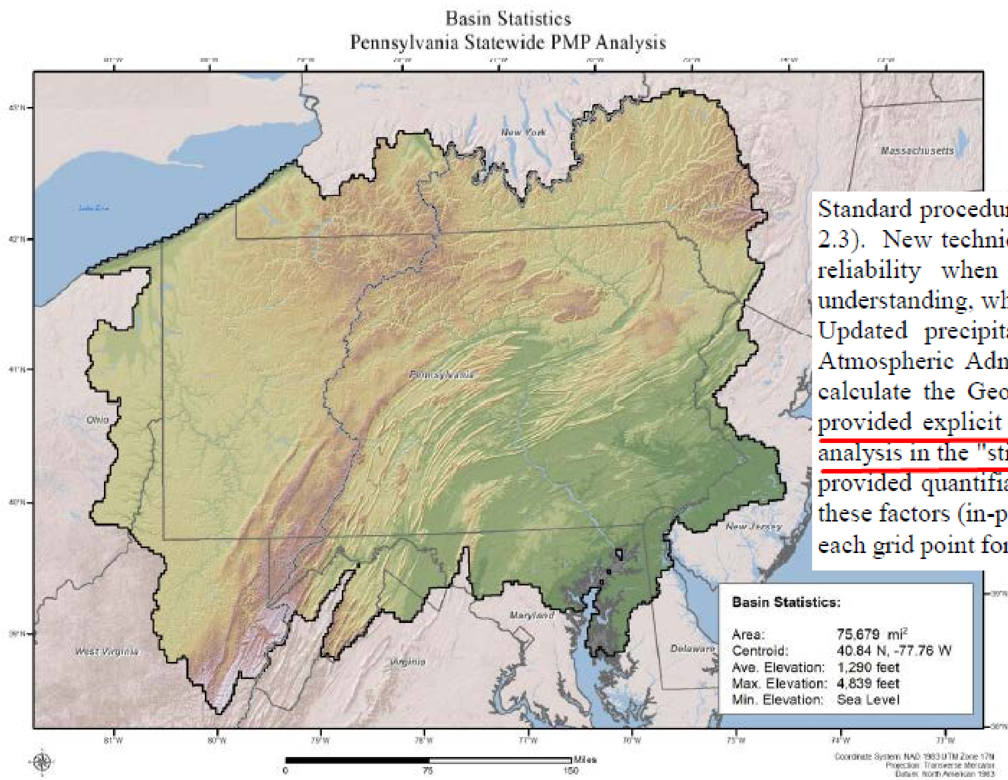


Figure 4.1: Topography across the domain analyzed

Standard procedures were applied for in-place maximization adjustments (e.g. HMR 51 Section 2.3). New techniques and new datasets were used in other procedures to increase accuracy and reliability when justified by utilizing advancements in technology and meteorological understanding, while adhering to the basic approach used in the HMRs and in the WMO Manual. Updated precipitation frequency analyses data available from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 were used for this study. These were used to calculate the Geographic Transposition Factors (GTFs) for each storm. The GTF procedure provided explicit evaluations of the effects of terrain on rainfall and corrected for the lack of analysis in the "stippled' region of HMR 51. The GTF procedure, through its correlation process, provided quantifiable and reproducible analyses of the effects of terrain on rainfall. Results of these factors (in-place maximization and geographic transposition) were applied for each storm at each grid point for each of the area sizes and durations used in this study to define the PMP values.

Storms in Pennsylvania PMP Analysis

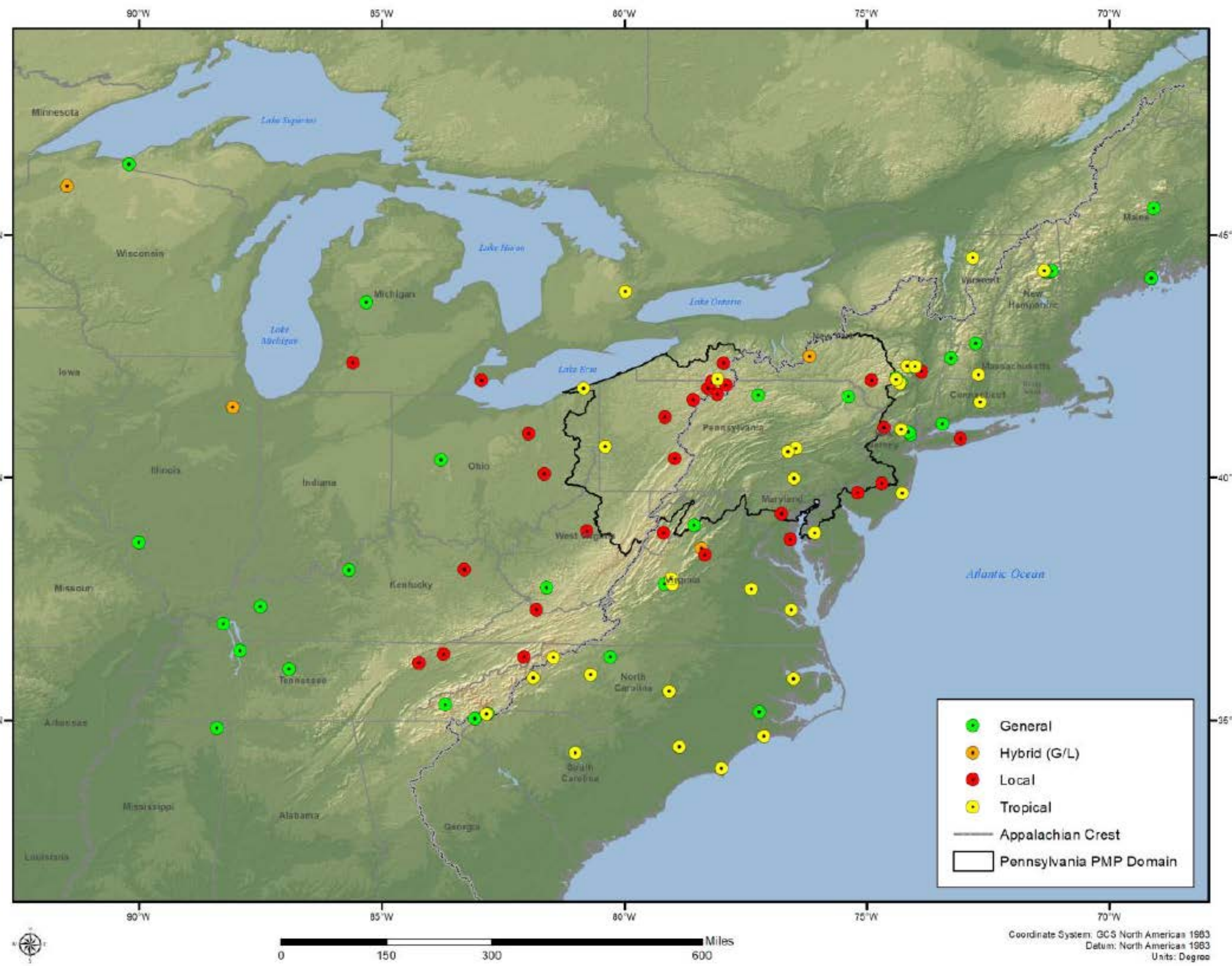


Figure 7.3: Short storm list locations, all storms

Local Storms in PA PMP Analysis

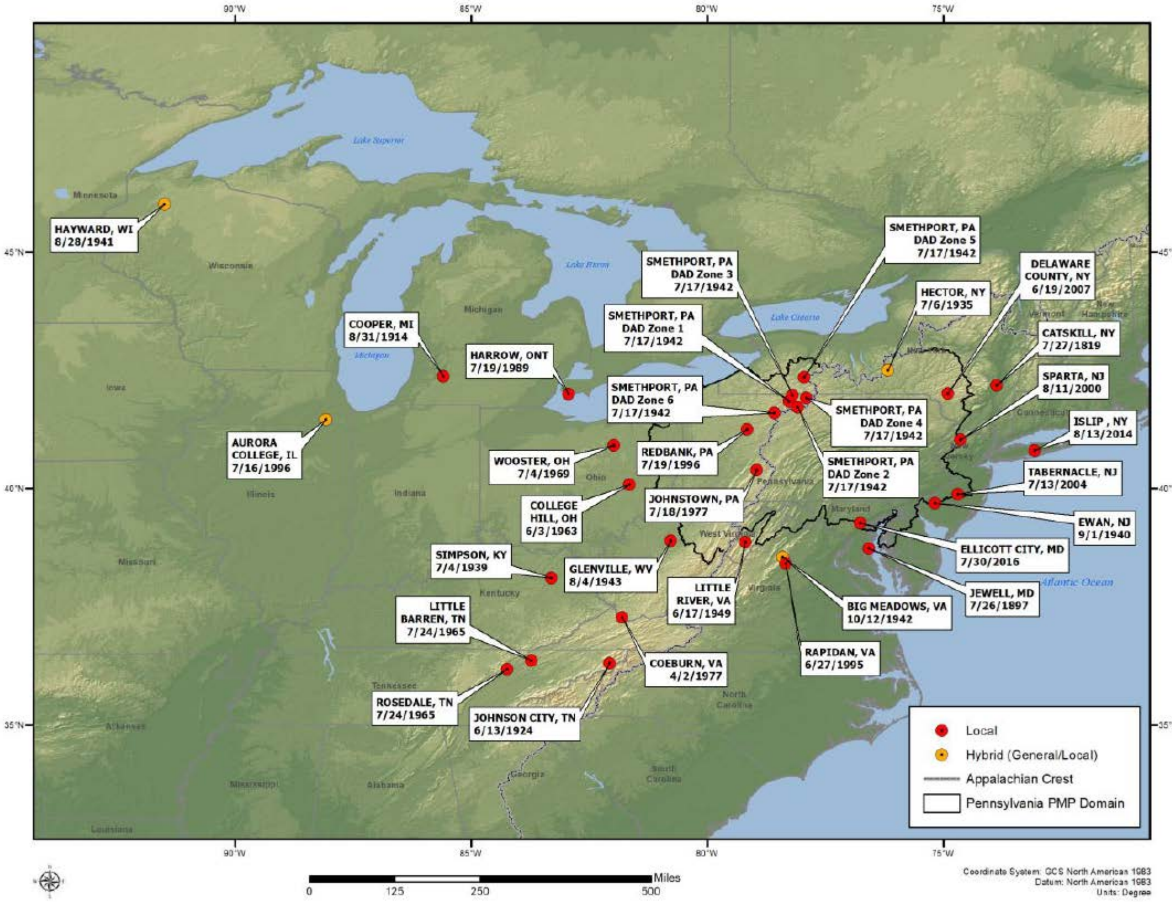


Figure 7.4: Location of local storms on the short list

Local storm: A storm event that occurs over a small area in a short time period. Precipitation rarely exceeds 6 hours in duration and the area covered by precipitation is less than 500 square miles. Frequently, local storms will last only 1 or 2 hours and precipitation will occur over areas of up to 200 square miles. Precipitation from local storms will be isolated from general-storm rainfall. Often these storms are thunderstorms.

General Storms in PA PMP Analysis

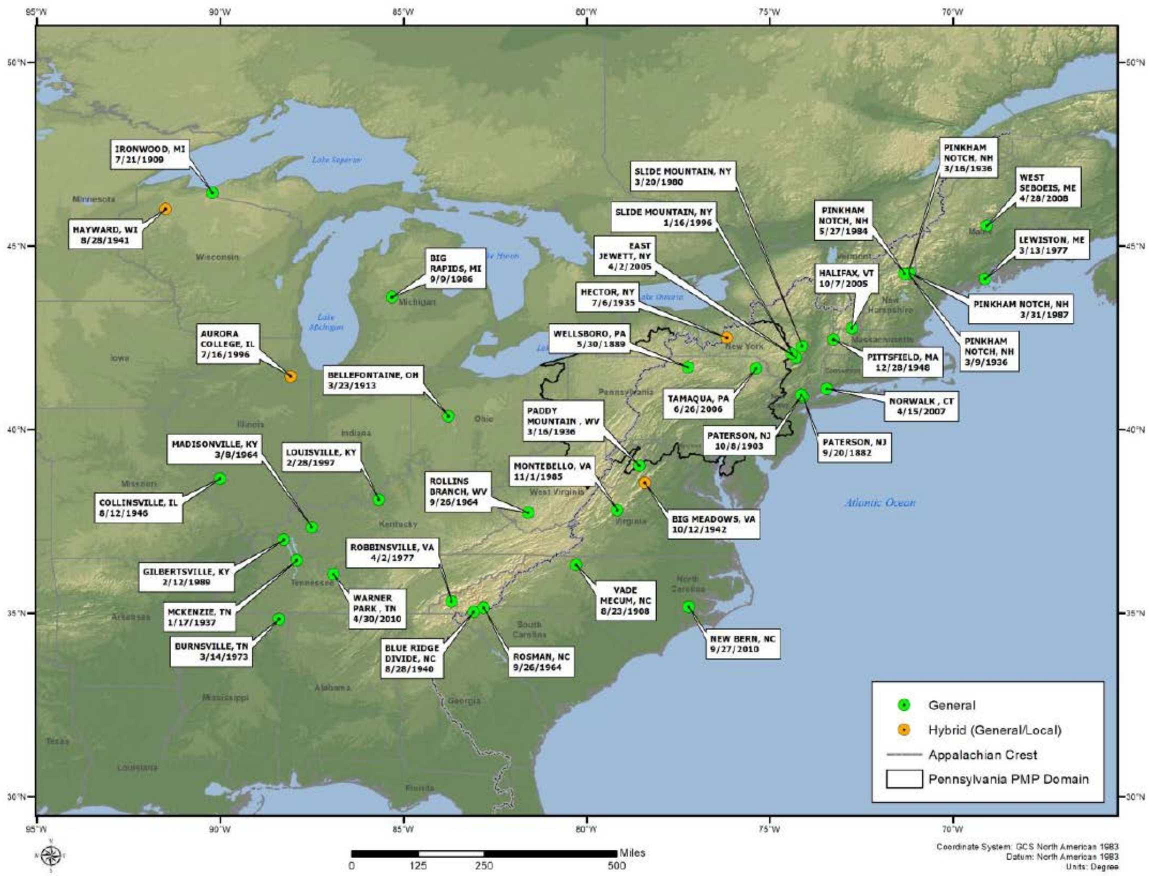


Figure 7.5: Location of general storms on the short list

General storm: A storm event that produces precipitation over areas in excess of 500-square miles, has a duration longer than 6 hours, and is associated with a major synoptic weather feature.

Tropical Storms in PA PMP Analysis

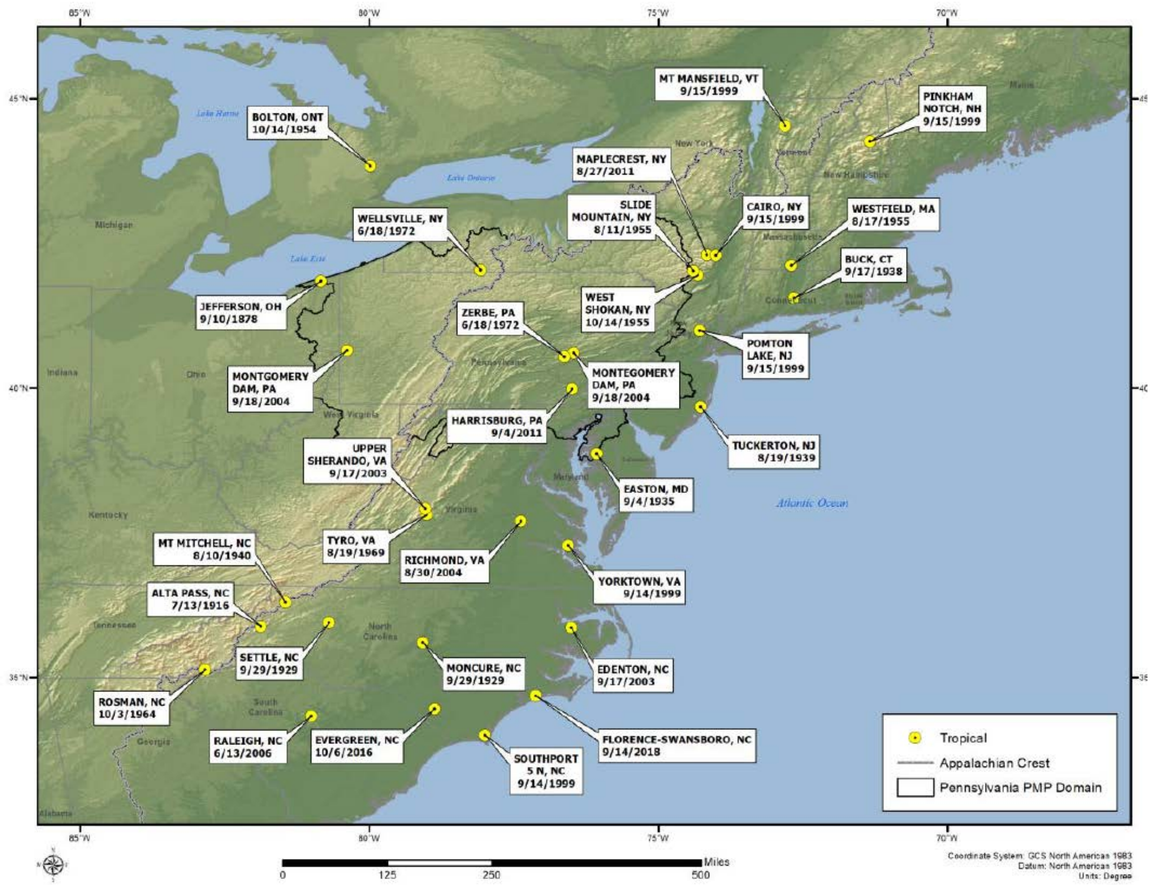
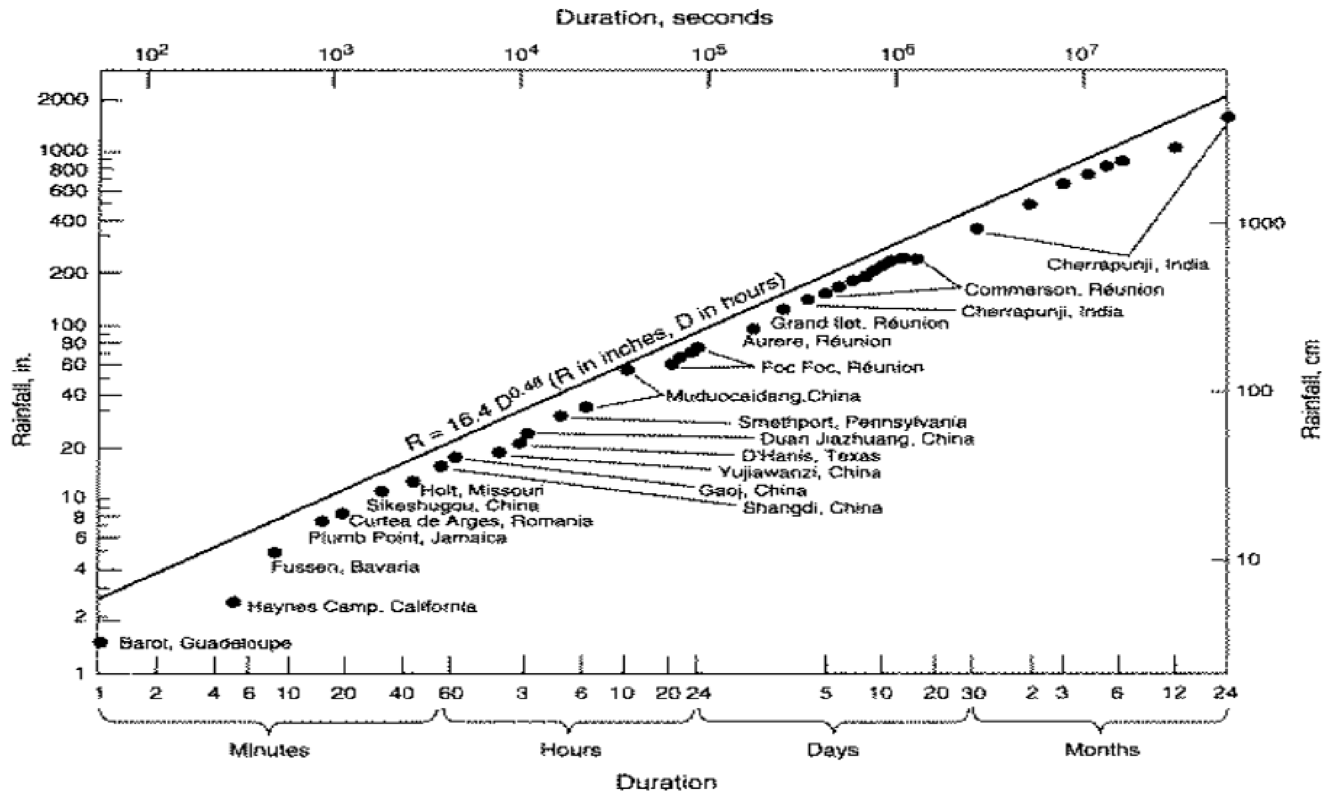


Figure 7.6: Location of tropical storms on the short list

Tropical Storm: A cyclone of tropical origin that derives its energy from the ocean surface.

Smethport Developments



Maximum observed point rainfalls as a function of duration.

Source: World Meteorological Organization WMO 332, Modified by NWS 1992.

Smethport Continued

Flood Analysis for the World-Record-Setting July 1942 "Smethport" Storm

Supporting the Pennsylvania Probable Maximum Precipitation Study

JOE BELLINI

BILL KAPPEL

Author Note

Study funded by the Pennsylvania Department of Environmental Protection

ABSTRACT

The Division of Dam Safety, Pennsylvania Department of Environmental Protection (PA DEP), is currently developing a Probable Maximum Precipitation (PMP) Study for the Commonwealth of Pennsylvania. The PMP depths for Pennsylvania, particularly along the western edge of the Allegheny Mountains, are greatly influenced by the exceptional magnitude of a world-record-setting storm that occurred in July 1942 in the north-central region of Pennsylvania. Available data from this storm includes numerous measurements of rainfall depths exceeding 30 inches in 4.5 hours. The July 1942 storm is critical for PMP development in the region. However, there are uncertainties related to the quality of the rainfall data collected in this rural region of Pennsylvania. Therefore, a critical component of the study is a hydrologic and hydraulic simulation of the watershed's response to the July 1942 rainfall event, using a combination of lumped and distributed (2D) techniques. The purpose of the flood analysis was to substantiate the recorded rainfall or identify, isolate, and quantify observational uncertainties in the recorded rainfall and develop rainfall depth, spatial, and/or temporal patterns that better match observed flood data. This article describes the approach taken to develop and calibrate the flood models, comparisons between modeled and observed flood data, and results of iterations to refine our understanding of the rainfall magnitude, spatial patterns, and/or temporal patterns.

OBJECTIVE

The Division of Dam Safety, Pennsylvania Department of Environmental Protection (PA DEP), is currently sponsoring a Probable Maximum Precipitation (PMP) Study for the Commonwealth of Pennsylvania, led by Applied Weather Associates (AWA). Without an updated study, PMP data are typically obtained from one or more of a series of Hydrometeorological Reports (HMRs) prepared by the National Weather Service (NWS). Areas of the United States east of the 105th meridian are covered by HMR 51 (Schreiner, 1978), which provides generalized depth-area-duration PMP data; with additional generalized temporal and spatial formation in HMR 52 (Hansen, 1982). The outcome of the updated PMP study will enable users in Pennsylvania, many of whom are dam owners, to access site-specific hourly PMP data for areas as small as 1 km2 for evaluating the impact of the Probable Maximum Flood (PMF) on critical infrastructure (existing or planned), particularly high-hazard dams. The Pennsylvania PMP study uses a storm-based method to transposition and maximize extreme rainfall events in the region to create an envelope of depth-area-duration relationships unique to specific locations in the Commonwealth. Because it is storm-based, PMP depths for Pennsylvania, and much of the larger region covered by HMR 51, are greatly influenced by the exceptional magnitude of a storm that occurred on July 18, 1942 in the region of McKean County (PA), Potter County (PA), and Cattaraugus County

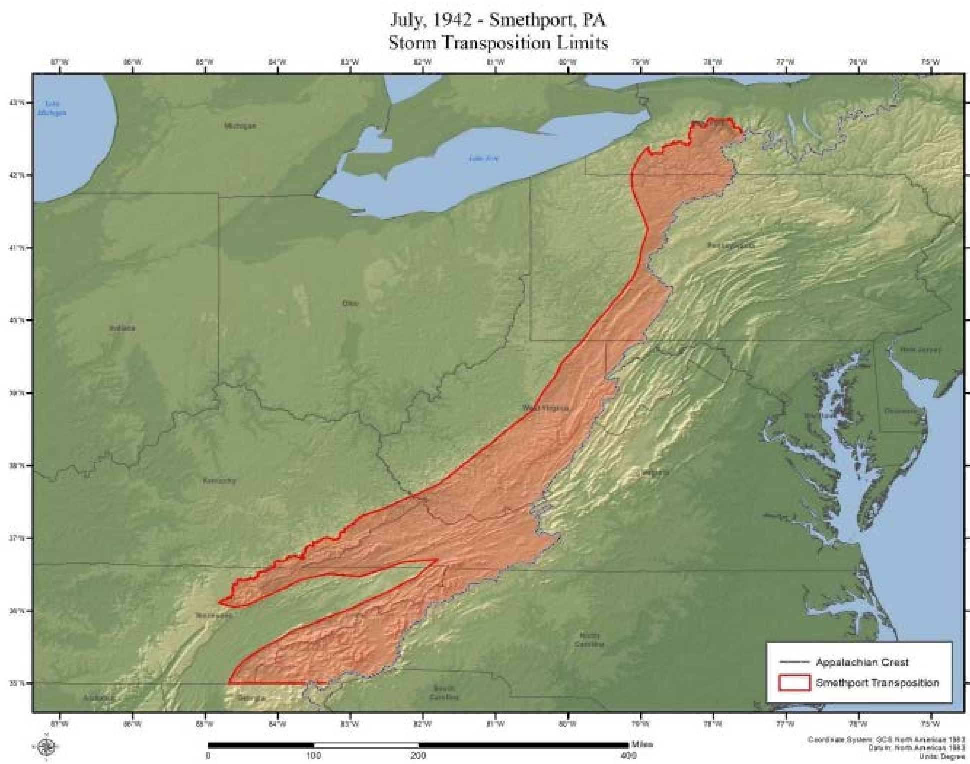
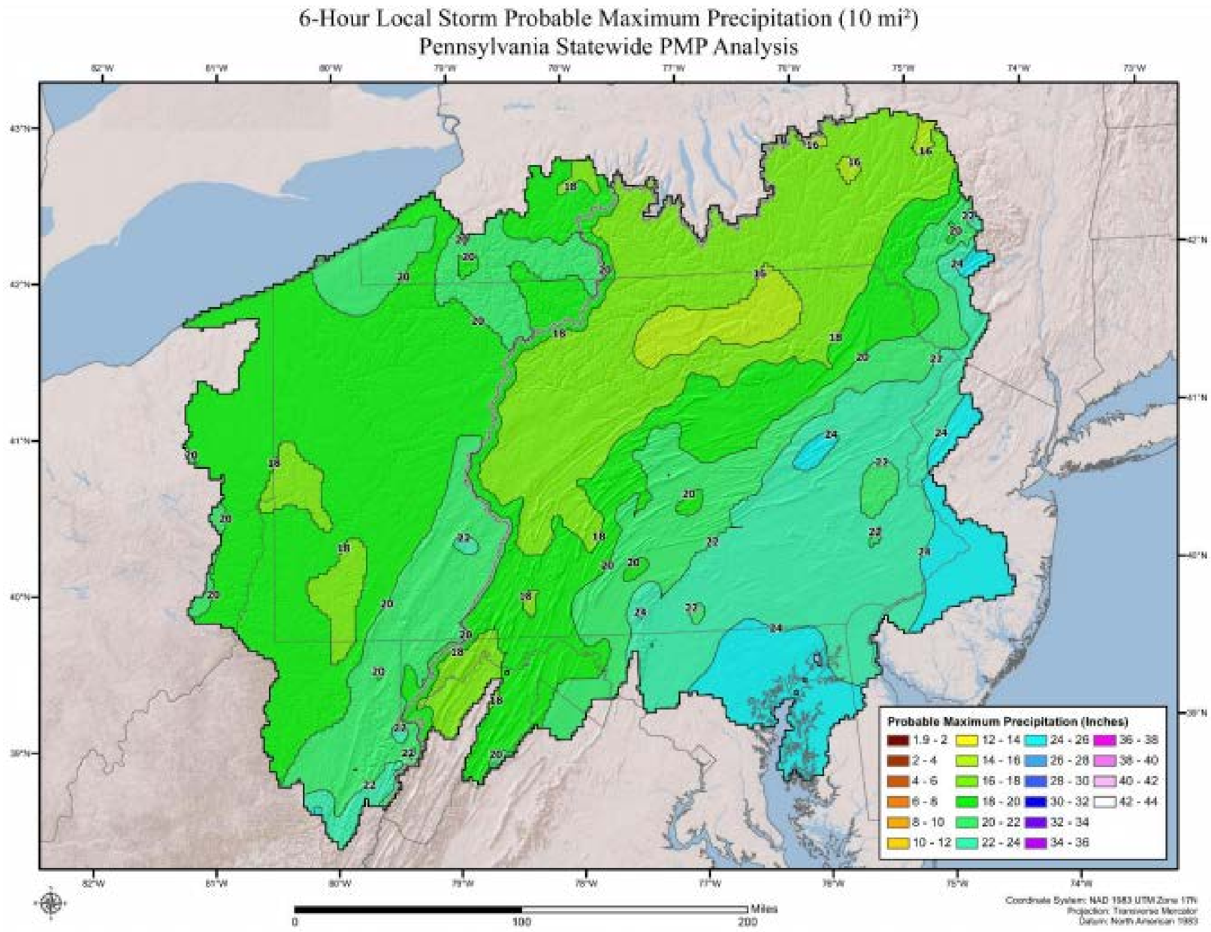


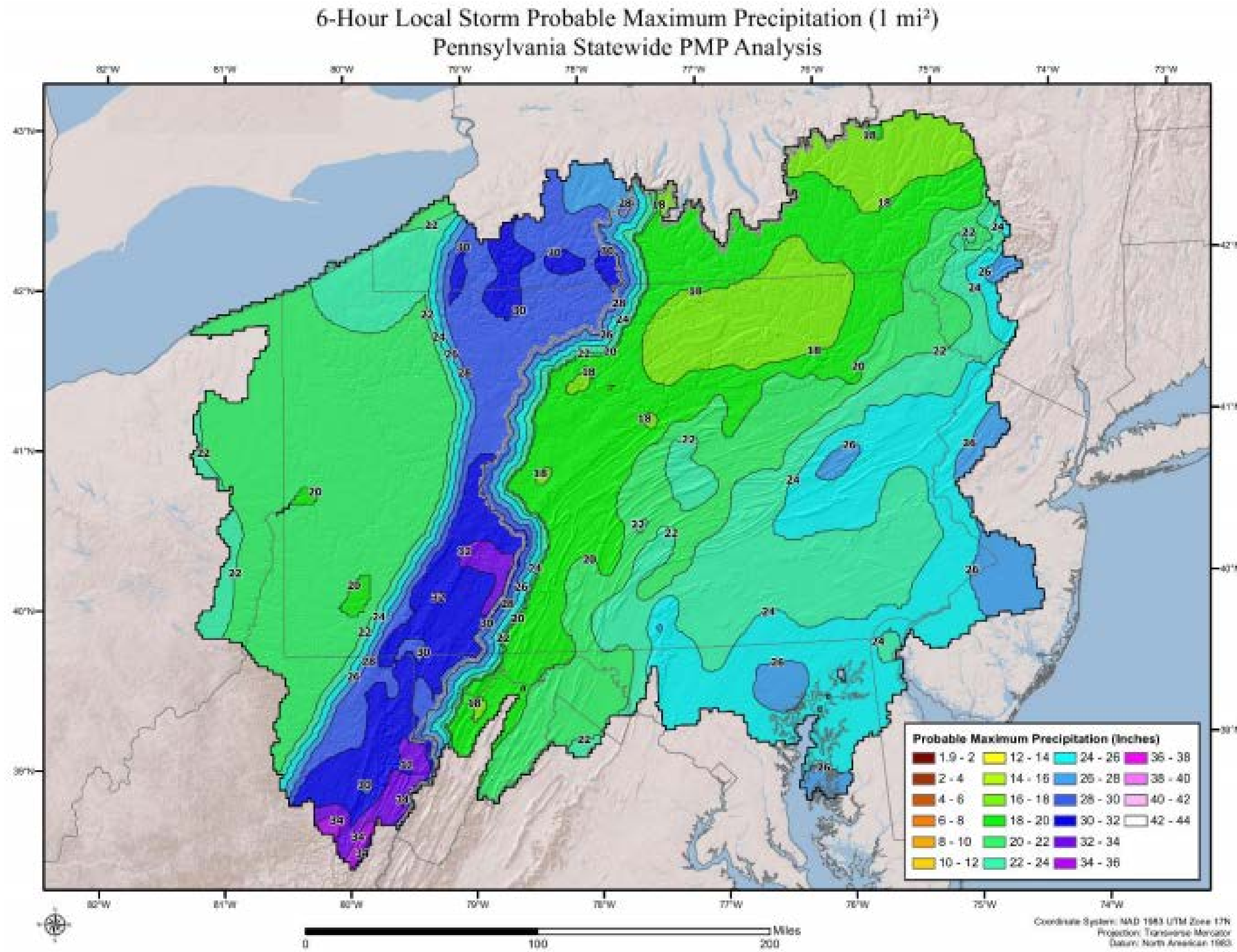
Figure 9: July 1942 Smethport PA Storm Transposition Limits

Source- ASDSO Journal of Dam Safety

Pennsylvania PMP Study – 6-hr 10 sq. mi.



Pennsylvania PMP Study – 6-hr 1 sq. mi.



Virginia and Pennsylvania Overlap

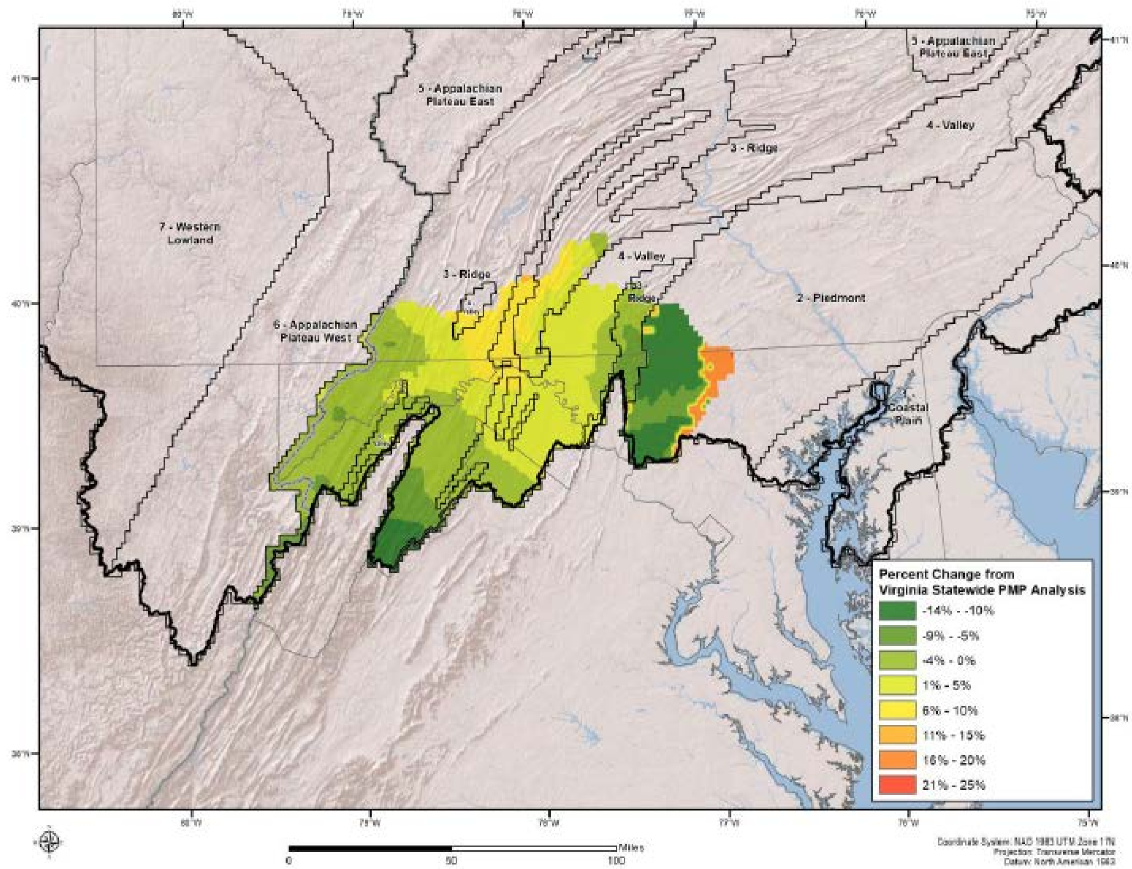


Figure 13.1: Percent change in combined storm type 100 square mile 6-hour PMP from Virginia Statewide PMP Analysis

Maryland PMP Study

1	Review Previous Work
2	Storm Search and Short Storm List Development
3	Storm Maximization, Transpositioning, Orographic Analysis

– First Portion Grant Awarded

4	Develop PMP Values
5	PMP Temporal Analysis
6	Annual Exceedance Probability of PMP for Risk Analysis and Sensitivity

7	Projected Effects of Climate Change on PMP through 2100
8	Draft and Final Report
9	GIS PMP Database and Tool