Xcel Energy

Calculation Signature Sheet

Document Information	
NSPM Calculation (Doc) No: 15-031	Revision: 0
Title: Site Specific PMP and Ancillary Meteorological Analysis	
Facility: ☒ MT ☐ PI	Unit: ☒ 1 ☐ 2
Safety Class: ☒ SR ☐ Aug Q ☐ Non SR	
Special Codes: ☐ Safeguards ☐ Proprietary	
Type: **Calc** Sub-Type:	

NOTE:	Print and sign name in signature blocks, as required.

Major Revisions		☐ N/A
EC Number: 25484	☒ Vendor Calc	
Vendor Name or Code: B & V	Vendor Doc No: 180999.51.1008	
Description of Revision: Revision 1		
The following calculation and attachments have been reviewed and deemed acceptable as a legible QA record		☒
Prepared by: (sign) / (print) by Vendor	Date: 3/4/15	
Reviewed by: (sign) D. Karpinski / (print) D Karpinski	Date: 4/1/15	
Type of Review: ☐ Design Verification ☐ Tech Review ☒ Suitability Review		
Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test		
Approved by: (sign) Michael P. Baldwin / (print) Michael P. Baldwin	Date: 4/17/2015	

Minor Revisions		☒ N/A
EC No:	☐ Vendor Calc:	
Minor Rev. No:		
Description of Change:		
Pages Affected:		
The following calculation and attachments have been reviewed and deemed acceptable as a legible QA record		☐
Prepared by: (sign) / (print) by Vendor	Date:	
Reviewed by: (sign) / (print)	Date:	
Type of Review: ☐ Design Verification ☐ Tech Review ☐ Suitability Review		
Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test		
Approved by: (sign) / (print)	Date:	

Record Retention: Retain this form with the associated calculation for the life of the plant.

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NOTE:	This reference table is used for data entry into the PassPort Controlled Documents Module reference tables (C012 Panel). It may also be used as the reference section of the calculation. The input documents, output documents and other references should all be listed here. Add additional lines as needed by using the "TAB" key and filling in the appropriate information in each column.

Reference Documents (PassPort C012 Panel from C020)

#	Controlled* Doc? + Type		Document Name	Document Number	Doc Rev	Ref Type**	
						INPUT	OUTPUT
1							
2							
3							
4							
5							
6							
7							
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17							

* Controlled Doc marked with an "X" means the reference can be entered on the C012 panel in black. Unmarked lines will be yellow. If marked with an "X", also list the Doc Type, e.g., CALC, DRAW, VTM, PROC, etc.

Record Retention: Retain this form with the associated calculation for the life of the plant.

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** Mark with an "X" if the calculation provides inputs and/or outputs or both. If not, leave blank. (Corresponds to PassPort "Ref Type" codes: **Inputs / Both** = "ICALC", **Outputs** = "OCALC", **Other / Unknown** = blank)

Other PassPort Data

Associated System (PassPort C011, first three columns) **OR** **Equipment References** (PassPort C025, all five columns):

Facility	Unit	System	Equipment Type	Equipment Number
MT	1			

Superseded Calculations (PassPort C019):

Facility	Calc Document Number	Title

Description Codes - Optional (PassPort C018):

Code	Description (optional)	Code	Description (optional)

Notes (Nts) - Optional (PassPort X293 from C020):

Topic Notes	Text
☐ Calc Introduction	☒ Copy directly from the calculation Intro Paragraph **or** ☐ See write-up below
☐ (Specify)	

Record Retention: Retain this form with the associated calculation for the life of the plant.

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Monticello Specific Information

☐ YES ☒ N/A Topic Code(s) (See MT Form 3805): _______

☐ YES ☒ N/A Structural Code(s) (See MT Form 3805):_______

Does the Calculation:

☐ YES ☒ No Require Fire Protection Review? (Using MT Form 3765, "Fire Protection Program Checklist", determine if a Fire Protection Review is required.) If YES, document the engineering review in the EC. If NO, then attach completed MT Form 3765 to the associated EC.

☐ YES ☒ No Affect piping or supports? (If Yes, Attach MT Form 3544.)

☐ YES ☒ No Affect IST Program Valve or Pump Reference Values, and/or Acceptance Criteria? (If Yes, inform IST Coordinator and provide copy of calculation.)

Record Retention: Retain this form with the associated calculation for the life of the plant.

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External Design Document Suitability Review Checklist

External Design Document Being Reviewed:B & V

Title: **Site Specific PMP and Ancillary Meteorological Analysis**

Number: 15-031 Rev: 0 Date: 4/1/15

This design document was received from:

Organization Name: B & V PO or DIA Reference: 00048375

The purpose of the suitability review is to ensure that a calculation, analysis or other design document provided by an External Design Organization complies with the conditions of the purchase order and/or Design Interface Agreement (DIA) and is appropriate for its intended use. The suitability review does not serve as an independent verification. Independent verification of the design document supplied by the External Design Organization should be evident in the document, if required.

The reviewer should use the criteria below as a guide to assess the overall quality, completeness and usefulness of the design document. The reviewer is not required to check calculations in detail.

REVIEW

		Reviewed	N/A
1	Design inputs correspond to those that were transmitted to the External Design Organization.	☒	☐
2	Assumptions are described and reasonable.	☒	☐
3	Applicabl e codes, standards and regulations are identified and met.	☒	☐
4	Applicable construction and operating experience is considered.	☐	☒
5	Applicable structure(s), system(s), and component(s) are listed.	☐	☒
6	Formulae and equations are documented. Unusual symbols are defined.	☒	☐
7	Acceptance criteria are identified, adequate and satisfied.	☒	☐
8	Results are reasonable compared to inputs.	☒	☐
9	Source documents are referenced.	☒	☐
10	The document is appropriate for its intended use.	☒	☐
11	The document complies with the terms of the Purchase Order and/or DIA.	☒	☐
12	Inputs, assumptions, outputs, etc. which could affect plant operation are enforced by adequate procedural controls.	☒	☐
13	Plant impact has been identified and either implemented or controlled. If not identified in the document itself, identify the plant impacts and their associated tracking A/Rs and descriptions are listed in Table 1.	☒	☐
14	Design and Operational Margin have been considered and documented per FP-E-CM-01.	☐	☒

Comments: N/C

Completed by: .Dariusz Karpinski / D. Karpinski Date: 4/1/15

Form retained in accordance with record retention schedule identified in FP-G-RM-01.

Xcel Energy	External Design Document Suitability Review Checklist

TABLE 1

Initiate an AR to track open items and plant impacts (e.g., procedure revisions, validation of assumptions, database updates, etc.), if any.

Item No.	AR Tracking Number	PLANT IMPACT DESCRIPTION
1		
2		
3		
4		
5		
6		
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9		
10		
11		
12		
13		
14		
15		

Xcel Energy	Design Review Comment Form

Sheet _1_ of 3

DOCUMENT NUMBER/ TITLE: 180999.51.1008 - MNGP Site Specific PMP and Ancillary Meteorological Analysis

REVISION: _1__ DATE: 3/10/15

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
1.	Page 12, Paragraph 3.2, Items 1 & 2: Items 1 & 2 state that the site-specific PMP and LIP calculations identified precipitation lower than what is provided by HMR-51 & 52, respectively. Aterra recommends providing the reasons why the values are lower than the HMR values and why the calculated values are more appropriate and should be used for the PMF calculation.	Added wording to reference sections where reasons for differences are described.	Concur with resolution.
2.	Page 13, Paragraph 4.4: Wherever possible, add references to support key assumptions, similar to what was done for Assumption #6. #7 and #8.	References added where appropriate.	Concur with resolution.
3.	Page 13 Paragraph 4.4, Item 1: The first sentence needs to be reworded.	Reworded sentence. Corrected in 12-14-2014 revision-track changes edits have now been updated correctly.	Concur with resolution.
4.	Page 13, Paragraph 4.4, Item 2: Although scientific judgment is ultimately used to determine if it is appropriate to transpose a storm, Aterra understands that this assessment is performed following an accepted set of parameters (e.g. elevation differences of +/- 1,000-feet or distances of more than +/- 6-degrees latitude as an initial screen). Aterra recommends adding a bit more detail regarding the framework within which the scientific judgment is applied.	Added wording to more explicitly discuss transposition guidelines.	Concur with resolution.
5.	Page 26, Paragraph 5.3.4.2: The second paragraph states: One of the factors given for determining if a storm is transposable is whether the distance from the storm to the MNGP basin centroid is more than 6 degrees latitude. In Table 4, the all-season PMP short storm list, the latitudes given for Storm 14W (Cole Camp, MO), 15W (Collinsville, IL), and 9W (Edgerton, MO) are more than 6 degrees latitude from the MNGP basin centroid. The reason for including these storms should be explained. Also, it was noted in the PINGP calculation that Storms 13W (Council Grove, KS), 3W (Fall River, KS), and 22W	Added description of reasoning and why the three storms were used at PINGP were not used at MNGP. Corrected in 12-14-2014 revision-track changes edits have now been updated correctly.	Concur with resolutions.

Xcel Energy	Design Review Comment Form

	(Neosho Falls, KS) were included for PINGP but excluded from the MNGP list. The latitude given for these three storms is more than 6 degrees distant from the PINGP basin centroid. The reason for excluding these storms from the MNGP calculation should be explained.		
6.	Page 29, Table 5: Similar to above, the cool-season PMP short storm list, Table 5, includes Storms 3C, 6C, 7C, 9C, and 10C which all are more than 6 degrees latitude from the basin centroid. Storm 3C is shown in Table 12 to be the controlling storm for the 72-hour storm that would be used in the PMF analysis for MN51.1011, Rev. 1GP. The reason these storms were considered transpositional and included in the short list for cool-season PMP storms should be explained.	Added description of reasoning.	Concur with resolution.
7.	Page 29, Table 5: It appears that the bottom of the table repeats the information provided in the top half of the table. Check to confirm that table information is accurate and update table as appropriate.	Removed track changes version of table to avoid confusion.	Concur with resolution.
8.	Page 34, Figure 10: Figure 10 gives an example of the HYSPLIT trajectory model results at 700 mb, 850 mb, and 960 mb levels for the Ashland, WI Storm 2C. It is unclear how this data translates to an inflow flow vector of SSW at 560 miles given in Table 2 of Attachment 2. An explanation would be helpful.	Added more description of how the HYSPLIT data was used.	Concur with resolution.
9.	An explanation should be provided for including the transposition example of the Fall River storm (3W) to the MGNP basin centroid when this storm was not included in the MGNP list of PMP storms.	Good point, a different storm has replaced the Fall River storm used as the example. Note, that initially the Fall River storm was transitioned and used and the further evaluations of its transposition limits determined that this storm was not transpositionable. Corrected in 12-14-2014 revision-track changes edits have now been updated correctly.	Concur with resolutions.
10.	Page 49, Table 6: If the transposition criteria for LIP storms is the same as the criteria for all-season and cool-season PMP storms, an explanation should be provided for including	Like the PMP development, a description was added detailing that the	Concur with resolution.

Xcel Energy	Design Review Comment Form

	Storms 10W, 19W, 26W, 31W, and 4W. These storms have latitudes that are more than 6 degrees distant from the MNGP site latitude. After maximization, the storm with the greatest 1-hour rainfall depth was 22W and the storm with the greatest 6-hour rainfall was 13W. Both of these storms were less than 6 degrees latitude from the MNGP site. However, the question remains – If one of the storms that was farther than 6 degrees from the site had the greatest rainfall, would that storm be considered as the LIP value.	transposition guidelines are just that, guidelines, and judgment is used when storms that are potentially important for PMP development and of the same storm type are still considered.	
11.	The text should be proof read to correct instances where PINGP is confused with MNGP such as the drainage area value on Page 10 of 68, Paragraph 5.3.11.1 on Page 43 of 68, and Table 7 listing the LIP values.	Corrected references to PINGP. Corrected in 12-14-2014 revision-track changes edits have now been updated correctly.	Concur with resolutions.
12.	Pages 26 & 37: References to Attachments B, C, and D on Pages 26 and 37 of 68 should be corrected (i.e. attachments are labeled numerically, not alphabetically).	Corrected to fit Attachments 1, 2, and 3. Corrected in 12-14-2014 revision-track changes edits have now been updated correctly.	Concur with resolution.
13.	Page 32, Paragraph 5.3.5 – Last paragraph, first line – Word "nine" should be deleted per track changes.	Track changes version showed "nine" to be deleted. Corrected in 12-14-2014 revision-track changes edits have now been updated correctly.	Concur with resolution.
14.	Page 35, Paragraph 5.3.6.2 – third paragraph, line 6 "direction an distance" should be changed to "direction and distance".	Incorporated	Concur with resolution.
15	Page 53 of 71, Table 7. The table on the right side of the page has the heading of Prairie Island but the values in the table are for Monticello. If this table is not deleted, it should be identified in the text and the appropriate PI values inserted.	Incorporated.	Concur with resolution.

Reviewer: [signature] Date: 3/10/2015	Preparer: Bill Kappel [signature] Date: 3/10/2015

DARIUSZ KARPINSKI
D. Karpinski 3/10/2015

Xcel Energy	**Design Review Comment Form**

Sheet _1__ of _1__

DOCUMENT NUMBER/ TITLE: Calc. 15-031 Site Specific PMP and Ancillary Meteorological Analysis for EC 25484

REVISION: _0________ DATE: _4/10/15________

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
	.		
2	Change page no. 13 to 14	N/A	N/A
3	Change page no. 13 to 14	N/A	N/A
4	Change page no. 13 to 14	N/A	N/A
5	Change page no. 26 to 27	N/A	N/A
6	Change page no. 29 to 31	N/A	N/A
7	Change page no. 29 to 31	N/A	N/A
8	Change page no. 34 to 36	N/A	N/A
10	Change page no. 49 to 51	N/A	N/A
11	Change pages no. 10 of 68 to 12 of 70 and 43 of 68 to 45 of 70	N/A	N/A
12	Change pages no. 26 to 27 and 37 of 68 to 39 of 70	N/A	N/A
15	Change pages no. 53 of 71 to 52 of 70	N/A	N/A
	Work with QF-0528 Rev.1 3/10/15		
	Reviewer: Dariusz Karpinski__Date: 4/10/15_ D. Karpinski	Preparer:____N/A______________Date:_____ ___	

MONTICELLO NUCLEAR GENERATING PLANT		15-031
TITLE:	Table of Contents	Revision 0
		Page 1 of 1

Item:	DESCRIPTION:	# PAGES:
QF0549	Calculation Signature Sheet	4
QF0547	External Design Document Suitability Review Checklist	2
QF0528	Design Review Comment Form	4
TOC	(this page)	1
Calculation	Body	331
		Total 342

Approval: PCR 01305173

Initiating Document: 15-031 Rev no. 0

Individual Completing Form:

Print Name: Dariusz Karpinski Date: 4/1/15

Signature: D. Karpinski

If the activity is obviously fire protection related, then obtain a review by the Fire Protection Program Engineer (typically documented in the EC or PCR) and discard this form.

If in the process of completing this form, one box is checked "yes", then obtain a review by the Fire Protection Program Engineer (typically documented in the EC or PCR) and discard this form.

If all boxes are checked "no", then the completed form should be retained with the parent process (PCR, EC, etc.).

	YES	NO
1. Independent Spent Fuel Storage Installation (ISFSI)		
Will the proposed change modify the physical location or quantity of any flammable or combustible liquids stored in tanks or contained in plant equipment (including outdoor tanks and equipment)?	☐	☒
Will the proposed change modify the combustible loading within the ISFSI Protected Area fence?	☐	☒
Will the proposed change modify the receiving location for flammable or combustible liquids or gases?	☐	☒
Will the proposed change modify the equipment used to load or transport the Dry Storage Cask (DSC) onto the transit vehicle or to the Horizontal Storage Module (HSM)?	☐	☒
Will the proposed change modify the path of travel (haul path) for loaded DSCs between the Reactor Building and the ISFSI?	☐	☒
Will the proposed change modify any Security procedures for allowing access into the Owner Controlled Area (OCA) for delivery trucks containing flammable or combustible liquids or gases?	☐	☒

	YES	NO
2. Fire Marshall Concerns		
Does the change affect the fire brigade's access to the area?	☐	☒
Does the change affect the fire brigade's ability to fight fires?	☐	☒
Does the change affect any prefire strategies?	☐	☒
3. Facility Arrangement/Access/Egress		
Will the proposed change temporarily or permanently alter or block access to or egress from an area or room, or modify the general arrangement of an area or room?	☐	☒
Will the proposed change renovate or alter the occupancy of an area or room such as enclosing or fencing off an area for use as storage space or establishing a personnel work station or office?	☐	☒
Will the proposed change modify the technical nature of surveillance or periodic test procedures for fire barriers or assemblies?	☐	☒
4. Walls/Barriers		
Are changes proposed to any floors, ceilings or walls, including exterior walls? Changes to floors ceilings and walls would include integral components such as doors and frames (including hardware), dampers, structural steel supports, hatches, curbs, and penetration seals.	☐	☒
5. Interior Finishes		
Are any floors, ceilings or walls being painted, coated or covered?	☐	☒
Are any drop ceilings, paneling, office partitions, windows, or viewing ports being installed, replace or modified?	☐	☒
Is any furniture, shelving or cabinets being removed, replaced or added to any plant operating area?	☐	☒

	YES	NO
6. Combustible Load/Ignition Sources		
Does the proposed change increase, decrease or rearrange the combustible loading in any area or room?	☐	☒
Typical combustibles include cable insulation, oils, fire retardant treated wood, flammable liquids, plastics, etc. If the change is the result of new cables being added or removed and the entire length of cable is or will be in conduit, or the cable is metal clad, this question may be answered no. If the change is the result of wiring, components or devices being installed totally inside an existing panel or removed from an existing panel, this question may be answered no.		
Are any special hazards being introduced into an area or room such as hydrogen or combustible metals such as titanium?	☐	☒
Is an ignition source being temporarily or permanently introduced into an area or room?	☐	☒
480V and above electrical devices are considered ignition sources.		
Are combustibles or hazards being permanently introduced in the owner controlled area?	☐	☒
Will thermal stress relieving be employed?	☐	☒
7. Detection		
Does the proposed change modify any fire detection system including quantity, type, circuitry, detector location, detector spacing, or sensitivity?	☐	☒
Will the proposed change temporarily or permanently remove a fire detection system or alarm capability from service?	☐	☒
Within any room or area, are changes proposed to internal structures, cable trays, ventilation ducts, etc. in close proximity to fire/smoke detectors?	☐	☒
Will the proposed change introduce heat producing or generating devices into an area or room containing fire, flame or smoke detectors?	☐	☒
Will the proposed change modify the technical nature or acceptance criteria of surveillance or periodic test procedures for the plant's fire detection systems?	☐	☒
Will the proposed change modify the response to any plant fire alarm?	☐	☒

	YES	NO
8. Suppression		
Will the proposed change install, modify or eliminate any fire suppression system or manual fire suppression feature, including water or gas supplies and extinguishers?	☐	☒
Will the proposed change temporarily or permanently remove a fire suppression system or component from service?	☐	☒
Is any structure, system or component being introduced or modified such that its final configuration could cause interference with suppression system spray patterns?	☐	☒
Will the proposed change modify the technical nature or acceptance criteria of surveillance or periodic test procedures for the plant's fire suppression systems or water supply equipment?	☐	☒
9. Ventilation		
Will the proposed change alter the location or type of air supply, or discharge registers or other openings intended for air circulation in a room or area containing smoke or fire detectors; or change the velocity, quantity or direction of air being supplied to or discharged from a room or area containing fire detectors?	☐	☒
10. Drainage		
Are temporary or permanent changes proposed to the Reactor or Turbine Building floor drain system including processing equipment?	☐	☒
11. Oil Systems		
Does the proposed change introduce, alter or eliminate any lube oil or fuel oil system including piping route, line pressure, or method of system operation?	☐	☒
Does the proposed change affect any lube oil or fuel oil storage device?	☐	☒
Does the proposed change affect any lube oil or fuel oil containment or collection feature?	☐	☒

	YES	NO
12. Fire Resistive Coatings/Fire Proofing		
Are changes proposed that will in any way install, modify, eliminate or change the type of fire resistive coating/fire proofing on structural steel or other commodities?	☐	☒
Will the proposed change alter the thickness acceptance criteria of fire coating/fire proofing material?	☐	☒

13. Safe Shutdown Systems

NOTE 1: Calculations and test/inspection procedures related to Tech Spec compliance or related to component operational readiness i.a.w. Tech Specs, USAR, or the IST Program are excluded from consideration (this includes component performance required to support the GE LOCA analysis).

NOTE 2: The preparer has the option to consult USAR Appendix J.4, Safe Shutdown Analysis, in answering this question. If USAR Appendix J.4 was consulted, complete PART A. Otherwise, complete PART B.

PART A – USAR Appendix J.4 ☒ **N/A**

	YES	NO
Is the affected component(s) identified in USAR Appendix J.4? If component is identified, answer question YES and note component below.	☐	☐

____

____

____

____

____

____

	YES	NO
PART B – N/A PART B if USAR Appendix J.4 was reviewed in PART A above. ☐ **N/A**		
Does the proposed change involve any of the following systems including components, devices, piping, circuits, cables, power supplies or support functions? If YES, check appropriate box(es)	☐	☒

- ☐ Core Spray
- ☐ Residual Heat Removal (Suppression Pool Cooling Mode)
- ☐ RHR Service Water System
- ☐ RHR Auxiliary Air System
- ☐ ECCS Room Coolers
- ☐ Reactor Pressure Relief System (SRV's)
- ☐ Main Steam (MSIV's)
- ☐ Suppression Pool Level
- ☐ Suppression Pool Temperature (SPOTMOS)
- ☐ Reactor Vessel Level
- ☐ Reactor Vessel Pressure
- ☐ Alternate Shutdown System (ASDS)
- ☐ Emergency Service Water System
- ☐ Control Rod Drive (P-201B)
- ☐ Reactor Water Cleanup (MO-2401)
- ☐ 120V AC Power System
- ☐ 125V DC Essential Power System
- ☐ 250V DC Power System
- ☐ 4kV/480V AC Essential Power System
- ☐ AC Emergency Power System (Diesel Generators, Support Equipment and Fuel Supply)
- ☐ Control Room Ventilation (including Instrumentation)

14. Circuits

	YES	NO
Are any changes proposed to the ASDS Panel (C-292) or ASDS Relay Panel (C-293)?	☐	☒

	YES	NO
15. Breaker Coordination/Associated Circuits		
Are changes proposed to vital power supplies including 125V DC, 120V AC, 480V, and 4160V, such that, the breaker coordination of these supplies may be affected (adding, deleting or revising loads)?	☐	☒
16. Alternate Shutdown/Control Room Evacuation		
Will the proposed change modify the technical nature of Procedure C.4-C?	☐	☒
Will the proposed change revise any procedure used to assure availability/accessibility of post-fire control room evacuation support equipment contained in the ASDS Panel Equipment Cabinet (procedures, portable lights, radios, etc.)?	☐	☒
17. Portable Fuel Oil Transfer Pump		
Will the proposed change alter the installation, surveillance or test procedures associated with the portable fuel oil transfer pump?	☐	☒
18. Communications		
Will the proposed change modify or replace the radio system, including power supply?	☐	☒
Will the proposed change alter the technical nature or acceptance criteria of the radio system surveillance or periodic test procedures?	☐	☒
19. Emergency Lights		
Will the proposed change add, eliminate, change the location or otherwise modify any battery powered emergency lights?	☐	☒
Will the proposed change introduce any commodities that may block the beam of battery powered emergency lights?	☐	☒
Will the proposed change modify the technical nature of the surveillance or periodic test procedures for battery powered emergency lights?	☐	☒

20. NEIL Design Review

NEIL is one of the plant's insurers and provides primary property insurance, excess property insurance and accidental outage insurance. In order to facilitate identification of actual risk and insured values NEIL requires that they be provided a design review for several types of changes.

If a planned addition, renovation or alteration involves a structure, system or component that is (or will be) insured by NEIL and the change is intended to be permanent (i.e., in place over 180 days), and any of the questions outlined below are answered yes, then the project requires a NEIL

Question	YES	NO
1. Is this design change a new structure?	☐	☒
2. Does the addition, renovation or alteration change the occupancy classification of any part of a NEIL insured structure?	☐	☒
3. Does the design change involve the addition of a new fire protection system?	☐	☒
4. Does the change significantly add to, renovate or alter an existing NEIL required fire detection or fire protection system? For example, this does not include relocation of less than 10% of the fire detectors or suppression heads/nozzles for a single system while still maintaining code compliance.	☐	☒
5. Does the change create an addition to an existing NEIL insured structure?	☐	☒
6. Does the change involve replacement of the roof decking and/or covering such that it would not meet the requirements of the NEIL Property Loss Control Standards?	☐	☒
7. Does the design change affect an interior finish such that it would not meet the requirements of the NEIL Property Loss Control Standards?	☐	☒
8. Does the design change reduce the fire rating of a NEIL required fire rated barrier?	☐	☒
9. Does the design change add to, renovate or alter the fire protection water supply or distribution systems, or use the fire protection water supply and distribution systems for other than emergency use?	☐	☒

	YES	NO
10. Does the design change add to, renovate or alter the cooling tower fill or supports?	☐	☒
11. Does the design change add oil filled components over 50 gallons oil capacity?	☐	☒
12. Does the change add to, renovate or alter oil collection systems, fire barriers or fire protection systems for oil filled component.	☐	☒

If all questions are answered NO:

If all boxes are checked "no", then the completed form should be retained with the parent process (PCR, EC, etc.).

If any question is answered YES:

A review is required by a Fire Protection and/or Appendix R Safe Shutdown Subject Matter Expert (SME) to determine if the proposed change affects the Fire Protection Program. It is possible that a question answered YES on this checklist eventually results in no impact to the Program. Document the review in the parent process. Typically Fire Protection/Appendix R review is documented in the parent process e.g. PROT review for PCRs, milestone reviews for ECs (type EQV and DOC ONLY).

BLACK & VEATCH Building a world of difference.	**CALCULATION CONTINUATION SHEET**

Client/Dept. Xcel –Monticello Record No. 180999.51.1008
Project Monticello Nuclear Generating Plant Flood Hazard Analysis Project No. 180999
Calculation No. 180999.51.1008 File No. 180999.51.1000
Calculation Title Site Specific PMP and Ancillary Meteorological Analysis Rev. 1

Calculation Type: ☐ Preliminary ☒ Final
Seismic Classification: ☐ I ☐ II ☒ NS ☐ Other
Safety-Related: ☒ Yes ☐ No ☐ Other

OBJECTIVE

The objective of this calculation is to determine the site-specific all-season and cool-season Probable Maximum Precipitation (PMP) and Local Intense Precipitation (LIP) at the site.

DEFERRED DESIGN VERIFICATION ITEMS

No.	Deferred Design Verification Description	DVR No.*	Date
	None		

COMPUTER PROGRAM CALCULATIONS

Computer Program Title SPAS Version 9.5 SCR-1700-01
Computer Program Title R Version 2.15.1 SCR-1710-01

REVIEW AND APPROVAL

Rev.	Prepared By		DVR No.*	Approved By	
	Print and Sign	Date		Print and Sign	Date
0	Doug Hultstrand,	08/31/2014	DVR-0011	Steve Thomas	9/11/2014
1			DVR-		

*Indicate Design Verification Review (DVR) number.

This calculation supersedes Calculation Number None
This calculation is superseded by Calculation Number None

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Attachment 2 - “Cool-Season Short Storm List Data " (37 pages)

Attachment 3 –“Local Intense Precipitation Short Storm List Data" (894 pages)

Attachment 4 – “100-year Return Frequency Average Dew Point Climatology Maps Used in the Storm Maximization and Transposition Calculations” (36 pages)

Attachment 5 – "Procedure for using Dew Point Temperatures for Storm Maximization and Transposition” (5 pages)

Attachment 6 –“ Procedure for Deriving PMP Values from Storm Depth-Area-Duration Analyses" (6 pages)

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1.0 Purpose and Scope

As part of a 10 CFR 50.54(f) letter to Xcel Energy, the Nuclear Regulatory Commission (NRC) requested that Monticello Nuclear Generating Plant (MNGP) perform a reevaluation of all appropriate external flooding sources, including the effects from Local Intense Precipitation (LIP) on the site, Probable Maximum Flood (PMF) on stream and rivers, storm surges, seiches, tsunami, and dam failures.

The purpose of this calculation is to estimate the site-specific Probable Maximum Precipitation (PMP) that can occur in the 14,051-square mile watershed to the MNGP watershed (Figure 1), and the LIP PMP event that can occur directly over the MNGP site. These PMP estimates are needed to calculate the PMF and maximum flood levels during the LIP event, respectively, at the plant site. PMP values representing all-season (May through October) and cool-season (November through April-also known as snow season PMP) are explicitly determined.

The PMP and LIP evaluation utilizes the most recent data available, building on several similar studies completed by Applied Weather Associates (AWA) in the region (Reference 14, Reference 23, Reference 24, Reference 25) and providing significant improvements to the Hydrometeorological Reports (HMRs) relevant for the site (HMRs 51, 52, and 53, (Reference 1, Reference 2, Reference 3). Parameters to estimate the MNGP PMP and LIP are derived based on past extreme rainfall events that have occurred in and around the locations after appropriate adjustments and maximizations have been applied. This process explicitly takes into account the characteristics that are specific to the overall watershed and MNGP site, including the unique meteorology, climatology, and topography of the region. The implementation of the updated data, methods, and meteorological understanding provides for a reliable estimation of PMP and LIP possible given the current scientific understanding and enhances the reliability of the calculations compared to the outdated HMRs.

This calculation also provides hourly meteorological data representing the temperature, dew point, and wind speeds which would be expected to occur at the same time as the cool-season PMP. These data are needed to

calculate the snowmelt that would occur during the cool-season PMP. The all-season PMP and the cool-season PMP plus snowmelt respectively address Alternatives I and III (Section 9.2.1.1, Reference 4).

This calculation is performed according to the guidelines presented in the following:

1) NUREG/CR-7046, Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America (Reference 22);
2) ANSI/ANS 2.8-1992, American National Standard for Determining Design Basis Flooding at Power Reactor Sites (Reference 4).
3) Hydrometeorological Report No. 51 (HMR 51), Probable Maximum Precipitation Estimates – United States East of the 105th Meridian (Reference 1)
4) Hydrometeorological Report No. 52 (HMR 52), Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian (Reference 2)
5) World Meteorological Organization, Manual for Estimation of Probable Maximum Precipitation, (Reference 28)

Revision 1 replaces several appendices with the correct appendices. Revision 1 also makes some minor editorial corrections.

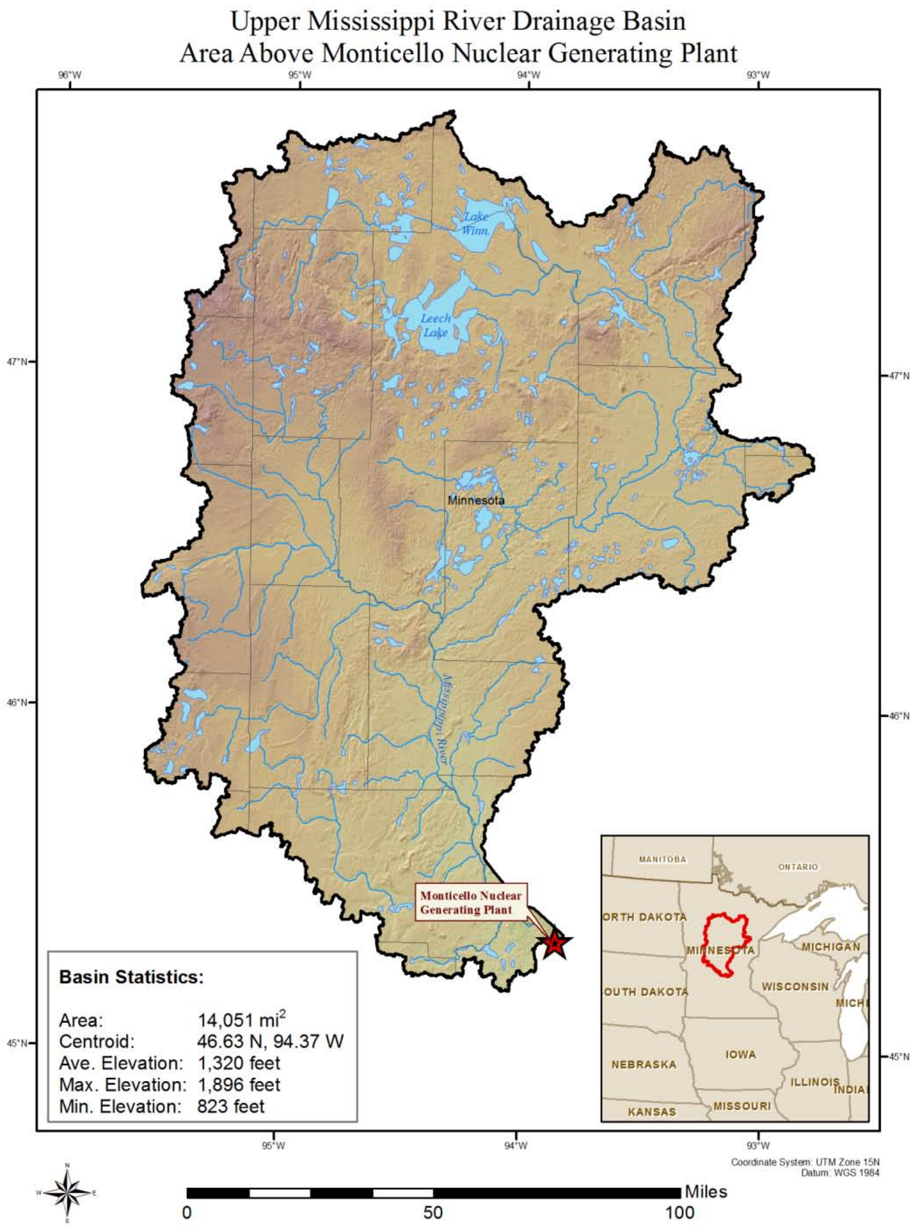

Figure 1. Overall watershed and regional location of MNGP

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3.0 Summary and Conclusions

3.1 Summary of Results

This calculation determines the site-specific rainfall during the all-season PMP and cool-season PMP storm events in the 45,24414,051 square mile watershed to MNGP. The analysis also provides the meteorological parameters used as input to the energy budget equation (Reference 29) used to determine the amount of snowmelt. The site-specific Depth-Area-Duration (DAD)values determined in this analysis are the following: (1) the all-season PMP values from 10-square miles to 100,000-square miles from 6-hours through 72-hours (Table 1), (2) the cool-season PMP values from 10-square miles to 100,000-square miles from 6-hours through 72-hours (Table 2), and (3) the site-specific LIP values for 5-, 15-, 30-minutes, 1- and 6-hours (Table 3). The tables summarizing these three results tables are replicated in this section in Tables 1, 2 and 3 respectively.

Table 1. Site-Specific All-Season Probable Maximum Precipitation

	Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
Monticello All-Season Site-Specific PMP Values (in inches) at the Basin Centroid	10sqmi	13.6	17.3	21.0	23.5	24.0
	100sqmi	11.7	14.9	19.4	22.3	22.7
	200sqmi	10.9	14.0	18.4	21.2	21.7
	500sqmi	9.7	12.6	16.6	19.0	19.9
	1000sqmi	8.6	11.5	15.0	17.3	18.3
	2000sqmi	7.5	10.0	13.2	15.6	16.4
	5000sqmi	5.8	7.9	11.0	13.6	14.0
	10000sqmi	4.7	6.5	9.1	12.0	12.2
	20000sqmi	3.7	5.1	7.3	10.0	10.2
	50000sqmi	2.4	3.6	5.0	7.0	7.2
	100000sqmi	1.4	2.3	3.0	4.5	4.7

Table 2. Site-Specific Cool-Season Probable Maximum Precipitation

	Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
Monticello Cool-Season Site-Specifc PMP Values (in Inches) at the Basin Centroid	10sqmi	5.2	6.1	8.0	9.1	9.9
	100sqmi	5.0	5.8	7.7	8.7	9.4
	200sqmi	4.8	5.6	7.5	8.5	9.2
	500sqmi	4.5	5.3	7.2	8.2	8.9
	1000sqmi	4.2	5.0	6.9	7.9	8.6
	2000sqmi	3.9	4.7	6.6	7.6	8.3
	5000sqmi	3.3	4.2	6.0	7.1	7.9
	10000sqmi	2.7	3.6	5.5	6.6	7.4
	20000sqmi	2.2	3.0	4.8	6.1	6.8
	50000sqmi	1.4	2.2	3.8	5.0	5.7
	100000sqmi	0.9	1.6	3.0	3.7	4.4

Table 3. Site-Specific Local Intense Precipitation

Time in minutes	Monticello Nuclear Generating Station PMP in Inches for 1-hour 1-square mile
5	4.5
15	7.2
30	10.2
60 (1 Hour)	13.2
Time in minutes	**Monticello Nuclear Generating Station PMP in Inches for 6-hour 1-square mile**
360 (6 Hours)	20.6

3.2 Conclusions

1) The site-specific all-season PMP values determined during this calculation were generally lower than those provided in HMR 51. Reasons for the differences in computed PMP values are discussed in Section 5.3.15 of this calculation. It should be noted that much of the data, process, and decisions utilized in HMR 51 to derive their PMP values are undocumented and unknown and therefore only limited comparisons can be made.

2) The site-specific LIP values determined during this calculation were lower than the values provided in HMR 52. Reasons for the differences in computed PMP values are discussed in Section 5.3.12.2.1 of this calculation. It should be noted that much of the data, process, and decisions utilized in HMR 51 to derive their PMP values are undocumented and unknown and therefore only limited comparisons can be made.

3) The storm search and selection of storms for PMP development emphasized storms with the largest rainfall values relevant to the overall basin area size of 14,051-square miles and at durations of 1-day and 3-days that are transpositionable to the basin. Therefore, PMP results derived in this calculation should not be used for basin sizes significantly smaller than evaluated here or in areas where these storms are not transpositionable.

4) The storm search and selection of storms for LIP development emphasized storms with the largest rainfall values relevant to the MNGP site with intense rainfall over area sizes less than 500-square miles, and at durations of 1-hour. Therefore, LIP results derived in this calculation should not be used for basin sizes significantly larger than 1-square mile or in areas where these storms are not transpositionable.

4.0 Design

4.1 Design Inputs

The following inputs are used in this calculation.

4.1.1 National Climatic Data Center (NCDC) Cooperative Summary of the Day and Hourly Weather Observations

The data are published by the NCDC. Data can be obtained by contacted the NCDC or using the NCDC online data request interface at http://www.ncdc.noaa.gov/data-access/quick-links.

4.1.2 Hydrometeorological Reports Storm Information

Depth-Area-Duration information in the Attachment of HMR 51, 1-hour rainfall information from HMR 52 Table 21, and sub-hourly rainfall ratios from HMR 52 Figures 36, 37, and 38 were used.

4.1.3 US Army Corps of Engineers (USACE) Storm Studies

Depth-Area-Duration data from USACE storm studies sheets were used. Each of the storm studies sheets used in this analysis are included in Attachments 1, 2, and 3.

4.1.4 Applied Weather Associates Storm Analyses

Storm analyses completed using AWA's Storm Precipitation Analysis System (SPAS) (Reference 21) which were used in previous PMP and LIP calculations were utilized in this analysis. Data for each SPAS analysis used in this calculation are included in Attachments 1, 2, and 3. Each SPAS analysis used in this calculation has been peer reviewed during the development of PMP and LIP values during other calculations. All SPAS analyses have been accepted for use in PMP and LIP determination by the Federal Energy Regulatory Commission (FERC)..

4.2 Design Margins

Client Margin – No specific margin is required by the client.
Safety Margin – No specific safety margin is applied.
Design Margin – No specific design margin is applied.
Operation Margin – No specific operation margin is applied.
Other Margin - No specific other margins are applied.

4.3 Acceptance Criteria

There are no acceptance criteria associated with this calculation. This calculation only determines input values for use in subsequent analyses.

4.4 Assumptions

There are no unverified assumptions used in this calculation.

The following verified assumptions are used in this calculation.

1) This calculation assumes that if we an appropriate set ofThe storm events has been identified, analyzed, and maximized, they will represent the meteorological environment associated with the PMP for the basin and the LIP for the site. This assumption is validated by including a large enough set of PMP-type and LIP-type storms to ensure no storms which could have potentially affected PMP or LIP values after all adjustments were applied were left out of the analysis. This same assumption is made in HMR 51 (Reference 1).
2) It is assumed that storms transposed to the MNGP basin centroid for PMP or the MNGP site location for LIP could have occurred over the area under similar meteorological conditions. This decision is made using scientific judgment related to the storm type, season of occurrence, similarity of topography between the original locations and the new location, and experience analyzing past storms. Parameters used in screening for transpositionability include not moving storms across the Appalachian crest, employing a +/- 1,000 foot limitation between the original storm location and the basin centroid or site location, and limiting the north/south region of transposition to approximately +/- 6° longitude. Note that judgment is still employed for storms that are questionable following these guidelines so that conservatism is applied when a storm potentially affecting PMP is near one of these boundaries. This follows the same guidance provided in HMR 51 Section 2.4.2 (Reference 1).
3) It is assumed that the cool-season PMP values are considered and analyzed as a rain-on-snow scenario where some amount of rainfall accumulates when snow is on the ground and are combined with a given amount of snow melt to derive the total runoff associated with a cool-season PMP The cool-season PMP values are considered and analyzed as a rain-on-snow scenario and are combined with a given amount of snow melt to derive the total runoff associated with a cool-season PMP rainfall.
4) The atmospheric air masses that provide moisture to both historic storms and the PMP storm are assumed to be saturated through the entire depth of the atmosphere and to contain the maximum moisture possible based on the surface dew point. This assumes moist pseudo-adiabatic temperature profiles for both the historic storms and the PMP storm. In addition, it is assumed that the maximum amount of moisture the atmosphere can hold is available to the PMP storm. This follows the same guidance provided in HMR 51 (Reference 1) and WMO Manual for PMP (Reference 28).
5) The assumption is made that if additional atmospheric moisture had been available, the storm would have maintained the same efficiency for converting atmospheric moisture to rainfall. The ratio of the maximized rainfall amounts to the actual rainfall amounts would be the same as the ratio of the precipitable water (the total atmospheric water vapor contained in a vertical column of unit cross-sectional area extending between any two specified levels in the atmosphere) in the atmosphere associated with each storm. For this analysis, the assumption of no change in storm efficiency is accepted, mirroring the HMR (Reference 1) and WMO assumptions (Reference 28).

6) The climatological maximum dew point for a date 15 days towards the warm season from the date that the storm actually occurred is applied in the storm maximization process. This procedure assumes that the storm could have occurred 15 days earlier or later in the year when maximum dew points (and moisture levels) are higher. This assumption follows HMR guidance and is consistent with procedures used to develop PMP values in all the current HMR documents (e.g., HMR 51, Section 2.3 Reference 1; HMR 59, Section 4.2, Reference 5; and World Meteorological Organization (WMO) (Reference 28), as well as all AWA PMP studies (Reference 15, Reference 23, Reference 24, Reference 25).

7) Storm efficiency does not change if additional atmospheric moisture is available. For this analysis, the assumption of no change in storm efficiency is accepted, mirroring the HMR (Reference 1) and WMO assumptions (Reference 28).

8)7) Changes in climate that will occur in the region are adequately accounted for by the rarity of the resulting PMP and LIP values. Further, changes in climate which have occurred during the past 150 years are captured in the storm record and rainfall data used in this analysis and therefore represent any changes that would be expected during the useful lifetime of the values. Therefore, no adjustment is made to account for potential changes in climate. This follows the same guidance provided in the HMRs (Reference 1) and WMO Manual for PMP of assuming no climate change (Reference 28).

5.0 Analysis

This calculation provides both all-season and cool-season PMP values for use in the computation of the Probable Maximum Flood (PMF) for the MNGP watershed and the LIP values for the MNGP site. The site-specific calculations build on the previous PMP studies completed by AWA in the region (e.g., Reference 15, Reference 23, Reference 24, Reference 25).

The PMP is a deterministic estimate of the theoretical maximum depth of precipitation that can occur over a specified area. Parameters to estimate the PMP were developed based on the storm based, deterministic approach as presented in HMR 51 and subsequently refined in the numerous site-specific, statewide, and regional PMP studies completed since its publication in 1978. All-season PMP, cool-season PMP, and LIP were calculated following the storm based approach and provide deterministic values for each.

5.1 PMP Development Background

Definitions of PMP are found in most HMRs published by the National Weather Service (NWS). The definition used in the most recently published HMR (HMR 59, p. 5 Reference 5) is *"theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year*." From the mid-1940s through the mid-1990's, several government agencies had been developing methods to calculate PMP in various regions of the United States. The NWS (formerly the U.S. Weather Bureau) and the Bureau of Reclamation had been the primary agencies involved in this activity. PMP values from their reports are used to calculate the PMF which, in turn, is often used for the design of significant hydraulic structures and in this case to determine flood protection actions.

The generalized PMP studies currently in use in the conterminous United States include HMR 49 (Reference 11) for the Colorado River and Great Basin drainage; HMRs 51 (Reference 1), 52 (Reference 2) and 53 (Reference 3) for the U.S. east of the 105th meridian; HMR 55A (13) for the area between the Continental Divide and the 103rd meridian; HMR 57 (12) for the Columbia River Drainage; and HMR 59 (5) for California. The region covered by HMR 51 constitutes the largest generalized region addressed by a single HMR. In addition to these HMRs, numerous Technical Papers and Reports deal with specific subjects concerning precipitation. Topics include maximum observed rainfall amounts, return periods for various rainfall amounts, and specific storm studies. Climatological atlases are available for use in determining rainfall amounts for specified return periods for selected regions of the U.S.

However, there are no concurrent HMR documents providing cool-season PMP values. In addition, very little documentation related to cool-season PMF scenarios and meteorological guidance exists. The USACE (1973, 1998) and American Nuclear Society (ANS,1992) have published documents with guidance related to snow accumulation and snow melt and use with rain-on-snow runoff situations. However, most of the data associated with cool-season PMF is outdated (e.g. HMR 22 US Weather Bureau 1946, Reference 26). Therefore, it was imperative that as part of this PMP calculation, the cool-season PMP was explicitly derived. In addition, the meteorological parameters used to model snowmelt that would occur during the cool-season PMP required extensive analyses using the same storm based approach to ensure consistency of such parameters from the proper modeling and development of the cool-season PMF.

A number of site-specific and regional PMP studies augment generalized HMRs. These studies are for specific regions or drainage basins within the large area addressed by HMR 51 (over half of the contiguous United States). The meteorological conditions producing extreme rainfall events vary significantly in different regions within this large geographic area. In much of the Midwest and the regional affecting the MNGP watershed, extreme events are usually linked to either Mesoscale Convective Systems (MCSs) or synoptic storms with embedded convection. The main storm type leading to PMF level flooding is a synoptic event with embedded convection. This type of storm provides steady rainfall over long durations and large area sizes, with periods of heavy rainfall. This same type of storm occurs in the spring, but with less moisture available. However, when antecedent snow pack is on the ground, the combination of rain-on-snow may overcome the limited moisture for rainfall production to produce PMF level floods. Because short duration, intense rainfalls produced by MCS storms do not produce large flood events for this basin, this storm type was excluded from the PMP analysis and therefore did not influence the all-season PMP values. This storm type was explicitly accounted for in the development of the LIP values (see Section 5.3.12). Not including this storm type for basin-wide PMP development only affects area sizes less than 500-square miles and durations less than 24-hours.

Although it provides generalized estimates of PMP values for a large, climatologically diverse area, HMR 51 recognizes that studies addressing PMP over specific regions can incorporate more site-specific considerations and provide improved PMP estimates. By periodically reviewing storm data and advances in meteorological concepts, PMP analysts can identify relevant new data and approaches for use in determining PMP estimates (HMR 51, Section 1.4.1).

As described previously, several site-specific, statewide, and regional PMP studies have been completed by AWA (e.g. Reference 15, Reference 23, Reference 24, Reference 25) within the region covered by HMR 51. Each of these studies provided PMP values which replaced those from HMR 51. In addition, in regions where rain-on-snow

scenarios could potentially produce the PMF, a cool-season analysis was also completed (e.g. Reference 15). These are good examples of PMP studies that explicitly consider the meteorology and topography of the study location along with characteristics of historic extreme storms over climatically similar regions. Information, experience, and data derived during these previous AWA PMP studies were utilized in this calculation. This included use of the previously analyzed storm events using the Storm Precipitation Analysis System (SPAS) program, the previously derived storm lists, the previously derived storm maximizations and climatologies, and the explicit understanding of the meteorology of the region. In addition, comparisons to these previous studies provided sensitivity and context against the results of this calculation. These regional and site-specific PMP studies have received extensive review and been accepted by the appropriate regulatory agencies, including the Federal Energy Regulatory Commission, state dam safety regulators, the Natural Resources Conservation Service (NRCS), the USACE, and the Bureau of Reclamation (USBR). Results have been used in computing the PMF for individual watersheds.

5.2 Approach

The approach used in this calculation follows the same basic procedures that were used in the development of the HMRs and as recommended in the WMO Manual for PMP. These procedures were applied considering the meteorological and topographic characteristics of the basin. The calculation maintains as much consistency as possible with the general method used in HMR 51 and the numerous site-specific, statewide, and regional PMP studies AWA has completed. Deviations are incorporated where justified by developments in meteorological analyses and available data. The basic approach identifies PMP-type storms that occurred within the central United States and southern Canada west of the first upslope of the west side of the Appalachians to approximately 100° longitude and south to the southern plains. This ensured a sufficiently large region was included in the storm list development so that any transpositionable storm that could potentially affect the all-season or cool-season PMP values at any area size or duration was included.

The moisture content of each of these storms is maximized to provide an estimate of the maximum rainfall for each storm at the location where it occurred. This is accomplished by computing the ratio of the *maximum* amount of atmospheric moisture that could have been entrained into the storm at that time of year to the *actual* atmospheric moisture entrained into the storm as it occurred in-place. After maximization, the storms are transpositioned to the basin centroid to the extent supportable by similarity of meteorological conditions and topography. Maximized and transpositioned adjusted rainfall values are enveloped at the basin centroid to provide PMP estimates for various area sizes and durations. Figure 2 shows the flow chart of the major steps in the PMP development process. There are a number of assumptions that need to be applied to establish a consistent application of meteorological principles. These assumptions are provided in Section 4.4.

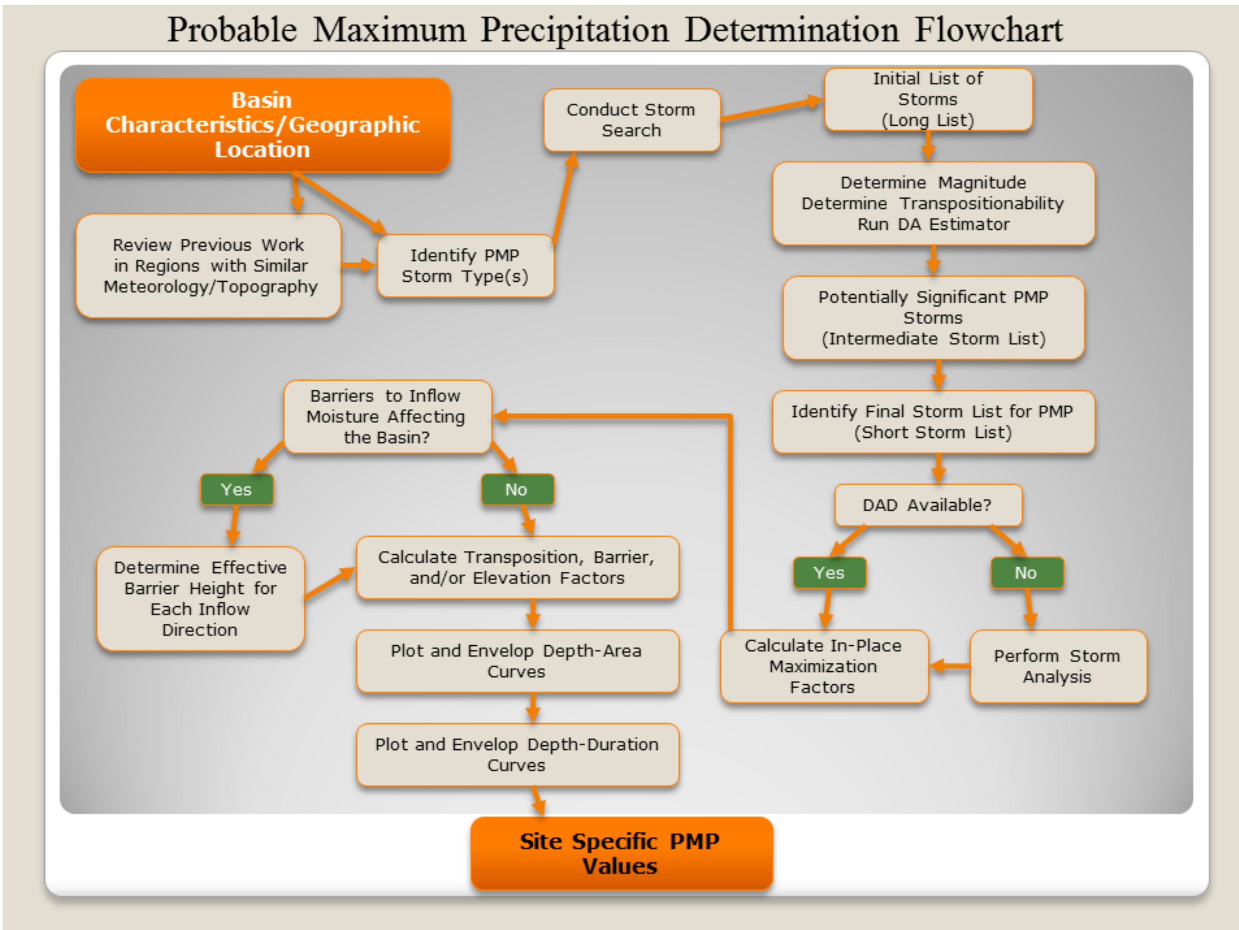


Figure 2. Flow chart detailing the major steps in PMP development

5.2.1 Watershed Location and Description

The MNGP watershed covers most of the central Minnesota (see Figure 1). The northerly latitude of the basin's location in the Upper Midwest plays an important role in the PMP storm types and the cool-season PMP/PMF scenarios. Often, a snow pack accumulates during the winter season and is available to melt in conjunction with spring rainfall. The large size of the basin and its geographic location have been explicitly evaluated and considered during the calculation to ensure appropriate PMP development. Elevation changes across the basin are not extreme and range from just over 800 feet at the MNGP site along the Mississippi River to over 1,896 feet in northwestern area of the watershed. Therefore, no elevation limitations are placed on storms within the basin, and instead the average basin elevation and basin centroid location are used in all storm maximization and transposition calculations.

5.3 Probable Maximum Precipitation Calculation

The all-season and cool-season PMP calculations, as well as the LIP, were completed using Microsoft Excel spreadsheets, SPAS and ESRI ArcGIS. The current state-of-the-science meteorological methodologies were employed as described below in identifying, maximization, and combining storms to produce PMP and LIP values. The deterministic, storm-based approach as described in the HMRs and follow in all previous AWA studies was utilized as the basic methodology during the calculation.

5.3.1 PMP Storm Type and Climatology

The region around the MNGP watershed is influenced by several factors that can potentially contribute to extreme rainfall. First is the proximity of the region to the Gulf of Mexico and the fact that no intervening barrier prevents moisture from moving north (Figure 3). This allows elevated amounts of moisture to move directly into the region. The limiting factor is the duration that these high levels of moisture are able to feed into storms in the region. Because of the basin's northerly locations and distance from the Gulf of Mexico, storm patterns generally do not stay fixed in one location for long periods. Therefore, the synoptic situations which lead to high levels of Gulf moisture moving into the region are transient and limit the magnitude of PMP-type rainfall as well as limiting the spatial extent of such storms. This lack of consistent moisture is somewhat compensated for by the stronger storm dynamics associated with synoptic weather systems which move through the region.

In addition to the moisture, a mechanism is required to produce rising motions in the atmosphere and condense the moisture. The lift required to convert these high levels of atmospheric moisture into rainfall on the ground is provided in several ways in and around the region. Synoptic storm dynamics are very effective in converting atmospheric moisture into rainfall on the ground. These are most often associated with fronts which affect the region (Figure 4). Numerous large scale weather systems with their associated fronts traverse the northern Great Plains and upper Midwest through the year, with the fewest and weakest occurring in the summer period. The fronts (boundaries between two different air masses) can be a focusing mechanism providing upward motion in the atmosphere. These are often locations where heavy rainfall is produced. Normally a front will move through with enough speed that no one area receives excessive amounts of rainfall. However, in extreme instances the pattern can become blocked and some of these fronts will stall or move very slowly across the region. This allows heavy amounts of rainfall to continue for several days in the same general area, which can lead to extreme widespread flooding.

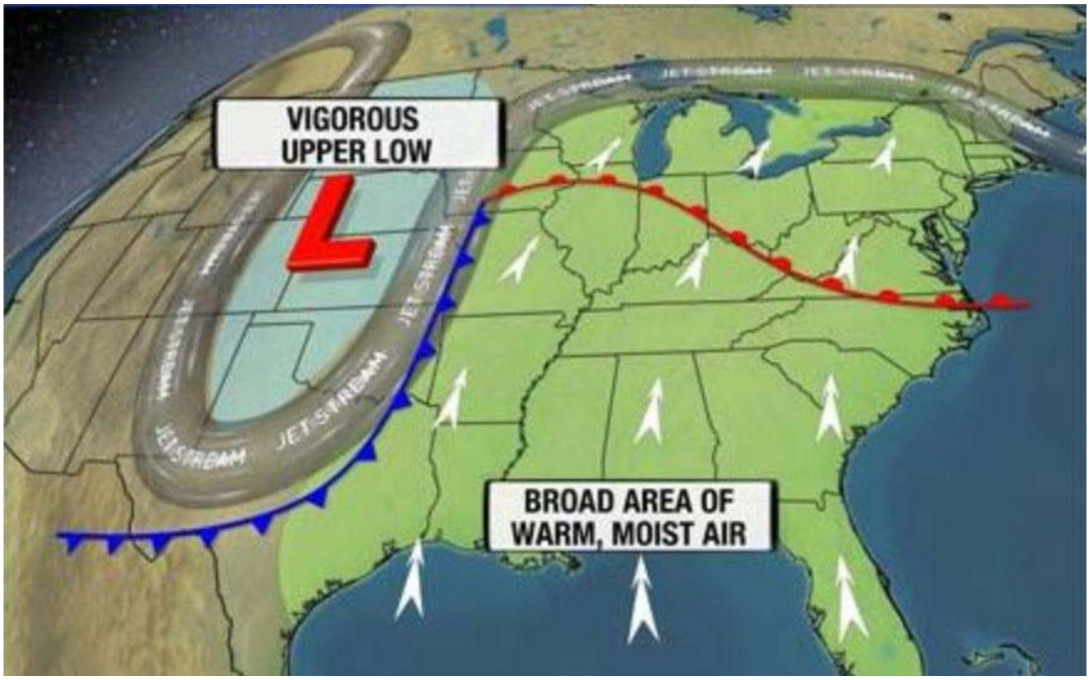


Figure 3. Surface features associated with moisture moving from the Gulf of Mexico to the upper Midwest

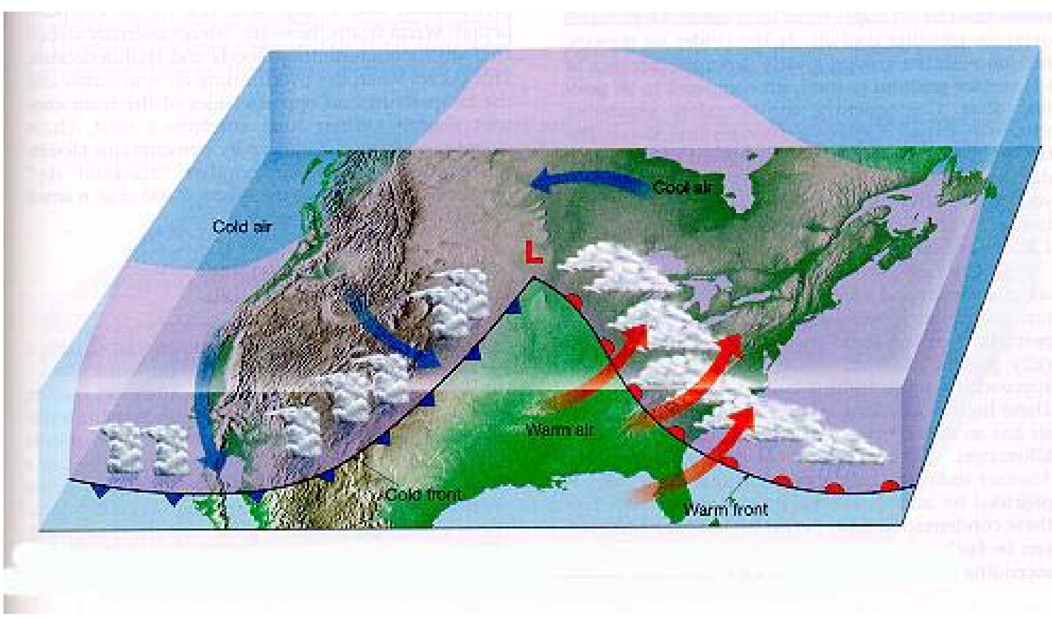


Figure 4. Surface fronts associated with synoptic pattern leading to heavy rainfall in the upper Midwest

Another mechanism which creates lift in the region is heating of the surface and lower atmosphere by the solar radiation. This creates warmer air below colder air resulting in atmospheric instability and leads to rising motions. This will often form ordinary afternoon and evening thunderstorms. However, in unique circumstances the instability and moisture levels in the atmosphere can reach very high levels and stay over the same region for an extended period of time. This can lead to intense thunderstorms and very heavy rainfall. If these storms are focused over the same area for a long period, flooding rains can be produced. This type of storm produces some of the largest point rainfall amounts recorded, but often do not affect larger areas with extreme rainfall amounts. Therefore, although this rainfall producing mechanism is common in the spring and summer, they do not lead to PMF level flood events across the very large MNGP watershed. However, this is the type of storm which could produce the LIP rainfall over the MNGP site.

5.3.2 General Weather Patterns

The weather patterns in the region are characterized by passages of fronts with differing air masses that lead to large ranges in temperatures and rainfall. Fronts are most prevalent in the fall, winter, and spring, with more stagnant patterns common from late spring through early fall (see Figure 5).

There are several air mass types that affect the weather and climate of the region and produce heavy rainfall. The continental polar (cP) air mass, with origins from the arctic regions of Canada, is most common during the winter months. This air mass is often associated with a strong cold front passage and stratiform snowfall events. When this air mass type arrives, it often collides with a more humid air mass from warmer regions to the south. Low pressure (rising air) often results, and when combined with strong winds aloft, can produce flooding. This is also a common storm type for cool-season rainfall events, occurring most often from March through April.

The second type of air mass observed in the region is the maritime polar (mP) which originates in the Gulf of Alaska and Pacific Ocean. This air mass often arrives on strong winds from the west and northwest, but is usually devoid of significant amounts of low level moisture because it has traveled across several mountain ranges. This storm type often produces precipitation (rain and snow) at these upstream locations, losing much of its low-level moisture on its way to the northern and central Plains. However, in extreme cases, moisture flowing north from the Gulf of Mexico can replenish low-level atmospheric moisture enough to produce heavy rainfall. If the storm system stalls over the region, flood producing rains can result. This storm type can occur anytime of the year, but is most common from fall through late spring. This scenario can produce heavy rain-on-snow during the cool-season PMP scenario.

Another type of air mass which affects the region and produces rainfall originates from the Gulf of Mexico and can contain copious amounts of atmospheric moisture in a conditionally unstable atmosphere. This type of air mass is called maritime tropical (mT). This type of air mass is most directly responsible for producing heavy rainfall in the region when interacting with a front and as well as an air mass of polar origins moving from the north. Generally, the frontal boundary is located just to the south or within the southern portions of the basin, allowing high amounts of moisture to stream in from the south and is lifted over the frontal boundary. The release of the conditional instability in the atmosphere provides a very efficient mechanism to convert atmospheric moisture to rain on the ground. If this pattern is able to remain in place for an extended period and continue to tap into Gulf of Mexico moisture, flooding can result. This storm type is most common in the summer to early fall and is therefore the most common storm type for the all-season PMP scenario.

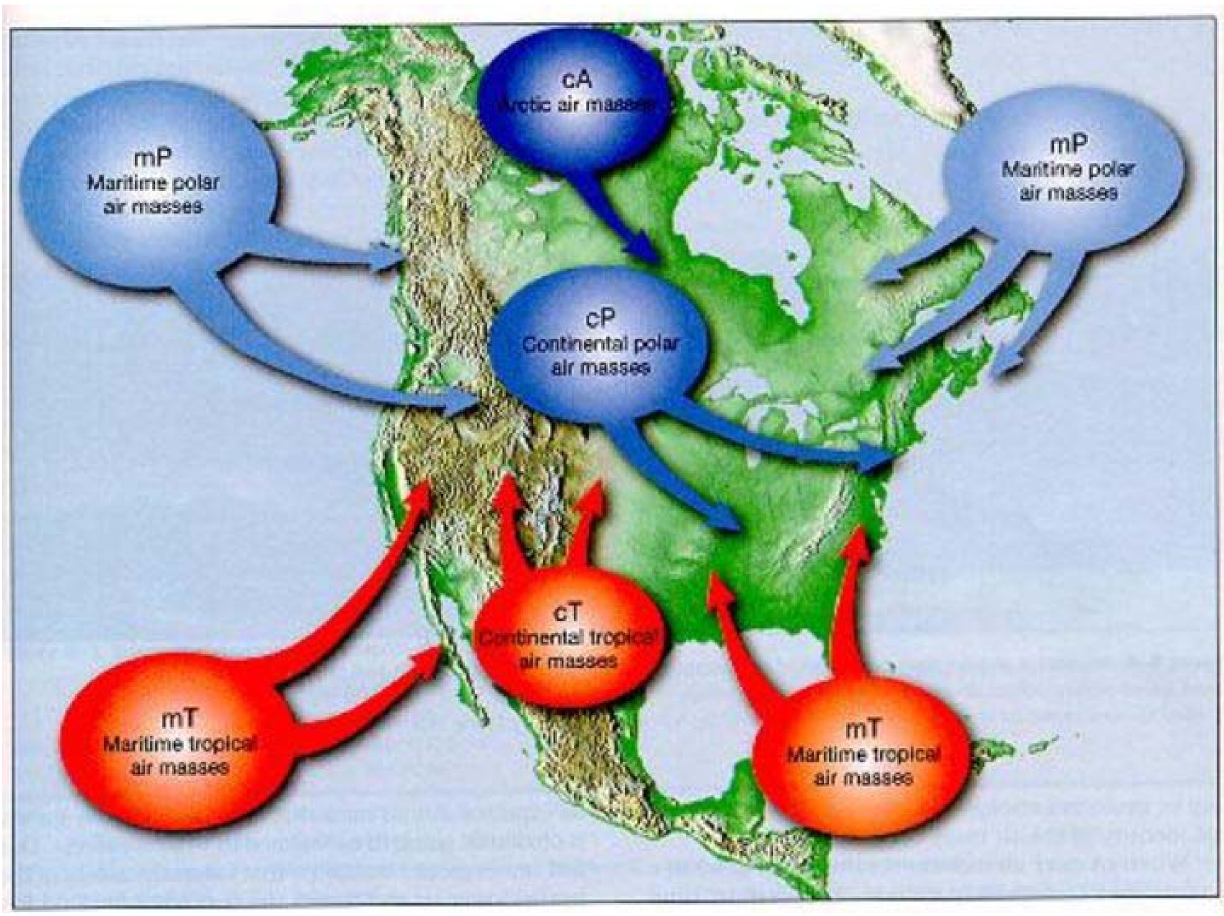


Figure 5. Locations of surface fronts associated

5.3.3 MNGP Storm Types

The MNGP watershed and the surrounding region have very active and varied weather patterns throughout the year. Consequently heavy rainfall events at both short and long durations are common. By far, the largest amount of moisture available for rainfall over the region comes from the Gulf of Mexico. The major types of extreme rainfall events in the region are produced by Mesoscale Convective Systems (MCS's), which produce high rainfalls at short durations and small area sizes and synoptic events/fronts, which produce rainfall over large areas sizes and longer durations.

5.3.3.1 Synoptic Scale Weather Systems

The polar front and jet stream, which separate cool, dry Canadian air to the north from warm, moist air to the south, is often a cause of heavy rainfall over large areas and long durations. This boundary provides large amounts of energy and strong storm dynamics to the atmosphere as fronts move through the region. These features are

strongest and most active over the area during fall, winter, and spring months. A common type of storm occurrence with the polar front is an overrunning event. Frontal overrunning occurs when warm, humid air carried northward around the western edge of the Bermuda High circulation encounters the frontal zone and is forced to rise over the cooler, drier air mass to the north of the front. This forced ascent condenses atmospheric moisture in the air mass, forming clouds and producing precipitation while releasing latent heat. This process most often results in widespread rainfall over longer durations, but can also help enhance convection. Air that arrives at the frontal location is conditionally unstable, where the lower layers are much warmer and more humid than the air above. This conditionally unstable air mass needs a mechanism to initiate lift to begin energy release, leading to more instability and further lift. The forced ascent over the polar front initiates the lifting of the moist air mass, release of its energy in the form of latent heat, and initiates the conversion of the atmospheric moisture to rainfall.

A stationary or slow moving polar front located near the MNGP watershed will often provide the mechanism necessary for this warm, humid air mass to release its convective potential. When this occurs, rainfall is produced, sometimes associated with pockets of convection and extremely heavy rainfall. The pockets of heavy rain are usually associated with a minor wave riding along the frontal boundary, called a shortwave. These are not strong enough to move the overall large scale pattern, but instead add to the storm dynamics and energy available for producing rainfall.

This type of storm environment (synoptic frontal) will usually not produce the highest rainfall rates over short durations, but instead leads to flooding situations as heavy to moderate rain continues to fall over the same regions for an extended period of time. In addition, this scenario can occur during the cool-season and therefore enhance snow melt runoff with an intense rain-on-snow even.

5.3.3.2 Mesoscale Convective Systems

Mesoscale Convective Systems (MCS, Reference 16, Reference 17) are capable of producing extreme amounts of rainfall for short durations and over small area sizes, generally 12 hours or less over area sizes of 500-square miles or less. The current understanding of MCS type storms has progressed tremendously with the advent of satellite technology starting in the 1970s and early 1980s. The current name of MCS was first applied in the late 1970s to these type of “flood producing”, strong thunderstorm complexes (Maddox 1980, Maddox 1981). Mesoscale systems are so named because they are small in areal extent (10's to 100's of square miles), whereas synoptic storm events are 100's to 1000's of square miles. MCSs also exhibit a distinctive signature on satellite imagery where they show rapidly growing cirrus clouds shields with very high cloud tops. Furthermore, the high level cloud shield associated with MCSs usually take on a nearly circular pattern about the size of the state of Iowa with constantly regenerating thunderstorms fed by a low-level-jet (LLJ) bringing an inflow of atmospheric moisture (Figure 6).

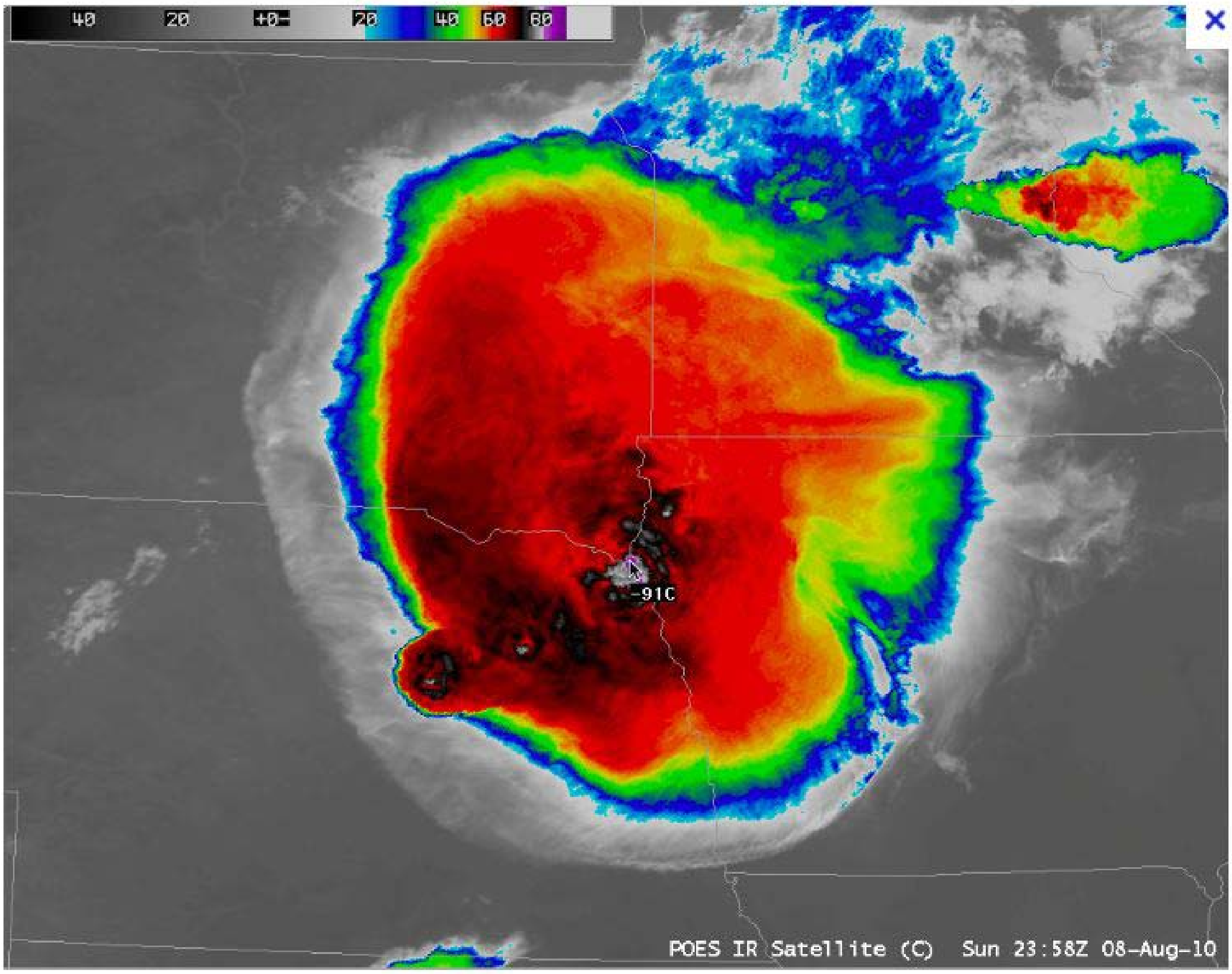


Figure 6. Color enhanced infrared satellite image of an MCS. Note the nearly circular structure, very cold/high clouds tops (signified by the red, black, and center white colors), and a size similar to the state of Iowa.

MCSs are included in the more general definition of Mesoscale Convective Complexes (MCCs), which include a wider variety of mesoscale sized storm systems, such as squall lines and tropical cyclones, and MCSs that do not fit the strict definition of size, duration, and/or appearance on satellite imagery. MCSs primarily form during the warm season months (May through October) around the MNGP region.

Many of the storms previously analyzed by the USACE and NWS Hydrometeorological Branch in support of pre-1979 PMP research have features that indicate they were most likely MCCs or MCSs. However, this nomenclature had not yet been introduced into the scientific literature, nor were the events fully understood. For MNGP watershed, pure MCS storms do not produce PMF level flood events because of the very large basin size and the relatively small areas of rainfall produced by MCSs. However, intense convection similar to this storm type can occur within an overall synoptic frontal event. This can lead to intense areas of embedded rainfall within the

overall lighter rainfall pattern. This combination of synoptic and convective storm types is very important for determining PMP values for the basin. Most importantly, these types of storms, along with individual thunderstorms, produce the LIP rainfall at the MNGP site.

5.3.4 Storm Identification and Storm List Development

A comprehensive storm search covering the region important for the MNGP watershed has been conducted during previous site-specific and regional PMP studies. This included an analysis of all extreme rainfall storms in meteorological and topographically similar regions, where extreme rainfall storms similar to those that could occur over some part of the basin may have been observed. These previous storm search results are current through mid-2014 and include all 12 months of the year, and therefore allowed for storm list development for both the all-season and cool-season storm lists (Figure 7). This insured a large enough area was analyzed to capture all significant storms that could potentially influence the final PMP values for the basin.

Figure 7. Storm search domain

5.3.4.1 Storm Search Data Sources

Storm searches and storm list development were completed by analyzing the storm lists used in the PMP studies completed by the NWS and AWA in the region within the storm search domain. All storms used in previous studies were equal to or greater than the 100-year recurrence interval value associated with the total storm accumulation at the storm center location. This ensures that only storms which could potentially influence PMP values were further analyzed. In addition, each of the storms used in the previous PMP analyses were important for PMP development after all adjustment calculations were applied. Storms used in PMP development during those studies were compiled into a long list of storms for this work. Each of these storms were verified for use in PMP

and LIP development as being accurate analyses of the given event. Numerous data sets and resources were used in the storm search and storm validation process during these previous studies. These include the NCDC, HMRs, USACE Storm Studies, United States Geological Survey reports, peer reviewed journal articles, Community Collaborative Rain, Hail, and Snow network (COCORAHS), NWS office reports, various weather books, and other publications. All of these data and the resulting storm events have been accepted through thorough peer review processes which included independent expert review and Federal and state dame safety acceptance.

5.3.4.2 Short Storm List Derivation

The final short storm list used to determine the PMP values for MNGP watershed was derived using the results of previous PMP studies in regions similar to this basin. These include the EPRI Michigan/Wisconsin Regional PMP study, the Nebraska Statewide PMP study, the Ohio Statewide PMP study, the Wyoming Statewide PMP study, the Tarrant Regional Water District PMP study, and the Quad Cities PMP study.

During this process, the final short storm lists used in each of these studies was combined and evaluated. The first set of parameters used to delineate the storms was whether they were transpositionable to the basin centroid. Factors such as elevation differences of more than +/- 1,000 feet and/or distances of more than +/- six degrees6° latitude were considered. These factors follow guidance in the HMRs (Reference 1, Reference 12, Reference 13). A few storms with storm centers in the southern Great Plains and Midwest were included even though they were slightly more than 6° latitude difference than the basin centroid latitude. This is because these storms are of the same type that would be expected over the basin and could produce PMP and they had rainfall accumulations which extended well north of the highest rainfall center location and therefore within the 6° latitude extent. In these situations, the conservative assumption is employed and the storm is allowed to be used in the PMP calculations. This applied to both cool-season and all-season storm transposition considerations. Finally, the storm type was evaluated. Storm types which would not result in a PMP/PMF scenario for the large MNGP watershed were not considered. This included storms which were individual MCS and thunderstorms.

Three storms used in the all-season PMP development of the Prairie Island Nuclear Generating Plant (PINGP) were not used in the PMP development for MNGP. This is because these three storms occurred furhter south than the storm used here and well south of the 6° latitude consideration. This combined with the fact that the majority of the MNGP basin is farther north than the Prairie Island Nuclear Generating Plant PINGP) meant that these storms were not used in the PMP development at MNGP. Next, the storm type was evaluated. Storm types which would not result in a PMP/PMF scenario for the large MNGP watershed were not considered. This included storms which were individual MCS and thunderstorms.

These analyses resulted in the final short storm lists used to derive both the all-season and cool-season PMP values for the basin. Tables 4 and 5 display the storm lists. Figures 8 and 9 display the locations of the storms on each list. The AWA Storm Number is used to identify each storm used in this calculation to derive PMP values, with the "W" designation representing the all-season storm period and the "C" representing the cool-season storm period. Note that the locator shown on the Figures 8 and 9 represents the location with the highest recorded total storm rainfall for each event. However, the overall rainfall pattern is generally much larger, often covering thousands of square miles. The total storm rainfall patterns for each storm, along with other relevant storm information, can be found in Attachments B1, C 2 and D3.

Many of the storms included in the final short storm list used to calculate PMP values occurred many hundreds of miles away from the MNGP watershed. Storm centers were used from locations as far north as southern Canada and as far as south as southern Missouri. This is required because it is unlikely that a storm has occurred over the basin being studied which controls PMP values at all area sizes and durations during the period of record for which data is available. Therefore, by including a large area from which to transposition storm events, one is trading space for time. And, as long as all the storms being moved in from these distant locations are considered transpositionable (similar topography and meteorology between the two locations), then standard procedures are being followed.

For cool-season storms, an additional consideration was applied to the storms used and whether they were considered transpositionable. In those scenarios, the storm dynamics (which provided the lift and turn moisture in the air to rainfall on the ground) had to be similar to what would have been expected to occur over the MNGP watershed during rain-on-snow events. Therefore, all the storms on the cool-season short storm list are of the general storm type where a slow moving (or stalled) front separating cold air to the north and west and warm air to the south and east is located over the Midwest. This synoptic situation is common in the winter and spring over the region, with storms in the historical record having occurred from southern Canada to the southern plains. These storms generally produce widespread rainfall over several days, often with embedded convection. In some instances, especially ones which have occurred over the more northern latitudes, snow is on the ground when the rain falls, while in other situations there is no snow on the ground. However, whether snow is on the ground or not during the actual storm occurrence was not a deciding factor in whether to include a given event in the analysis. Instead, the storm had to be able to occur hypothetically over the MNGP watershed (be transpositionable) in a situation when snow *could* have been on the ground and be of the appropriate synoptic storm type to be a storm which could occur with snow on the ground whether there was any during the actual storm or not. This is similar to the assumptions of using past extreme rainfall events and assuming they represent what a PMP storm would look like after maximization and transposition and is fundamental to the storm-based deterministic procedures..

Table 4. All-season short storm list

Storm Name	State	AWA Storm Number	Lat	Lon	Year	Month	Day	Maximum Rainfall in Inches	Precipitation Source
DULUTH	MN	41W	47.0200	-91.6700	2012	6	19	10.73	SPAS 1296
DUBUQUE	IA	1W	42.4400	90.7500	2011	7	27	15.14	SPAS 1220
HOKAH	MN	4W	43.8125	-91.3625	2007	8	18	18.32	SPAS 1048
WARROAD	MN	43W	48.8792	-95.0792	2002	6	9	14.55	SPAS 1297
AURORA COLLEGE	IL	5W	41.4575	-88.0699	1996	7	16	18.13	SPAS 1286
BIG RAPIDS	MI	6W	43.6125	-85.3125	1986	9	9	13.42	SPAS 1206
WOOSTER	OH	8W	40.9146	-81.9729	1969	7	4	14.95	SPAS 1209
EDGERTON	MO	9W	40.4125	-95.5125	1965	7	18	20.76	SPAS 1183
IDA GROVE	IA	11W	42.3167	-95.4667	1962	8	30	12.85	EPRI
PRAGUE	NE	12W	41.3583	-96.8794	1959	8	1	13.09	SPAS 1031
COLE CAMP	MO	14W	38.4600	-93.2027	1946	8	12	19.40	MR 7-2A
COLLINSVILLE	IL	15W	38.6717	-89.9800	1946	8	12	18.70	MR 7-2B
HAYWARD	WI	18W	46.0130	-91.4846	1941	8	28	15.00	UMV 1-22
IRONWOOD	MI	21W	46.4500	-90.1833	1909	7	21	13.20	UMV 1-11B
MEDFORD	WI	23W	45.1333	-90.3333	1905	6	4	11.20	GL 2-12
WOODBURN	IA	24W	41.0120	-93.5991	1903	8	24	15.50	MR 1-10
LAMBERT	MN	25W	47.8000	-96.0000	1897	7	18	8.00	UMV 1-2

Locations of All-Season Storms - Short List
Monticello Nuclear Generating Plant

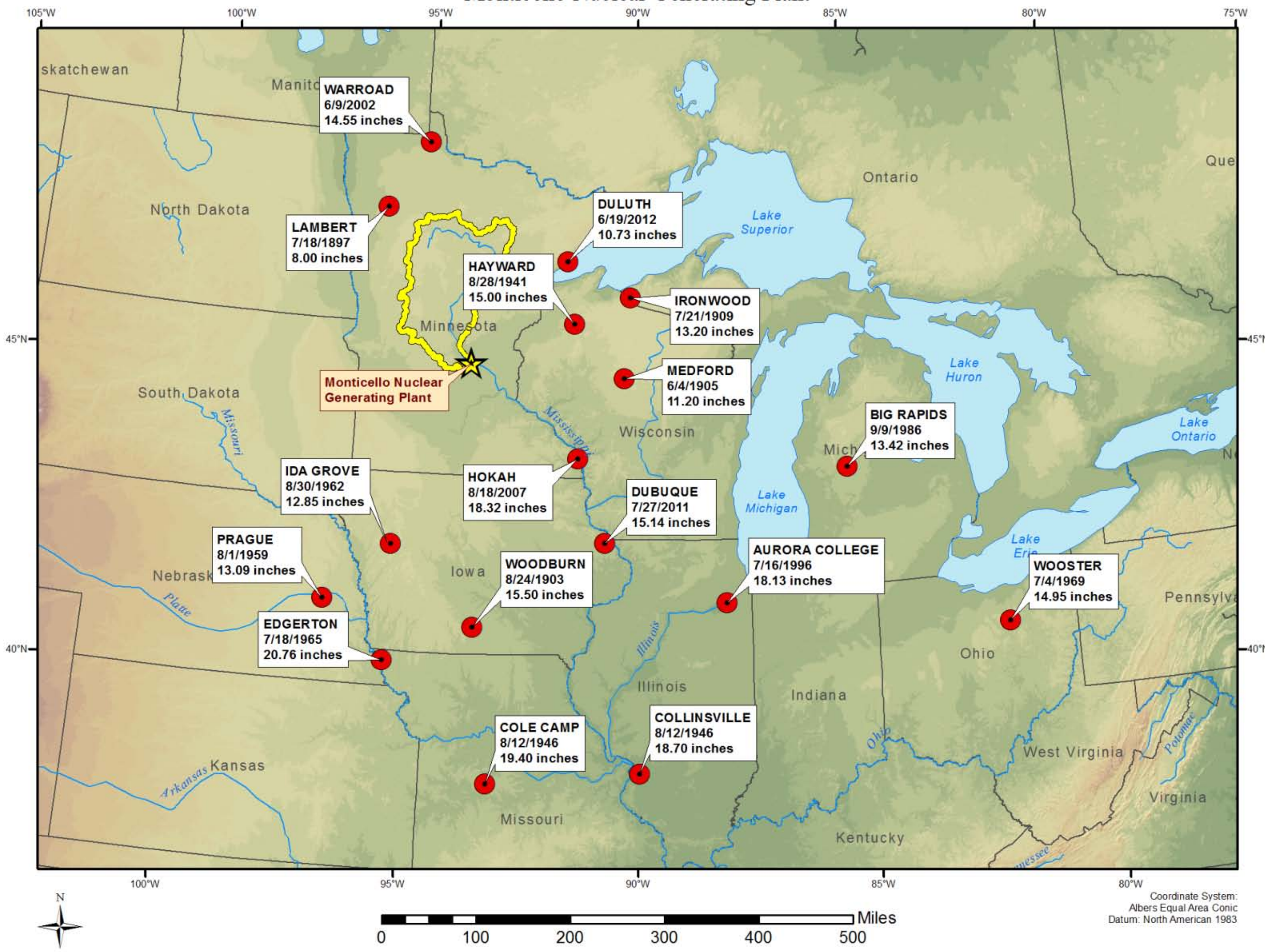


Figure 8. All-season short storm list locations in relation to the MNGP watershed

Table 5. Cool-season short storm list

Storm Name	State	AWA Storm Number	Lat	Lon	Year	Month	Day	Maximum Rainfall in Inches	Precipitation Source
ASHLAND	WI	2C	46.5542	-90.9100	2001	4	20	8.62	SPAS 1245
BELLEFONTAINE	OH	7C	40.3670	-83.7670	1913	3	23	11.20	OR 1-15
CONCEPTION	MO	10C	40.2428	-94.6869	1919	5	2	6.20	MR 2-20
LANSING	MI	4C	42.7300	-84.5600	1975	4	18	5.12	EPRI
LOUISVILLE	KY	3C	38.1000	-85.6700	1997	2	28	13.51	SPAS 1244
MADISONVILLE	KY	6C	37.3167	-87.4833	1964	3	8	11.53	SPAS 1278
OCONTO	WI	11C	44.8900	-87.8700	1919	4	5	4.50	GL 2-19
TUSCUMBIA	MO	9C	38.2331	-92.4585	1927	3	17	5.50	MR 3-10A

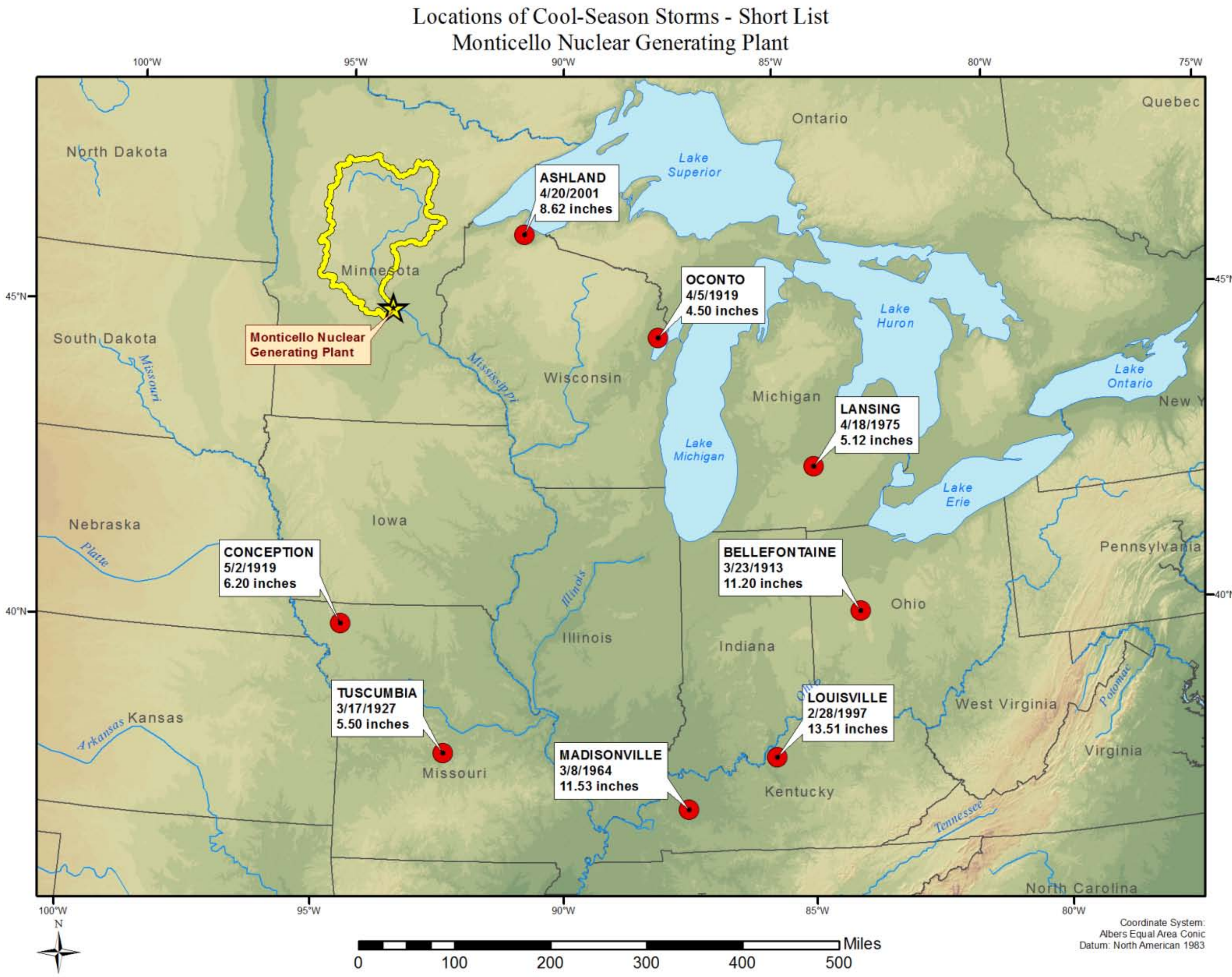


Figure 9. Cool-season short storm list locations in relation to the MNGP watershed

5.3.5 Storm Depth-Area-Duration Analyses and Development Using SPAS

For newly identified extreme rainfall events without published DAD analyses, full storm analyses needed to be completed. SPAS was used to compute DADs for these storms.

The DAD analysis is completed by creation of high-resolution hourly precipitation grids and computation of depth-area rainfall amounts for various durations. Reliability of results depends on the accuracy of hourly rainfall grids. SPAS utilizes Geographic Information Systems (GIS) concepts to create more spatially-oriented and accurate results in an efficient manner (step 1). Furthermore, the availability of NEXRAD data allows SPAS to better account

for the spatial and temporal variability of storm precipitation for events occurring since the early 1990s. Prior to NEXRAD, the National Weather Service (NWS) developed and used a method based on the research of several scientists (Reference 6). Because this process has been the standard for many years and holds merit, the DAD analysis process developed within the SPAS program attempts to mimic it as much as possible. By adopting this approach, consistency between the newly analyzed storms and the hundreds of storms already analyzed is achieved.

As part of the development of the PMP values for the MNGP basin, nine 12 SPAS storms were used, nine all-season storms and three cool-season storms. The results of each SPAS storm analysis are included in Attachments 1, 2, and 3.

5.3.5.1 SPAS Data Collection

The areal extent of a storm's rainfall was evaluated using existing maps and documents along with plots of total storm rainfall. Based on the storm's spatial domain (longitude-latitude box), hourly and daily data were extracted for the specified area, date and time. To account for the temporal variability in observation times at daily stations, the extracted hourly data must capture the entire observational period of all extracted daily stations. For example, if a station takes daily observations at 8:00 AM local time, then the hourly data needs to be complete from 8:00 AM local time the day prior. As long as the hourly data are sufficient to capture all of the daily station observations, the hourly variability in the daily observations can be properly addressed.

The daily database is comprised of data from NCDC TD-3206 (pre 1948) and TD-3200 (1948 through present). The hourly database is comprised of data from NCDC TD-3240 and NOAAs Meteorological Assimilation Data Ingest System (MADIS). The daily supplemental database is largely comprised of data from "bucket surveys," local rain gauge networks (e.g. ALERT, USGS) and daily gauges with accumulated data.

5.3.5.2 Mass Curve

The most complete rainfall observational dataset available is compiled for each storm. To obtain temporal resolution to the nearest hour in the final DAD results, it is necessary to distribute the daily precipitation observations (at daily stations) into hourly bins. This process has traditionally been accomplished by anchoring each of the daily stations to a single hourly timer station. However, this may introduce biases and may not correctly represent hourly precipitation at locations between hourly stations. A preferred approach is to anchor the daily station to some set of the nearest hourly stations. This is accomplished using a spatially based approach that is called the spatially based mass curve (SMC) process.

5.3.5.3 Hourly or Sub-Hourly Precipitation Maps

At this point, SPAS can either operate in its standard mode or in NEXRAD-mode to create high resolution hourly or sub-hourly (for NEXRAD storms) grids. In practice both modes are run when NEXRAD data are available so that a comparison can be made between the methods. Regardless of the mode, the resulting rainfall grids serve as the basis for the DAD computations.

5.3.5.4 Depth-Area-Duration Program

The DAD extension of SPAS runs from within a Geographic Resource Analysis Support System (GRASS) GIS environment and utilizes many of the built-in functions for calculation of area sizes and average depths. The following is an outline of the procedure:

1) Given a duration (e.g. x-hours) and cumulative precipitation, sum up the appropriate hourly or sub-hourly precipitation grids to obtain an x-hour total precipitation grid starting with the first x-hour moving window.
2) Determine x-hour precipitation total and its associated areal coverage. Store these values. Repeat for various lower rainfall thresholds. Store the average rainfall depths and area sizes.
3) The result is a table of depth of precipitation and associated area sizes for each x-hour window location. Summarize the results by moving through each of the area sizes and choosing the maximum precipitation amount. A log-linear plot of these values provides the depth-area curve for the x-hour duration.
4) Based on the log-linear plot of the rainfall depth-area curve for the x-hour duration, determine rainfall amounts for the standard area sizes for the final DAD table. Store these values as the rainfall amounts for the standard sizes for the x-duration period. Determine if the x-hour duration period is the longest duration period being analyzed. If it is not, analyze the next longest duration period and return to step 1.

Construct the final DAD table with the stored rainfall values for each standard area for each duration period most.

5.3.6 Updated data sets used in this study

Updated data sets not used in the development of HMR 51 were used as part of this calculation in the development of the PMP values. These include the derivation of an updated maximum dew point climatology for use in storm maximization and transposition, the use of the Hybrid Single Particle Lagrangian Integrated Trajectory Model trajectory model (HYSPLIT) (Reference 7) to help in identifying the moisture source region for individual storm events, and the new SPAS storm analyses discussed previously. The identification and use of these data sets provide a significant improvement in storm adjustments, especially relating to the determination of each storm's moisture source and derivation of appropriate maximization factor.

5.3.6.1 Development of the updated dew point climatology

As part of previous and ongoing AWA PMP studies, updated dew point climatologies have been developed. These updated maximum average dew point climatologies provide 20-year, 50-year, and 100-year return frequency values for 6-hour, 12-hour, and 24-hour durations. This process followed the same reasoning and use as described in the other AWA PMP studies (Reference 15, Reference, 23, Reference 24). These analyses demonstrated that the maximum 12-hour persisting dew point climatology used in HMR 51 was outdated and more importantly did not adequately represent the atmospheric moisture available in the PMP storm environment. The updated climatology more accurately represents the atmospheric moisture fueling storms by using average maximum dew point values observed over durations specific to each storm's rainfall duration. The average maximum dew point values replace the maximum 12-hour persisting dew point values which often missed or underestimated the atmospheric moisture available and hence lead to overly conservative maximization calculations.

5.3.6.2 HYSPLIT trajectory model

The HYSPLIT trajectory model developed by the NOAA Air Resources Laboratory (Reference 7) was used during the analysis of each of the rainfall events included on the short storm list when available 1948-present from the National Centers for Environmental Prediction (NCEP) Global Reanalysis fields. Use of a trajectory model provides increased confidence for determining moisture inflow vectors and storm representative dew points. The HYSPLIT model trajectories have been used to analyze the moisture inflow vectors in other PMP studies completed by AWA over the past several years. During these analyses, the model trajectory results were verified and the utility explicitly evaluated.

Instead of subjectively determining the moisture inflow trajectory using hand analysis of weather observations, the HYSPLIT model web interface was used to determine the trajectory of the moisture inflow, both location and altitude, for various levels in the atmosphere associated with the storm's rainfall production. The HYSPLIT model was run for trajectories at several levels of the lower atmosphere to capture the moisture source for each storm event. These included 700mb (approximately 10,000 feet), 850mb (approximately 5,000 feet), and storm center location surface elevation. For the majority of the analyses a combination of all three levels was determined to be most appropriate for use in evaluation of the upwind moisture source location. It is important to note that the resulting HYSPLIT model trajectories are only used as a general guide of where to evaluate the moisture source for storms in space and time. The final determination of the storm representative dew point and its location is determined following the standard procedures used by AWA in previous PMP studies and as outlined in the HMRs and WMO manuals. As an example, Figure 10 shows the HYSPLIT trajectory model results used to analyze the inflow vector for the Ashland, WI, April 2001.

In this example, all three levels of the HYSPLIT trajectory analysis show air parcels (and hence moisture) advecting into the storm center from a southerly component. This information is then used with other data sources such as surface dew point observations, synoptic weather patterns, and moisture source regions to help identify regions for evaluation of the moisture source and storm representative dew point used in the storm maximization process. The point selected as the storm representative dew point location is then connected to the storm center location (location of highest rainfall accumulation) and the direction an distance connecting these two points becomes the inflow vector associated with the storm. For the example shown in Figure 10, the inflow vector for the Ashland, WI April 2001 storm is SSW at 560 miles.

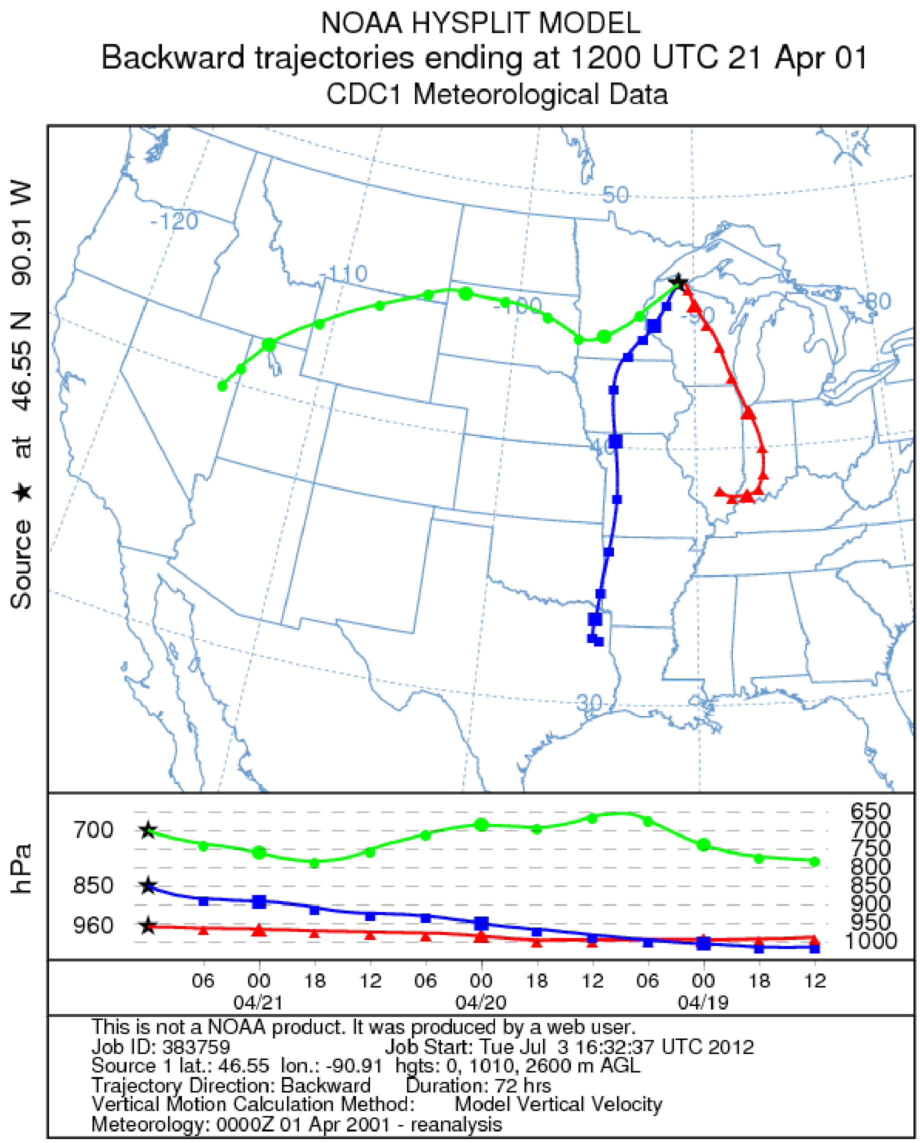


Figure 10. HYSPLIT Model trajectory example

5.3.7 In-place storm maximization process

Storm maximization is the process of increasing rainfall associated with a historical observed extreme storm under the potential condition that additional moisture could have been available to the storm for rainfall production. This is accomplished by increasing the surface dew points to some climatological maximum and calculating the enhanced rainfall amounts that could potentially have been produced if those enhanced amounts of moisture had been available when the storm occurred. In this calculation, surface-based dew points were used in the maximization calculations. The dew points were subsequently adjusted to the elevation of the storm location. This was done to remove the amount of moisture associated with the analyzed dew point that would not be available

below that elevation, as the moisture associated with those values represents moisture in the atmospheric column above ground level.

An additional consideration is usually applied that selects the climatological maximum dew point for a date 15 days towards the warm season from the date that the storm actually occurred. This procedure assumes that the storm could have occurred 15 days earlier or later in the year when maximum dew points (and moisture levels) are higher. This assumption follows HMR guidance and is consistent with procedures used to develop PMP values in all the current HMR, as well as all AWA PMP studies.

HMR and WMO procedures for storm maximization use a representative storm dew point as the parameter to represent available moisture to a storm (assuming the atmosphere is saturated). Storm precipitation amounts are maximized using the ratio of precipitable water for the maximum dew point to precipitable water for the observed storm representative dew point.

Maximum dew point climatologies are used to determine the maximum atmospheric moisture that could have been available. This study utilized the 6-, 12-, and 24-hour average 100-year recurrence interval dew point climatology developed during the Nebraska statewide PMP study (Reference 24) and updated during the Ohio statewide PMP study (Reference 25). Figure 11 displays an example of the 24-hour 100-year recurrence interval dew point climatology for the month of July. Similar maps for each month of the year for each duration (6-, 12-, and 24-hours) were utilized and are provided in Attachment 4.

Client/Dept. Xcel –Monticello | Record No. 180999.51.1008
Project Monticello Nuclear Generating Plant Flood Hazard Analysis | Project No. 180999
Calculation No. 180999.51.1008 | File No. 180999.51.1000
Calculation Title Site Specific PMP and Ancillary Meteorological Analysis | Rev. 1

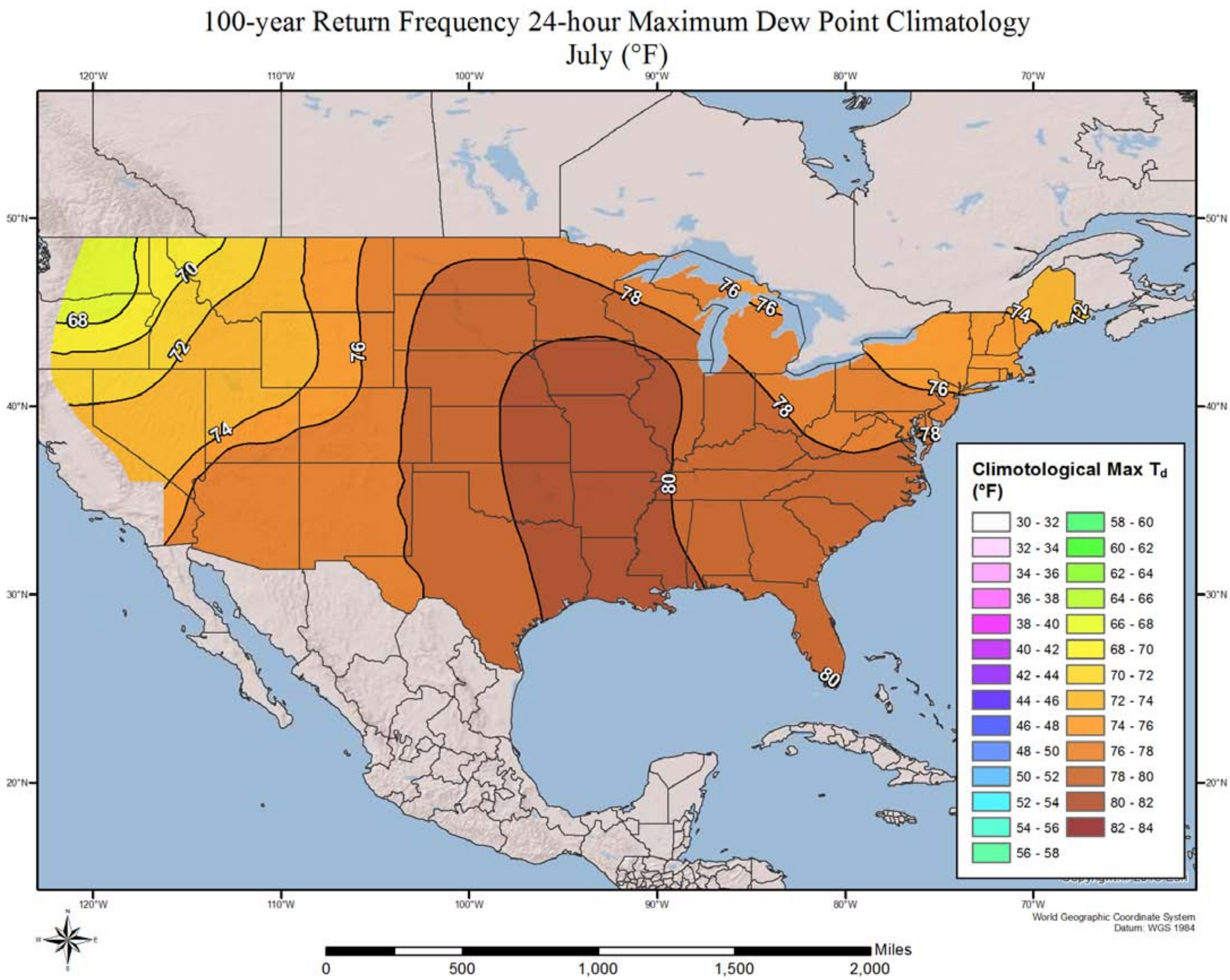


Figure 11. July 24-hour 100-year recurrence interval dew point climatology

Observed storm rainfall amounts are maximized using the ratio of precipitable water for the maximum dew point to precipitable water for the storm representative dew point, assuming a vertically saturated atmosphere. The ratio of the maximum precipitable water and actual precipitable water is converted into a percent and the storm rainfall totals as they occurred are maximized by this value. This value is called the in-place maximization factor (IPMF). By definition, IPMFs are always greater than or equal to 1.

The storm representative dew point was derived for each of the events analyzed during this study either by the USACE/NWS or AWA during previous work. The HYSPLIT trajectory model provides detailed analyses for determining the upwind trajectories of atmospheric moisture that was advected into the storm being analyzed.

Using these trajectories, the moisture source location is determined. The procedures followed are similar to the approach used in HMRs. However, by utilizing the HYSPLIT model trajectories, much of the subjectivity is eliminated. Once the general upwind location of the moisture source region feeding into the given storm event was determined, the hourly surface observations were analyzed for all available stations/reports within the vicinity of the inflow vector and general region.

Once the moisture source region is identified, hourly surface dew point observations are gathered and analyzed over the general region where the moisture originated from. These surface-based dew point values are adjusted to the 1,000mb level (approximately sea level). In addition, the total storm isohyetal pattern is displayed, along with the HYSPLIT trajectories. For storm maximization, average dew point values for the appropriate duration which was most representative of the actual rainfall accumulation period for an individual storm (6-, 12-, or 24-hour) was used to determine the storm representative dew point. To determine which time frame was most appropriate, the total rainfall amount was analyzed. The duration (6-, 12- or 24-hour) closest to when approximately 90% of the rainfall had accumulated was used to determine the duration used, i.e. 6-hour, 12-hour, or 24-hour. From these data, the appropriate dew point value representing the x-hour average value was determined which best represents the core rainfall period associated with the storm being analyzed. The storm representative dew point value is typically an average of two or more stations in a given region where the values are showing consistency in time and space. In Figure 12, the region chosen is circled in red. The center of this region then becomes the storm representative dew point location. The line connecting this point with the storm center location (point of maximum rainfall accumulation) is termed the moisture inflow vector. The moisture inflow vector is then used in the moisture transposition calculation process PMP.

The storm spreadsheets presented in Attachments B1, C2, and D3, list the moisture source region for each storm and dew point values used in the maximization calculations. Figure 12 is an example map used to determine the storm representative dew point for the Duluth, MN June 2012 storm event.

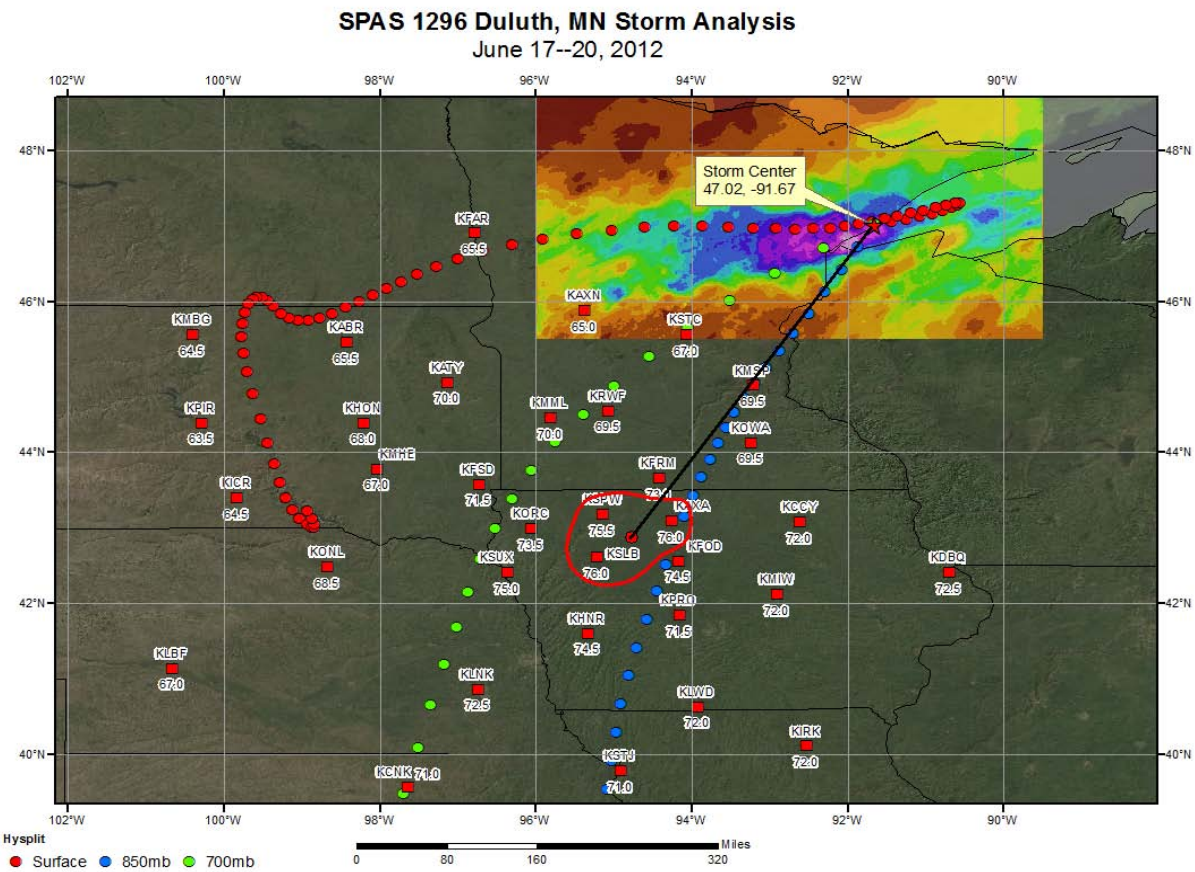


Figure 12. Surface dew point 12-hour average observations used in the storm representative dew point analysis for the Duluth, MN June 2012 storm event

5.3.8 Storm transposition adjustment process

Once each storm is maximized in-place, it is then transpositioned from its original location to the site. Transfer of a storm from where it occurred to a location that is meteorologically and topographically similar is termed storm transpositioning (e.g., HMR 51, Section 2.4.1 Reference 1). The transpositioning process provides a way to quantify how much rainfall the storm would have produced over the MNGP basin and at the MNGP site had it occurred there instead of its original location. In this transposition process, differences in moisture and elevation between the original location and the site are accounted for and quantified. For a given storm event to be considered transpositionable, there must be similar meteorological/climatological and topographical characteristics at its original location versus the new location. This is a qualitative measure and is left up to the judgment of the meteorologist performing the analysis. AWA provides exceptional experience and capability to analyze storms in this region and assess the transposition limits of each event in relations to the MNGP basin and MNGP site location. It is also important to note that AWA always chooses the most conservative transposition limits (i.e., a larger potential domain of influence) for storms that are in question or near boundaries unless further analysis or data

can be used to justify including or not including an individual storm. This is because the transposition process requires a binary answer, a storm is either transpositionable to a location or not. However, in the science of meteorology, the limits follow more of a transitional process where gradients exist. Therefore, utilizing a more conservative approach (i.e., larger transposition limits) compensates for these potential unknowns.

Extreme rain events that occurred over topographically and meteorologically/climatologically similar regions surrounding a study area are a very important part of the historical evidence on which PMP estimates are based. Study locations usually have a limited period of record for rainfall data collected at that location and hence have a limited number of extreme storms that have been observed. As such, the storm transpositioning process uses additional space to compensate for the limited time frame of instrumental climate records at any location. Storms observed regionally with similar meteorology and topography are analyzed and adjusted to provide information describing the storm rainfall as if the storm had occurred over the study location. The underlying assumption is that storms transposed to the study area could have occurred over the study area location under similar meteorological conditions. This decision is made using scientific judgment related to the storm type, season of occurrence, similarity of topography between the two locations, and experience analyzing past storms. To properly relocate such storms, it is necessary to address issues of similarity as they relate to topography and atmospheric moisture availability, and make appropriate adjustments. The adjustments which calculate the difference between the original storm location and the MNGP location are calculated following the process described in Section 5.3.9.1 and shown in equation 3. This process is also detailed in HMR 51 Section 2.4.3 (Reference 1).

The same maps used for maximum dew points during the IPMF process were used in the storm transpositioning calculation. The procedure for deriving the climatological maximum dew points for use in calculating the transposition maximization ratio uses information derived during the calculation of the IPMF. The moisture inflow vector connecting the storm location with the storm representative location was transpositioned to the CNP site for each storm. The value of the maximum dew point at the upwind location provided the transpositioned maximum value used to compute the transposition adjustment factor for relocating the storm to the site. The resulting moisture transposition factor (MTF) can be greater than or less than 1, depending on whether the transpositioned location and inflow vector produced higher or lower maximum dew point values and while taking into account the difference in elevation between the two locations.

5.3.9 Total adjustment factor calculation and use of the storm spreadsheet

AWA has developed Excel spreadsheets for each storm used in this calculation, which incorporates relevant storm information, automatically calculates appropriate adjustment factors, and computes the adjusted values for each storm. These adjusted values then become the basis for determining the PMP and LIP input values. Each storm spreadsheet used the observed storm rainfall amounts, storm representative dew points, maximum dew points (both in-place and transpositioned), storm elevation, and transposition location elevation information. Using the storm center location and inflow vector, the in-place and transpositioned maximum dew point values were determined. This information was entered into the storm spreadsheet to calculate the IPMF, the MTF, and finally the total adjustment factor (TAF). The TAF is a product of the IMPF and MTF and produces a value that represents what the amount of rainfall would have been for a given storm had it occurred over the site instead of its original location. This TAF was applied to the observed storm rainfall values to provide the final adjusted values for the maximized and transpositioned storm rainfall for a given storm.

5.3.9.1 Moisture maximization calculations

The adjusted rainfall for a given storm event was determined by applying a TAF to the observed rainfall value. The TAF is the product of the two storm adjustment factors, the IPMF and the MTF. These calculations were completed for all storms used in this analysis.

The available atmospheric moisture, in terms of precipitable water depth, must be determined for the storm center location to calculate both the IPMF and MTF. The IPMF is determined by taking the ratio of the maximum precipitable water depth at the storm representative dew point location to the storm representative precipitable water depth at the same location. The MTF is determined by taking the ratio of the maximum precipitable water depth at the transposition dew point location to the maximum precipitable water depth at the storm representative dew point location. Note that in the final TAF calculation, the precipitable water depth at the storm center is used in both the numerator of the IPMF and denominator of the MTF and is ultimately canceled out of the equation, having no impact on the TAF. However, it is still important to calculate the storm center precipitable water and the MTF and IPMF individually, so that each component can be quantified for completeness and quality/error control purposes.

The precipitable water depth is calculated from a lookup table stored within the storm adjustment spreadsheets. The lookup table is a digital version of the precipitable water table found in the WMO PMP manual (Reference 28) with dew point temperatures for elevations from sea level to 30,000 feet (Equation 1).

$$W_p = W_{p,30{,}000'} - W_{p,elev} \qquad \text{(Equation 1)}$$

In-place storm maximization is applied to each storm event using the methodology described in Section 2.2. Storm maximization is quantified by computing the IPMF using Equation 2.

$$IPMF = \frac{W_{p,max}}{W_{p,rep}} \qquad \text{(Equation 2)}$$

Where:

$W_{p,max}$ = precipitable water for the maximum dew point; and
$W_{p,rep}$ = precipitable water for the representative dew point.

The change in available atmospheric moisture between the storm center location and the site is quantified as the MTF. The MTF is calculated as the ratio of precipitable water for the maximum dew point at the MNGP basin centroid for PMP and MNGP site for LIP to precipitable water for the storm maximum dew point at the storm center location using Equation 3.

$$MTF = \frac{W_{p,trans}}{W_{p,max}} \qquad \text{(Equation 3)}$$

Where:

$W_{p,trans}$ = precipitable water at the target location; and
$W_{p,max}$ = precipitable water at the storm center location.

The TAF is a product of the linear multiplication of the IPMF and MTF. The TAF is a combination of the total moisture difference and terrain influences on rainfall when maximized and transpositioned to the MNGP basin centroid for PMP and MNGP site location for LIP.

$$TAF = IPMF * MTF \quad \text{(Equation 4)}$$

5.3.10 Storm spreadsheet development process

AWA has developed an Excel spreadsheet for each storm on the short storm list which incorporates relevant storm information, automatically calculates appropriate adjustment factors, and computes the adjusted rainfall DAD table. These storm spreadsheets used the observed storm DADs, storm representative dew points, maximum dew points (both in-place and transposition), storm elevation, and transposition location elevation information either as published in the USACE Storm Studies reports, HMR 51 tables, or as developed during AWA SPAS storm analyses. This information was entered into individual storm spreadsheets, one for each short list storm at the basin centroid. Using the storm center location and inflow vector, the in-place maximum dew point was determined. The same inflow vector was then moved to the basin centroid to determine the transpositioned maximum dew point value and total adjustment factor for that storm. This information was entered into the storm spreadsheet to calculate the in-place maximization factor, the transposition factor, and finally the total adjustment factor. This total adjustment factor was applied to the storm DAD table values to provide the final adjusted DAD table for the maximized and transpositioned storm rainfall values at each location.

Once all the storms were adjusted to the basin centroid, DA and DD plots were constructed for analysis and envelopment. This ensured spatial and temporal continuity of the PMP values for the basin. Attachments 1, 2, and 3 include the storm spreadsheets developed for each storm transpositioned to the basin centroid. Figure 13 displays an example storm spreadsheet for the Big Rapids, MI September 1986 Fall River, KS June 2007 adjusted to the basin centroid.

Storm Name:	SPAS 1206 Big Rapids, MI
Storm Date:	9/9-12/1986
AWA Analysis Date:	12/14/2014

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date 1-Sep

	Lat	Long
Storm Center Location	43.61 N	85.31 W
Storm Rep Dew Point Location	41.36 N	88.68 W
Transposition Dew Point Locatioi	44.37 N	97.91 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	SW @ 230	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	950	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	70.5 F	with total precipitable water above sea level of			2.31	inches.
The in-place maximum dew point is	77.0 F	with total precipitable water above sea level of			3.14	inches.
The transpositioned maximum dew point is	75.5 F	with total precipitable water above sea level of			2.92	inches.
The in-place storm elevation is	950	which subtracts	0.21	inches of precipitable water at	70.5 F	
The in-place storm elevation is	950	which subtracts	0.26	inches of precipitable water at	77.0 F	
The transposition storm elevation at	1,300	which subtracts	0.33	inches of precipitable water at	75.5 F	
The moisture inflow barrier height is	1,300	which subtracts	0.33	inches of precipitable water at	75.5 F	

The in-place maximization factor is	1.38
The transposition factor is	0.90
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.24

Notes: DAD values taken from SPAS 1206. Storm representative dew point value was based on maximum 24-hr Td values between September 8-12, 1986 at KMMO. Values were selected in region where temperature did not vary more than a 1-degree over a large area.

Observed Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	2.7	4.3	4.7	6.1	7.6	9.7	11.3	12.7	13.0
10 sq miles	2.6	4.2	4.6	6.0	7.6	9.7	11.3	12.7	13.0
100 sq miles	2.2	3.5	3.9	5.8	7.5	9.4	11.2	12.7	13.0
200 sq miles	2.0	3.2	3.8	5.6	7.3	9.3	11.1	12.6	12.9
500 sq miles	1.7	2.7	3.6	5.4	7.1	9.0	10.9	12.3	12.6
1000 sq miles	1.4	2.1	3.4	5.2	6.9	8.6	10.7	11.9	12.2
2000 sq miles	1.1	1.9	3.0	4.9	6.5	8.1	10.3	11.2	11.6
5000 sq miles	0.7	1.6	2.7	4.4	6.0	7.5	9.7	10.6	10.7
10000 sq miles	0.5	1.2	2.2	3.8	5.3	6.6	8.7	9.5	9.5
20000 sq miles	0.3	0.9	1.6	3.1	4.2	5.4	7.4	7.9	8.1

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	3.3	5.3	5.8	7.6	9.4	12.0	13.9	15.7	16.0
10 sq miles	3.3	5.1	5.6	7.4	9.4	12.0	13.9	15.7	16.0
100 sq miles	2.8	4.4	4.8	7.1	9.2	11.7	13.8	15.7	16.0
200 sq miles	2.5	4.0	4.7	6.9	9.1	11.5	13.7	15.6	16.0
500 sq miles	2.1	3.3	4.4	6.6	8.8	11.1	13.5	15.2	15.6
1000 sq miles	1.8	2.6	4.2	6.4	8.5	10.6	13.2	14.7	15.0
2000 sq miles	1.4	2.3	3.7	6.1	8.1	10.1	12.8	13.8	14.3
5000 sq miles	0.8	1.9	3.3	5.4	7.4	9.2	12.0	13.1	13.3
10000 sq miles	0.6	1.5	2.8	4.7	6.5	8.2	10.7	11.8	11.8
20000 sq miles	0.4	1.1	2.0	3.8	5.2	6.6	9.1	9.7	10.1

Storm or Storm Center Name	**SPAS 1206 Big Rapids, MI**			
Storm Date(s)	9/9-12/1986			
Storm Type	Synoptic			
Storm Location	43.61 N	85.31 W		
Storm Center Elevation	950			
Precipitation Total & Duration	13.18 Inches 72-hours			
Storm Representative Dew Point	70.5 F	24		
Storm Representative Dew Point Location	41.36 N	88.68 W	Aug	Sep
Maximum Dew Point	77.0 F		79	74.5
Moisture Inflow Vector	SW @ 230	Miles		
In-place Maximization Factor	**1.38**			
Temporal Transposition (Date)	1-Sep			
Transposition Dew Point Location	44.37 N	97.91 W	Aug	Sep
Transposition Maximum Dew Point	75.5 F		78.29	72.99
Transposition Adjustment Factor	**0.90**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.24**			

Storm Name: SPAS 1228 Fall River, KS
Storm Date: 6/28 - 7/2/2007
AWA Analysis Date: 9/1/2014

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date 15-Jul

	Lat	Long
Storm Center Location	37.63 N	96.05 W
Storm Rep Dew Point Location	31.00 N	95.50 W
Transposition Dew Point Locatioi	39.99 N	93.75 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	S @ 460	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	900	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	76.5 F	with total precipitable water above sea level of		3.07	inches.
The in-place maximum dew point is	80.0 F	with total precipitable water above sea level of		3.60	inches.
The transpositioned maximum dew point is	80.5 F	with total precipitable water above sea level of		3.68	inches.
The in-place storm elevation is	900	which subtracts	0.21	inches of precipitable water at	76.5 F
The in-place storm elevation is	900	which subtracts	0.27	inches of precipitable water at	80.0 F
The transposition storm elevation at	1,300	which subtracts	0.38	inches of precipitable water at	80.5 F
The moisture inflow barrier height is	1,300	which subtracts	0.38	inches of precipitable water at	80.5 F

The in-place maximization factor is	1.17
The transposition factor is	0.99
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.16

Notes: DAD values taken from SPAS 1228. Storm representative dew point value was based on maximum 24-hr Td values between June 27-28, 2007 at KDKR and KUTS.

Observed Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	4.6	6.4	8.9	11.0	14.4	14.5	17.2	22.1	24.8
10 sq miles	4.2	6.3	8.8	10.7	13.8	13.9	17.1	21.9	24.8
100 sq miles	3.1	5.1	7.6	10.2	12.7	13.0	15.7	18.1	21.7
200 sq miles	2.8	4.7	7.0	9.6	11.8	11.9	14.8	17.1	20.7
500 sq miles	2.2	3.5	5.9	8.4	10.4	10.7	13.2	15.5	19.2
1000 sq miles	1.6	3.3	4.8	7.2	9.0	10.0	12.1	14.2	18.1
2000 sq miles	1.1	2.4	3.9	6.0	7.8	9.0	10.8	12.6	16.0
5000 sq miles	0.7	1.8	2.9	4.7	6.3	6.4	9.0	10.4	13.7
10000 sq miles	0.4	1.4	2.2	3.7	5.1	6.0	7.5	8.7	11.1
20000 sq miles	0.3	0.6	1.5	2.7	3.8	4.6	5.7	7.0	9.2

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	5.3	7.4	10.2	12.7	16.6	16.7	19.9	25.5	28.7
10 sq miles	4.8	7.3	10.2	12.4	15.9	16.1	19.7	25.3	28.7
100 sq miles	3.6	5.9	8.8	11.8	14.7	15.0	18.1	21.0	25.1
200 sq miles	3.2	5.4	8.1	11.1	13.6	13.8	17.1	19.7	23.9
500 sq miles	2.5	4.1	6.8	9.7	12.0	12.3	15.3	18.0	22.2
1000 sq miles	1.8	3.8	5.5	8.3	10.4	11.6	14.0	16.4	21.0
2000 sq miles	1.3	2.7	4.5	7.0	9.1	10.3	12.5	14.6	18.5
5000 sq miles	0.8	2.1	3.4	5.5	7.3	7.3	10.4	12.0	15.9
10000 sq miles	0.5	1.6	2.5	4.3	5.9	6.9	8.7	10.1	12.8
20000 sq miles	0.3	0.7	1.7	3.2	4.4	5.3	6.6	8.0	10.6

Storm or Storm Center Name	**SPAS 1228 Fall River, KS**		
Storm Date(s)	6/28 - 7/2/2007		
Storm Type	Synoptic		
Storm Location	37.63 N	96.05 W	
Storm Center Elevation	900		
Precipitation Total & Duration	25.50 Inches 95-hours		
Storm Representative Dew Point	76.5 F	24	
Storm Representative Dew Point Location	31.00 N	95.50 W	
Maximum Dew Point	80.0 F		
Moisture Inflow Vector	S @ 460	Miles	
In-place Maximization Factor	**1.17**		
Temporal Transposition (Date)	15-Jul		
Transposition Dew Point Location	39.99 N	93.75 W	
Transposition Maximum Dew Point	80.5 F		
Transposition Adjustment Factor	**0.99**		
Average Basin Elevation	1,300		
Highest Elevation in Basin	1,896		
Inflow Barrier Height	1,300		
Elevation Adjustment Factor	**1.00**		
Total Adjustment Factor	**1.16**		

Figure 13. Storm spreadsheet for Fall RiverBig Rapids, KS MI June 2007September 1986 transpositioned to the basin centroid

5.3.11 Development of PMP values

Storm maximization and transposition provide an indication of the maximum amount of rainfall that a particular storm could have produced at any location within the region analyzed for the MNGP watershed. Use of these values alone does not ensure that PMP values are provided for all area sizes and durations since some of the maximized and transpositioned values could be less than the PMP. By enveloping the rainfall amounts from all the major storms, rainfall values indicative of the PMP magnitude are produced. The standard process for deriving a DAD table (Reference 1, Reference 28) of PMP values at the basin centroid was used in the project.

5.3.11.1 Envelopment procedures and DAD development

Enveloping is a process for selecting the largest value from a set of data. This technique provides continuous smooth curves based on the largest rainfall values from the set of maximized and transpositioned storm rainfall values. The largest rainfall amounts provide guidance for drawing the curves.

During the enveloping process, values which are not consistent (are either high or low) are re-evaluated to insure reliability. High values are enveloped unless an explanation can be provided to justify undercutting the value. No undercutting of rainfall values was done in this calculation. Low values are also re-evaluated for reliability and then enveloped to maintain consistency with surrounding values. Enveloping the largest adjusted storm values ensures that PMP is achieved at all area sizes and durations. This is necessary because the limited storm record (approximately 150 years of data) in the region transpositionable to the PINGP MNGP basin may not have recorded a storm event that would result in PMP at certain area sizes and durations. The result of this envelopment procedure is a set of smooth curves that maintain continuity among temporal periods and areal sizes.

The envelopment process was used in PMP determination for this calculation, following the same procedures used for envelopment in the derivation of PMP in the HMRs (Reference 1), the WMO PMP Manual (Reference 28), and previous AWA PMP studies (Reference 15, Reference 25). Once the total storm adjusted rainfall values for the appropriate storms were determined, they were plotted on individual DA charts for each duration for analysis. Envelopment was applied to each DA curve for each duration. The DA envelopment curves were drawn to provide continuity in space. Figure 14 is an example of an all-season DA chart and Figure 15 is an example of a cool-season DA chart with the envelopment curve plotted on both for the 24-hour duration at the MNGP watershed basin centroid.

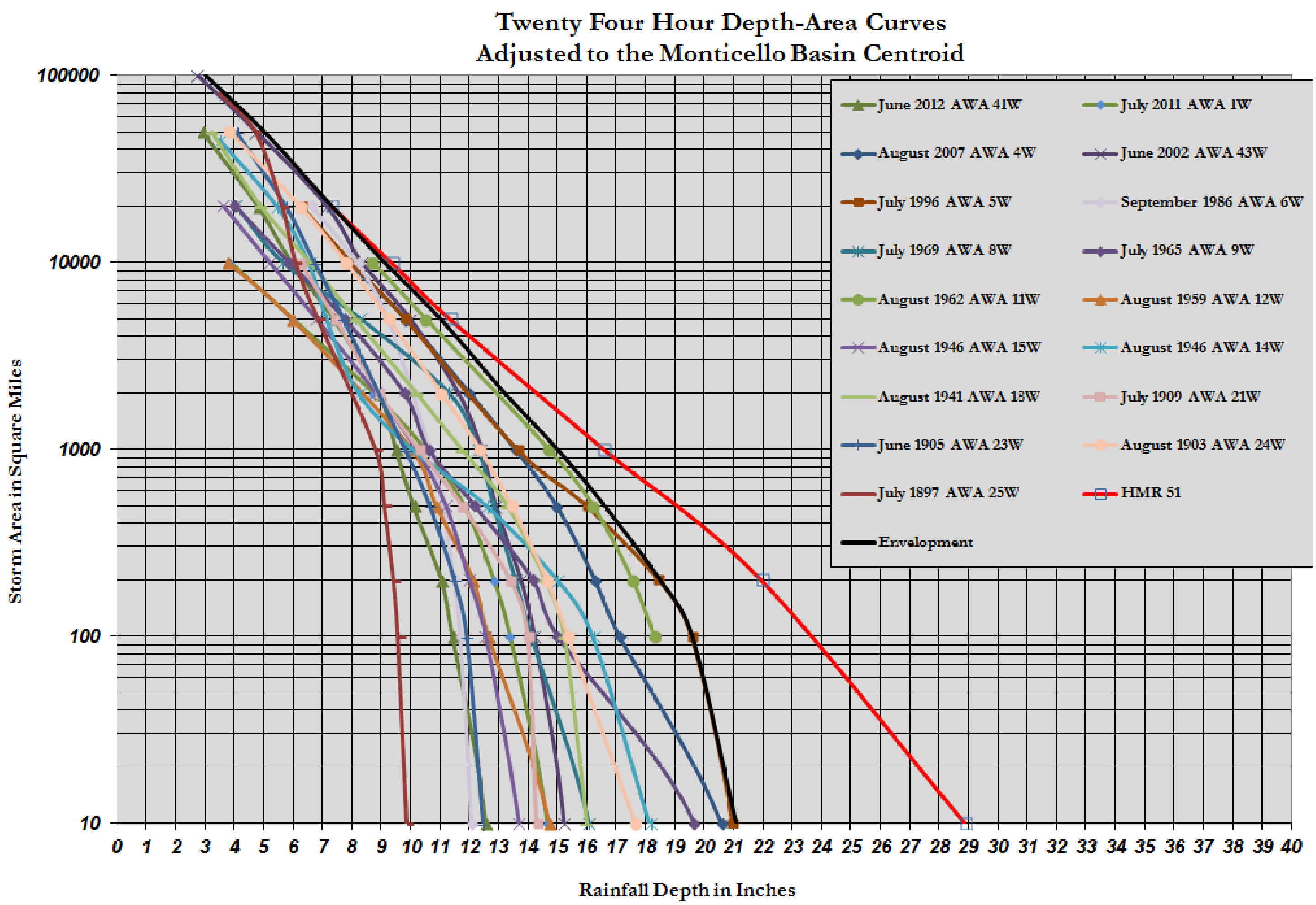


Figure 14. 24-hour all-season Depth-Area curves at the MNGP basin centroid

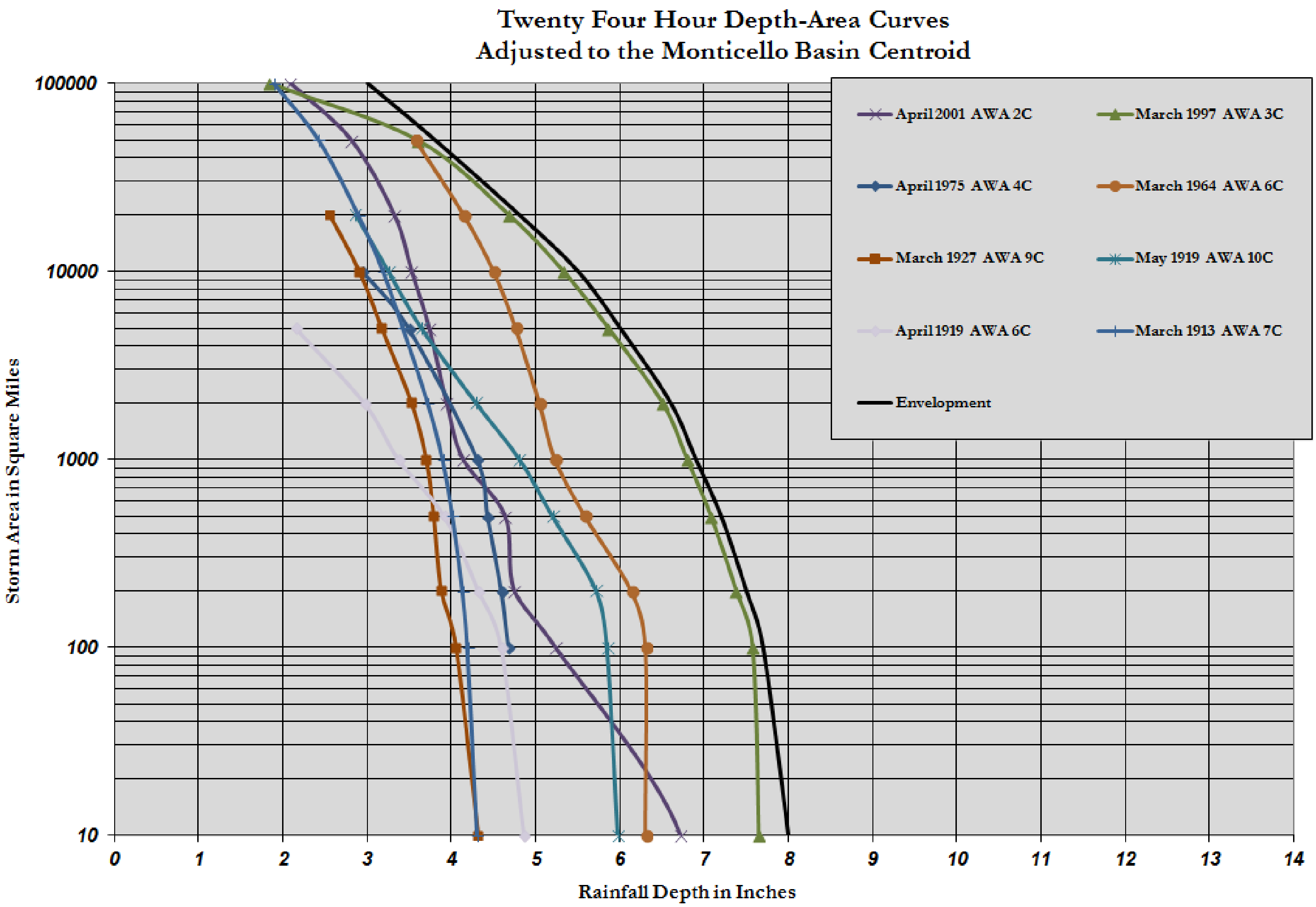


Figure 15. 24-hour cool-season Depth-Area curves at the MNGP basin centroid

The second application of the envelopment process was used with the DD curves. Curves for each area size were constructed using results from the DA analysis described previously the basin centroid for the all-season storms and the cool-season storms. The DD curves were drawn to produce smooth curves that provide continuity in time among all durations. Figure 16 and Figure 17 display the DD curves for the basin centroid all-season and cool-season PMP. All DA and DD charts developed during this calculation are included in Attachment 7. The final set of DD curves for all durations at the basin centroid defines the initial set of PMP values for both all-season and cool-season PMP. The envelopment of the adjusted storms together with the curve smoothing process insured that all storm data were included and that the resulting set of PMP values provides rainfall values that are consistent spatially and temporally.

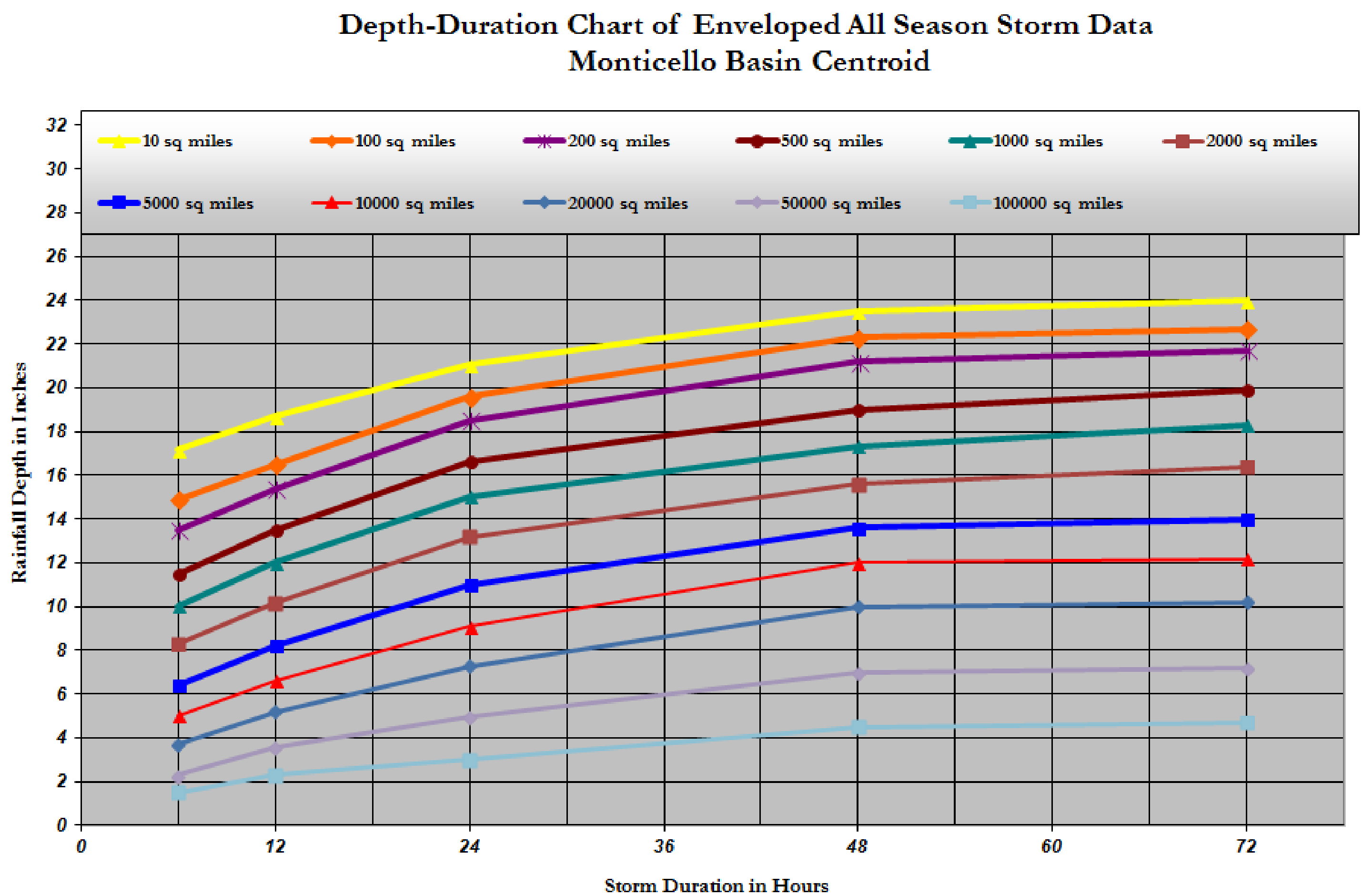


Figure 16. All-season Depth-Duration curves at the MNGP basin centroid

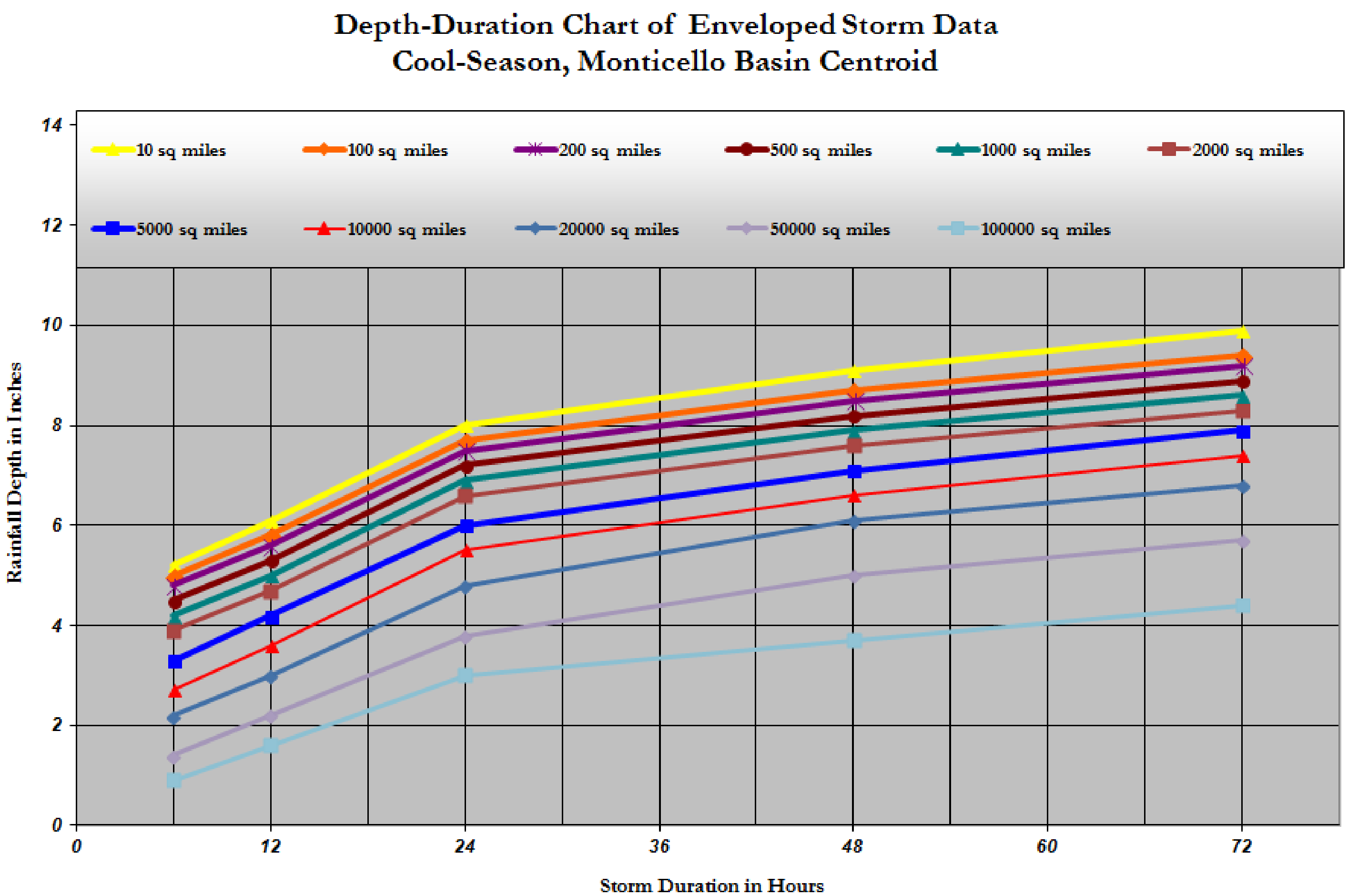


Figure 17. Cool- season Depth-Duration curves at the MNGP basin centroid

5.3.12 Local Intense Precipitation Analysis

LIP calculated for the 1-hour and 6-hour 1-square mile PMP for the MNGP site location. This analysis followed the storm-based approach as used in the overall PMP development and as described in HMR 51 (Reference 1) and HMR 52 (Reference 2). The storm-based approach utilizes actual data from rainfall events which have occurred over the site and in regions transpositionable to the MNGP location. These rainfall data are maximized in-place following standard maximization procedures, then transpositioned to the MNGP location as described in Sections 5.3.7, 5.3.8, and 5.3.9. The transpositioning process accounts for differences in moisture and elevation between the original location and the MNGP site. The process produces a total adjustment factor that is applied to the original rainfall data for each storm. The result represents the maximum rainfall each storm could have produced at the site had all factors leading to the rainfall been ideal and maximized. Information is included in this section detailing the storms used, how they were analyzed, and how the LIP values were derived. Information on each storm event evaluated for LIP development is included in Attachment 3.

5.3.12.1 Local Intense Precipitation Development

The PMP values provided in HMR 51 for the MNGP site provide values starting at 6-hours and 10-square miles. There are no explicit values provided at the 1-hour duration and/or 1-square miles. HMR 52 (Reference 2) provides information to derive the 1-hour 1-square mile values based on HMR 51 6-hour 10-square mile PMP values. Unfortunately, the most recent storm evaluated in HMR 51 occurred in 1972, with the most recent LIP storm from HMR 52 occurring in 1973. In addition, HMR 51 and HMR 52 both cover a large and diverse domain, and generalization was necessarily employed in the development of the respective PMP and LIP values. In addition, because HMR 51 and HMR 52 covers a large and diverse domain, and generalization was necessarily employed in the development of the respective PMP and LIP values. This resulted in LIP values which were influenced by storms not appropriate for the MNGP site (e.g. Smethport, PA July 1942) and therefore are not accurate values for the MNGP site.

This site-specific LIP analysis corrects many of the issues in the HMRs by explicitly evaluating storms which are directly transpositionable to the MNGP site. In addition, the understanding of the meteorology of these events has advanced significantly since HMR 51 was published. These corrections and the updated storm database were employed in this calculation. In addition, the results and data from numerous SPAS storm analyses used in the PMP development during this calculation and several others in the region were used extensively in this analysis.

5.3.12.1.1 Local Intense Precipitation Storm List

The initial step in the development of the LIP values was to identify a set of storms which represent rainfall events that are LIP-type local storm events. This included storms where extreme heavy rainfall accumulated over short durations and small area sizes. These include thunderstorms and intense rainfall associated with MCC and individual thunderstorms. This procedure is similar to what is described in HMR 52 Section 6.

AWA evaluated all storms used in previous PMP studies in the region considered transpositionable to the MNGP location to develop a list of the storms needed for proper LIP evaluation and determination. The same evaluations were considered in the transposition evaluations as used in the PMP development. Factors such as elevation differences of more than +/- 1,000 feet and/or distances of more than +/- 6° latitude were considered. These factors follow guidance in the HMRs (Reference 1, Reference 12, Reference 13). A few storms with storm centers in the southern Great Plains and Midwest were included even though they were slightly more than 6° latitude difference than the basin centroid latitude. This is because these storms are of the same type (individual thunderstorms and MCCs) that would be expected over the basin and could produce LIP. In these situations, the conservative assumption is employed and the storm is allowed to be used in the PMP calculations. This applied to both cool-season and all-season storm transposition considerations. Finally, the storm type was evaluated. Storm types which would not result in a PMP/PMF scenario for the large MNGP watershed were not considered. This included storms which were individual MCS and thunderstorms. This resulted in 20 events being evaluated (Table 6). Twelve of these storms were previously analyzed in HMR 33 (Reference 27), HMR 51 (Reference 1), and HMR 52 (Reference 2) by the NWS and USACE. The remaining 8 were analyzed using SPAS program during previous LIP calculations.

Table 6. Local Intense Precipitation storm list

Storm Name	State	AWA Storm Number	Lat	Lon	Year	Month	Day	Maximum 1-hour 1mi^2 Rainfall Using HMR 52 Ratio or SPAS Data	Maximum 6-hour 1mi^2 Rainfall Using HMR 52 Ratio or SPAS Data	Monticello Total Adjustment Factor	Monticello 1-hour 1mi2 PMP	Monticello 6-hour 1mi2 PMP	Precipitation Source
AURORA COLLEGE	IL	5W	41.4575	-88.0699	1996	7	16	6.06	14.40	1.29	7.82	18.58	SPAS 1286
BEAULIEU	MN	33W	47.3000	-95.9000	1909	7	18	7.48	11.17	1.26	9.42	14.07	UMV 1-11A
BOYDEN	IA	30W	43.1900	-96.0100	1926	9	17	10.75	18.40	1.06	11.40	19.50	MR 4-24
COOPER	MI	32W	42.3764	-85.6103	1914	8	31	8.97	13.40	1.29	11.57	17.29	GL 2-16
DAVID CITY	NE	13W	41.2132	-97.0710	1963	6	24	3.87	14.10	1.46	5.65	20.59	SPAS 1030
DUBUQUE	IA	1W	42.4400	-90.7500	2011	7	27	4.10	10.60	1.07	4.39	11.34	SPAS 1220
DUMONT	IA	21W	42.7519	-92.9755	1951	6	25	6.55	9.40	1.33	8.71	12.50	UMV 3-29
ENID	OK	10W	36.3805	-97.8683	1973	10	10	7.40	11.20	0.98	7.25	10.98	SPAS 1034
FALL RIVER	KS	4W	37.6300	-96.0500	2007	6	30	4.68	8.90	1.19	5.57	10.59	SPAS 1228
FOREST CITY	MN	8W	45.2394	-94.5404	1983	6	20	3.66	8.40	1.46	5.34	12.26	SPAS 1035
GRANT TOWNSHIP	NE	29W	42.2400	-96.5900	1940	6	3	9.26	13.83	1.33	12.31	18.39	MR 4-5
HOLT	MO	22W	39.4528	-94.3422	1947	6	18	12.00	12.00	1.10	13.20	13.20	MR 8-20
KELSO	MO	19W	37.1906	-89.5495	1952	8	11	9.26	13.83	1.19	11.01	16.46	UMV 3-30
LARRABEE	IA	42W	42.8608	-95.5453	1891	9	10	6.41	10.40	1.11	7.11	11.54	MR 4-2
MINNEAPOLIS	MN	6W	44.8890	-93.4021	1987	7	23	4.97	11.10	1.16	5.77	12.88	SPAS 1210
MOUNDS	OK	26W	35.8770	-96.0610	1943	5	16	11.32	16.91	1.13	12.79	19.11	SW 2-21
NEOSHO FALLS	KS	31W	38.0820	-95.7010	1926	9	12	9.54	13.60	1.28	12.21	17.41	SW 2-1
STANTON	NE	25W	41.8670	-97.0500	1944	6	10	9.54	15.50	1.32	12.59	20.46	MR 6-15
WOODBURN	IA	38W	41.0120	-93.5991	1903	8	24	4.91	7.34	1.30	6.39	9.54	MR 1-10
WOOSTER	OH	11W	40.9146	-81.9729	1969	7	4	4.62	8.80	1.23	5.68	10.82	SPAS 1209

5.3.12.1.2 Local Intense Precipitation Calculation Process

Most of the 16 storms analyzed by the NWS/USACE did not contain explicit 1-hour 1-square mile data. This is the result of a lack of hourly recording information available during the original analyses. To correct for this, information presented in HMR 52, Section 6 was utilized. This information provided ratios which allowed for the computation of the 1-hour 1-square mile value to be derived from the 6-hour 10-square mile value (HMR 52 Figure 23, Reference 2). Although these ratios were derived to apply to the HMR 51 PMP values, they are implicitly relevant for use in this calculation because both processes are using the same data set and following the storm-based approach, i.e. it is only a scaling variation that is occurring. No inherent change or adjustment to the data is taking place that would result in a different data set or storm type. For the Bonaparte, IA June 1905 and Holt, MO June 1947 storm events analyzed by the NWS/USACE (Reference 6), explicit 1-hour data was available and therefore no ratio application was required. The 8 storms analyzed using SPAS allowed for explicit hourly rainfall to be evaluated with a spatial resolution of 1/3rd square mile. This provided data for the storm rainfall 1-hour 1-square mile area sizes to be explicitly evaluated.

Once all the storms were identified and their 1- and 6-hour 1-square mile values derived, the final step in the process was to maximize each storm specific to the MNGP location. This was a two-step process. First, the in-place maximization factor was calculated. This provides a value that is applied to the observed storm values which represents what the storm would have looked like had the atmospheric conditions and moisture been at maximum levels when the storm occurred. Next, the resulting in-place maximized values for each storm needed to be adjusted as if the storm had occurred over the MNGP site. To accomplish this, the transposition calculation process was followed to adjust the storm from its original location to the MNGP site. The transposition calculation adjusts for differences in available moisture both in the horizontal (north/south and east/west directions) and vertical

(differences in elevation) at the site versus the original storm location. All the calculations and resulting values for each storm used in the LIP analysis are provided in Attachment 3.

After the maximization and transposition factors were calculated for each of the storms, the results were applied to the maximum 1- and 6-hour value for each storm to calculate the maximized 1-hour 1-square mile values. The largest of these values results in the site-specific LIP for the MNGP site. After adjustments were applied, the Holt, MO June 1947 storm event had the highest 1-hour rainfall, while the David City, NE June 1963 storm had the highest 6-hour rainfall. In both cases, several other storms providing slightly smaller values and support for this value. For final application of the LIP hydrology, the 1-hour value is then required to be split into sub-hourly increments of 5-, 15-, 30-minutes. Updated evaluations of the appropriate amount of rainfall to assign to each increment for the site based on storm data would have been ideal. However, a lack of sub-hourly PMP-type storm data from the storms analyzed by the NWS/USACE prevented an updated evaluation from being completed. Therefore, it is recommended that the ratios derived in HMR 52 be applied at the MNGP site (HMR 52 Figures 36-38, Reference 2).

5.3.12.2 Local Intense Precipitation Results

The previous sections provided details on the selection and maximization of the storms used in this analysis. The results of this analysis resulted in the Holt, MO June 1947 and David City, NE June 1963 storm events having the highest 1- and 6-hour maximized rainfall values at the 1-square mile area size of all the storms evaluated. Table 7 provides the final PMP values for 1- and 6-hours 1-square miles and the subsequent sub-hourly values using the data calculated in this calculation.

Table 7. Site-Specific Local Intense Precipitation

Time in minutes	Monticello Nuclear Generating Station PMP in Inches for 1-hour 1-square mile	Time in minutes	Prairie Island Nuclear Generating Station PMP in Inches for 1-hour 1-square mile
5	4.5	5	4.5
15	7.2	15	7.2
30	10.2	30	10.2
60 (1 Hour)	13.2	60 (1 Hour)	13.2
Time in minutes	**Monticello Nuclear Generating Station PMP in Inches for 6-hour 1-square mile**	**Time in minutes**	**Prairie Island Nuclear Generating Station PMP in Inches for 6-hour 1-square mile**
360 (6 Hours)	20.6	360 (6 Hours)	20.6

5.3.12.2.1 Reason for reduction from HMR 52 Local Intense Precipitation values

This site-specific LIP calculation provided differences in LIP values from those presented in HMR 52 (Reference 2). All else being equal, if only more storms were added to those used in HMR 51/52, the values would only be the same or higher. However, this calculation explicitly addressed elevation, used updated maximization factors, and explicitly defined transposition limits for each storm considered.

Since the site-specific analysis followed the same basic storm rainfall adjustment procedures as HMR 51 and HMR 52, it would be useful to understand the cause of the differences in the values. Working papers are not available for HMR 51 or HMR 52, so explicit differences in calculations and procedures cannot be evaluated. However, the following methods and data were treated differently between the studies:

1) HMRs 51 and 52 provide generalized and smoothed LIP values over a large geographic domain that covers the United States east of the 105th meridian. Specific characteristics unique to the MNGP watershed and the MNGP site were not addressed. This calculation considered characteristics specific to the site, and produced PMP values that explicitly considered the meteorology of the PMP storm type which would result in the 1-and 6-hour 1- square mile area size LIP values.
2) The transposition limits of the Smethport, PA July 1942 (Reference 30), which produced the 4- and 6-hour world record rainfall, were not allowed to influence the LIP values at the MNGP site. The refined transposition limits used in this calculation result in lower LIP values compared to HMR 52 for locations where the Smethport storm apparently influenced PMP values in HMR 51. Smoothing of the PMP/LIP isolines in HMRs 51 and 52 necessarily had to encompass the Smethport maximized in-place rainfall far beyond its explicit transposition limits. Note, Section 3.2.4 of HMR 51 states that they "slightly undercut" the maximized 6-, 12-, and 24-hour values by up to 7% to avoid "excessive envelopment of all other data in a large region surrounding the Smethport location." This over envelopment effect extended well beyond the intended transposition limits of the Smethport storm because the PMP/LIP isolines required smoothing and fitting over surrounding regions.
3) Each storm's inflow vector was re-evaluated and combined with an updated set of dew point climatologies and when necessary, updated storm representative dew point values were used for the in-place maximization and transposition factors. The HYSPLIT trajectory model (Reference 7) was used to evaluate moisture inflow vectors for storms on the short storm list. Trajectory models were not available in previous HMR studies. Use of HYSPLIT allowed for a high degree of confidence when evaluating moisture inflow vectors and storm representative dew points.
4) Several new storms have been analyzed and included in this LIP analysis that were not included in HMRs 33, 51, and 52. This provided a higher level of confidence in the final PMP values. Further, this allowed for a refined set of values that better represent the LIP estimates at the site. This expanded the data set used to derive LIP includes a large number of recent storms.
5) The calculation provided adjustments for storm elevation to the nearest 100 feet of elevation, whereas HMRs 51 and 52 made no explicit adjustment for elevation. This adjustment depends on the elevation of the historic storm's maximum rainfall location and therefore varies from storm to storm. Further, the elevation at the MNGP site was determined in this analysis, providing more accurate calculations to account for differences in available atmospheric moisture due to elevation differences between the original

storm location and the site. Note that each 100 feet of elevation change equates to approximately a 0.8% difference in the maximization factor.

6) Storms analyzed by the NWS/USACE which occurred prior to 1948 and used 12-hour persisting dew points in the storm maximization process were adjusted so that the updated dew point climatology could be utilized consistently. For thunderstorms and MCC storm events 7°F was added to the NWS/USACE storm representative dew point. This was done to adjust for using average dew point values for varying durations vs. 12-hour persisting dew point values. Evaluations of 12-hour persisting storm representative dew points showed those used in HMR 51 underestimated the storm representative values used in storm maximizations.

5.3.13 Site-Specific PMP values calculated during this study

This calculation has produced PMP values for use in computing the PMF for the MNGP watershed. Values for all durations and area sizes provided in HMR 51 and for the area size specific to the basin have been computed using the procedures described in this report. These include durations of 6-, 12-, 24-, 48-, and 72-hour durations and area sizes from 10-square miles to 100,000-square miles. AWA has provided a comparison of the PMP values to HMR 51 PMP values at the centroid of the basin at area sizes where information is available. This comparison is provided in Table 8. The all-season PMP values calculated are included in Table 9 and the cool-season PMP values calculated are included in Table 10. Comparisons of the cool-season PMP values against an appropriate HMR are not provided because HMR 51 does not provide explicit cool-season PMP values and no other HMR provides explicit cool-season PMP values. Instead, cool-season PMP values are derived using ratios based on seasonality analysis from HMR 33 and HMR 53 applied to the all-season PMP. This process is significantly different from deriving cool-season PMP values using a storm based, deterministic approach and therefore it is not appropriate to compare the cool-season PMP values derived in this study to those using seasonality methods.

Table 8. Site-Specific All-Season Probable Maximum Precipitation compared to HMR 51 values

Monticello Basin Centroid All-Season Site-Specific PMP vs HMR 51						
	Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
HMR 51 PMP Values at the Basin Centroid in Inches	10sqmi	22.8	27.0	28.9	31.1	32.8
	200sqmi	17.0	20.5	21.9	24.7	26.0
	1000sqmi	12.7	15.0	16.6	19.2	20.8
	5000sqmi	7.7	9.8	11.3	14.0	15.7
	10000sqmi	6.0	7.8	9.3	11.9	13.7
	20000sqmi	4.3	5.9	7.3	9.8	11.4
	Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
Monticello All-Season Site-Specific Basin Centroid PMP	10sqmi	17.2	18.7	21.1	23.5	24.0
	200sqmi	13.5	15.4	18.5	21.2	21.7
	1000sqmi	10.0	12.0	15.0	17.3	18.3
	5000sqmi	6.4	8.2	11.0	13.6	14.0
	10000sqmi	5.0	6.6	9.1	12.0	12.2
	20000sqmi	3.7	5.2	7.3	10.0	10.2
	Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
% Reduction from HMR 51	10sqmi	24%	31%	27%	24%	27%
	200sqmi	21%	25%	16%	14%	16%
	1000sqmi	21%	20%	10%	10%	12%
	5000sqmi	17%	16%	3%	3%	11%
	10000sqmi	17%	15%	3%	-1%	11%
	20000sqmi	13%	12%	0%	-2%	10%

Table 9. Site-Specific All-Season Probable Maximum Precipitation

	Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
Monticello All-Season Site-Specific PMP Values (in inches) at the Basin Centroid	10sqmi	17.2	18.7	21.1	23.5	24.0
	100sqmi	14.9	16.5	19.6	22.3	22.7
	200sqmi	13.5	15.4	18.5	21.2	21.7
	500sqmi	11.5	13.5	16.6	19.0	19.9
	1000sqmi	10.0	12.0	15.0	17.3	18.3
	2000sqmi	8.3	10.2	13.2	15.6	16.4
	5000sqmi	6.4	8.2	11.0	13.6	14.0
	10000sqmi	5.0	6.6	9.1	12.0	12.2
	20000sqmi	3.7	5.2	7.3	10.0	10.2
	50000sqmi	2.3	3.6	5.0	7.0	7.2
	100000sqmi	1.5	2.3	3.0	4.5	4.7

Table 10. Site-Specific Cool-Season Probable Maximum Precipitation

	Area Size	6-Hour	12-Hour	24-Hour	48-Hour	72-Hour
Monticello Cool-Season Site-Specifc PMP Values (in Inches) at the Basin Centroid	10sqmi	5.2	6.1	8.0	9.1	9.9
	100sqmi	5.0	5.8	7.7	8.7	9.4
	200sqmi	4.8	5.6	7.5	8.5	9.2
	500sqmi	4.5	5.3	7.2	8.2	8.9
	1000sqmi	4.2	5.0	6.9	7.9	8.6
	2000sqmi	3.9	4.7	6.6	7.6	8.3
	5000sqmi	3.3	4.2	6.0	7.1	7.9
	10000sqmi	2.7	3.6	5.5	6.6	7.4
	20000sqmi	2.2	3.0	4.8	6.1	6.8
	50000sqmi	1.4	2.2	3.8	5.0	5.7
	100000sqmi	0.9	1.6	3.0	3.7	4.4

5.3.14 Controlling storms for the Site-Specific PMP values

Several different storm events control the PMP values at various area sizes and durations. This was expected in this type of storm-based PMP analysis. In this situation, a single storm would not be expected to have occurred that contained moisture and storm dynamics at the most efficient levels for all area sizes and durations. Instead, it is expected that one or more of those events would be very efficient at short durations (less than 24-hours), one or more would be very efficient at medium durations (24- to 48-hours), and one or more would be very efficient at the longest durations (72-hours). Then, by combining those most efficient storms as if they were a single PMP storm event, the largest of the maximized storms at each duration and area size have been used to determine the PMP values. This allows the PMP values for the basin to reach the theoretical upper limit threshold. Table 11 and Table 12 display the storms which control the PMP values at the standard HMR 51 area sizes and durations for the all-season and cool-season PMP depths. Refer to Table 4 and Table 5 under the column titled AWA Storm Number for the information on each of these controlling storms.

Table 11. Site-specific all-season Probable Maximum Precipitation controlling storms

Area Size	6-Hour	12-Hour	24-Hour	48-Hour	72-Hour
10sqmi	5W	5W	5W	14W	14W
200sqmi	5W	5W	5W	14W	14W
1000sqmi	5W	5W	11W	15W	15W
5000sqmi	5W	24W	11W	6W/43W	43W
10000sqmi	5W/23W	24W	11W	6W	43W
20000sqmi	23W	24W	43W	43W	43W
50000sqmi	23W	25W	43W	43W	25W
100000sqmi	25W	25W	43W	43W	43W

Table 12. Site-specific cool-season Probable Maximum Precipitation controlling storms

Area Size	*6-Hour*	*12-Hour*	*24-Hour*	*48-Hour*	*72-Hour*
10sqmi	10C	10C	3C	3C	2C
200sqmi	10C	10C	3C	3C	3C
1000sqmi	10C	10C	3C	3C	3C
5000sqmi	4C	4C	3C	3C	3C
10000sqmi	4C	3C	3C	3C	3C
20000sqmi	10C	2C	3C	3C	3C
50000sqmi	6C	3C	6C	3C	3C
100000sqmi	2C	2C	6C	3C	3C

5.3.14.1 Comparison of the all-season PMP against precipitation frequency estimates

Site-specific PMP values from the basin centroid location were compared with 24-hour 100-year recurrence interval rainfall values as a general check for reasonableness. The ratio of the 10-square mile 24-hour PMP to the 24-hour 100-year recurrence interval rainfall amounts is generally expected to range between 2 and 4, with values as low as 1.7 and as high as 5.5 found in HMRs 57 and 59. Further, as stated in HMR 59 "*…the comparison indicates that larger ratios are in lower elevations where short-duration, convective precipitation dominates, and smaller ratios in higher elevations where general storm, long duration precipitation is prevalent*" (HMR 59 Section 11.1). Comparison of PMP values with rainfall frequencies is made for point locations, i.e., individual locations. Sufficient data are not available to make the comparison at other area sizes. For example, comparisons for the actual area size of the entire basin would be more useful for this task, but return frequency statistics are not available for spatial areas larger than point locations. Values above four indicate that the PMP values are relatively large compared with the return frequency values (i.e. are "conservative").

The 100-year 24-hour recurrence interval rainfall values are derived from NOAA Atlas 14, Vol. 8 produced by the National Weather Service (Reference 9). Comparison of the all-season 10-square mile 24-hour site-specific PMP values with the 100-year 24-hour rainfall return frequency value was made. The site-specific 10-square mile, 24-hour PMP value of 21.0 inches was divided by the 100-year 24-hour value of 6.24 to derive the ratio for the basin centroid for both data sources. This resulted in a ratio of 3.4:1, within the expected range of 2 to 4.

5.3.15 Reasons for reductions of all-season PMP values versus HMR 51

For every area size and duration, the all-season PMP values derived in this calculation resulted in reduced PMP values from those provided in HMR 51, with unique PMP values calculated for the cool-season PMP. This calculation explicitly addressed variations in meteorology and topography in regions outside of the basin where storms occurred that are considered to be transpositionable. All storms on the short storm list were re-evaluated to determine updated storm representative and maximum dew points.

Since this calculation followed the same basic storm rainfall adjustment procedures as HMR 51, it would be useful to understand the cause of the differences in the PMP values calculated during this calculation and those provided in HMR 51. Detailed working papers for the storms analyzed, the exact processes employed to derive the final

values, and information used to derive PMP are not available for HMR 51, so explicit differences in calculations and procedures cannot be determined. However, the following issues were treated differently in this calculation:

- HMR 51 provides generalized and smoothed PMP values over a large geographic domain covering the United States east of the 105th meridian. Specific characteristics unique to individual basins, such as the MNGP basin, were not addressed at the time. This calculation, however, considered characteristics specific to the basin, and produced PMP values explicitly considering the meteorology of the PMP storm type and topography of the region which would result in the PMF for the basin.

- Each storm's moisture inflow vector was re-evaluated and combined with an updated set of storm representative dew point values and climatology values. When necessary, updated storm representative dew point values were used in the calculation of in-place maximization and transposition factors. The HYSPLIT trajectory model was used to evaluate and verify moisture inflow vectors for storms on the short storm list. The trajectory model was not available for use in HMR studies. The use of HYSPLIT allowed for a high degree of confidence when determining moisture inflow vectors and storm representative dew points.

- Several new storms have been analyzed and included in this site-specific PMP calculation that were not included in HMR 51. This provided a higher level of confidence in the final PMP values. Further, this allowed for a refined set of values that better represent the PMP values for both the all-season and cool-season PMP scenarios, as the data set used to derive PMP has been expanded to include a larger set of more recent storms.

- The site-specific PMP calculation provided adjustments for storm elevation to the nearest 100 feet of elevation, whereas HMR 51 makes no explicit adjustment for elevation for PMP values. This adjustment depends on the elevation of the historic storm's maximum rainfall location and therefore varies from storm to storm. Further, the average basin elevation was evaluated in this calculation using GIS, providing an accurate representation and calculation to account for loss of available moisture up to that elevation.

- SPAS was used in conjunction with NEXRAD data (when available) to evaluate the spatial and temporal distribution of rainfall. Use of NEXRAD data generally produced higher point rainfall amounts than were observed using only rain gauge observations and provides objective spatial distributions of storm rainfall for locations among rain gauges. SPAS results provided storm DADs, total storm precipitation patterns, and mass curves for the newly analyzed storms. Using these technologies, significant improvements of the storm rainfall analyses were achieved.

- Previously analyzed storm events that occurred prior to 1948 that used 12-hour persisting dew points were re-evaluated to determine an updated storm representative dew point. This was done to adjust for using average maximum dew point values for varying durations vs. maximum 12-hour persisting dew point values. Recent evaluations of maximum 12-hour persisting storm representative dew points show those used in HMR 51 underestimated many of the storm representative dew point values. An updated set of maximum dew point climatology maps were produced.

Only storm types that would explicitly produce a PMF event for the basin of this size were evaluated and included in the PMP development. Therefore, small area size, high intensity, short duration events were not included in the all-season and cool-season PMP calculations.

5.3.16 Recommendations for application of site-specific PMP and LIP values

PMP and LIP values have been computed that provide maximum rainfall amounts for use in computing the PMF within the MNGP watershed and the maximum water levels at the MNGP site location. This calculation provided both all-season and cool-season PMP values. The cool-season PMP values are considered as a rain-on-snow scenario and are combined with a given amount of snow melt to derive the total runoff associated with a cool-season PMP rainfall.

The calculation addressed several issues that could potentially affect the magnitude of the PMP storm over basin as compared with HMR 51 (Reference 1). Analysis of moisture availability for previously analyzed storms and analysis of recent extreme storms with up to date state-of-the-science techniques resulted in PMP values which replace HMR 51 and provide explicit cool-season PMP values. These represent the most current PMP values that should be used together with the procedures in HMR 52 (Reference 2) and updated PMP design storm parameters to provide PMP rainfall at any location within the basin and at the site location.

HMR 52 uses a procedure for locating the largest amounts of rainfall associated with the PMP storm (Reference 2), such that the largest volume of rain falls within the watershed boundaries. No restrictions or adjustments to those procedures are recommended from this study.

The storm search and selection of storms for the basin-wide PMP emphasized storms with the largest rainfall values covering large area sizes and long durations. Therefore, results of the all-season and cool-season PMP from this calculation should not be used for basin sizes where the PMF would potentially result from small area sizes, short duration intense rainfall. This would include basins affected by individual thunderstorms or MCC storm types.

The LIP values were derived using storms with high intensity, short duration rainfalls, such as individual thunderstorms and MCCs. They were calculated based on the specific meteorological and topographical characteristics unique to the MNGP site. Therefore, use of the LIP values at other locations or where other storm type(s) would control LIP values is not recommended.

5.4 Meteorological Time Series Development

AWA used a procedure to determine the maximum temperature, maximum dew point temperature, and maximum wind speed for each of the Monticello and Monticello basins for three historic rainfall/flood events which best represent an expected cool-season PMP rainfall scenario (April 1954, April 1965, and April 2001). Hourly time series were created for a 120-hour period. This duration encompassed the maximum 72-hour precipitation period needed for PMF rain-on-snow modeling. The hourly temperature and dew point values were maximized to ensure continuity with the similar maximized PMP rainfall amounts using the average in-place maximization temperature difference of the cool-season storms used to derive PMP. This represented the average temperature difference between the storm representative dew point and the climatological maximum dew point. This was done in order

to best represent what the meteorological parameters would look like during a cool-season PMP rainfall event and to be consistent with the maximizations of the storm events used to derive those values. This process followed the same procedures as were completed during PMP studies where rain-on-snow PMP was determined (e.g. Reference 15, Reference 24, Reference 25).

5.4.1 Data and Methods

Hourly reporting surface stations were identified in and around the Monticello and Monticello basin. Only those stations considered NWS official stations and representative the regional climate were included. Initially, all meteorological stations within a latitude/longitude box of 48.5°N/98.0°W to 41.0°N/88.0°W were identified for each storm event analyzed. Only those stations considered representative to each sub-basin's climate were included (Figure 18, Figure 19, Figure 20). The hourly data were extracted from on-line resources, quality controlled, and assembled into a consistent format. For April 1965, some hourly stations only recorded data every three hours, in order to get a complete hourly time series, data were linearly interpolated between observations.

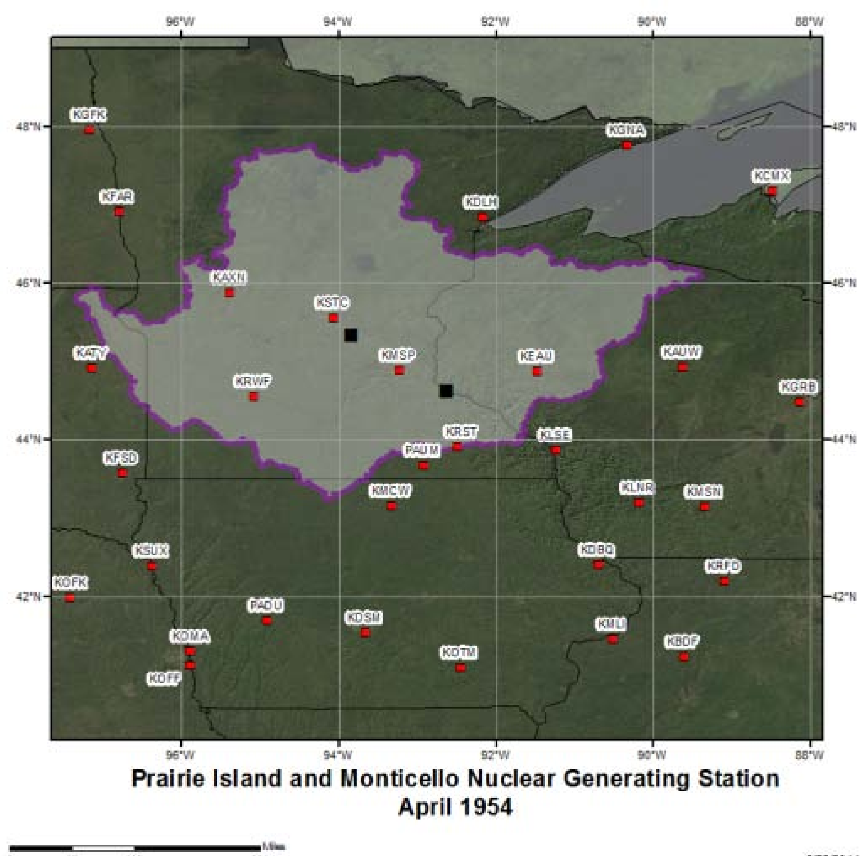


Figure 18. Stations used in the April 1954 meteorological time series development

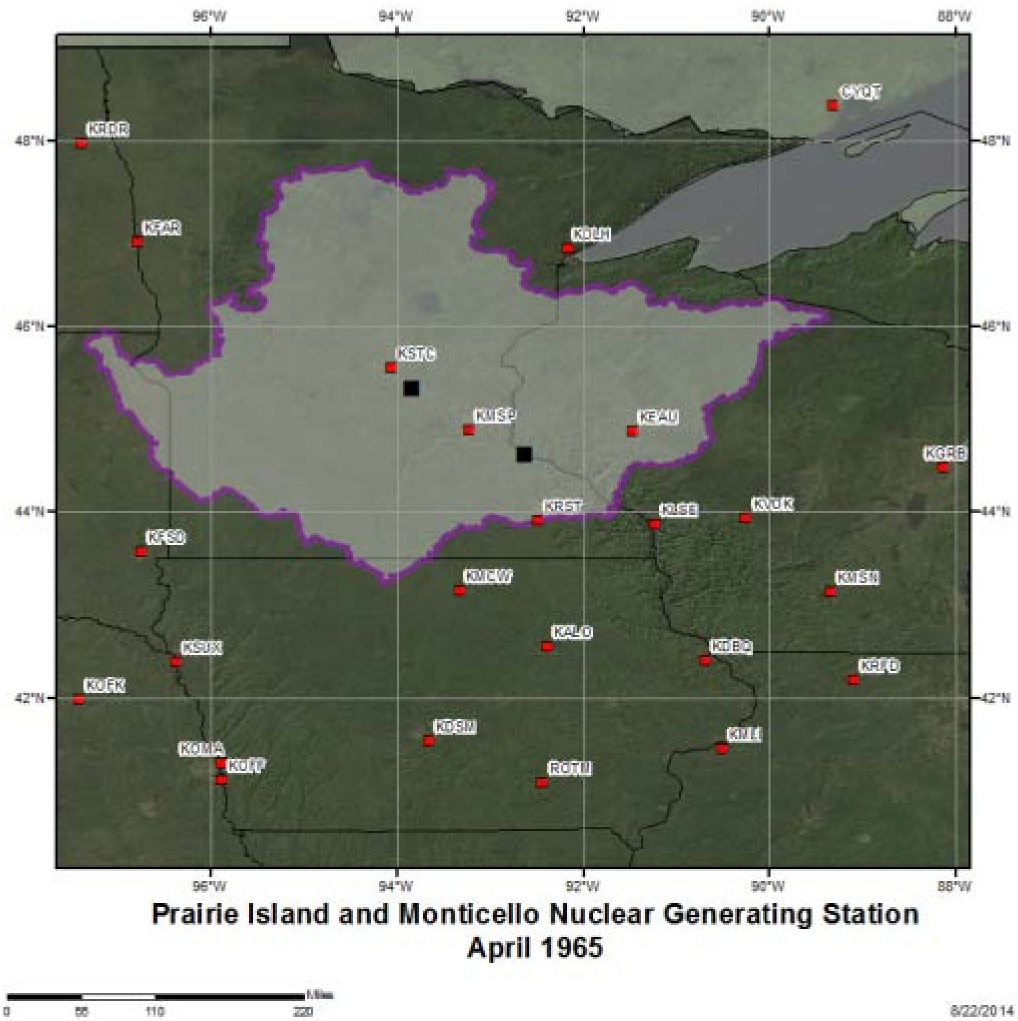


Figure 19. Stations used in the April 1965 meteorological time series development

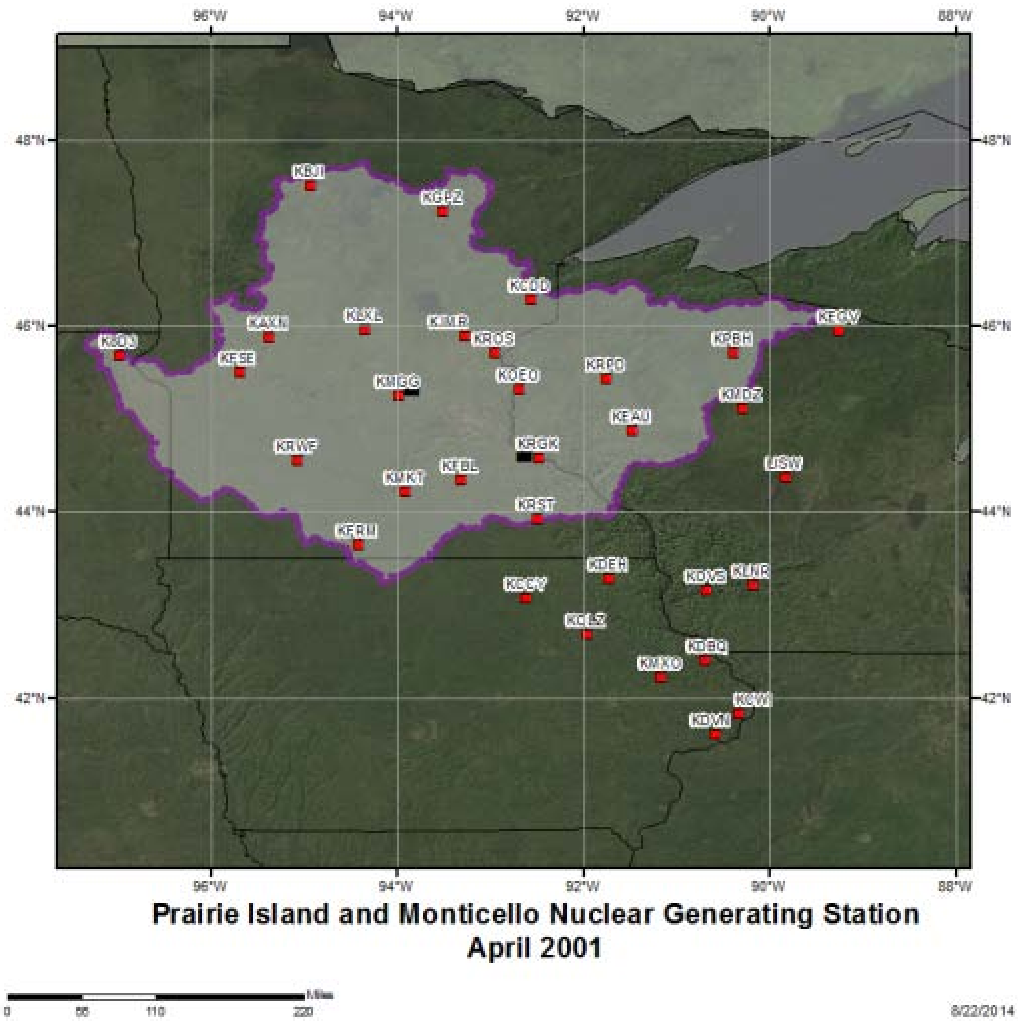


Figure 20. Stations used in the April 2001 meteorological time series development

5.4.1.1 Hourly time series

The hourly stations used in this analysis were quality controlled to ensure all data used had no missing hours and erroneous values. The data were then assembled into a consistent format using Excel for efficient analysis. Hourly precipitation data were collected from hourly gridded precipitation data generated from SPAS. The hourly rainfall data were used to determine the maximum 72-hour rainfall window to associate with the cool-season PMP analysis period.

In order to determine the proper 72-hour timing, an indexing approach was used because the maximum 72-hour rainfall did not always occur at the same time and each storm had different durations. To overcome the duration

differences, precipitation start time, and peak 72-hour rainfall variability from all storms were normalized to have a similar index period of 120-hours. For each storm, the index time of the maximum 72-hour accumulated rainfall was determined (green line, Figure 21). The 72-hour mid-point was determined by shifting the maximum 72-hour accumulated rainfall index hour 36-hours earlier (red line, Figure 21). The 72-hour mid-point was used to determine the start and end times/index hours of the 120-hour analysis window (blue lines, Figure 21). This procedure was performed on the three storm events in order to make comparisons for the 72-hour PMP meteorological time series profile.

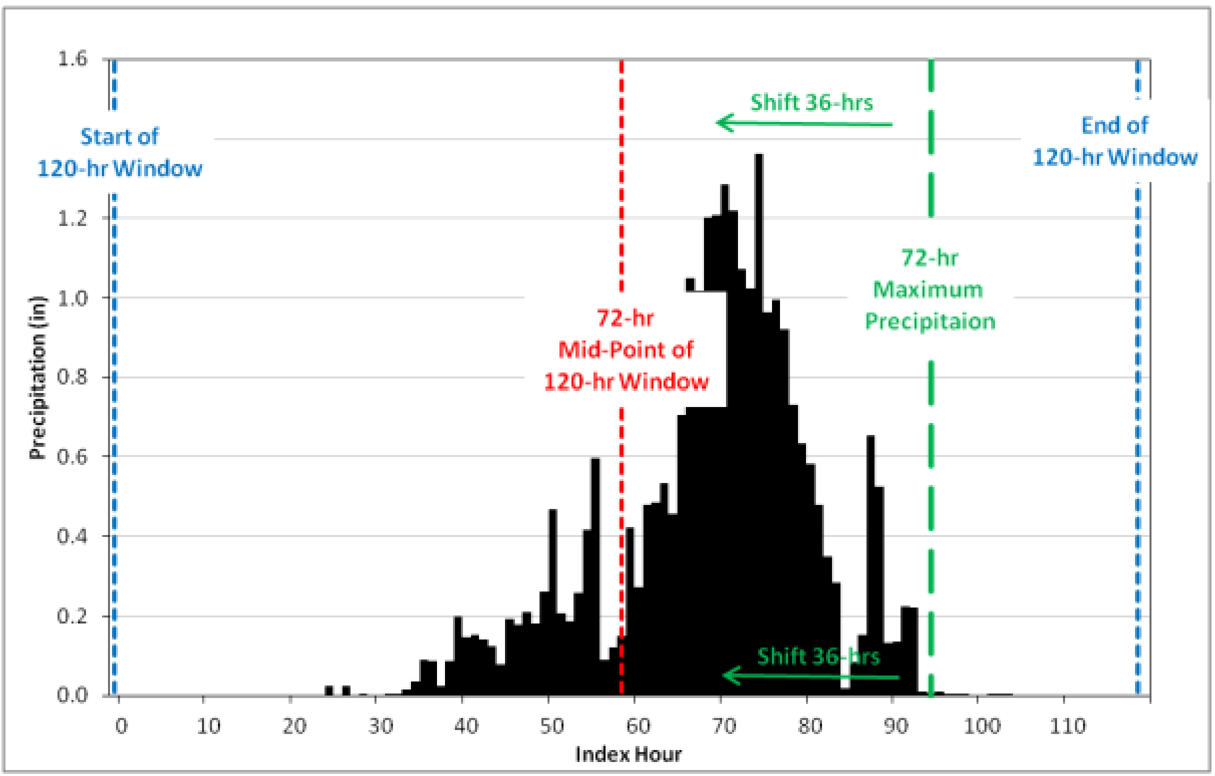


Figure 21. Example of methodology to create normalized profiles. Maximum 72-hour accumulated precipitation (green line). Mid-point of 72-hour window based on 36-hour shift from maximum 72-hour accumulation (red line). Start and end point of the 120-hour duration used in analysis (blue lines).

Once the proper 120-hour window was identified for each storm, hourly data were grouped together into an Excel spreadsheet. An example of a hourly station data for KSTC April 1954 is shown in Table 13. In addition to the hourly tables created for each station, plots of hourly temperature, dew point, wind speed, and rainfall were created. An example of plotted hourly station data for KSTC April 1954 is shown in Figure 22.

Table 13. Example of hourly station data for KSTC, April 1954

index	Hour	Year	Mo	Day	cntr	Ta (F)	Td (F)	Ws (mph)	Ppt
1	800	1954	4	23	1	41.0	26.6	4.6	0.00
2	900	1954	4	23	2	39.2	26.6	6.9	0.00
3	1000	1954	4	23	3	39.2	26.6	4.6	0.00
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
118	500	1954	4	28	118	42.8	39.2	6.9	0.00
119	600	1954	4	28	119	41.0	39.2	8.1	0.00
120	700	1954	4	28	120	41.0	39.2	6.9	0.00

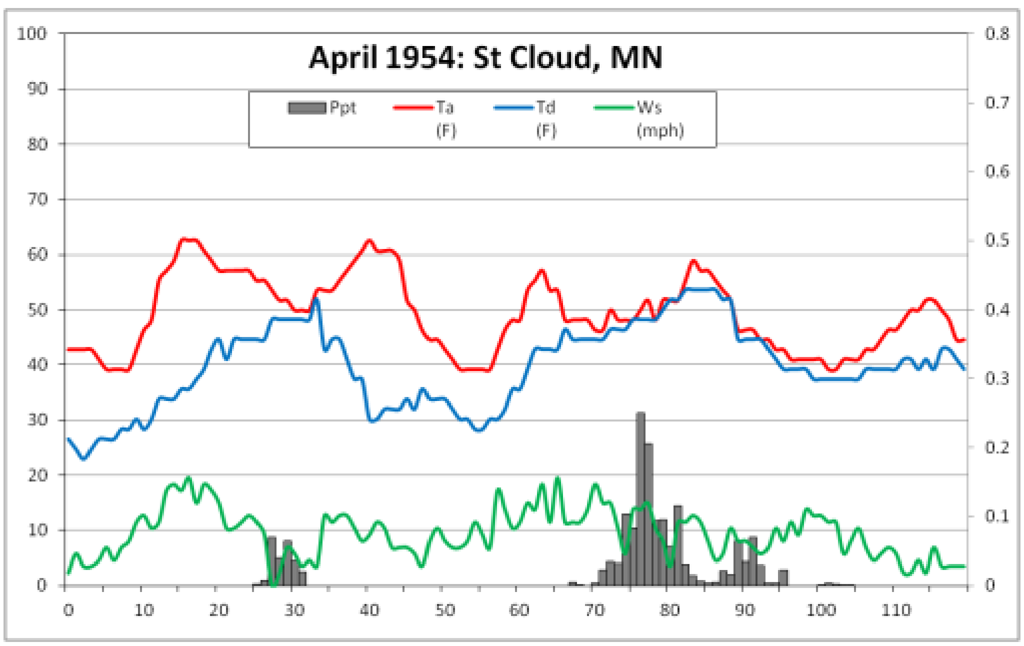


Figure 22. Example of plotted hourly station data for KSTC, April 1954

5.4.1.2 Temperature time series maximization

For each of the three storm events analyzed (April 1954, April 1965, and April 2001), a maximum time series was created based on calculating the maximum individual hourly station meteorological data of the stations used in different areas of the overall basin. For example, three stations for the April 1954 time series, KSTC, KMSP, and KDLH, were compared. The maximum of these three stations hourly meteorological data were used to create the maximum time series profile for the area of the basin they represent meteorologically for April 1954. The same

process was then completed for the other two events, with the maximum at each hours used in the final analysis. The final application of maximization for the meteorological time series was to apply the average temperature difference between the storm representative dew point value of each cool-season PMP storm against the maximum dew point climatological value. The values associated with the storms which control the cool-season PMP values were averaged and the resulting value was then applied to each hourly temperature value. The value derived from this process was 4.0°F. This was the value applied in the maximization process to the temperature and dew point hourly time series used in the snow melt calculations.

5.4.1.3 Creation of gridded time series datasets

Gridded datasets were produced for the 120-hour time series using the maximum temperature, dew point, and wind speeds described in the previous sections. ArcGIS desktop 10.2 (Reference 10) was used to interpolate continuous gridded data between each of the station locations for the three analyzed storm events over the MNGP watershed. The final gridded datasets were converted to ASCII format. All geographic data used in these procedures utilized the World Geodetic System 1984 (WGS 84) spatial reference. The gridded time series data sets were produced using the following geoprocessing procedures:

1) For each storm, an Excel spreadsheet was composed containing the station data for each of the 120 hourly time steps. A separate sheet was created for each meteorological parameter (T_a, T_d, and W_s).
2) Point features were created for each station using the *Make XY Event Layer* tool. Each parameter was stored as a separate feature class with each hour stored as a separate attribute. NoData values were ignored.
3) The *Spline* Spatial Analyst tool was used to interpolate raster datasets from the station point features for each storm/parameter. The *tension* spline type was used with the weight set to 500 and number of points set to 12. These relatively tight settings ensured the gridded data adheres to the station point values at the station locations without exaggerated inflation or deflation of values between station points. The output rasters were created in the GRID format with a spatial resolution of 30-arc seconds and were masked to the study area domain.
4) The temperature and dew point GRIDs were maximized by adding 4° to the value of each grid. This was done using the *Plus* Spatial Analyst tool and adding 4 to the value of each GRID.
5) For each parameter, the maximum gridded values from each of the three storms were taken. This was done using the *Mosaic to New Raster* tool with the *Maximum* mosaic operator.
6) For each parameter, the hourly GRIDs were converted to ASCII format using the *Raster to ASCII* conversion tool.

For quality control, if any dew point (T_d) values were interpolated to be greater than the temperature (T_a) values, they were reassigned to match the T_a values. This was done using the *Con()* map algebra function. For each parameter, values were extracted at four control points over the grid domain; 1 - the northern region (47.5°, -94.5°), 2 – the centroid of the domain (45.5°, -97.6°), 3- the MNGP site (45.3°, -93.9°), and 4 – the MNGP site (44.6°, -92.6°) as shown in Figure 23. The extracted data were plotted over the 120-hour duration at each of the four points for analysis and comparisons. These results are displayed in Figure 24, Figure 25, Figure 26 and Figure 27.

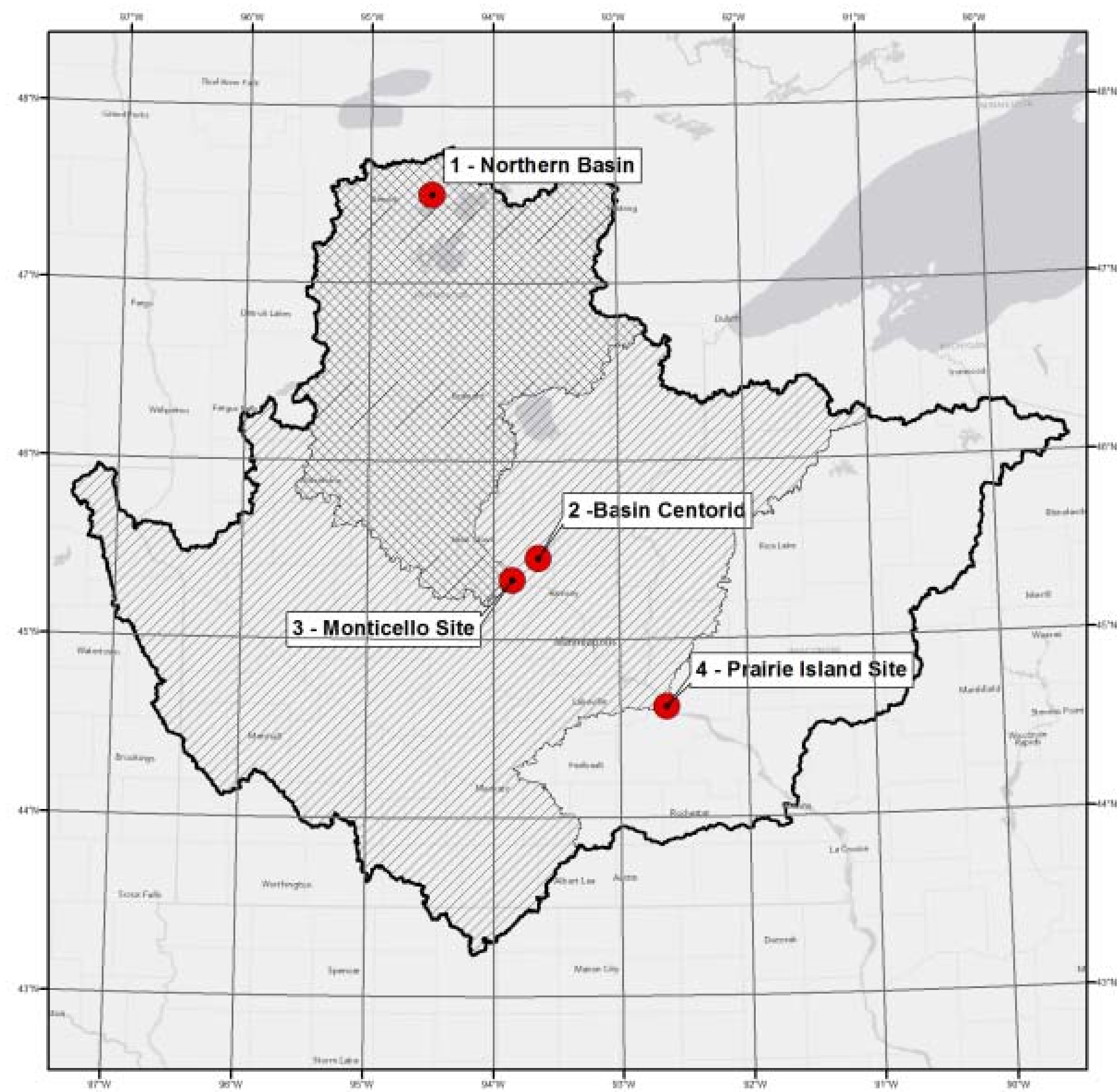


Figure 23. Four points used for QC of the meteorological time series data

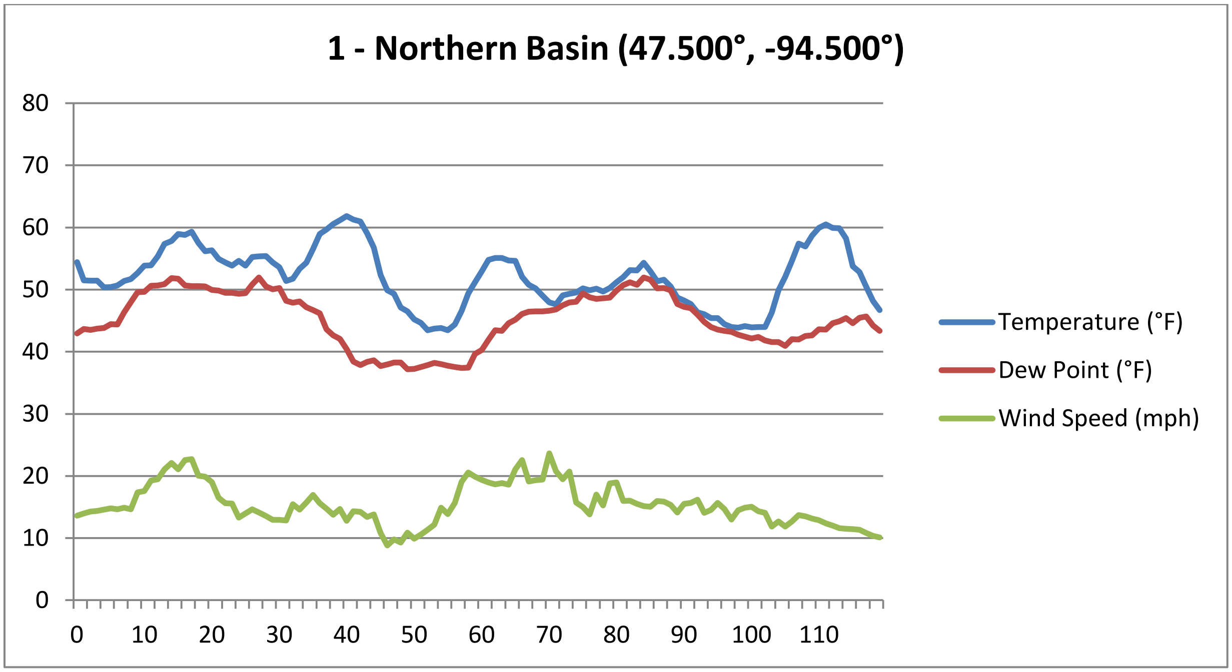


Figure 24. Maximized meteorological time series data for the northern portion of the basin

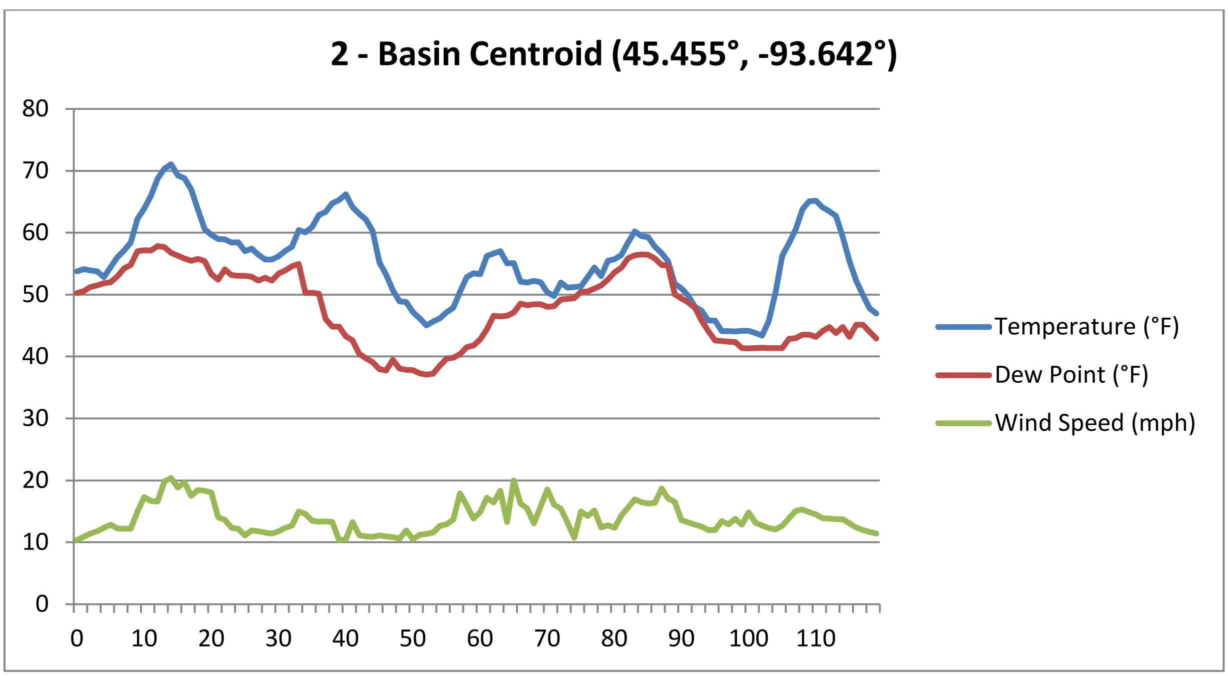


Figure 25. Maximized meteorological time series data for overall basin centroid

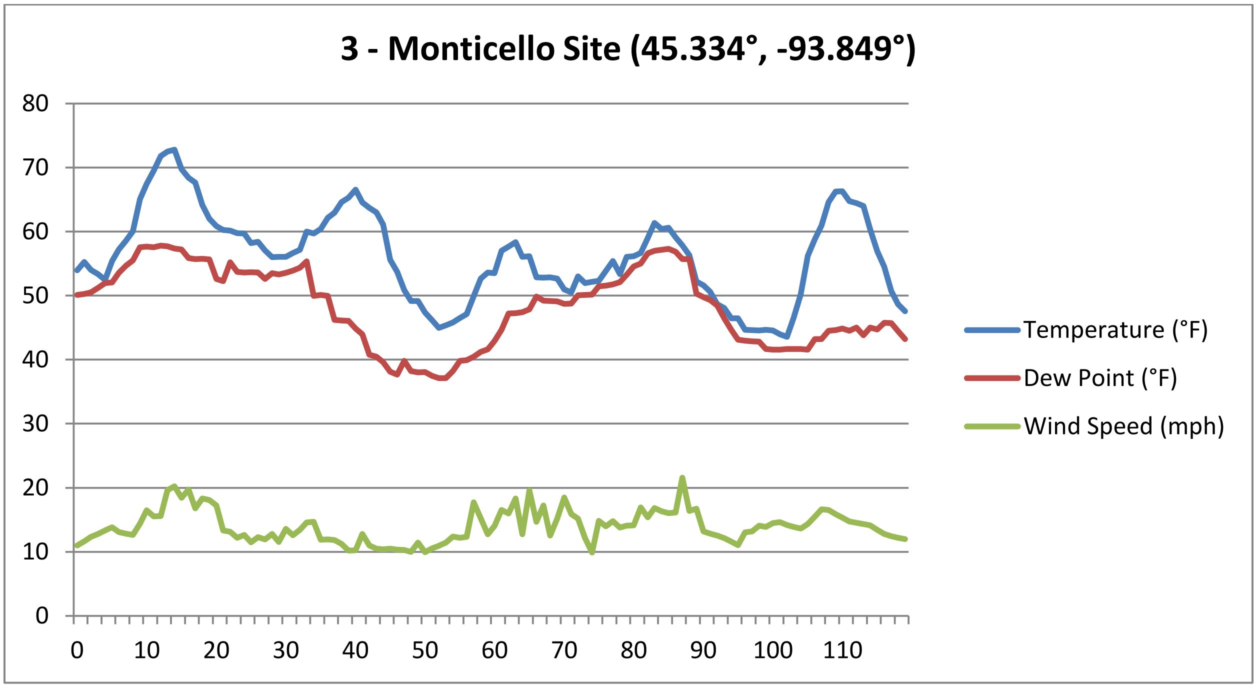


Figure 26. Maximized meteorological time series data at the Monticello site

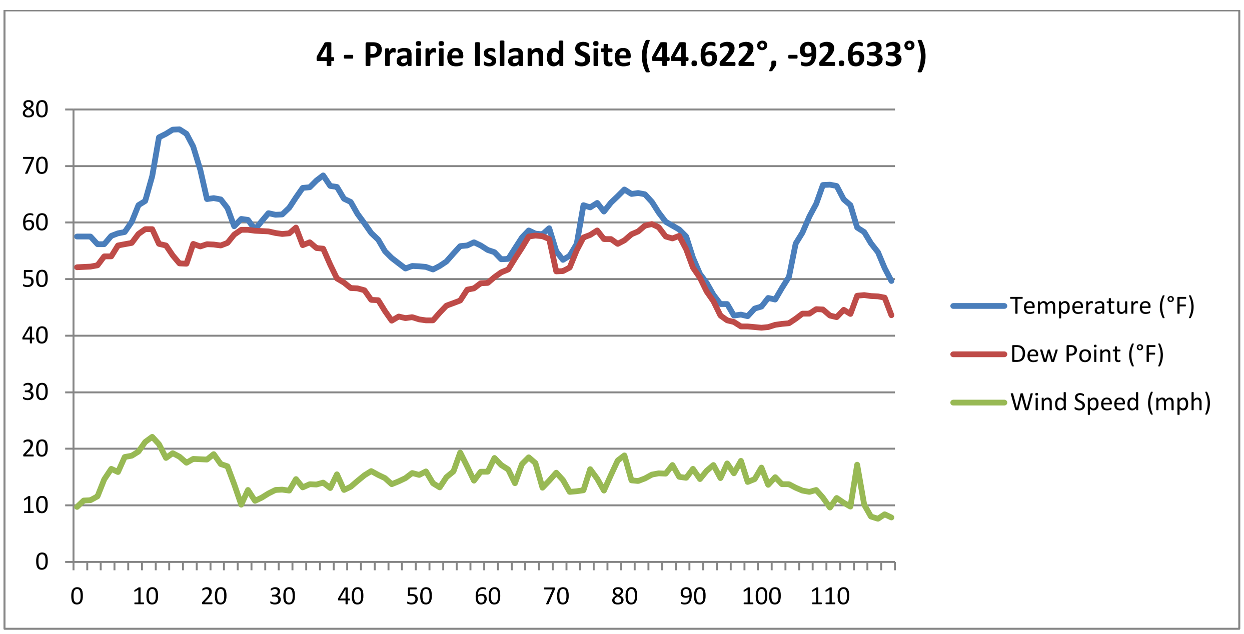


Figure 27. Maximized meteorological time series data at the Monticello site

6.0 Final Results

The following summarizes the results of this calculation:

- HMR 51 PMP values are outdated. This calculation provided updated PMP values to replace HMR 51 PMP values using current storm data and state-of-the-science meteorological techniques and understanding.

- No previous cool-season PMP values were developed by the NWS for this basin. This calculation explicitly derived cool-season PMP values at standard area sizes and durations following the standard storm based approach.

- No MCCs were evaluated for PMP development. Therefore, PMP depths derived for areas less than 500-square miles and at durations less than 24-hours are for general storms only. These values may be less than would have been determined if MCCs were included in the calculation.

- The most recent storm used to derive PMP values in HMR 51 occurred in 1972 (Attachment, Reference 1) and the most recent storm in HMR 52 occurred in 1973 (Table 21, Reference 2). This calculation updated the storm database to include storms through 2014.

- HMR 51 and HMR 52 did not use computer based technologies in the storm analyses procedures. This calculation used computer technology and GIS to more accurately analyze storm rainfall patterns and implement the spatially distributed PMP values.

- HMR 51 and HMR 52 did not have weather radar to help spatially distribute rainfall among rain gauge locations. SPAS storm analyses incorporates this information when available to provide the most advanced spatial representation of rainfall storm patterns possible.

- Understanding of meteorological processes, interactions, and storm patterns have advanced greatly since the publication of HMR 51. Satellite and radar technology have greatly added to the understanding of storm patterns over the last 40 years. This calculation incorporated the state-of-the-science understanding and technology associated with analyzing extreme rainfall events.

- Storm based analysis of expected meteorological conditions associated with rain-on-snow scenarios were not developed in HMR 51 or HMR 52. This calculation explicitly evaluated meteorological parameters that would reasonably be expected to occur during a cool-season PMP event.

The final results of this analysis are the following: (1) the all-season PMP depths (Table 9), (2) the cool-season PMP depths (Table 10), and (3) LIP depths (Table 7).

7.0 Attachments

Attachment 1 –"All-Season Short Storm List Data" (80 pages)

Attachment 2 - "Cool-Season Short Storm List Data " (37 pages)

Attachment 3 –"Local Intense Precipitation Short Storm List Data" (894 pages)

Attachment 4 – "100-year Return Frequency Average Dew Point Climatology Maps Used in the Storm Maximization and Transposition Calculations" (36 pages)

Attachment 5 – "Procedure for using Dew Point Temperatures for Storm Maximization and Transposition" (5 pages)

Attachment 6 –" Procedure for Deriving PMP Values from Storm Depth-Area-Duration Analyses" (6 pages)

Attachment 7 –" Depth-Area and Depth-Duration Curves" (13 pages)

ATTACHMENT 1: All-Season Short Storm List Data

Storm Name	State	AWA Storm Number	Lat	Lon	Year	Month	Day	Maximum Rainfall in Inches	Precipitation Source
DULUTH	MN	41W	47.0200	-91.6700	2012	6	19	10.73	SPAS 1296
DUBUQUE	IA	1W	42.4400	90.7500	2011	7	27	15.14	SPAS 1220
HOKAH	MN	4W	43.8125	-91.3625	2007	8	18	18.32	SPAS 1048
WARROAD	MN	43W	48.8792	-95.0792	2002	6	9	14.55	SPAS 1297
AURORA COLLEGE	IL	5W	41.4575	-88.0699	1996	7	16	18.13	SPAS 1286
BIG RAPIDS	MI	6W	43.6125	-85.3125	1986	9	9	13.42	SPAS 1206
WOOSTER	OH	8W	40.9146	-81.9729	1969	7	4	14.95	SPAS 1209
EDGERTON	MO	9W	40.4125	-95.5125	1965	7	18	20.76	SPAS 1183
IDA GROVE	IA	11W	42.3167	-95.4667	1962	8	30	12.85	EPRI
PRAGUE	NE	12W	41.3583	-96.8794	1959	8	1	13.09	SPAS 1031
COLE CAMP	MO	14W	38.4600	-93.2027	1946	8	12	19.40	MR 7-2A
COLLINSVILLE	IL	15W	38.6717	-89.9800	1946	8	12	18.70	MR 7-2B
HAYWARD	WI	18W	46.0130	-91.4846	1941	8	28	15.00	UMV 1-22
IRONWOOD	MI	21W	46.4500	-90.1833	1909	7	21	13.20	UMV 1-11B
MEDFORD	WI	23W	45.1333	-90.3333	1905	6	4	11.20	GL 2-12
WOODBURN	IA	24W	41.0120	-93.5991	1903	8	24	15.50	MR 1-10
LAMBERT	MN	25W	47.8000	-96.0000	1897	7	18	8.00	UMV 1-2

Attachment 1 Table 1: List of storms used in the all-season PMP development

Storm Name:	**SPAS 1286-Aurora College, IL**
Storm Date:	**17-Jul-1996**
AWA Analysis Date:	**8/24/2014**

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	**41.46 N**	**88.07 W**
Storm Rep Dew Point Location	**38.63 N**	**92.24 W**
Transposition Dew Point Locati	**43.79 N**	**98.88 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SW @ 300**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**650**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**74.0 F**	with total precipitable water above sea level of			**2.73**	inches.
The in-place maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The transpositioned maximum dew point is	**79.5 F**	with total precipitable water above sea level of			**3.52**	inches.
The in-place storm elevation is	**650**	which subtracts	**0.16**	inches of precipitable water at	**74.0 F**	
The in-place storm elevation is	**650**	which subtracts	**0.20**	inches of precipitable water at	**80.5 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**79.5 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**79.5 F**	

The in-place maximization factor is	**1.35**
The transposition factor is	**0.90**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.22**

Notes: 24hr average Td from 07-17-96 0000 CDT to 07-17-96 2300 CDT.

Observed Storm Depth-Area-Duration

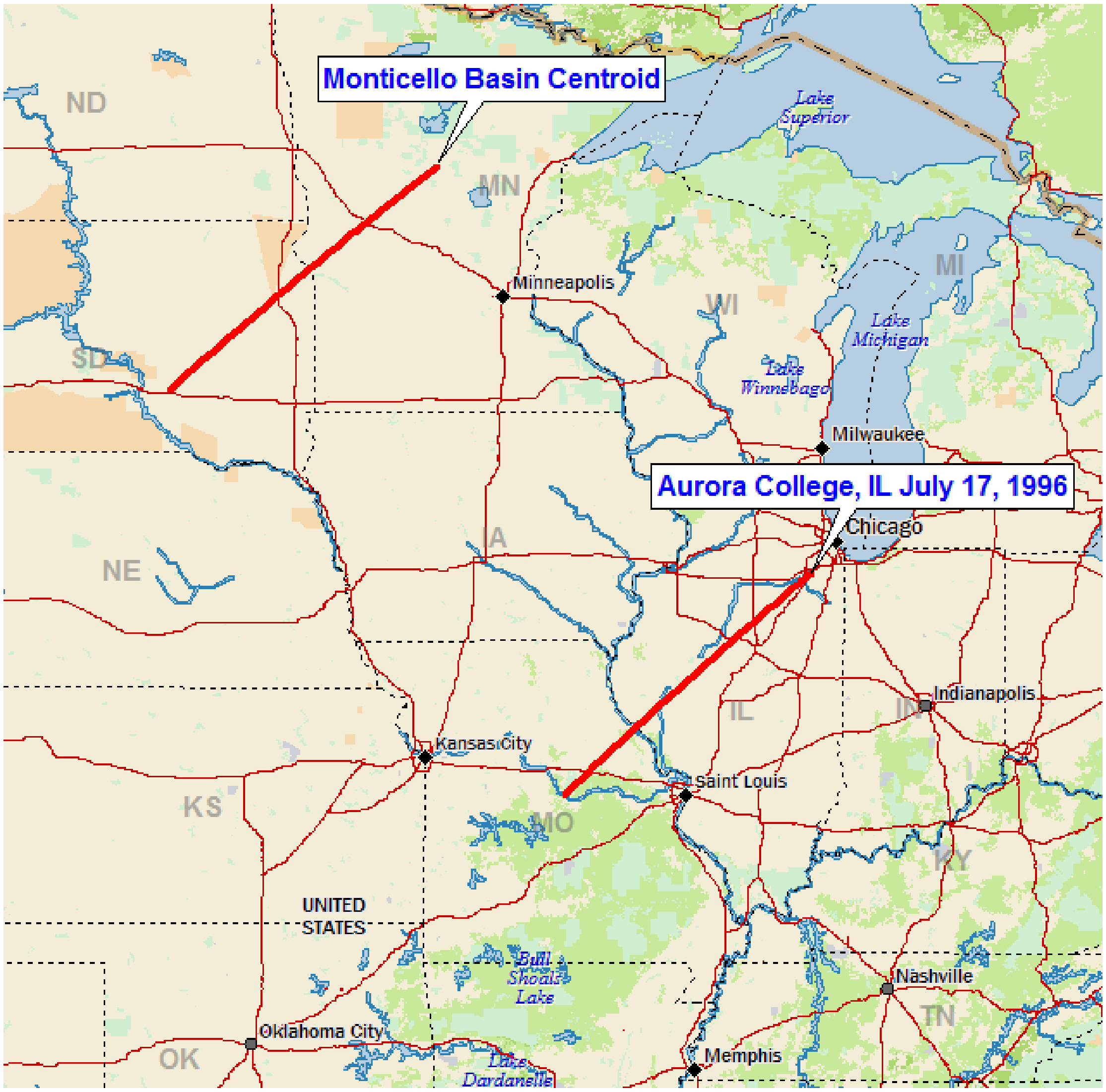
	1 Hour	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**6.1**	**14.4**	**15.4**	**17.3**	**17.6**	-	**17.6**	-	-	-
10 sq miles	**5.9**	**14.0**	**15.1**	**17.2**	**17.2**	-	**17.5**	-	-	-
100 sq miles	**4.3**	**12.1**	**13.4**	**15.6**	**16.0**	-	**16.1**	-	-	-
200 sq miles	**3.6**	**10.4**	**12.5**	**14.6**	**15.1**	-	**15.1**	-	-	-
500 sq miles	**3.1**	**9.0**	**10.9**	**12.8**	**13.1**	-	**13.4**	-	-	-
1000 sq miles	**2.5**	**7.9**	**9.7**	**11.0**	**11.2**	-	**12.1**	-	-	-
5000 sq miles	**1.6**	**4.8**	**6.2**	**7.8**	**8.1**	-	**8.4**	-	-	-
10000 sq miles	**0.7**	**3.5**	**5.0**	**6.1**	**6.6**	-	**7.0**	-	-	-
20000 sq miles	**0.4**	**1.6**	**3.6**	**4.6**	**5.2**	-	**5.4**	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hour	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**7.4**	**17.6**	**18.8**	**21.2**	**21.5**	-	**21.6**	-	-	-
10 sq miles	**7.2**	**17.1**	**18.4**	**21.0**	**21.0**	-	**21.4**	-	-	-
100 sq miles	**5.3**	**14.8**	**16.4**	**19.1**	**19.6**	-	**19.6**	-	-	-
200 sq miles	**4.4**	**12.7**	**15.2**	**17.8**	**18.5**	-	**18.5**	-	-	-
500 sq miles	**3.8**	**11.0**	**13.3**	**15.6**	**16.0**	-	**16.4**	-	-	-
1000 sq miles	**3.0**	**9.7**	**11.9**	**13.5**	**13.7**	-	**14.8**	-	-	-
5000 sq miles	**1.9**	**5.9**	**7.5**	**9.6**	**9.8**	-	**10.2**	-	-	-
10000 sq miles	**0.8**	**4.3**	**6.1**	**7.4**	**8.0**	-	**8.6**	-	-	-
20000 sq miles	**0.5**	**1.9**	**4.4**	**5.6**	**6.3**	-	**6.6**	-	-	-

Storm or Storm Center Name	**SPAS 1286-Aurora College, IL**	
Storm Date(s)	17-Jul-1996	
Storm Type	Synoptic-Thunderstorms	
Storm Location	41.46 N	88.07 W
Storm Center Elevation	650	
Precipitation Total & Duration	18.13 in 24hrs from SPAS 1286	
Storm Representative Dew Point	74.0 F	24
Storm Representative Dew Point Location	38.63 N	92.24 W
Maximum Dew Point	80.5 F	
Moisture Inflow Vector	SW @ 300	
In-place Maximization Factor	**1.35**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	43.79 N	98.88 W
Transposition Maximum Dew Point	79.5 F	
Transposition Adjustment Factor	**0.90**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.22**	

Attachment 1 Table 2: Storm spreadsheet for Aurora College, IL July 1996

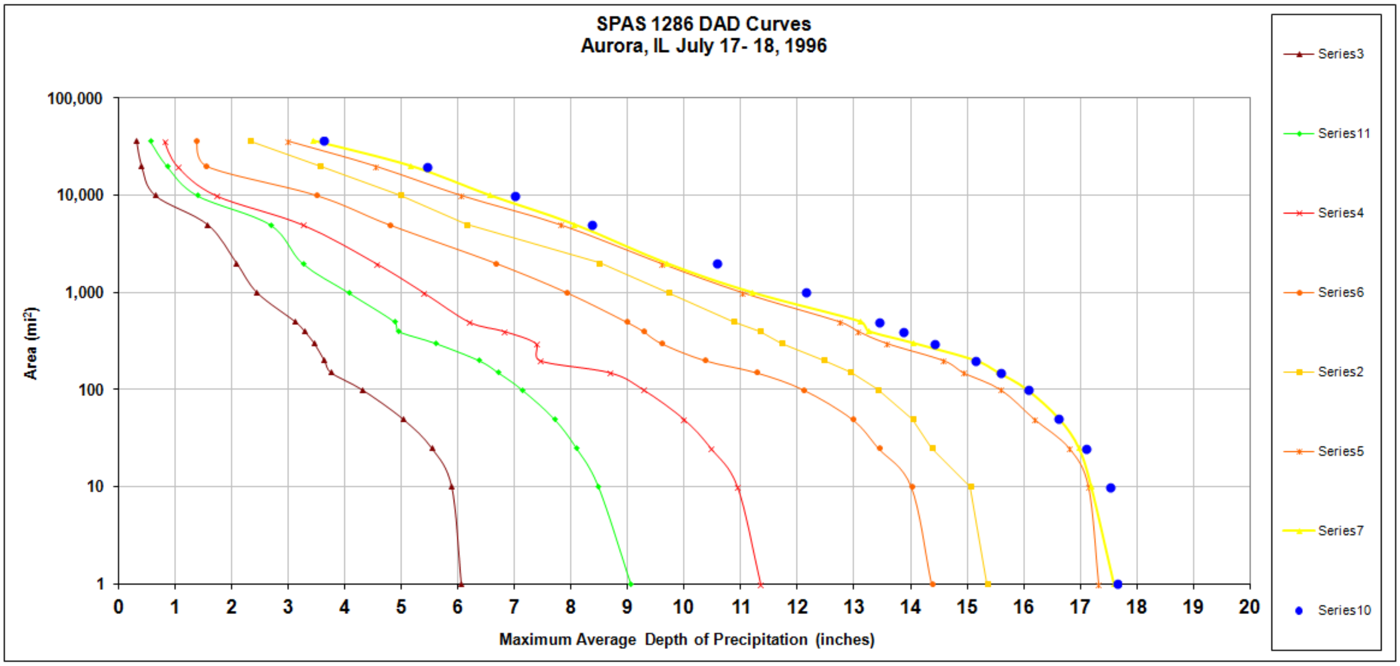


Attachment 1 Figure 1: Moisture inflow map for Aurora College, IL July 1996

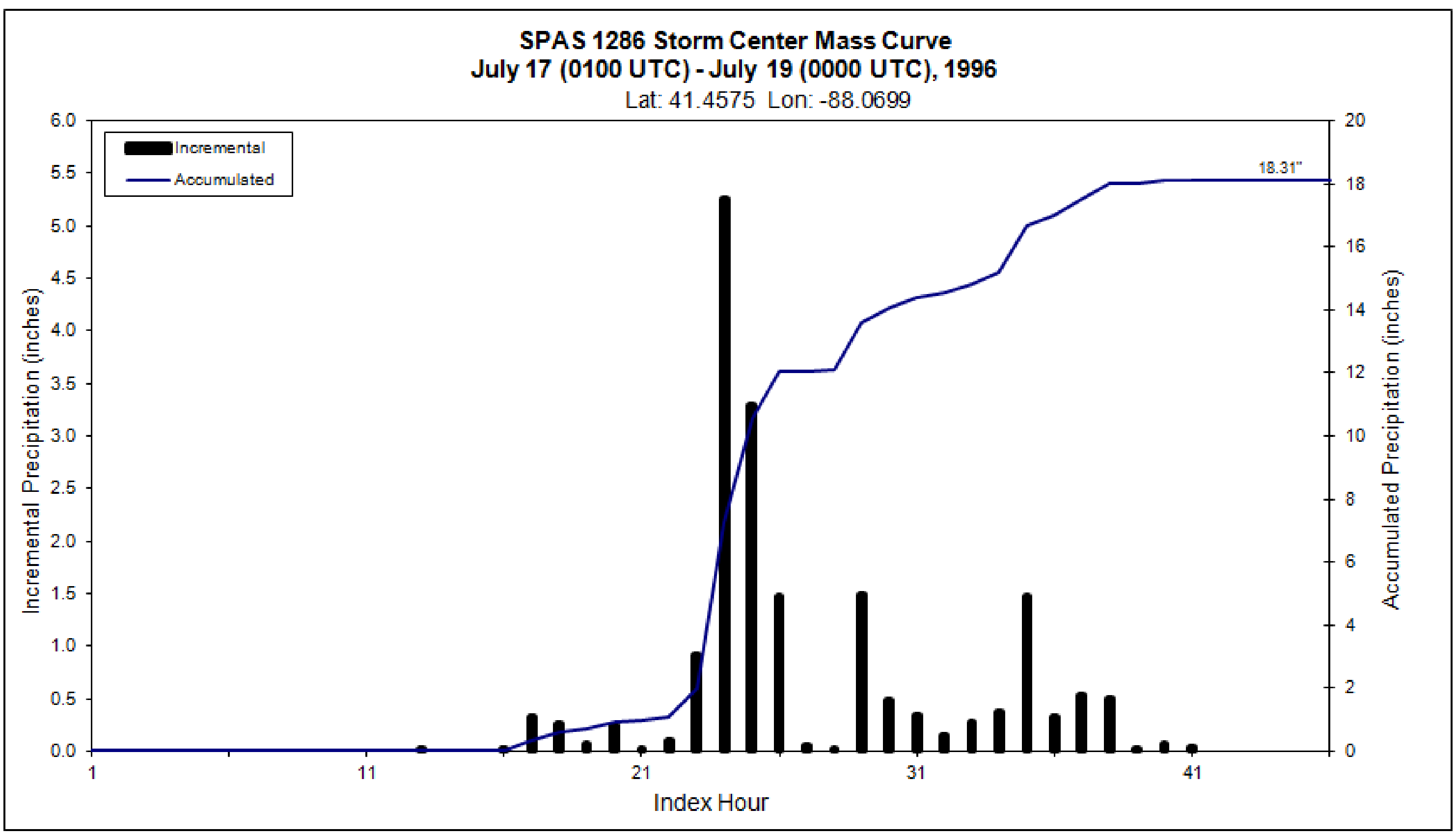
Storm 1286 - Aurora, IL July 17- 18, 1996
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

Area (mi^2)	Duration (hours)												
	1	2	3	4	5	6	12	18	24				total (36-hr)
1	6.06	9.05	11.35			14.38	15.35	17.33	17.58				17.64
10	5.89	8.48	10.94			14.02	15.05	17.15	17.18				17.51
25	5.54	8.09	10.47			13.44	14.38	16.81	16.96				17.09
50	5.03	7.70	9.99			12.97	14.04	16.19	16.61				16.61
100	4.31	7.13	9.28			12.11	13.42	15.60	16.04				16.06
150	3.76	6.71	8.69			11.28	12.94	14.94	15.53				15.58
200	3.64	6.37	7.45			10.37	12.46	14.59	15.12				15.14
300	3.46	5.61	7.38			9.60	11.71	13.59	14.04				14.42
400	3.29	4.95	6.82			9.28	11.34	13.08	13.24				13.86
500	3.13	4.88	6.20			8.98	10.87	12.76	13.10				13.43
1,000	2.45	4.07	5.40			7.93	9.72	11.04	11.18				12.13
2,000	2.09	3.26	4.56			6.68	8.50	9.60	9.67				10.56
5,000	1.58	2.69	3.26			4.79	6.15	7.82	8.05				8.36
10,000	0.65	1.40	1.73			3.51	4.98	6.07	6.55				7.00
20,000	0.41	0.87	1.05			1.56	3.57	4.56	5.16				5.44
36,456	0.32	0.57	0.82			1.38	2.33	3.00	3.43				3.61

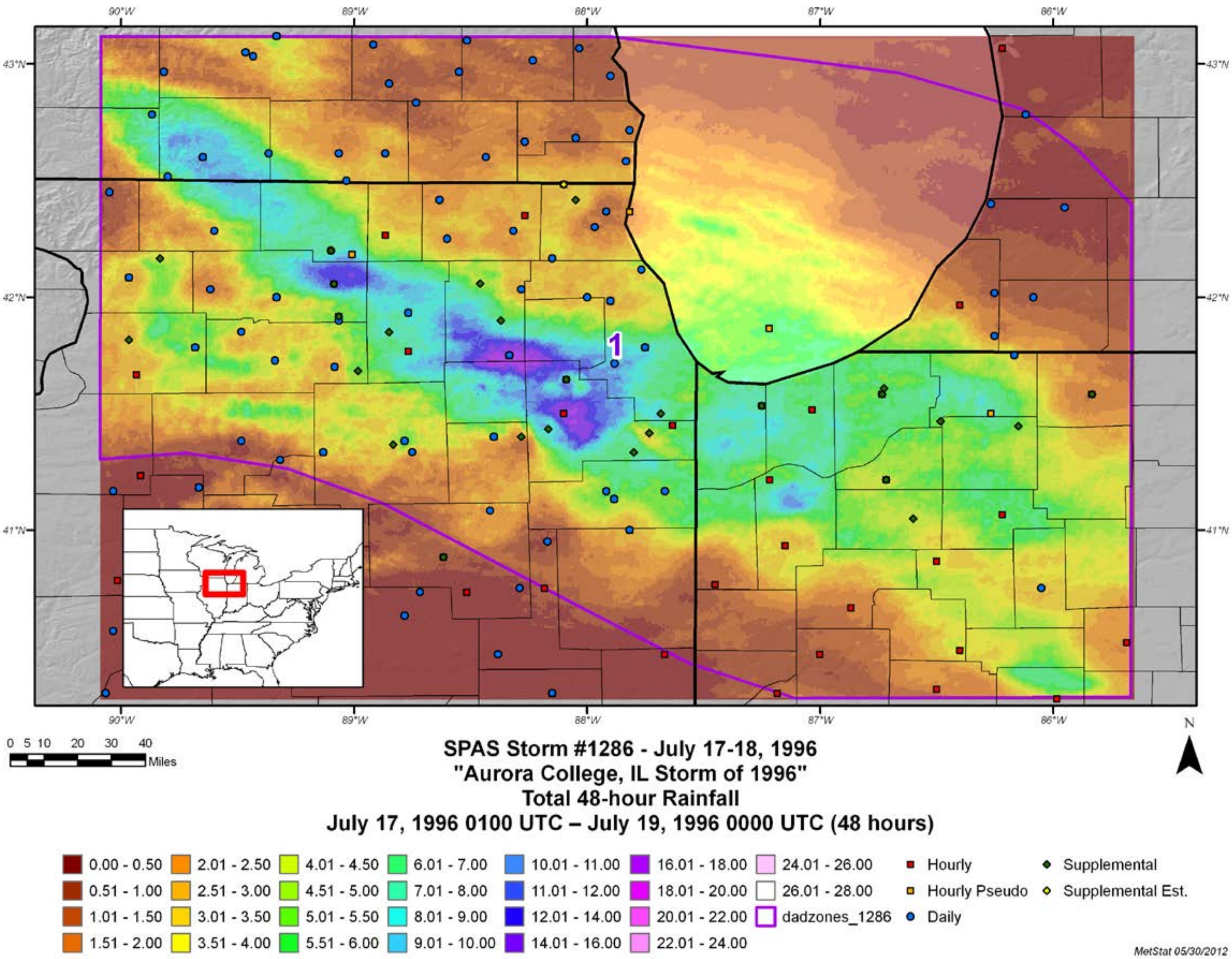
Attachment 1 Table 3: Depth-area-duration values for Aurora College, IL July 1996



Attachment 1 Figure 2: Depth-area-duration chart for Aurora College, IL July 1996



Attachment 1 Figure 3: Mass curve chart for Aurora College, IL July 1996



Attachment 1 Figure 4: Total storm isohyetal analysis for Aurora College, IL July 1996

Storm Name:	**SPAS 1206 Big Rapids, MI**		**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**9/9-12/1986**		
AWA Analysis Date:	**8/24/2014**		

Temporal Transposition Date	**1-Sep**	
	Lat	**Long**
Storm Center Location	**43.61 N**	**85.31 W**
Storm Rep Dew Point Location	**41.36 N**	**88.68 W**
Transposition Dew Point Locat	**44.37 N**	**97.91 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SW @ 230**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**950**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**70.5 F**	with total precipitable water above sea level of			**2.31**	inches.
The in-place maximum dew point is	**77.0 F**	with total precipitable water above sea level of			**3.14**	inches.
The transpositioned maximum dew point is	**75.5 F**	with total precipitable water above sea level of			**2.92**	inches.
The in-place storm elevation is	**950**	which subtracts	**0.21**	inches of precipitable water at	**70.5 F**	
The in-place storm elevation is	**950**	which subtracts	**0.26**	inches of precipitable water at	**77.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.33**	inches of precipitable water at	**75.5 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.33**	inches of precipitable water at	**75.5 F**	

The in-place maximization factor is	**1.38**
The transposition factor is	**0.90**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.24**

Notes: DAD values taken from SPAS 1206. Storm representative dew point value was based on maximum 24-hr Td values between September 8-12, 1986 at KMMO. Values were selected in region where temperature did not vary more than a 1-degree over a large area.

Observed Storm Depth-Area-Duration

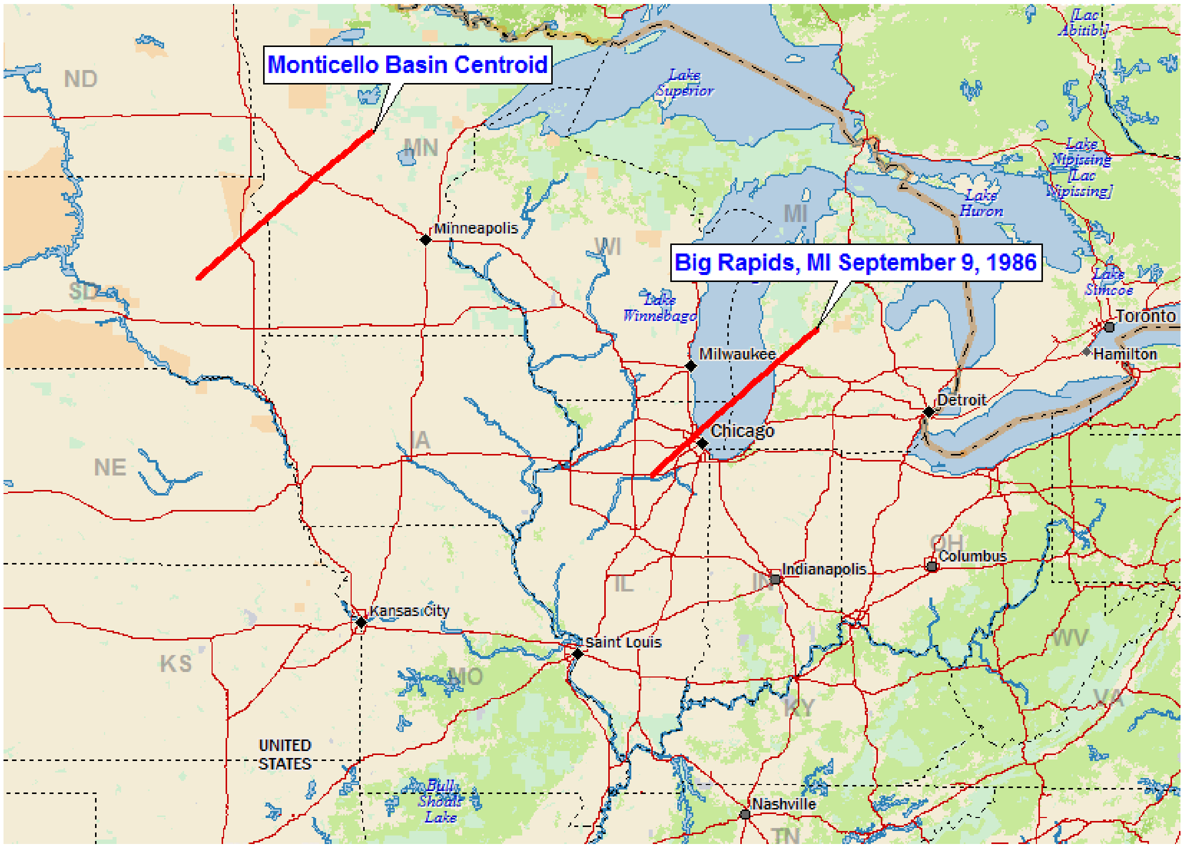
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**2.7**	**4.3**	**4.7**	**6.1**	**7.6**	**9.7**	**11.3**	**12.7**	**13.0**
10 sq miles	**2.6**	**4.2**	**4.6**	**6.0**	**7.6**	**9.7**	**11.3**	**12.7**	**13.0**
100 sq miles	**2.2**	**3.5**	**3.9**	**5.8**	**7.5**	**9.4**	**11.2**	**12.7**	**13.0**
200 sq miles	**2.0**	**3.2**	**3.8**	**5.6**	**7.3**	**9.3**	**11.1**	**12.6**	**12.9**
500 sq miles	**1.7**	**2.7**	**3.6**	**5.4**	**7.1**	**9.0**	**10.9**	**12.3**	**12.6**
1000 sq miles	**1.4**	**2.1**	**3.4**	**5.2**	**6.9**	**8.6**	**10.7**	**11.9**	**12.2**
2000 sq miles	**1.1**	**1.9**	**3.0**	**4.9**	**6.5**	**8.1**	**10.3**	**11.2**	**11.6**
5000 sq miles	**0.7**	**1.6**	**2.7**	**4.4**	**6.0**	**7.5**	**9.7**	**10.6**	**10.7**
10000 sq miles	**0.5**	**1.2**	**2.2**	**3.8**	**5.3**	**6.6**	**8.7**	**9.5**	**9.5**
20000 sq miles	**0.3**	**0.9**	**1.6**	**3.1**	**4.2**	**5.4**	**7.4**	**7.9**	**8.1**

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**3.3**	**5.3**	**5.8**	**7.6**	**9.4**	**12.0**	**13.9**	**15.7**	**16.0**
10 sq miles	**3.3**	**5.1**	**5.6**	**7.4**	**9.4**	**12.0**	**13.9**	**15.7**	**16.0**
100 sq miles	**2.8**	**4.4**	**4.8**	**7.1**	**9.2**	**11.7**	**13.8**	**15.7**	**16.0**
200 sq miles	**2.5**	**4.0**	**4.7**	**6.9**	**9.1**	**11.5**	**13.7**	**15.6**	**16.0**
500 sq miles	**2.1**	**3.3**	**4.4**	**6.6**	**8.8**	**11.1**	**13.5**	**15.2**	**15.6**
1000 sq miles	**1.8**	**2.6**	**4.2**	**6.4**	**8.5**	**10.6**	**13.2**	**14.7**	**15.0**
2000 sq miles	**1.4**	**2.3**	**3.7**	**6.1**	**8.1**	**10.1**	**12.8**	**13.8**	**14.3**
5000 sq miles	**0.8**	**1.9**	**3.3**	**5.4**	**7.4**	**9.2**	**12.0**	**13.1**	**13.3**
10000 sq miles	**0.6**	**1.5**	**2.8**	**4.7**	**6.5**	**8.2**	**10.7**	**11.8**	**11.8**
20000 sq miles	**0.4**	**1.1**	**2.0**	**3.8**	**5.2**	**6.6**	**9.1**	**9.7**	**10.1**

Storm or Storm Center Name	**SPAS 1206 Big Rapids, MI**			
Storm Date(s)	9/9-12/1986			
Storm Type	Synoptic			
Storm Location	43.61 N	85.31 W		
Storm Center Elevation	950			
Precipitation Total & Duration	13.18 Inches	72-hours		
Storm Representative Dew Point	70.5 F	24		
Storm Representative Dew Point Location	41.36 N	88.68 W	Aug	Sep
Maximum Dew Point	77.0 F		79	74.5
Moisture Inflow Vector	SW @ 230	Miles		
In-place Maximization Factor	**1.38**			
Temporal Transposition (Date)	1-Sep			
Transposition Dew Point Location	44.37 N	97.91 W	Aug	Sep
Transposition Maximum Dew Point	75.5 F		78.29	72.99
Transposition Adjustment Factor	**0.90**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.24**			

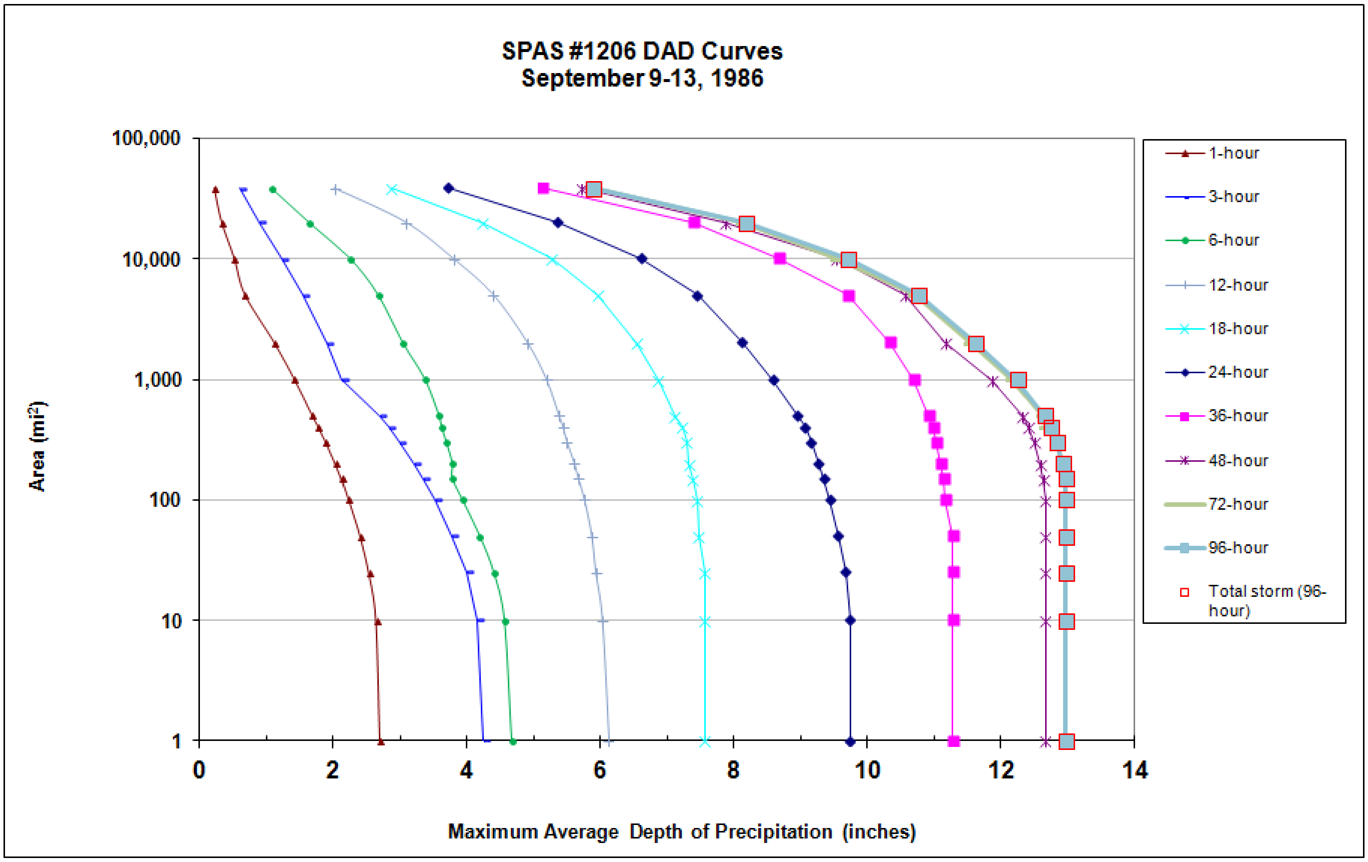
Attachment 1 Table 4: Storm spreadsheet for Big Rapids, MI September 1986



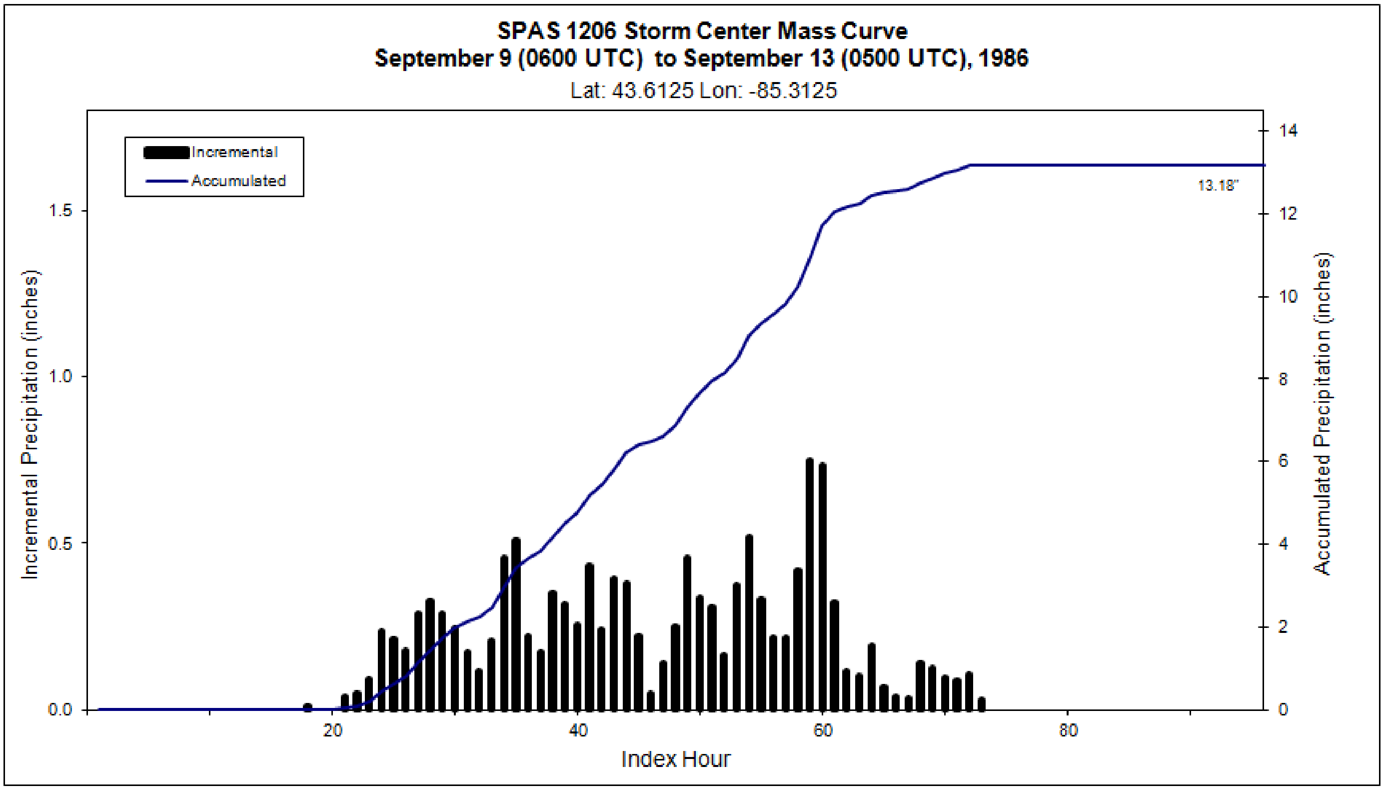
Attachment 1 Figure 5: Moisture inflow map for Big Rapids, MI September 1986

Storm 1206 - Sep 9 (0600 UTC) - Sep 13 (0500 UTC), 1986											
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)											
	Duration (hours)										
Area (mi^2)	1	3	6	12	18	24	36	48	72	96	Total
0	2.73	4.29	4.69	6.18	7.69	9.86	11.42	12.86	13.18	13.18	13.18
1	2.7	4.25	4.66	6.12	7.57	9.74	11.28	12.66	12.97	12.97	12.97
10	2.64	4.15	4.55	6.02	7.57	9.74	11.28	12.66	12.97	12.97	12.97
25	2.53	3.99	4.39	5.92	7.56	9.68	11.28	12.66	12.97	12.97	12.97
50	2.4	3.78	4.18	5.86	7.48	9.57	11.28	12.66	12.97	12.97	12.97
100	2.23	3.52	3.92	5.75	7.45	9.44	11.17	12.66	12.97	12.97	12.97
150	2.12	3.35	3.77	5.66	7.39	9.35	11.14	12.63	12.96	12.96	12.96
200	2.03	3.21	3.77	5.6	7.33	9.28	11.1	12.59	12.91	12.91	12.91
300	1.89	2.99	3.68	5.49	7.29	9.16	11.04	12.5	12.82	12.82	12.82
400	1.78	2.82	3.61	5.43	7.22	9.07	10.98	12.41	12.67	12.73	12.73
500	1.69	2.69	3.57	5.37	7.12	8.96	10.92	12.33	12.63	12.65	12.65
1,000	1.42	2.13	3.36	5.18	6.87	8.59	10.69	11.86	12.17	12.23	12.23
2,000	1.12	1.9	3.03	4.9	6.54	8.13	10.33	11.17	11.55	11.61	11.61
5,000	0.68	1.55	2.66	4.39	5.96	7.45	9.71	10.56	10.72	10.75	10.75
10,000	0.52	1.23	2.24	3.79	5.27	6.61	8.67	9.54	9.54	9.71	9.71
20,000	0.33	0.9	1.63	3.08	4.23	5.36	7.39	7.86	8.13	8.17	8.17
38,326	0.22	0.6	1.07	2.02	2.87	3.73	5.13	5.72	5.88	5.88	5.88

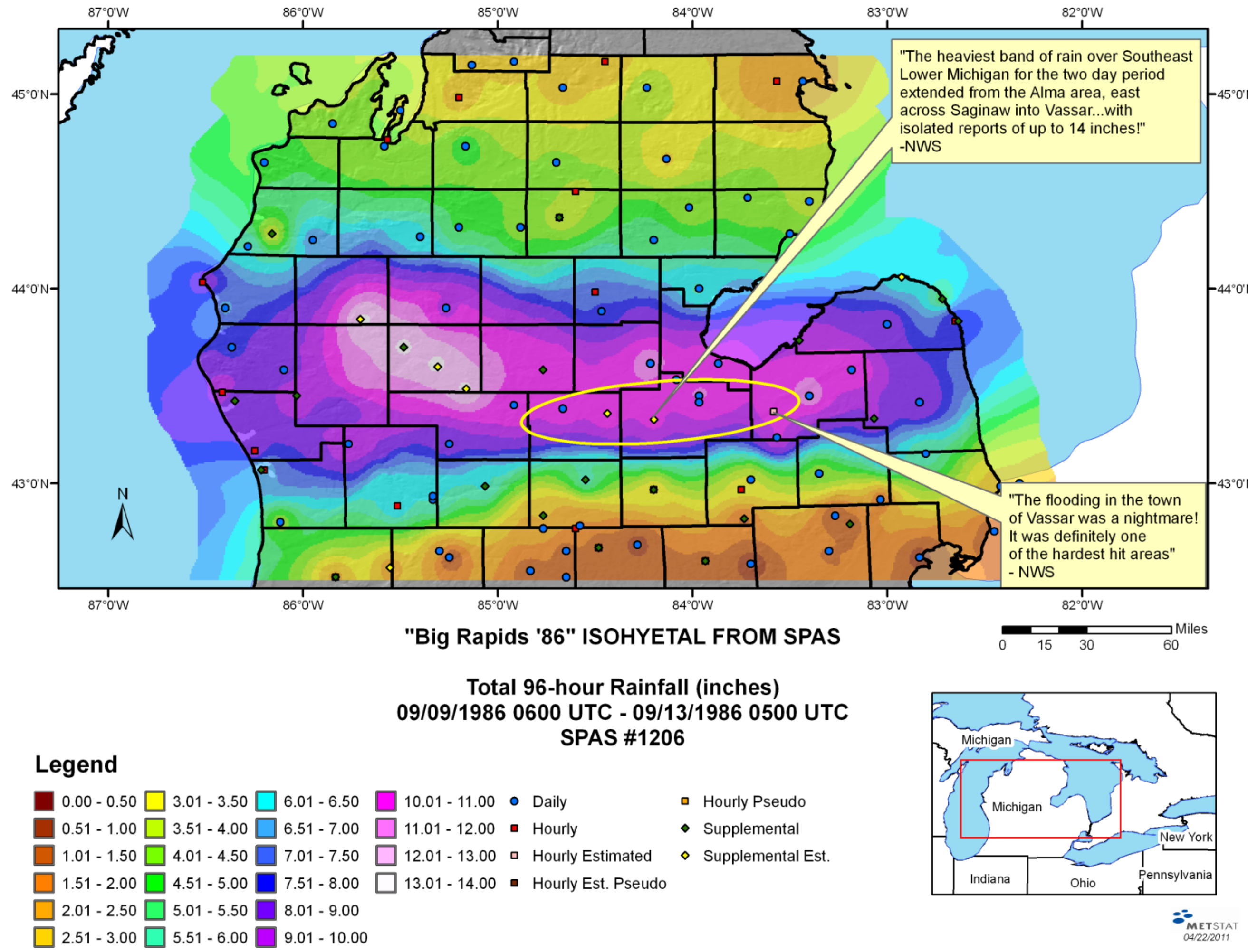
Attachment 1 Table 5: Depth-area-duration values for Big Rapids, MI September 1986



Attachment 1 Figure 6: Depth-area-duration chart for Big Rapids, MI September 1986



Attachment 1 Figure 7: Mass curve chart for Big Rapids, MI September 1986



Attachment 1 Figure 8: Total storm isohyetal analysis for Big Rapids, MI September 1986

Storm Name:	Cole Camp, MO MR 7-2A	Storm Adjustment for Basin Centroid-Monticello
Storm Date:	8/12-15/1946	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	1-Aug	
	Lat	Long
Storm Center Location	38.46 N	93.20 W
Storm Rep Dew Point Location	32.55 N	93.00 W
Transposition Dew Point Locat	40.72 N	94.15 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	S @ 410	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,000	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	76.0 F	with total precipitable water above sea level of			2.99	inches.
The in-place maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The transpositioned maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The in-place storm elevation is	1,000	which subtracts	0.26	inches of precipitable water at	76.0 F	
The in-place storm elevation is	1,000	which subtracts	0.29	inches of precipitable water at	80.5 F	
The transposition storm elevation at	1,300	which subtracts	0.38	inches of precipitable water at	80.5 F	
The moisture inflow barrier height is	1,300	which subtracts	0.38	inches of precipitable water at	80.5 F	

The in-place maximization factor is	1.24
The transposition factor is	0.97
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.21

Notes: DAD values taken from HMR 51 DAD Table Storm Index N. 80-USACE MR 7-2B. Storm representative dew point value was based on maximum 24-hr Td values between August 10-11, 1946 at KBAD and KMLU.

Observed Storm Depth-Area-Duration

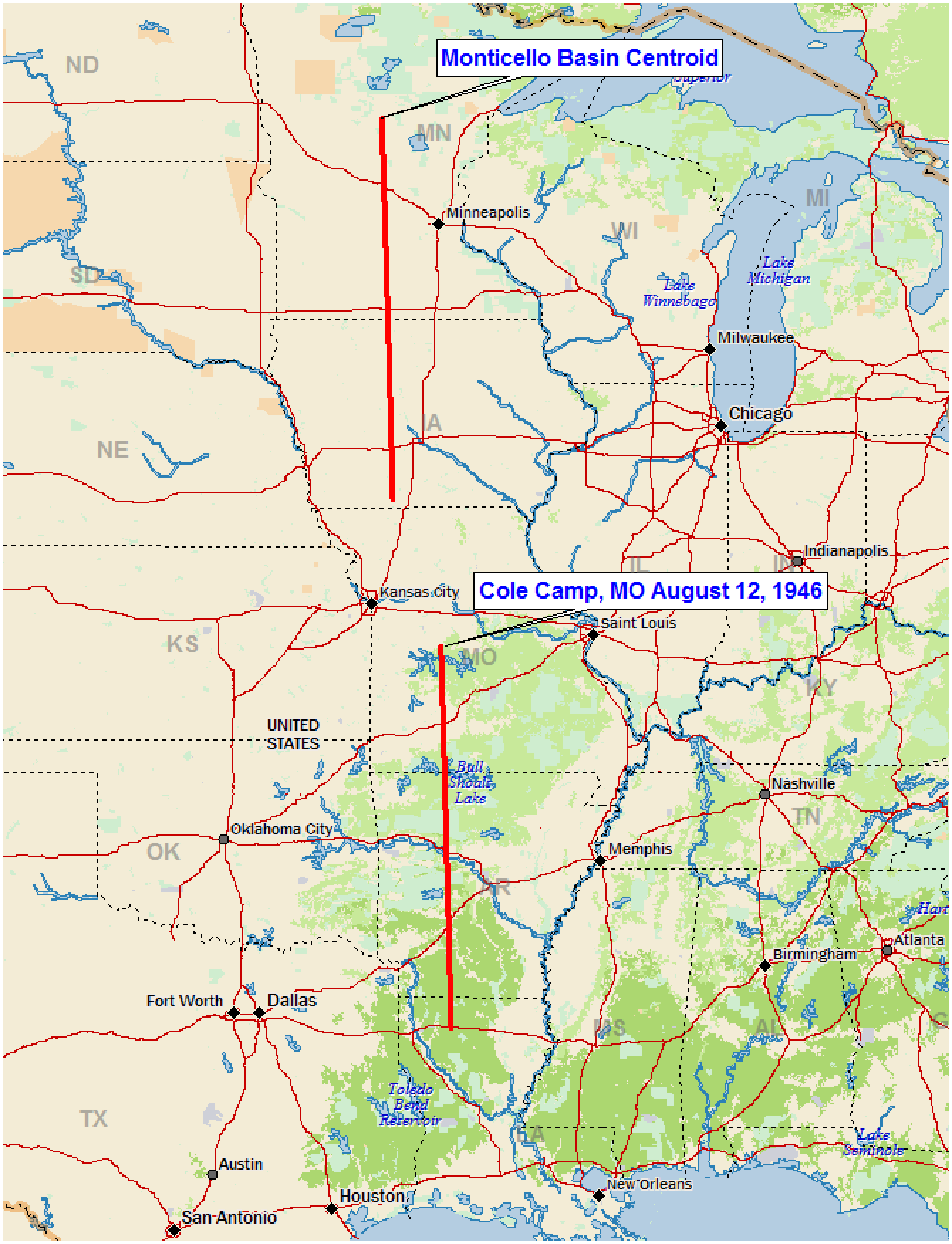
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	10.6	11.0	11.1	15.0	17.4	18.5	19.0	19.4	19.4
100 sq miles	9.0	9.9	10.0	13.4	16.0	17.0	18.3	18.6	18.6
200 sq miles	8.3	9.2	9.4	12.4	15.0	16.1	17.4	17.7	17.7
500 sq miles	7.0	7.9	8.0	10.4	12.9	14.1	15.5	15.9	15.9
1000 sq miles	5.5	6.6	7.0	8.3	10.9	12.0	13.7	14.1	14.1
2000 sq miles	4.2	5.5	6.3	6.8	9.4	10.4	11.8	12.3	12.3
5000 sq miles	3.3	4.7	5.6	5.9	7.8	8.6	9.6	10.0	10.1
10000 sq miles	2.8	4.2	5.0	5.4	6.5	7.2	8.1	8.4	8.7
20000 sq miles	2.3	3.4	4.2	4.5	5.1	5.7	6.6	6.9	7.2

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	12.8	13.3	13.4	18.1	21.0	22.4	23.0	23.5	23.5
100 sq miles	10.9	12.0	12.1	16.2	19.3	20.5	22.1	22.5	22.5
200 sq miles	10.0	11.1	11.4	15.0	18.1	19.5	21.0	21.4	21.4
500 sq miles	8.5	9.5	9.7	12.6	15.6	17.0	18.7	19.2	19.2
1000 sq miles	6.6	8.0	8.5	10.0	13.2	14.5	16.6	17.0	17.0
2000 sq miles	5.1	6.6	7.6	8.2	11.4	12.6	14.3	14.9	14.9
5000 sq miles	4.0	5.7	6.8	7.1	9.4	10.4	11.6	12.1	12.2
10000 sq miles	3.4	5.1	6.0	6.5	7.9	8.7	9.8	10.2	10.5
20000 sq miles	2.8	4.1	5.1	5.4	6.2	6.9	8.0	8.3	8.7

Storm or Storm Center Name	Cole Camp, MO MR 7-2A			
Storm Date(s)	8/12-15/1946			
Storm Type	General Storm			
Storm Location	38.46 N	93.20 W		
Storm Center Elevation	1000			
Precipitation Total & Duration (10 sq mi)	19.40 Inches in 60-hours			
Storm Representative Dew Point	76.0 F	24		
Storm Representative Dew Point Location	32.55 N	93.00 W	Jul	Aug
Maximum Dew Point	80.5 F		80.5	80
Moisture Inflow Vector	S @ 410			
In-place Maximization Factor	1.24			
Temporal Transposition (Date)	1-Aug			
Transposition Dew Point Location	40.72 N	94.15 W	Jul	Aug
Transposition Maximum Dew Point	80.5 F		80.55	80.43
Transposition Adjustment Factor	0.97			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	1.00			
Total Adjustment Factor	1.21			

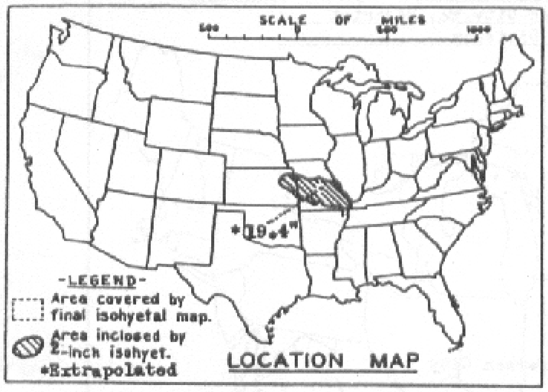
Attachment 1 Table 6: Storm spreadsheet for Cole Camp, MO August 1946



Attachment 1 Figure 9: Moisture inflow map for Cole Camp, MO August 1946

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 12-15 August 1946
Assignment MR 7-2A
Location Kansas & Missouri
Study Prepared by:
Missouri River Division
Kansas City District

Part I Reviewed by H. M. Sec. of Weather Bureau, 8/30/48
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 3/20/60
Remarks: Center near Cole Camp, Mo.
Dewpt. 74° - Ref. Pt. 140 S Grid F-14

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 1,000,000
Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	64
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	18
Miscl. precip. records, meteorological data, etc.	30
Form 5002 (Mass rainfall curves)	51

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000
Data and computation sheets:

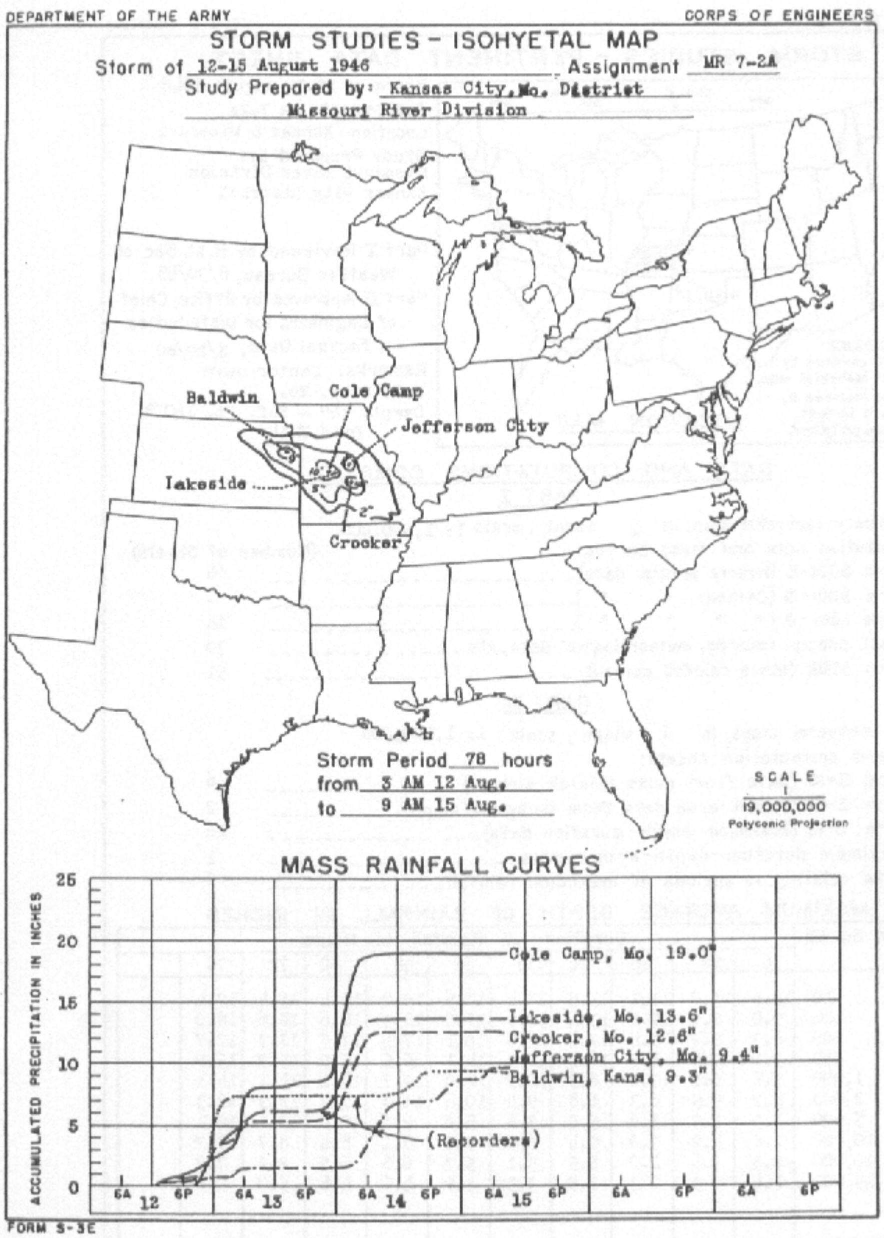
Form S-10 (Data from mass rainfall curves)	6
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	16
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	78
10	10.6	11.0	11.1	15.0	17.4	18.5	19.0	19.4	19.4	19.4
100	9.0	9.9	10.0	13.4	16.0	17.0	18.3	18.6	18.6	18.6
200	8.3	9.2	9.4	12.4	15.0	16.1	17.4	17.7	17.7	17.7
500	7.0	7.9	8.0	10.4	12.9	14.1	15.5	15.9	15.9	15.9
1,000	5.5	6.6	7.0	8.3	10.9	12.0	13.7	14.1	14.1	14.1
2,000	4.2	5.5	6.3	6.8	9.4	10.4	11.8	12.3	12.3	12.3
5,000	3.3	4.7	5.6	5.9	7.8	8.6	9.6	10.0	10.1	10.1
10,000	2.8	4.2	5.0	5.4	6.5	7.2	8.1	8.4	8.7	8.7
20,000	2.3	3.4	4.2	4.5	5.1	5.7	6.6	6.9	7.2	7.2
45,000	1.4	2.3	2.7	2.9	3.3	3.9	4.5	4.8	5.0	5.0

Form S-2

Attachment 1 Table 7: Depth-area-duration values for Cole Camp, MO August 1946



Attachment 1 Figure 10 and Attachment 1 Figure 11: Isohyetal map and Mass curve chart for Cole Camp, MO August 1946

Storm Name:	**USACE MR 7-2B-Collinsville, IL**		
Storm Date:	**8/12-15/1946**		
AWA Analysis Date:	**8/24/2014**		

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date	**1-Aug**	
	Lat	**Long**
Storm Center Location	**38.67 N**	**89.98 W**
Storm Rep Dew Point Location	**32.55 N**	**93.00 W**
Transposition Dew Point Locat	**40.50 N**	**97.72 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SSW @ 455**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**500**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**76.0 F**	with total precipitable water above sea level of			**2.99**	inches.
The in-place maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The in-place storm elevation is	**500**	which subtracts	**0.13**	inches of precipitable water at	**76.0 F**	
The in-place storm elevation is	**500**	which subtracts	**0.16**	inches of precipitable water at	**80.5 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.23**
The transposition factor is	**0.91**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.13**

Notes: DAD values taken from HMR 51 DAD Table Storm Index N. 80-USACE MR 7-2B. Storm representative dew point value was based on maximum 24-hr Td values between August 10-11, 1946 at KBAD and KMLU.

Observed Storm Depth-Area-Duration

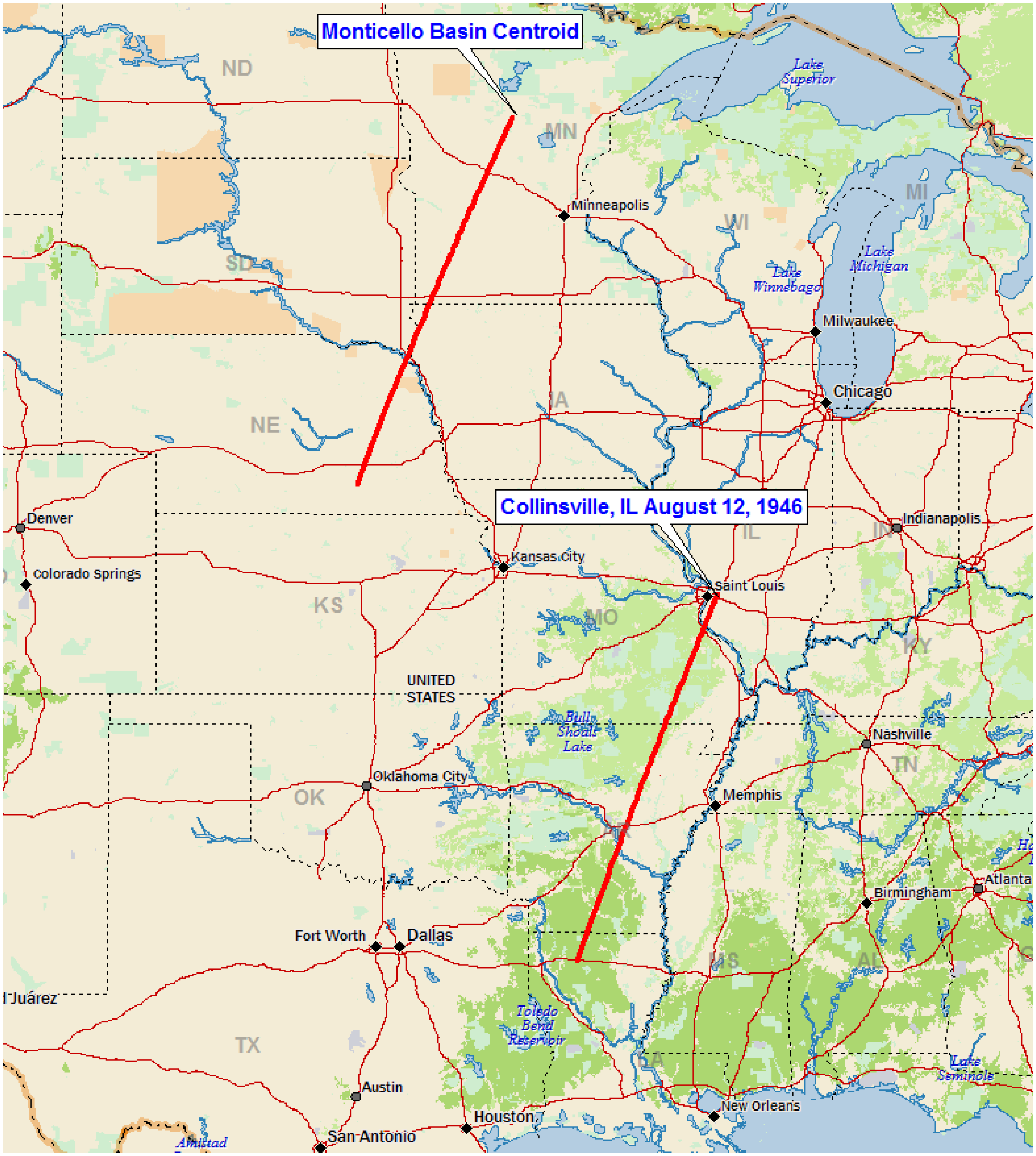
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**6.4**	**10.2**	**12.6**	**12.7**	**14.1**	**18.0**	**18.1**	**18.6**	**18.7**
10 sq miles	**6.0**	**9.8**	**12.1**	**12.1**	**13.7**	**17.5**	**17.6**	**18.3**	**18.3**
100 sq miles	**5.6**	**8.8**	**10.9**	**11.1**	**13.2**	**16.6**	**16.7**	**17.5**	**17.6**
200 sq miles	**5.4**	**8.3**	**10.5**	**10.6**	**13.0**	**16.2**	**16.3**	**17.2**	**17.3**
500 sq miles	**5.2**	**7.7**	**9.7**	**9.9**	**12.8**	**15.5**	**15.6**	**16.7**	**16.9**
1000 sq miles	**4.9**	**7.0**	**8.9**	**9.0**	**12.6**	**14.7**	**14.8**	**15.9**	**16.0**
2000 sq miles	**4.3**	**6.1**	**7.6**	**7.8**	**11.2**	**13.3**	**13.4**	**14.3**	**14.3**
5000 sq miles	**3.3**	**4.8**	**5.9**	**6.0**	**8.6**	**10.4**	**10.6**	**11.3**	**11.4**
10000 sq miles	**2.4**	**3.7**	**4.5**	**4.6**	**6.6**	**8.0**	**8.2**	**8.7**	**8.8**
20000 sq miles	**1.5**	**2.5**	**3.1**	**3.2**	**4.6**	**5.6**	**5.8**	**6.0**	**6.1**

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**7.2**	**11.5**	**14.2**	**14.3**	**15.9**	**20.3**	**20.4**	**20.9**	**21.1**
10 sq miles	**6.8**	**11.0**	**13.6**	**13.6**	**15.4**	**19.7**	**19.8**	**20.6**	**20.6**
100 sq miles	**6.3**	**9.9**	**12.3**	**12.5**	**14.9**	**18.7**	**18.8**	**19.7**	**19.8**
200 sq miles	**6.1**	**9.3**	**11.8**	**11.9**	**14.6**	**18.2**	**18.4**	**19.4**	**19.5**
500 sq miles	**5.9**	**8.7**	**10.9**	**11.1**	**14.4**	**17.5**	**17.6**	**18.8**	**19.0**
1000 sq miles	**5.5**	**7.9**	**10.0**	**10.1**	**14.2**	**16.6**	**16.7**	**17.9**	**18.0**
2000 sq miles	**4.8**	**6.9**	**8.6**	**8.8**	**12.6**	**15.0**	**15.1**	**16.1**	**16.1**
5000 sq miles	**3.7**	**5.4**	**6.6**	**6.8**	**9.7**	**11.7**	**11.9**	**12.7**	**12.8**
10000 sq miles	**2.7**	**4.2**	**5.1**	**5.2**	**7.4**	**9.0**	**9.2**	**9.8**	**9.9**
20000 sq miles	**1.7**	**2.8**	**3.5**	**3.6**	**5.2**	**6.3**	**6.5**	**6.8**	**6.9**

Storm or Storm Center Name	**USACE MR 7-2B-Collinsville, IL**			
Storm Date(s)	8/12-15/1946			
Storm Type	General Storm			
Storm Location	38.67 N	89.98 W		
Storm Center Elevation	500			
Precipitation Total & Duration (10 sq mi)	18.7 Inches in 72-hours			
Storm Representative Dew Point	76.0 F	24		
Storm Representative Dew Point Location	32.55 N	93.00 W	Jul	Aug
Maximum Dew Point	80.5 F		80.5	80
Moisture Inflow Vector	SSW @ 455			
In-place Maximization Factor	**1.23**			
Temporal Transposition (Date)	1-Aug			
Transposition Dew Point Location	40.50 N	97.72 W	Jul	Aug
Transposition Maximum Dew Point	80.0 F		80.09	79.85
Transposition Adjustment Factor	**0.91**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.13**			

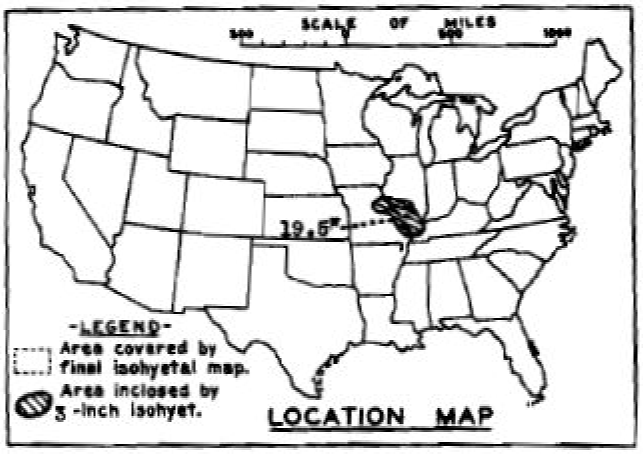
Attachment 1 Table 8: Storm spreadsheet for Collinsville, IL August 1946



Attachment 1 Figure 12: Moisture inflow map for Collinsville, IL August 1946

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES – PERTINENT DATA SHEET



Storm of 12-16 August 1946
Assignment MR 7-2B
Location Mo., Ill., Ind. & Ky.
Study Prepared by: Upper Mississippi Valley Division
St. Louis District

Part I Reviewed by H. M. Sec. of Weather Bureau, 3/8/49
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 3/20/50
Remarks: Center near Collinsville, Ill.
Dewpt. 74° Ref. Pt. 225 S
Grid F-12

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 1,000,000

Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 58
- Form 5001-B (24-hour " ") ---------- --
- Form 5001-D (" " " ") ---------- 16
- Miscl. precip. records, meteorological data, etc. ---------- 15
- Form 5002 (Mass rainfall curves) ---------- 44

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000

Data and computation sheets:

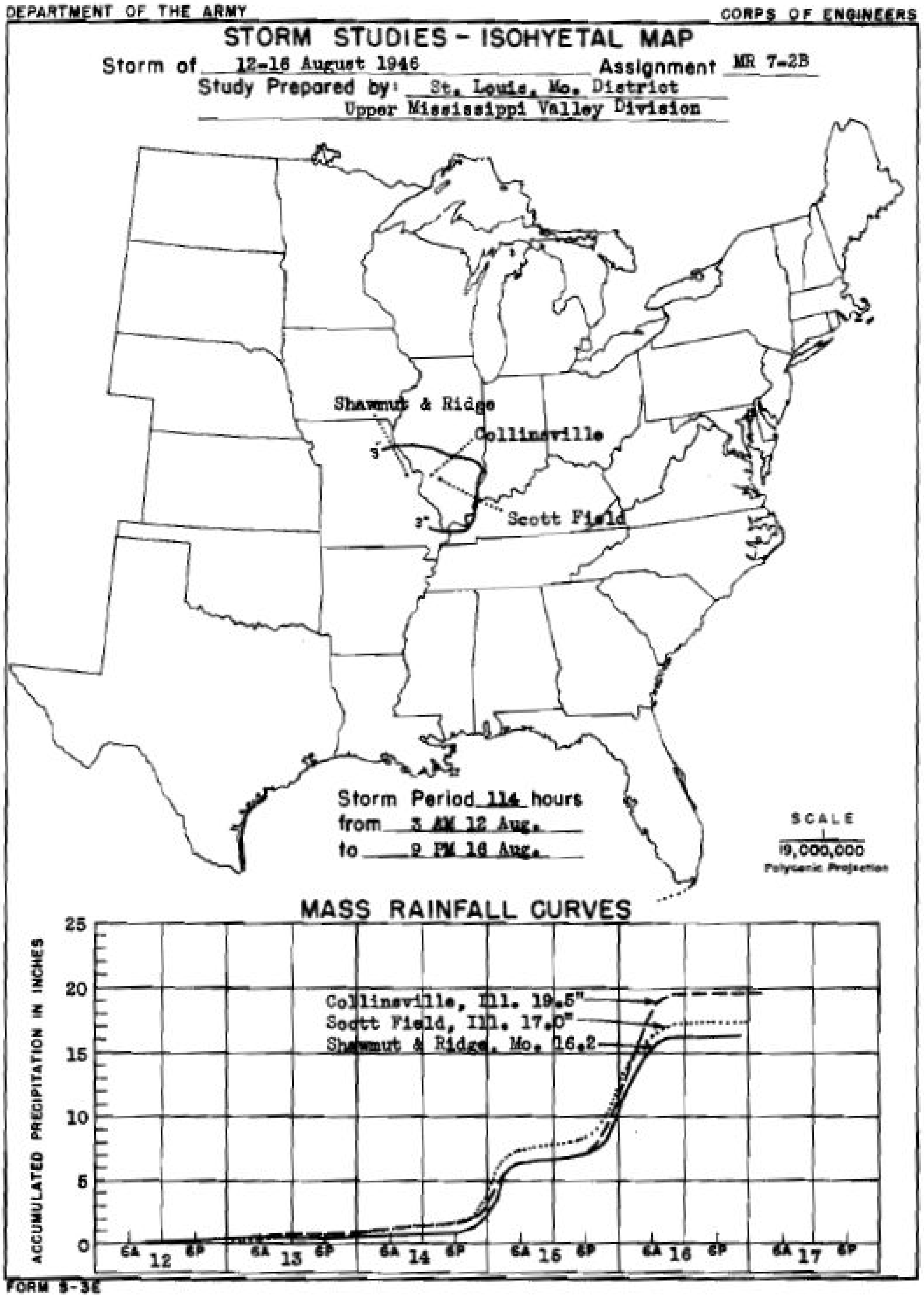
- Form S-10 (Data from mass rainfall curves) ---------- 5
- Form S-11 (Depth-area data from isohyetal map) ---------- 3
- Form S-12 (Maximum depth-duration data) ---------- 7
- Maximum duration-depth-area curves ---------- 1
- Data relating to periods of maximum rainfall ---------- 2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	114
Max. Sta.	6.4	10.2	12.6	12.7	14.1	18.0	18.1	18.6	18.7	19.4	19.5
10	6.0	9.8	12.1	12.1	13.7	17.5	17.6	18.3	18.3	18.9	19.0
100	5.6	8.8	10.9	11.1	13.2	16.6	16.7	17.5	17.6	18.0	18.1
200	5.4	8.3	10.5	10.6	13.0	16.2	16.3	17.2	17.3	17.7	17.8
500	5.2	7.7	9.7	9.9	12.8	15.5	15.6	16.7	16.9	17.1	17.2
1,000	4.9	7.0	8.9	9.0	12.6	14.7	14.8	15.9	16.0	16.3	16.4
2,000	4.3	6.1	7.6	7.8	11.2	13.3	13.4	14.3	14.3	14.6	14.7
5,000	3.3	4.8	5.9	6.0	8.6	10.4	10.6	11.3	11.4	11.6	11.8
10,000	2.4	3.7	4.5	4.6	6.6	8.0	8.2	8.7	8.8	9.0	9.1
20,000	1.5	2.5	3.1	3.2	4.5	5.6	5.8	6.0	6.1	6.3	6.5
20,400	1.5	2.5	3.1	3.2	4.5	5.5	5.7	6.0	6.1	6.3	6.4

Form S-2

Attachment 1 Table 9: Depth-area-duration values for Collinsville, IL August 1946



Attachment 1 Figure 13 and Attachment 1 Figure 14: Isohyetal map and Mass curve chart for Collinsville, IL August 1946

Storm Name:	**SPAS 1220 Dubuque, IA**		**Storm Adjustment for Basin Centroid-Monticello**				
Storm Date:	**7/27-28/2011**						
AWA Analysis Date:	**8/24/2014**						
Temporal Transposition Date	**15-Jul**						
	Lat	**Long**		**Moisture Inflow Direction**	**SSE @ 105**	miles	
Storm Center Location	**42.44 N**	**90.75 W**		**Basin Average Elevation**	**1,300**	feet	
Storm Rep Dew Point Location	**40.95 N**	**90.27 W**		**Storm Center Elevation**	**900**	feet	
Transposition Dew Point Locat	**45.14 N**	**93.86 W**		**Storm Analysis Duration**	**12**	hours	
Basin Location	**46.63 N**	**94.37 W**					

The storm representative dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The in-place maximum dew point is	**81.0 F**	with total precipitable water above sea level of			**3.76**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The in-place storm elevation is	**900**	which subtracts	**0.26**	inches of precipitable water at	**79.0 F**	
The in-place storm elevation is	**900**	which subtracts	**0.28**	inches of precipitable water at	**81.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.09**
The transposition factor is	**0.93**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.01**

Notes: DAD values taken from SPAS 1220. Storm representative dew point value was based on maximum 12-hr Td values between July 25-28, 2011 at WBAN 04949, 14842, and 14923.

Observed Storm Depth-Area-Duration

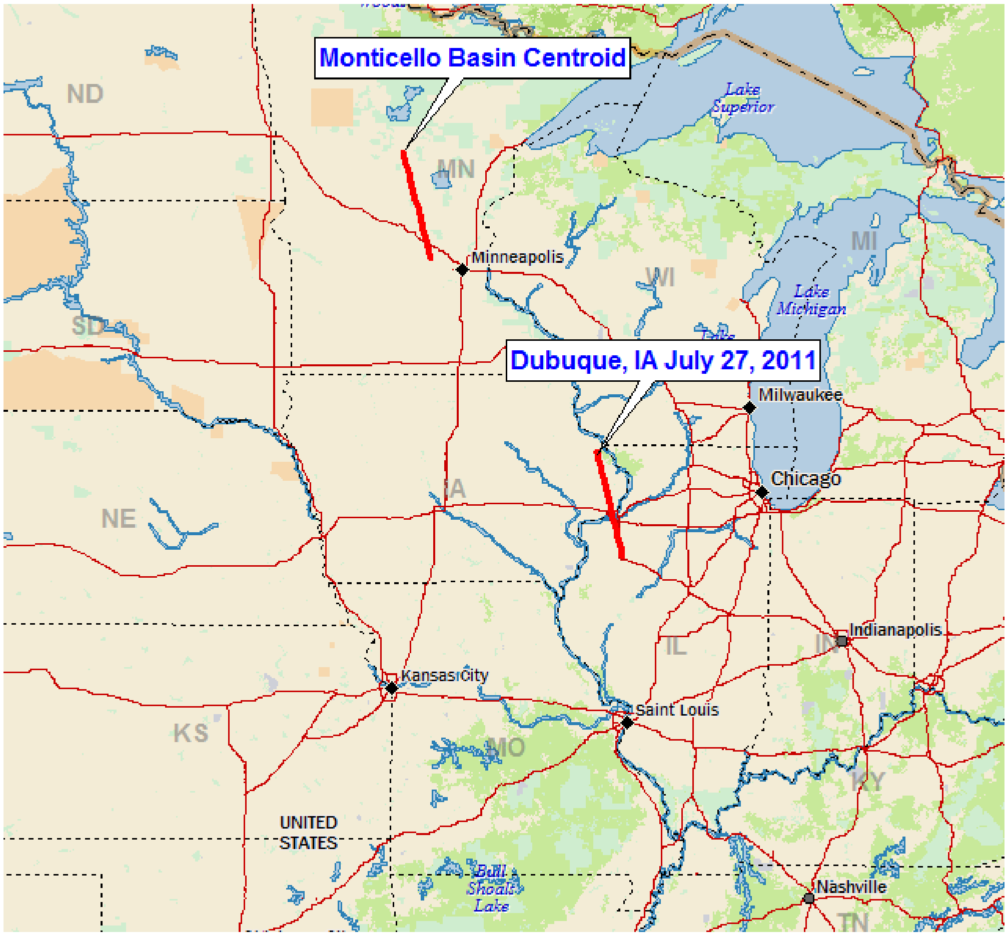
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.1**	**9.1**	**10.6**	**14.4**	**14.7**	**14.7**	-	-	-
10 sq miles	**3.9**	**8.6**	**10.2**	**13.7**	**14.4**	**14.5**	-	-	-
100 sq miles	**2.9**	**5.7**	**9.1**	**12.4**	**13.2**	**13.3**	-	-	-
200 sq miles	**2.3**	**5.6**	**8.8**	**11.9**	**12.6**	**12.7**	-	-	-
500 sq miles	**2.1**	**4.6**	**7.9**	**10.9**	**11.7**	**11.7**	-	-	-
1000 sq miles	**1.7**	**3.9**	**7.0**	**9.6**	**10.2**	**10.4**	-	-	-
2000 sq miles	**1.3**	**3.0**	**5.2**	**7.7**	**8.4**	**8.6**	-	-	-
5000 sq miles	**0.7**	**1.6**	**3.3**	**4.9**	**5.4**	**5.9**	-	-	-
10000 sq miles	**0.4**	**1.0**	**1.9**	**2.9**	**3.5**	**3.8**	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.2**	**9.2**	**10.7**	**14.6**	**14.9**	**14.9**	-	-	-
10 sq miles	**3.9**	**8.7**	**10.4**	**13.9**	**14.6**	**14.7**	-	-	-
100 sq miles	**2.9**	**5.8**	**9.2**	**12.6**	**13.3**	**13.4**	-	-	-
200 sq miles	**2.4**	**5.7**	**9.0**	**12.1**	**12.8**	**12.9**	-	-	-
500 sq miles	**2.1**	**4.6**	**8.0**	**11.1**	**11.8**	**11.8**	-	-	-
1000 sq miles	**1.7**	**3.9**	**7.1**	**9.7**	**10.3**	**10.5**	-	-	-
2000 sq miles	**1.3**	**3.0**	**5.3**	**7.8**	**8.5**	**8.7**	-	-	-
5000 sq miles	**0.7**	**1.7**	**3.4**	**4.9**	**5.5**	**6.0**	-	-	-
10000 sq miles	**0.4**	**1.0**	**1.9**	**2.9**	**3.5**	**3.8**	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**SPAS 1220 Dubuque, IA**	
Storm Date(s)	7/27-28/2011	
Storm Type	MCC	
Storm Location	42.44 N	90.75 W
Storm Center Elevation	900	
Precipitation Total & Duration	15.14 Inches 24-hours	
Storm Representative Dew Point	79.0 F	12
Storm Representative Dew Point Location	40.95 N	90.27 W
Maximum Dew Point	81.0 F	
Moisture Inflow Vector	SSE @ 105	Miles
In-place Maximization Factor	**1.09**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	45.14 N	93.86 W
Transposition Maximum Dew Point	80.0 F	
Transposition Adjustment Factor	**0.93**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.01**	

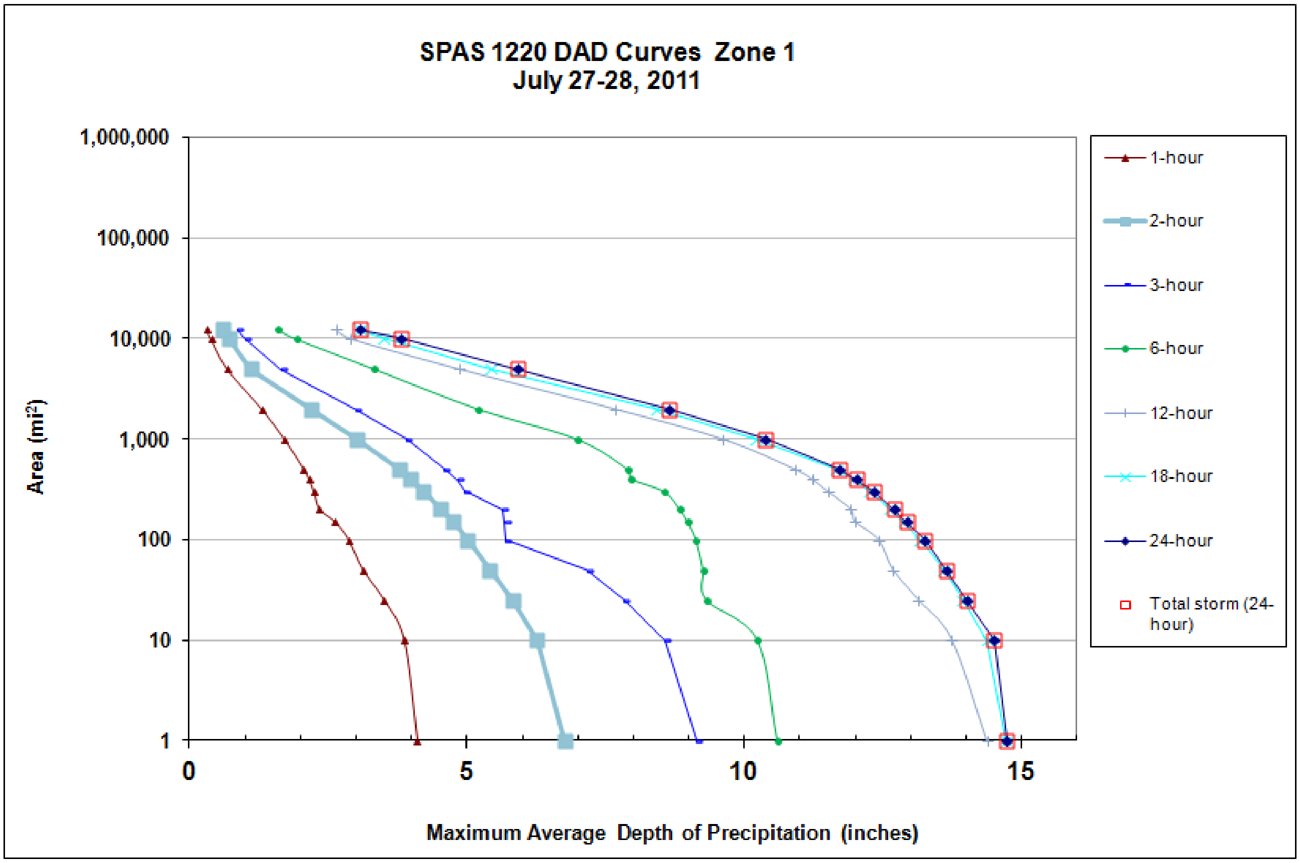
Attachment 1 Table 10: Storm spreadsheet for Dubuque, IA July 2011



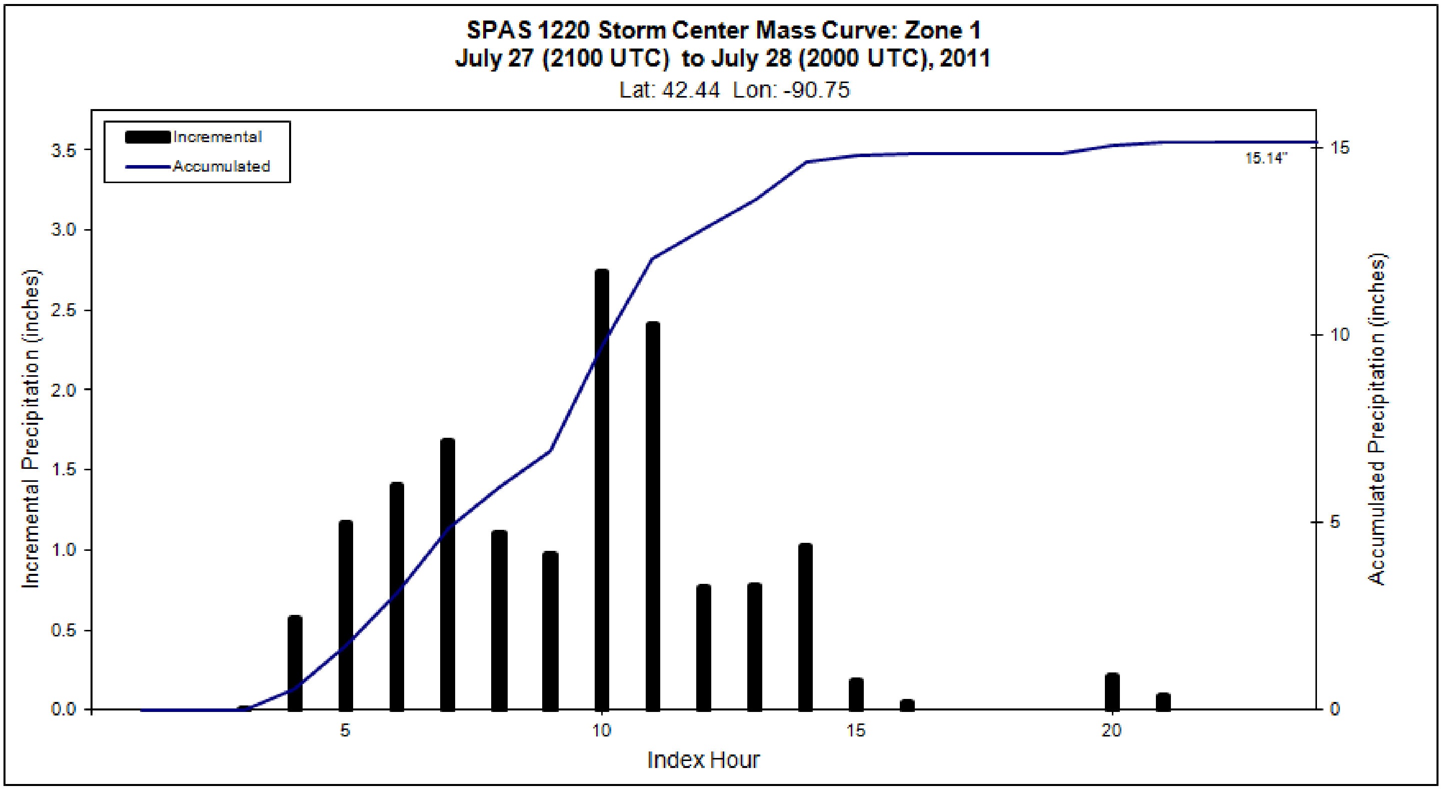
Attachment 1 Figure 15: Moisture inflow map for Dubuque, IA July 2011

Storm 1220 - July 27 (2100 UTC) - July 28 (2000 UTC), 2011								
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)								
	Duration (hours)							
Area (mi^2)	1	2	3	6	12	18	24	Total
0.4	4.2	6.92	9.38	10.9	14.8	15.14	15.14	15.14
1	4.1	6.76	9.13	10.6	14.37	14.72	14.73	14.73
10	3.86	6.26	8.56	10.24	13.74	14.38	14.5	14.50
25	3.5	5.82	7.83	9.32	13.14	13.94	14	14.00
50	3.12	5.41	7.15	9.26	12.68	13.59	13.64	13.64
100	2.86	5.01	5.69	9.13	12.42	13.17	13.25	13.25
150	2.62	4.75	5.68	8.98	12	12.87	12.93	12.93
200	2.34	4.53	5.63	8.84	11.92	12.63	12.7	12.70
300	2.24	4.21	4.95	8.56	11.51	12.26	12.33	12.33
400	2.15	3.98	4.82	7.97	11.22	11.97	12.02	12.02
500	2.06	3.78	4.58	7.9	10.92	11.65	11.7	11.70
1,000	1.71	3.01	3.9	6.99	9.62	10.19	10.38	10.38
2,000	1.3	2.18	2.98	5.2	7.67	8.4	8.63	8.63
5,000	0.68	1.1	1.64	3.33	4.86	5.44	5.91	5.91
10,000	0.39	0.71	0.99	1.92	2.91	3.49	3.8	3.80
12,295	0.31	0.6	0.86	1.59	2.63	3.06	3.07	3.07

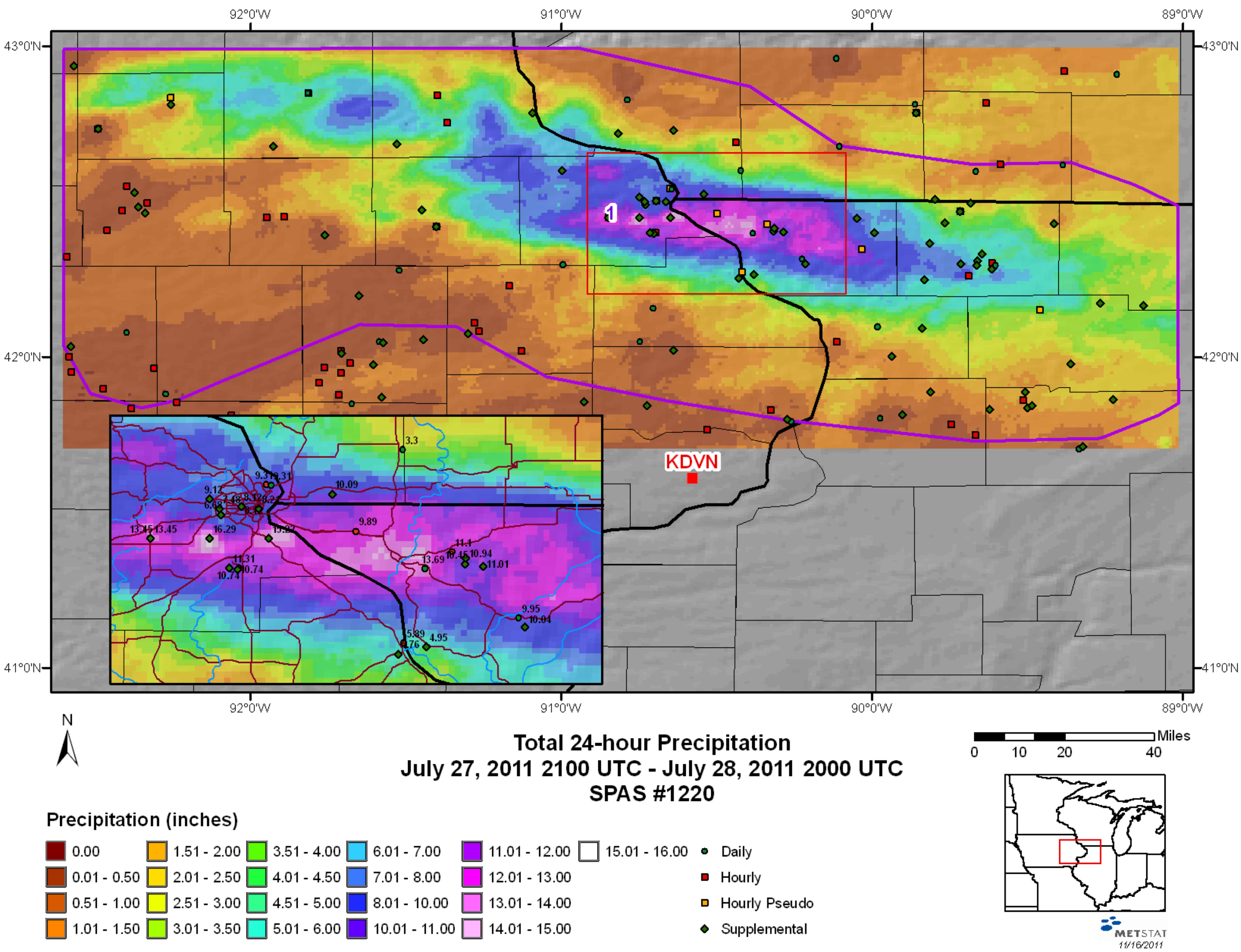
Attachment 1 Table 11: Depth-area-duration values for Dubuque, IA July 2011



Attachment 1 Figure 16: Depth-area-duration chart for Dubuque, IA July 2011



Attachment 1 Figure 17: Mass curve chart for Dubuque, IA July 2011



Attachment 1 Figure 18: Total storm isohyetal analysis for Dubuque, IA July 2011

Storm Name:	**SPAS 1296 Duluth, MN**	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**6/19-21/2012**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date **5-Jul**

	Lat	Long
Storm Center Location	**47.02 N**	**91.67 W**
Storm Rep Dew Point Location	**42.87 N**	**94.78 W**
Transposition Dew Point Locati	**42.48 N**	**97.47 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SW @ 325**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**1,400**	feet
Storm Analysis Duration	**12**	hours

The storm representative dew point is	**76.0 F**	with total precipitable water above sea level of			**2.99**	inches.
The in-place maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The in-place storm elevation is	**1,400**	which subtracts	**0.36**	inches of precipitable water at	**76.0 F**	
The in-place storm elevation is	**1,400**	which subtracts	**0.41**	inches of precipitable water at	**80.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.21**
The transposition factor is	**1.01**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.22**

Notes: DAD values taken from SPAS 1296 Zone 1. Storm representative dew point value was based on maximum 12-hr Td values between June 18-19, 2012 at KSLB, KSPW, and KAXA.

Observed Storm Depth-Area-Duration

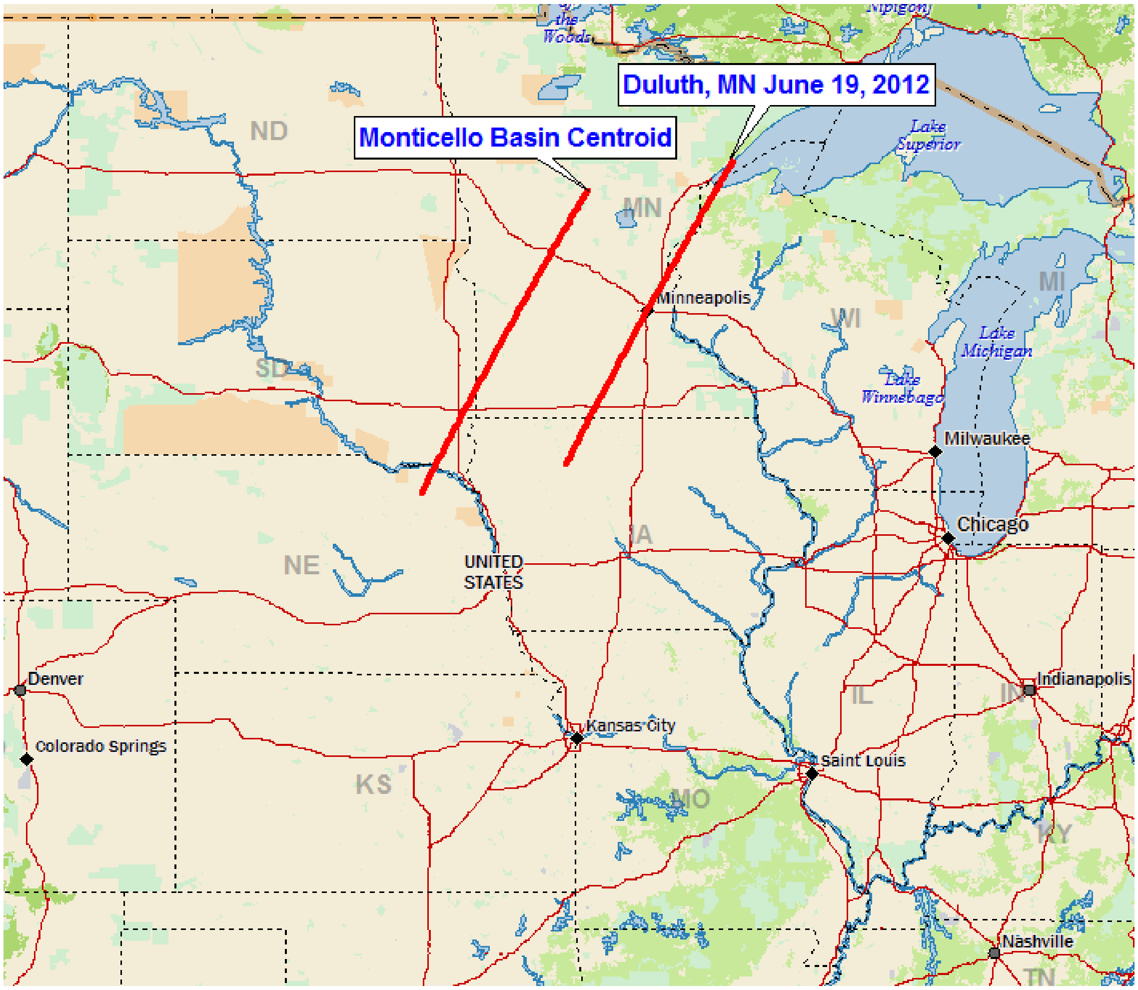
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	45 Hours	72 Hours	96 Hours
1 sq miles	2.3	3.9	6.4	8.9	9.1	10.3	10.4	10.5	-	-
10 sq miles	2.2	3.9	6.3	8.8	9.1	10.3	10.4	10.5	-	-
100 sq miles	1.9	3.2	5.1	7.3	8.5	9.4	9.8	9.8	-	-
200 sq miles	1.9	3.1	4.7	6.6	8.1	9.1	9.4	9.4	-	-
500 sq miles	1.7	2.8	4.3	6.3	7.2	8.3	8.7	8.9	-	-
1000 sq miles	1.6	2.6	3.8	5.6	6.7	7.8	8.2	8.4	-	-
2000 sq miles	1.4	2.3	3.3	5.1	6.5	7.3	7.9	7.9	-	-
5000 sq miles	1.0	1.8	2.7	4.5	5.2	6.1	6.7	6.8	-	-
10000 sq miles	0.7	1.4	2.3	3.8	4.4	4.9	5.7	5.8	-	-
20000 sq miles	0.3	1.0	1.7	3.0	3.4	3.9	4.6	4.7	-	-
50000 sq miles	0.2	0.5	0.9	1.6	2.0	2.4	2.8	2.9	-	-

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	45 Hours	72 Hours	96 Hours
1 sq miles	2.8	4.8	7.8	10.8	11.1	12.6	12.8	12.8	-	-
10 sq miles	2.7	4.7	7.7	10.8	11.1	12.6	12.8	12.8	-	-
100 sq miles	2.3	3.9	6.2	9.0	10.4	11.5	11.9	12.0	-	-
200 sq miles	2.3	3.8	5.8	8.1	9.9	11.1	11.5	11.5	-	-
500 sq miles	2.1	3.4	5.3	7.7	8.9	10.1	10.6	10.9	-	-
1000 sq miles	1.9	3.2	4.6	6.8	8.2	9.5	10.0	10.3	-	-
2000 sq miles	1.7	2.8	4.0	6.2	7.9	9.0	9.6	9.6	-	-
5000 sq miles	1.2	2.2	3.3	5.5	6.4	7.4	8.2	8.3	-	-
10000 sq miles	0.8	1.7	2.8	4.6	5.4	6.0	7.0	7.1	-	-
20000 sq miles	0.4	1.2	2.1	3.6	4.2	4.8	5.7	5.8	-	-
20000 sq miles	0.2	0.6	1.2	2.0	2.5	2.9	3.4	3.5	-	-

Storm or Storm Center Name	**SPAS 1296 Duluth, MN**				
Storm Date(s)	6/19-21/2012				
Storm Type	MCC				
Storm Location	47.02 N	91.67 W			
Storm Center Elevation	1,400		650 at storm center, but 1400 used as it fell over the basin		
Precipitation Total & Duration	10.73 Inches 45-hours				
Storm Representative Dew Point	76.0 F	12			
Storm Representative Dew Point Location	42.87 N	94.78 W		Jun	Jul
Maximum Dew Point	80.0 F			78.00	81.00
Moisture Inflow Vector	SW @ 325	Miles			
In-place Maximization Factor	**1.21**				
Temporal Transposition (Date)	5-Jul				
Transposition Dew Point Location	42.48 N	97.47 W		Jun	Jul
Transposition Maximum Dew Point	80.0 F			77.94	81.14
Transposition Adjustment Factor	**1.01**				
Average Basin Elevation	1,300				
Highest Elevation in Basin	1,896				
Inflow Barrier Height	1,300				
Elevation Adjustment Factor	**1.00**				
Total Adjustment Factor	**1.22**				

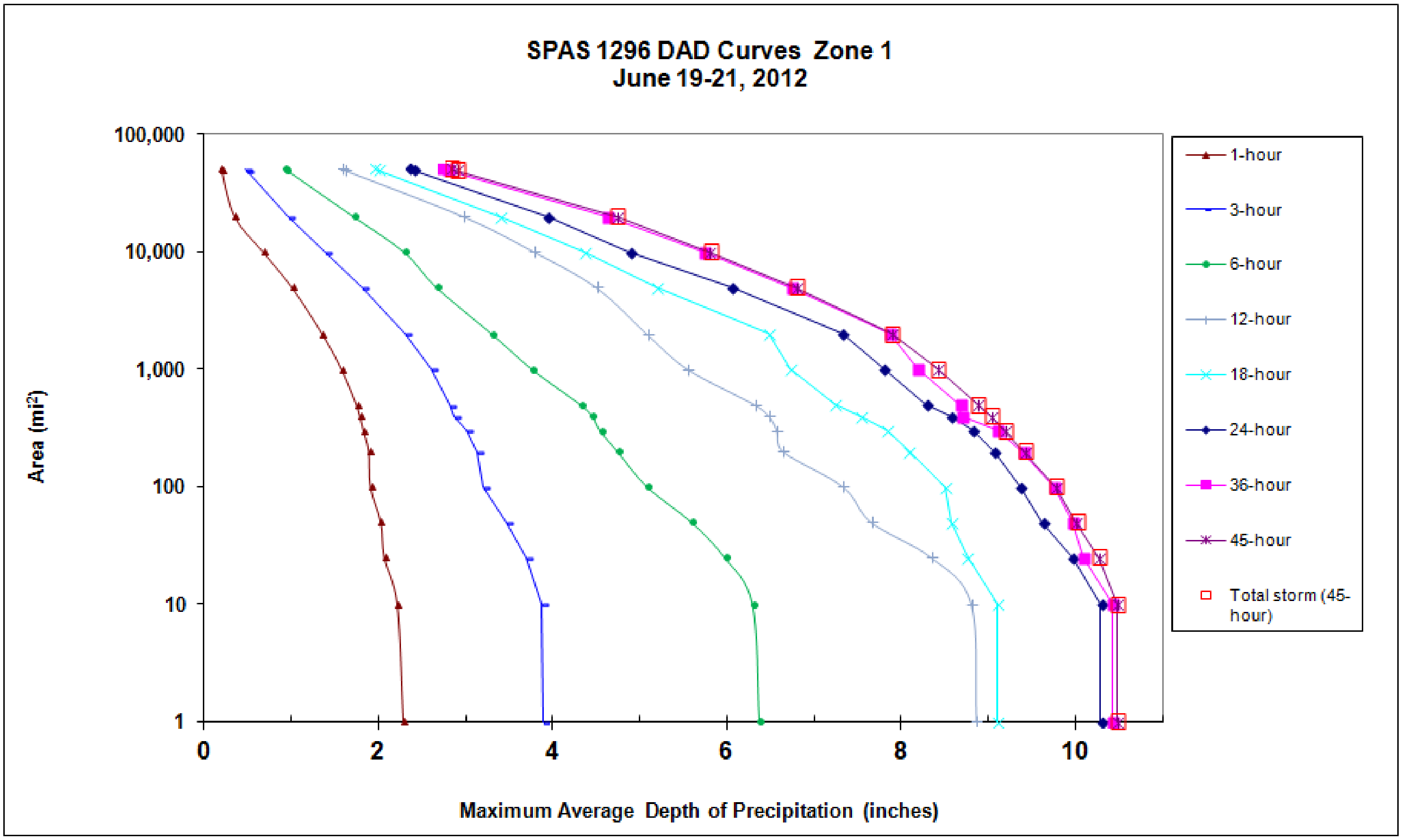
Attachment 1 Table 12: Storm spreadsheet for Duluth, MN June 2012



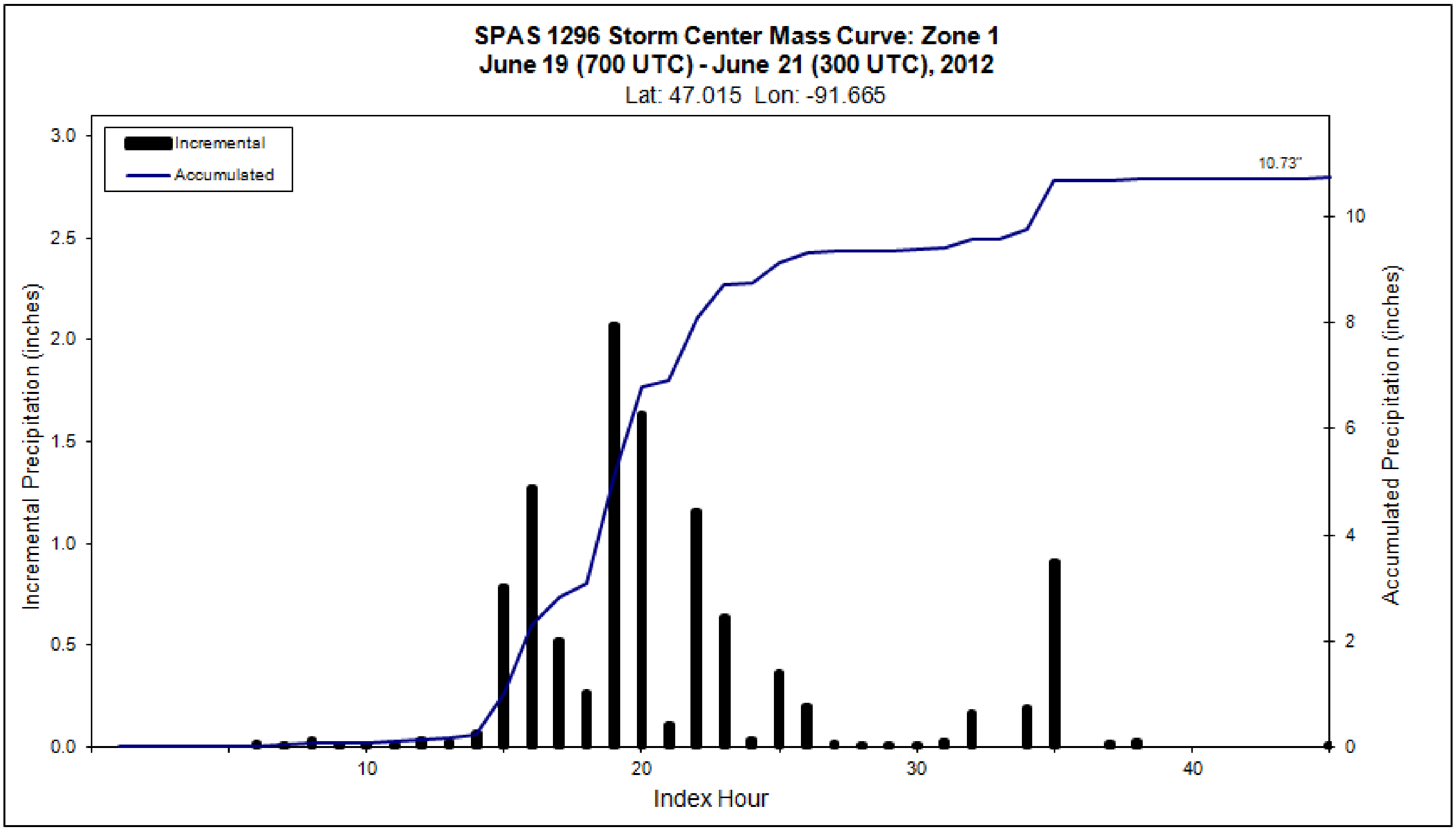
Attachment 1 Figure 19: Moisture inflow map for Duluth, MN June 2012

Storm 1296 - June 19 (700 UTC) - June 21 (300 UTC), 2012									
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)									
	Duration (hours)								
Area (mi^2)	1	3	6	12	18	24	36	45	Total
0.3	2.34	3.98	6.56	9.08	9.33	10.57	10.72	10.73	10.73
1	2.28	3.88	6.37	8.86	9.10	10.29	10.42	10.47	10.47
10	2.21	3.87	6.29	8.80	9.10	10.29	10.42	10.47	10.47
25	2.06	3.69	5.97	8.34	8.76	9.96	10.09	10.26	10.26
50	2.02	3.46	5.59	7.65	8.58	9.62	9.96	10.00	10.00
100	1.90	3.20	5.08	7.33	8.51	9.37	9.75	9.77	9.77
200	1.88	3.13	4.74	6.64	8.09	9.06	9.39	9.41	9.41
300	1.82	3.00	4.54	6.57	7.83	8.82	9.10	9.18	9.18
400	1.78	2.86	4.45	6.48	7.53	8.57	8.70	9.03	9.03
500	1.74	2.81	4.32	6.32	7.24	8.28	8.67	8.87	8.87
1,000	1.57	2.60	3.76	5.55	6.73	7.79	8.19	8.41	8.41
2,000	1.35	2.30	3.30	5.08	6.48	7.32	7.87	7.88	7.88
5,000	1.00	1.81	2.66	4.50	5.20	6.05	6.73	6.78	6.78
10,000	0.67	1.38	2.29	3.79	4.37	4.88	5.74	5.79	5.79
20,000	0.34	0.96	1.71	2.98	3.40	3.94	4.63	4.73	4.73
50,000	0.19	0.48	0.94	1.61	2.01	2.40	2.79	2.89	2.89
51,308	0.18	0.47	0.92	1.58	1.96	2.36	2.73	2.83	2.83

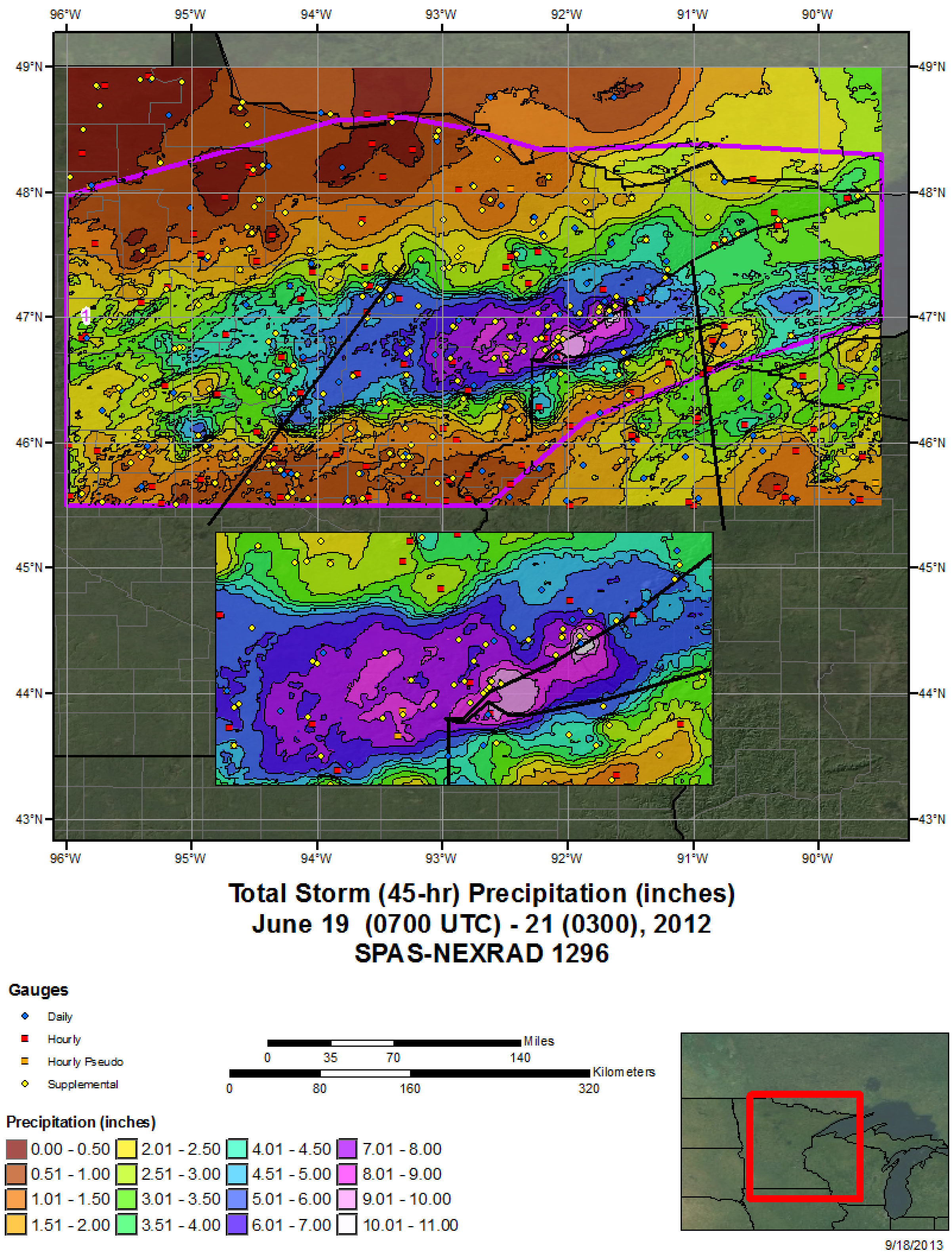
Attachment 1 Table 13: Depth-area-duration values for Duluth, MN June 2012



Attachment 1 Figure 20: Depth-area-duration chart for Duluth, MN June 2012



Attachment 1 Figure 21: Mass curve chart for Duluth, MN June 2012



Attachment 1 Figure 22: Total storm isohyetal analysis for Duluth, MN June 2012

Storm Name:	**SPAS 1183-Edgerton, MO**	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**18-Jul-1965**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	**40.41 N**	**95.51 W**
Storm Rep Dew Point Location	**39.22 N**	**96.58 W**
Transposition Dew Point Locat	**45.44 N**	**95.55 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SW @ 100**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**950**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**76.0 F**	with total precipitable water above sea level of		**2.99**	inches.
The in-place maximum dew point is	**80.5 F**	with total precipitable water above sea level of		**3.68**	inches.
The transpositioned maximum dew point is	**79.0 F**	with total precipitable water above sea level of		**3.44**	inches.
The in-place storm elevation is	**950**	which subtracts	**0.25**	inches of precipitable water at	**76.0 F**
The in-place storm elevation is	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**
The transposition storm elevation at	**1,300**	which subtracts	**0.37**	inches of precipitable water at	**79.0 F**
The moisture inflow barrier height is	**1,300**	which subtracts	**0.37**	inches of precipitable water at	**79.0 F**

The in-place maximization factor is	**1.24**
The transposition factor is	**0.91**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.12**

Notes:

Observed Storm Depth-Area-Duration

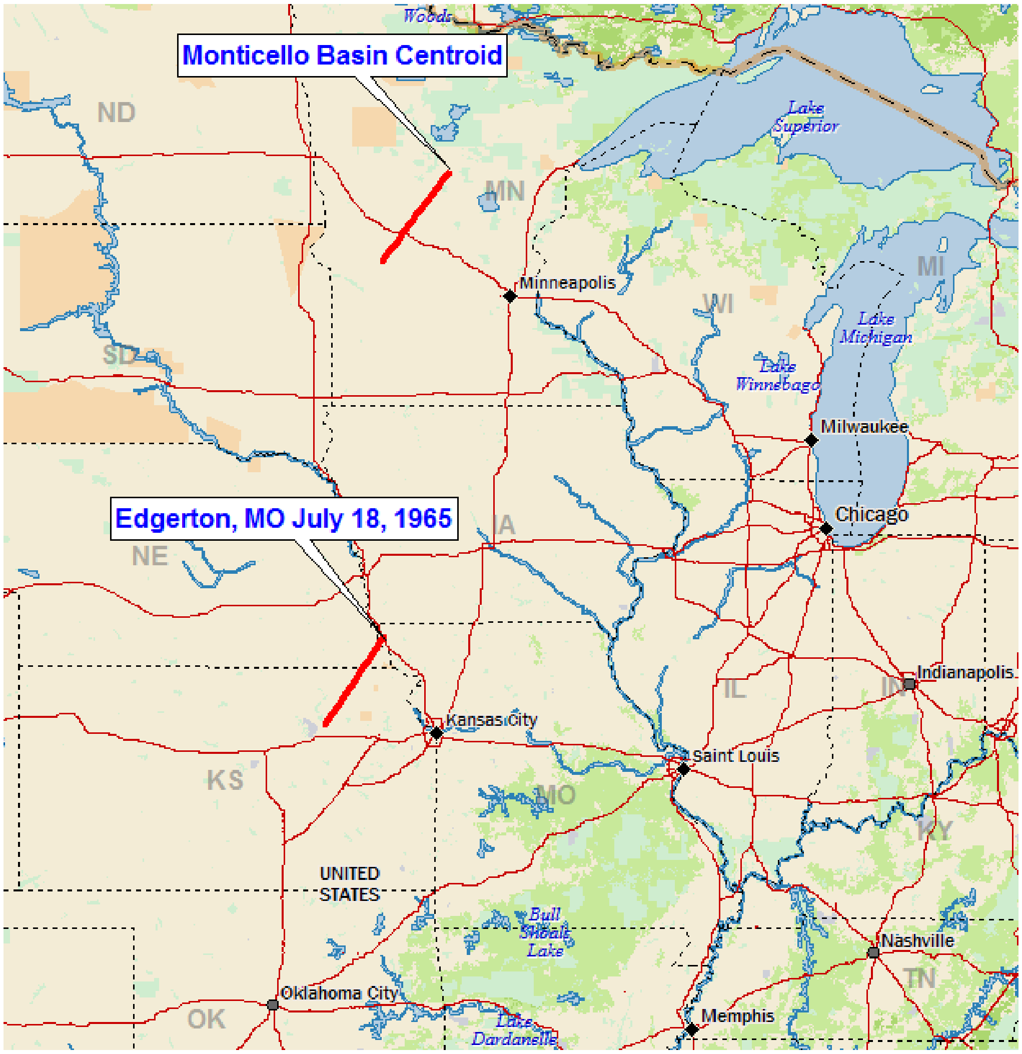
	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**3.7**	**11.8**	**16.7**	**17.3**	**18.0**	-	**19.3**	**19.4**	**20.1**	-
10 sq miles	**3.5**	**11.1**	**15.4**	**16.5**	**17.6**	-	**19.0**	**19.1**	**19.7**	-
100 sq miles	**2.4**	**7.5**	**11.0**	**11.5**	**13.4**	-	**15.3**	**16.4**	**17.2**	-
200 sq miles	**1.8**	**6.2**	**9.2**	**9.9**	**12.7**	-	**14.2**	**15.4**	**16.2**	-
500 sq miles	**1.4**	**4.4**	**6.1**	**8.2**	**10.9**	-	**13.4**	**13.9**	**15.2**	-
1000 sq miles	**1.2**	**3.7**	**5.8**	**7.6**	**9.5**	-	**12.1**	**13.0**	**13.8**	-
2000 sq miles	**1.0**	**3.5**	**4.9**	**6.8**	**8.7**	-	**10.8**	**11.8**	**12.7**	-
5000 sq miles	**0.6**	**2.7**	**3.8**	**5.6**	**6.9**	-	**8.5**	**9.7**	**10.4**	-
10000 sq miles	**0.4**	**2.1**	**3.2**	**4.0**	**5.2**	-	**7.0**	**7.7**	**8.2**	-
20000 sq miles	**0.3**	**1.4**	**2.2**	**2.8**	**3.6**	-	**4.9**	**5.4**	**5.8**	-

Adjusted Storm Depth-Area-Duration

	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**4.1**	**13.2**	**18.7**	**19.3**	**20.2**	-	**21.6**	**21.6**	**22.5**	-
10 sq miles	**3.9**	**12.4**	**17.2**	**18.4**	**19.6**	-	**21.2**	**21.3**	**22.0**	-
100 sq miles	**2.7**	**8.4**	**12.2**	**12.9**	**15.0**	-	**17.1**	**18.3**	**19.3**	-
200 sq miles	**2.0**	**6.9**	**10.3**	**11.1**	**14.2**	-	**15.9**	**17.2**	**18.1**	-
500 sq miles	**1.6**	**4.9**	**6.9**	**9.1**	**12.2**	-	**15.0**	**15.5**	**17.0**	-
1000 sq miles	**1.4**	**4.1**	**6.5**	**8.5**	**10.6**	-	**13.5**	**14.6**	**15.5**	-
2000 sq miles	**1.1**	**3.9**	**5.5**	**7.6**	**9.8**	-	**12.0**	**13.2**	**14.2**	-
5000 sq miles	**0.7**	**3.0**	**4.3**	**6.2**	**7.7**	-	**9.5**	**10.8**	**11.7**	-
10000 sq miles	**0.5**	**2.3**	**3.5**	**4.5**	**5.8**	-	**7.9**	**8.6**	**9.2**	-
20000 sq miles	**0.3**	**1.6**	**2.5**	**3.1**	**4.0**	-	**5.4**	**6.0**	**6.5**	-

Storm or Storm Center Name	**SPAS 1183-Edgerton, MO**	
Storm Date(s)	18-Jul-1965	
Storm Type	General Storm/MCC	
Storm Location	40.41 N	95.51 W
Storm Center Elevation	950	
Precipitation Total & Duration (10 sq mi)	20.76 inches in 60hrs, 18.59" in 24hrs	
Storm Representative Dew Point	76.0 F	24
Storm Representative Dew Point Location	39.22 N	96.58 W
Maximum Dew Point	80.5 F	
Moisture Inflow Vector	SW @ 100	
In-place Maximization Factor	**1.24**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	45.44 N	95.55 W
Transposition Maximum Dew Point	79.0 F	
Transposition Adjustment Factor	**0.91**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.12**	

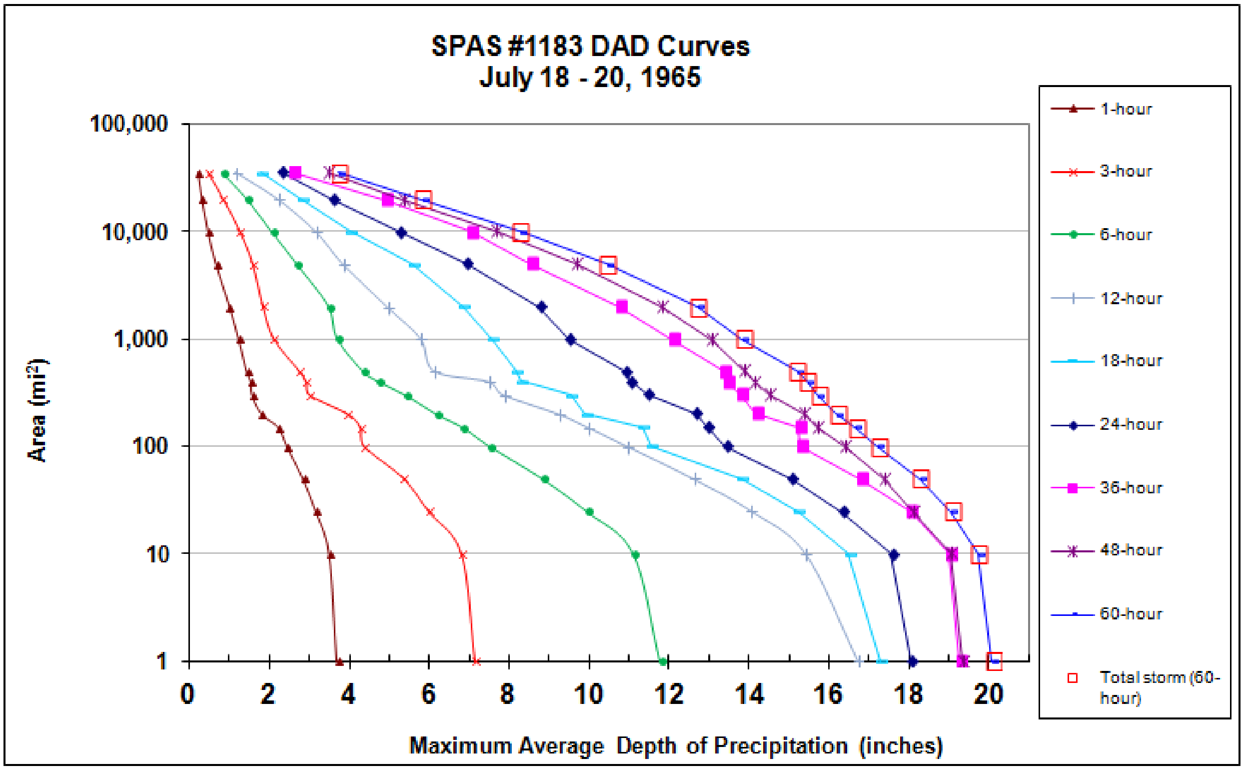
Attachment 1 Table 14: Storm spreadsheet for Edgerton, MO July 1965



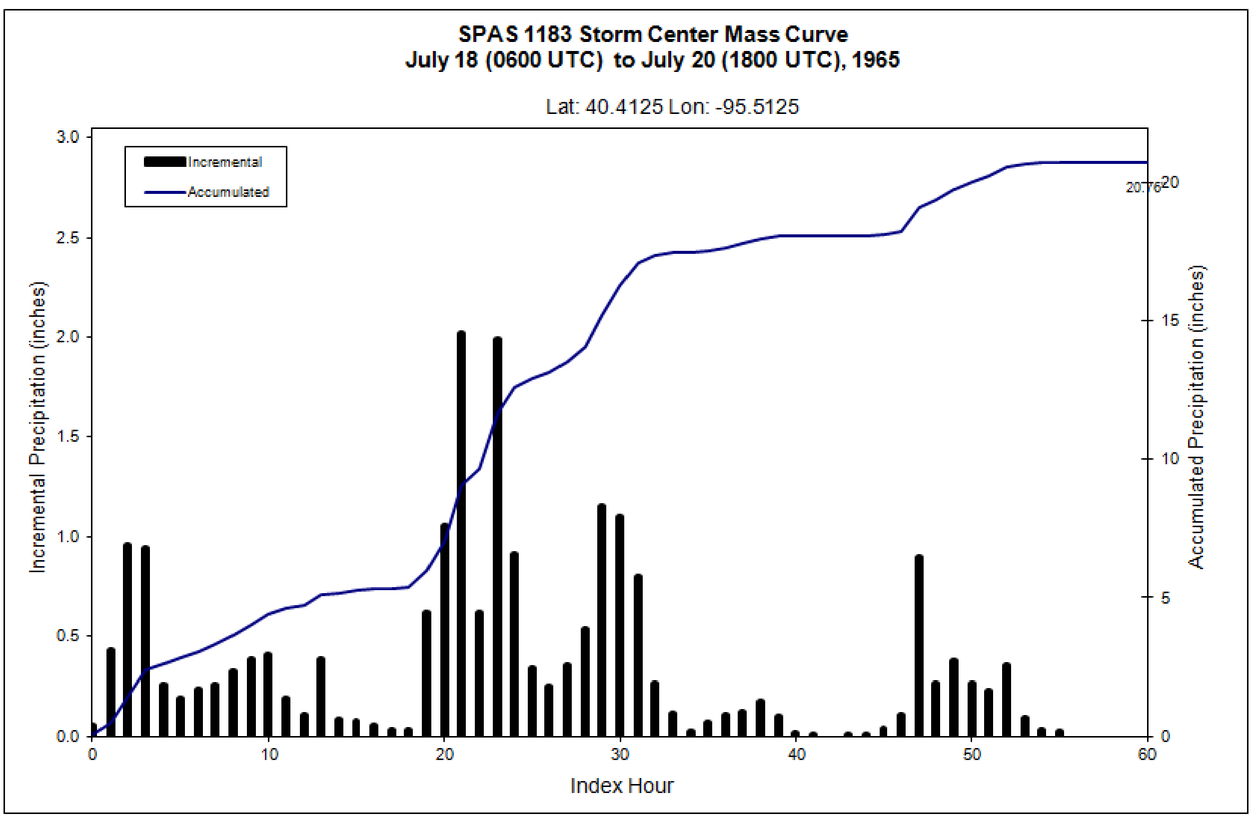
Attachment 1 Figure 23: Moisture inflow map for Edgerton, MO July 1965

Storm 1183 - July 18, 1965 (0600 UTC) to July 20 (1800 UTC), 1965 MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)										
	Duration (hours)									
Area (mi^2)	1	3	6	12	18	24	36	48	60	Total
0.30	3.77	7.34	12.06	17.13	17.80	18.59	19.82	19.86	20.76	20.76
1	3.68	7.13	11.77	16.72	17.29	18.04	19.27	19.35	20.08	20.08
10	3.49	6.79	11.11	15.41	16.49	17.56	19.00	19.06	19.71	19.71
25	3.15	5.96	9.93	14.05	15.23	16.32	18.04	18.12	19.06	19.06
50	2.83	5.35	8.83	12.60	13.81	15.05	16.79	17.37	18.27	18.27
100	2.43	4.36	7.52	10.95	11.54	13.41	15.27	16.39	17.22	17.22
150	2.21	4.26	6.84	9.96	11.34	12.96	15.23	15.69	16.66	16.66
200	1.79	3.94	6.18	9.23	9.90	12.66	14.18	15.38	16.18	16.18
300	1.55	2.99	5.41	7.86	9.53	11.45	13.80	14.49	15.71	15.71
400	1.52	2.90	4.74	7.48	8.30	11.04	13.43	14.13	15.44	15.44
500	1.41	2.73	4.35	6.13	8.17	10.88	13.37	13.88	15.17	15.17
1,000	1.21	2.09	3.71	5.79	7.57	9.48	12.08	13.04	13.83	13.83
2,000	0.98	1.82	3.49	4.94	6.83	8.74	10.76	11.80	12.70	12.70
5,000	0.64	1.56	2.69	3.84	5.57	6.92	8.50	9.66	10.42	10.42
10,000	0.44	1.24	2.06	3.16	4.00	5.23	7.03	7.67	8.24	8.24
20,000	0.29	0.82	1.44	2.21	2.81	3.59	4.86	5.36	5.81	5.81
35,221	0.19	0.45	0.83	1.17	1.78	2.29	2.57	3.46	3.72	3.72

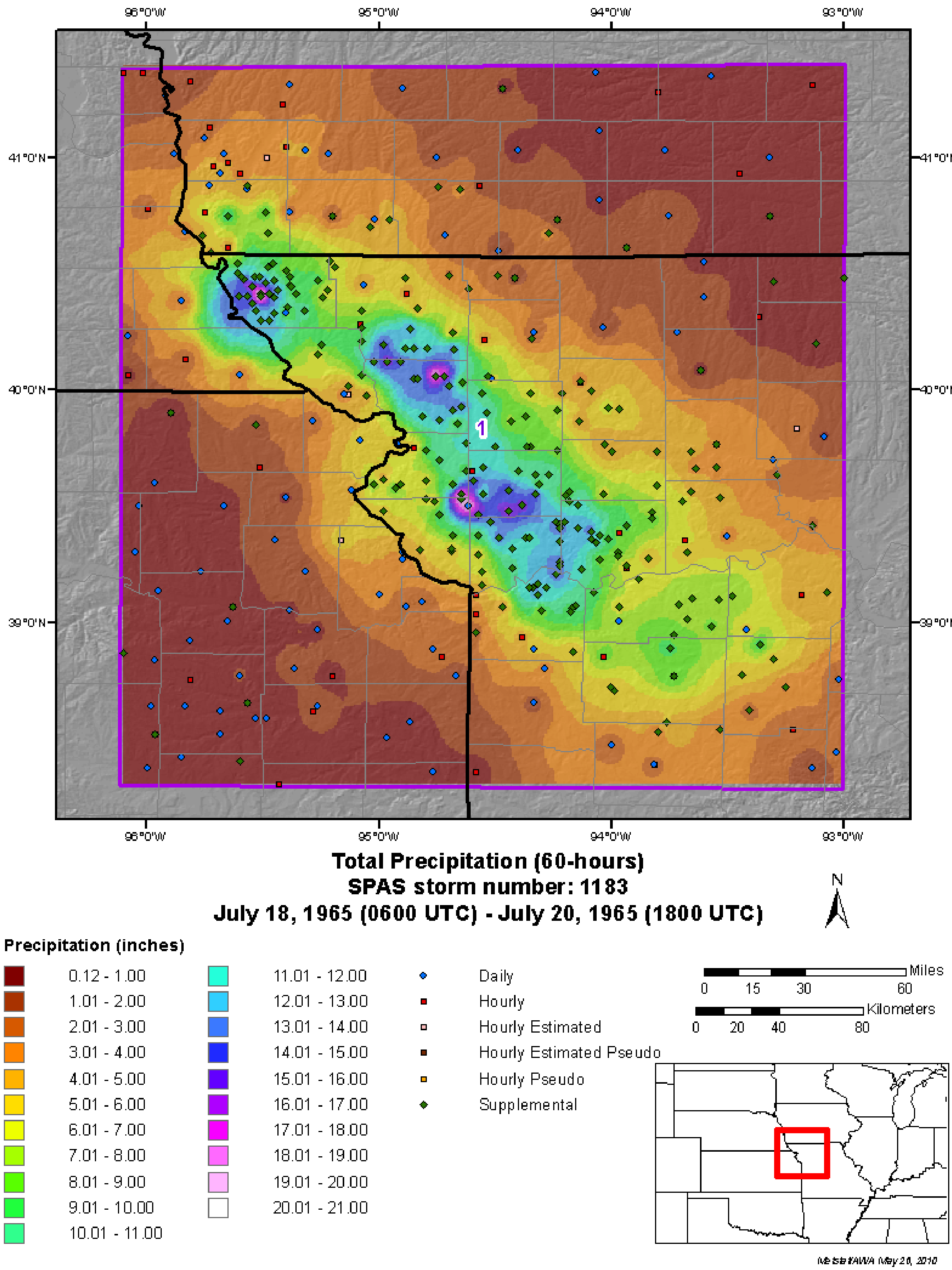
Attachment 1 Table 15: Depth-area-duration values for Edgerton, MO July 1965



Attachment 1 Figure 24: Depth-area-duration chart for Edgerton, MO July 1965



Attachment 1 Figure 25: Mass curve chart for Edgerton, MO July 1965



Attachment 1 Figure 26: Total storm isohyetal analysis for Edgerton, MO July 1965

Storm Name:	**UMV 1-22-Hayward, WI**		**Storm Adjustment for Basin Centroid-Monticello**			
Storm Date:	**8/28-30/1941**					
AWA Analysis Date:	**8/24/2014**					
Temporal Transpostion Date	**15-Aug**					
	Lat	**Long**	**Moisture Inflow Direction**	**SSE @ 225**	miles	
Storm Center Location	**46.01 N**	**91.48 W**	**Basin Average Elevation**	**1,300**	feet	
Storm Rep Dew Point Location	**42.99 N**	**89.78 W**	**Storm Center Elevation**	**1,200**	feet	
Transposition Dew Point Locat	**43.61 N**	**92.65 W**	**Storm Analysis Duration**	**24**	hours	
Basin Location	**46.63 N**	**94.37 W**				

The storm representative dew point is	**73.0 F**	with total precipitable water above sea level of			**2.60**	inches.
The in-place maximum dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The transpositioned maximum dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The in-place storm elevation is	**1,200**	which subtracts	**0.28**	inches of precipitable water at	**73.0 F**	
The in-place storm elevation is	**1,200**	which subtracts	**0.34**	inches of precipitable water at	**79.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.37**	inches of precipitable water at	**79.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.37**	inches of precipitable water at	**79.0 F**	

The in-place maximization factor is	**1.30**
The transposition factor is	**0.99**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.29**

Notes: DAD values taken from USACE UMV 1-22. Storm representative dew point value was based on adding 2°F to the USACE analyzed storm rep Td following EPRI, Nebraska, and TRWD studies.

Observed Storm Depth-Area-Duration

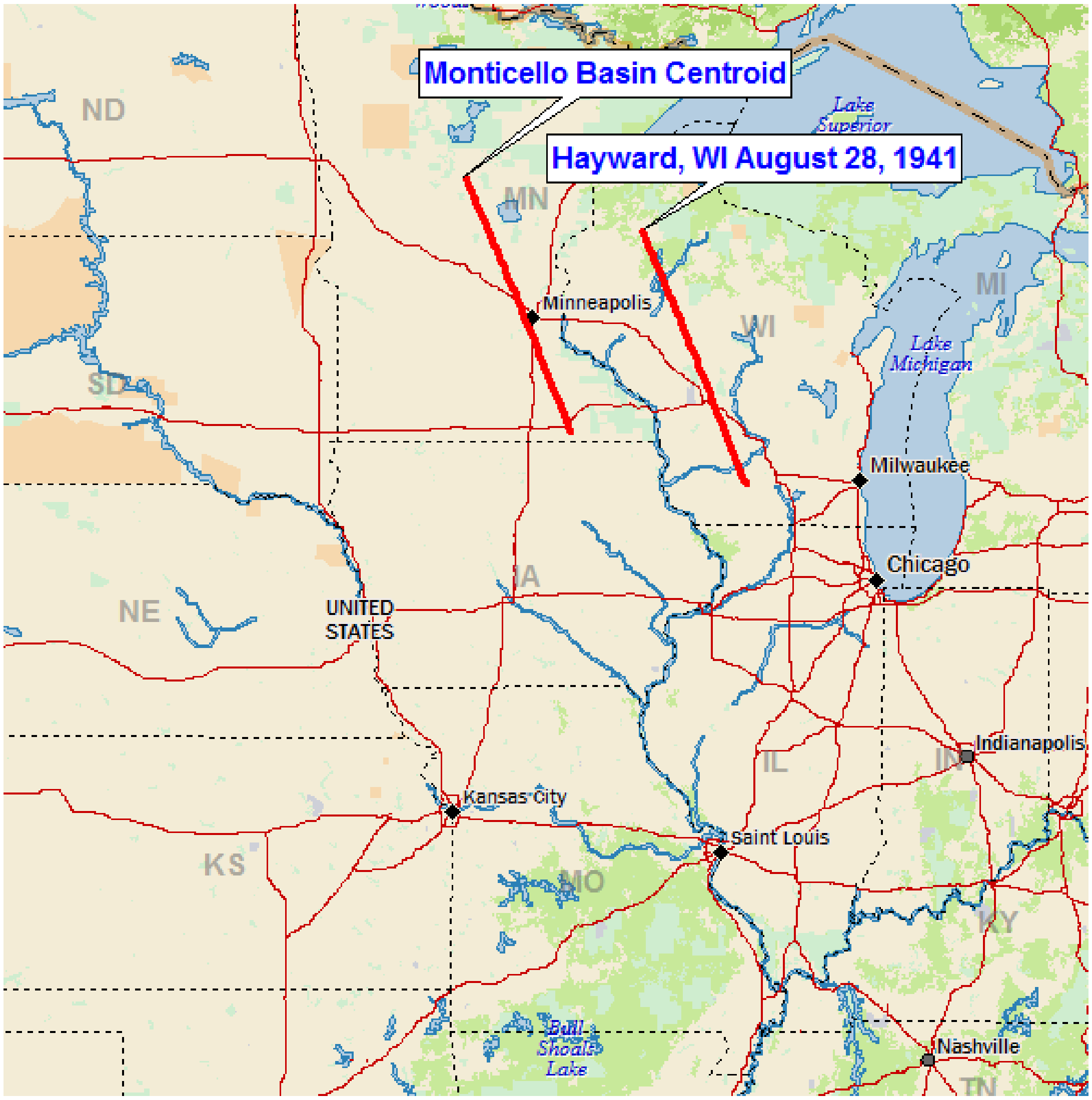
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**8.5**	**11.5**	**12.4**	**12.4**	**13.3**	**13.8**	**14.4**	**15.0**	**15.0**
100 sq miles	**8.1**	**11.0**	**11.8**	**11.8**	**12.7**	**13.3**	**13.8**	**14.3**	**14.5**
200 sq miles	**7.8**	**10.6**	**11.3**	**11.3**	**12.3**	**13.0**	**13.4**	**13.9**	**14.1**
500 sq miles	**6.8**	**9.5**	**10.2**	**10.3**	**11.2**	**12.0**	**12.5**	**12.9**	**13.1**
1000 sq miles	**5.6**	**8.2**	**9.0**	**9.1**	**10.0**	**10.9**	**11.5**	**11.9**	**12.0**
2000 sq miles	**4.3**	**6.9**	**7.7**	**7.9**	**8.8**	**9.7**	**10.4**	**10.8**	**10.9**
5000 sq miles	**3.0**	**5.2**	**5.9**	**6.3**	**7.2**	**8.1**	**8.9**	**9.3**	**9.5**
10000 sq miles	**2.1**	**3.8**	**4.6**	**5.1**	**5.9**	**6.0**	**7.8**	**8.2**	**8.4**
20000 sq miles	**1.5**	**2.7**	**3.4**	**3.8**	**4.7**	**5.5**	**6.5**	**7.1**	**7.3**

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**10.9**	**14.8**	**16.0**	**16.0**	**17.1**	**17.8**	**18.5**	**19.3**	**19.3**
100 sq miles	**10.4**	**14.2**	**15.2**	**15.2**	**16.4**	**17.1**	**17.8**	**18.4**	**18.7**
200 sq miles	**10.0**	**13.6**	**14.5**	**14.5**	**15.8**	**16.7**	**17.3**	**17.9**	**18.2**
500 sq miles	**8.8**	**12.2**	**13.1**	**13.3**	**14.4**	**15.4**	**16.1**	**16.6**	**16.9**
1000 sq miles	**7.2**	**10.6**	**11.6**	**11.7**	**12.9**	**14.0**	**14.8**	**15.3**	**15.4**
2000 sq miles	**5.5**	**8.9**	**9.9**	**10.2**	**11.3**	**12.5**	**13.4**	**13.9**	**14.0**
5000 sq miles	**3.9**	**6.7**	**7.6**	**8.1**	**9.3**	**10.4**	**11.5**	**12.0**	**12.2**
10000 sq miles	**2.7**	**4.9**	**5.9**	**6.6**	**7.6**	**7.7**	**10.0**	**10.6**	**10.8**
20000 sq miles	**1.9**	**3.5**	**4.4**	**4.9**	**6.1**	**7.1**	**8.4**	**9.1**	**9.4**

Storm or Storm Center Name	**UMV 1-22-Hayward, WI**		
Storm Date(s)	8/28-30/1941		
Storm Type	Synoptic		
Storm Location	46.01 N	91.48 W	
Storm Center Elevation	1,200		
Precipitation Total & Duration	15.00 Inches 72-hours USACE UMV 1-22		
Storm Representative Dew Point	73.0 F	24	
Storm Representative Dew Point Location	42.99 N	89.78 W	
Maximum Dew Point	79.0 F		Aug
Moisture Inflow Vector	SSE @ 225		78.5
In-place Maximization Factor	**1.30**		
Temporal Transposition (Date)	15-Aug		
Transposition Dew Point Location	43.61 N	92.65 W	
Transposition Maximum Dew Point	79.0 F		
Transposition Adjustment Factor	**0.99**		
Average Basin Elevation	1,300		
Highest Elevation in Basin	1,896		
Inflow Barrier Height	1,300		
Elevation Adjustment Factor	**1.00**		
Total Adjustment Factor	**1.29**		

Attachment 1 Table 16: Storm spreadsheet for Hayward, WI August 1941



Attachment 1 Figure 27: Moisture inflow map for Hayward, WI August 1941

WAR DEPARTMENT CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES - PERTINENT DATA SHEET

Storm of August 28 - 31, 1941
Assignment U M V 1 - 22
Location Northern Wisconsin and Minn.
Study Prepared by: Upper Mississippi Valley Division
St. Paul District Office
Part I Reviewed by H. M. Sec. of Weather Bureau, 3/24/42
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 4/11/45
Remarks: Center at: Haywood and Moose Lake, Wisc.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 4 sheet, scale 1 : 1,000,000
Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 33
- Form 5001-B (24-hour " ") ---------- -
- Form 5001-D (" " " ") ---------- 14
- Miscl. precip. records, meteorological data, etc. ---------- 3
- Form 5002 (Mass rainfall curves) ---------- 42

PART II

Final isohyetal maps, in 1 sheet, scale 1,000,000
Data and computation sheets:

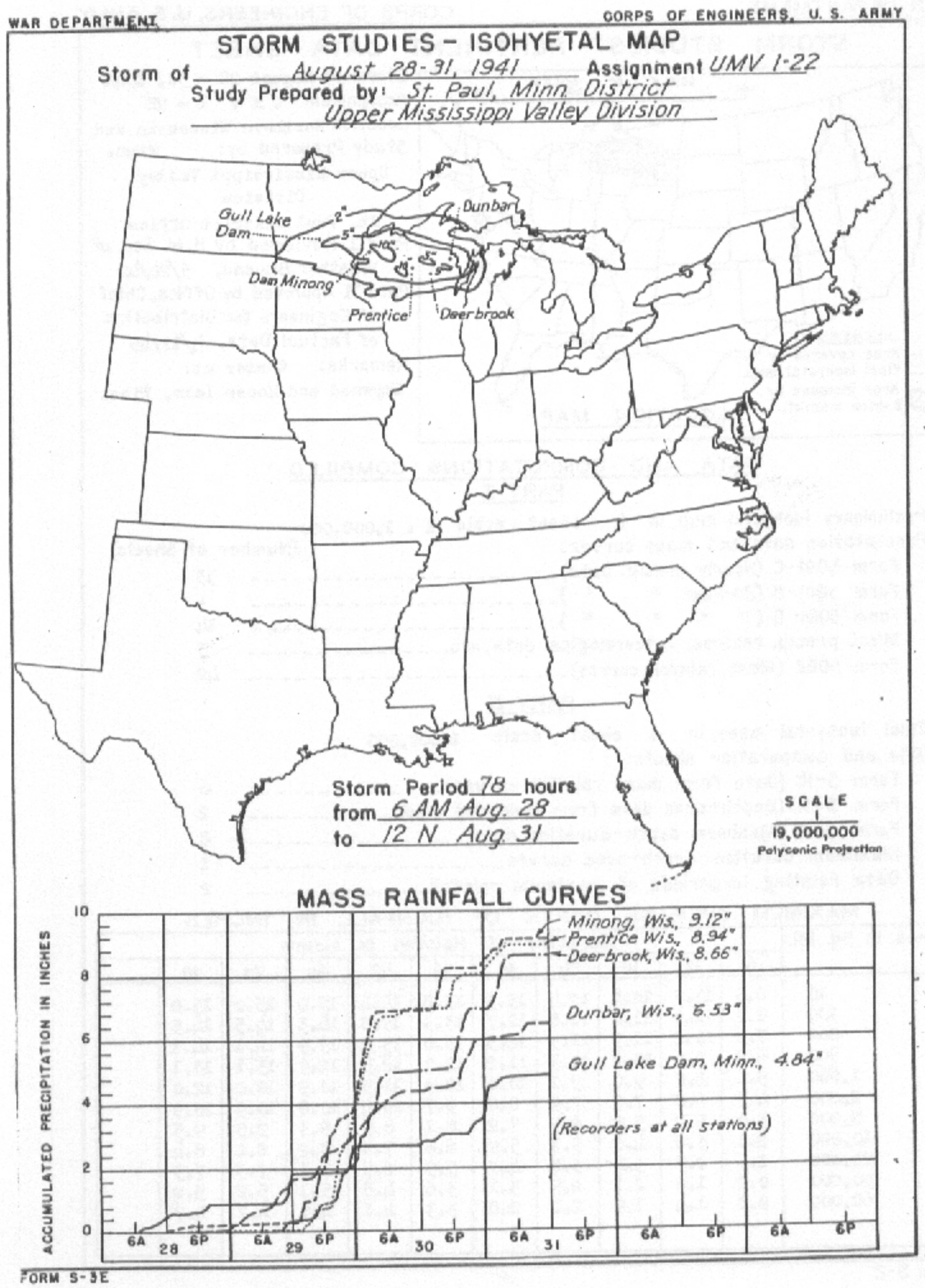
- Form S-10 (Data from mass rainfall curves) ---------- 6
- Form S-11 (Depth-area data from isohyetal map) ---------- 2
- Form S-12 (Maximum depth-duration data) ---------- 8
- Maximum duration-depth-area curves ---------- 1
- Data relating to periods of maximum rainfall ---------- 2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	78
10	8.5	11.5	12.4	12.4	13.3	13.8	14.4	15.0	15.0	15.0
100	8.1	11.0	11.8	11.8	12.7	13.3	13.8	14.3	14.5	14.5
200	7.8	10.6	11.3	11.3	12.3	13.0	13.4	13.9	14.1	14.1
500	6.8	9.5	10.2	10.3	11.2	12.0	12.5	12.9	13.1	13.1
1,000	5.6	8.2	9.0	9.1	10.0	10.9	11.5	11.9	12.0	12.0
2,000	4.3	6.9	7.7	7.9	8.8	9.7	10.4	10.8	10.9	10.9
5,000	3.0	5.2	5.9	6.3	7.2	8.1	8.9	9.3	9.5	9.5
10,000	2.1	3.8	4.6	5.1	5.9	6.8	7.8	8.2	8.4	8.4
20,000	1.5	2.7	3.4	3.8	4.7	5.5	6.5	7.1	7.3	7.3
50,000	0.9	1.6	2.1	2.5	3.1	3.6	4.5	5.1	5.2	5.2
60,000	0.8	1.4	1.9	2.2	2.8	3.3	4.1	4.5	4.7	4.7

Form S-2

Attachment 1 Table 17: Depth-area-duration values for Hayward, WI August 1941



Attachment 1 Figure 28 and Attachment 1 Figure 29: Isohyetal map and Mass curve chart for Hayward, WI August 1941

Storm Name:	**Hokah, MN-SPAS 1048**	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**18-Aug-2007**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date		**3-Aug**
	Lat	**Long**
Storm Center Location	**43.81 N**	**91.52 W**
Storm Rep Dew Point Location	**38.91 N**	**93.85 W**
Transposition Dew Point Locat	**41.73 N**	**96.80 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SSW @ 360**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**1,000**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**74.0 F**	with total precipitable water above sea level of			**2.73**	inches.
The in-place maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The in-place storm elevation is	**1,000**	which subtracts	**0.24**	inches of precipitable water at	**74.0 F**	
The in-place storm elevation is	**1,000**	which subtracts	**0.30**	inches of precipitable water at	**80.5 F**	
The transposition basin elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	
The inflow barrier/basin elevation height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.36**
The transposition factor is	**0.95**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.29**

Notes: DAD values taken from SPAS 1048. 24hr ave Td from KIXD, KLXT, KMCI, KMKC, KOJC, KSTJ, KSZL 17th 00Z to 18th 00Z

Observed Storm Depth-Area-Duration

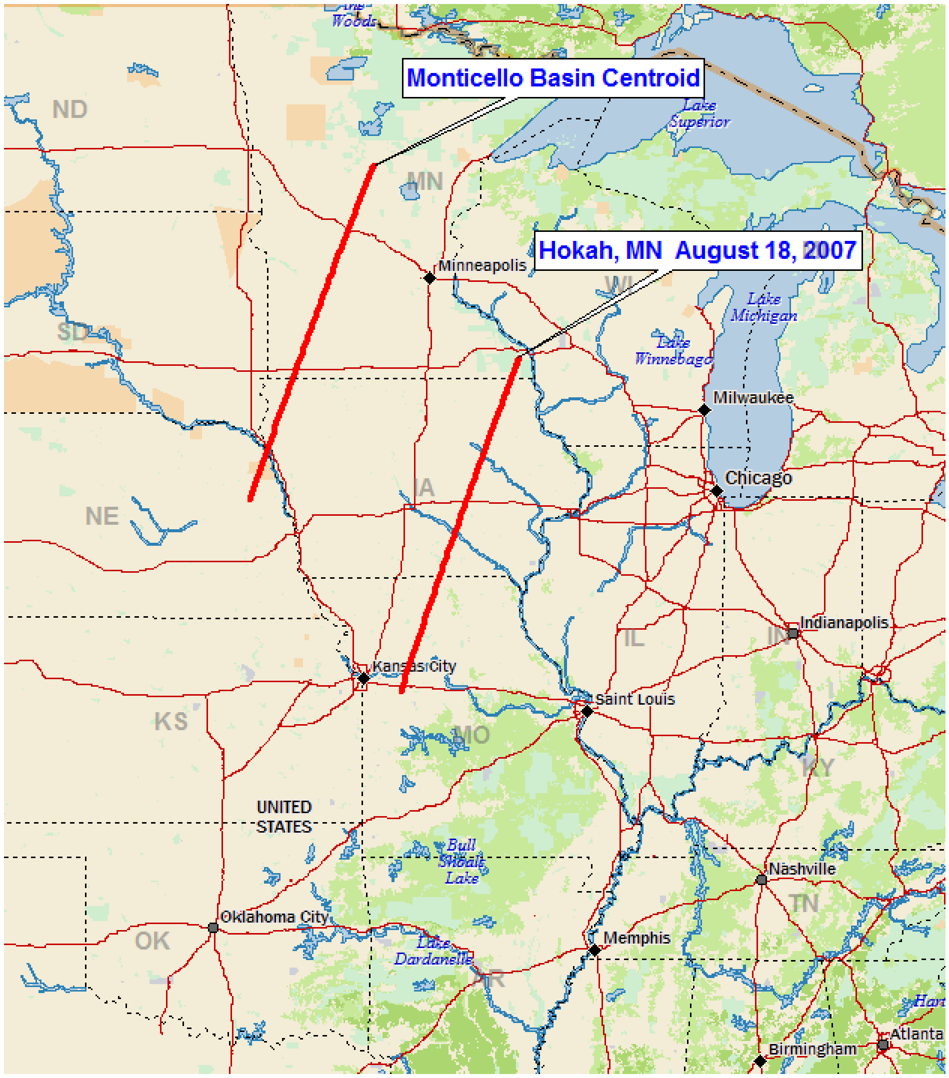
	1 Hour	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**2.12**	**7.6**	**11.6**	**14.6**	**17.1**	-	**17.6**	**18.2**	-	**18.3**
10 sq miles	**2.12**	**7.5**	**11.1**	**13.9**	**16.0**	-	**16.3**	**17.0**	-	**17.2**
100 sq miles	**2.09**	**6.3**	**9.4**	**11.5**	**13.3**	-	**13.9**	**14.8**	-	**15.1**
200 sq miles	**2.03**	**6.0**	**8.9**	**11.0**	**12.6**	-	**13.4**	**14.2**	-	**14.5**
500 sq miles	**1.79**	**5.5**	**8.1**	**10.1**	**11.6**	-	**12.3**	**13.0**	-	**13.3**
1000 sq miles	**1.53**	**5.0**	**7.3**	**9.2**	**10.5**	-	**11.1**	**11.8**	-	**12.1**
2000 sq miles	**0.95**	**4.4**	**6.2**	**8.1**	**9.3**	-	**9.9**	**10.5**	-	**10.8**
5000 sq miles	**0.87**	**3.5**	**5.2**	**6.5**	**7.6**	-	**8.2**	**8.8**	-	**9.0**
10000 sq miles	**0.63**	**2.7**	**4.0**	**5.4**	**6.1**	-	**6.8**	**7.3**	-	**7.5**
20000 sq miles	**0.41**	**1.8**	**3.0**	**4.0**	**4.5**	-	**5.1**	**5.6**	-	**5.9**

Adjusted Storm Depth-Area-Duration

	1 Hour	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**2.7**	**9.8**	**15.1**	**18.9**	**22.0**	-	**22.7**	**23.5**	-	**23.6**
10 sq miles	**2.7**	**9.7**	**14.4**	**17.9**	**20.6**	-	**21.1**	**22.0**	-	**22.2**
100 sq miles	**2.7**	**8.2**	**12.1**	**14.9**	**17.2**	-	**18.0**	**19.1**	-	**19.6**
200 sq miles	**2.6**	**7.8**	**11.5**	**14.2**	**16.3**	-	**17.3**	**18.4**	-	**18.8**
500 sq miles	**2.3**	**7.1**	**10.5**	**13.1**	**15.0**	-	**15.9**	**16.8**	-	**17.2**
1000 sq miles	**2.0**	**6.4**	**9.5**	**11.9**	**13.6**	-	**14.4**	**15.3**	-	**15.6**
2000 sq miles	**1.2**	**5.6**	**8.0**	**10.5**	**12.0**	-	**12.7**	**13.6**	-	**13.9**
5000 sq miles	**1.1**	**4.5**	**6.7**	**8.4**	**9.8**	-	**10.6**	**11.4**	-	**11.6**
10000 sq miles	**0.8**	**3.5**	**5.2**	**7.0**	**7.9**	-	**8.8**	**9.5**	-	**9.7**
20000 sq miles	**0.5**	**2.4**	**3.9**	**5.1**	**5.9**	-	**6.6**	**7.3**	-	**7.6**

Storm or Storm Center Name	**Hokah, MN-SPAS 1048**			
Storm Date(s)	18-Aug-2007			
Storm Type	Synoptic/Thunderstorms			
Storm Location	43.81 N	91.52 W		
Storm Center Elevation	1,000			
Precipitation Total & Duration	18.93 Inches 72-hours-SPAS 1048			
Storm Representative Dew Point	74.0 F	24		
Storm Representative Dew Point Location	38.91 N	93.85 W		
Maximum Dew Point	80.5 F			
Moisture Inflow Vector	SSW @ 360			
In-place Maximization Factor	**1.36**			
Temporal Transposition (Date)	3-Aug			
Transposition Dew Point Location	41.73 N	96.80 W	July	Aug
Transposition Maximum Dew Point	80.0 F		80.14	79.99
Transposition Adjustment Factor	**0.95**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.29**			

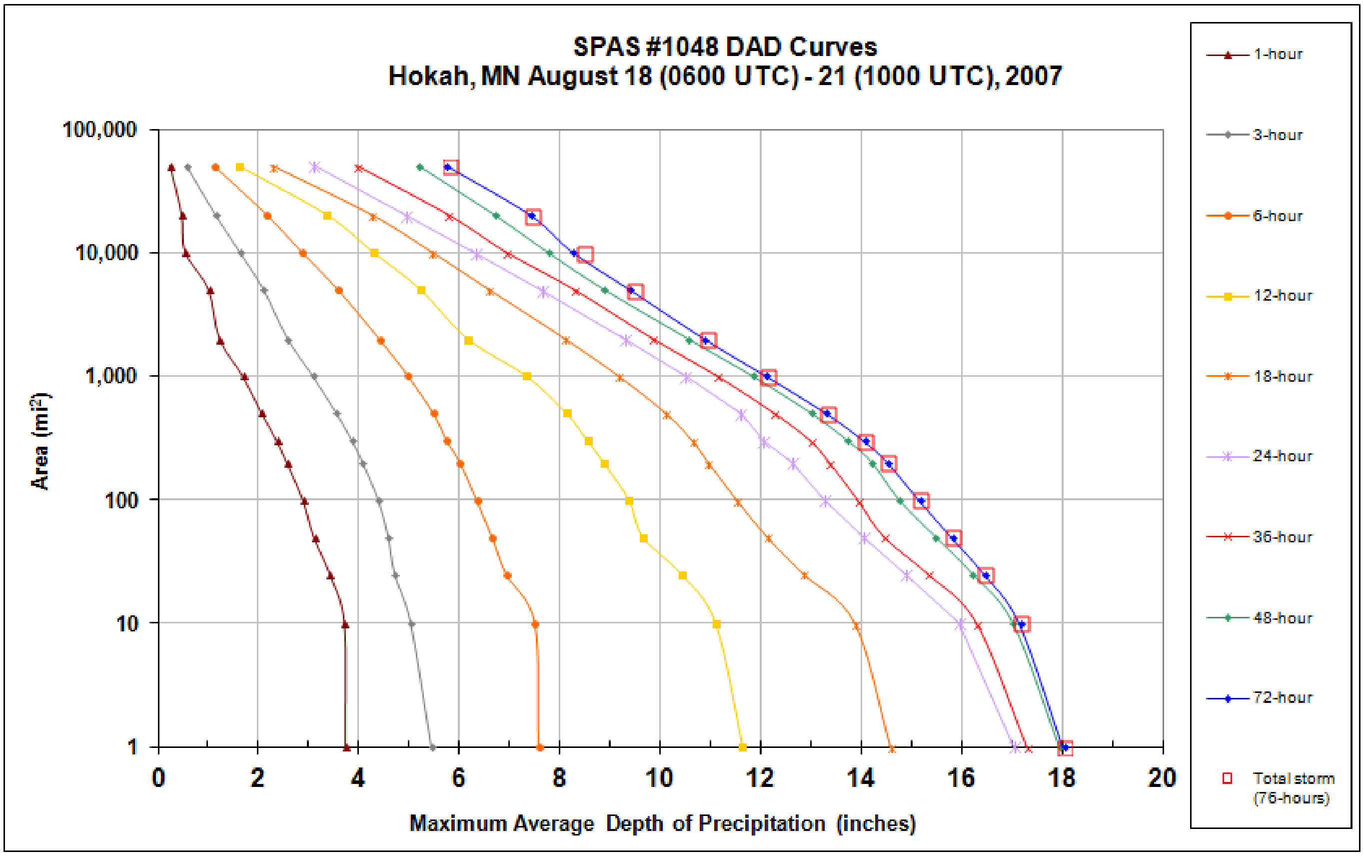
Attachment 1 Table 18: Storm spreadsheet for Hokah, MN, August 2007



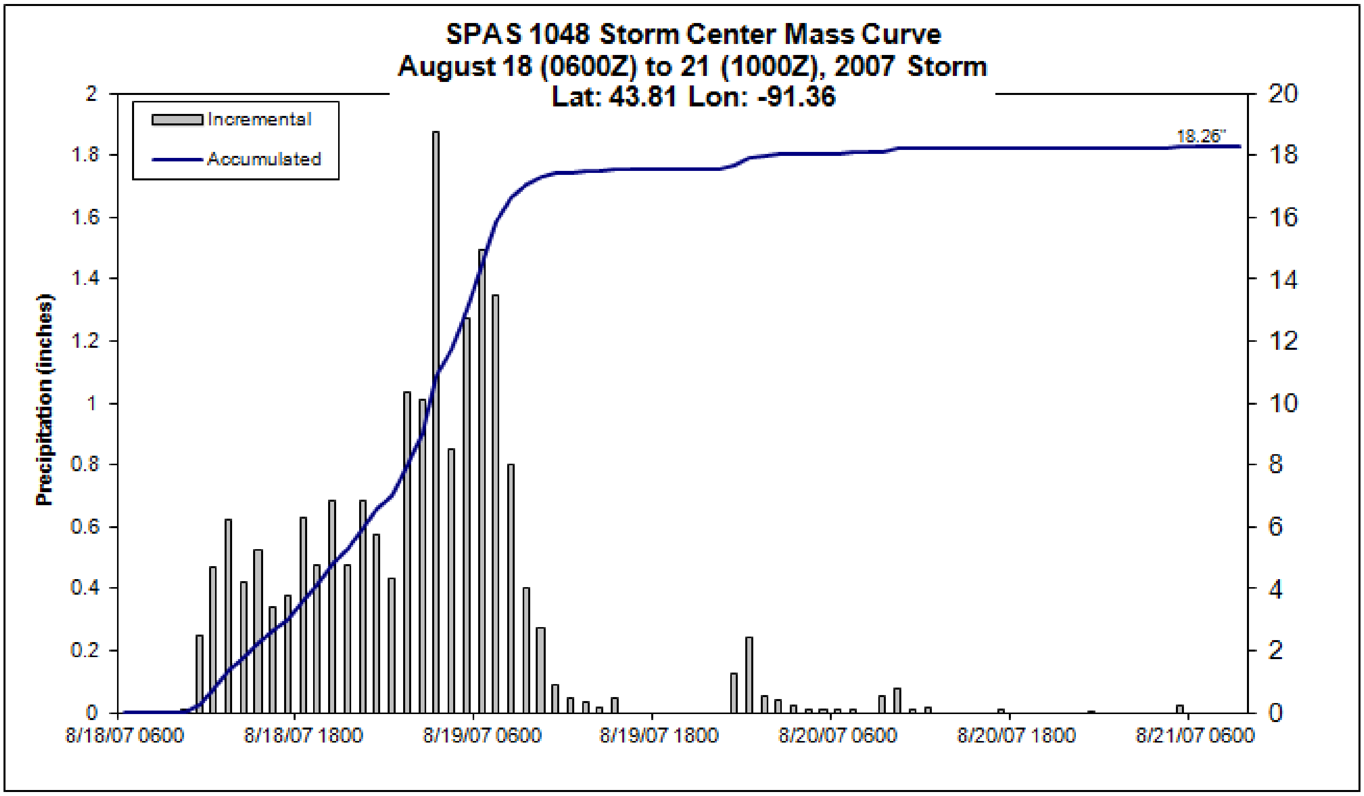
Attachment 1 Figure 30: Moisture inflow map for Hokah, MN, August 2007

Storm 1048 - Hokah, MN August 18 - August 21, 2007										
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)										
	Duration (hours)									
Area (mi^2)	1	3	6	12	18	24	36	48	72	Total
0.24	4.02	5.71	7.85	11.89	14.88	17.31	17.55	18.19	18.26	18.26
1	3.72	5.43	7.56	11.64	14.59	17.05	17.31	17.95	18.02	18.02
10	3.70	5.02	7.49	11.10	13.88	15.96	16.31	17.03	17.15	17.17
25	3.41	4.70	6.92	10.42	12.86	14.89	15.34	16.23	16.45	16.46
50	3.09	4.57	6.64	9.65	12.13	14.05	14.46	15.49	15.79	15.79
100	2.87	4.37	6.33	9.37	11.52	13.27	13.93	14.76	15.14	15.14
200	2.55	4.06	6.00	8.87	10.96	12.62	13.37	14.22	14.52	14.52
300	2.35	3.85	5.74	8.55	10.64	12.06	12.99	13.74	14.04	14.04
500	2.05	3.54	5.47	8.13	10.11	11.60	12.27	13.01	13.29	13.30
1,000	1.67	3.07	4.97	7.33	9.17	10.51	11.13	11.84	12.09	12.12
2,000	1.21	2.57	4.39	6.16	8.10	9.30	9.85	10.56	10.86	10.92
5,000	0.99	2.09	3.57	5.23	6.59	7.65	8.28	8.89	9.37	9.47
10,000	0.53	1.62	2.86	4.29	5.46	6.33	6.93	7.77	8.24	8.45
20,000	0.46	1.14	2.16	3.37	4.26	4.95	5.78	6.71	7.39	7.43
50,000	0.23	0.56	1.11	1.61	2.28	3.11	3.95	5.20	5.72	5.80

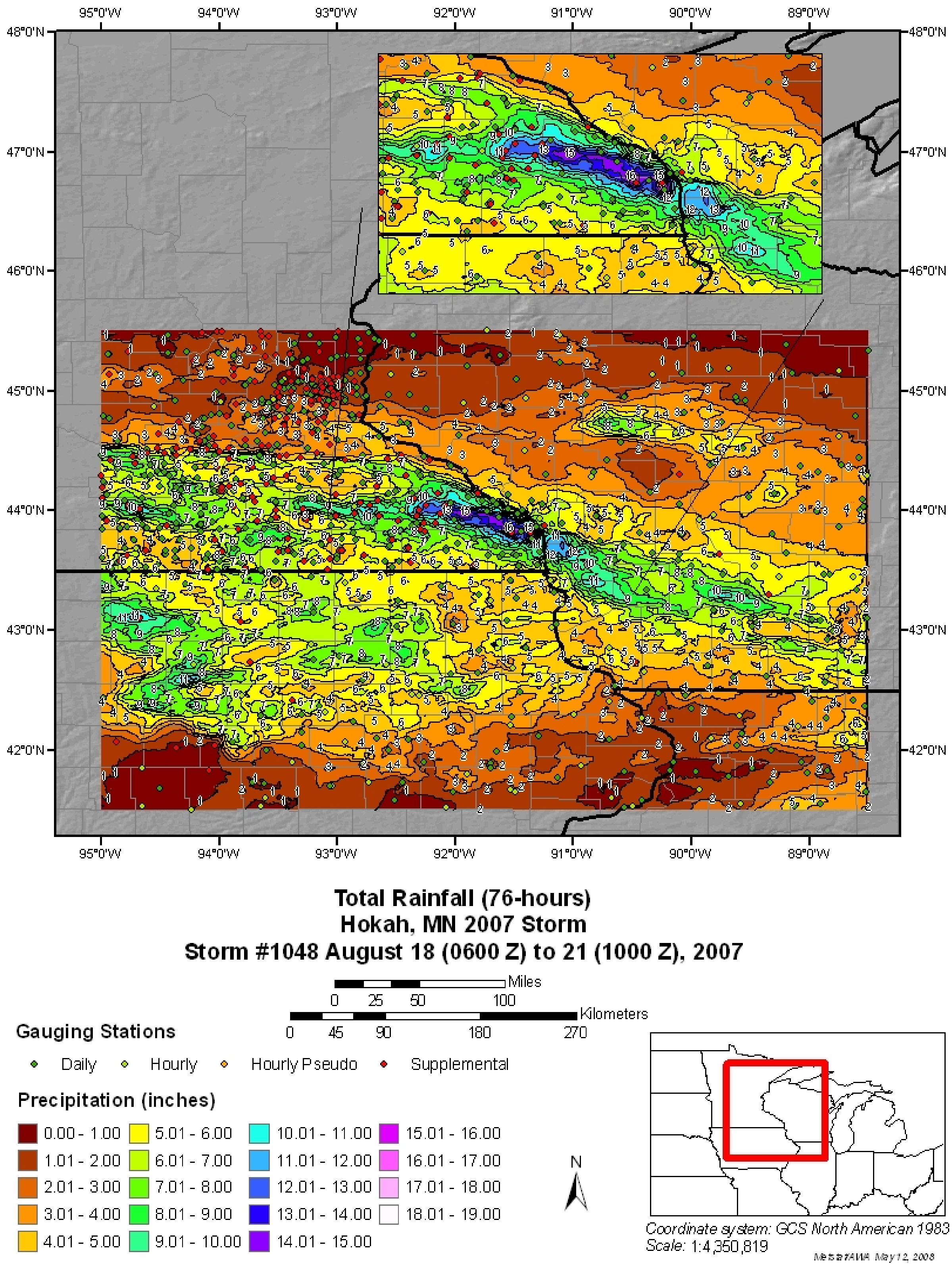
Attachment 1 Table 19: Depth-area-duration values for Hokah, MN, August 2007



Attachment 1 Figure 31: Depth-area-duration chart for Hokah, MN, August 2007



Attachment 1 Figure 32: Mass curve chart for Hokah, MN, August 2007



Attachment 1 Figure 33: Total storm isohyetal analysis for Hokah, MN, August 2007

Storm Name:	**EPRI Storm 19 Ida Grove, IA**	
Storm Date:	**30-Aug-1962**	
AWA Analysis Date:	**8/24/2014**	

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date 15-Aug

	Lat	Long
Storm Center Location	**42.32 N**	**95.47 W**
Storm Rep Dew Point Location	**39.10 N**	**95.47 W**
Transposition Dew Point Locat	**43.41 N**	**94.37 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**S @ 225**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**1,200**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**71.0 F**	with total precipitable water above sea level of			**2.36**	inches.
The in-place maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The transpositioned maximum dew point is	**79.5 F**	with total precipitable water above sea level of			**3.52**	inches.
The in-place storm elevation is	**1,200**	which subtracts	**0.27**	inches of precipitable water at	**71.0 F**	
The in-place storm elevation is	**1,200**	which subtracts	**0.35**	inches of precipitable water at	**80.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**79.5 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**79.5 F**	

The in-place maximization factor is	**1.50**
The transposition factor is	**0.97**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.45**

Notes: DAD values taken from EPRI Storm Number 19. Storm representative dew point value was based on average 24-hr Td values between August 30-31, 1962 at KGVW, KIXD, and KFOE. In place max factor held to 1.50 based on HMR guidance, calculated at 1.56.

Observed Storm Depth-Area-Duration

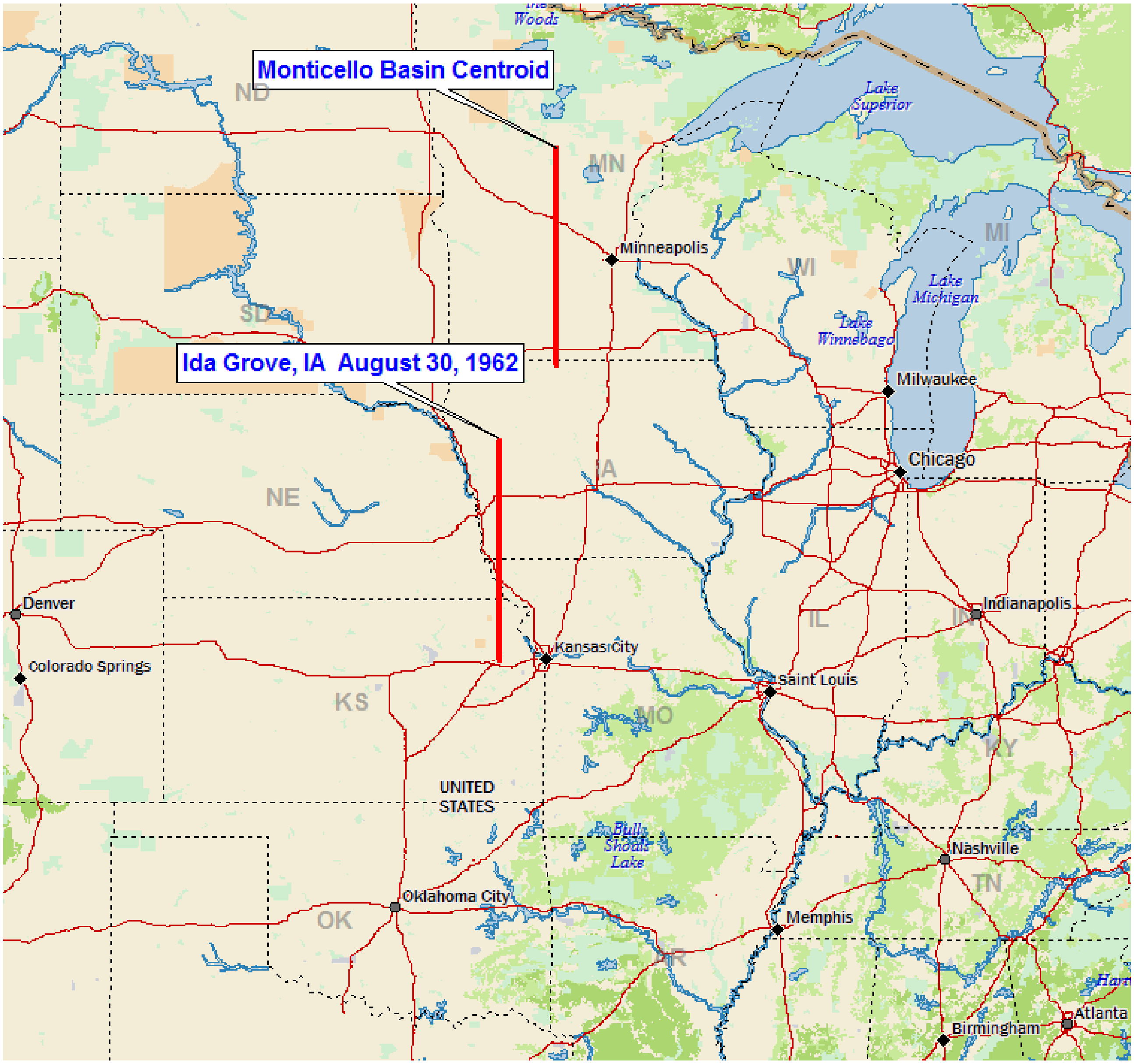
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	-	-	-	-	-	-	-	-	-
100 sq miles	**5.7**	**8.0**	-	**12.2**	-	**12.9**	-	-	-
200 sq miles	**5.4**	**7.6**	-	**11.7**	-	**12.3**	-	-	-
500 sq miles	**4.8**	**7.0**	-	**10.8**	-	**11.3**	-	-	-
1000 sq miles	**4.2**	**6.3**	-	**9.8**	-	**10.3**	-	-	-
5000 sq miles	**2.6**	**4.3**	-	**7.0**	-	**7.6**	-	-	-
10000 sq miles	**2.1**	**3.5**	-	**5.8**	-	**6.6**	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

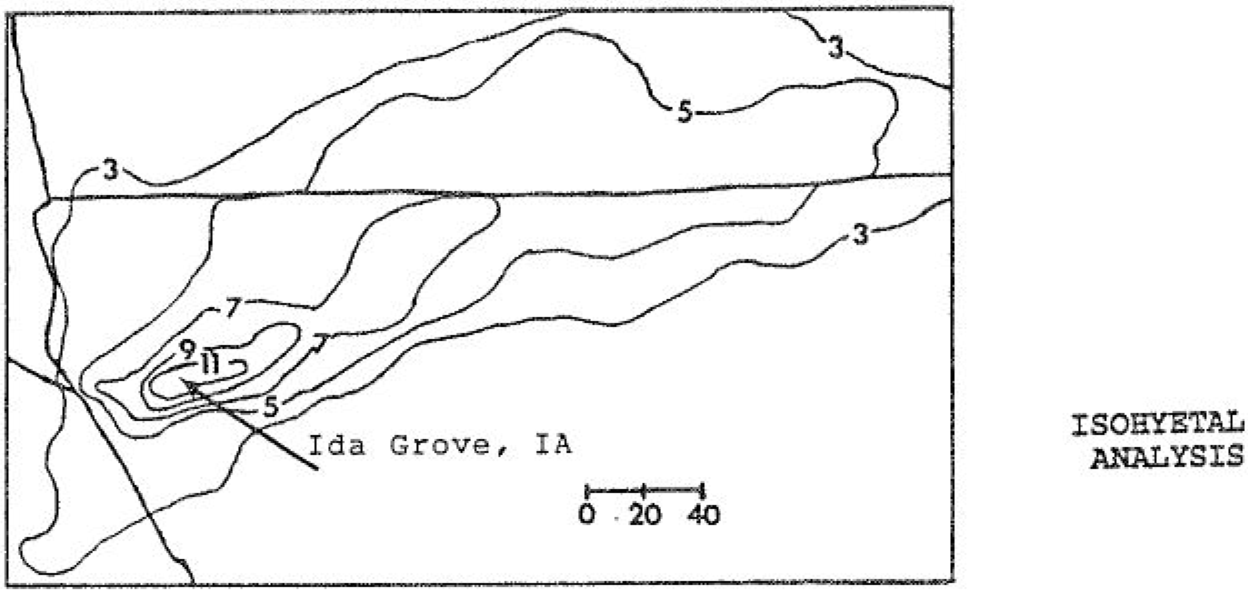
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	-	-	-	-	-	-	-	-	-
100 sq miles	**8.3**	**11.6**	-	**17.7**	-	**18.7**	-	-	-
200 sq miles	**7.8**	**11.0**	-	**17.0**	-	**17.8**	-	-	-
500 sq miles	**7.0**	**10.1**	-	**15.7**	-	**16.4**	-	-	-
1000 sq miles	**6.1**	**9.1**	-	**14.2**	-	**14.9**	-	-	-
5000 sq miles	**3.8**	**6.2**	-	**10.1**	-	**11.0**	-	-	-
10000 sq miles	**3.0**	**5.1**	-	**8.4**	-	**9.6**	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**EPRI Storm 19 Ida Grove, IA**	
Storm Date(s)	30-Aug-1962	
Storm Type	Synoptic	
Storm Location	42.32 N	95.47 W
Storm Center Elevation	1,200	
Precipitation Total & Duration	12.85 Inches 48-hours EPRI Storm Number 19	
Storm Representative Dew Point	71.0 F	24
Storm Representative Dew Point Location	39.10 N	95.47 W
Maximum Dew Point	80.0 F	
Moisture Inflow Vector	S @ 225	
In-place Maximization Factor	**1.50**	
Temporal Transposition (Date)	15-Aug	
Transposition Dew Point Location	43.41 N	94.37 W
Transposition Maximum Dew Point	79.5 F	
Transposition Adjustment Factor	**0.97**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.45**	

Attachment 1 Table 20: Storm spreadsheet for Ida Grove, IA August 1962



Attachment 1 Figure 34: Moisture inflow map for Ida Grove, IA August 1962



MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Miles	Duration of Rainfall in Hours 6	12	24	48
100	5.73	7.97	12.2	12.85
200	5.42	7.62	11.65	12.34
500	4.82	6.98	10.82	11.3
1000	4.18	6.25	9.78	10.32
5000	2.59	4.31	7.01	7.6
10000	2.1	3.51	5.82	6.58

Attachment 1 Figure 35 and Attachment 1 Table 21: Total storm isohyetal analysis and Depth-area-duration values for Ida Grove, IA August 1962

Storm Name:	Ironwood, MI UMV 1-11B	**Storm Adjustment for Basin Centroid-Monticello**	
Storm Date:	18-Jul-1909		
AWA Analysis Date:	8/24/2014		
Temporal Transposition Date	15-Jul		

	Lat	Long
Storm Center Location	46.45 N	90.18 W
Storm Rep Dew Point Location	42.75 N	92.25 W
Transposition Dew Point Locat	42.93 N	96.45 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	SSW @ 270	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,500	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	72.0 F	with total precipitable water above sea level of			2.47	inches.
The in-place maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The transpositioned maximum dew point is	80.0 F	with total precipitable water above sea level of			3.60	inches.
The in-place storm elevation is	1,500	which subtracts	0.34	inches of precipitable water at	72.0 F	
The in-place storm elevation is	1,500	which subtracts	0.44	inches of precipitable water at	80.5 F	
The transposition storm elevation at	1,300	which subtracts	0.38	inches of precipitable water at	80.0 F	
The moisture inflow barrier height is	1,300	which subtracts	0.38	inches of precipitable water at	80.0 F	

The in-place maximization factor is	1.50
The transposition factor is	0.99
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.49

Notes: DAD values taken from USACE UMV 1-11b. Added 2° to USACE storm rep analyzed Td based on guidance from EPRI, Nebraska, and TRWD. In Place max factor held to 1.50 based on HMR guidance, calculated at 1.52.

Observed Storm Depth-Area-Duration

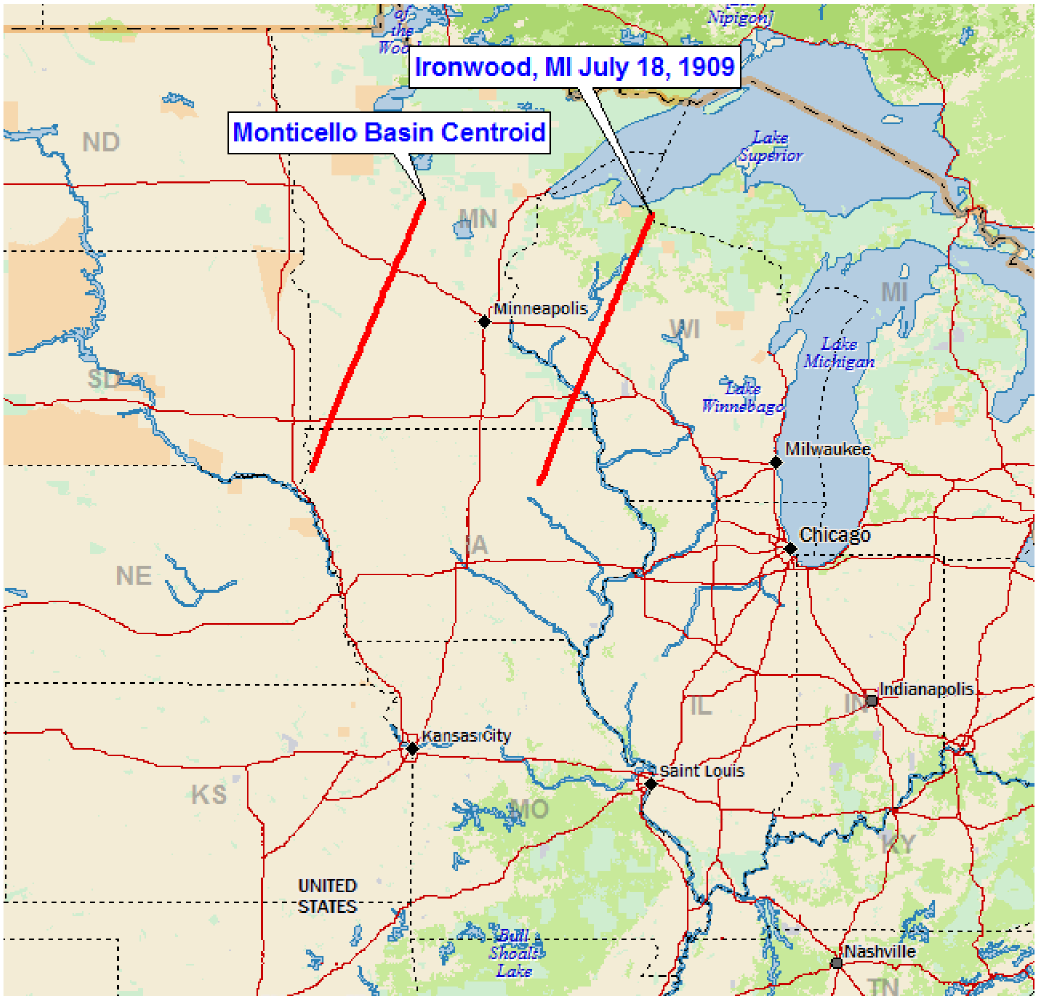
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	5.2	6.3	6.7	9.6	11.1	11.7	12.1	12.8	13.2
100 sq miles	5.1	6.2	6.6	9.4	10.8	11.4	11.8	12.5	12.9
200 sq miles	4.6	6.0	6.3	9.0	10.5	11.1	11.5	12.1	12.5
500 sq miles	3.9	5.5	5.8	7.9	9.8	10.1	10.7	11.2	11.5
1000 sq miles	3.2	5.0	5.3	6.9	9.0	9.3	9.7	10.3	10.5
2000 sq miles	2.8	4.4	4.6	6.0	7.9	8.2	8.7	9.2	9.5
5000 sq miles	2.3	3.6	3.8	5.0	6.5	6.8	7.2	7.8	8.0
10000 sq miles	2.1	3.2	3.4	4.2	5.4	5.6	6.0	6.5	6.7
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	7.8	9.4	10.0	14.3	16.6	17.5	18.1	19.1	19.7
100 sq miles	7.6	9.3	9.8	14.0	16.1	17.0	17.6	18.7	19.3
200 sq miles	6.9	9.0	9.4	13.4	15.7	16.6	17.2	18.1	18.7
500 sq miles	5.8	8.2	8.7	11.8	14.6	15.1	16.0	16.7	17.2
1000 sq miles	4.8	7.5	7.9	10.3	13.4	13.9	14.5	15.4	15.7
2000 sq miles	4.2	6.6	6.9	9.0	11.8	12.2	13.0	13.7	14.2
5000 sq miles	3.4	5.4	5.7	7.5	9.7	10.1	10.7	11.6	11.9
10000 sq miles	3.1	4.8	5.1	6.3	8.1	8.4	9.0	9.7	10.0
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**Ironwood, MI UMV 1-11B**	
Storm Date(s)	18-Jul-1909	
Storm Type	Synoptic	
Storm Location	46.45 N	90.18 W
Storm Center Elevation	1,500	
Precipitation Total & Duration	13.20 Inches 72-hours USACE UMV 1-11b	
Storm Representative Dew Point	72.0 F	24
Storm Representative Dew Point Location	42.75 N	92.25 W
Maximum Dew Point	80.5 F	
Moisture Inflow Vector	SSW @ 270	
In-place Maximization Factor	**1.50**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	42.93 N	96.45 W
Transposition Maximum Dew Point	80.0 F	
Transposition Adjustment Factor	**0.99**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.49**	

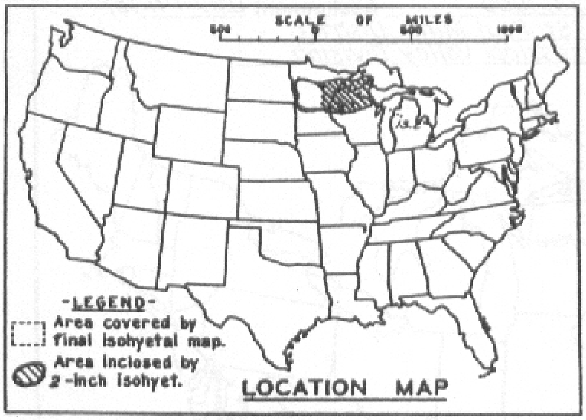
Attachment 1 Table 22: Storm spreadsheet for Ironwood, MI July 1909



Attachment 1 Figure 36: Moisture inflow map for Ironwood, MI July 1909

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET (REV.)



Storm of 18-23 July 1909
Assignment UMV 1-11-(b)
Location Northern Minn. & Wis.
Study Prepared by:
Upper Mississippi Valley Division
St. Paul District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 6/7/39
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 5/24/41
Remarks: Rainfall Data only for Ironwood, Mich. center Dewpt. 70° - Ref. Pt. 275 SSW Grid B-12

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 1,000,000
Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	4
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	8
Miscl. precip. records, meteorological data, etc.	1
Form 5002 (Mass rainfall curves)	24

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000
Data and computation sheets:

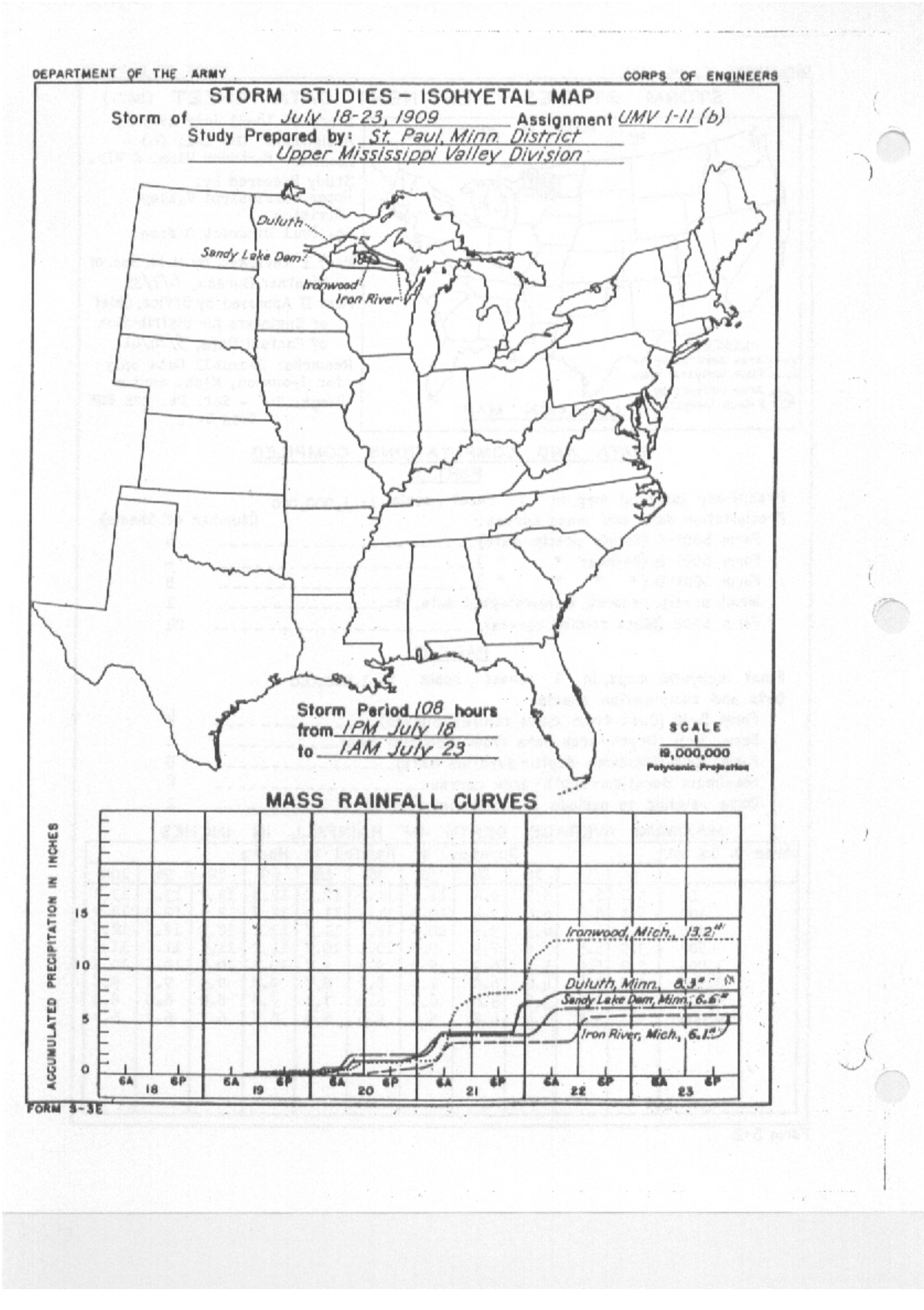
Form S-10 (Data from mass rainfall curves)	4
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	8
Maximum duration-depth-area curves	2
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	108
10	5.2	6.3	6.7	9.6	11.1	11.7	12.1	12.8	13.2	13.2	13.2
100	5.1	6.2	6.6	9.4	10.8	11.4	11.8	12.5	12.9	12.9	12.9
200	4.6	6.0	6.3	9.0	10.5	11.1	11.5	12.1	12.5	12.5	12.5
500	3.9	5.5	5.8	7.9	9.8	10.1	10.7	11.2	11.5	11.5	11.5
1,000	3.2	5.0	5.3	6.9	9.0	9.3	9.7	10.3	10.5	10.5	10.5
2,000	2.8	4.4	4.6	6.0	7.9	8.2	8.7	9.2	9.5	9.5	9.5
5,000	2.3	3.6	3.8	5.0	6.5	6.8	7.2	7.8	8.0	8.0	8.0
10,000	2.1	3.2	3.4	4.2	5.4	5.6	6.0	6.5	6.7	6.9	6.9

Form S-2

Attachment 1 Table 23: Depth-area-duration values for Ironwood, MI July 1909



Attachment 1 Figure 37 and Attachment 1 Figure 38: Isohyetal map and Mass curve chart for Ironwood, MI July 1909

Storm Name:	Lambert, MN UMV 1-2	Storm Adjustment for Basin Centroid-Monticello
Storm Date:	7/18-22/1897	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date 15-Jul

	Lat	Long
Storm Center Location	47.80 N	96.00 W
Storm Rep Dew Point Location	43.70 N	93.60 W
Transposition Dew Point Locat:	42.53 N	92.01 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	SSE @ 300	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,150	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	71.0 F	with total precipitable water above sea level of			2.36	inches.
The in-place maximum dew point is	80.0 F	with total precipitable water above sea level of			3.60	inches.
The transpositioned maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The in-place storm elevation is	1,150	which subtracts	0.25	inches of precipitable water at	71.0 F	
The in-place storm elevation is	1,150	which subtracts	0.35	inches of precipitable water at	80.0 F	
The transposition storm elevation at	1,300	which subtracts	0.38	inches of precipitable water at	80.5 F	
The moisture inflow barrier height is	1,300	which subtracts	0.38	inches of precipitable water at	80.5 F	

The in-place maximization factor is	1.50
The transposition factor is	1.02
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.52

Notes: DAD values taken from USACE UMV 1-2. In-place maximization factor of 1.54, although a factor of 1.50 was adopted as the upper limit for this study through guidance from HMR.

Observed Storm Depth-Area-Duration

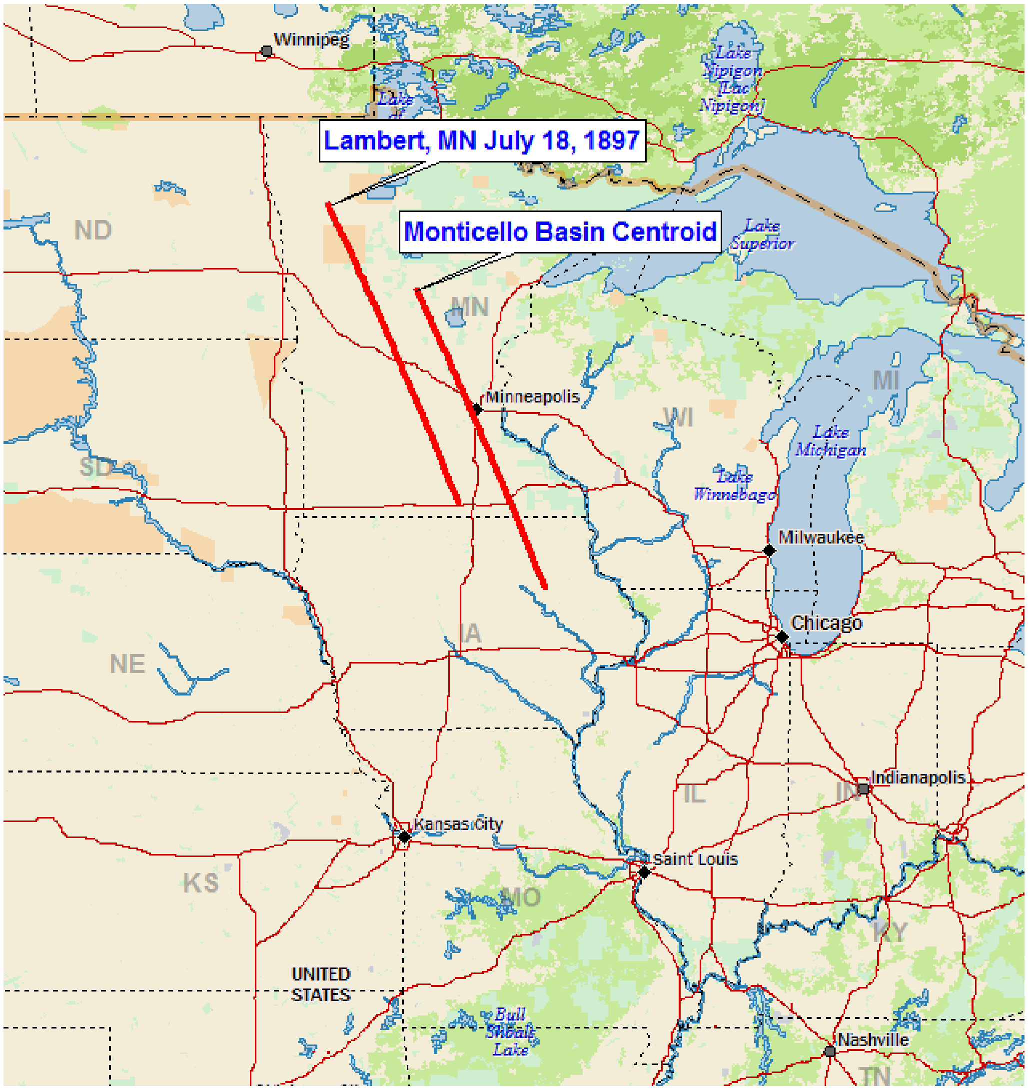
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	3.2	5.2	6.2	6.5	6.5	6.5	6.9	8.0	8.0
100 sq miles	3.1	4.8	6.0	6.3	6.3	6.3	6.8	7.9	7.9
200 sq miles	3.0	4.6	5.9	6.2	6.2	6.2	6.7	7.8	7.8
500 sq miles	2.9	4.4	5.7	6.0	6.0	6.0	6.5	7.6	7.6
1000 sq miles	2.7	4.2	5.5	5.8	5.8	5.8	6.3	7.3	7.3
5000 sq miles	2.3	3.4	4.3	4.5	4.7	4.7	5.2	6.1	6.2
10000 sq miles	1.9	3.0	3.8	4.0	4.2	4.2	4.5	5.4	5.5
20000 sq miles	1.7	2.8	3.5	3.7	3.8	3.8	4.2	4.8	5.0

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	4.9	7.9	9.4	9.9	9.9	9.9	10.5	12.2	12.2
100 sq miles	4.7	7.3	9.1	9.6	9.6	9.6	10.4	12.0	12.0
200 sq miles	4.6	7.0	9.0	9.4	9.4	9.4	10.2	11.9	11.9
500 sq miles	4.4	6.7	8.7	9.1	9.1	9.1	9.9	11.6	11.6
1000 sq miles	4.1	6.4	8.4	8.8	8.8	8.8	9.6	11.1	11.1
5000 sq miles	3.5	5.2	6.5	6.9	7.2	7.2	7.9	9.3	9.4
10000 sq miles	2.9	4.6	5.8	6.1	6.4	6.4	6.9	8.2	8.4
20000 sq miles	2.6	4.3	5.3	5.6	5.8	5.8	6.4	7.3	7.6

Storm or Storm Center Name	**Lambert, MN UMV 1-2**	
Storm Date(s)	7/18-22/1897	
Storm Type	Synoptic/Thunderstorms	
Storm Location	47.80 N	96.00 W
Storm Center Elevation	1,150	
Precipitation Total & Duration	8.00 Inches 72-hours USACE UMV 1-2	
Storm Representative Dew Point	71.0 F	24
Storm Representative Dew Point Location	43.70 N	93.60 W
Maximum Dew Point	80.0 F	
Moisture Inflow Vector	S @ 285	
In-place Maximization Factor	**1.50**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	42.53 N	92.01 W
Transposition Maximum Dew Point	80.5 F	
Transposition Adjustment Factor	**1.02**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.52**	

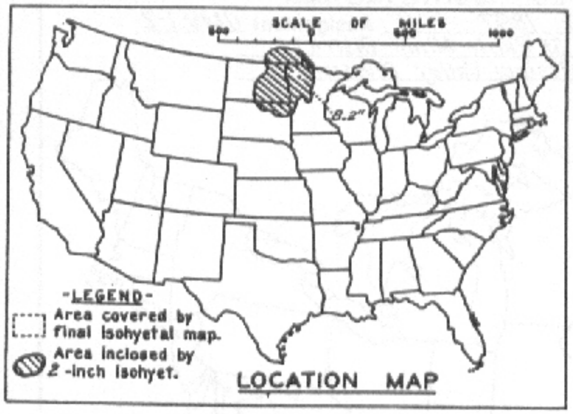
Attachment 1 Table 24: Storm spreadsheet for Lambert, MN July 1897



Attachment 1 Figure 39: Moisture inflow map for Lambert, MN July 1897

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET (REV.)



Storm of 18 - 22 July 1897
Assignment UMV 1-2
Location Minn. and N. D.
Study Prepared by:
Upper Mississippi Valley Division
St. Paul District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 12-7-40
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 7-19-45
Remarks: Center at:
Lambert, Minn.
Dewpt. 65° - Ref. Pt. 300 S
Grid A-16

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 1,000,000
Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 4
- Form 5001-B (24-hour " ") ---------- -
- Form 5001-D (" " " ") ---------- 5
- Miscl. precip. records, meteorological data, etc. ---------- 6
- Form 5002 (Mass rainfall curves) ---------- 13

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000
Data and computation sheets:

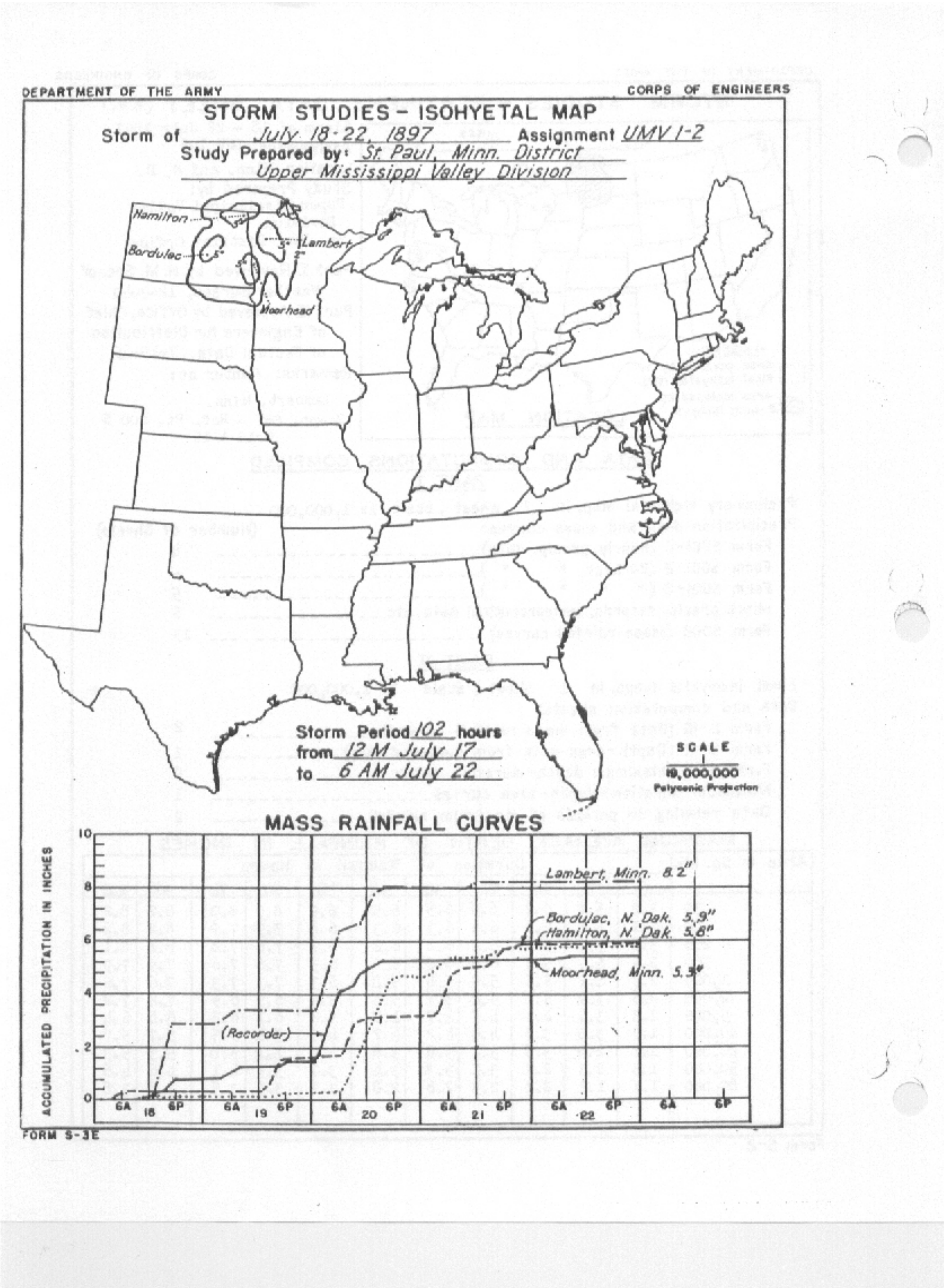
- Form S-10 (Data from mass rainfall curves) ---------- 2
- Form S-11 (Depth-area data from isohyetal map) ---------- 1
- Form S-12 (Maximum depth-duration data) ---------- 9
- Maximum duration-depth-area curves ---------- 1
- Data relating to periods of maximum rainfall ---------- 2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	102
10	3.2	5.2	6.2	6.5	6.5	6.5	6.9	8.0	8.0	8.2	8.2
100	3.1	4.8	6.0	6.3	6.3	6.3	6.8	7.9	7.9	8.2	8.2
200	3.0	4.6	5.9	6.2	6.2	6.2	6.7	7.8	7.8	8.1	8.1
500	2.9	4.4	5.7	6.0	6.0	6.0	6.5	7.6	7.6	7.9	7.9
1,000	2.7	4.2	5.5	5.8	5.8	5.8	6.3	7.3	7.3	7.6	7.6
2,000	2.6	3.9	5.1	5.4	5.5	5.5	5.9	6.9	6.9	7.2	7.2
5,000	2.3	3.4	4.3	4.5	4.7	4.7	5.2	6.1	6.2	6.4	6.4
10,000	1.9	3.0	3.8	4.0	4.2	4.2	4.5	5.4	5.5	5.7	5.7
20,000	1.7	2.8	3.5	3.7	3.8	3.8	4.2	4.8	5.0	5.3	5.3
50,000	1.3	2.3	2.9	3.1	3.3	3.4	3.7	3.9	4.1	4.6	4.6
80,000	1.1	1.7	2.2	2.3	2.8	2.8	3.1	3.3	3.5	3.8	3.8

Form S-2

Attachment 1 Table 25: Depth-area-duration values for Lambert, MN July 1897



Attachment 1 Figure 40 and Attachment 1 Figure 41: Isohyetal map and Mass curve chart for Lambert, MN July 1897

Storm Name:	Medford, WI GL 2-12	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	6/3-8/1905	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	15-Jun	
	Lat	Long
Storm Center Location	45.14 N	90.34 W
Storm Rep Dew Point Location	43.06 N	93.14 W
Transposition Dew Point Locat	44.55 N	97.24 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	SW @ 200	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,500	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	70.0 F	with total precipitable water above sea level of			2.25	inches.
The in-place maximum dew point is	76.5 F	with total precipitable water above sea level of			3.07	inches.
The transpositioned maximum dew point is	76.5 F	with total precipitable water above sea level of			3.07	inches.
The in-place storm elevation is	1,500	which subtracts	0.31	inches of precipitable water at	70.0 F	
The in-place storm elevation is	1,500	which subtracts	0.39	inches of precipitable water at	76.5 F	
The transposition storm elevation at	1,300	which subtracts	0.34	inches of precipitable water at	76.5 F	
The moisture inflow barrier height is	1,300	which subtracts	0.34	inches of precipitable water at	76.5 F	

The in-place maximization factor is	1.38
The transposition factor is	1.02
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.40

Notes: DAD values taken from USACE GL 2-12. Added 2°F to USACE storm rep Td based on 12hr persisting to average Td adjustment.

Observed Storm Depth-Area-Duration

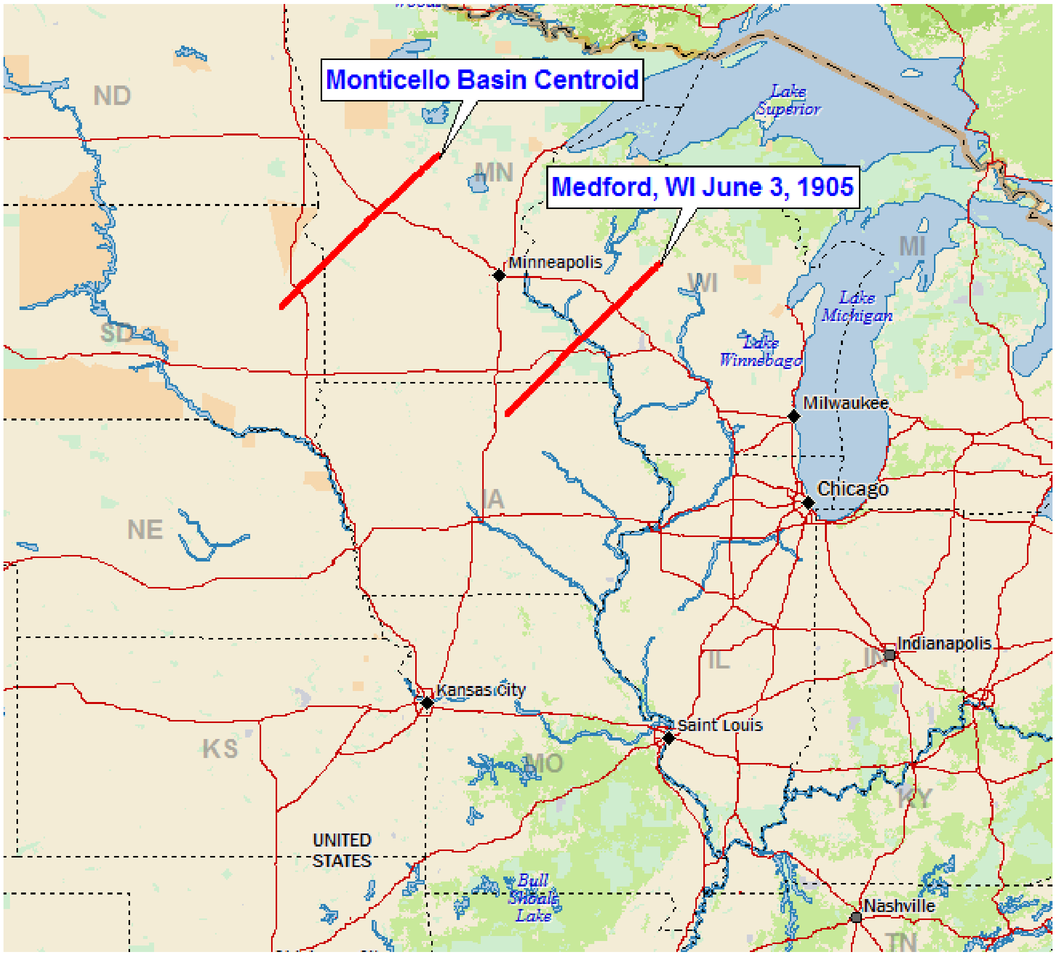
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	7.2	8.4	8.5	8.9	9.1	9.9	10.5	11.2	11.2
100 sq miles	6.8	8.1	8.3	8.5	8.7	9.6	10.1	10.7	10.7
200 sq miles	6.6	7.8	8.0	8.2	8.5	9.2	9.9	10.5	10.5
500 sq miles	6.0	7.0	7.1	7.6	8.1	8.6	9.3	9.9	9.9
1000 sq miles	5.4	6.2	6.4	7.0	7.6	8.0	8.7	9.3	9.3
5000 sq miles	3.8	4.5	4.8	5.5	6.1	6.5	7.0	7.6	7.7
10000 sq miles	3.1	3.8	4.0	4.8	5.4	5.8	6.2	6.9	7.0
20000 sq miles	2.4	3.0	3.3	4.1	4.8	5.1	5.3	6.1	6.2

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	10.1	11.8	11.9	12.5	12.8	13.9	14.7	15.7	15.7
100 sq miles	9.6	11.4	11.7	11.9	12.2	13.5	14.2	15.0	15.0
200 sq miles	9.3	11.0	11.2	11.5	11.9	12.9	13.9	14.7	14.7
500 sq miles	8.4	9.8	10.0	10.7	11.4	12.1	13.1	13.9	13.9
1000 sq miles	7.6	8.7	9.0	9.8	10.7	11.2	12.2	13.1	13.1
5000 sq miles	5.3	6.3	6.7	7.7	8.6	9.1	9.8	10.7	10.8
10000 sq miles	4.4	5.3	5.6	6.7	7.6	8.1	8.7	9.7	9.8
20000 sq miles	3.4	4.2	4.6	5.8	6.7	7.2	7.4	8.6	8.7

Storm or Storm Center Name	**Medford, WI GL 2-12**	
Storm Date(s)	6/3-8/1905	
Storm Type	Synoptic	
Storm Location	45.14 N	90.34 W
Storm Center Elevation	1,500	
Precipitation Total & Duration	11.20 Inches 72-hours USACE GL 2-12	
Storm Representative Dew Point	70.0 F	24
Storm Representative Dew Point Location	43.06 N	93.14 W
Maximum Dew Point	76.5 F	
Moisture Inflow Vector	SW @ 200 Miles	
In-place Maximization Factor	**1.38**	
Temporal Transposition (Date)	15-Jun	
Transposition Dew Point Location	44.55 N	97.24 W
Transposition Maximum Dew Point	76.5 F	
Transposition Adjustment Factor	**1.02**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.40**	

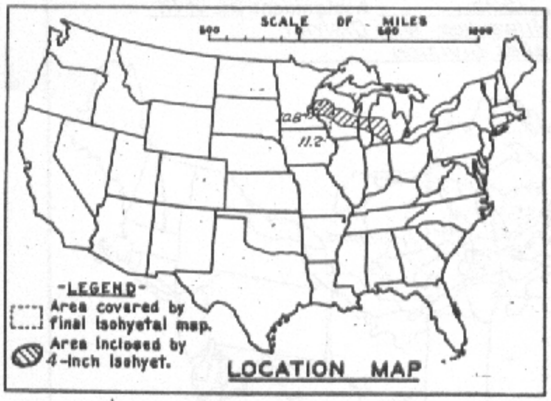
Attachment 1 Table 26: Storm spreadsheet for Medford, WI June 1905



Attachment 1 Figure 42: Moisture inflow map for Medford, WI June 1905

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES – PERTINENT DATA SHEET



Storm of 3-8 June 1905
Assignment G L 2 - 12
Location Minn., Wis., Mich., Ohio
Study Prepared by:
Great Lakes Division
Milwaukee District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 6-17-40
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 12-6-45
Remarks: Centers at Medford and Barron, Wis.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1:2,500,000
Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	16
Form 5001-B (24-hour " ")	—
Form 5001-D (" " " ")	10
Miscl. precip. records, meteorological data, etc.	20
Form 5002 (Mass rainfall curves)	29

PART II

Final isohyetal maps, in 1 sheet, scale 1:1,000,000
Data and computation sheets:

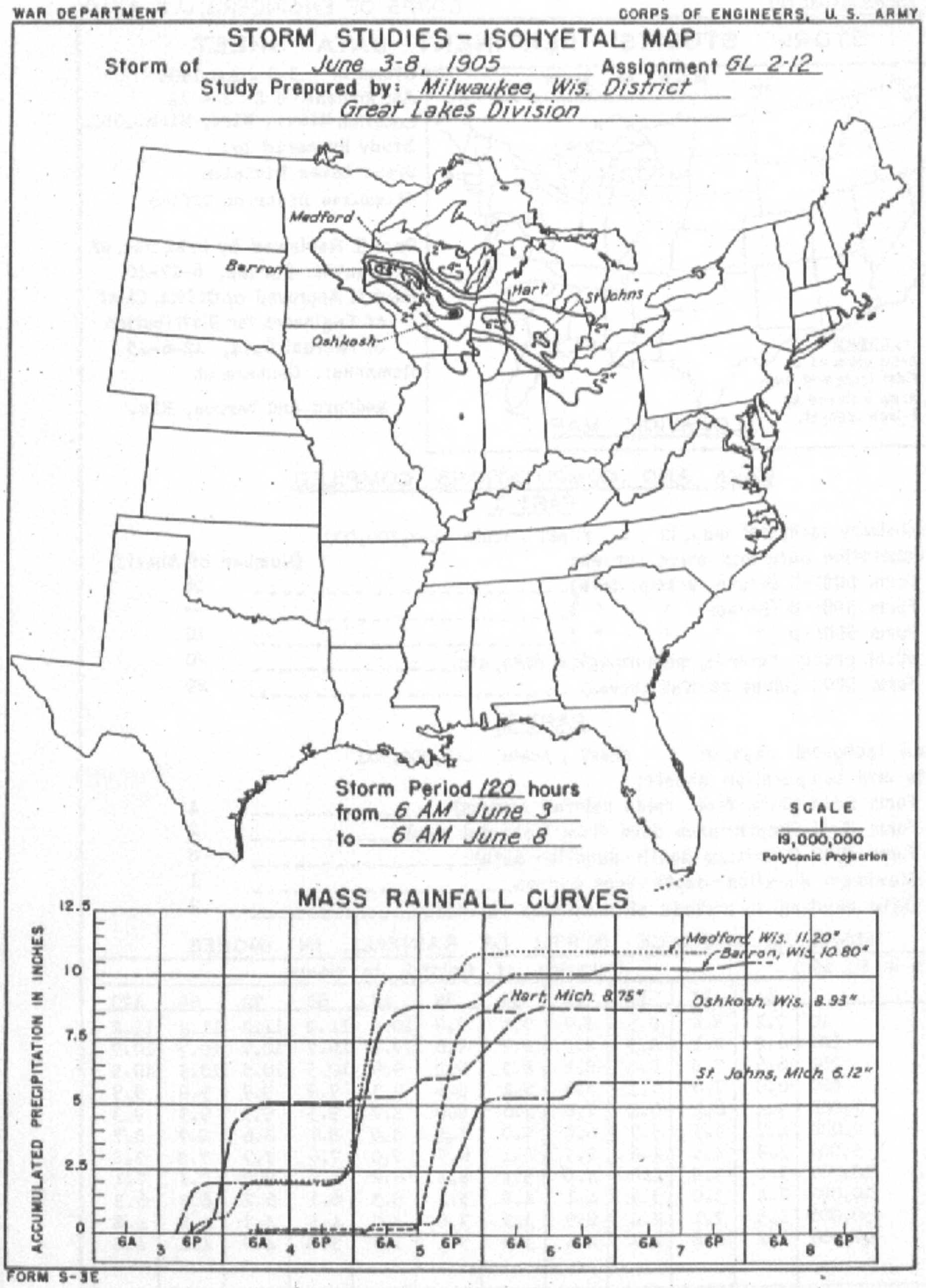
Form S-10 (Data from mass rainfall curves)	4
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	8
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	120
10	7.2	8.4	8.5	8.9	9.1	9.9	10.5	11.2	11.2	11.2	11.2
100	6.8	8.1	8.3	8.5	8.7	9.6	10.1	10.7	10.7	10.7	10.7
200	6.6	7.8	8.0	8.2	8.5	9.2	9.9	10.5	10.5	10.5	10.5
500	6.0	7.0	7.1	7.6	8.1	8.6	9.3	9.9	9.9	9.9	9.9
1,000	5.4	6.2	6.4	7.0	7.6	8.0	8.7	9.3	9.3	9.3	9.3
2,000	4.7	5.5	5.7	6.4	7.0	7.4	8.0	8.6	8.6	8.7	8.7
5,000	3.8	4.5	4.8	5.5	6.1	6.5	7.0	7.6	7.7	7.8	7.8
10,000	3.1	3.8	4.0	4.8	5.4	5.8	6.2	6.9	7.0	7.1	7.1
20,000	2.4	3.0	3.3	4.1	4.8	5.1	5.3	6.1	6.2	6.3	6.3
50,000	1.5	2.1	2.4	2.9	3.5	3.6	4.0	4.5	4.7	4.8	4.8
67,000	1.2	1.8	2.1	2.4	3.0	3.1	3.3	3.8	4.0	4.2	4.2

Form S-2

Attachment 1 Table 27: Depth-area-duration values for Medford, WI June 1905



Attachment 1 Figure 43 and Attachment 1 Figure 44: Isohyetal map and Mass curve chart for Medford, WI June 1905

Storm Name:	**SPAS 1031-Prague, NE**		
Storm Date:	**01-Aug-1959**		
AWA Analysis Date:	**8/24/2014**		

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date	**1-Aug**	
	Lat	**Long**
Storm Center Location	**41.36 N**	**96.88 W**
Storm Rep Dew Point Location	**39.22 N**	**95.71 W**
Transposition Dew Point Locat	**44.49 N**	**93.10 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SSE @ 160**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**1,500**	feet
Storm Analysis Duration	**12**	hours

The storm representative dew point is	**72.5 F**	with total precipitable water above sea level of			**2.54**	inches.
The in-place maximum dew point is	**78.5 F**	with total precipitable water above sea level of			**3.37**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The in-place storm elevation is	**1,500**	which subtracts	**0.35**	inches of precipitable water at	**72.5 F**	
The in-place storm elevation is	**1,500**	which subtracts	**0.42**	inches of precipitable water at	**78.5 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.35**
The transposition factor is	**1.09**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.47**

Notes: 12hr average taken from KMCK and KTOP from 8-1 8Z to 8-1 20Z. DAD values taken from SPAS 1031.

Observed Storm Depth-Area-Duration

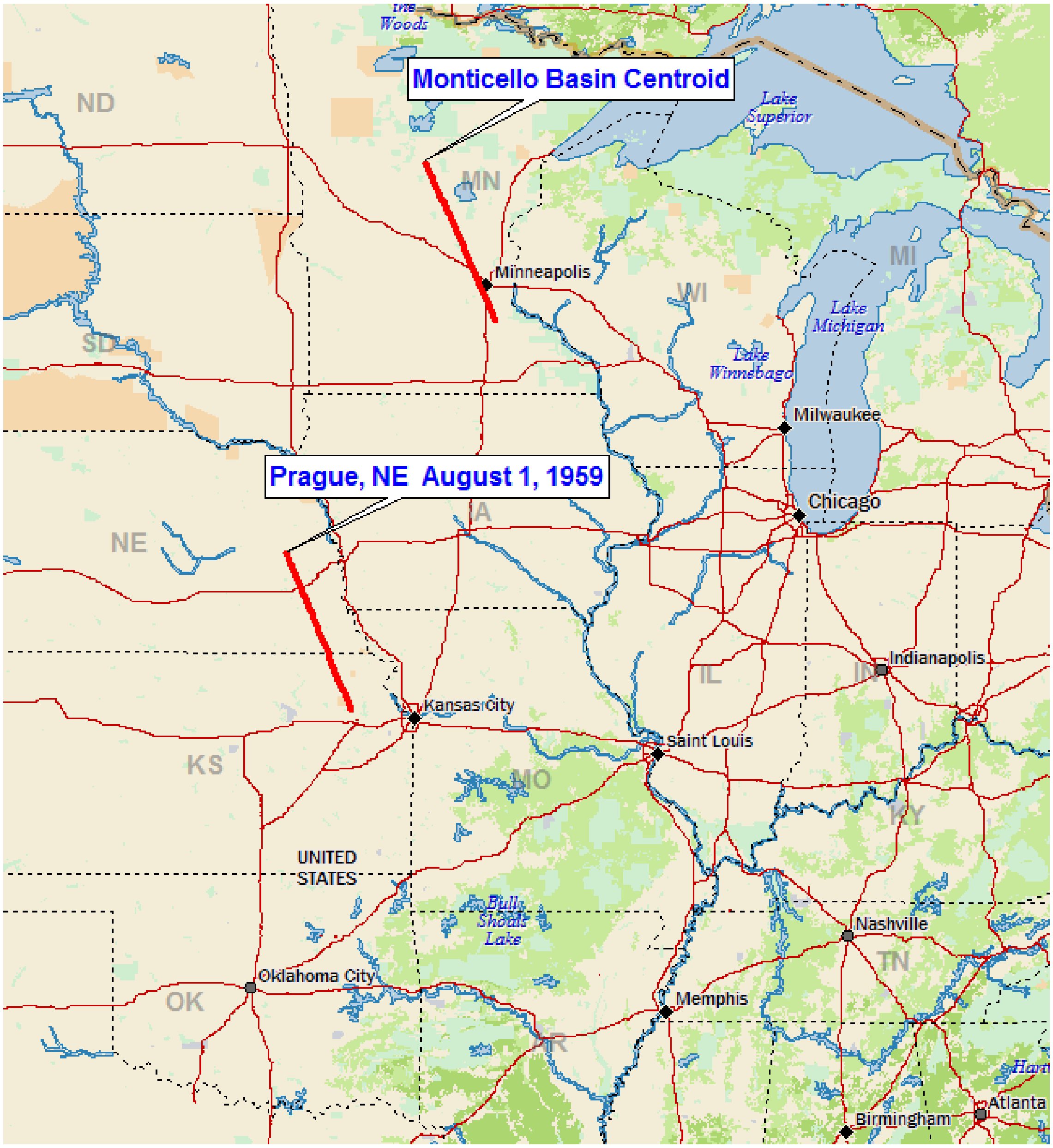
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**7.1**	**9.6**	**10.1**	**10.4**	-	**10.4**	**10.8**	-	**10.9**
10 sq miles	**6.8**	**9.3**	**9.7**	**10.0**	-	**10.0**	**10.5**	-	**10.5**
100 sq miles	**5.5**	**7.8**	**8.4**	**8.6**	-	**8.6**	**9.0**	-	**9.1**
200 sq miles	**5.0**	**7.3**	**7.9**	**8.3**	-	**8.3**	**8.7**	-	**8.7**
500 sq miles	**4.5**	**6.6**	**7.1**	**7.4**	-	**7.4**	**7.9**	-	**8.0**
1000 sq miles	**4.0**	**5.8**	**6.4**	**6.8**	-	**6.8**	**7.3**	-	**7.4**
5000 sq miles	**2.2**	**3.3**	**3.8**	**4.1**	-	**4.1**	**4.6**	-	**4.6**
10000 sq miles	**1.3**	**2.0**	**2.4**	**2.6**	-	**2.6**	**3.0**	-	**3.0**
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**10.4**	**14.1**	**14.9**	**15.4**	-	**15.4**	**16.0**	-	**16.0**
10 sq miles	**10.0**	**13.6**	**14.3**	**14.8**	-	**14.8**	**15.5**	-	**15.5**
100 sq miles	**8.1**	**11.4**	**12.3**	**12.7**	-	**12.7**	**13.2**	-	**13.4**
200 sq miles	**7.3**	**10.8**	**11.7**	**12.2**	-	**12.2**	**12.8**	-	**12.9**
500 sq miles	**6.6**	**9.7**	**10.4**	**10.9**	-	**10.9**	**11.7**	-	**11.8**
1000 sq miles	**5.9**	**8.5**	**9.4**	**10.1**	-	**10.1**	**10.8**	-	**10.9**
5000 sq miles	**3.3**	**4.8**	**5.6**	**6.0**	-	**6.0**	**6.7**	-	**6.8**
10000 sq miles	**1.9**	**3.0**	**3.5**	**3.8**	-	**3.8**	**4.4**	-	**4.4**
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**SPAS 1031-Prague, NE**			
Storm Date(s)	1-Aug-1959			
Storm Type	MCC			
Storm Location	41.36 N	96.88 W		
Storm Center Elevation	1,500			
Precipitation Total & Duration	13.09 Inches 24-hours USACE Bucket Survey Data			
Storm Representative Dew Point	72.5 F	12		
Storm Representative Dew Point Location	39.22 N	95.71 W		
Maximum Dew Point	78.5 F			
Moisture Inflow Vector	SSE @ 160			
In-place Maximization Factor	**1.35**			
Temporal Transposition (Date)	1-Aug		July	Aug
Transposition Dew Point Location	44.49 N	93.10 W	80.24	79.93
Transposition Maximum Dew Point	80.0 F			
Transposition Adjustment Factor	**1.09**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.47**			

Attachment 1 Table 28: Storm spreadsheet for Prague, NE August 1959

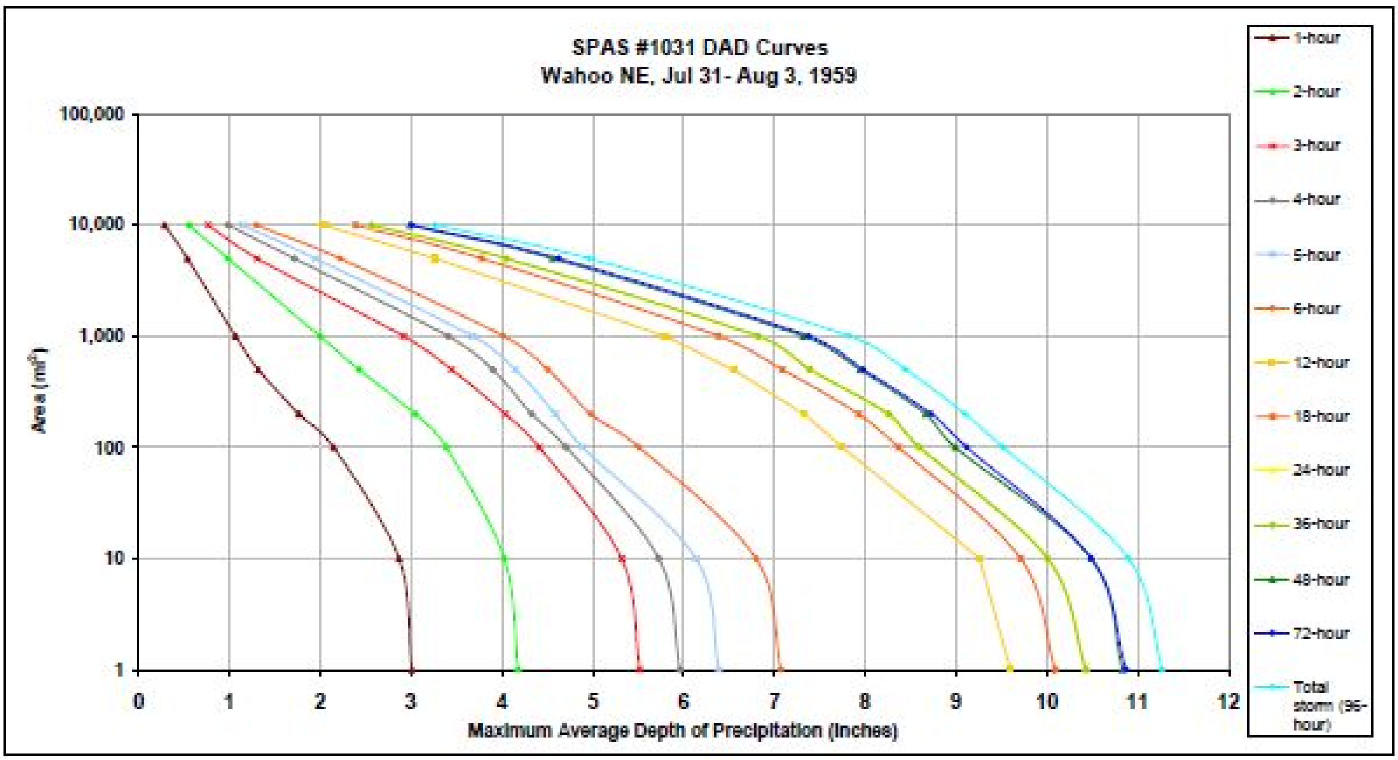


Attachment 1 Figure 45: Moisture inflow map for Prague, NE August 1959

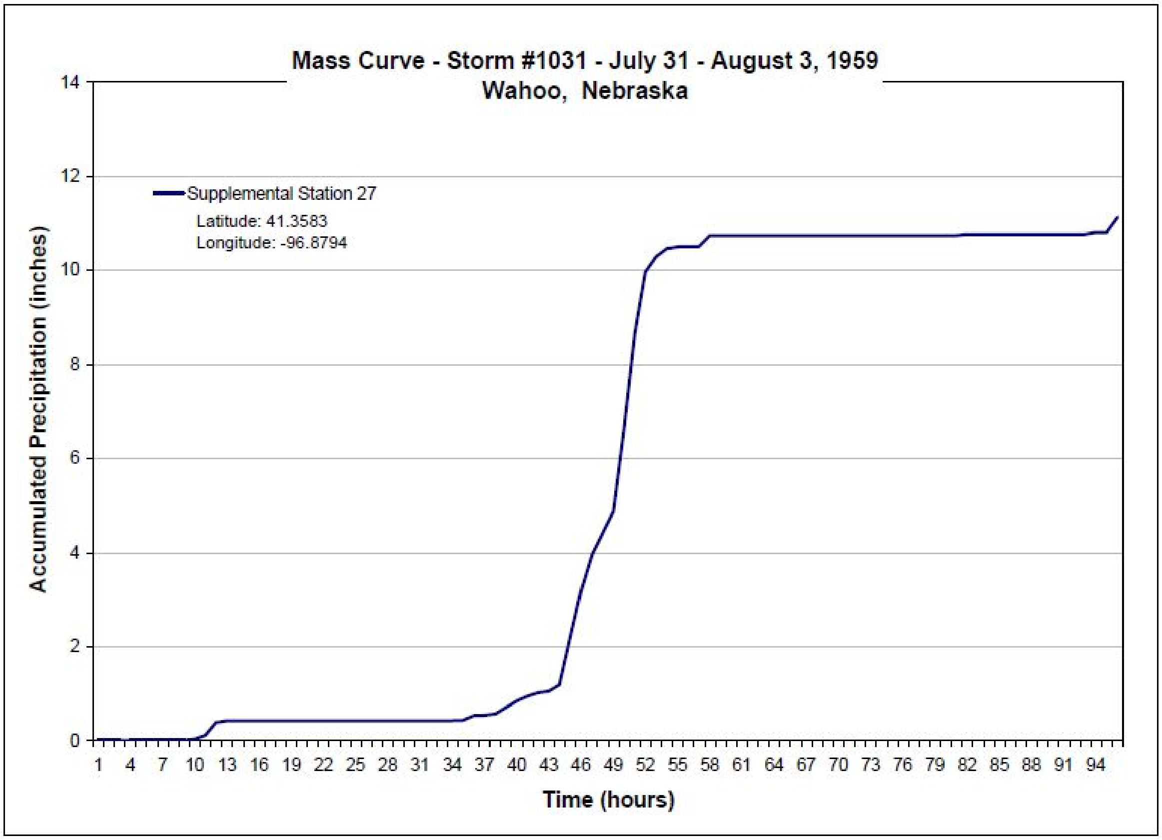
Storm 1031 - Wahoo NE, Jul 31 - Aug 3, 1959

MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

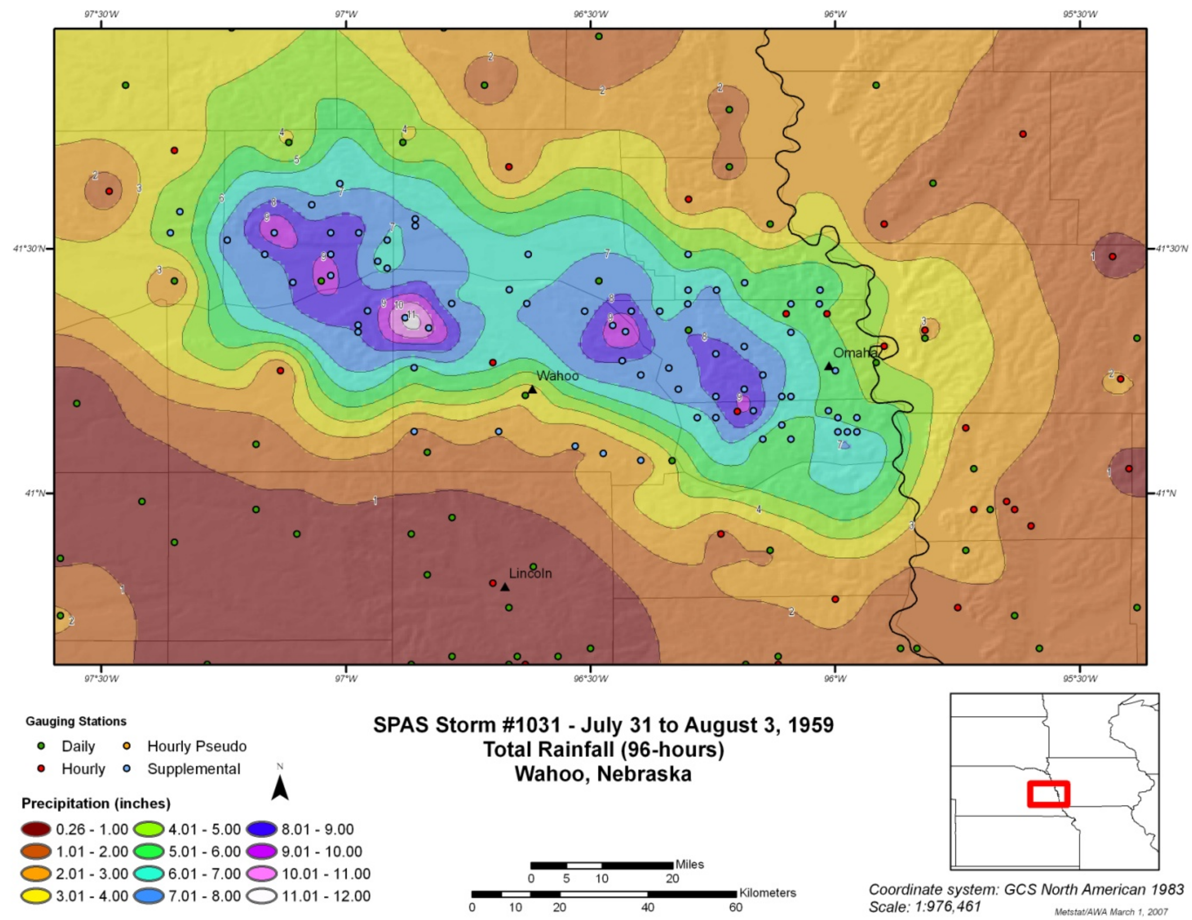
Area (mi²)	Duration (hours)													
	1	2	3	4	5	6	12	18	24	36	48	72	96	total
1	3.01	4.18	5.52	5.96	6.39	7.07	9.60	10.09	10.43	10.43	10.83	10.87	11.27	11.27
10	2.87	4.03	5.32	5.73	6.14	6.80	9.26	9.71	10.01	10.01	10.49	10.49	10.90	10.90
100	2.15	3.39	4.41	4.71	4.89	5.51	7.75	8.37	8.60	8.60	8.99	9.12	9.52	9.52
200	1.77	3.05	4.04	4.33	4.59	4.98	7.33	7.93	8.25	8.26	8.67	8.73	9.10	9.10
500	1.32	2.43	3.45	3.90	4.15	4.51	6.55	7.09	7.39	7.39	7.94	7.98	8.45	8.45
1,000	1.07	2.00	2.92	3.41	3.68	4.02	5.80	6.39	6.82	6.82	7.32	7.38	7.83	7.83
5,000	0.54	0.99	1.31	1.72	1.95	2.22	3.27	3.78	4.05	4.05	4.56	4.63	4.96	4.96
10,000	0.29	0.56	0.77	0.99	1.15	1.30	2.04	2.39	2.57	2.57	2.99	3.01	3.27	3.27



Attachment 1 Table 29 and Attachment 1 Figure 46: Depth-area-duration values and Depth-area-duration chart for Prague, NE August 1959



Attachment 1 Figure 47: Mass curve chart for Prague, NE August 1959



Attachment 1 Figure 48: Total storm isohyetal analysis for Prague, NE August 1959

Storm Name:	SPAS 1297 Warroad, MN	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	6/7-11/2002	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	25-Jun	
	Lat	Long
Storm Center Location	48.88 N	95.08 W
Storm Rep Dew Point Location	43.55 N	99.55 W
Transposition Dew Point Locatic	41.31 N	98.69 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction:	SSW @ 425	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,100	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	72.0 F	with total precipitable water above sea level of			2.47	inches.
The in-place maximum dew point is	77.5 F	with total precipitable water above sea level of			3.22	inches.
The transpositioned maximum dew point is	78.0 F	with total precipitable water above sea level of			3.29	inches.
The in-place storm elevation is	1,100	which subtracts	0.25	inches of precipitable water at	72.0 F	
The in-place storm elevation is	1,100	which subtracts	0.30	inches of precipitable water at	77.5 F	
The transposition storm elevation at	1,300	which subtracts	0.36	inches of precipitable water at	78.0 F	
The moisture inflow barrier height is	1,300	which subtracts	0.36	inches of precipitable water at	78.0 F	

The in-place maximization factor is	1.31
The transposition factor is	1.01
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.32

Notes: Storm representative dew point value was based on maximum 24-hr Td values for June 6-9, 2002 at KSFD and K9V9.

Observed Storm Depth-Area-Duration

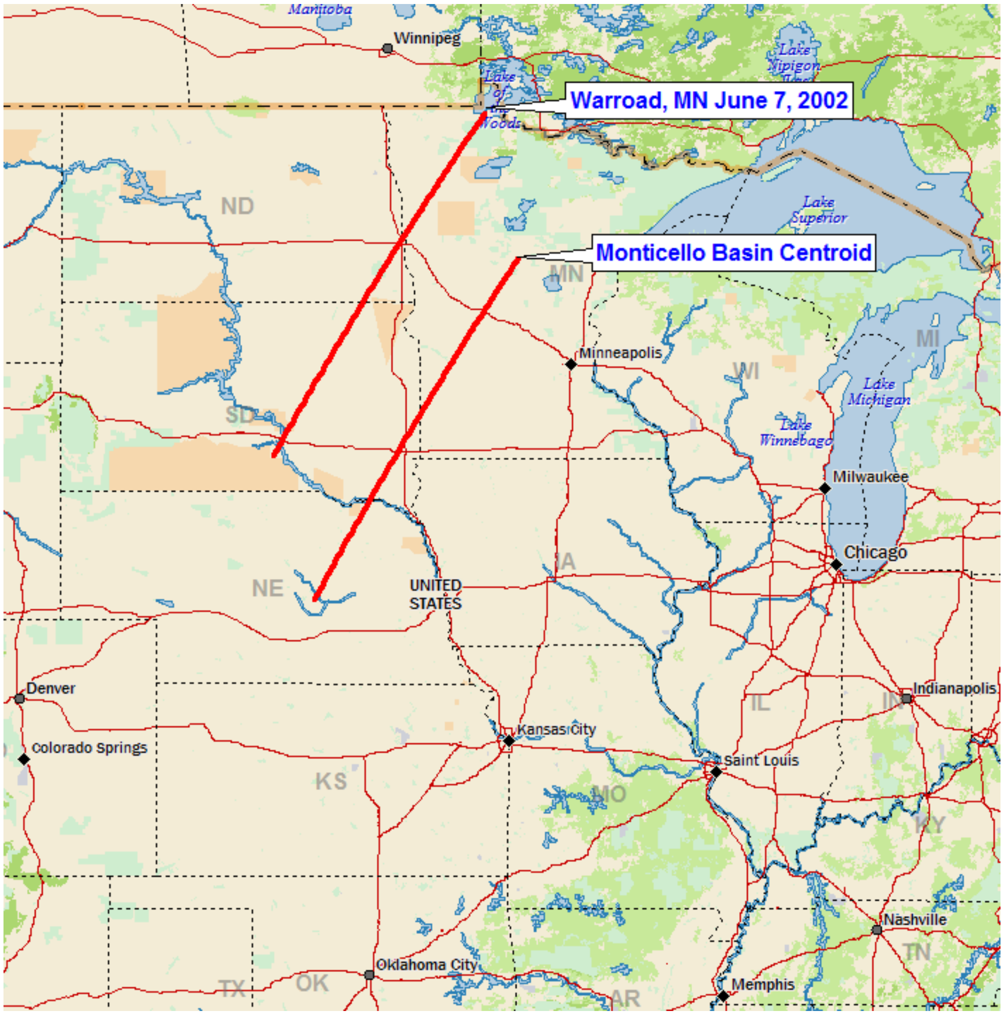
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	60 Hours
1 sq miles	2.4	5.5	6.9	8.6	10.9	11.5	12.4	14.2	14.2
10 sq miles	2.3	5.4	6.9	8.6	10.9	11.5	12.4	14.2	14.2
100 sq miles	2.0	4.9	6.0	8.1	10.1	10.8	11.9	13.7	13.7
200 sq miles	1.8	4.6	5.5	8.0	9.5	10.4	11.5	13.2	13.4
500 sq miles	1.6	4.2	4.9	7.7	8.7	9.8	11.1	12.6	12.8
1000 sq miles	1.5	3.7	4.2	7.2	8.2	9.4	10.6	12.0	12.2
2000 sq miles	1.3	3.0	4.0	6.3	7.3	8.8	10.0	11.4	11.5
5000 sq miles	1.0	2.2	3.2	5.0	6.3	7.6	8.9	9.9	10.3
10000 sq miles	0.9	1.7	2.4	4.0	5.4	6.3	7.7	8.5	9.1
20000 sq miles	0.7	1.2	1.9	3.3	4.4	5.4	6.3	7.5	7.7
50000 sq miles	0.3	0.7	0.9	2.0	2.9	3.6	4.1	5.2	5.4
100000 sq miles	0.2	0.4	0.6	1.1	1.7	2.1	2.7	3.2	3.4

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	60 Hours
1 sq miles	3.1	7.2	9.1	11.3	14.3	15.2	16.4	18.8	18.8
10 sq miles	3.0	7.2	9.1	11.3	14.3	15.2	16.4	18.8	18.8
100 sq miles	2.6	6.4	7.9	10.6	13.3	14.2	15.7	18.0	18.1
200 sq miles	2.4	6.1	7.2	10.6	12.5	13.7	15.2	17.4	17.6
500 sq miles	2.1	5.5	6.5	10.1	11.5	12.9	14.6	16.6	16.9
1000 sq miles	1.9	4.9	5.6	9.5	10.8	12.4	14.0	15.9	16.1
2000 sq miles	1.7	3.9	5.2	8.3	9.6	11.6	13.2	15.1	15.1
5000 sq miles	1.3	2.8	4.2	6.6	8.4	10.0	11.7	13.1	13.5
10000 sq miles	1.2	2.2	3.1	5.3	7.2	8.3	10.2	11.2	12.0
20000 sq miles	0.9	1.6	2.5	4.4	5.8	7.1	8.3	9.9	10.1
50000 sq miles	0.3	1.0	1.2	2.6	3.8	4.7	5.4	6.9	7.1
100000 sq miles	0.2	0.5	0.8	1.5	2.2	2.7	3.5	4.3	4.5

Storm or Storm Center Name	**SPAS 1297 Warroad, MN**			
Storm Date(s)	6/7-11/2002			
Storm Type	MCC			
Storm Location	48.88 N	95.08 W		
Storm Center Elevation	1100			
Precipitation Total & Duration (10 sq mi)	14.62 inches in 48 hours			
Storm Representative Dew Point	72.0 F			
Storm Representative Dew Point Location	43.55 N	99.55 W	Jun	Jul
Maximum Dew Point	77.5 F		76.3	79.4
Moisture Inflow Vector	SSW @ 425			
In-place Maximization Factor	**1.31**			
Temporal Transposition (Date)	25-Jun			
Transposition Dew Point Location	41.31 N	98.69 W	Jun	Jul
Transposition Maximum Dew Point	78.0 F		77.296	79.88
Transposition Adjustment Factor	**1.01**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.32**			

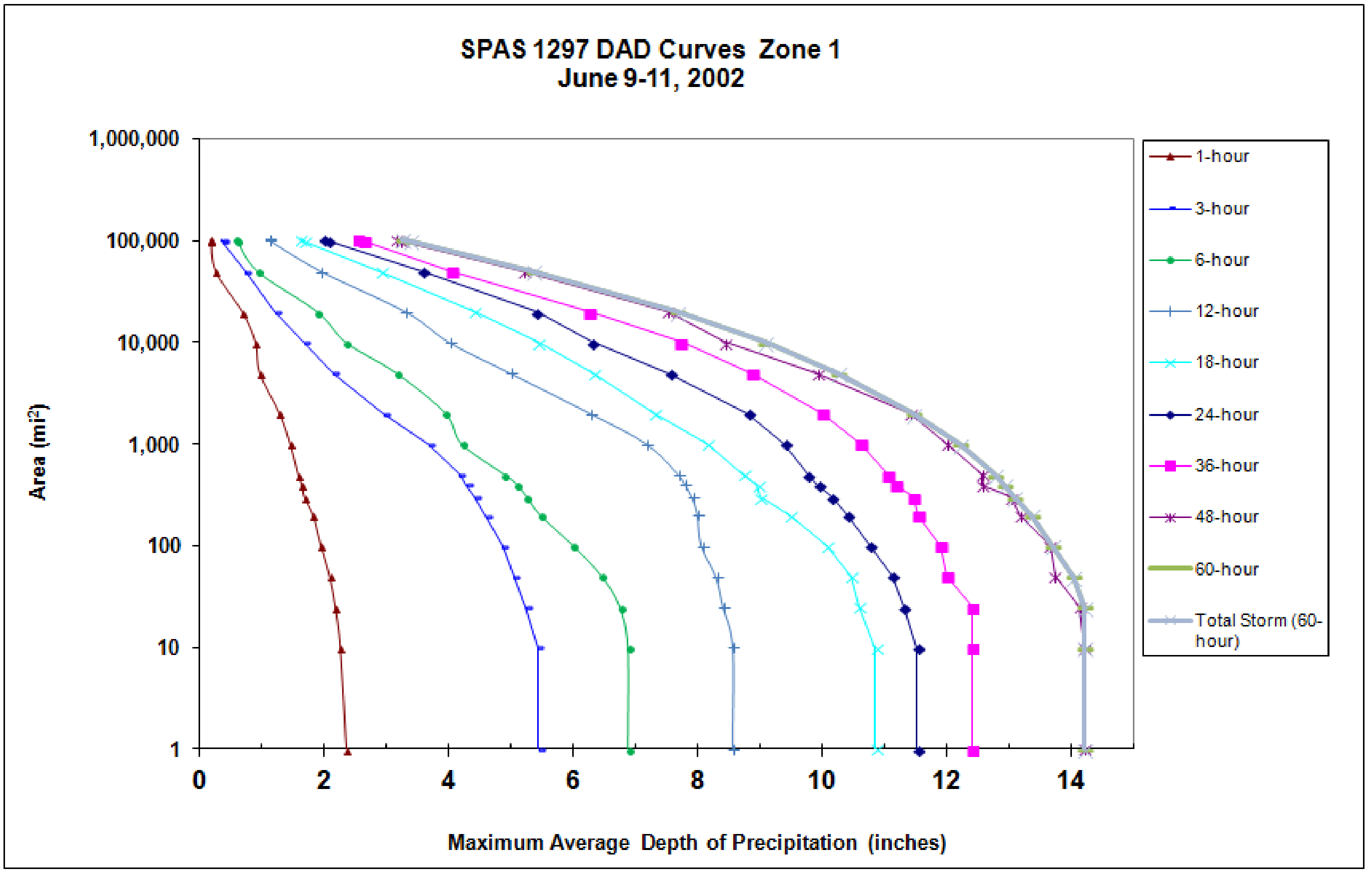
Attachment 1 Table 30: Storm spreadsheet for Warroad, MN June 2002



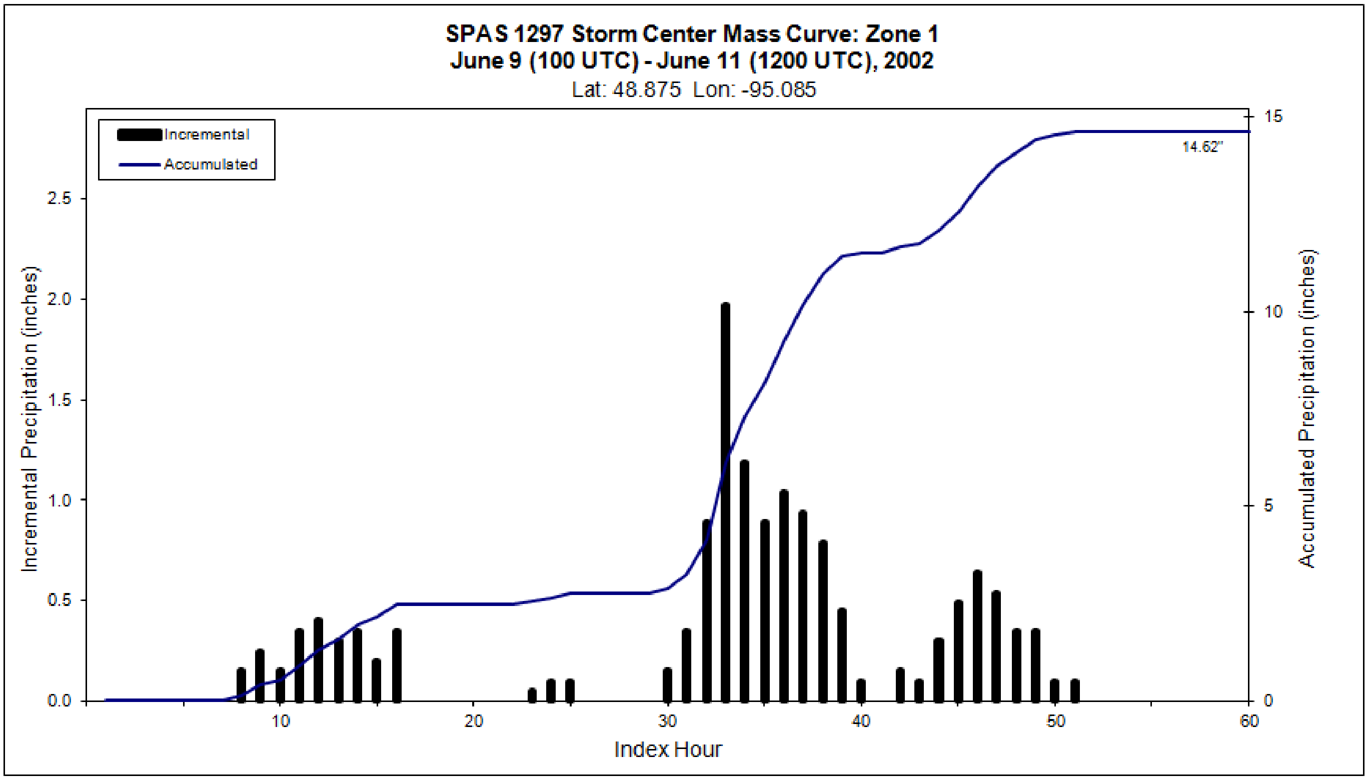
Attachment 1 Figure 49: Moisture inflow map for Warroad, MN June 2002

Storm 1297 - June 9 (100 UTC) - June 11 (1200 UTC), 2002										
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)										
	Duration (hours)									
Area (mi^2)	1	3	6	12	18	24	36	48	60	Total
0.3	2.42	5.6	7.11	8.81	11.18	11.88	12.83	14.62	14.62	14.62
1	2.37	5.45	6.89	8.57	10.86	11.52	12.41	14.22	14.22	14.22
10	2.27	5.43	6.89	8.57	10.86	11.52	12.41	14.22	14.22	14.22
25	2.19	5.24	6.76	8.41	10.6	11.3	12.41	14.14	14.21	14.21
50	2.1	5.05	6.47	8.29	10.46	11.13	12.01	13.74	14.03	14.03
100	1.96	4.87	6.01	8.06	10.08	10.76	11.91	13.66	13.69	13.69
200	1.83	4.6	5.48	8	9.48	10.41	11.54	13.18	13.37	13.37
300	1.69	4.42	5.27	7.91	8.99	10.15	11.46	13.04	13.08	13.08
400	1.65	4.29	5.11	7.8	8.96	9.93	11.19	12.58	12.92	12.92
500	1.59	4.17	4.91	7.69	8.73	9.76	11.05	12.57	12.77	12.77
1,000	1.46	3.68	4.22	7.18	8.15	9.4	10.62	12.01	12.2	12.20
2,000	1.29	2.96	3.96	6.27	7.3	8.8	10	11.42	11.47	11.47
5,000	0.97	2.15	3.17	4.98	6.34	7.55	8.88	9.92	10.26	10.26
10,000	0.9	1.67	2.36	4.01	5.44	6.3	7.74	8.45	9.09	9.09
20,000	0.69	1.21	1.9	3.31	4.4	5.4	6.27	7.51	7.66	7.66
50,000	0.26	0.74	0.94	1.95	2.91	3.58	4.06	5.21	5.36	5.36
100,000	0.18	0.37	0.61	1.13	1.68	2.07	2.65	3.24	3.39	3.39
103,535	0.18	0.37	0.59	1.12	1.62	2	2.56	3.17	3.27	3.27

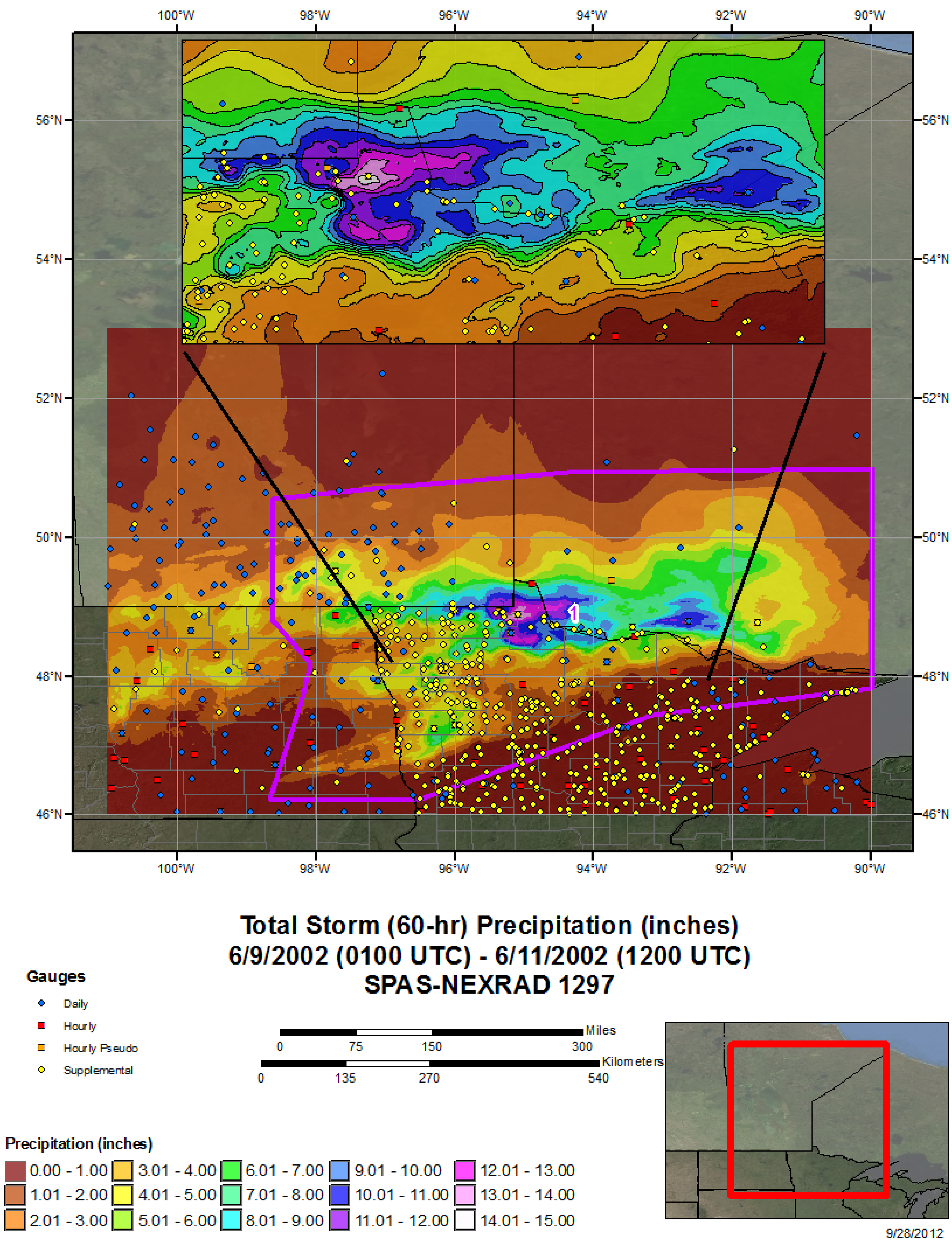
Attachment 1 Table 31: Depth-area-duration values for Warroad, MN June 2002



Attachment 1 Figure 50: Depth-area-duration chart for Warroad, MN June 2002



Attachment 1 Figure 51: Mass curve chart for Warroad, MN June 2002



Attachment 1 Figure 52: Total storm isohyetal analysis for Warroad, MN June 2002

Storm Name:	Woodburn, IA MR 1-10	**Storm Adjustment for Basin Centroid-Monticello**	
Storm Date:	24-Aug-1903		
AWA Analysis Date:	8/24/2014		
Temporal Transposition Date	5-Aug		

	Lat	Long
Storm Center Location	41.01 N	93.60 W
Storm Rep Dew Point Location	38.52 N	91.81 W
Transposition Dew Point Locat	44.14 N	92.42 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	SE @ 140	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,150	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	75.0 F	with total precipitable water above sea level of			2.85	inches.
The in-place maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The transpositioned maximum dew point is	79.0 F	with total precipitable water above sea level of			3.44	inches.
The in-place storm elevation is	1,150	which subtracts	0.30	inches of precipitable water at	75.0 F	
The in-place storm elevation is	1,150	which subtracts	0.34	inches of precipitable water at	80.5 F	
The transposition storm elevation at	1,300	which subtracts	0.37	inches of precipitable water at	79.0 F	
The moisture inflow barrier height is	1,300	which subtracts	0.37	inches of precipitable water at	79.0 F	

The in-place maximization factor is	1.31
The transposition factor is	0.92
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.20

Notes: DAD values taken from USACE MR 1-10. 2° added to the storm rep based on EPRI and Nebraska analyses to adjust 12-hr persisting Td to 24-hr average Td.

Observed Storm Depth-Area-Duration

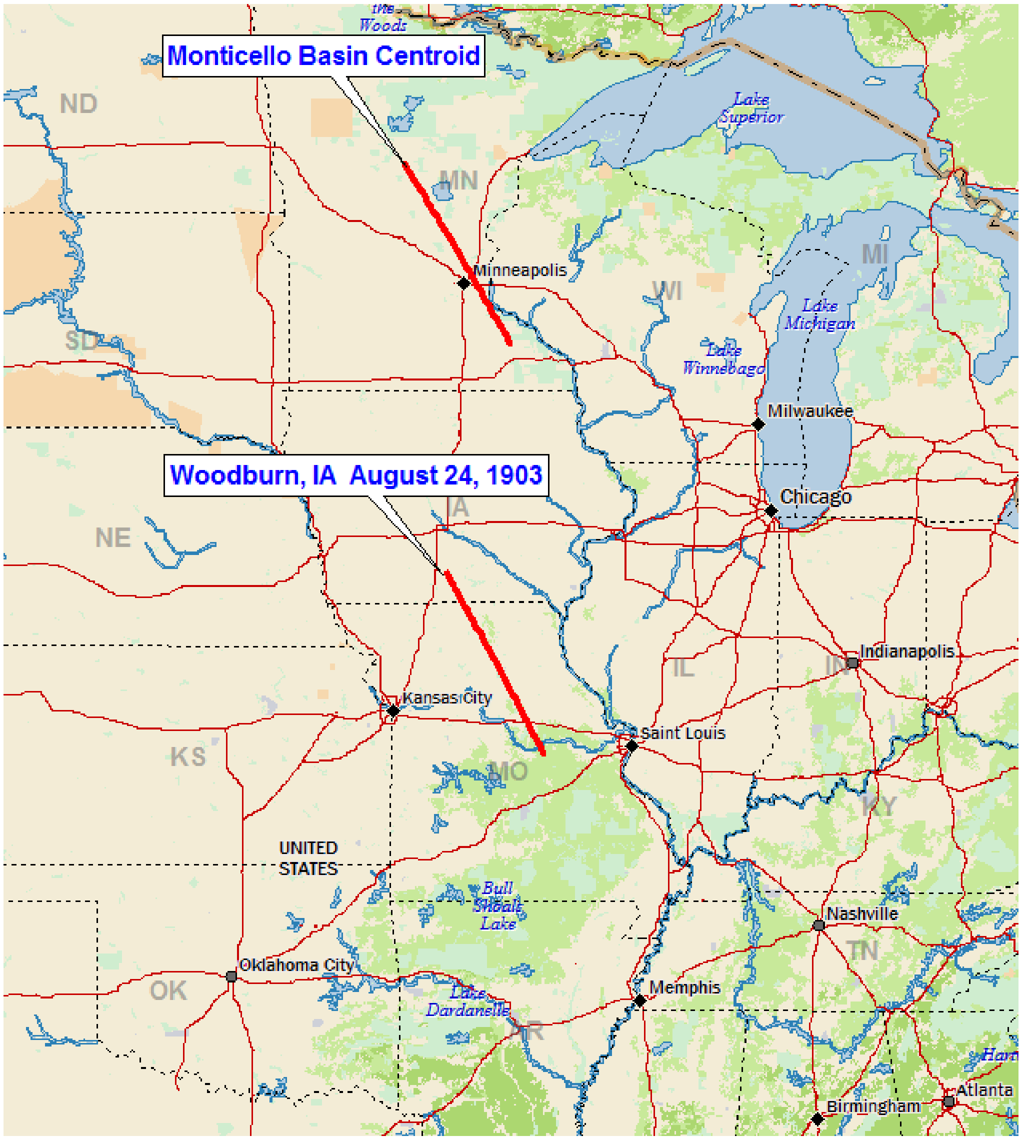
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	6.9	11.5	11.9	14.7	14.7	14.7	15.4	15.5	15.5
100 sq miles	6.6	10.3	11.4	12.8	13.8	13.8	13.9	14.4	14.6
200 sq miles	6.3	9.9	11.0	12.2	13.2	13.2	13.2	13.8	13.9
500 sq miles	5.7	9.3	10.3	11.2	12.2	12.2	12.6	12.8	12.8
1000 sq miles	5.2	8.7	9.5	10.3	11.1	11.2	11.2	11.5	11.7
2000 sq miles	4.6	7.8	8.6	9.2	10.0	10.1	10.2	10.4	10.6
5000 sq miles	3.7	6.4	7.3	7.7	8.4	8.7	8.8	8.8	9.0
10000 sq miles	3.0	5.2	6.3	6.5	7.1	7.3	7.5	7.5	7.7
20000 sq miles	2.3	4.0	5.0	5.2	5.6	5.9	6.1	6.1	6.3

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	8.3	13.8	14.3	17.7	17.7	17.7	18.5	18.6	18.6
100 sq miles	7.9	12.4	13.7	15.4	16.6	16.6	16.7	17.3	17.5
200 sq miles	7.6	11.9	13.2	14.7	15.9	15.9	15.9	16.6	16.7
500 sq miles	6.8	11.2	12.4	13.5	14.7	14.7	15.1	15.4	15.4
1000 sq miles	6.2	10.5	11.4	12.4	13.3	13.5	13.5	13.8	14.1
2000 sq miles	5.5	9.4	10.3	11.1	12.0	12.1	12.3	12.5	12.7
5000 sq miles	4.4	7.7	8.8	9.3	10.1	10.5	10.6	10.6	10.8
10000 sq miles	3.6	6.2	7.6	7.8	8.5	8.8	9.0	9.0	9.3
20000 sq miles	2.8	4.8	6.0	6.2	6.7	7.1	7.3	7.3	7.6

Storm or Storm Center Name	**Woodburn, IA MR 1-10**			
Storm Date(s)	24-Aug-1903			
Storm Type	MCC			
Storm Location	41.01 N	93.60 W		
Storm Center Elevation	1,150			
Precipitation Total & Duration	14.70 Inches 24-hours USACE MR 1-10			
Storm Representative Dew Point	75.0 F	24		
Storm Representative Dew Point Location	38.52 N	91.81 W		
Maximum Dew Point	80.5 F			
Moisture Inflow Vector	SE @ 140			
In-place Maximization Factor	**1.31**			
Temporal Transposition (Date)	5-Aug			
Transposition Dew Point Location	44.14 N	92.42 W	July	Aug
Transposition Maximum Dew Point	79.0 F		79.66	78.72
Transposition Adjustment Factor	**0.92**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.20**			

Attachment 1 Table 32: Storm spreadsheet for Woodburn, IA August 1903



Attachment 1 Figure 53: Moisture inflow map for Woodburn, IA August 1903

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES - PERTINENT DATA SHEET

LOCATION MAP

Storm of August 24 - 28, 1903
Assignment MR 1 - 10
Location Iowa
Study Prepared by:
Missouri River Division
Kansas City District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 6/6/39
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 11/4/44
Remarks: Centers at Woodburn, Ia., and Council Bluffs, Ia.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1 : 2,500,000

Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	5
Form 5001-B (24-hour " ")	21
Form 5001-D (" " " ")	-
Miscl. precip. records, meteorological data, etc.	-
Form 5002 (Mass rainfall curves)	11

PART II

Final isohyetal maps, in 1 sheet, scale 1 : 1,000,000

Data and computation sheets:

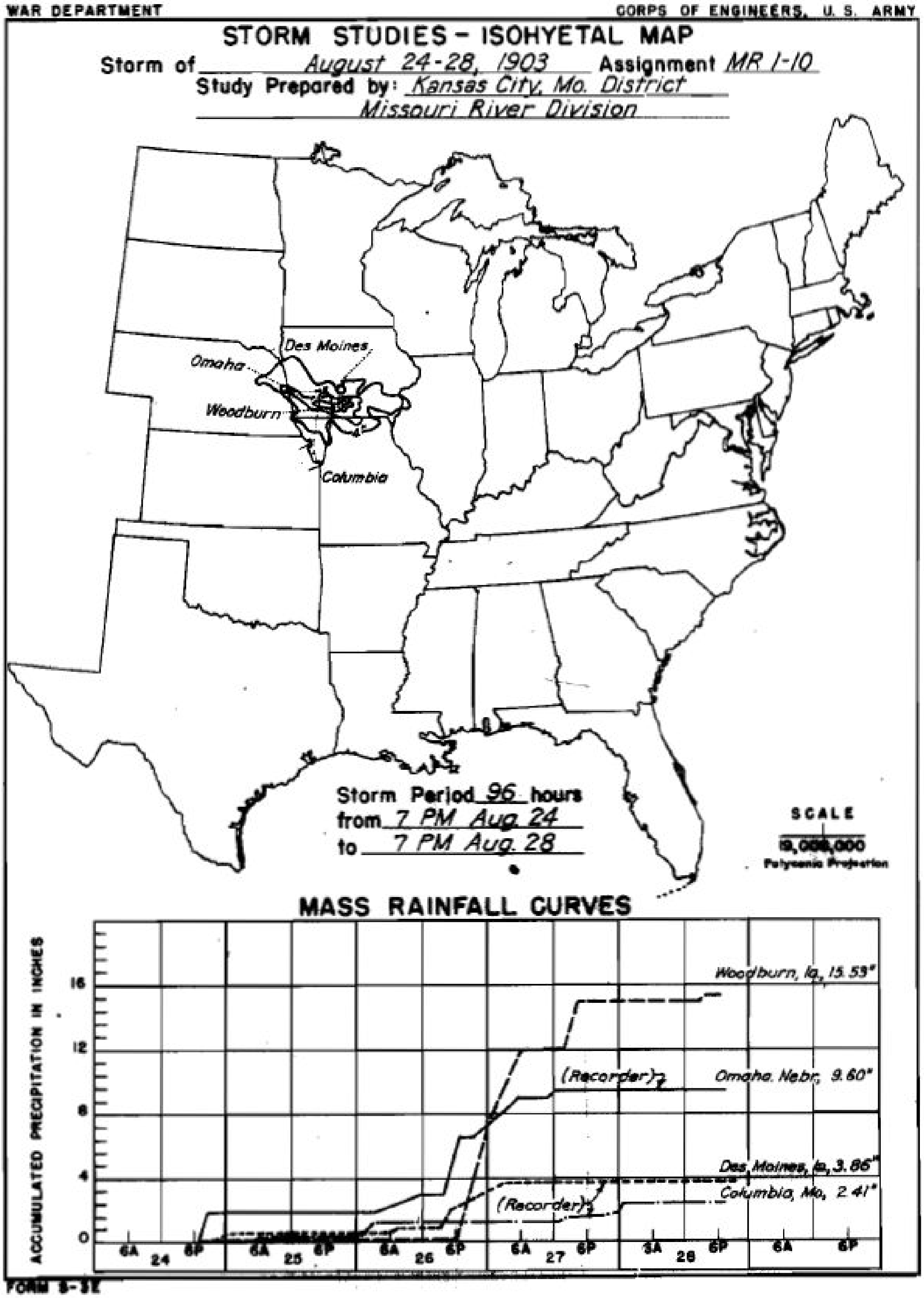
Form S-10 (Data from mass rainfall curves)	4
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	6
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	96
10	6.9	11.5	11.9	14.7	14.7	14.7	15.4	15.5	15.5	15.5
100	6.6	10.3	11.4	12.8	13.8	13.8	13.9	14.4	14.6	14.6
200	6.3	9.9	11.0	12.2	13.2	13.2	13.2	13.8	13.9	13.9
500	5.7	9.3	10.3	11.2	12.2	12.2	12.2	12.6	12.8	12.8
1,000	5.2	8.7	9.5	10.3	11.1	11.2	11.2	11.5	11.7	11.7
2,000	4.6	7.8	8.6	9.2	10.0	10.1	10.2	10.4	10.6	10.7
5,000	3.7	6.4	7.3	7.7	8.4	8.7	8.8	8.8	9.0	9.2
10,000	3.0	5.2	6.3	6.5	7.1	7.3	7.5	7.5	7.7	7.9
20,000	2.3	4.0	5.0	5.2	5.6	5.9	6.1	6.1	6.3	6.5
50,000	1.3	2.4	3.1	3.2	3.5	4.0	4.2	4.3	4.4	4.7
59,000	1.1	2.1	2.8	2.9	3.2	3.6	3.9	4.0	4.1	4.4

Form S-2

Attachment 1 Table 33: Depth-area-duration values for Woodburn, IA August 1903



Attachment 1 Figure 54 and Attachment 1 Figure 55: Isohyetal map and Mass curve chart for Woodburn, IA August 1903

Storm Name:	**Wooster, OH SPAS 1209**		
Storm Date:	**7/4-7/1969**		
AWA Analysis Date:	**8/24/2014**		

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	**40.91 N**	**81.97 W**
Storm Rep Dew Point Location	**39.43 N**	**83.80 W**
Transposition Dew Point Locat	**45.15 N**	**96.38 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SW @ 140**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**1,150**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**76.0 F**	with total precipitable water above sea level of			**2.99**	inches.
The in-place maximum dew point is	**78.0 F**	with total precipitable water above sea level of			**3.29**	inches.
The transpositioned maximum dew point is	**79.5 F**	with total precipitable water above sea level of			**3.52**	inches.
The in-place storm elevation is	**1,150**	which subtracts	**0.30**	inches of precipitable water at	**76.0 F**	
The in-place storm elevation is	**1,150**	which subtracts	**0.32**	inches of precipitable water at	**78.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**79.5 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.38**	inches of precipitable water at	**79.5 F**	

The in-place maximization factor is	**1.10**
The transposition factor is	**1.06**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.17**

Notes: DAD values taken from SPAS 1209. Storm representative dew point value was based on maximum 24-hr Td values between July 4-5, 1969 at KILN, KFFO, and KCVG.

Observed Storm Depth-Area-Duration

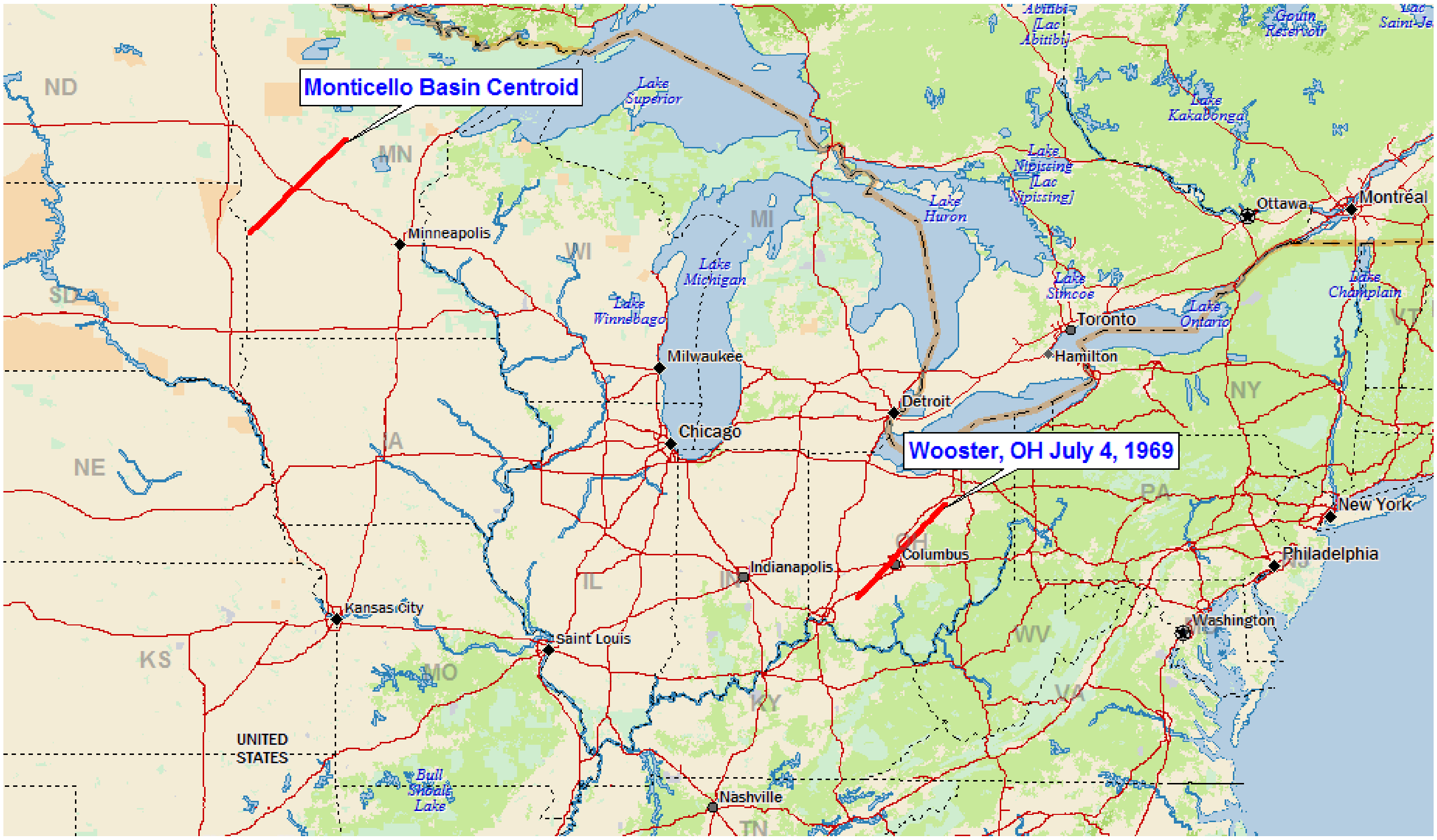
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.6**	**6.2**	**8.8**	**12.7**	**14.3**	**14.4**	**14.5**	**14.6**	**14.7**
10 sq miles	**4.2**	**6.0**	**8.7**	**12.3**	**13.7**	**13.7**	**13.8**	**14.0**	**14.0**
100 sq miles	**2.9**	**5.7**	**8.0**	**10.7**	**12.0**	**12.1**	**12.1**	**12.6**	**12.8**
200 sq miles	**2.5**	**5.5**	**7.7**	**10.4**	**11.6**	**11.6**	**11.7**	**12.2**	**12.4**
500 sq miles	**2.1**	**4.8**	**7.3**	**9.9**	**11.0**	**11.0**	**11.2**	**11.6**	**11.8**
1000 sq miles	**1.7**	**4.2**	**6.9**	**9.3**	**10.3**	**10.5**	**10.7**	**11.0**	**11.3**
2000 sq miles	**1.5**	**3.7**	**6.2**	**8.5**	**9.4**	**9.7**	**9.8**	**10.2**	**10.4**
5000 sq miles	**1.0**	**2.6**	**4.5**	**6.3**	**7.0**	**7.1**	**7.4**	**7.6**	**7.9**
10000 sq miles	**0.5**	**1.6**	**2.7**	**4.4**	**4.7**	**4.8**	**5.4**	**5.5**	**5.8**
20000 sq miles	**0.3**	**1.0**	**1.8**	**2.6**	**3.4**	**3.5**	**3.7**	**3.8**	**4.0**

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**5.4**	**7.3**	**10.3**	**14.8**	**16.7**	**16.8**	**16.8**	**17.0**	**17.2**
10 sq miles	**4.9**	**7.0**	**10.1**	**14.3**	**15.9**	**16.0**	**16.0**	**16.3**	**16.3**
100 sq miles	**3.4**	**6.7**	**9.3**	**12.5**	**14.0**	**14.1**	**14.1**	**14.7**	**14.9**
200 sq miles	**3.0**	**6.3**	**9.0**	**12.1**	**13.5**	**13.5**	**13.6**	**14.2**	**14.5**
500 sq miles	**2.4**	**5.6**	**8.6**	**11.5**	**12.8**	**12.8**	**13.0**	**13.5**	**13.8**
1000 sq miles	**2.0**	**4.9**	**8.0**	**10.8**	**12.0**	**12.3**	**12.4**	**12.9**	**13.1**
2000 sq miles	**1.7**	**4.3**	**7.3**	**9.9**	**10.9**	**11.3**	**11.5**	**11.8**	**12.1**
5000 sq miles	**1.2**	**3.1**	**5.2**	**7.3**	**8.2**	**8.3**	**8.6**	**8.9**	**9.2**
10000 sq miles	**0.6**	**1.8**	**3.1**	**5.1**	**5.5**	**5.6**	**6.3**	**6.4**	**6.8**
20000 sq miles	**0.4**	**1.1**	**2.1**	**3.1**	**3.9**	**4.0**	**4.3**	**4.4**	**4.6**

Storm or Storm Center Name	**Wooster, OH SPAS 1209**	
Storm Date(s)	7/4-7/1969	
Storm Type	Synoptic	
Storm Location	40.91 N	81.97 W
Storm Center Elevation	1,150	
Precipitation Total & Duration	14.73 Inches 72-hours	
Storm Representative Dew Point	76.0 F	24
Storm Representative Dew Point Location	39.43 N	83.80 W
Maximum Dew Point	78.0 F	
Moisture Inflow Vector	SW @ 140	Miles
In-place Maximization Factor	**1.10**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	45.15 N	96.38 W
Transposition Maximum Dew Point	79.5 F	
Transposition Adjustment Factor	**1.06**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.17**	

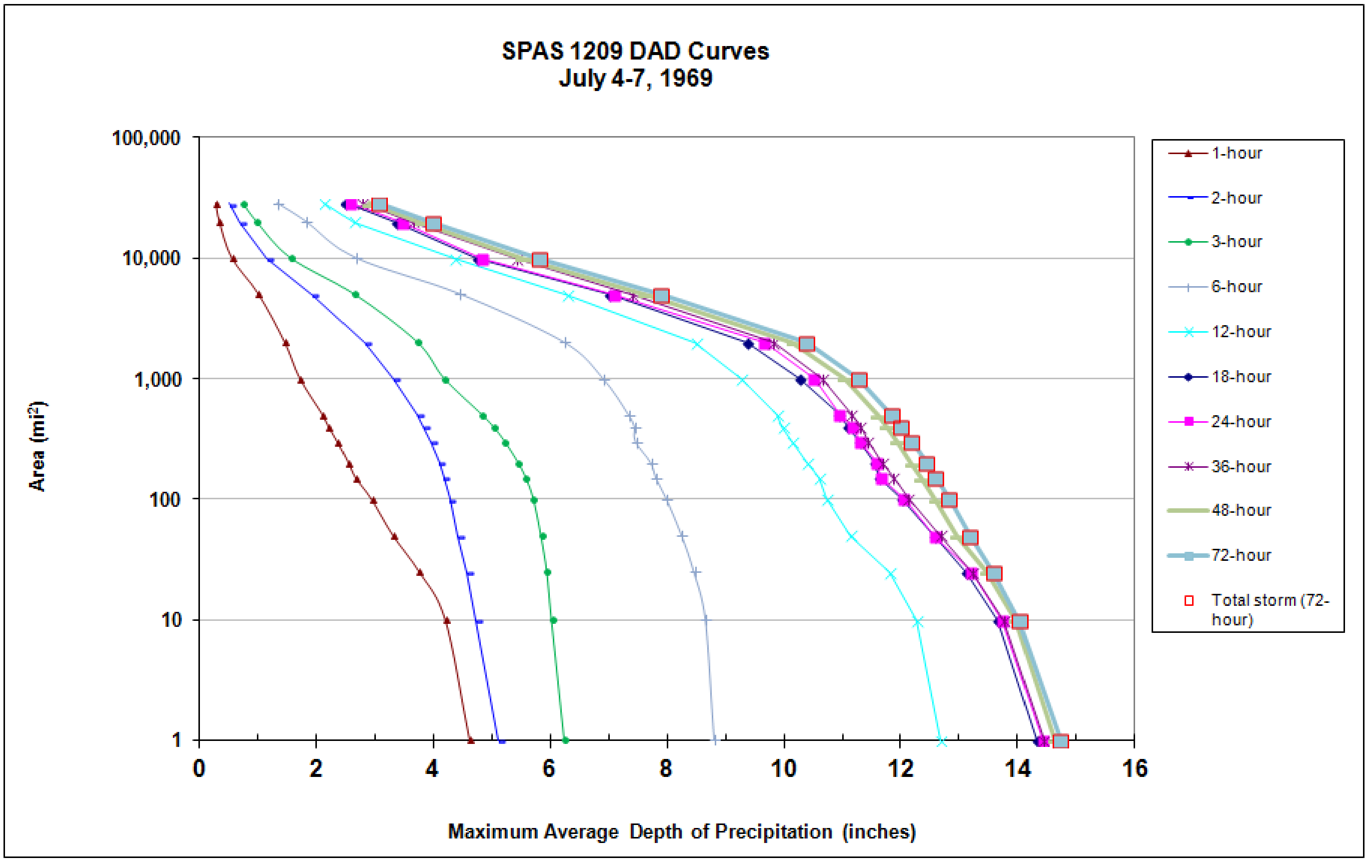
Attachment 1 Table 34: Storm spreadsheet for Wooster, OH July 1969



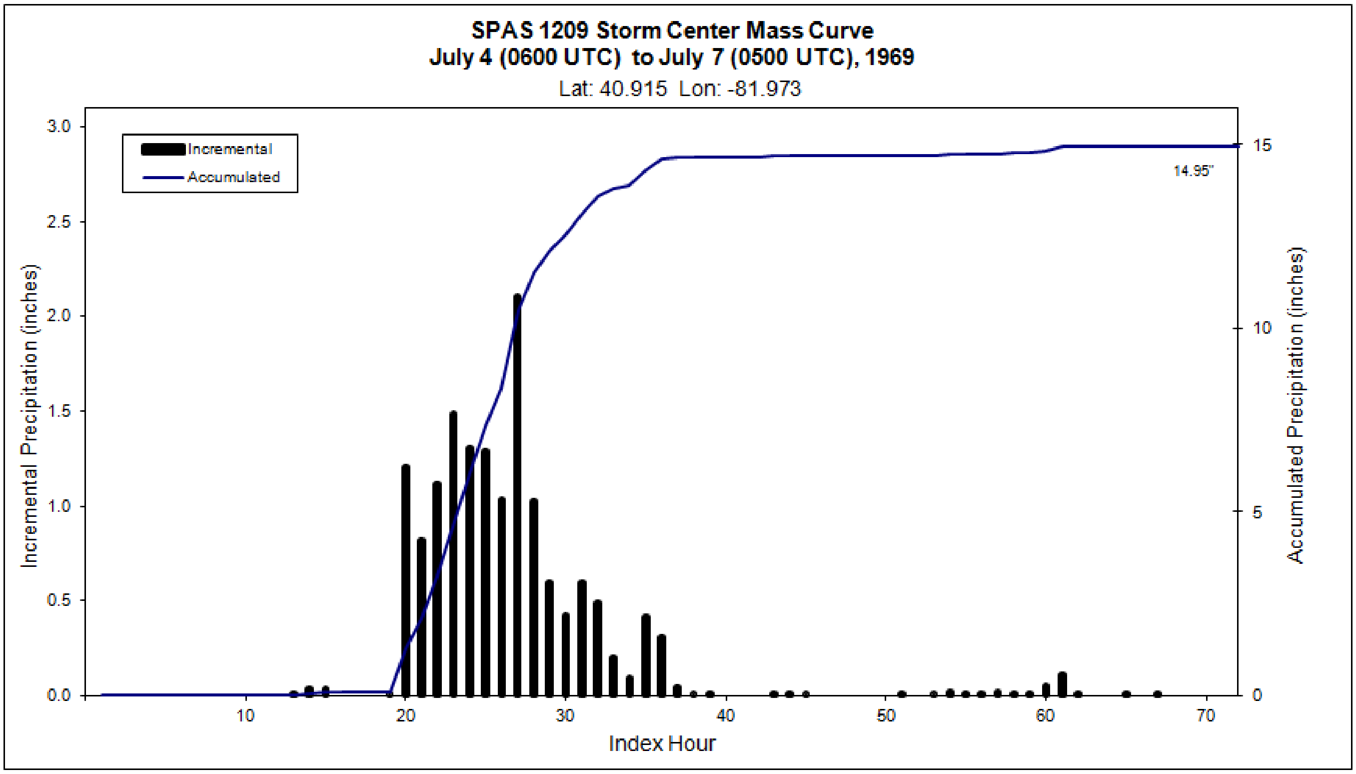
Attachment 1 Figure 56: Moisture inflow map for Wooster, OH July 1969

Storm 1209 - July 4 (0600 UTC) - July 7 (0500 UTC),1969											
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)											
	Duration (hours)										
Area (mi^2)	1	2	3	6	12	18	24	36	48	72	Total
0.3	4.82	5.33	6.41	8.95	13.02	14.58	14.67	14.69	14.94	14.95	14.95
1	4.62	5.11	6.24	8.81	12.67	14.32	14.44	14.45	14.63	14.73	14.73
10	4.2	4.72	6.02	8.66	12.26	13.66	13.74	13.77	13.97	14.02	14.02
25	3.75	4.56	5.94	8.46	11.81	13.13	13.21	13.23	13.47	13.58	13.58
50	3.3	4.42	5.84	8.25	11.14	12.57	12.59	12.69	12.97	13.19	13.19
100	2.93	4.27	5.71	7.99	10.72	12.02	12.06	12.14	12.59	12.83	12.83
150	2.66	4.17	5.58	7.81	10.59	11.63	11.66	11.88	12.35	12.6	12.60
200	2.54	4.09	5.45	7.72	10.4	11.56	11.6	11.69	12.18	12.44	12.44
300	2.35	3.96	5.22	7.46	10.14	11.3	11.3	11.44	11.94	12.19	12.19
400	2.2	3.83	5.02	7.44	9.97	11.1	11.18	11.31	11.75	12	12.00
500	2.1	3.72	4.83	7.34	9.88	10.95	10.96	11.16	11.61	11.84	11.84
1,000	1.71	3.31	4.18	6.9	9.27	10.28	10.52	10.66	11.04	11.27	11.27
2,000	1.45	2.82	3.72	6.23	8.48	9.38	9.67	9.83	10.15	10.39	10.39
5,000	1	1.93	2.64	4.45	6.27	7.02	7.09	7.4	7.62	7.9	7.90
10,000	0.54	1.14	1.55	2.66	4.35	4.74	4.83	5.42	5.52	5.81	5.81
20,000	0.33	0.69	0.97	1.82	2.64	3.37	3.47	3.65	3.78	3.98	3.98
28,279	0.27	0.51	0.74	1.33	2.13	2.5	2.59	2.79	2.89	3.06	3.06

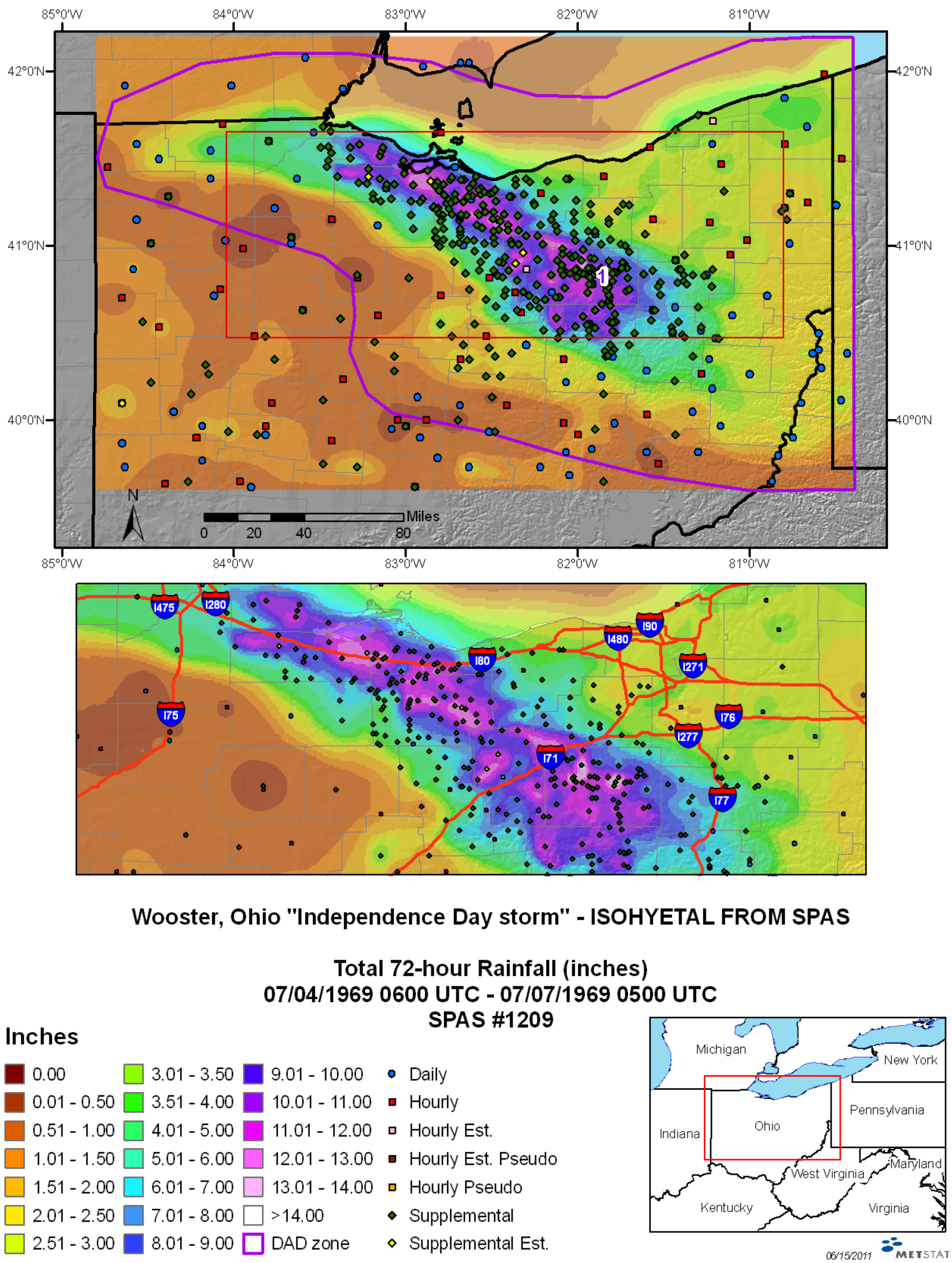
Attachment 1 Table 35: Depth-area-duration values for Wooster, OH July 1969



Attachment 1 Figure 57: Depth-area-duration chart for Wooster, OH July 1969



Attachment 1 Figure 58: Mass curve chart for Wooster, OH July 1969



Attachment 1 Figure 59: Total storm isohyetal analysis for Wooster, OH July 1969

ATTACHMENT 2: Cool-Season Short Storm List Data

Storm Name	State	AWA Storm Number	Lat	Lon	Year	Month	Day	Maximum Rainfall in Inches	Precipitation Source
ASHLAND	WI	2C	46.5542	-90.9100	2001	4	20	8.62	SPAS 1245
BELLEFONTAINE	OH	7C	40.3670	-83.7670	1913	3	23	11.20	OR 1-15
CONCEPTION	MO	10C	40.2428	-94.6869	1919	5	2	6.20	MR 2-20
LANSING	MI	4C	42.7300	-84.5600	1975	4	18	5.12	EPRI
LOUISVILLE	KY	3C	38.1000	-85.6700	1997	2	28	13.51	SPAS 1244
MADISONVILLE	KY	6C	37.3167	-87.4833	1964	3	8	11.53	SPAS 1278
OCONTO	WI	11C	44.8900	-87.8700	1919	4	5	4.50	GL 2-19
TUSCUMBIA	MO	9C	38.2331	-92.4585	1927	3	17	5.50	MR 3-10A

Attachment 2 Table 1: List of storm used in the cool-season PMP development

Storm Name:	**Ashland, WI SPAS 1245**		
Storm Date:	**4/21-25/2001**	**Storm Adjustment for Basin Centroid-Monticello**	
AWA Analysis Date:	**8/24/2014**		
Temporal Transposition Date	**5-May**		

	Lat	Long
Storm Center Location	**46.55 N**	**90.91 W**
Storm Rep Dew Point Location	**39.00 N**	**94.90 W**
Transposition Dew Point Locati	**39.08 N**	**98.37 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SSW @ 560**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**800**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**66.0 F**	with total precipitable water above sea level of			**1.86**	inches.
The in-place maximum dew point is	**71.5 F**	with total precipitable water above sea level of			**2.42**	inches.
The transpositioned maximum dew point is	**71.0 F**	with total precipitable water above sea level of			**2.36**	inches.
The in-place storm elevation is	**800**	which subtracts	**0.15**	inches of precipitable water at	**66.0 F**	
The in-place storm elevation is	**800**	which subtracts	**0.18**	inches of precipitable water at	**71.5 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.28**	inches of precipitable water at	**71.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.28**	inches of precipitable water at	**71.0 F**	

The in-place maximization factor is	**1.31**
The transposition factor is	**0.93**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.22**

Notes: Storm representative dew point value was based on maximum 24-hr Td values for April 20-21, 2001 at KMKC, KLWC, and KIXD.

Observed Storm Depth-Area-Duration

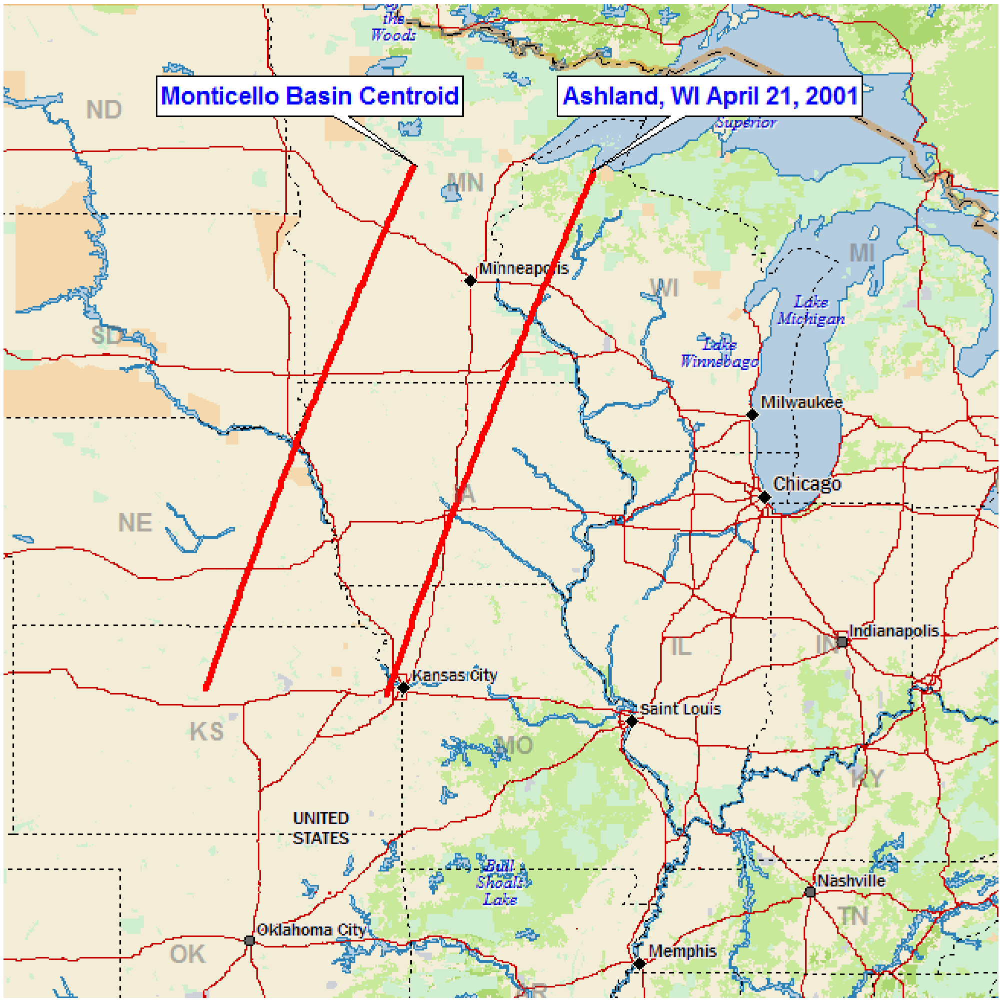
	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**1.7**	**2.8**	**4.1**	**4.9**	**5.7**	**6.1**	**7.1**		**8.5**
10 sq miles	**1.6**	**2.8**	**4.0**	**4.8**	**5.5**	**5.9**	**6.9**		**8.1**
100 sq miles	**1.5**	**2.6**	**3.3**	**3.9**	**4.3**	**4.7**	**5.5**		**6.8**
200 sq miles	**1.4**	**2.4**	**3.2**	**3.6**	**3.9**	**4.3**	**5.4**		**6.1**
500 sq miles	**1.2**	**2.3**	**3.0**	**3.4**	**3.8**	**4.1**	**5.0**		**6.0**
1000 sq miles	**1.1**	**2.2**	**2.9**	**3.2**	**3.4**	**3.9**	**4.8**		**5.8**
2000 sq miles	**0.9**	**2.1**	**2.8**	**3.1**	**3.2**	**3.6**	**4.4**		**5.2**
5000 sq miles	**0.8**	**1.8**	**2.4**	**2.9**	**3.1**	**3.5**	**4.1**		**5.0**
10000 sq miles	**0.6**	**1.5**	**2.4**	**2.8**	**2.9**	**3.3**	**3.8**		**4.5**
20000 sq miles	**0.3**	**1.3**	**2.2**	**2.6**	**2.7**	**3.0**	**3.3**		**4.1**
50000 sq miles	**0.3**	**1.1**	**1.6**	**2.2**	**2.3**	**2.6**	**3.0**		**3.5**
100000 sq miles	**0.2**	**0.7**	**1.2**	**1.6**	**1.7**	**1.8**	**2.0**		**2.5**

Adjusted Storm Depth-Area-Duration

	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**2.1**	**3.4**	**5.0**	**6.0**	**6.9**	**7.4**	**8.6**	-	**10.3**
10 sq miles	**1.9**	**3.4**	**4.9**	**5.8**	**6.7**	**7.1**	**8.3**	-	**9.8**
100 sq miles	**1.8**	**3.1**	**4.1**	**4.8**	**5.2**	**5.7**	**6.7**	-	**8.3**
200 sq miles	**1.7**	**3.0**	**3.9**	**4.4**	**4.7**	**5.3**	**6.6**	-	**7.4**
500 sq miles	**1.5**	**2.8**	**3.6**	**4.1**	**4.6**	**5.0**	**6.1**	-	**7.3**
1000 sq miles	**1.3**	**2.7**	**3.5**	**3.9**	**4.1**	**4.8**	**5.9**	-	**7.1**
2000 sq miles	**1.1**	**2.5**	**3.4**	**3.8**	**3.9**	**4.4**	**5.4**	-	**6.4**
5000 sq miles	**0.9**	**2.2**	**3.0**	**3.6**	**3.7**	**4.2**	**5.0**	-	**6.1**
10000 sq miles	**0.8**	**1.8**	**2.9**	**3.4**	**3.5**	**4.0**	**4.6**	-	**5.5**
20000 sq miles	**0.4**	**1.6**	**2.6**	**3.1**	**3.3**	**3.6**	**4.1**	-	**5.0**
50000 sq miles	**0.4**	**1.3**	**1.9**	**2.6**	**2.8**	**3.2**	**3.7**	-	**4.2**
100000 sq miles	**0.2**	**0.9**	**1.4**	**1.9**	**2.1**	**2.2**	**2.4**	-	**3.0**

Storm or Storm Center Name	**Ashland, WI SPAS 1245**			
Storm Date(s)	4/21-25/2001			
Storm Type	General Storm			
Storm Location	46.55 N	90.91 W		
Storm Center Elevation	800			
Precipitation Total & Duration	8.62 inches in 95 hours			
Storm Representative Dew Point	66.0 F	24		
Storm Representative Dew Point Location	39.00 N	94.90 W	Apr	May
Maximum Dew Point	71.5 F		67.5	73.5
Moisture Inflow Vector	SSW @ 560			
In-place Maximization Factor	**1.31**			
Temporal Transposition (Date)	5-May			
Transposition Dew Point Location	39.08 N	98.37 W	Apr	May
Transposition Maximum Dew Point	71.0 F		67.07	73.18
Transposition Adjustment Factor	**0.93**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.22**			

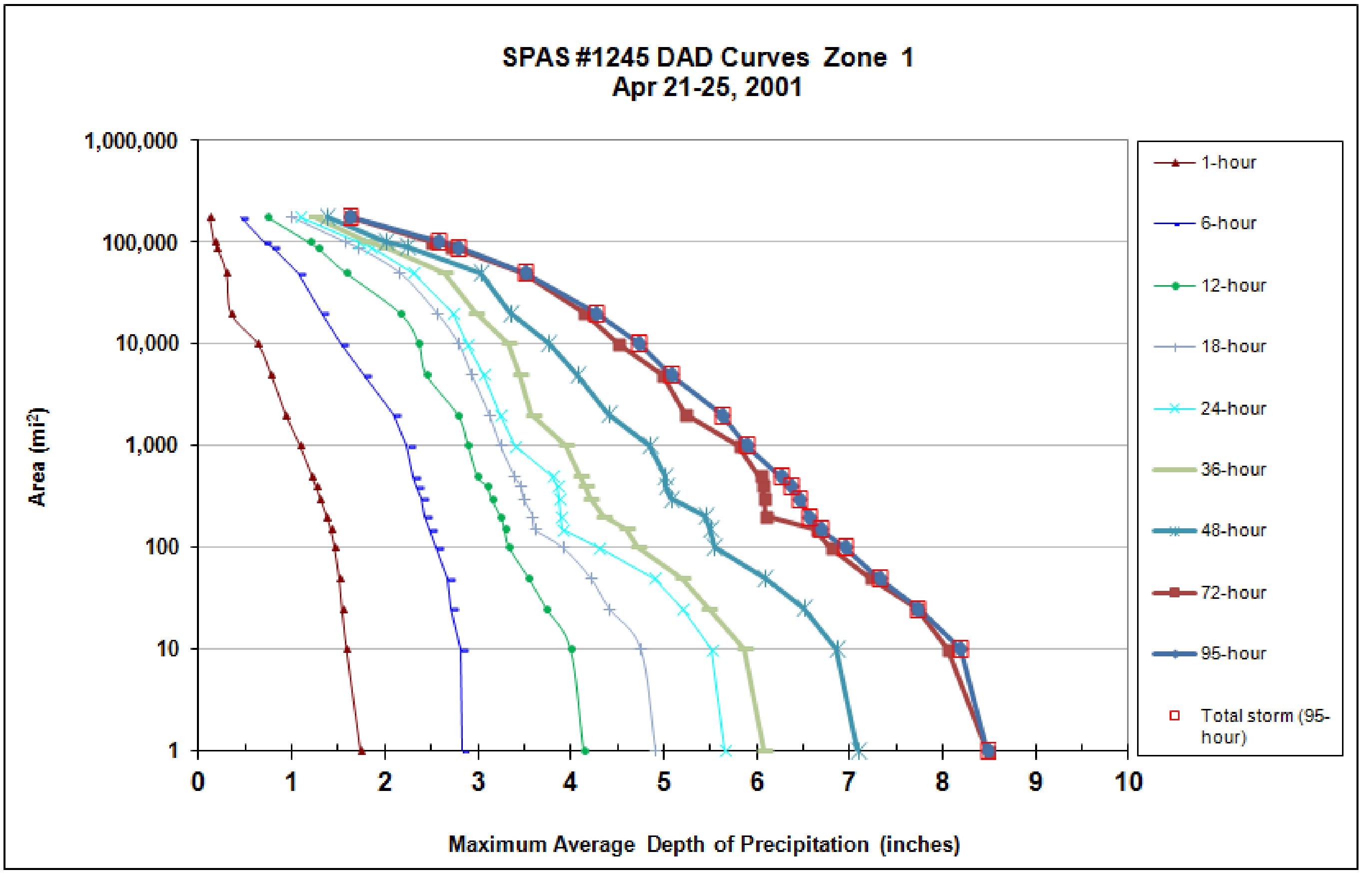
Attachment 2 Table 2: Storm spreadsheet for Ashland, WI April 2001



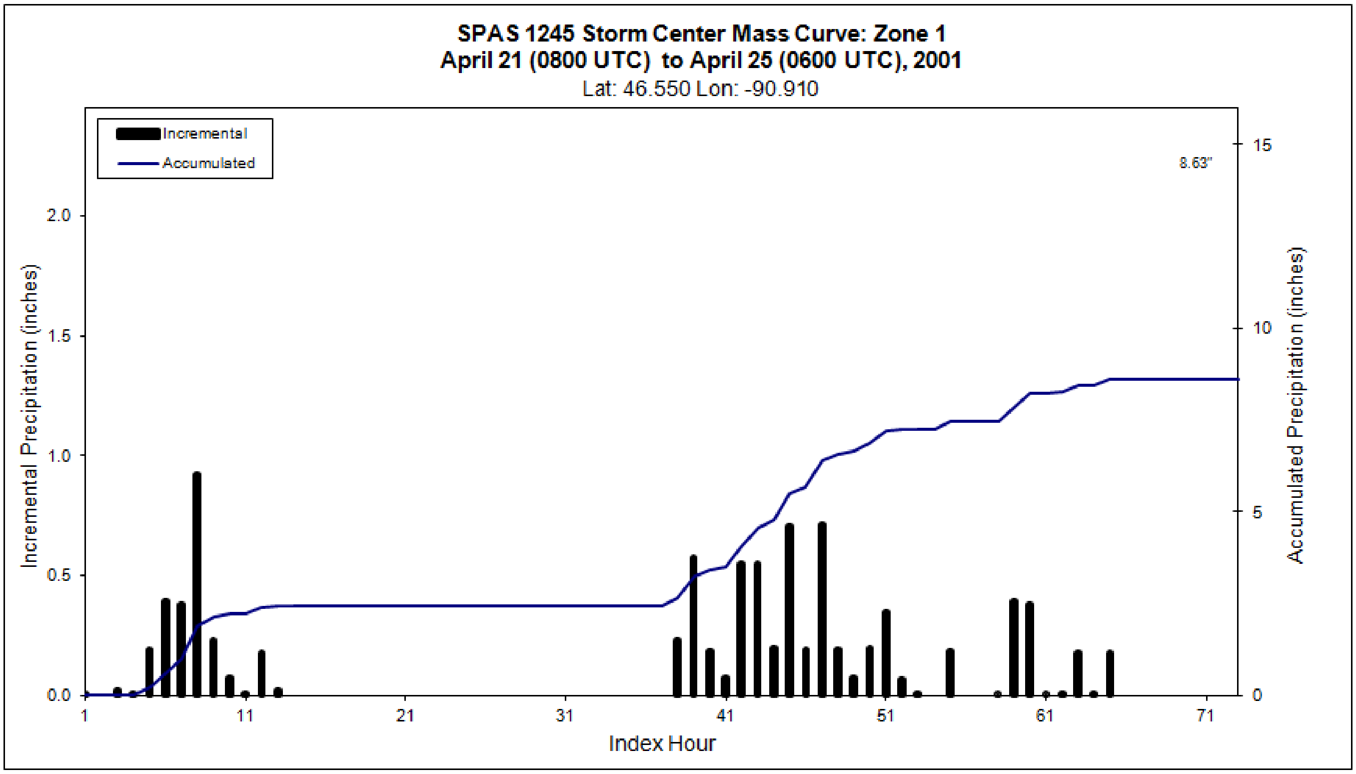
Attachment 2 Figure 1: Moisture inflow map for Ashland, WI April 2001

Storm 1245 - April 21 (0800 UTC) - April 25 (0600 UTC), 2001										
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)										
	Duration (hours)									
Area (mi^2)	1	6	12	18	24	36	48	72	95	Total
0.3	1.75	2.93	4.23	5.03	5.82	6.20	7.28	8.62	8.62	8.62
1	1.73	2.83	4.13	4.91	5.65	6.08	7.09	8.48	8.48	8.48
10	1.58	2.81	3.99	4.75	5.51	5.86	6.85	8.05	8.19	8.19
25	1.53	2.71	3.73	4.41	5.20	5.47	6.50	7.71	7.73	7.73
50	1.50	2.67	3.54	4.21	4.90	5.19	6.09	7.22	7.31	7.31
100	1.45	2.55	3.33	3.91	4.29	4.72	5.54	6.79	6.94	6.94
150	1.41	2.48	3.28	3.61	3.90	4.59	5.50	6.63	6.68	6.68
200	1.37	2.43	3.24	3.59	3.89	4.34	5.44	6.09	6.56	6.56
300	1.30	2.39	3.14	3.49	3.87	4.20	5.07	6.07	6.46	6.46
400	1.25	2.33	3.09	3.46	3.86	4.15	5.02	6.05	6.36	6.36
500	1.21	2.30	2.99	3.39	3.80	4.10	5.01	6.03	6.26	6.26
1,000	1.08	2.24	2.89	3.24	3.39	3.94	4.84	5.80	5.89	5.89
2,000	0.93	2.09	2.78	3.12	3.23	3.58	4.40	5.23	5.62	5.62
5,000	0.77	1.77	2.44	2.93	3.06	3.45	4.07	4.98	5.08	5.08
10,000	0.63	1.52	2.36	2.79	2.89	3.32	3.76	4.51	4.73	4.73
20,000	0.34	1.32	2.16	2.56	2.72	2.97	3.34	4.14	4.26	4.26
50,000	0.29	1.06	1.58	2.16	2.30	2.64	3.03	3.49	3.50	3.50
89,000	0.19	0.78	1.27	1.71	1.84	1.99	2.23	2.71	2.78	2.78
100,000	0.16	0.70	1.18	1.58	1.71	1.81	2.01	2.49	2.58	2.58
177,564	0.11	0.45	0.73	0.99	1.09	1.25	1.38	1.62	1.63	1.63

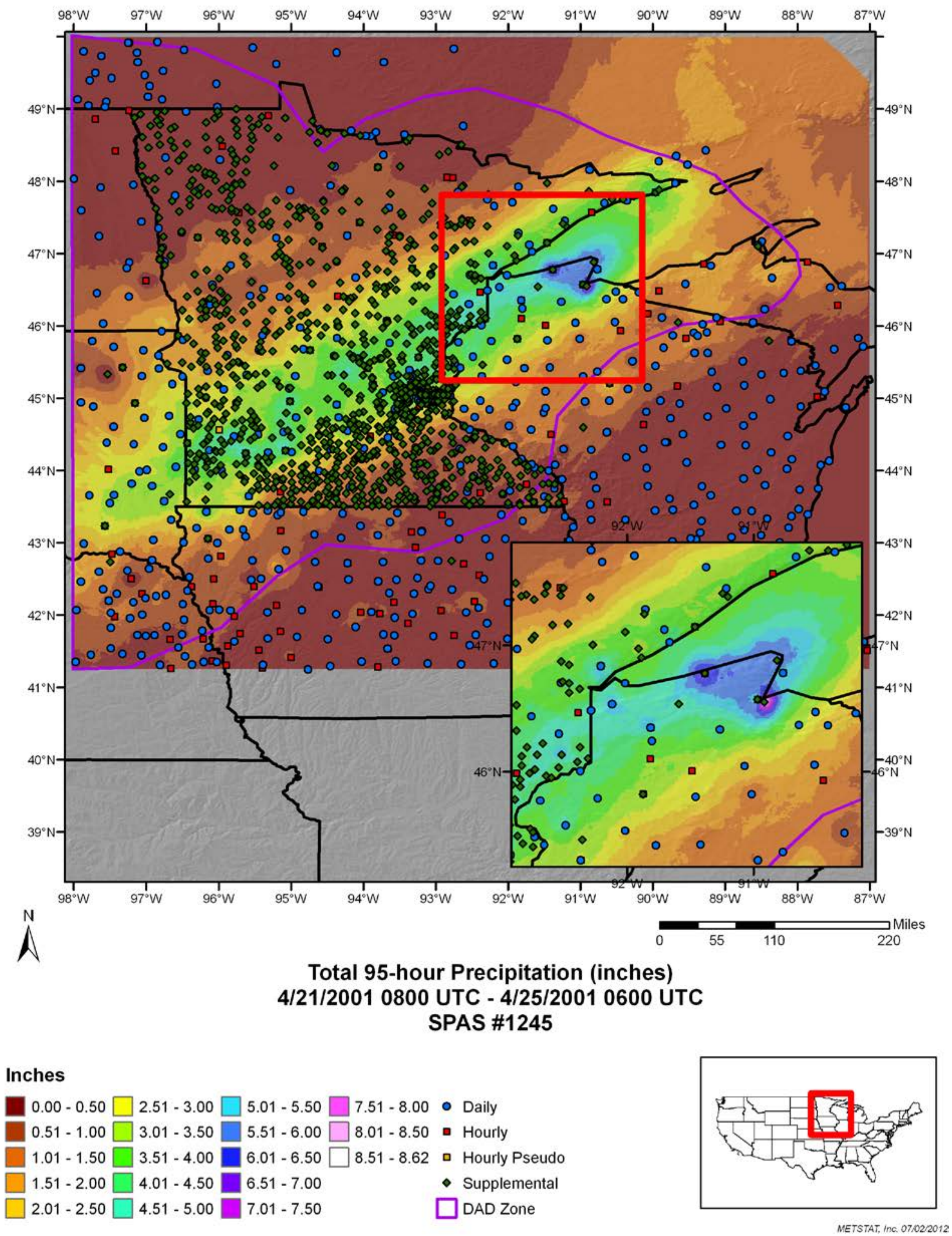
Attachment 2 Table 3: Depth-area-duration values for Ashland, WI April 2001



Attachment 2 Figure 2: Depth-area-duration chart for Ashland, WI April 2001



Attachment 2 Figure 3: Mass curve chart for Ashland, WI April 2001



Attachment 2 Figure 4: Total storm isohyetal analysis for Ashland, WI April 2001

Storm Name:	OR 1-15, Bellefontaine, OH	Storm Adjustment for Basin Centroid-Monticello
Storm Date:	3/23-27/1913	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	5-Apr	
	Lat	Long
Storm Center Location	40.37 N	83.77 W
Storm Rep Dew Point Location	38.00 N	90.45 W
Transposition Dew Point Locati	44.21 N	101.71 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	WSW @ 395	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	1,220	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	69.0 F	with total precipitable water above sea level of			2.14	inches.
The in-place maximum dew point is	70.0 F	with total precipitable water above sea level of			2.25	inches.
The transpositioned maximum dew point is	59.0 F	with total precipitable water above sea level of			1.31	inches.
The in-place storm elevation is	1,220	which subtracts	0.25	inches of precipitable water at	69.0 F	
The in-place storm elevation is	1,220	which subtracts	0.25	inches of precipitable water at	70.0 F	
The transposition storm elevation at	1,300	which subtracts	0.19	inches of precipitable water at	59.0 F	
The moisture inflow barrier height is	1,300	which subtracts	0.19	inches of precipitable water at	59.0 F	

The in-place maximization factor is	1.06
The transposition factor is	0.56
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	0.59

Notes: Added 2°F to the USACE 12-hr persisting Td to account for difference in average versus persisting Td climatologies.

Observed Storm Depth-Area-Duration

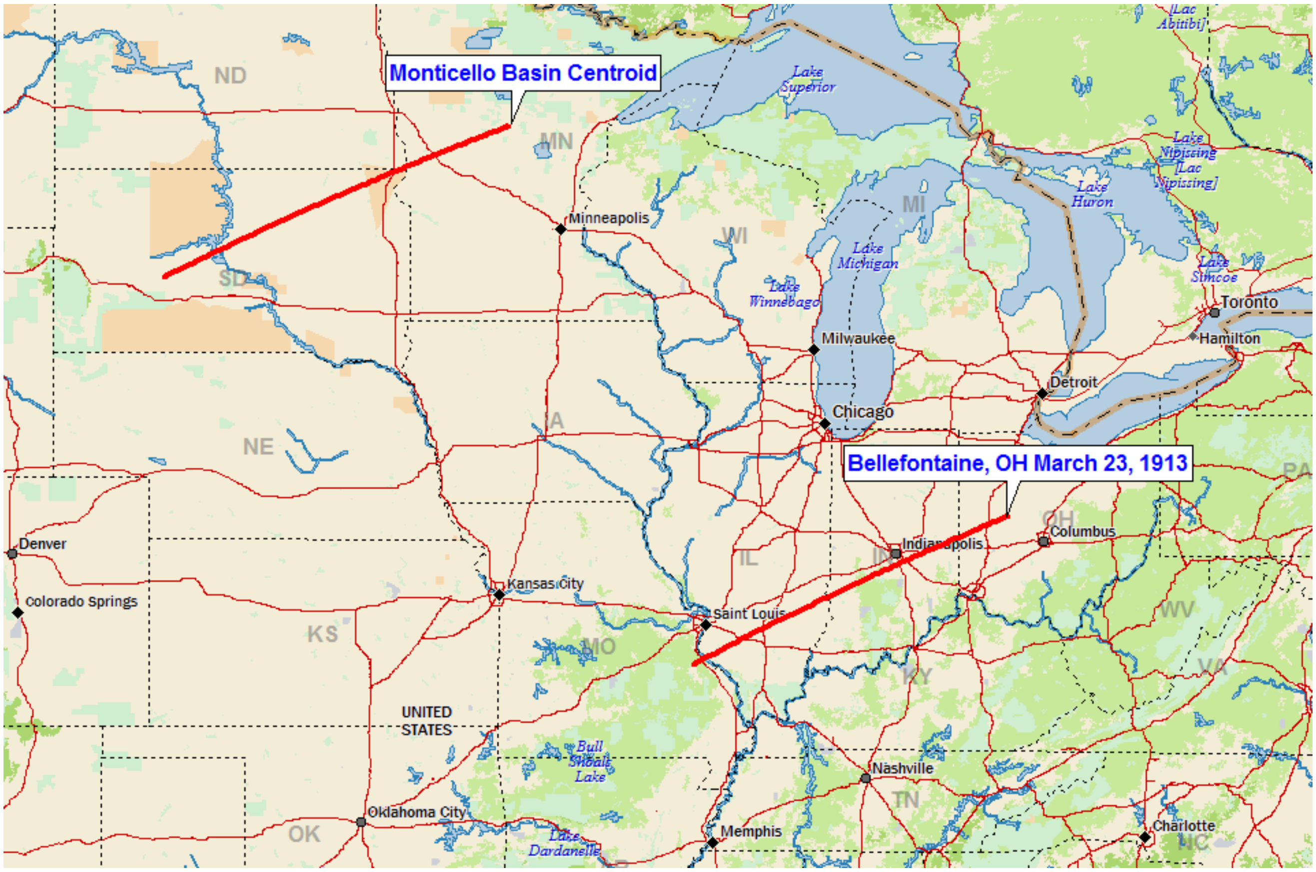
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	3.4	6.0	6.6	7.3	8.2	8.5	9.5	10.4	10.4
100 sq miles	3.3	5.6	6.5	7.1	7.9	8.2	9.3	10.2	10.2
200 sq miles	3.3	5.4	6.4	7.0	7.8	8.1	9.2	10.0	10.1
500 sq miles	3.2	5.1	6.2	6.8	7.5	7.8	9.0	9.7	9.9
1000 sq miles	3.1	4.9	6.0	6.6	7.3	7.6	8.7	9.5	9.7
2000 sq miles	2.9	4.6	5.7	6.3	7.0	7.4	8.4	9.1	9.4
5000 sq miles	2.6	4.1	5.2	5.8	6.5	6.9	7.9	8.6	9.0
10000 sq miles	2.3	3.6	4.8	5.4	6.1	6.5	7.5	8.2	8.6
20000 sq miles	2.0	3.4	4.3	4.9	5.5	5.9	6.9	7.6	8.1
50000 sq miles	1.6	2.7	3.5	4.1	4.5	4.9	5.8	6.5	7.1
100000 sq miles	1.1	2.0	2.7	3.2	3.6	4.0	4.8	5.4	6.0

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	2.0	3.6	3.9	4.3	4.9	5.0	5.6	6.2	6.2
100 sq miles	2.0	3.3	3.9	4.2	4.7	4.9	5.5	6.0	6.0
200 sq miles	2.0	3.2	3.8	4.1	4.6	4.8	5.5	5.9	6.0
500 sq miles	1.9	3.0	3.7	4.0	4.4	4.6	5.3	5.7	5.9
1000 sq miles	1.8	2.9	3.6	3.9	4.3	4.5	5.2	5.6	5.7
2000 sq miles	1.7	2.7	3.4	3.7	4.1	4.4	5.0	5.4	5.6
5000 sq miles	1.5	2.4	3.1	3.4	3.9	4.1	4.7	5.1	5.3
10000 sq miles	1.4	2.1	2.8	3.2	3.6	3.9	4.4	4.9	5.1
20000 sq miles	1.2	2.0	2.5	2.9	3.3	3.5	4.1	4.5	4.8
50000 sq miles	0.9	1.6	2.1	2.4	2.7	2.9	3.4	3.9	4.2
100000 sq miles	0.7	1.2	1.6	1.9	2.1	2.4	2.8	3.2	3.6

Storm or Storm Center Name	**OR 1-15, Bellefontaine, OH**			
Storm Date(s)	3/23-27/1913			
Storm Type	Frontal/Convection			
Storm Location	40.37 N	83.77 W		
Storm Center Elevation	1220			
Precipitation Total & Duration	11.20 Inches in 96-hours			
Storm Representative Dew Point	69.0 F	24		
Storm Representative Dew Point Location	38.00 N	90.45 W	March	April
Maximum Dew Point	70.0 F		68	71
Moisture Inflow Vector	WSW @ 395			
In-place Maximization Factor	**1.06**			
Temporal Transposition (Date)	5-Apr			
Transposition Dew Point Location	44.21 N	101.71 W	March	April
Transposition Maximum Dew Point	59.0 F		55.61	60.6
Transposition Adjustment Factor	**0.56**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**0.59**			

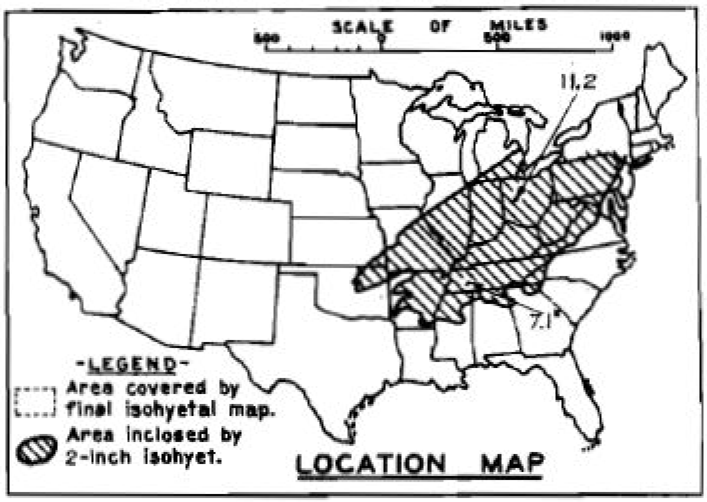
Attachment 2 Table 4: Storm spreadsheet for Bellefontaine, OH March 1913



Attachment 2 Figure 5: Moisture inflow map for Bellefontaine, OH March 1913

WAR DEPARTMENT — CORPS OF ENGINEERS, U.S. ARMY

STORM STUDIES – PERTINENT DATA SHEET



Storm of March 23 - 27, 1913
Assignment O R 1 - 15
Location Arkansas - New York
Study Prepared by:
Ohio River Division
Cincinnati District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 7/13/41
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 5/15/45
Remarks: Centers at; Bellefontaine, Ohio and Savannah, Tenn.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in sheet, scale

Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	18
Form 5001-B (24-hour " ")	63
Form 5001-D (" " " ")	1
Miscl. precip. records, meteorological data, etc.	-
Form 5002 (Mass rainfall curves)	62

PART II

Final isohyetal maps, in 1 sheet, scale 1 : 1,000,000

Data and computation sheets:

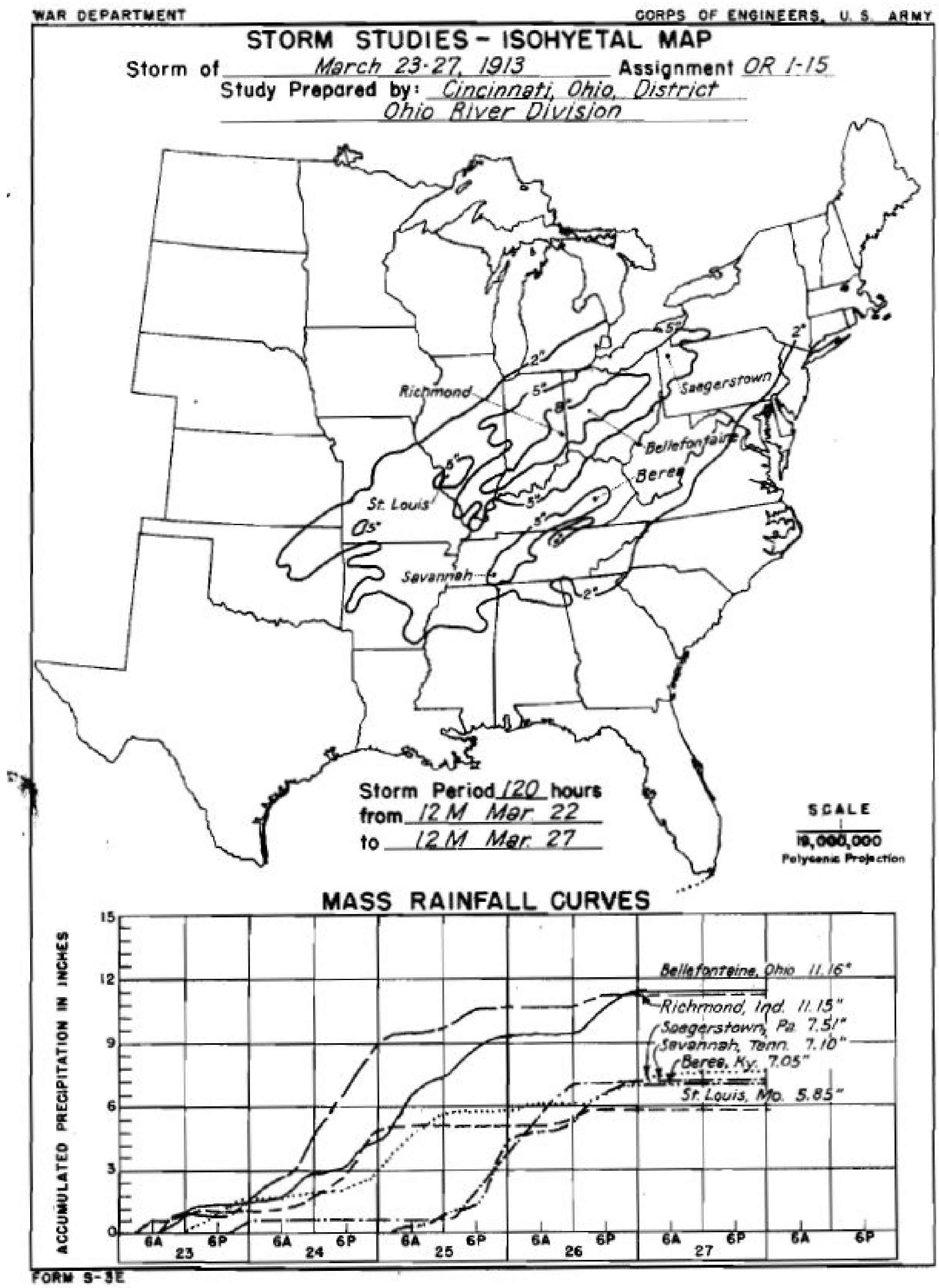
Form S-10 (Data from mass rainfall curves)	13
Form S-11 (Depth-area data from isohyetal map)	5
Form S-12 (Maximum depth-duration data)	50
Maximum duration-depth-area curves	5
Data relating to periods of maximum rainfall	10

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	120
10	3.4	6.0	6.6	7.3	8.2	8.5	9.5	10.4	10.4	11.2	11.2
100	3.3	5.6	6.5	7.1	7.9	8.2	9.3	10.2	10.2	11.1	11.1
200	3.3	5.4	6.4	7.0	7.8	8.1	9.2	10.0	10.1	11.1	11.1
500	3.2	5.1	6.2	6.8	7.5	7.8	9.0	9.7	9.9	10.9	10.9
1,000	3.1	4.9	6.0	6.6	7.3	7.6	8.7	9.5	9.7	10.7	10.8
2,000	2.9	4.6	5.7	6.3	7.0	7.4	8.4	9.1	9.4	10.5	10.6
5,000	2.6	4.1	5.2	5.8	6.5	6.9	7.9	8.6	9.0	10.1	10.2
10,000	2.3	3.8	4.8	5.4	6.1	6.5	7.5	8.2	8.6	9.6	9.7
20,000	2.0	3.4	4.3	4.9	5.5	5.9	6.9	7.6	8.1	9.1	9.2
50,000	1.6	2.7	3.5	4.1	4.5	4.9	5.8	6.5	7.1	8.1	8.2
100,000	1.1	2.0	2.7	3.2	3.6	4.0	4.8	5.4	6.0	6.9	7.0
160,000	0.7	1.4	2.0	2.5	2.9	3.3	4.0	4.5	5.1	6.0	6.1

Form S-2

Attachment 2 Table 5: Depth-area-duration values for Bellefontaine, OH March 1913



Attachment 2 Figure 6 and Attachment 2 Figure 7: Isohyetal map and Mass curve chart for Bellefontaine, OH March 1913

Storm Name:	**MR 2-20, Conception, MO**		**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**5/2-4/1919**		
AWA Analysis Date:	**8/24/2014**		

Temporal Transposition Date **15-May**

	Lat	Long
Storm Center Location	**40.24 N**	**94.69 W**
Storm Rep Dew Point Location	**35.50 N**	**92.30 W**
Transposition Dew Point Locati	**41.88 N**	**91.76 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SSE @ 350**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**1,100**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**66.0 F**	with total precipitable water above sea level of			**1.86**	inches.
The in-place maximum dew point is	**74.5 F**	with total precipitable water above sea level of			**2.79**	inches.
The transpositioned maximum dew point is	**72.0 F**	with total precipitable water above sea level of			**2.47**	inches.
The in-place storm elevation is	**1,100**	which subtracts	**0.20**	inches of precipitable water at	**66.0 F**	
The in-place storm elevation is	**1,100**	which subtracts	**0.28**	inches of precipitable water at	**74.5 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.29**	inches of precipitable water at	**72.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.29**	inches of precipitable water at	**72.0 F**	

The in-place maximization factor is	**1.50**
The transposition factor is	**0.87**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.30**

Notes: Added 2°F to the USACE 12-hr persisting Td to account for difference in average versus persisting Td climatologies. In-place max factor calculated at 1.51, held to 1.50 based on HMR guidance.

Observed Storm Depth-Area-Duration

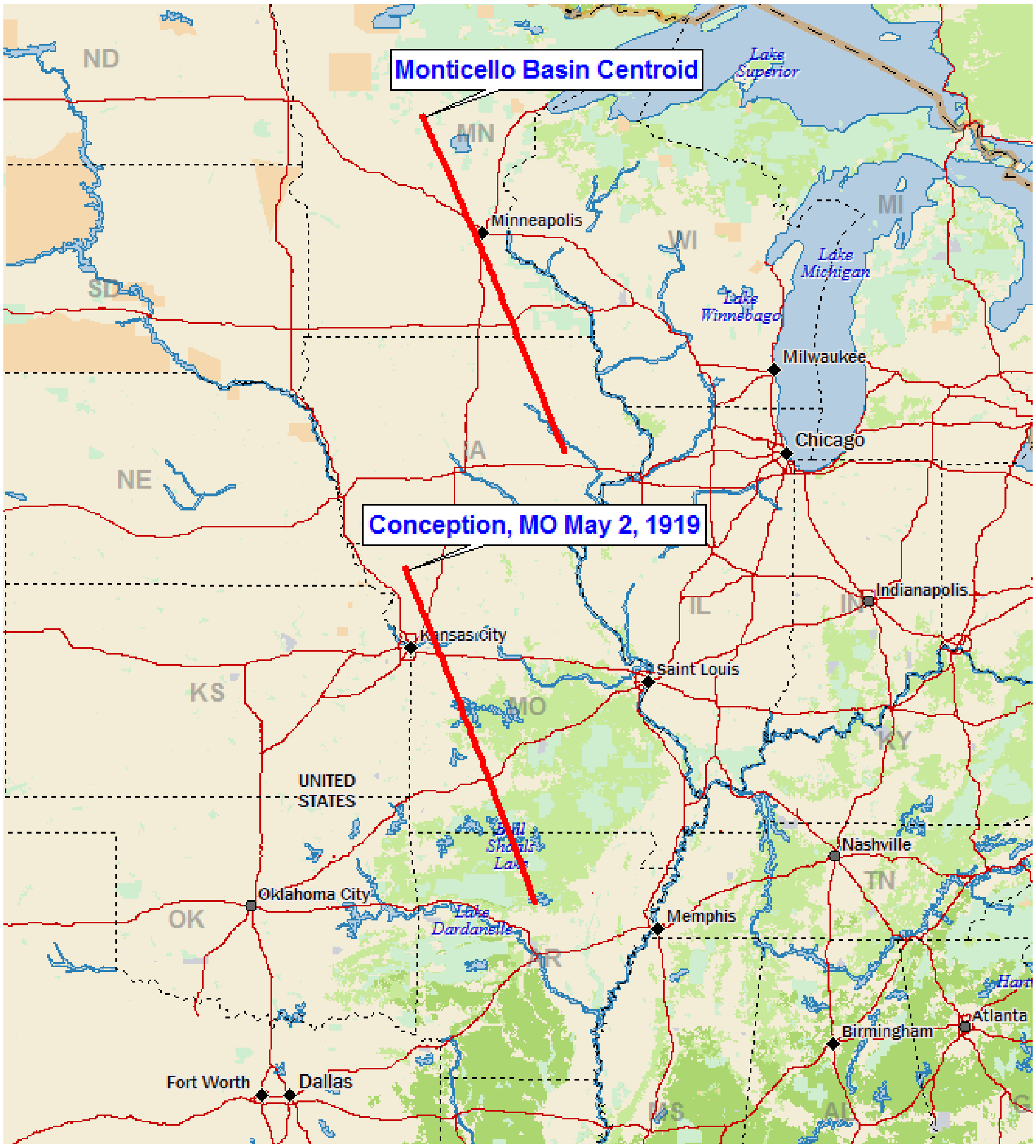
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**3.9**	**4.5**	**4.6**	**4.6**	**5.9**	**6.2**	**6.2**	-	-
100 sq miles	**3.8**	**4.3**	**4.5**	**4.5**	**5.4**	**6.0**	**6.1**	-	-
200 sq miles	**3.7**	**4.2**	**4.3**	**4.4**	**5.2**	**5.9**	**6.0**	-	-
500 sq miles	**3.4**	**3.8**	**3.9**	**4.0**	**4.8**	**5.6**	**5.7**	-	-
1000 sq miles	**3.2**	**3.5**	**3.6**	**3.7**	**4.4**	**5.2**	**5.3**	-	-
2000 sq miles	**2.8**	**3.1**	**3.2**	**3.3**	**4.1**	**4.8**	**4.9**	-	-
5000 sq miles	**2.3**	**2.6**	**2.7**	**2.8**	**3.6**	**4.2**	**4.4**	-	-
10000 sq miles	**1.9**	**2.2**	**2.4**	**2.5**	**3.2**	**3.7**	**3.9**	-	-
20000 sq miles	**1.5**	**1.9**	**2.1**	**2.2**	**2.8**	**3.2**	**3.4**	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**5.1**	**5.9**	**6.0**	**6.0**	**7.7**	**8.1**	**8.1**	-	-
100 sq miles	**5.0**	**5.6**	**5.9**	**5.9**	**7.0**	**7.8**	**7.9**	-	-
200 sq miles	**4.8**	**5.5**	**5.6**	**5.7**	**6.8**	**7.7**	**7.8**	-	-
500 sq miles	**4.4**	**5.0**	**5.1**	**5.2**	**6.3**	**7.3**	**7.4**	-	-
1000 sq miles	**4.2**	**4.6**	**4.7**	**4.8**	**5.7**	**6.8**	**6.9**	-	-
2000 sq miles	**3.6**	**4.0**	**4.2**	**4.3**	**5.3**	**6.3**	**6.4**	-	-
5000 sq miles	**3.0**	**3.4**	**3.5**	**3.6**	**4.7**	**5.5**	**5.7**	-	-
10000 sq miles	**2.5**	**2.9**	**3.1**	**3.3**	**4.2**	**4.8**	**5.1**	-	-
20000 sq miles	**2.0**	**2.5**	**2.7**	**2.9**	**3.6**	**4.2**	**4.4**	-	-

Storm or Storm Center Name	**MR 2-20, Conception, MO**	
Storm Date(s)	5/2-4/1919	
Storm Type	Frontal	
Storm Location	40.24 N	94.69 W
Storm Center Elevation	1100	
Precipitation Total & Duration	6.20 Inches in 36-hours	
Storm Representative Dew Point	66.0 F	24
Storm Representative Dew Point Location	35.50 N	92.30 W
Maximum Dew Point	74.5 F	
Moisture Inflow Vector	SSE @ 350	
In-place Maximization Factor	**1.50**	
Temporal Transposition (Date)	15-May	
Transposition Dew Point Location	41.88 N	91.76 W
Transposition Maximum Dew Point	72.0 F	
Transposition Adjustment Factor	**0.87**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.30**	

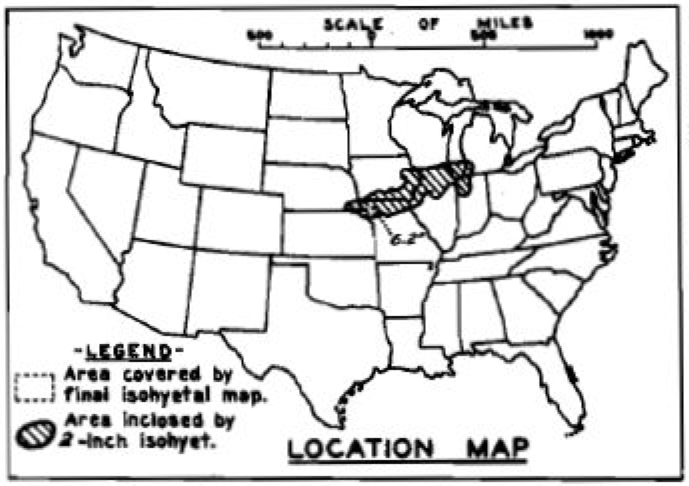
Attachment 2 Table 6: Storm spreadsheet for Conception, MO May 1919



Attachment 2 Figure 8: Moisture inflow map for Conception, MO May 1919

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES – PERTINENT DATA SHEET



Storm of 2-4 May 1919
Assignment MR 2-20
Location Ill, Ia. & Mo.
Study Prepared by:
Missouri River Division
Kansas City District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 10/10/46
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 9/19/47
Remarks: Center at Conception, Mo.
Dewpt. 64° - Ref. Pt. 350 SSE
Grid E-14

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1:2,500,000

Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 9
- Form 5001-B (24-hour " ") ---------- -
- Form 5001-D (" " " ") ---------- 6
- Miscl. precip. records, meteorological data, etc. ---------- 8
- Form 5002 (Mass rainfall curves) ---------- 14

PART II

Final isohyetal maps, in 1 sheet, scale 1:1,000,000

Data and computation sheets:

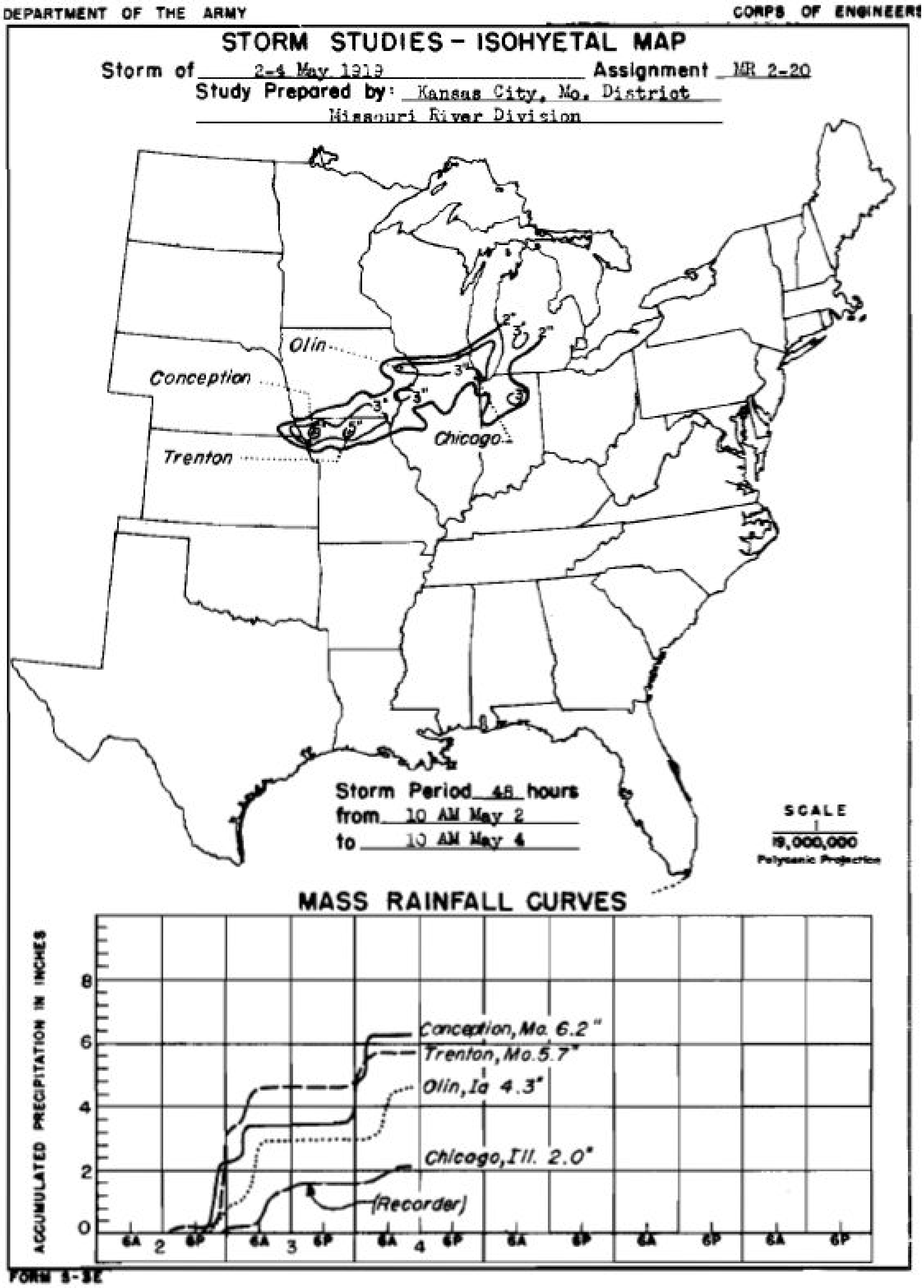
- Form S-10 (Data from mass rainfall curves) ---------- 2
- Form S-11 (Depth-area data from isohyetal map) ---------- 1
- Form S-12 (Maximum depth-duration data) ---------- 4
- Maximum duration-depth-area curves ---------- 1
- Data relating to periods of maximum rainfall ---------- 2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48			
10	3.9	4.5	4.6	4.6	5.9	6.2	6.2			
100	3.8	4.3	4.5	4.5	5.4	6.0	6.1			
200	3.7	4.2	4.3	4.4	5.2	5.9	6.0			
500	3.4	3.8	3.9	4.0	4.8	5.6	5.7			
1,000	3.2	3.5	3.6	3.7	4.4	5.2	5.3			
2,000	2.8	3.1	3.2	3.3	4.1	4.8	4.9			
5,000	2.3	2.6	2.7	2.8	3.6	4.2	4.4			
10,000	1.9	2.2	2.4	2.5	3.2	3.7	3.9			
20,000	1.5	1.9	2.1	2.2	2.8	3.2	3.4			
30,000	1.2	1.9	2.1	2.1	2.7	3.0	3.2			

Form S-2

Attachment 2 Table 7: Depth-area-duration values for Conception, MO May 1919



Attachment 2 Figure 9 and Attachment 2 Figure 10: Isohyetal map and Mass curve chart for Conception, MO May 1919

Storm Name:	**Lansing, MI**	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**4/18-19/1975**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**30-Apr**	
	Lat	**Long**
Storm Center Location	**42.73 N**	**84.56 W**
Storm Rep Dew Point Location	**38.00 N**	**90.45 W**
Transposition Dew Point Locati	**41.88 N**	**100.60 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SW @ 450**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**850**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**67.0 F**	with total precipitable water above sea level of			**1.95**	inches.
The in-place maximum dew point is	**72.0 F**	with total precipitable water above sea level of			**2.47**	inches.
The transpositioned maximum dew point is	**67.0 F**	with total precipitable water above sea level of			**1.95**	inches.
The in-place storm elevation is	**850**	which subtracts	**0.17**	inches of precipitable water at	**67.0 F**	
The in-place storm elevation is	**850**	which subtracts	**0.20**	inches of precipitable water at	**72.0 F**	
The transposition storm elevation at	**1,300**	which subtracts	**0.25**	inches of precipitable water at	**67.0 F**	
The moisture inflow barrier height is	**1,300**	which subtracts	**0.25**	inches of precipitable water at	**67.0 F**	

The in-place maximization factor is	**1.27**
The transposition factor is	**0.75**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**0.95**

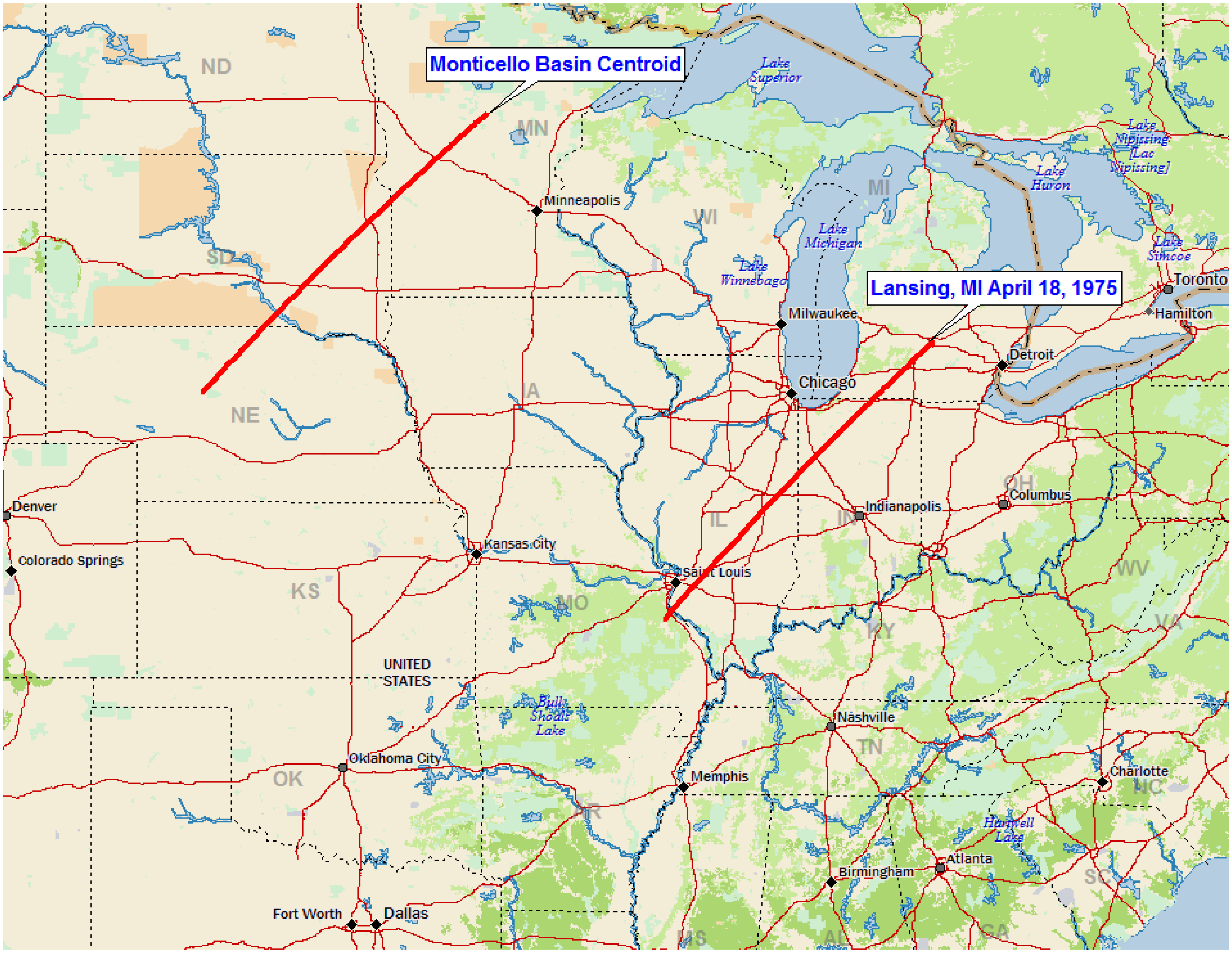
Notes: Storm mamximzation and DAD taken from the EPRI report.

Observed Storm Depth-Area-Duration	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
100 sq miles	**4.6**	**4.9**	-	**4.9**	-	-	-	-	-
200 sq miles	**4.4**	**4.8**	-	**4.8**	-	-	-	-	-
500 sq miles	**4.3**	**4.6**	-	**4.7**	-	-	-	-	-
1000 sq miles	**4.1**	**4.5**	-	**4.5**	-	-	-	-	-
5000 sq miles	**3.3**	**3.6**	-	**3.7**	-	-	-	-	-
10000 sq miles	**2.6**	**3.0**	-	**3.1**	-	-	-	-	-

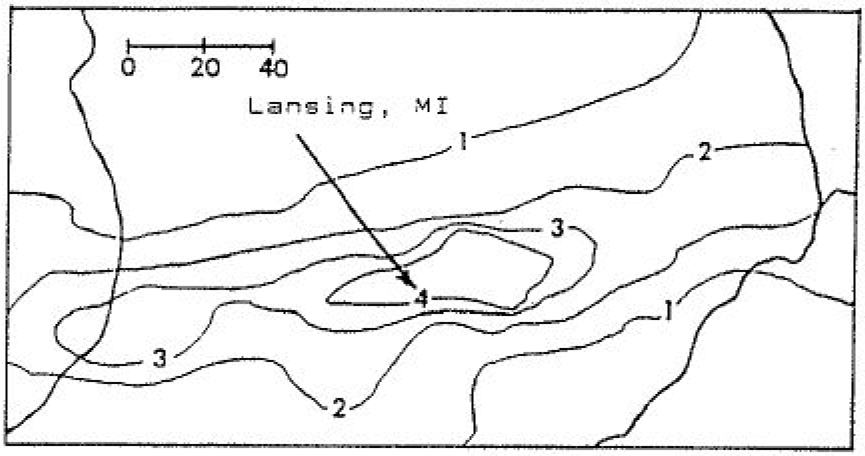
Adjusted Storm Depth-Area-Duration	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
100 sq miles	**4.4**	**4.6**	-	**4.7**	-	-	-	-	-
200 sq miles	**4.2**	**4.6**	-	**4.6**	-	-	-	-	-
500 sq miles	**4.1**	**4.4**	-	**4.4**	-	-	-	-	-
1000 sq miles	**3.9**	**4.3**	-	**4.3**	-	-	-	-	-
5000 sq miles	**3.1**	**3.4**	-	**3.5**	-	-	-	-	-
10000 sq miles	**2.5**	**2.8**	-	**3.0**	-	-	-	-	-

Storm or Storm Center Name	**Lansing, MI**			
Storm Date(s)	4/18-19/1975			
Storm Type	Frontal/Convection			
Storm Location	42.73 N	84.56 W		
Storm Center Elevation	850			
Precipitation Total & Duration	5.12 Inches in 2 6			
Storm Representative Dew Point	67.0 F	6		
Storm Representative Dew Point Location	38.00 N	90.45 W	April	May
Maximum Dew Point	72.0 F		69	75
Moisture Inflow Vector	SW @ 450			
In-place Maximization Factor	**1.27**			
Temporal Transposition (Date)	30-Apr			
Transposition Dew Point Location	41.88 N	100.60 W	April	May
Transposition Maximum Dew Point	67.0 F		64.76	71.75
Transposition Adjustment Factor	**0.75**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**0.95**			

Attachment 2 Table 8: Storm spreadsheet for Lansing, MI April 1975



Attachment 2 Figure 11: Moisture inflow map for Lansing, MI April 1975



ISOHYETAL ANALYSIS

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Miles	Duration of Rainfall in Hours 6	12	24
100	4.57	4.88	4.92
200	4.42	4.79	4.83
500	4.27	4.58	4.66
1000	4.12	4.47	4.53
5000	3.29	3.58	3.67
10000	2.69	2.97	3.1

Attachment 2 Figure 12 and Attachment 2 Table 9: Total storm isohyetal analysis and Depth-area-duration values for Lansing, MI April 1975

Storm Name:	Louisville, KY SPAS 1244	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	2/28/1997 - 3/4/1997	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	15-Mar	
	Lat	Long
Storm Center Location	38.10 N	85.67 W
Storm Rep Dew Point Location	30.80 N	85.70 W
Transposition Dew Point Locati	39.33 N	94.40 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	S @ 505	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	550	feet
Storm Analysis Duration	24	hrs

The storm representative dew point is	68.5 F	with total precipitable water above sea level of			2.10	inches.
The in-place maximum dew point is	70.0 F	with total precipitable water above sea level of			2.25	inches.
The transpositioned maximum dew point is	63.5 F	with total precipitable water above sea level of			1.64	inches.
The in-place storm elevation is	550	which subtracts	0.12	inches of precipitable water at	68.5 F	
The in-place storm elevation is	550	which subtracts	0.12	inches of precipitable water at	70.0 F	
The transposition storm elevation at	1,300	which subtracts	0.22	inches of precipitable water at	63.5 F	
The moisture inflow barrier height is	1,300	which subtracts	0.22	inches of precipitable water at	63.5 F	

The in-place maximization factor is	1.08
The transposition factor is	0.67
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	0.72

Notes: Storm representative dew point value was based on maximum 24-hr Td values for February 27-28, 1997 at KTOI, KDHN, KOZR and KPAM.

Observed Storm Depth-Area-Duration

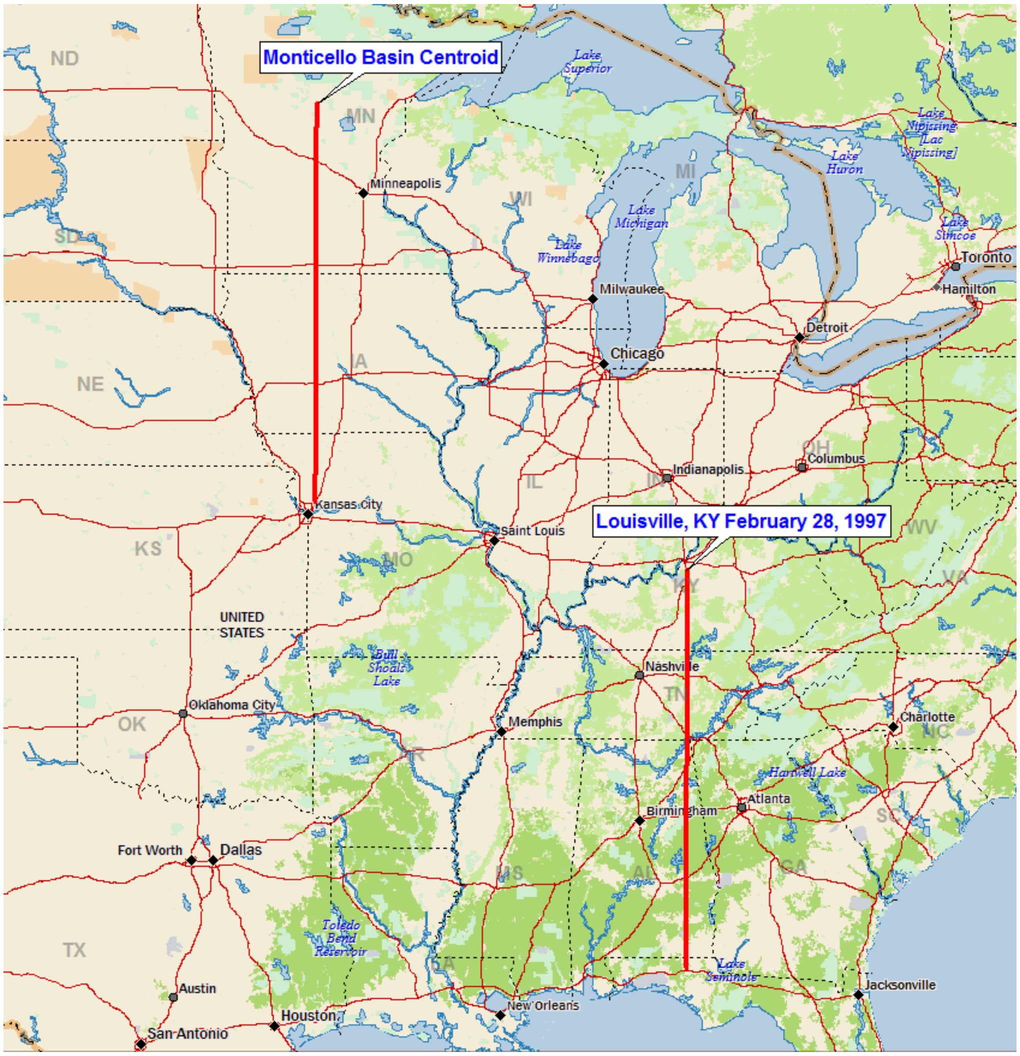
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	3.0	4.1	5.3	7.0	9.7	10.6	12.2	12.3	13.1
10 sq miles	3.0	4.1	5.3	7.0	9.7	10.6	12.2	12.3	13.1
100 sq miles	2.5	3.8	5.0	6.7	8.6	10.5	11.8	11.8	12.6
200 sq miles	2.4	3.7	4.8	6.4	8.2	10.3	11.7	11.7	12.4
500 sq miles	2.1	3.3	4.4	6.0	7.6	9.8	11.3	11.3	12.0
1000 sq miles	1.6	3.1	4.1	5.6	7.1	9.4	10.8	10.9	11.7
2000 sq miles	1.5	2.6	3.7	5.2	6.8	9.0	10.3	10.3	11.3
5000 sq miles	1.1	2.3	3.2	4.4	6.3	8.1	9.7	9.7	10.7
10000 sq miles	0.8	1.9	2.9	4.2	5.6	7.4	9.0	9.1	10.0
20000 sq miles	0.6	1.5	2.5	3.6	4.9	6.5	8.2	8.3	9.2
50000 sq miles	0.4	1.0	1.6	2.8	3.6	5.0	6.4	6.6	7.5
100000 sq miles	0.2	0.6	1.0	1.6	2.1	2.6	3.7	4.3	5.6

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	2.2	3.0	3.8	5.1	7.0	7.6	8.8	8.8	9.4
10 sq miles	2.1	3.0	3.8	5.1	7.0	7.6	8.8	8.8	9.4
100 sq miles	1.8	2.7	3.6	4.8	6.2	7.6	8.5	8.5	9.1
200 sq miles	1.7	2.6	3.5	4.6	5.9	7.4	8.4	8.4	8.9
500 sq miles	1.5	2.4	3.2	4.3	5.4	7.1	8.1	8.1	8.7
1000 sq miles	1.2	2.2	2.9	4.0	5.1	6.8	7.8	7.8	8.4
2000 sq miles	1.0	1.9	2.7	3.8	4.9	6.5	7.4	7.4	8.2
5000 sq miles	0.8	1.6	2.3	3.2	4.5	5.9	7.0	7.0	7.7
10000 sq miles	0.6	1.4	2.1	3.0	4.1	5.3	6.5	6.5	7.2
20000 sq miles	0.4	1.1	1.8	2.6	3.5	4.7	5.9	6.0	6.6
50000 sq miles	0.3	0.7	1.2	2.0	2.6	3.6	4.6	4.7	5.4
100000 sq miles	0.1	0.4	0.7	1.2	1.5	1.8	2.7	3.1	4.0

Storm or Storm Center Name	**Louisville, KY SPAS 1244**	
Storm Date(s)	2/28/1997 - 3/4/1997	
Storm Type	General Storm	
Storm Location	38.10 N	85.67 W
Storm Center Elevation	550	
Precipitation Total & Duration	13.51 inches in 95 hours	
Storm Representative Dew Point	68.5 F	24
Storm Representative Dew Point Location	30.80 N	85.70 W
Maximum Dew Point	70.0 F	
Moisture Inflow Vector	S @ 505	
In-place Maximization Factor	**1.08**	
Temporal Transposition (Date)	15-Mar	
Transposition Dew Point Location	39.33 N	94.40 W
Transposition Maximum Dew Point	63.5 F	
Transposition Adjustment Factor	**0.67**	
Average Basin Elevation	1,300	
Highest Elevation in Basin	1,896	
Inflow Barrier Height	1,300	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**0.72**	

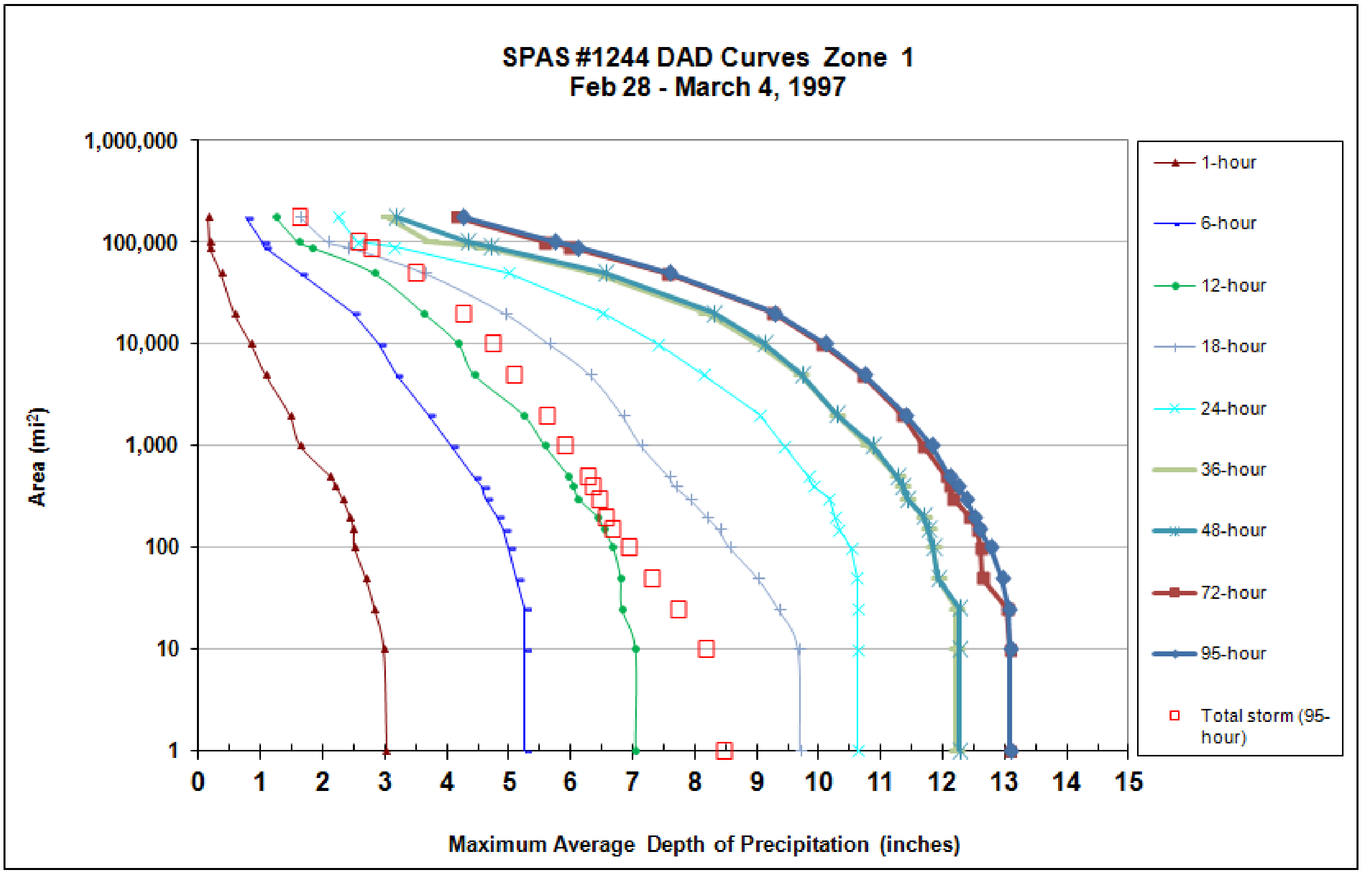
Attachment 2 Table 10: Storm spreadsheet for Louisville, KY February 1997



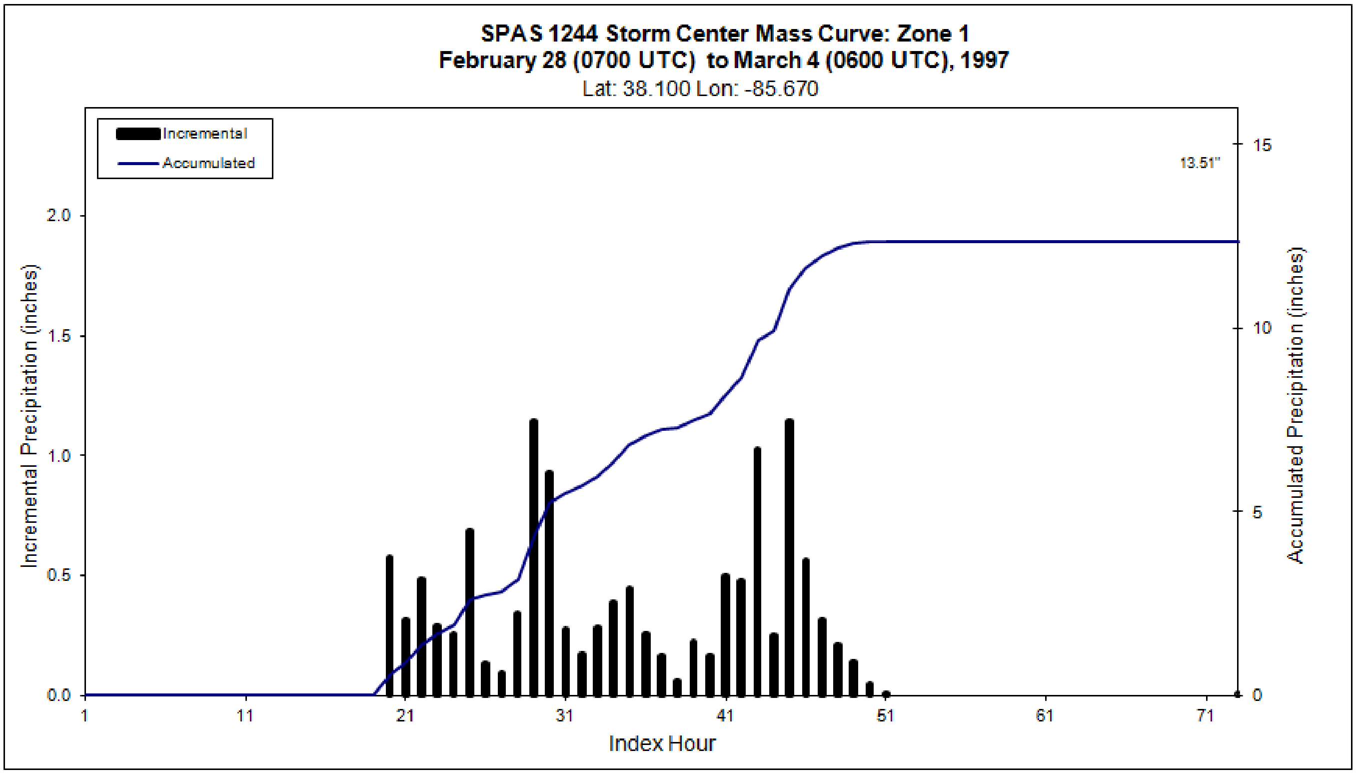
Attachment 2 Figure 13: Moisture inflow map for Louisville, KY February 1997

Storm 1244 - February 28 (0800 UTC) - March 4 (0600 UTC), 1997										
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)										
	Duration (hours)									
Area (mi^2)	1	6	12	18	24	36	48	72	95	Total
0.3	3.06	5.42	7.26	9.97	10.94	12.61	12.61	13.51	13.51	8.62
1	3.02	5.25	7.03	9.70	10.62	12.21	12.27	13.07	13.07	8.48
10	2.97	5.25	7.03	9.67	10.62	12.21	12.27	13.07	13.07	8.19
25	2.82	5.25	6.81	9.34	10.62	12.21	12.27	13.02	13.05	7.73
50	2.68	5.13	6.79	9.01	10.61	11.91	11.92	12.64	12.96	7.31
100	2.50	4.98	6.67	8.56	10.52	11.83	11.84	12.60	12.77	6.94
150	2.49	4.91	6.52	8.38	10.32	11.75	11.76	12.56	12.59	6.68
200	2.43	4.80	6.42	8.19	10.25	11.67	11.68	12.41	12.50	6.56
300	2.31	4.63	6.12	7.91	10.16	11.42	11.42	12.15	12.37	6.46
400	2.20	4.56	6.04	7.67	9.90	11.34	11.35	12.10	12.24	6.36
500	2.11	4.43	5.96	7.57	9.83	11.26	11.27	12.04	12.11	6.26
1,000	1.63	4.06	5.57	7.13	9.44	10.79	10.86	11.68	11.80	5.89
2,000	1.46	3.69	5.23	6.82	9.03	10.28	10.29	11.34	11.38	5.62
5,000	1.07	3.18	4.44	6.30	8.14	9.69	9.72	10.70	10.73	5.08
10,000	0.84	2.91	4.18	5.64	7.40	9.02	9.11	10.03	10.09	4.73
20,000	0.57	2.48	3.63	4.92	6.50	8.17	8.29	9.24	9.28	4.26
50,000	0.35	1.64	2.82	3.62	4.99	6.37	6.56	7.54	7.59	3.50
89,000	0.17	1.04	1.82	2.40	3.15	4.57	4.70	5.96	6.10	2.78
100,000	0.17	1.02	1.61	2.07	2.56	3.71	4.33	5.57	5.73	2.58
177,564	0.15	0.76	1.24	1.62	2.25	3.04	3.18	4.15	4.26	1.63

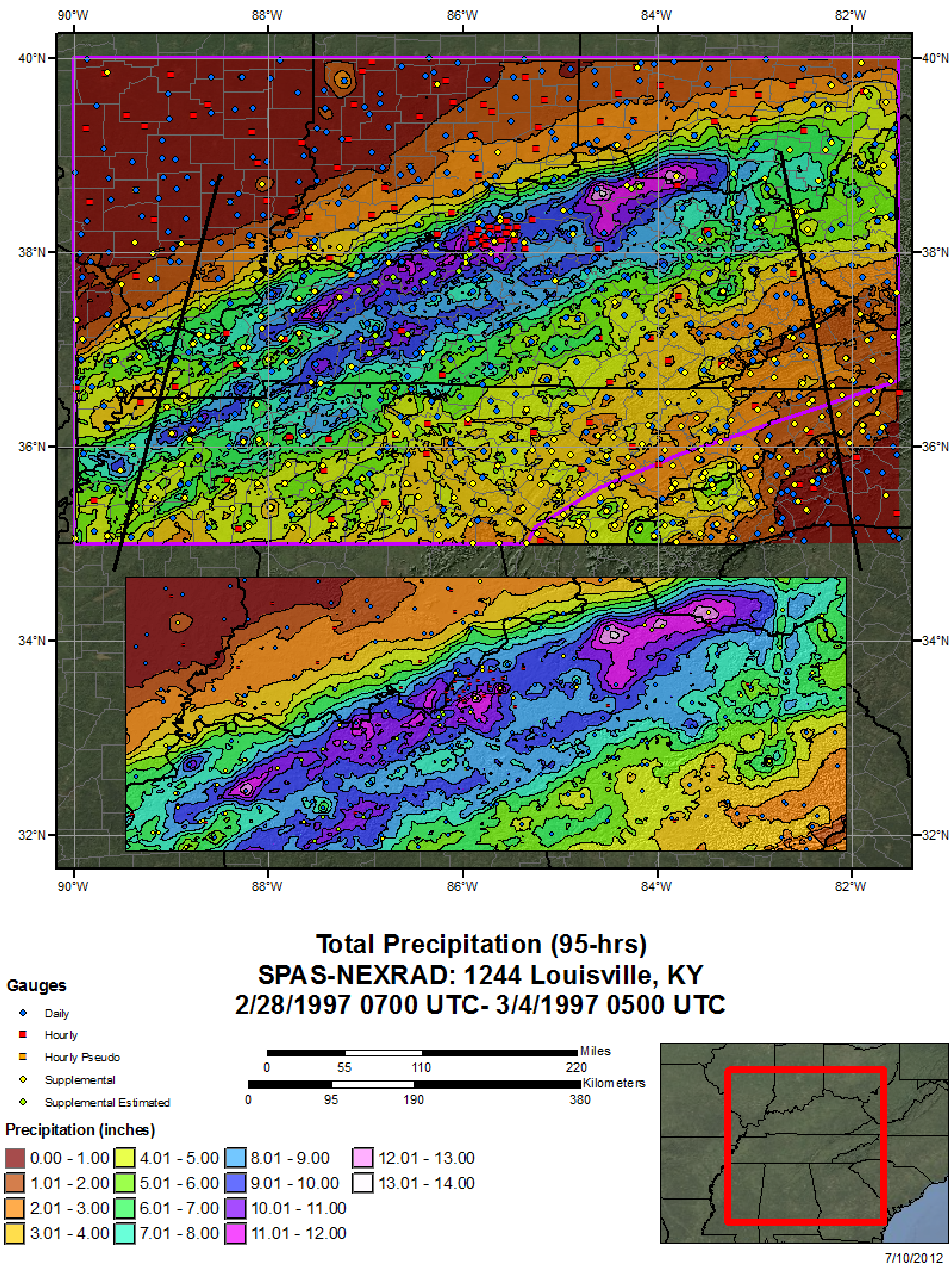
Attachment 2 Table 11: Depth-area-duration values for Louisville, KY February 1997



Attachment 2 Figure 14: Depth-area-duration chart for Louisville, KY February 1997



Attachment 2 Figure 15: Mass curve chart for Louisville, KY February 1997



Attachment 2 Figure 16: Total storm isohyetal analysis for Louisville, KY February 1997

Storm Name:	Madisonville-KY-SPAS 1278
Storm Date:	3/7-11/1964
AWA Analysis Date:	8/24/2014

Storm Adjustment for Basin Centroid-Monticello

Temporal Transposition Date	25-Mar	
	Lat	Long
Storm Center Location	37.35 N	87.50 W
Storm Rep Dew Point Location	29.61 N	91.20 W
Transposition Dew Point Locati	38.87 N	98.51 W
Basin Location	46.63 N	94.37 W

Moisture Inflow Direction	SSW @ 575	miles
Basin Average Elevation	1,300	feet
Storm Center Elevation	500	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	70.0 F	with total precipitable water above sea level of			2.25	inches.
The in-place maximum dew point is	73.0 F	with total precipitable water above sea level of			2.60	inches.
The transpositioned maximum dew point is	65.5 F	with total precipitable water above sea level of			1.82	inches.
The in-place storm elevation is	500	which subtracts	0.11	inches of precipitable water at	70.0 F	
The in-place storm elevation is	500	which subtracts	0.12	inches of precipitable water at	73.0 F	
The transposition storm elevation at	1,300	which subtracts	0.24	inches of precipitable water at	65.5 F	
The moisture inflow barrier height is	1,300	which subtracts	0.24	inches of precipitable water at	65.5 F	

The in-place maximization factor is	1.16
The transposition factor is	0.64
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	0.74

Notes: DAD values taken from SPAS 1278 Zone 1. Used Td values on March 8-9 at KARA and KMSY. Values were selected in region where temperature did not vary more than a degree over a large area.

Observed Storm Depth-Area-Duration

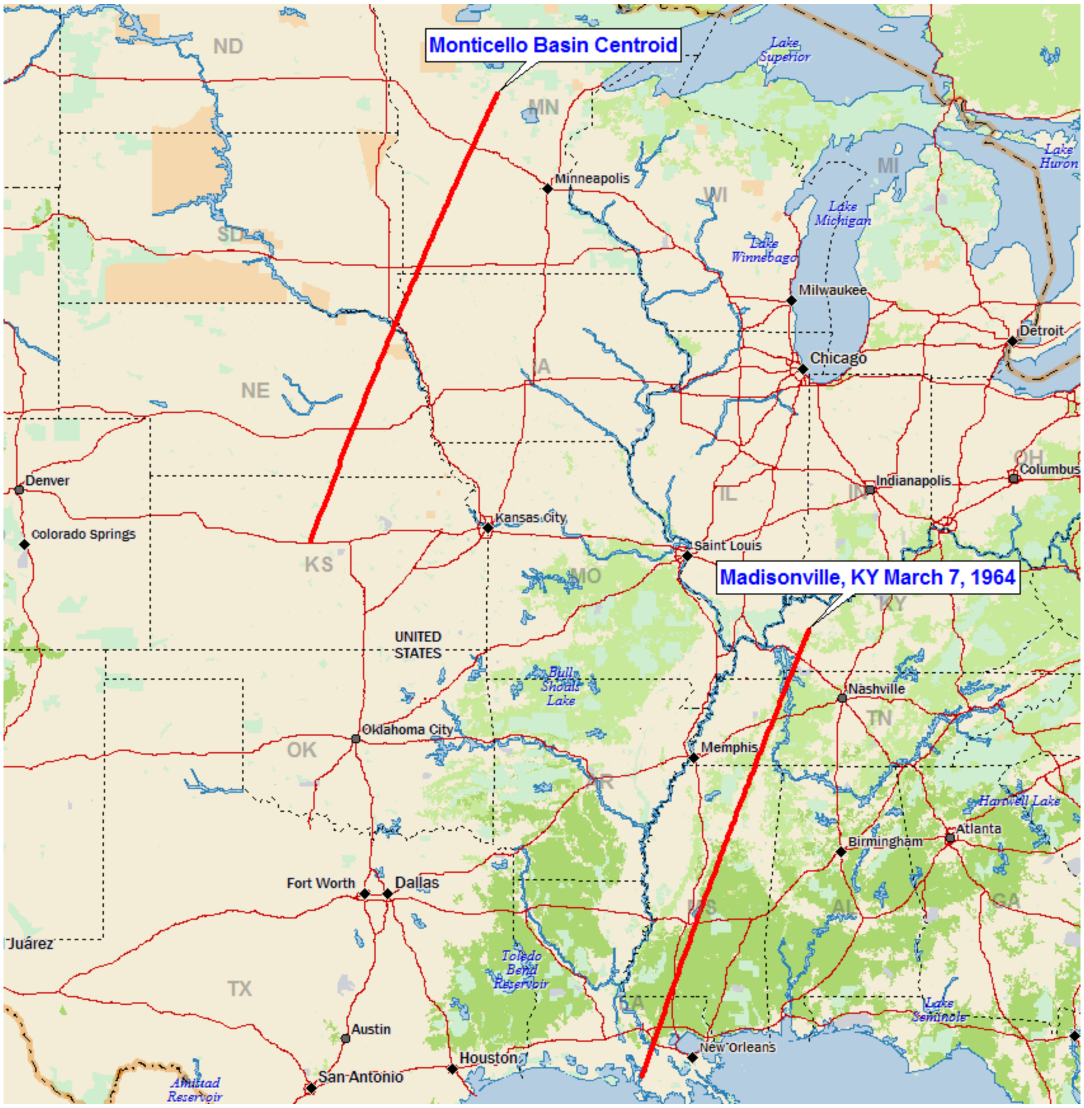
	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours	96 Hours
1 sq miles	2.0	3.8	5.6	7.6	8.5	9.2	11.0	11.3	11.4
10 sq miles	2.0	3.8	5.6	7.6	8.5	9.2	11.0	11.3	11.4
100 sq miles	1.9	3.7	5.5	7.5	8.5	9.2	11.0	11.3	11.4
200 sq miles	1.8	3.7	5.4	7.2	8.3	9.0	10.8	11.1	11.3
500 sq miles	1.7	3.5	5.1	6.7	7.6	8.3	9.9	10.5	10.6
1000 sq miles	1.5	3.4	4.7	6.5	7.1	8.0	9.6	10.1	10.2
2000 sq miles	1.4	3.2	4.5	6.3	6.8	7.6	9.1	9.7	9.8
5000 sq miles	1.2	2.8	4.0	5.8	6.4	7.2	8.6	9.3	9.3
10000 sq miles	1.0	2.5	3.7	5.3	6.1	6.9	8.3	8.8	8.8
20000 sq miles	0.8	2.1	3.4	4.6	5.6	6.5	7.8	8.2	8.2
50000 sq miles	0.6	1.8	2.6	3.8	4.8	5.7	6.4	7.1	7.2

Adjusted Storm Depth-Area-Duration

	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours	96 Hours
1 sq miles	1.4	2.8	4.2	5.6	6.3	6.7	8.1	8.3	8.4
10 sq miles	1.4	2.8	4.1	5.6	6.3	6.7	8.1	8.3	8.4
100 sq miles	1.4	2.8	4.1	5.5	6.3	6.7	8.1	8.3	8.4
200 sq miles	1.3	2.7	4.0	5.3	6.1	6.6	8.0	8.2	8.3
500 sq miles	1.2	2.6	3.7	4.9	5.6	6.1	7.3	7.7	7.8
1000 sq miles	1.1	2.5	3.5	4.7	5.2	5.9	7.1	7.4	7.5
2000 sq miles	1.0	2.3	3.3	4.6	5.0	5.6	6.7	7.2	7.2
5000 sq miles	0.9	2.0	2.9	4.3	4.7	5.3	6.3	6.8	6.9
10000 sq miles	0.8	1.8	2.7	3.9	4.5	5.0	6.1	6.5	6.5
20000 sq miles	0.6	1.6	2.5	3.4	4.1	4.8	5.8	6.1	6.1
50000 sq miles	0.4	1.3	1.9	2.8	3.6	4.2	4.7	5.2	5.3

Storm or Storm Center Name	**Madisonville-KY-SPAS 1278**			
Storm Date(s)	3/7-11/1964			
Storm Type	Synoptic			
Storm Location	37.35 N	87.50 W		
Storm Center Elevation	500			
Precipitation Total & Duration	11.69 Inches 120-hours			
Storm Representative Dew Point	70.0 F	24		
Storm Representative Dew Point Location	29.61 N	91.20 W	Mar	Apr
Maximum Dew Point	73.0 F		72.02	74.21
Moisture Inflow Vector	SSW @ 575	Miles		
In-place Maximization Factor	**1.16**			
Temporal Transposition (Date)	25-Mar			
Transposition Dew Point Location	38.87 N	98.51 W	Mar	Apr
Transposition Maximum Dew Point	65.5 F		64.33	67.21
Transposition Adjustment Factor	**0.64**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**0.74**			

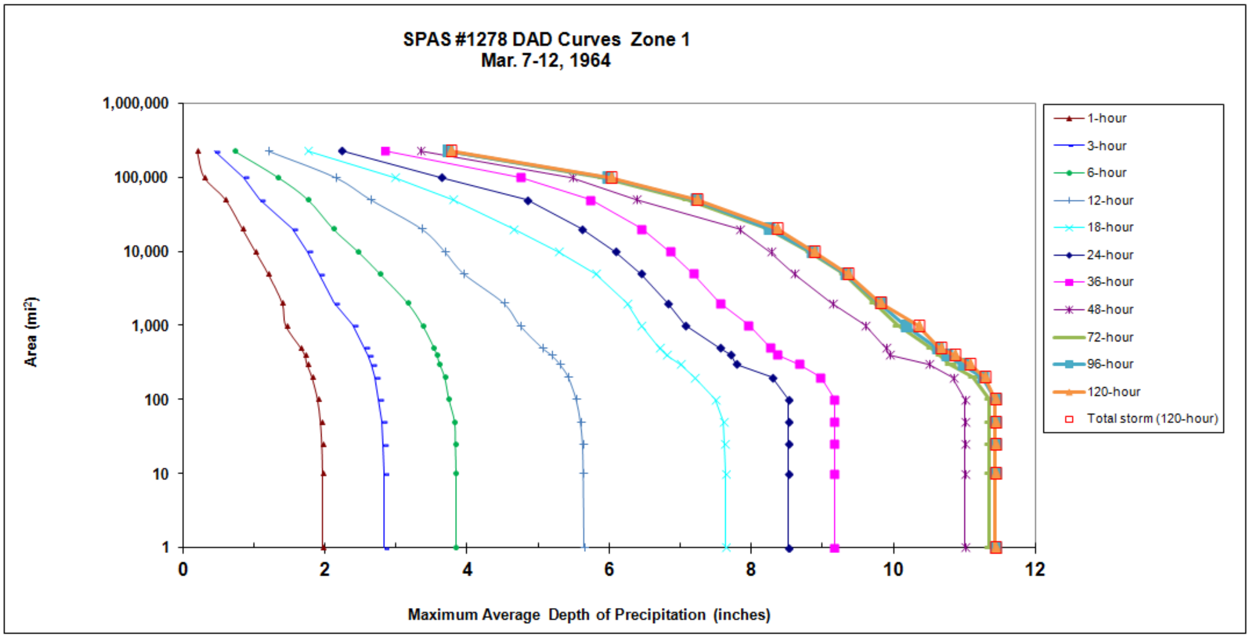
Attachment 2 Table 12: Storm spreadsheet for Madisonville, KY March 1964



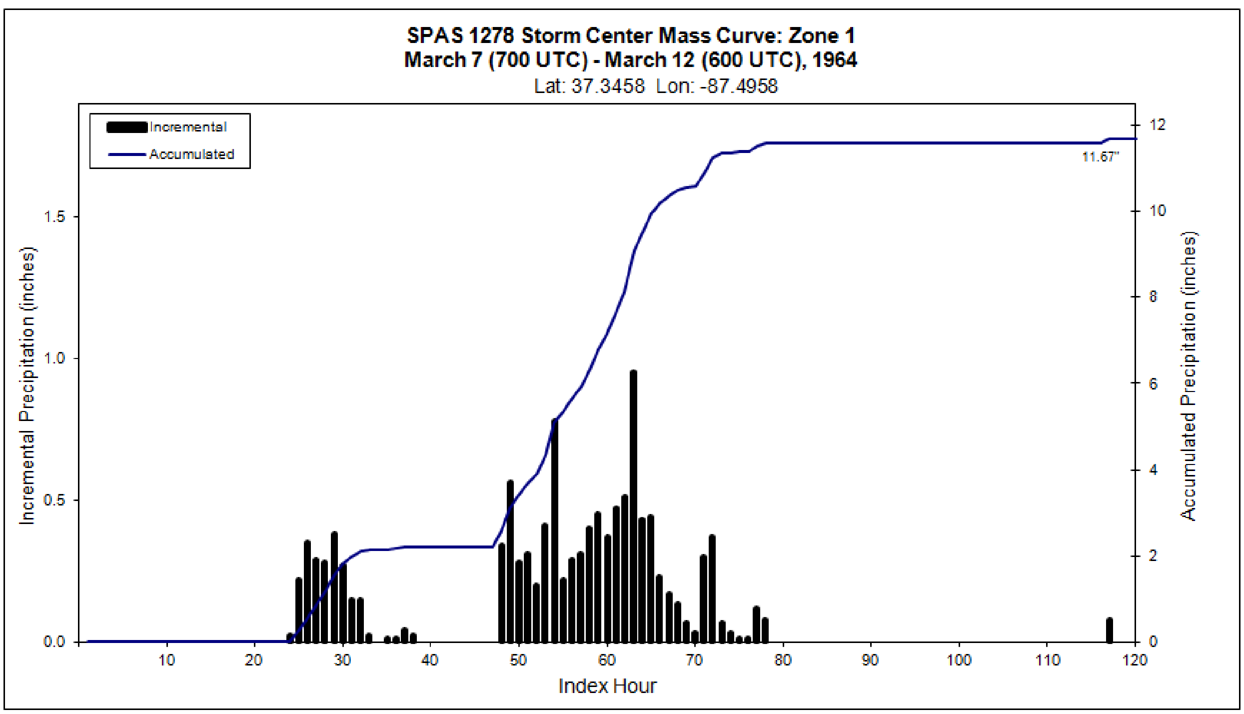
Attachment 2 Figure 17: Moisture inflow map for Madisonville, KY March 1964

Storm 1278 - March 7 (0700 UTC) - Mach 12 (0600 UTC), 1964												
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)												
	Duration (hours)											
Area (mi^2)	1	3	6	12	18	24	36	48	72	96	120	Total
0.3	2	2.89	3.9	5.64	7.74	8.71	9.37	11.25	11.59	11.67	11.67	11.67
1	1.97	2.83	3.84	5.64	7.63	8.52	9.17	11	11.34	11.43	11.43	11.43
10	1.97	2.83	3.84	5.63	7.63	8.52	9.17	11	11.34	11.43	11.43	11.43
25	1.96	2.82	3.83	5.62	7.62	8.52	9.17	11	11.34	11.43	11.43	11.43
50	1.94	2.8	3.82	5.59	7.61	8.52	9.17	11	11.34	11.43	11.43	11.43
100	1.9	2.76	3.74	5.53	7.49	8.52	9.17	11	11.34	11.43	11.43	11.43
200	1.82	2.7	3.68	5.42	7.19	8.29	8.97	10.83	11.12	11.25	11.28	11.28
300	1.75	2.65	3.61	5.3	7	7.78	8.67	10.49	10.79	10.96	11.06	11.06
400	1.72	2.6	3.57	5.18	6.81	7.71	8.37	9.94	10.65	10.74	10.85	10.85
500	1.66	2.55	3.53	5.05	6.7	7.55	8.27	9.89	10.53	10.61	10.65	10.65
1,000	1.45	2.39	3.37	4.74	6.45	7.07	7.96	9.59	10.05	10.16	10.34	10.34
2,000	1.4	2.13	3.16	4.51	6.25	6.82	7.56	9.13	9.72	9.8	9.81	9.81
5,000	1.2	1.92	2.77	3.95	5.81	6.44	7.18	8.6	9.3	9.32	9.35	9.35
10,000	1.02	1.75	2.46	3.68	5.29	6.09	6.86	8.26	8.82	8.84	8.88	8.88
20,000	0.84	1.54	2.12	3.36	4.64	5.61	6.46	7.82	8.23	8.24	8.36	8.36
50,000	0.6	1.08	1.76	2.64	3.79	4.84	5.74	6.38	7.1	7.2	7.23	7.23
100,000	0.3	0.86	1.34	2.14	2.98	3.63	4.76	5.47	5.9	5.97	6.01	6.01
227,343	0.2	0.45	0.73	1.2	1.76	2.24	2.85	3.34	3.72	3.72	3.77	3.77

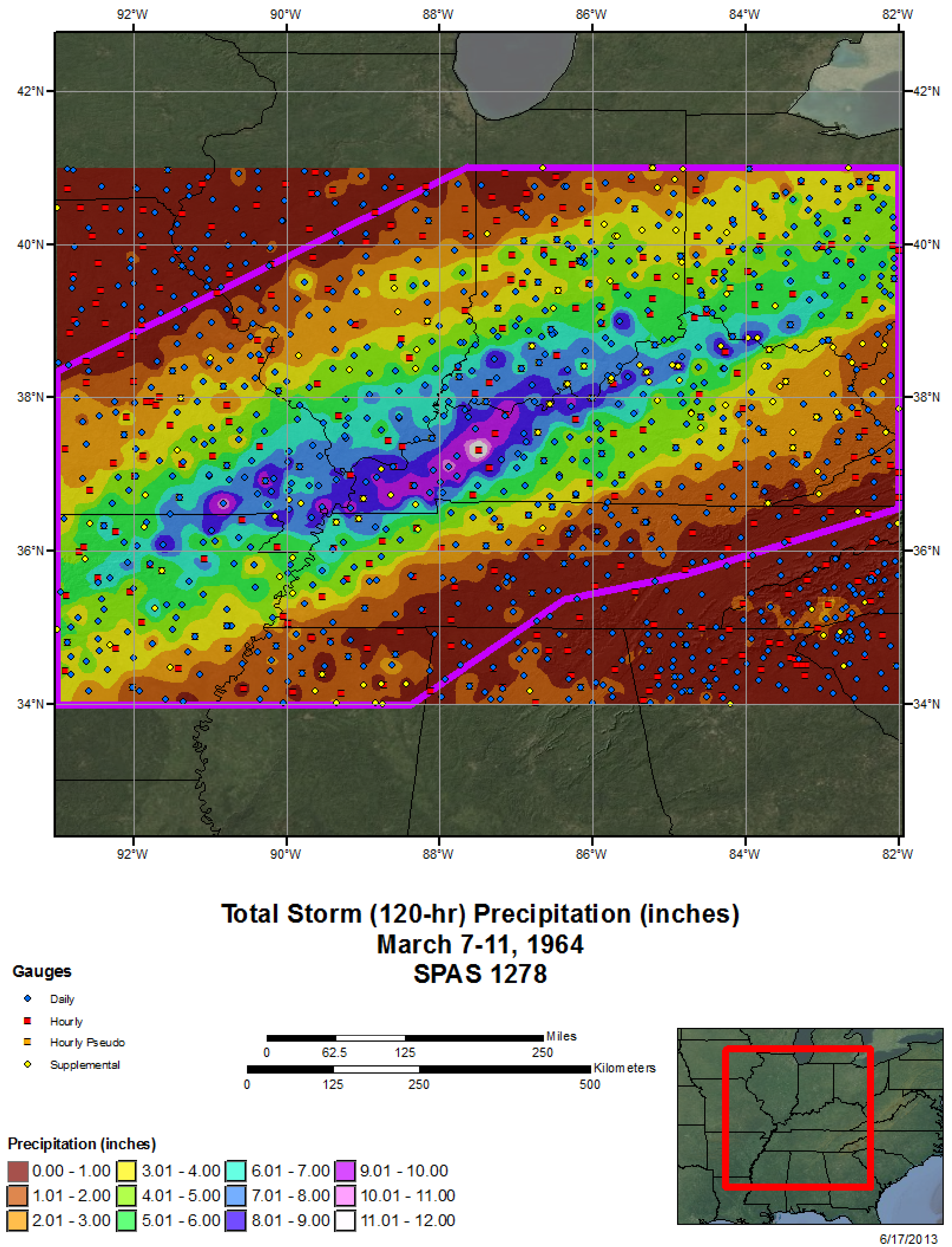
Attachment 2 Table 13: Depth-area-duration values for Madisonville, KY March 1964



Attachment 2 Figure 18: Depth-area-duration chart for Madisonville, KY March 1964



Attachment 2 Figure 19: Mass curve chart for Madisonville, KY March 1964



Attachment 2 Figure 20: Total storm isohyetal analysis for Madisonville, KY March 1964

Storm Name:	**Oconto, WI GL 2-19**	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**4/5-11/1919**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**20-Apr**	
	Lat	**Long**
Storm Center Location	**44.89 N**	**87.87 W**
Storm Rep Dew Point Location	**41.85 N**	**86.20 W**
Transposition Dew Point Locati	**43.59 N**	**92.66 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**SSE @ 225**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**600**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**56.0 F**	with total precipitable water above sea level of		**1.13**	inches.
The in-place maximum dew point is	**66.0 F**	with total precipitable water above sea level of		**1.86**	inches.
The transpositioned maximum dew point is	**65.5 F**	with total precipitable water above sea level of		**1.82**	inches.
The in-place storm elevation is	**600**	which subtracts **0.08**	inches of precipitable water at	**56.0 F**	
The in-place storm elevation is	**600**	which subtracts **0.11**	inches of precipitable water at	**66.0 F**	
The transposition storm elevation at	**1,300**	which subtracts **0.24**	inches of precipitable water at	**65.5 F**	
The moisture inflow barrier height is	**1,300**	which subtracts **0.24**	inches of precipitable water at	**65.5 F**	

The in-place maximization factor is	**1.50**
The transposition factor is	**0.90**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.35**

Notes: In-place maximization factor calculated as 1.67, held to 1.50 based on HMR guidance. Added 2°F to the USACE 12-hr persisting Td to account for difference in average versus persisting Td climatologies.

Observed Storm Depth-Area-Duration

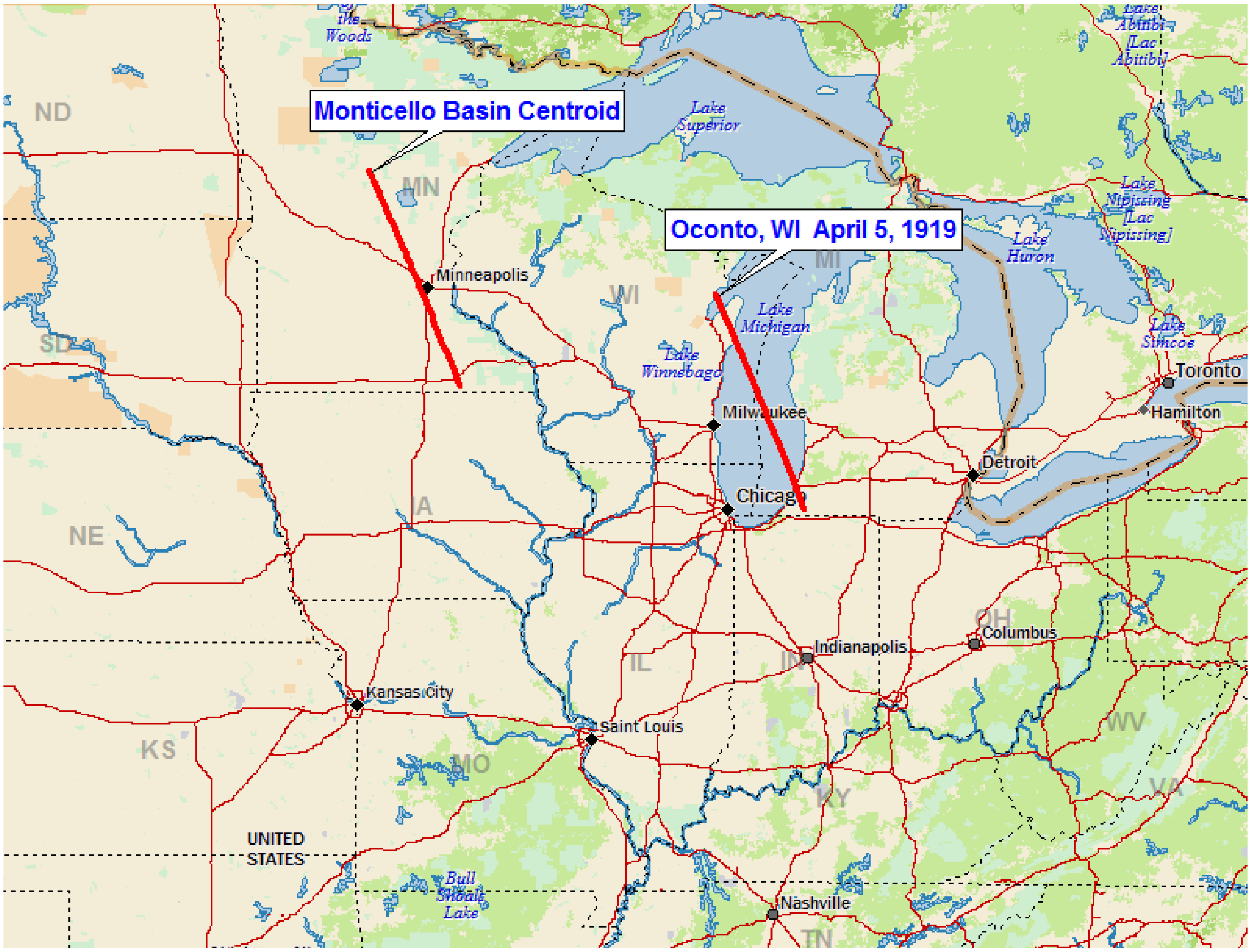
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**2.9**	**3.0**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.8**	**4.2**
100 sq miles	**2.7**	**2.8**	**3.3**	**3.4**	**3.4**	**3.4**	**3.4**	**3.5**	**3.8**
200 sq miles	**2.5**	**2.6**	**3.1**	**3.2**	**3.2**	**3.2**	**3.2**	**3.3**	**3.7**
500 sq miles	**2.2**	**2.4**	**2.8**	**2.9**	**2.9**	**2.9**	**2.9**	**3.1**	**3.4**
1000 sq miles	**1.9**	**2.0**	**2.4**	**2.5**	**2.5**	**2.5**	**2.5**	**2.9**	**3.2**
2000 sq miles	**1.6**	**1.7**	**2.1**	**2.2**	**2.2**	**2.2**	**2.2**	**2.4**	**2.8**
5000 sq miles	**1.0**	**1.1**	**1.5**	**1.6**	**1.6**	**1.6**	**1.6**	**1.7**	**2.1**
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**3.9**	**4.1**	**4.9**	**4.9**	**4.9**	**4.9**	**4.9**	**5.1**	**5.7**
100 sq miles	**3.6**	**3.8**	**4.5**	**4.6**	**4.6**	**4.6**	**4.6**	**4.7**	**5.1**
200 sq miles	**3.4**	**3.5**	**4.2**	**4.3**	**4.3**	**4.3**	**4.3**	**4.5**	**5.0**
500 sq miles	**3.0**	**3.2**	**3.8**	**3.9**	**3.9**	**3.9**	**3.9**	**4.2**	**4.6**
1000 sq miles	**2.6**	**2.7**	**3.2**	**3.4**	**3.4**	**3.4**	**3.4**	**3.9**	**4.3**
2000 sq miles	**2.2**	**2.3**	**2.8**	**3.0**	**3.0**	**3.0**	**3.0**	**3.2**	**3.8**
5000 sq miles	**1.4**	**1.5**	**2.0**	**2.2**	**2.2**	**2.2**	**2.2**	**2.3**	**2.8**
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**Oconto, WI GL 2-19**			
Storm Date(s)	4/5-11/1919			
Storm Type	Frontal/Convection			
Storm Location	44.89 N	87.87 W		
Storm Center Elevation	600			
Precipitation Total & Duration	4.50 Inches in 156-hours			
Storm Representative Dew Point	56.0 F	24		
Storm Representative Dew Point Location	41.85 N	86.20 W	April	May
Maximum Dew Point	66.0 F		64	71.5
Moisture Inflow Vector	SSE @ 225			
In-place Maximization Factor	**1.50**			
Temporal Transposition (Date)	20-Apr			
Transposition Dew Point Location	43.59 N	92.66 W	April	May
Transposition Maximum Dew Point	65.5 F		64.34	70.62
Transposition Adjustment Factor	**0.90**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.35**			

Attachment 2 Table 14: Storm spreadsheet for Oconto, WI April 1919



Attachment 2 Figure 21: Moisture inflow map for Oconto, WI April 1919

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES – PERTINENT DATA SHEET

Storm of 5-11 April 1919
Assignment G L 2 - 19
Location Wis., – Mich.
Study Prepared by:

Great Lakes Division
Milwaukee District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 8-26-44
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 11-9-45
Remarks: Center at:

Oconto, Wis.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1:2,500,000

Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	5
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	1
Miscl. precip. records, meteorological data, etc.	5
Form 5002 (Mass rainfall curves)	3

PART II

Final isohyetal maps, in 1 sheet, scale 1:1,000,000

Data and computation sheets:

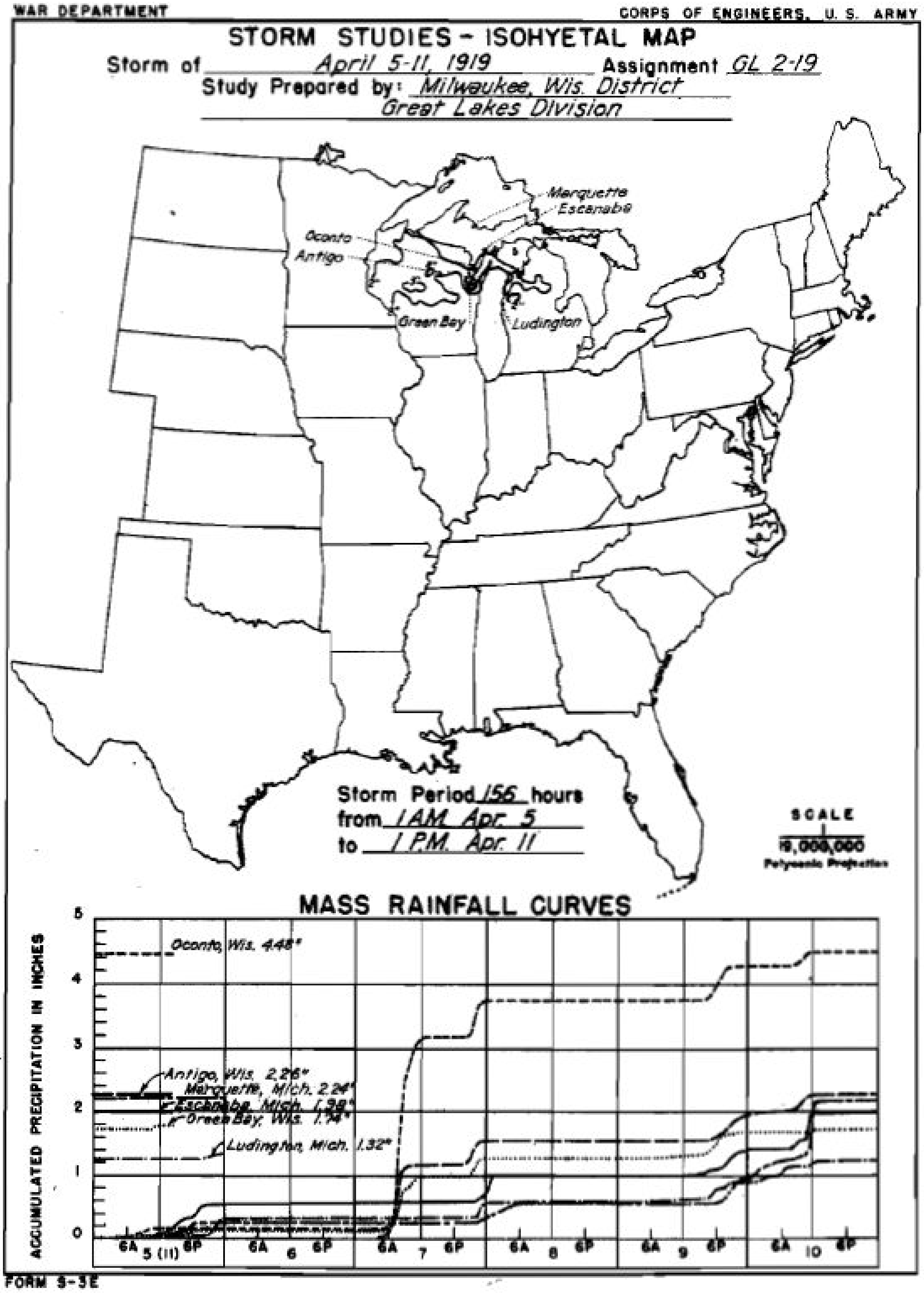
Form S-10 (Data from mass rainfall curves)	1
Form S-11 (Depth-area data from isohyetal map)	1
Form S-12 (Maximum depth-duration data)	1
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	1

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	156
10	2.9	3.0	3.6	3.6	3.6	3.6	3.6	3.8	4.2	4.4	4.5
50	2.8	2.9	3.5	3.5	3.5	3.5	3.5	3.6	4.0	4.2	4.3
100	2.7	2.8	3.3	3.4	3.4	3.4	3.4	3.5	3.8	4.0	4.1
200	2.5	2.6	3.1	3.2	3.2	3.2	3.2	3.3	3.7	3.9	4.0
500	2.2	2.4	2.8	2.9	2.9	2.9	2.9	3.1	3.4	3.6	3.7
1,000	1.9	2.0	2.4	2.5	2.5	2.5	2.5	2.9	3.2	3.4	3.5
2,000	1.6	1.7	2.1	2.2	2.2	2.2	2.2	2.4	2.8	3.1	3.2
5,000	1.0	1.1	1.5	1.6	1.6	1.6	1.6	1.7	2.1	2.5	2.7

Form S-2

Attachment 2 Table 15: Depth-area-duration values for Oconto, WI April 1919



Attachment 2 Figure 22 and Attachment 2 Figure 23: Isohyetal map and Mass curve chart for Oconto, WI April 1919

Storm Name:	**Tuscumbia, MO MR 3-10A**	**Storm Adjustment for Basin Centroid-Monticello**
Storm Date:	**3/17-20/1927**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**5-Apr**	
	Lat	**Long**
Storm Center Location	**38.23 N**	**92.46 W**
Storm Rep Dew Point Location	**34.60 N**	**92.46 W**
Transposition Dew Point Locati	**43.00 N**	**94.37 W**
Basin Location	**46.63 N**	**94.37 W**

Moisture Inflow Direction	**S @ 250**	miles
Basin Average Elevation	**1,300**	feet
Storm Center Elevation	**600**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**64.0 F**	with total precipitable water above sea level of		**1.68**	inches.
The in-place maximum dew point is	**69.5 F**	with total precipitable water above sea level of		**2.20**	inches.
The transpositioned maximum dew point is	**63.0 F**	with total precipitable water above sea level of		**1.60**	inches.
The in-place storm elevation is	**600**	which subtracts	**0.11**	inches of precipitable water at	**64.0 F**
The in-place storm elevation is	**600**	which subtracts	**0.13**	inches of precipitable water at	**69.5 F**
The transposition basin elevation at	**1,300**	which subtracts	**0.22**	inches of precipitable water at	**63.0 F**
The inflow barrier/basin elevation height is	**1,300**	which subtracts	**0.22**	inches of precipitable water at	**63.0 F**

The in-place maximization factor is	**1.32**
The transposition factor is	**0.67**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**0.88**

Notes: Added 2°F to the USACE 12-hr persisting Td to account for difference in average versus persisting Td climatologies.

Observed Storm Depth-Area-Duration

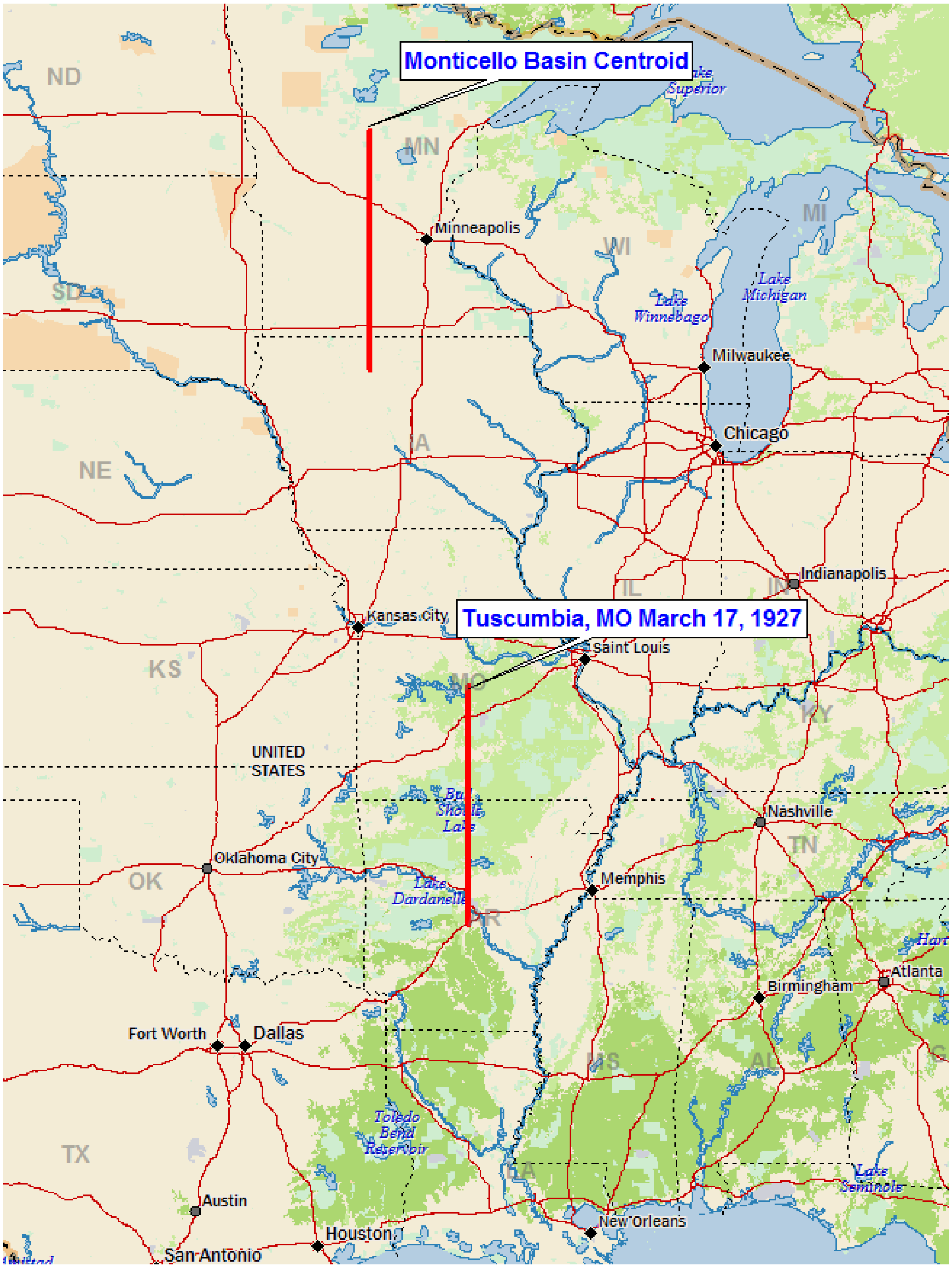
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**3.3**	**3.4**	**4.6**	**4.9**	**5.4**	**5.5**	**5.5**	**5.5**	-
100 sq miles	**3.3**	**3.4**	**4.1**	**4.6**	**5.3**	**5.4**	**5.4**	**5.4**	-
200 sq miles	**3.3**	**3.4**	**3.9**	**4.4**	**5.2**	**5.4**	**5.4**	**5.4**	-
500 sq miles	**3.2**	**3.3**	**3.7**	**4.3**	**5.1**	**5.3**	**5.3**	**5.3**	-
1000 sq miles	**3.1**	**3.3**	**3.5**	**4.2**	**5.0**	**5.2**	**5.2**	**5.2**	-
2000 sq miles	**3.0**	**3.2**	**3.4**	**4.0**	**4.9**	**5.1**	**5.1**	**5.1**	-
5000 sq miles	**2.7**	**2.9**	**3.1**	**3.6**	**4.5**	**4.7**	**4.7**	**4.7**	-
10000 sq miles	**2.4**	**2.6**	**2.8**	**3.3**	**4.1**	**4.3**	**4.4**	**4.4**	-
20000 sq miles	**2.0**	**2.2**	**2.4**	**2.9**	**3.6**	**3.8**	**3.9**	**3.9**	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**2.9**	**3.0**	**4.0**	**4.3**	**4.7**	**4.8**	**4.8**	**4.8**	-
100 sq miles	**2.9**	**3.0**	**3.6**	**4.0**	**4.7**	**4.7**	**4.7**	**4.7**	-
200 sq miles	**2.9**	**3.0**	**3.4**	**3.9**	**4.6**	**4.7**	**4.7**	**4.7**	-
500 sq miles	**2.8**	**2.9**	**3.3**	**3.8**	**4.5**	**4.7**	**4.7**	**4.7**	-
1000 sq miles	**2.7**	**2.9**	**3.1**	**3.7**	**4.4**	**4.6**	**4.6**	**4.6**	-
2000 sq miles	**2.6**	**2.8**	**3.0**	**3.5**	**4.3**	**4.5**	**4.5**	**4.5**	-
5000 sq miles	**2.4**	**2.5**	**2.7**	**3.2**	**4.0**	**4.1**	**4.1**	**4.1**	-
10000 sq miles	**2.1**	**2.3**	**2.5**	**2.9**	**3.6**	**3.8**	**3.9**	**3.9**	-
20000 sq miles	**1.8**	**1.9**	**2.1**	**2.5**	**3.2**	**3.3**	**3.4**	**3.4**	-

Storm or Storm Center Name	**Tuscumbia, MO MR 3-10A**			
Storm Date(s)	3/17-20/1927			
Storm Type	Frontal			
Storm Location	38.23 N	92.46 W		
Storm Center Elevation	600			
Precipitation Total & Duration	5.50 Inches in 36-hours			
Storm Representative Dew Point	64.0 F	24		
Storm Representative Dew Point Location	34.60 N	92.46 W	March	April
Maximum Dew Point	69.5 F		66.5	71
Moisture Inflow Vector	S @ 250			
In-place Maximization Factor	**1.32**			
Temporal Transposition (Date)	5-Apr			
Transposition Dew Point Location	43.00 N	94.37 W	March	April
Transposition Maximum Dew Point	63.0 F		59.55	64.69
Transposition Adjustment Factor	**0.67**			
Average Basin Elevation	1,300			
Highest Elevation in Basin	1,896			
Inflow Barrier Height	1,300			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**0.88**			

Attachment 2 Table 16: Storm spreadsheet for Tuscumbia, MO March 1927



Attachment 2 Figure 24: Moisture inflow map for Tuscumbia, MO March 1927

DEPARTMENT OF THE ARMY | CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET

Storm of 17-20 March 1927
Assignment MR 3-10 (a)
Location Mo.-Kans.
Study Prepared by:
Missouri River Division
Kansas City District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 12/21/45
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 9/23/47
Remarks: Center at Tuscumbia, Mo.
Dewpt. 62°- Ref. Pt. 250 S
Grid F-13

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1:2,500,000

Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	7
Form 5001-B (24-hour " ")	-
Form 5001-D (" " ")	7
Miscl. precip. records, meteorological data, etc.	4
Form 5002 (Mass rainfall curves)	16

PART II

Final isohyetal maps, in 1 sheet, scale 1:1,000,000

Data and computation sheets:

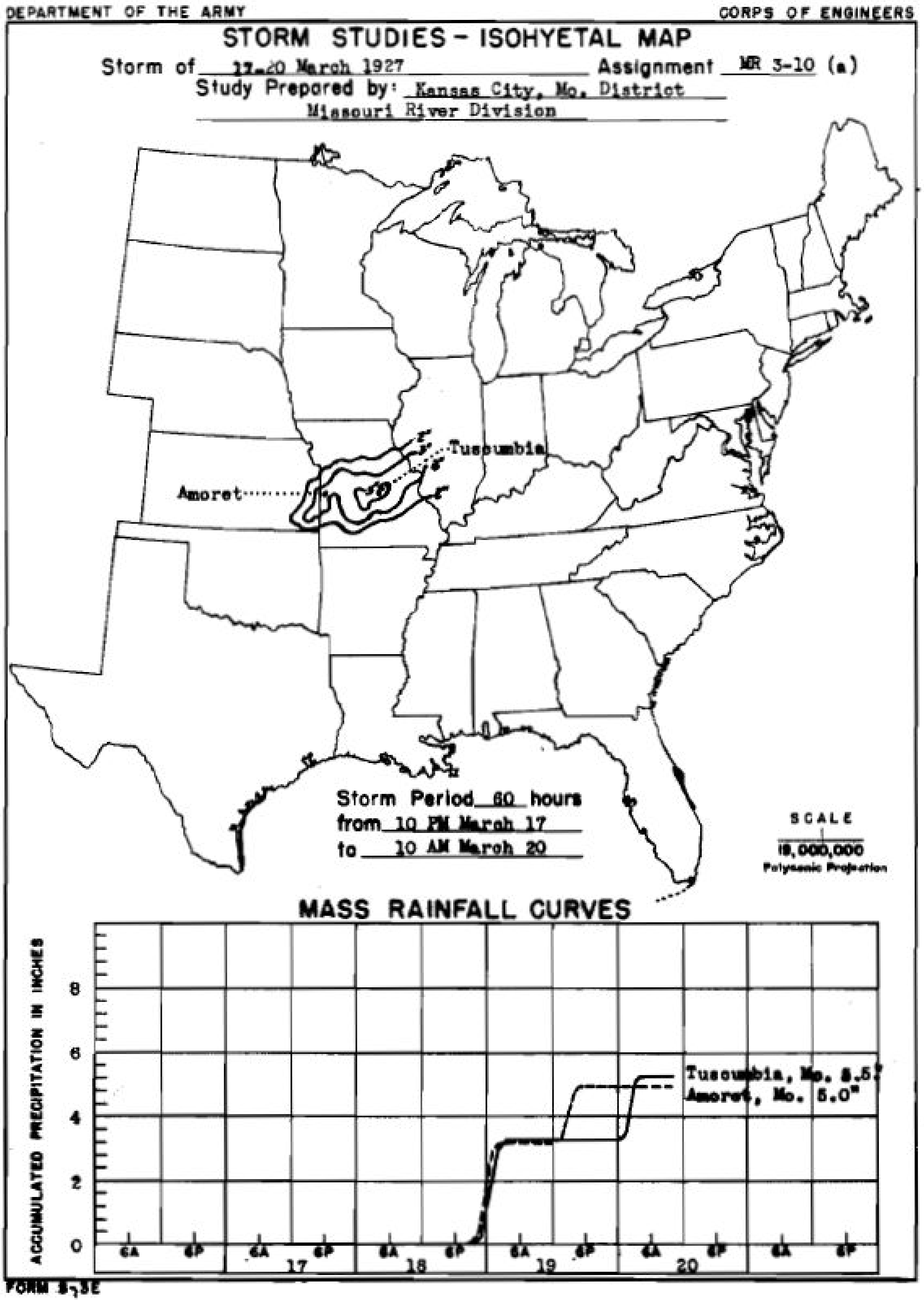
Form S-10 (Data from mass rainfall curves)	3
Form S-11 (Depth-area data from isohyetal map)	1
Form S-12 (Maximum depth-duration data)	4
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60			
10	3.3	3.4	4.6	4.9	5.4	5.5	5.5	5.5			
100	3.3	3.4	4.1	4.6	5.3	5.4	5.4	5.4			
200	3.3	3.4	3.9	4.4	5.2	5.4	5.4	5.4			
500	3.2	3.3	3.7	4.3	5.1	5.3	5.3	5.3			
1,000	3.1	3.3	3.5	4.2	5.0	5.2	5.2	5.2			
2,000	3.0	3.2	3.4	4.0	4.9	5.1	5.1	5.1			
5,000	2.7	2.9	3.1	3.6	4.5	4.7	4.7	4.7			
10,000	2.4	2.6	2.8	3.3	4.1	4.3	4.4	4.4			
20,000	2.0	2.2	2.4	2.9	3.6	3.8	3.9	3.9			
32,000	1.6	1.8	2.1	2.4	3.0	3.2	3.3	3.4			

Form S-2

Attachment 2 Table 17: Depth-area-duration values for Tuscumbia, MO March 1927



Attachment 2 Figure 25 and Attachment 2 Figure 26: Isohyetal map and Mass curve chart for Tuscumbia, MO March 1927

ATTACHMENT 3: Local Intense Precipitation Short Storm List Data

Storm Name	State	AWA Storm Number	Lat	Lon	Year	Month	Day	Maximum 1-hour 1mi^2 Rainfall Using HMR 52 Ratio or SPAS Data	Maximum 6-hour 1mi^2 Rainfall Using HMR 52 Ratio or SPAS Data	Monticello Total Adjustment Factor	Monticello 1-hour 1mi2 PMP	Monticello 6-hour 1mi2 PMP	Precipitation Source
AURORA COLLEGE	IL	5W	41.4575	-88.0699	1996	7	16	6.06	14.40	1.29	7.82	18.58	SPAS 1286
BEAULIEU	MN	33W	47.3000	-95.9000	1909	7	18	7.48	11.17	1.26	9.42	14.07	UMV 1-11A
BOYDEN	IA	30W	43.1900	-96.0100	1926	9	17	10.75	18.40	1.06	11.40	19.50	MR 4-24
COOPER	MI	32W	42.3764	-85.6103	1914	8	31	8.97	13.40	1.29	11.57	17.29	GL 2-16
DAVID CITY	NE	13W	41.2132	-97.0710	1963	6	24	3.87	14.10	1.46	5.65	20.59	SPAS 1030
DUBUQUE	IA	1W	42.4400	-90.7500	2011	7	27	4.10	10.60	1.07	4.39	11.34	SPAS 1220
DUMONT	IA	21W	42.7519	-92.9755	1951	6	25	6.55	9.40	1.33	8.71	12.50	UMV 3-29
ENID	OK	10W	36.3805	-97.8683	1973	10	10	7.40	11.20	0.98	7.25	10.98	SPAS 1034
FALL RIVER	KS	4W	37.6300	-96.0500	2007	6	30	4.68	8.90	1.19	5.57	10.59	SPAS 1228
FOREST CITY	MN	8W	45.2394	-94.5404	1983	6	20	3.66	8.40	1.46	5.34	12.26	SPAS 1035
GRANT TOWNSHIP	NE	29W	42.2400	-96.5900	1940	6	3	9.26	13.83	1.33	12.31	18.39	MR 4-5
HOLT	MO	22W	39.4528	-94.3422	1947	6	18	12.00	12.00	1.10	13.20	13.20	MR 8-20
KELSO	MO	19W	37.1906	-89.5495	1952	8	11	9.26	13.83	1.19	11.01	16.46	UMV 3-30
LARRABEE	IA	42W	42.8608	-95.5453	1891	9	10	6.41	10.40	1.11	7.11	11.54	MR 4-2
MINNEAPOLIS	MN	6W	44.8890	-93.4021	1987	7	23	4.97	11.10	1.16	5.77	12.88	SPAS 1210
MOUNDS	OK	26W	35.8770	-96.0610	1943	5	16	11.32	16.91	1.13	12.79	19.11	SW 2-21
NEOSHO FALLS	KS	31W	38.0820	-95.7010	1926	9	12	9.54	13.60	1.28	12.21	17.41	SW 2-1
STANTON	NE	25W	41.8670	-97.0500	1944	6	10	9.54	15.50	1.32	12.59	20.46	MR 6-15
WOODBURN	IA	38W	41.0120	-93.5991	1903	8	24	4.91	7.34	1.30	6.39	9.54	MR 1-10
WOOSTER	OH	11W	40.9146	-81.9729	1969	7	4	4.62	8.80	1.23	5.68	10.82	SPAS 1209

Attachment 3 Table 1: List of storm used in the Local Intense Precipitation PMP development

Storm Name:	SPAS 1286-Aurora College, IL	Storm Adjustment for Monticello-LIP
Storm Date:	17-Jul-1996	
AWA Analysis Date:	8/25/2014	

Temporal Transposition Date	15-Jul	
	Lat	Long
Storm Center Location	41.46 N	88.07 W
Storm Rep Dew Point Location	38.63 N	92.24 W
Transposition Dew Point Locati	42.49 N	98.27 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	SW @ 300	miles
Basin Average Elevation	950	feet
Storm Center Elevation	650	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	74.0 F	with total precipitable water above sea level of			2.73	inches.
The in-place maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The transpositioned maximum dew point is	80.0 F	with total precipitable water above sea level of			3.60	inches.
The in-place storm elevation is	650	which subtracts	0.16	inches of precipitable water at	74.0 F	
The in-place storm elevation is	650	which subtracts	0.20	inches of precipitable water at	80.5 F	
The transposition storm elevation at	950	which subtracts	0.28	inches of precipitable water at	80.0 F	
The moisture inflow barrier height is	950	which subtracts	0.28	inches of precipitable water at	80.0 F	

The in-place maximization factor is	1.35
The transposition factor is	0.95
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.29

Notes: 24hr average Td from 07-17-96 0000 CDT to 07-17-96 2300 CDT.

Observed Storm Depth-Area-Duration

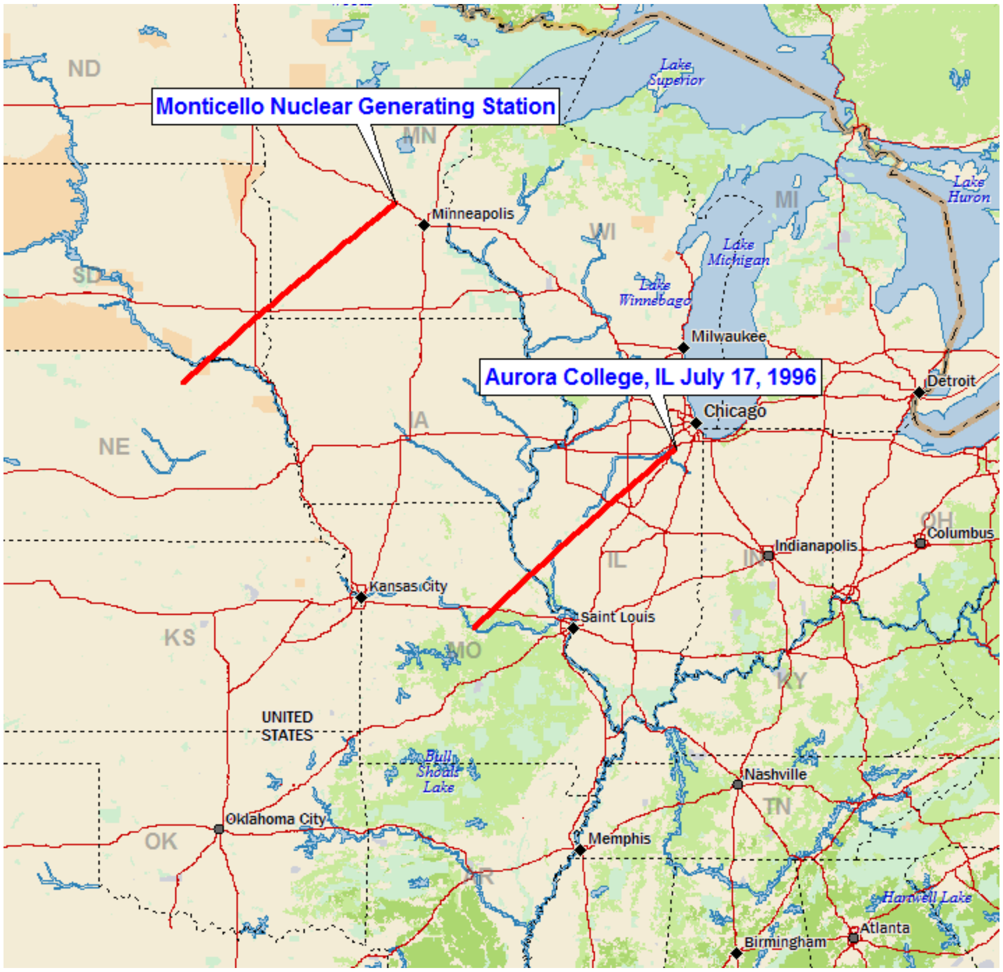
	1 Hour	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	6.1	14.4	15.4	17.3	17.6	-	17.6	-	-	-
10 sq miles	5.9	14.0	15.1	17.2	17.2	-	17.5	-	-	-
100 sq miles	4.3	12.1	13.4	15.6	16.0	-	16.1	-	-	-
200 sq miles	3.6	10.4	12.5	14.6	15.1	-	15.1	-	-	-
500 sq miles	3.1	9.0	10.9	12.8	13.1	-	13.4	-	-	-
1000 sq miles	2.5	7.9	9.7	11.0	11.2	-	12.1	-	-	-
5000 sq miles	1.6	4.8	6.2	7.8	8.1	-	8.4	-	-	-
10000 sq miles	0.7	3.5	5.0	6.1	6.6	-	7.0	-	-	-
20000 sq miles	0.4	1.6	3.6	4.6	5.2	-	5.4	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hour	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	7.8	18.6	19.8	22.4	22.7	-	22.8	-	-	-
10 sq miles	7.6	18.1	19.4	22.2	22.2	-	22.6	-	-	-
100 sq miles	5.6	15.6	17.3	20.2	20.7	-	20.7	-	-	-
200 sq miles	4.7	13.4	16.1	18.8	19.5	-	19.6	-	-	-
500 sq miles	4.0	11.6	14.0	16.5	16.9	-	17.3	-	-	-
1000 sq miles	3.2	10.2	12.6	14.3	14.4	-	15.7	-	-	-
5000 sq miles	2.0	6.2	7.9	10.1	10.4	-	10.8	-	-	-
10000 sq miles	0.8	4.5	6.4	7.8	8.5	-	9.0	-	-	-
20000 sq miles	0.5	2.0	4.6	5.9	6.7	-	7.0	-	-	-

Storm or Storm Center Name	**SPAS 1286-Aurora College, IL**	
Storm Date(s)	17-Jul-1996	
Storm Type	Synoptic-Thunderstorms	
Storm Location	41.46 N	88.07 W
Storm Center Elevation	650	
Precipitation Total & Duration	18.13 in 24hrs from SPAS 1286	
Storm Representative Dew Point	74.0 F	24
Storm Representative Dew Point Location	38.63 N	92.24 W
Maximum Dew Point	80.5 F	
Moisture Inflow Vector	SW @ 300	
In-place Maximization Factor	**1.35**	
Temporal Transposition (Date)	15-Jul	
Transposition Dew Point Location	42.49 N	98.27 W
Transposition Maximum Dew Point	80.0 F	
Transposition Adjustment Factor	**0.95**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.29**	

Attachment 3 Table 2: Storm spreadsheet for Aurora College, IL July 1996



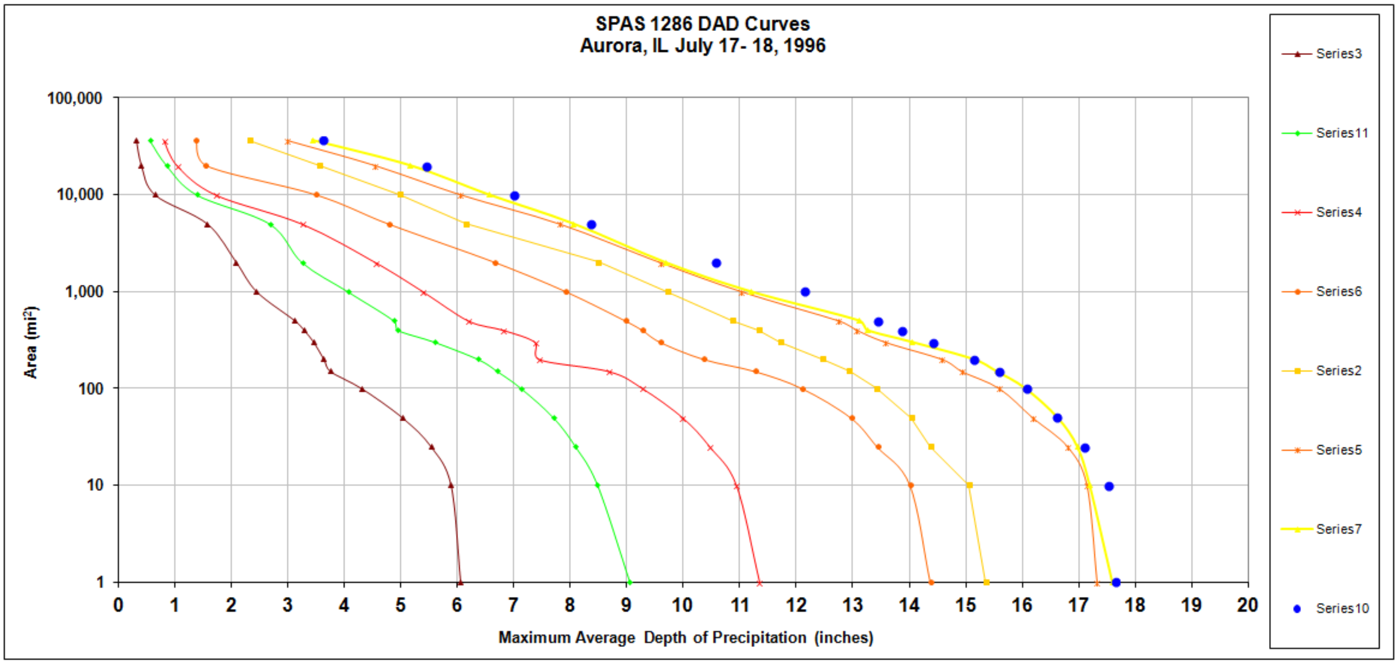
Attachment 3 Figure 1: Moisture inflow map for Aurora College, IL July 1996

Storm 1286 - Aurora, IL July 17- 18, 1996

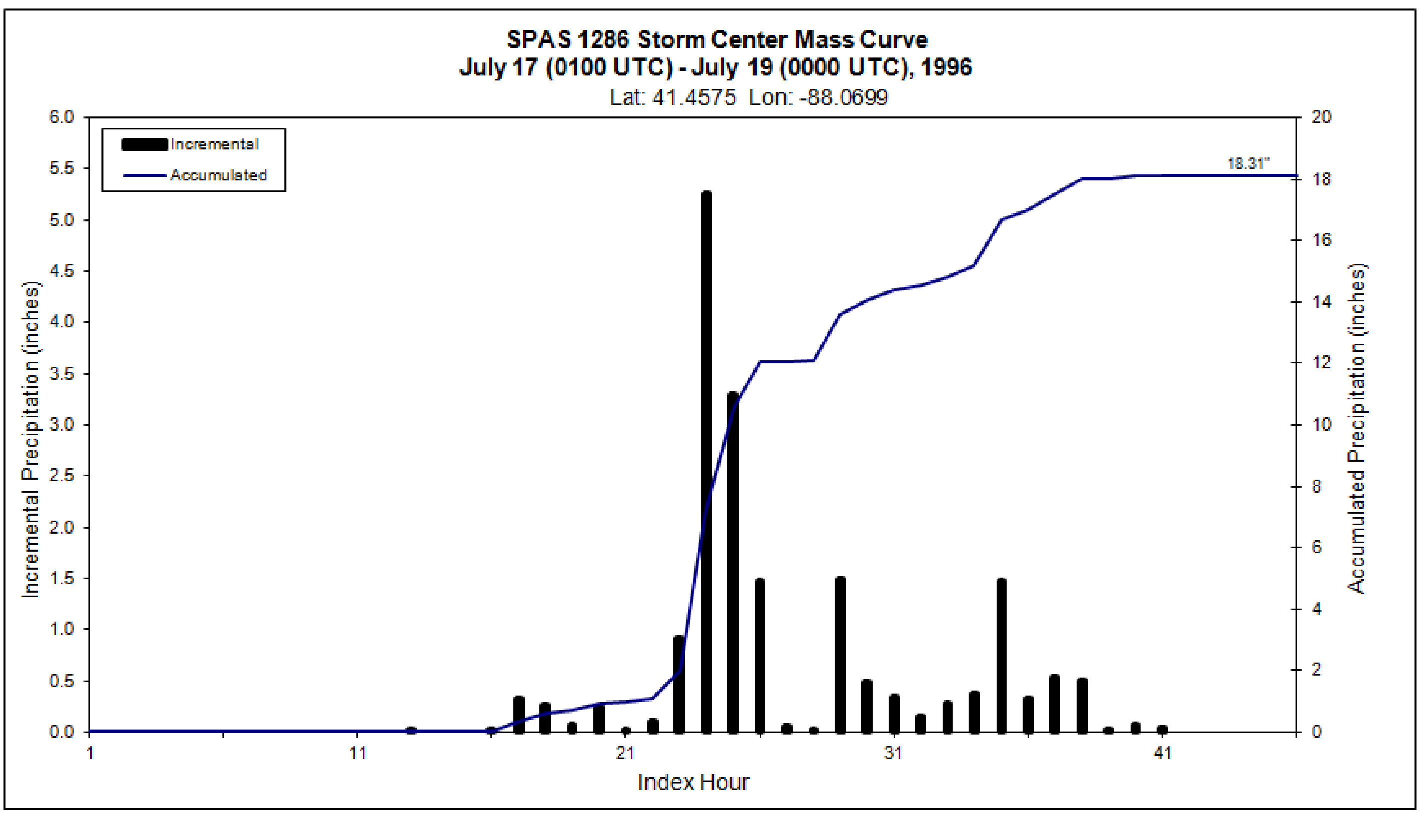
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)												
Area (mi²)	1	2	3	4	5	6	12	18	24				total (36-hr)
1	6.06	9.05	11.35			14.38	15.35	17.33	17.58				17.64
10	5.89	8.48	10.94			14.02	15.05	17.15	17.18				17.51
25	5.54	8.09	10.47			13.44	14.38	16.81	16.96				17.09
50	5.03	7.70	9.99			12.97	14.04	16.19	16.61				16.61
100	4.31	7.13	9.28			12.11	13.42	15.60	16.04				16.06
150	3.76	6.71	8.69			11.28	12.94	14.94	15.53				15.58
200	3.64	6.37	7.45			10.37	12.46	14.59	15.12				15.14
300	3.46	5.61	7.38			9.60	11.71	13.59	14.04				14.42
400	3.29	4.95	6.82			9.28	11.34	13.08	13.24				13.86
500	3.13	4.88	6.20			8.98	10.87	12.76	13.10				13.43
1,000	2.45	4.07	5.40			7.93	9.72	11.04	11.18				12.13
2,000	2.09	3.26	4.56			6.68	8.50	9.60	9.67				10.56
5,000	1.58	2.69	3.26			4.79	6.15	7.82	8.05				8.36
10,000	0.65	1.40	1.73			3.51	4.98	6.07	6.55				7.00
20,000	0.41	0.87	1.05			1.56	3.57	4.56	5.16				5.44
36,456	0.32	0.57	0.82			1.38	2.33	3.00	3.43				3.61

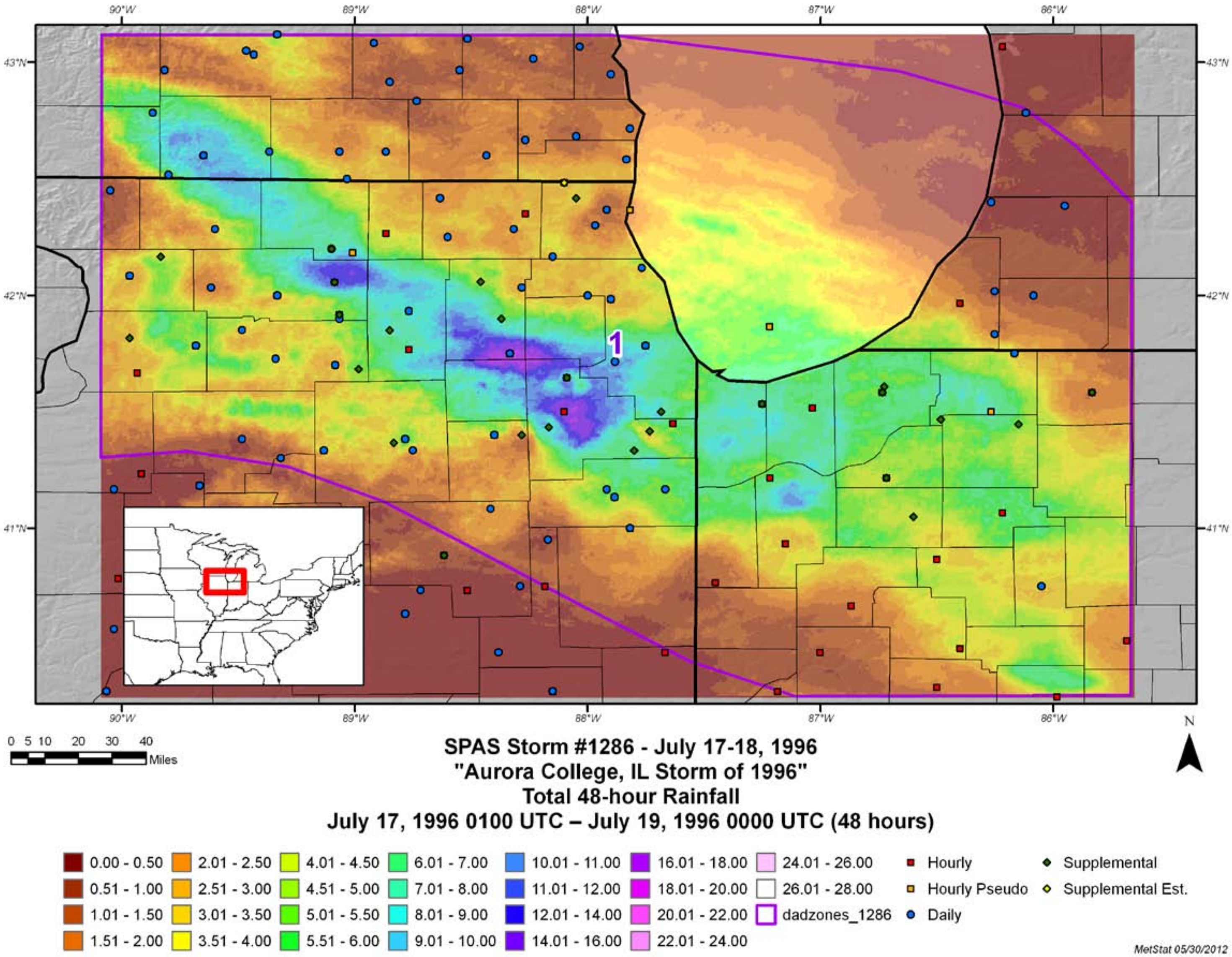
Attachment 3 Table 3: Depth-area-duration values for Aurora College, IL July 1996



Attachment 3 Figure 2: Depth-area-duration chart for Aurora College, IL July 1996



Attachment 3 Figure 3: Mass curve chart for Aurora College, IL July 1996



Attachment 3 Figure 4: Total storm isohyetal analysis for Aurora College, IL July 1996

Storm Name:	USACE- UMV 1-11A-Beaulieu, MN	**Storm Adjustment for Monticello-LIP**
Storm Date:	18-Jul-1909	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	47.30 N	95.90 W
Storm Rep Dew Point Location	43.32 N	98.08 W
Transposition Dew Point Locati	41.35 N	95.96 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	SSW @ 295	miles
Basin Average Elevation	950	feet
Storm Center Elevation	1,300	feet
Storm Analysis Duration	6	hours

The storm representative dew point is	**78.0 F**	with total precipitable water above sea level of			**3.29**	inches.
The in-place maximum dew point is	**81.5 F**	with total precipitable water above sea level of			**3.83**	inches.
The transpositioned maximum dew point is	**82.5 F**	with total precipitable water above sea level of			**3.98**	inches.
The in-place storm elevation is	**1,300**	which subtracts	**0.36**	inches of precipitable water at	**78.0 F**	
The in-place storm elevation is	**1,300**	which subtracts	**0.40**	inches of precipitable water at	**81.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.31**	inches of precipitable water at	**82.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.31**	inches of precipitable water at	**82.5 F**	

The in-place maximization factor is	**1.17**
The transposition factor is	**1.07**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.26**

Notes: DAD values taken from USACE UMV 1-11. Added 7° to USACE storm rep analyzed Td based on guidance from all previous PMP studies in the region.

Observed Storm Depth-Area-Duration

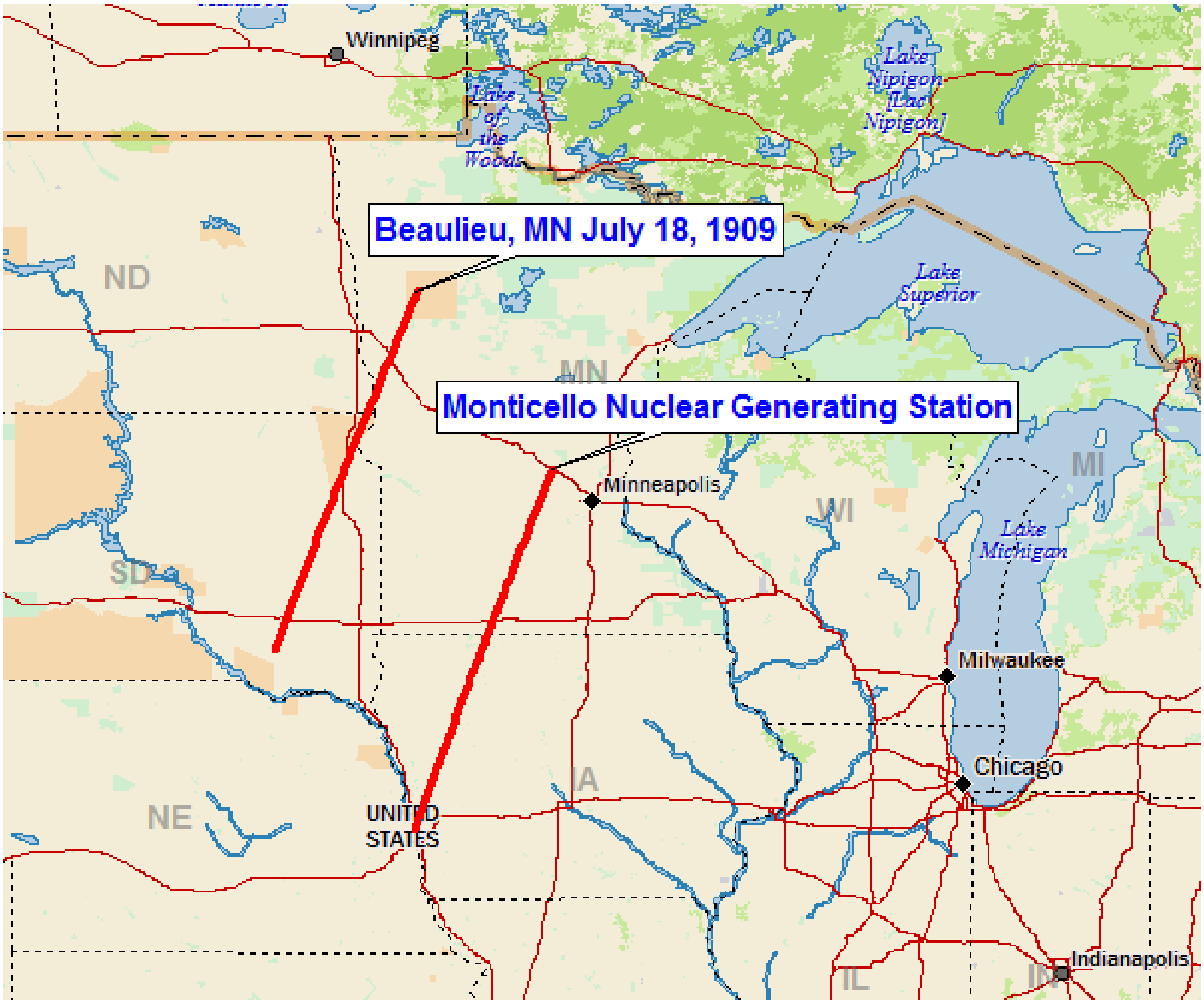
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**10.5**	**10.7**	**10.8**	**11.5**	**11.7**	**11.8**	**11.8**	**12.0**	**12.1**
100 sq miles	**10.3**	**10.5**	**10.7**	**11.3**	**11.5**	**11.7**	**11.7**	**12.0**	**12.0**
200 sq miles	**10.1**	**10.4**	**10.5**	**11.1**	**11.3**	**11.5**	**11.5**	**11.8**	**11.8**
500 sq miles	**9.7**	**10.1**	**10.2**	**10.6**	**11.0**	**11.2**	**11.2**	**11.5**	**11.5**
1000 sq miles	**9.2**	**9.6**	**9.7**	**10.0**	**10.4**	**10.5**	**10.6**	**10.8**	**10.9**
2000 sq miles	**7.9**	**8.5**	**8.6**	**8.7**	**9.3**	**9.4**	**9.5**	**9.8**	**9.9**
5000 sq miles	**4.8**	**5.9**	**6.0**	**6.1**	**7.1**	**7.3**	**7.5**	**7.9**	**8.0**
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**13.2**	**13.4**	**13.6**	**14.4**	**14.7**	**14.8**	**14.8**	**15.1**	**15.2**
100 sq miles	**12.9**	**13.2**	**13.4**	**14.2**	**14.4**	**14.7**	**14.7**	**15.1**	**15.1**
200 sq miles	**12.7**	**13.1**	**13.2**	**13.9**	**14.2**	**14.4**	**14.4**	**14.8**	**14.8**
500 sq miles	**12.2**	**12.7**	**12.8**	**13.3**	**13.8**	**14.1**	**14.1**	**14.4**	**14.4**
1000 sq miles	**11.5**	**12.0**	**12.2**	**12.6**	**13.1**	**13.2**	**13.3**	**13.6**	**13.7**
2000 sq miles	**9.9**	**10.7**	**10.8**	**10.9**	**11.7**	**11.8**	**11.9**	**12.3**	**12.4**
5000 sq miles	**6.0**	**7.4**	**7.5**	**7.7**	**8.9**	**9.2**	**9.4**	**9.9**	**10.0**
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**USACE- UMV 1-11A-Beaulieu, MN**	
Storm Date(s)	18-Jul-1909	
Storm Type	MCC	
Storm Location	47.30 N	95.90 W
Storm Center Elevation	1,300	
Precipitation Total & Duration	13.20 Inches 72-hours USACE UMV 1-11	
Storm Representative Dew Point	78.0 F	6
Storm Representative Dew Point Location	43.32 N	98.08 W
Maximum Dew Point	81.5 F	
Moisture Inflow Vector	SSW @ 295	
In-place Maximization Factor	**1.17**	
Temporal Transposition Date	15-Jul	
Transposition Dew Point Location	41.35 N	95.96 W
Transposition Maximum Dew Point	82.5 F	
Transposition Adjustment Factor	**1.07**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.26**	

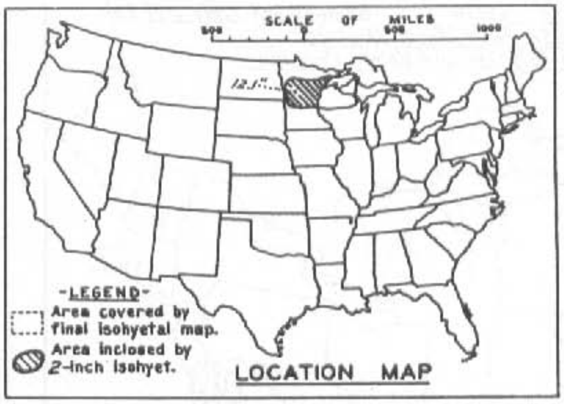
Attachment 3 Table 4: Storm spreadsheet for Beaulieu, MN July 1909



Attachment 3 Figure 5: Moisture inflow map for Beaulieu, MN July 1909

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES – PERTINENT DATA SHEET (REV.)



Storm of 18-23 July 1909
Assignment UMV 1-11 (a)
Location Northern Minn. & Wis.
Study Prepared by:
Upper Mississippi Valley Division
St. Paul District Office
Part I Reviewed by H. M. Sec. of Weather Bureau, 6/7/39
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 5/24/41
Remarks: Rainfall data only for Beaulieu, Minn. center
Dewpt. 71° - Ref. Pt. 300 SSW
Grid A-15

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1 : 1,000,000
Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 4
- Form 5001-B (24-hour " ") ---------- -
- Form 5001-D (" " " ") ---------- 8
- Miscl. precip. records, meteorological data, etc. ---------- 1
- Form 5002 (Mass rainfall curves) ---------- 24

PART II

Final isohyetal maps, in 1 sheet, scale 1 : 1,000,000
Data and computation sheets:

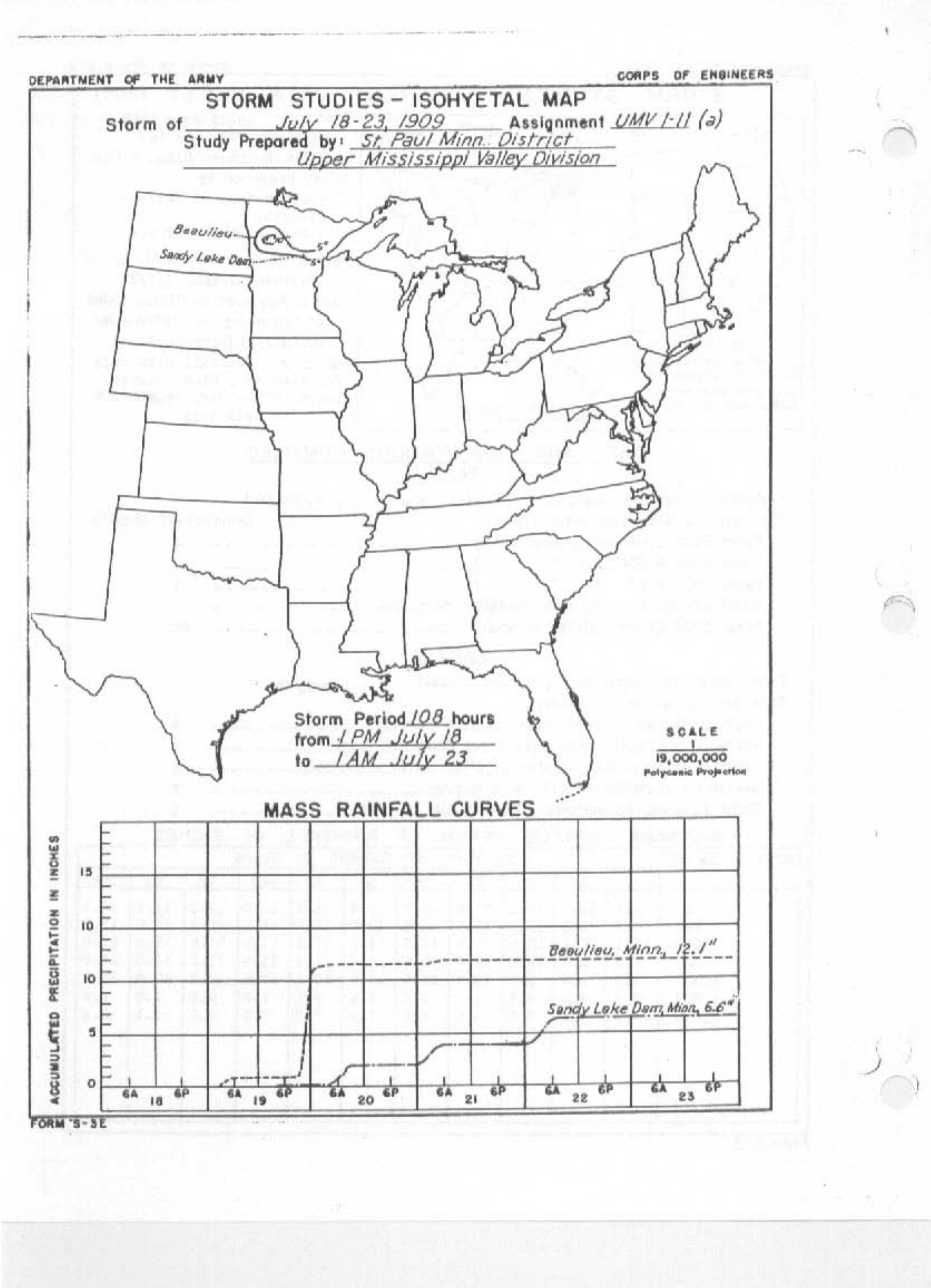
- Form S-10 (Data from mass rainfall curves) ---------- 4
- Form S-11 (Depth-area data from isohyetal map) ---------- 2
- Form S-12 (Maximum depth-duration data) ---------- 8
- Maximum duration-depth-area curves ---------- 2
- Data relating to periods of maximum rainfall ---------- 2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	108
10	10.5	10.7	10.8	11.5	11.7	11.8	11.8	12.0	12.1	12.1	12.1
100	10.3	10.5	10.7	11.3	11.5	11.7	11.7	12.0	12.0	12.0	12.0
200	10.1	10.4	10.5	11.1	11.3	11.5	11.5	11.8	11.8	11.8	11.8
500	9.7	10.1	10.2	10.6	10.9	11.2	11.2	11.4	11.5	11.5	11.5
1,000	9.2	9.6	9.7	10.0	10.4	10.6	10.6	10.8	10.9	10.9	10.9
2,000	7.9	8.5	8.6	8.7	9.3	9.4	9.5	9.8	9.9	9.9	9.9
5,000	4.8	5.9	6.0	6.1	6.7	7.0	7.2	7.9	8.0	8.1	8.1

Form S-2

Attachment 3 Table 5: Depth-area-duration values for Beaulieu, MN July 1909



Attachment 3 Figure 6 and Attachment 3 Figure 7: Isohyetal map and Mass curve chart for Beaulieu, MN July 1909

Storm Name:	**Boyden, IA MR4-24**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**17-Sep-1926**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**3-Sep**	
	Lat	**Long**
Storm Center Location	**43.19 N**	**96.01 W**
Storm Rep Dew Point Location	**40.85 N**	**94.75 W**
Transposition Dew Point Locati	**42.99 N**	**92.55 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSE @ 175**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,400**	feet
Storm Analysis Duration	**12**	hours

The storm representative dew point is	**77.0 F**	with total precipitable water above sea level of			**3.14**	inches.
The in-place maximum dew point is	**78.5 F**	with total precipitable water above sea level of			**3.37**	inches.
The transpositioned maximum dew point is	**77.5 F**	with total precipitable water above sea level of			**3.22**	inches.
The in-place storm elevation is	**1,400**	which subtracts	**0.37**	inches of precipitable water at	**77.0 F**	
The in-place storm elevation is	**1,400**	which subtracts	**0.39**	inches of precipitable water at	**78.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.27**	inches of precipitable water at	**77.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.27**	inches of precipitable water at	**77.5 F**	

The in-place maximization factor is	**1.07**
The transposition factor is	**0.99**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.06**

Notes: DAD values taken from USACE MR 4-24. Storm representative dew point value was based on adding 7° to the USACE analysis following standard guidance.

Observed Storm Depth-Area-Duration

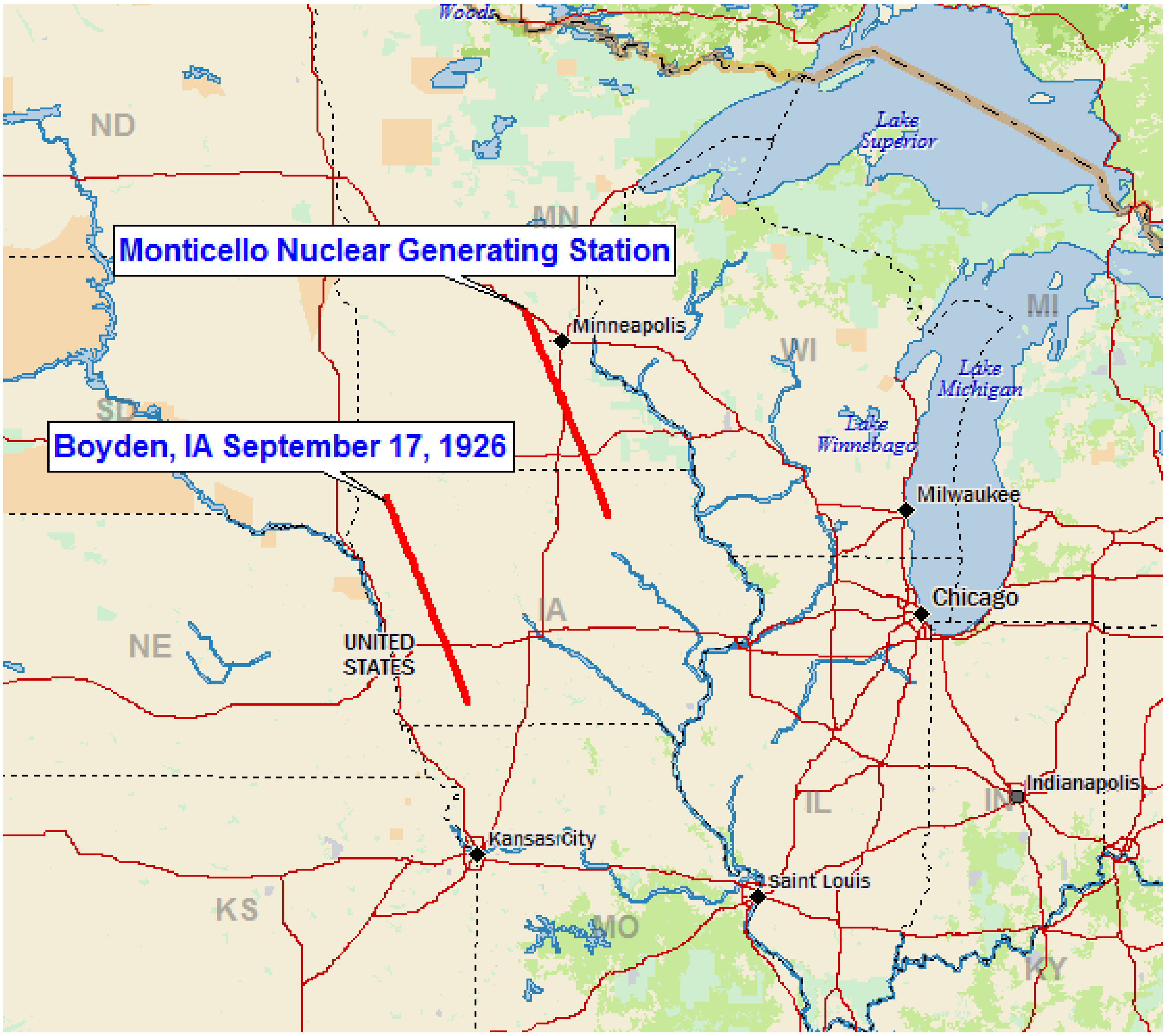
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**18.4**	**23.8**	**24.0**	**24.0**	**24.0**	**24.0**	**24.0**	-	-
10 sq miles	**15.1**	**20.7**	**21.7**	**21.7**	**21.7**	**21.7**	**21.7**	-	-
100 sq miles	**12.8**	**17.1**	**17.8**	**17.8**	**17.8**	**17.8**	**17.8**	-	-
200 sq miles	**11.7**	**15.8**	**16.6**	**16.6**	**16.6**	**16.6**	**16.6**	-	-
500 sq miles	**9.4**	**12.6**	**13.3**	**13.3**	**13.3**	**13.3**	**13.3**	-	-
1000 sq miles	**7.5**	**10.1**	**10.4**	**10.6**	**10.6**	**10.6**	**10.6**	-	-
2000 sq miles	**5.9**	**8.0**	**8.2**	**8.6**	**8.6**	**8.6**	**8.6**	-	-
5000 sq miles	**4.1**	**6.3**	**6.4**	**6.6**	**6.6**	**6.6**	**6.6**	-	-
10000 sq miles	**3.0**	**5.2**	**5.4**	**5.5**	**5.6**	**5.6**	**5.6**	-	-
20000 sq miles	**2.1**	**4.1**	**4.3**	**4.4**	**4.6**	**4.8**	**4.9**	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**19.6**	**25.3**	**25.6**	**25.6**	**25.6**	**25.6**	**25.6**	-	-
10 sq miles	**16.1**	**22.0**	**23.1**	**23.1**	**23.1**	**23.1**	**23.1**	-	-
100 sq miles	**13.6**	**18.2**	**19.0**	**19.0**	**19.0**	**19.0**	**19.0**	-	-
200 sq miles	**12.5**	**16.8**	**17.7**	**17.7**	**17.7**	**17.7**	**17.7**	-	-
500 sq miles	**10.0**	**13.4**	**14.2**	**14.2**	**14.2**	**14.2**	**14.2**	-	-
1000 sq miles	**8.0**	**10.8**	**11.1**	**11.3**	**11.3**	**11.3**	**11.3**	-	-
2000 sq miles	**6.3**	**8.5**	**8.7**	**9.2**	**9.2**	**9.2**	**9.2**	-	-
5000 sq miles	**4.4**	**6.7**	**6.8**	**7.0**	**7.0**	**7.0**	**7.0**	-	-
10000 sq miles	**3.2**	**5.5**	**5.8**	**5.9**	**6.0**	**6.0**	**6.0**	-	-
20000 sq miles	**2.2**	**4.4**	**4.6**	**4.7**	**4.9**	**5.1**	**5.2**	-	-

Storm or Storm Center Name	**Boyden, IA MR4-24**			
Storm Date(s)	17-Sep-1926			
Storm Type	MCC			
Storm Location	43.19 N	96.01 W		
Storm Center Elevation	1,400			
Precipitation Total & Duration	24.00 Inches 18-hours USACE Storm Studies MR 4-24			
Storm Representative Dew Point	77.0 F	12		
Storm Representative Dew Point Location	40.85 N	94.75 W	Aug	Sep
Maximum Dew Point	78.5 F		81	76
Moisture Inflow Vector	SSE @ 175			
In-place Maximization Factor	**1.07**			
Temporal Transposition Date	3-Sep			
Transposition Dew Point Location	42.99 N	92.55 W	Aug	Sep
Transposition Maximum Dew Point	77.5 F		80.45	75.27
Transposition Adjustment Factor	**0.99**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.06**			

Attachment 3 Table 6: Storm spreadsheet for Boyden, IA September 1926



Attachment 3 Figure 8: Moisture inflow map for Boyden, IA September 1926

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET

Storm of 17-19 September 1926
Assignment MR 4-24
Location Ia,Minn,Nebr.S.D. & Wisc
Study Prepared by:
Missouri River Division
Omaha District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 8/5/47
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 12/23/47
Remarks: Centers near Boyden & Maurice, Ia.
Dewpt. 70° - Ref. Pt. 175 SSE Grid C-15

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 2 sheets, scale 1:500,000

Precipitation data and mass curves:	(Number of Sheets)
Form 5001-C (Hourly precip. data)	8
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	11
Miscl. precip. records, meteorological data, etc.	29
Form 5002 (Mass rainfall curves)	27

PART II

Final isohyetal maps, in 1 sheet, scale 1:1,000,000

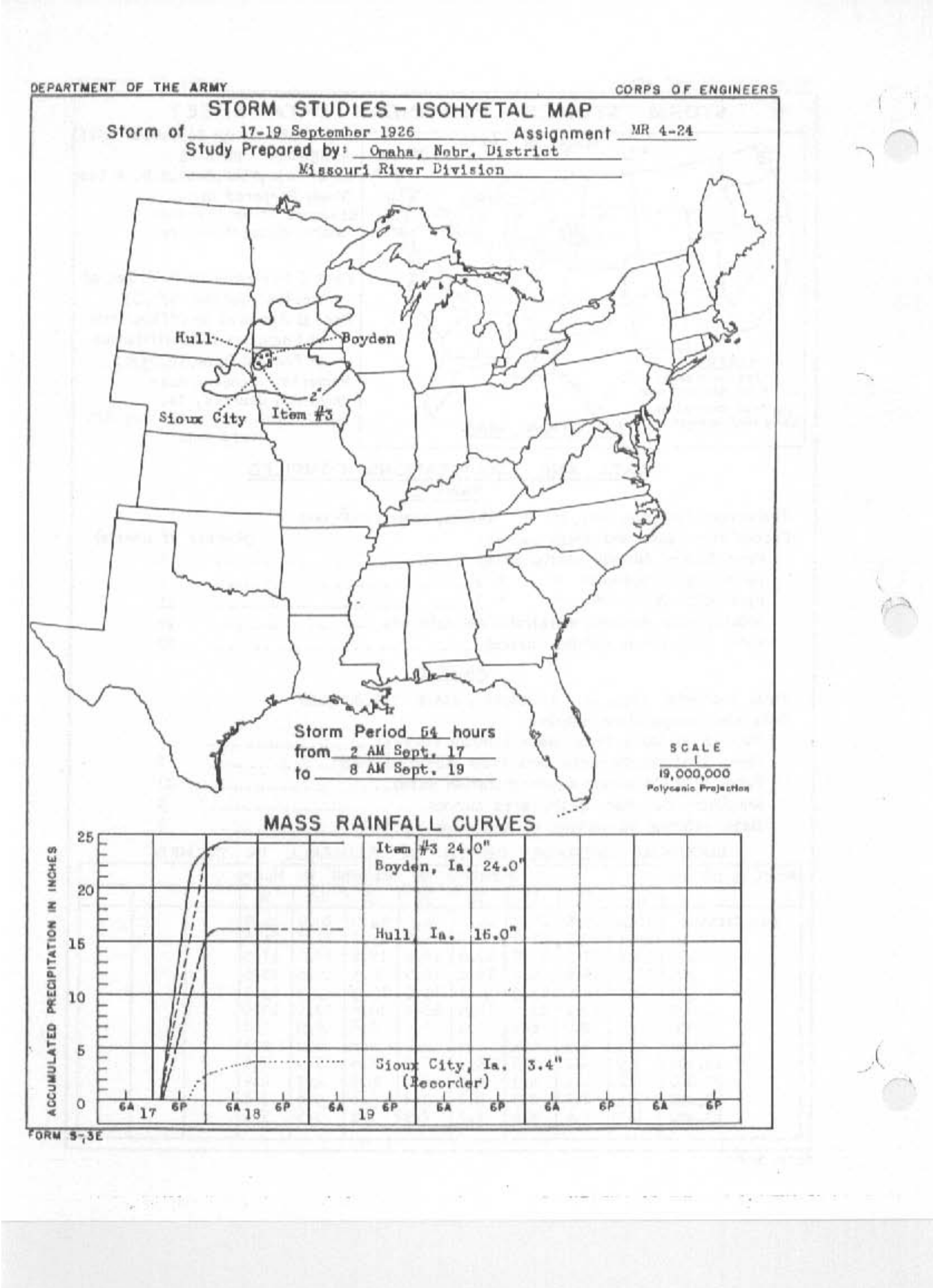
Data and computation sheets:	
Form S-10 (Data from mass rainfall curves)	3
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	17
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	7

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	54			
Max.Station	18.4	23.8	24.0	24.0	24.0	24.0	24.0	24.0			
10	15.1	20.7	21.7	21.7	21.7	21.7	21.7	21.7			
100	12.8	17.1	17.8	17.8	17.8	17.8	17.8	17.8			
200	11.7	15.8	16.6	16.6	16.6	16.6	16.6	16.6			
500	9.4	12.6	13.3	13.3	13.3	13.3	13.3	13.3			
1,000	7.5	10.1	10.4	10.6	10.6	10.6	10.6	10.6			
2,000	5.9	8.0	8.2	8.6	8.6	8.6	8.6	8.6			
5,000	4.1	6.3	6.4	6.6	6.6	6.6	6.6	6.6			
10,000	3.0	5.2	5.4	5.5	5.6	5.6	5.6	5.6			
20,000	2.1	4.1	4.3	4.4	4.6	4.8	4.9	4.9			
50,000	1.4	2.7	2.9	3.0	3.2	3.6	3.8	3.8			
63,000	1.2	2.4	2.6	2.7	2.9	3.3	3.5	3.5			

Form S-2

Attachment 3 Table 7: Depth-area-duration values for Boyden, IA September 1926



Attachment 3 Figure 9 and Attachment 3 Figure 10: Isohyetal map and Mass curve chart for Boyden, IA September 1926

Storm Name:	USACE GL 2-16-Cooper, MI		Storm Adjustment for Monticello-LIP
Storm Date:	August 31, 1914		
AWA Analysis Date:	8/24/2014		

Temporal Transposition Date	16-Aug	
	Lat	Long
Storm Center Location	42.38 N	85.61 W
Storm Rep Dew Point Location	40.10 N	89.00 W
Transposition Dew Point Locati	43.04 N	97.40 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	SW @ 235	miles
Basin Average Elevation	950	feet
Storm Center Elevation	900	feet
Storm Analysis Duration	6	hours

The storm representative dew point is	75.0 F	with total precipitable water above sea level of			2.85	inches.
The in-place maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The transpositioned maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The in-place storm elevation is	900	which subtracts	0.23	inches of precipitable water at	75.0 F	
The in-place storm elevation is	900	which subtracts	0.28	inches of precipitable water at	80.5 F	
The transposition storm elevation at	950	which subtracts	0.29	inches of precipitable water at	80.5 F	
The moisture inflow barrier height is	950	which subtracts	0.29	inches of precipitable water at	80.5 F	

The in-place maximization factor is	1.30
The transposition factor is	1.00
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.29

Notes: DAD values taken from USACE GL 2-16. Storm representative dew point value was based on adding 7° to the USACE analysis using EPRI, Nebraska, and TRWD guidance.

Observed Storm Depth-Area-Duration

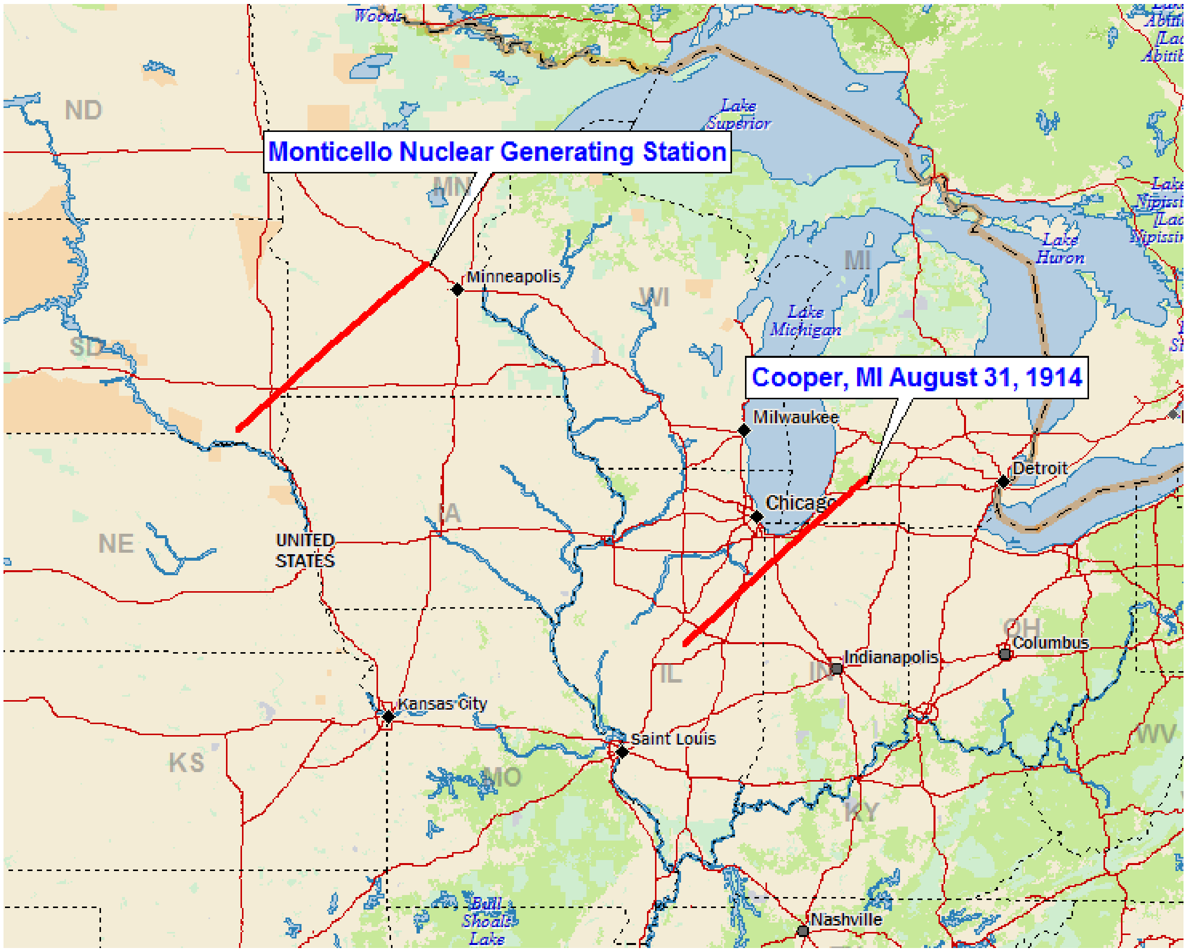
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	-	-	-	-	-	-	-	-	-
10 sq miles	12.6	-	-	-	-	-	-	-	-
100 sq miles	11.3	-	-	-	-	-	-	-	-
200 sq miles	10.0	-	-	-	-	-	-	-	-
500 sq miles	7.6	-	-	-	-	-	-	-	-
1000 sq miles	5.7	-	-	-	-	-	-	-	-
5000 sq miles	-	-	-	-	-	-	-	-	-
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	-	-	-	-	-	-	-	-	-
10 sq miles	16.3	-	-	-	-	-	-	-	-
100 sq miles	14.6	-	-	-	-	-	-	-	-
200 sq miles	12.9	-	-	-	-	-	-	-	-
500 sq miles	9.8	-	-	-	-	-	-	-	-
1000 sq miles	7.4	-	-	-	-	-	-	-	-
5000 sq miles	-	-	-	-	-	-	-	-	-
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**USACE GL 2-16-Cooper, MI**	
Storm Date(s)	31-Aug-1914	
Storm Type	MCS	
Storm Location	42.38 N	85.61 W
Storm Center Elevation	900	
Precipitation Total & Duration	12.60 Inches 6-hours USACE GL 2-16	
Storm Representative Dew Point	75.0 F	6
Storm Representative Dew Point Location	40.10 N	89.00 W
Maximum Dew Point	80.5 F	
Moisture Inflow Vector	SW @ 235	
In-place Maximization Factor	**1.30**	
Temporal Transposition Date	16-Aug	
Transposition Dew Point Location	43.04 N	97.40 W
Transposition Maximum Dew Point	80.5 F	
Transposition Adjustment Factor	**1.00**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.29**	

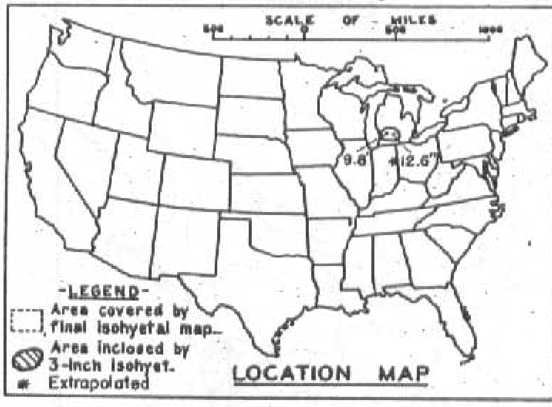
Attachment 3 Table 8: Storm spreadsheet for Cooper, MI August 1914



Attachment 3 Figure 11: Moisture inflow map for Cooper, MI August 1914

WAR DEPARTMENT CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES - PERTINENT DATA SHEET



Storm of 31 Aug.-1 Sept. 1914
Assignment GL 2-16
Location Michigan
Study Prepared by:
Great Lakes Division
Milwaukee District Office and
Hydrometeorological Section of
U. S. Weather Bureau.
Part I Reviewed by H. M. Sec. of Weather Bureau, 10/26/39
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 10/26/46
Remarks: Centers near Cooper and Bloomingdale, Mich.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1 : 2,500,000
Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	8
Form 5001-B (24-hour " ")	5
Form 5001-D (" " " ")	-
Miscl. precip. records, meteorological data, etc.	6
Form 5002 (Mass rainfall curves)	4

PART II

Final isohyetal maps, in 1 sheet, scale 1 : 1,000,000
Data and computation sheets:

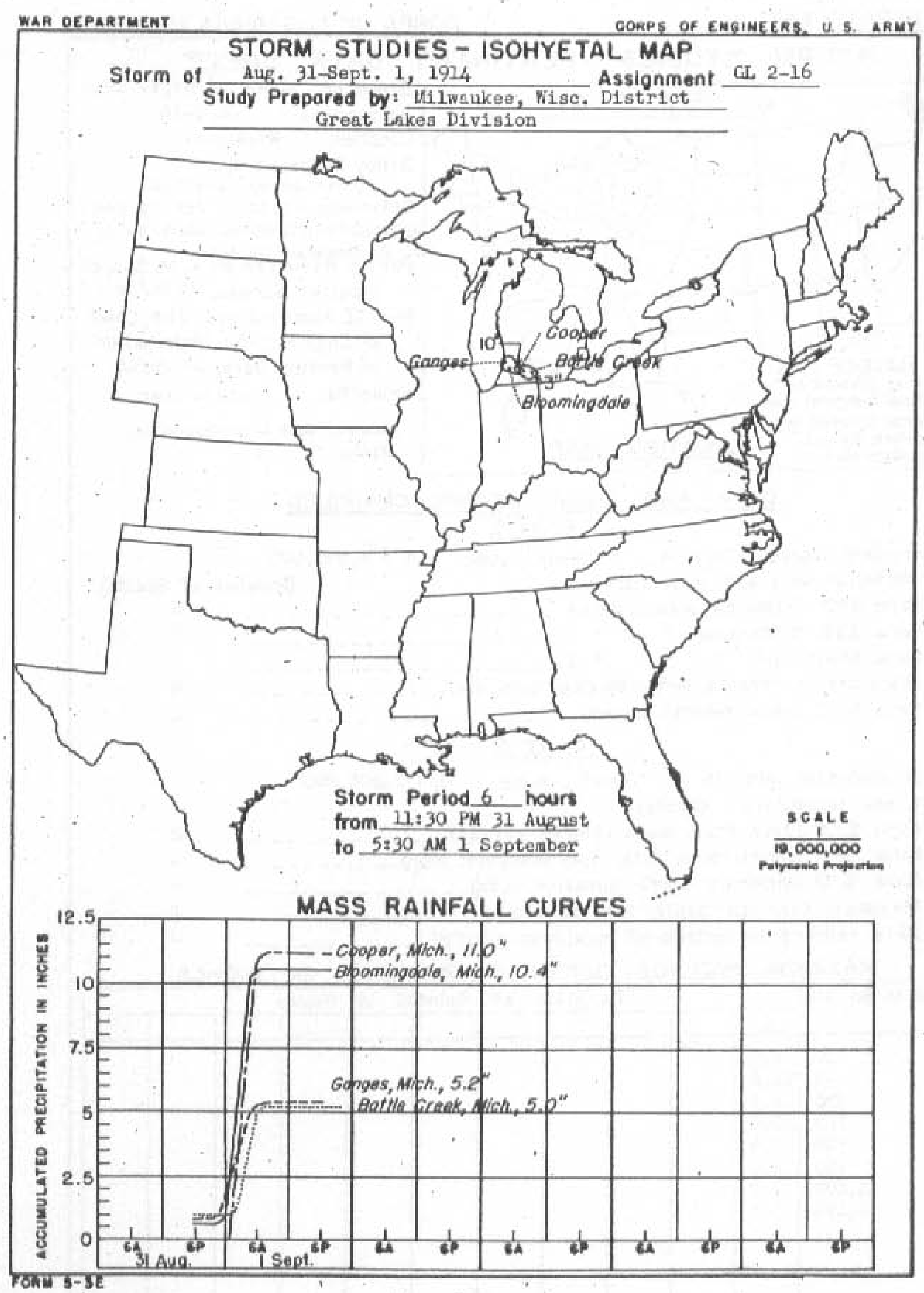
Form S-10 (Data from mass rainfall curves)	2
Form S-11 (Depth-area data from isohyetal map)	-
Form S-12 (Maximum depth-duration data)	-
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	-

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6										
10	12.6										
50	12.0										
100	11.3										
200	10.0										
500	7.6										
800	6.3										
1,000	5.7										
1,200	5.2										

Form S-2

Attachment 3 Table 9: Depth-area-duration values for Cooper, MI August 1914



Attachment 3 Figure 12 and Attachment 3 Figure 13: Isohyetal map and Mass curve chart for Cooper, MI August 1914

Storm Name:	SPAS 1030-David City, NE	Storm Adjustment for Monticello-LIP
Storm Date:	24-Jun-1963	
AWA Analysis Date:	8/24/2014	

Temporal Transposition Date	9-Jul	
	Lat	Long
Storm Center Location	41.23 N	97.11 W
Storm Rep Dew Point Location	39.41 N	94.83 W
Transposition Dew Point Locati	43.51 N	91.42 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	SE @ 175	miles
Basin Average Elevation	950	feet
Storm Center Elevation	1,650	feet
Storm Analysis Duration	6	hours

The storm representative dew point is	73.5 F	with total precipitable water above sea level of		2.67	inches.
The in-place maximum dew point is	81.0 F	with total precipitable water above sea level of		3.76	inches.
The transpositioned maximum dew point is	80.0 F	with total precipitable water above sea level of		3.60	inches.
The in-place storm elevation is	1,650	which subtracts	0.39	inches of precipitable water at	73.5 F
The in-place storm elevation is	1,650	which subtracts	0.51	inches of precipitable water at	81.0 F
The transposition storm elevation at	950	which subtracts	0.28	inches of precipitable water at	80.0 F
The moisture inflow barrier height is	950	which subtracts	0.28	inches of precipitable water at	80.0 F

The in-place maximization factor is	1.43
The transposition factor is	1.02
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.46

Notes: In place of 1.56 adjusted to 1.50 based on HMR 51 and 55A guidance. DAD values taken from SPAS 1030.

Observed Storm Depth-Area-Duration

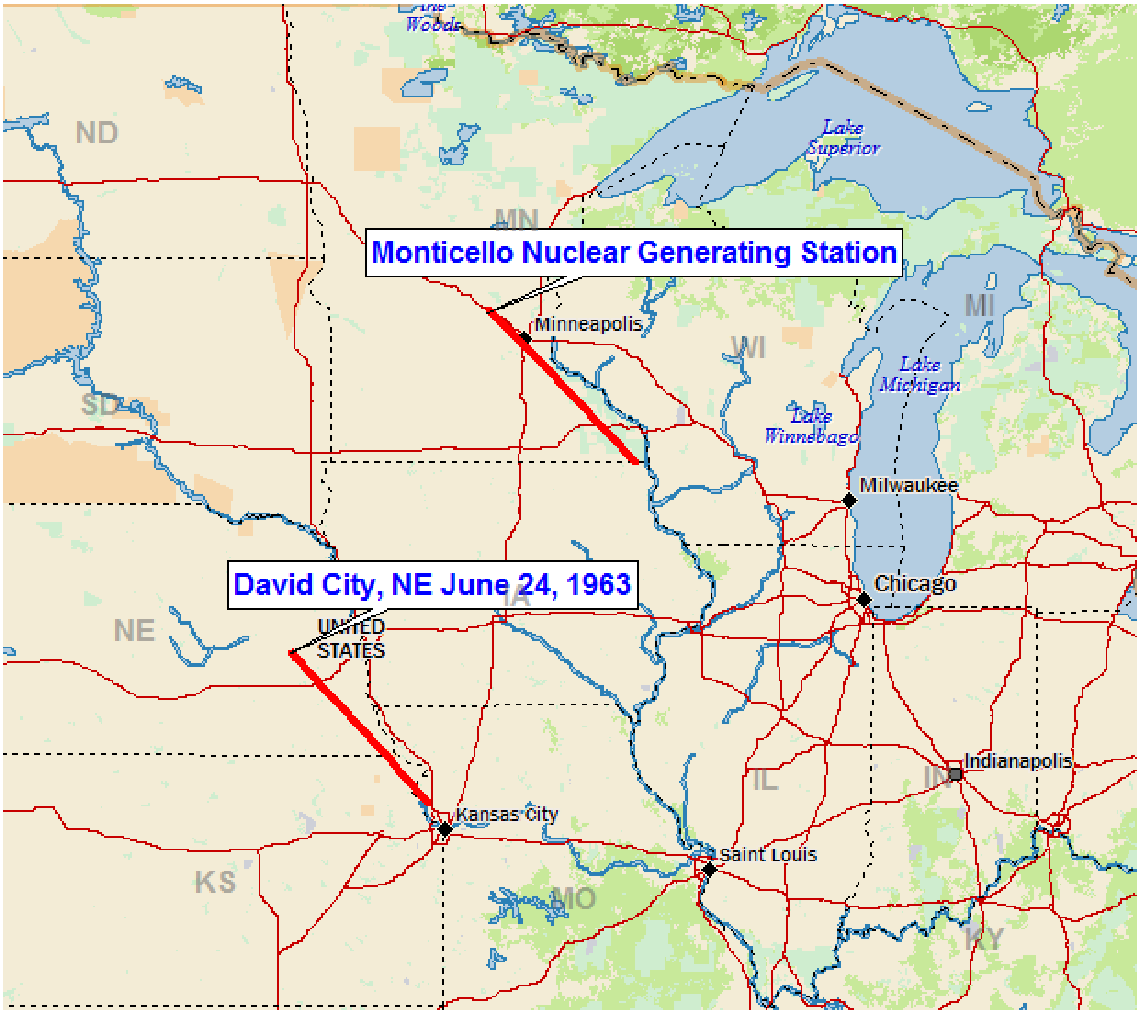
	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	3.9	14.1	15.6	15.9	16.0	-	16.0	16.0	-	16.0
10 sq miles	3.7	13.3	14.6	15.0	15.2	-	15.2	15.2	-	15.2
100 sq miles	3.0	11.2	12.7	13.1	13.2	-	13.2	13.2	-	13.2
200 sq miles	2.8	10.5	12.0	12.4	12.5	-	12.5	12.5	-	12.5
500 sq miles	2.4	9.0	10.4	10.8	10.8	-	10.8	10.9	-	10.9
1000 sq miles	2.0	7.8	9.0	9.4	9.5	-	9.5	9.5	-	9.5
5000 sq miles	0.9	4.2	5.9	6.6	6.8	-	6.9	6.9	-	6.9
10000 sq miles	0.6	2.6	4.1	4.6	4.9	-	4.9	5.0	-	5.0
20000 sq miles	0.4	1.5	2.4	2.9	3.1	-	3.1	3.1	-	3.1

Adjusted Storm Depth-Area-Duration

	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	5.6	20.6	22.8	23.2	23.3	-	23.3	23.3	-	23.3
10 sq miles	5.4	19.4	21.4	21.9	22.1	-	22.2	22.2	-	22.1
100 sq miles	4.4	16.4	18.6	19.2	19.3	-	19.3	19.3	-	19.3
200 sq miles	4.1	15.3	17.5	18.1	18.2	-	18.2	18.2	-	18.2
500 sq miles	3.5	13.2	15.2	15.7	15.8	-	15.8	15.8	-	15.9
1000 sq miles	2.9	11.3	13.1	13.7	13.8	-	13.8	13.8	-	13.9
5000 sq miles	1.3	6.1	8.7	9.7	9.9	-	10.0	10.0	-	10.0
10000 sq miles	0.9	3.9	6.0	6.7	7.2	-	7.2	7.2	-	7.2
20000 sq miles	0.5	2.2	3.6	4.2	4.5	-	4.6	4.6	-	4.6

Storm or Storm Center Name	**SPAS 1030-David City, NE**			
Storm Date(s)	24-Jun-1963			
Storm Type	MCC			
Storm Location	41.23 N	97.11 W		
Storm Center Elevation	1,650			
Precipitation Total & Duration	16.50 Inches 24-hours USACE Bucket Survey Data			
Storm Representative Dew Point	73.5 F	6		
Storm Representative Dew Point Location	39.41 N	94.83 W		
Maximum Dew Point	81.0 F			
Moisture Inflow Vector	SE @ 175			
In-place Maximization Factor	**1.43**			
Temporal Transposition Date	9-Jul			
Transposition Dew Point Location	43.51 N	91.42 W	June	July
Transposition Maximum Dew Point	80.0 F		78.07	80.6
Transposition Adjustment Factor	**1.02**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.46**			

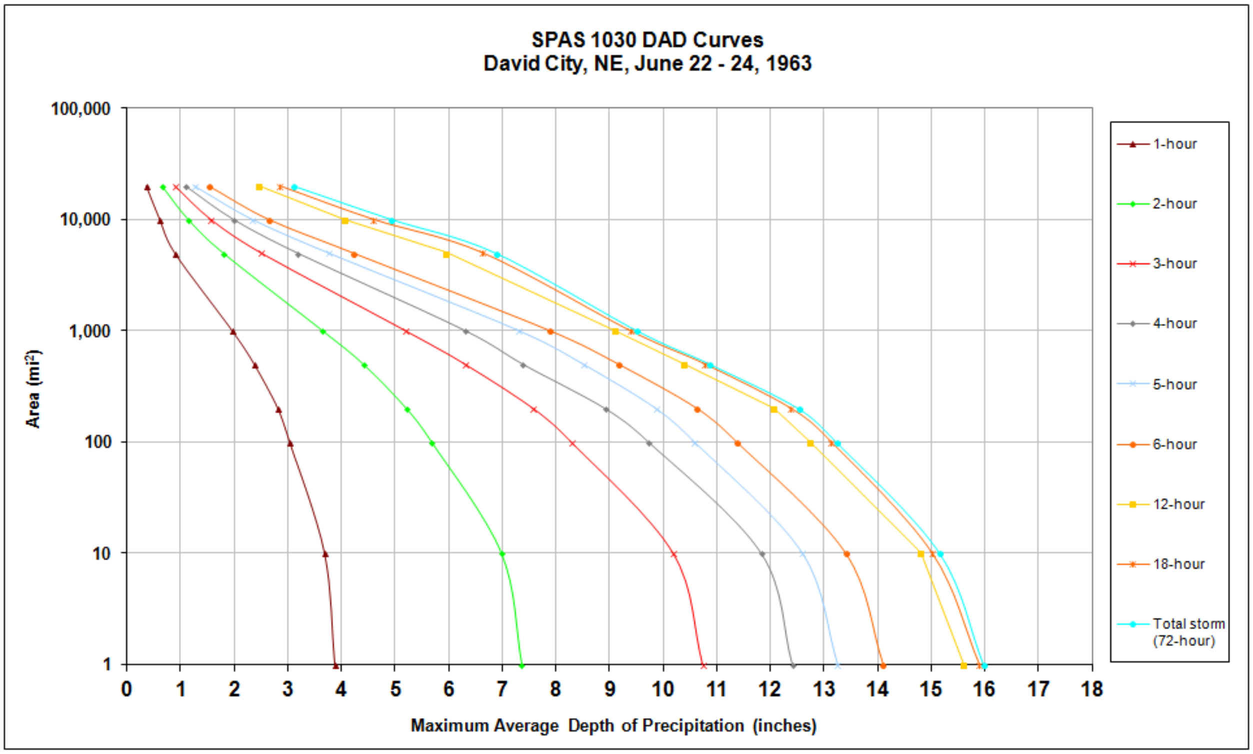
Attachment 3 Table 10: Storm spreadsheet for David City, NE June 1963



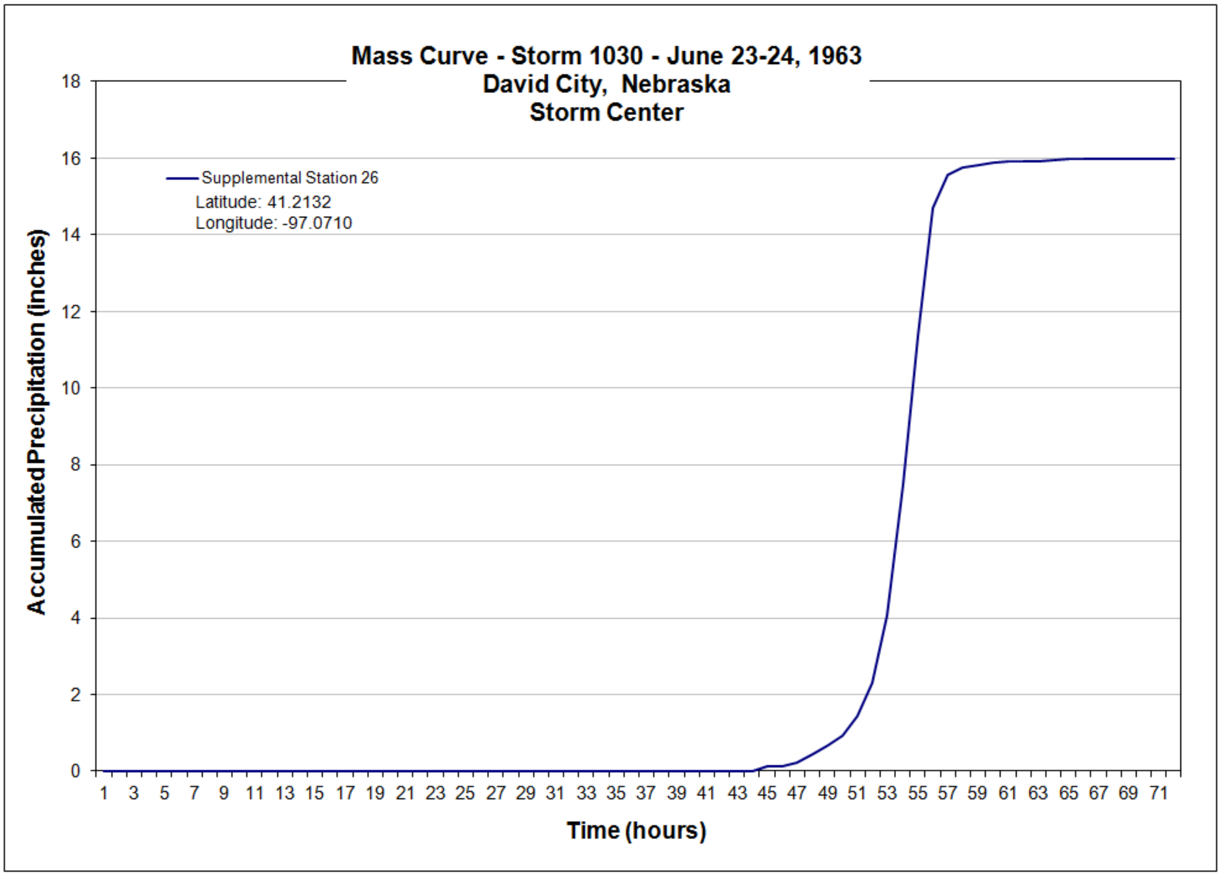
Attachment 3 Figure 14: Moisture inflow map for David City, NE June 1963

SPAS Storm 1030 - David City, NE, June 22 - 24, 1963													
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)													
	Duration (hours)												
Area (mi^2)	1	2	3	4	5	6	12	18	24	36	48	72	total
1	3.87	7.36	10.73	12.40	13.26	14.10	15.61	15.90	15.98	15.98	15.98	15.98	15.98
10	3.68	6.98	10.18	11.82	12.60	13.40	14.80	15.02	15.15	15.13	15.13	15.16	15.16
100	3.03	5.68	8.28	9.72	10.59	11.37	12.75	13.14	13.23	13.23	13.23	13.23	13.23
200	2.81	5.21	7.57	8.91	9.87	10.63	12.07	12.39	12.49	12.49	12.50	12.52	12.52
500	2.37	4.41	6.30	7.38	8.52	9.17	10.39	10.79	10.82	10.84	10.86	10.87	10.87
1,000	1.96	3.65	5.19	6.31	7.32	7.89	9.10	9.39	9.45	9.47	9.48	9.51	9.51
5,000	0.89	1.80	2.50	3.18	3.77	4.22	5.96	6.64	6.80	6.83	6.87	6.87	6.87
10,000	0.61	1.15	1.56	1.99	2.35	2.65	4.07	4.60	4.84	4.91	4.92	4.93	4.93
20,000	0.36	0.66	0.89	1.09	1.27	1.53	2.46	2.85	3.04	3.09	3.10	3.10	3.10

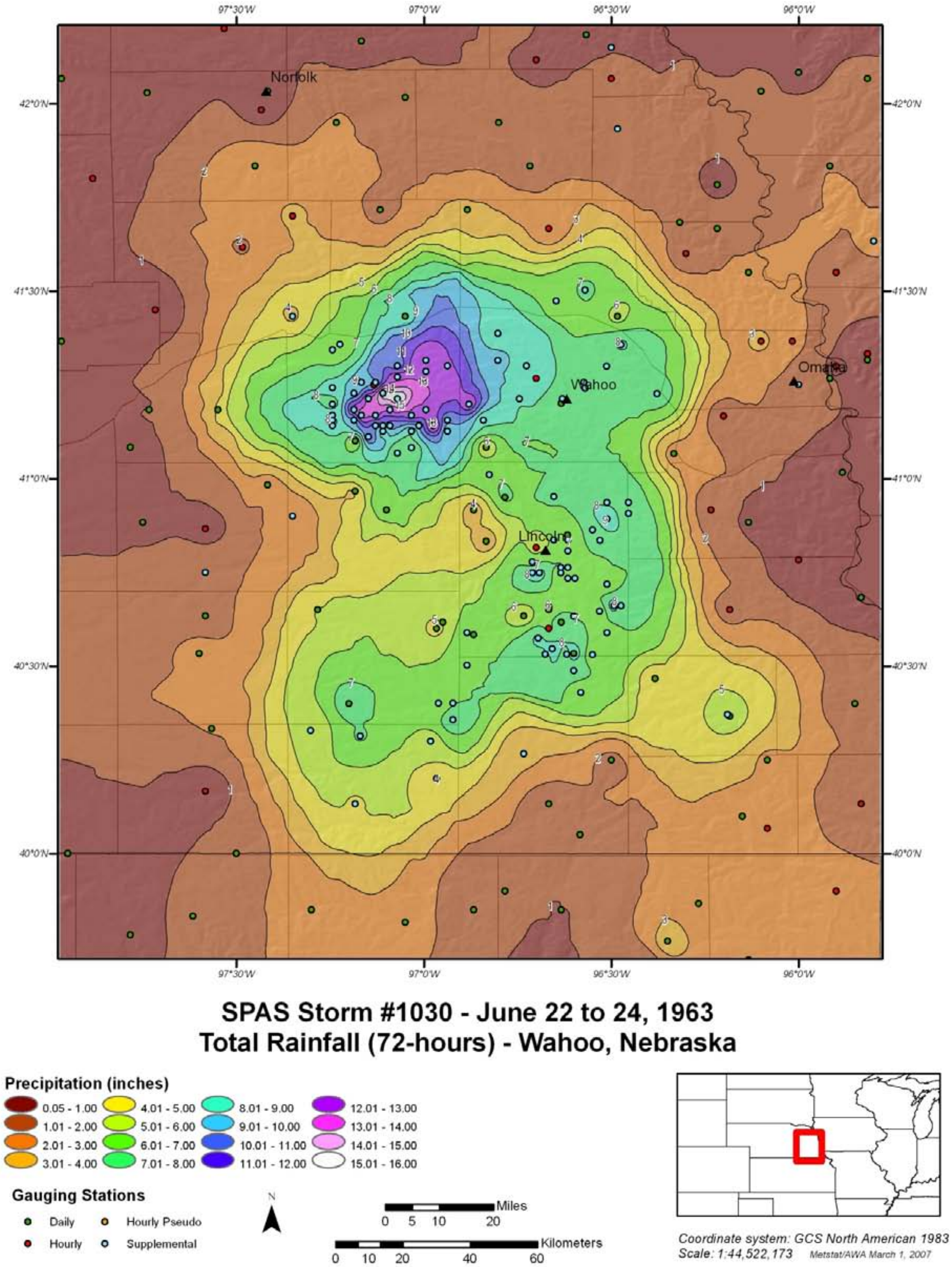
Attachment 3 Table 11: Depth-area-duration values for David City, NE June 1963



Attachment 3 Figure 15: Depth-area-duration chart for David City, NE June 1963



Attachment 3 Figure 16: Mass curve chart for David City, NE June 1963



Attachment 3 Figure 17: Total storm isohyetal analysis for David City, NE June 1963

Storm Name:	**SPAS 1220 Dubuque, IA**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**7/27-28/2011**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	**42.44 N**	**90.75 W**
Storm Rep Dew Point Location	**40.95 N**	**90.27 W**
Transposition Dew Point Locati	**43.84 N**	**93.35 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSE @ 105**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**900**	feet
Storm Analysis Duration	**12**	hours

The storm representative dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The in-place maximum dew point is	**81.0 F**	with total precipitable water above sea level of			**3.76**	inches.
The transpositioned maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The in-place storm elevation is	**900**	which subtracts	**0.26**	inches of precipitable water at	**79.0 F**	
The in-place storm elevation is	**900**	which subtracts	**0.28**	inches of precipitable water at	**81.0 F**	
The transposition storm elevation at	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**	

The in-place maximization factor is	**1.09**
The transposition factor is	**0.97**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.07**

Notes: DAD values taken from SPAS 1220. Storm representative dew point value was based on maximum 12-hr Td values between July 25-28, 2011 at WBAN 04949, 14842, and 14923.

Observed Storm Depth-Area-Duration

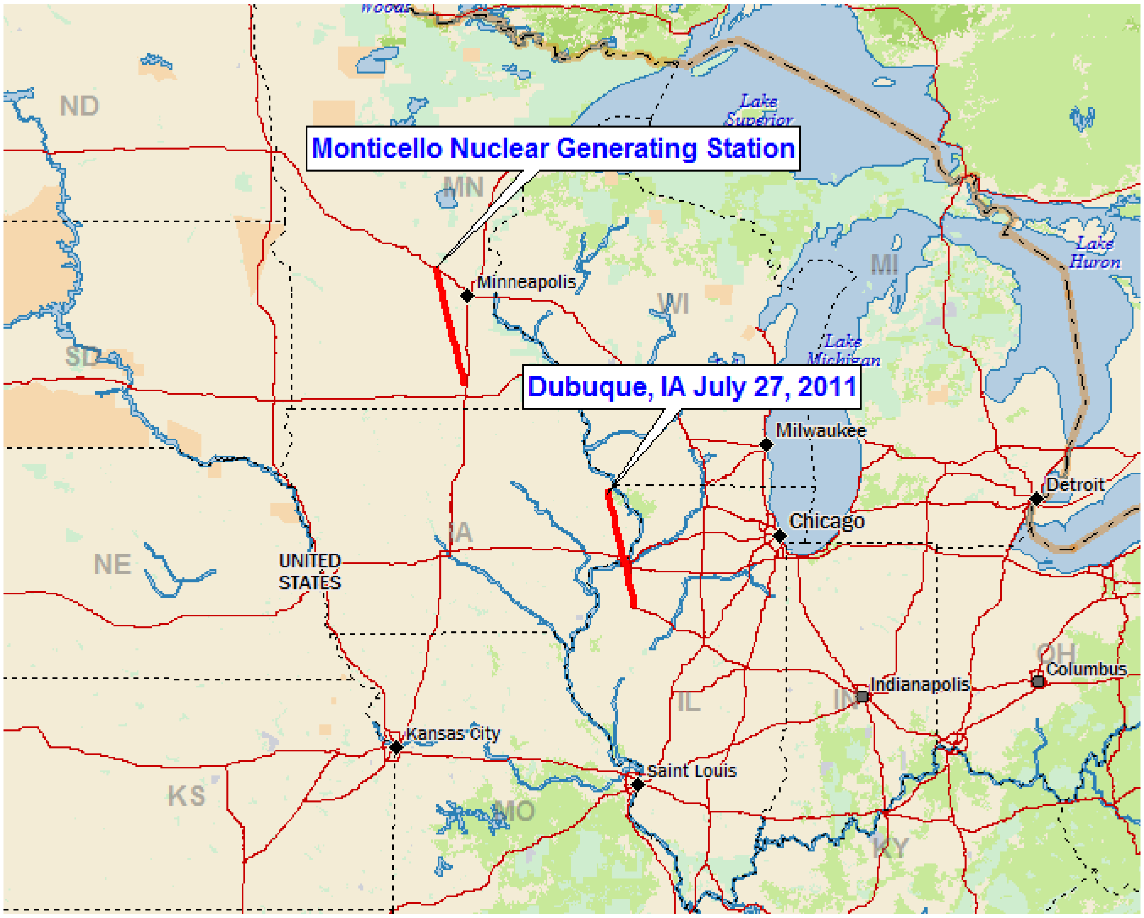
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.1**	**9.1**	**10.6**	**14.4**	**14.7**	**14.7**	-	-	-
10 sq miles	**3.9**	**8.6**	**10.2**	**13.7**	**14.4**	**14.5**	-	-	-
100 sq miles	**2.9**	**5.7**	**9.1**	**12.4**	**13.2**	**13.3**	-	-	-
200 sq miles	**2.3**	**5.6**	**8.8**	**11.9**	**12.6**	**12.7**	-	-	-
500 sq miles	**2.1**	**4.6**	**7.9**	**10.9**	**11.7**	**11.7**	-	-	-
1000 sq miles	**1.7**	**3.9**	**7.0**	**9.6**	**10.2**	**10.4**	-	-	-
2000 sq miles	**1.3**	**3.0**	**5.2**	**7.7**	**8.4**	**8.6**	-	-	-
5000 sq miles	**0.7**	**1.6**	**3.3**	**4.9**	**5.4**	**5.9**	-	-	-
10000 sq miles	**0.4**	**1.0**	**1.9**	**2.9**	**3.5**	**3.8**	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.4**	**9.7**	**11.3**	**15.3**	**15.7**	**15.7**	-	-	-
10 sq miles	**4.1**	**9.1**	**10.9**	**14.6**	**15.3**	**15.5**	-	-	-
100 sq miles	**3.0**	**6.1**	**9.7**	**13.2**	**14.0**	**14.1**	-	-	-
200 sq miles	**2.5**	**6.0**	**9.4**	**12.7**	**13.5**	**13.5**	-	-	-
500 sq miles	**2.2**	**4.9**	**8.4**	**11.6**	**12.4**	**12.5**	-	-	-
1000 sq miles	**1.8**	**4.2**	**7.5**	**10.3**	**10.9**	**11.1**	-	-	-
2000 sq miles	**1.4**	**3.2**	**5.5**	**8.2**	**9.0**	**9.2**	-	-	-
5000 sq miles	**0.7**	**1.7**	**3.5**	**5.2**	**5.8**	**6.3**	-	-	-
10000 sq miles	**0.4**	**1.1**	**2.0**	**3.1**	**3.7**	**4.1**	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**SPAS 1220 Dubuque, IA**	
Storm Date(s)	7/27-28/2011	
Storm Type	MCC	
Storm Location	42.44 N	90.75 W
Storm Center Elevation	900	
Precipitation Total & Duration	15.14 Inches 24-hours	
Storm Representative Dew Point	79.0 F	12
Storm Representative Dew Point Location	40.95 N	90.27 W
Maximum Dew Point	81.0 F	
Moisture Inflow Vector	SSE @ 105	Miles
In-place Maximization Factor	**1.09**	
Temporal Transposition Date	15-Jul	
Transposition Dew Point Location	43.84 N	93.35 W
Transposition Maximum Dew Point	80.5 F	
Transposition Adjustment Factor	**0.97**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.07**	

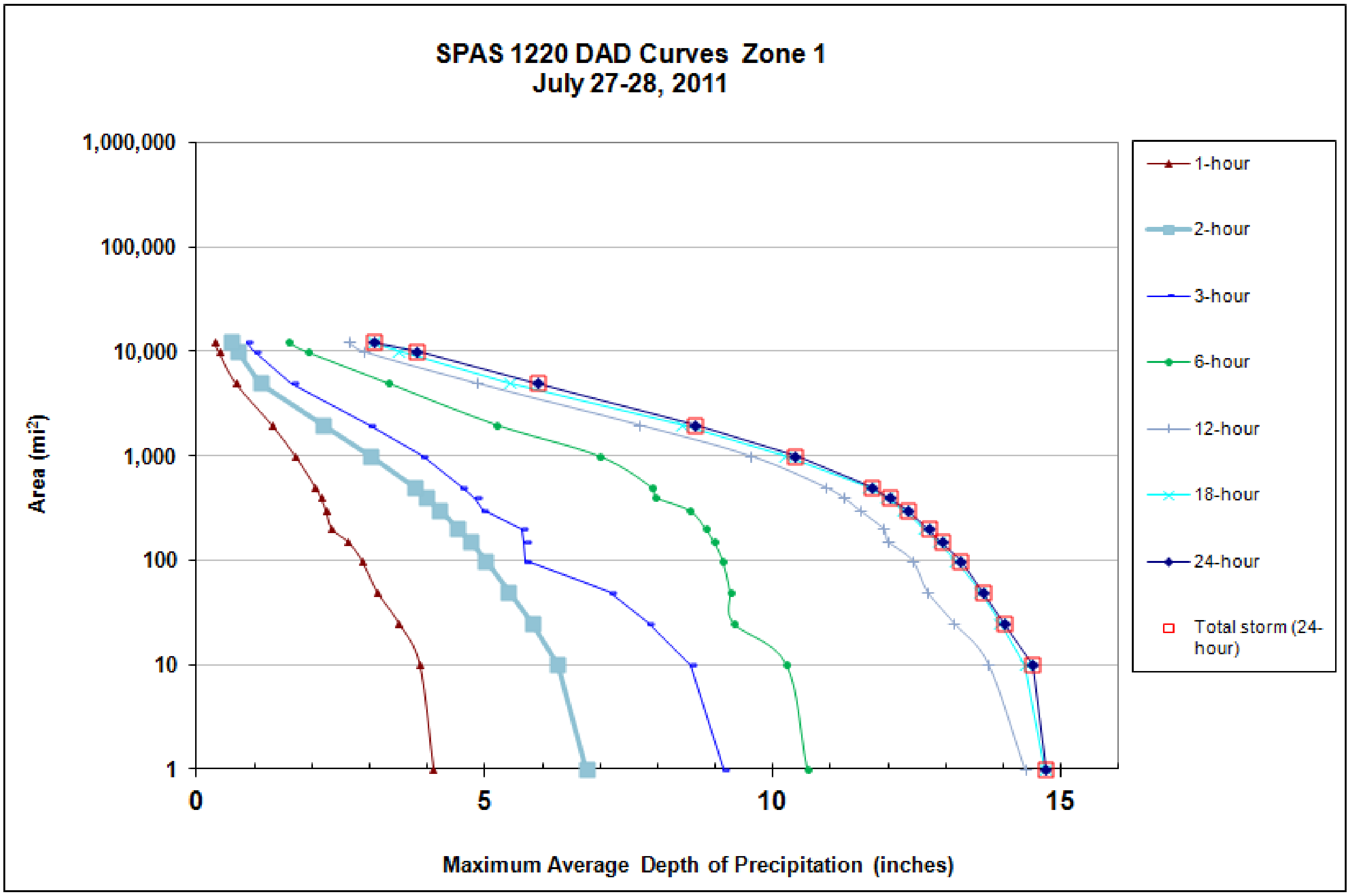
Attachment 3 Table 12: Storm spreadsheet for Dubuque, IA July 2011



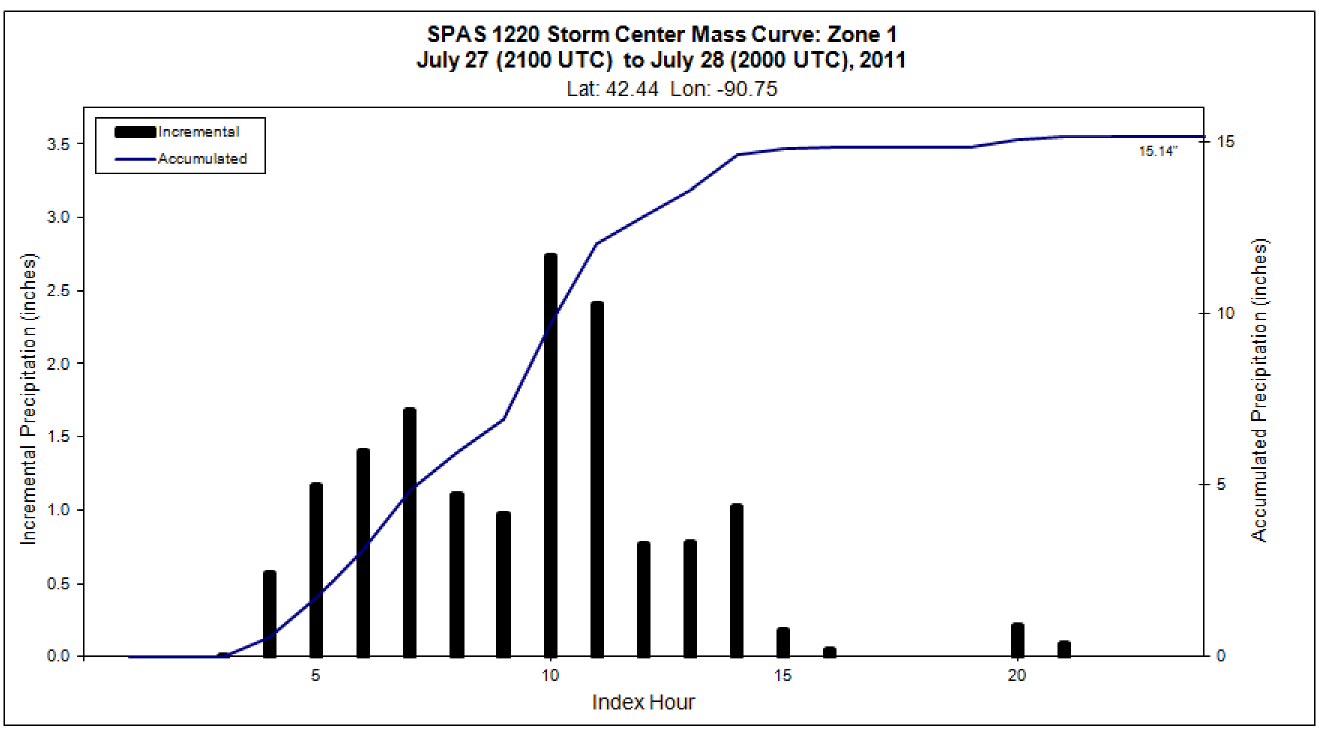
Attachment 3 Figure 18: Moisture inflow map for Dubuque, IA July 2011

Storm 1220 - July 27 (2100 UTC) - July 28 (2000 UTC), 2011								
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)								
	Duration (hours)							
Area (mi^2)	1	2	3	6	12	18	24	Total
0.4	4.2	6.92	9.38	10.9	14.8	15.14	15.14	15.14
1	4.1	6.76	9.13	10.6	14.37	14.72	14.73	14.73
10	3.86	6.26	8.56	10.24	13.74	14.38	14.5	14.50
25	3.5	5.82	7.83	9.32	13.14	13.94	14	14.00
50	3.12	5.41	7.15	9.26	12.68	13.59	13.64	13.64
100	2.86	5.01	5.69	9.13	12.42	13.17	13.25	13.25
150	2.62	4.75	5.68	8.98	12	12.87	12.93	12.93
200	2.34	4.53	5.63	8.84	11.92	12.63	12.7	12.70
300	2.24	4.21	4.95	8.56	11.51	12.26	12.33	12.33
400	2.15	3.98	4.82	7.97	11.22	11.97	12.02	12.02
500	2.06	3.78	4.58	7.9	10.92	11.65	11.7	11.70
1,000	1.71	3.01	3.9	6.99	9.62	10.19	10.38	10.38
2,000	1.3	2.18	2.98	5.2	7.67	8.4	8.63	8.63
5,000	0.68	1.1	1.64	3.33	4.86	5.44	5.91	5.91
10,000	0.39	0.71	0.99	1.92	2.91	3.49	3.8	3.80
12,295	0.31	0.6	0.86	1.59	2.63	3.06	3.07	3.07

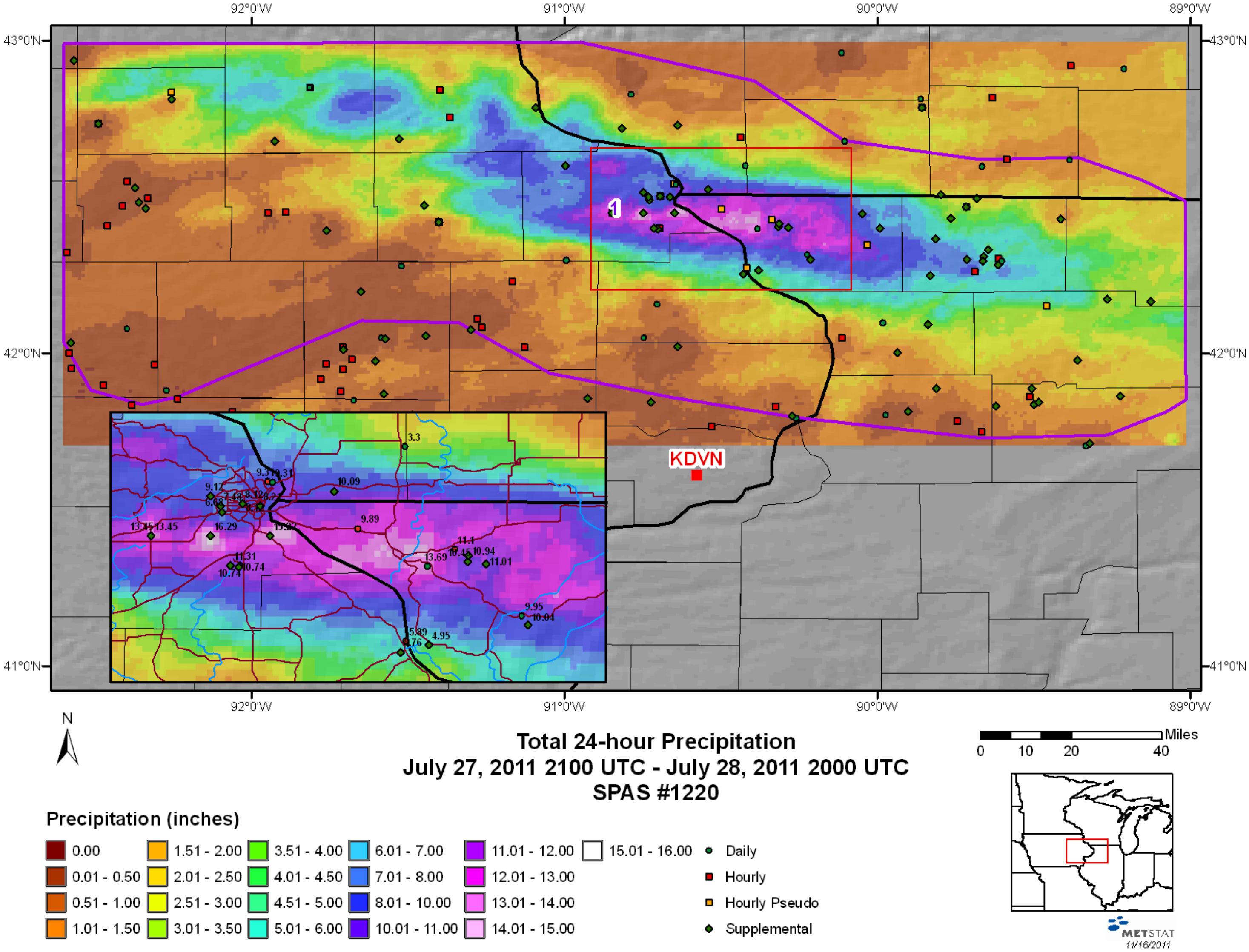
Attachment 3 Table 13: Depth-area-duration values for Dubuque, IA July 2011



Attachment 3 Figure 19: Depth-area-duration chart for Dubuque, IA July 2011



Attachment 3 Figure 20: Mass curve chart for Dubuque, IA July 2011



Attachment 3 Figure 21: Total storm isohyetal analysis for Dubuque, IA July 2011

Storm Name:	**USACE UMV 3-29-Dumont, IA**		
Storm Date:	**25-Jun-1951**		**Storm Adjustment for Monticello-LIP**
AWA Analysis Date:	**8/24/2014**		

Temporal Transposition Date	**10-Jul**	
	Lat	**Long**
Storm Center Location	**42.75 N**	**92.98 W**
Storm Rep Dew Point Location	**39.40 N**	**94.80 W**
Transposition Dew Point Locati	**41.98 N**	**95.74 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSW @ 250**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,000**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**75.5 F**	with total precipitable water above sea level of			**2.92**	inches.
The in-place maximum dew point is	**81.5 F**	with total precipitable water above sea level of			**3.83**	inches.
The transpositioned maximum dew point is	**81.5 F**	with total precipitable water above sea level of			**3.83**	inches.
The in-place storm elevation is	**1,000**	which subtracts	**0.26**	inches of precipitable water at	**75.5 F**	
The in-place storm elevation is	**1,000**	which subtracts	**0.31**	inches of precipitable water at	**81.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.30**	inches of precipitable water at	**81.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.30**	inches of precipitable water at	**81.5 F**	

The in-place maximization factor is	**1.32**
The transposition factor is	**1.00**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.33**

Notes: DAD values taken from USACE UMV 3-29. Storm representative Td value was based on maximum 6-hr Td values between June 25, 1951 at KSTJ, KMKC, and KTOP.

Observed Storm Depth-Area-Duration

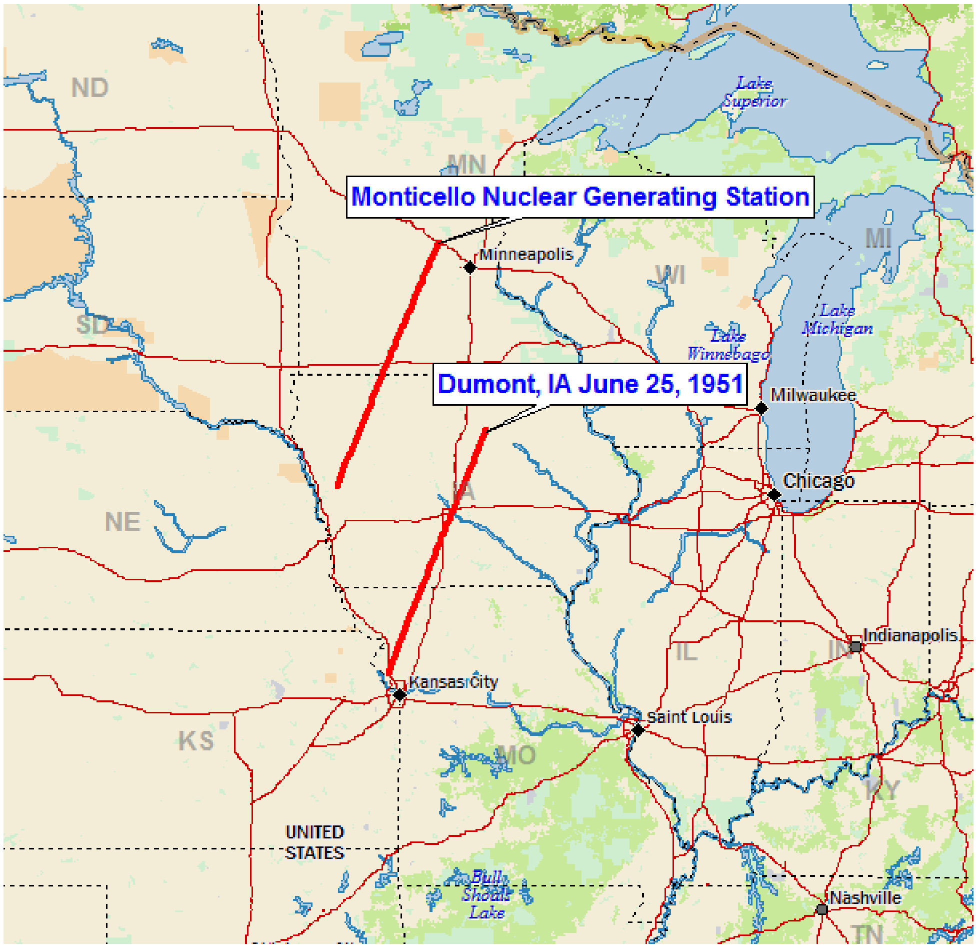
	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**6.8**	**9.4**	**12.0**	-	-	-	-	-	-
10 sq miles	**5.8**	**9.2**	**12.0**	-	-	-	-	-	-
100 sq miles	**4.4**	**7.7**	**10.0**	-	-	-	-	-	-
200 sq miles	**4.1**	**7.1**	**8.9**	-	-	-	-	-	-
500 sq miles	**3.6**	**6.1**	**7.5**	-	-	-	-	-	-
1000 sq miles	**3.2**	**5.3**	**6.6**	-	-	-	-	-	-
5000 sq miles	**2.1**	**3.5**	**4.4**	-	-	-	-	-	-
10000 sq miles	**1.6**	**2.7**	**3.5**	-	-	-	-	-	-
20000 sq miles	**1.2**	**1.9**	**2.5**	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**9.0**	**12.5**	**15.9**	-	-	-	-	-	-
10 sq miles	**7.7**	**12.2**	**15.9**	-	-	-	-	-	-
100 sq miles	**5.8**	**10.2**	**13.3**	-	-	-	-	-	-
200 sq miles	**5.4**	**9.4**	**11.8**	-	-	-	-	-	-
500 sq miles	**4.8**	**8.1**	**10.0**	-	-	-	-	-	-
1000 sq miles	**4.3**	**7.0**	**8.8**	-	-	-	-	-	-
5000 sq miles	**2.8**	**4.7**	**5.8**	-	-	-	-	-	-
10000 sq miles	**2.1**	**3.6**	**4.7**	-	-	-	-	-	-
20000 sq miles	**1.6**	**2.5**	**3.3**	-	-	-	-	-	-

Storm or Storm Center Name	**USACE UMV 3-29-Dumont, IA**			
Storm Date(s)	25-Jun-1951			
Storm Type	MCC			
Storm Location	42.75 N	92.98 W		
Storm Center Elevation	1,000			
Precipitation Total & Duration	12.00 Inches 6-hours USACE UMV 3-29			
Storm Representative Dew Point	75.5 F	6		
Storm Representative Dew Point Location	39.40 N	94.80 W	Jun	Jul
Maximum Dew Point	81.5 F		79	82.5
Moisture Inflow Vector	SSW @ 250	Miles		
In-place Maximization Factor	**1.32**			
Temporal Transpostion Date	10-Jul		Jun	Jul
Transposition Dew Point Location	41.98 N	95.74 W	78.92	82.15
Transposition Maximum Dew Point	81.5 F			
Transposition Adjustment Factor	**1.00**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.33**			

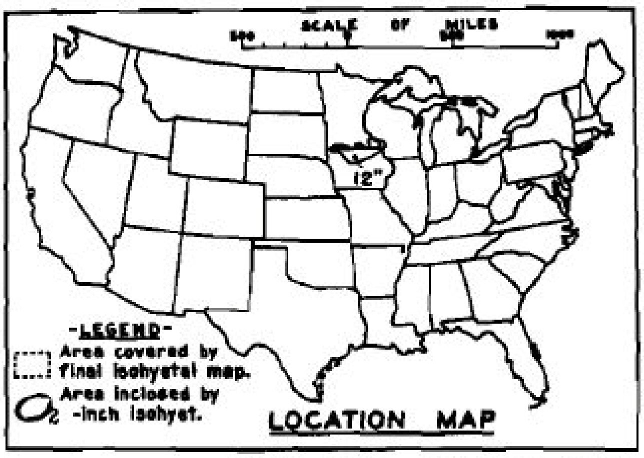
Attachment 3 Table 14: Storm spreadsheet for Dumont, IA June 1951



Attachment 3 Figure 22: Moisture inflow map for Dumont, IA June 1951

DEPARTMENT OF THE ARMY | CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 25-26 June 1951
Assignment UMV 3-29
Location Iowa, Minnesota & Wisc.
Study Prepared by:
North Central Division
Rock Island District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 11-21-55
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 7-18-57
Remarks:
Center near Dumont, Iowa. Rep. Dewpoint 72°, Ref. Pt. 160 SW

DATA AND COMPUTATIONS COMPILED
Grid D-13

PART I

Preliminary isohyetal map, in 1 sheet , scale 1:1,000,000

Precipitation data and mass curves:	(Number of Sheets)
Form 5001-C (Hourly precip. data)	56
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	11
Miscl. precip. records, meteorological data, etc.	1
Form 5002 (Mass rainfall curves)	45

PART II

Final isohyetal maps, in 1 sheet , scale 1:500,000

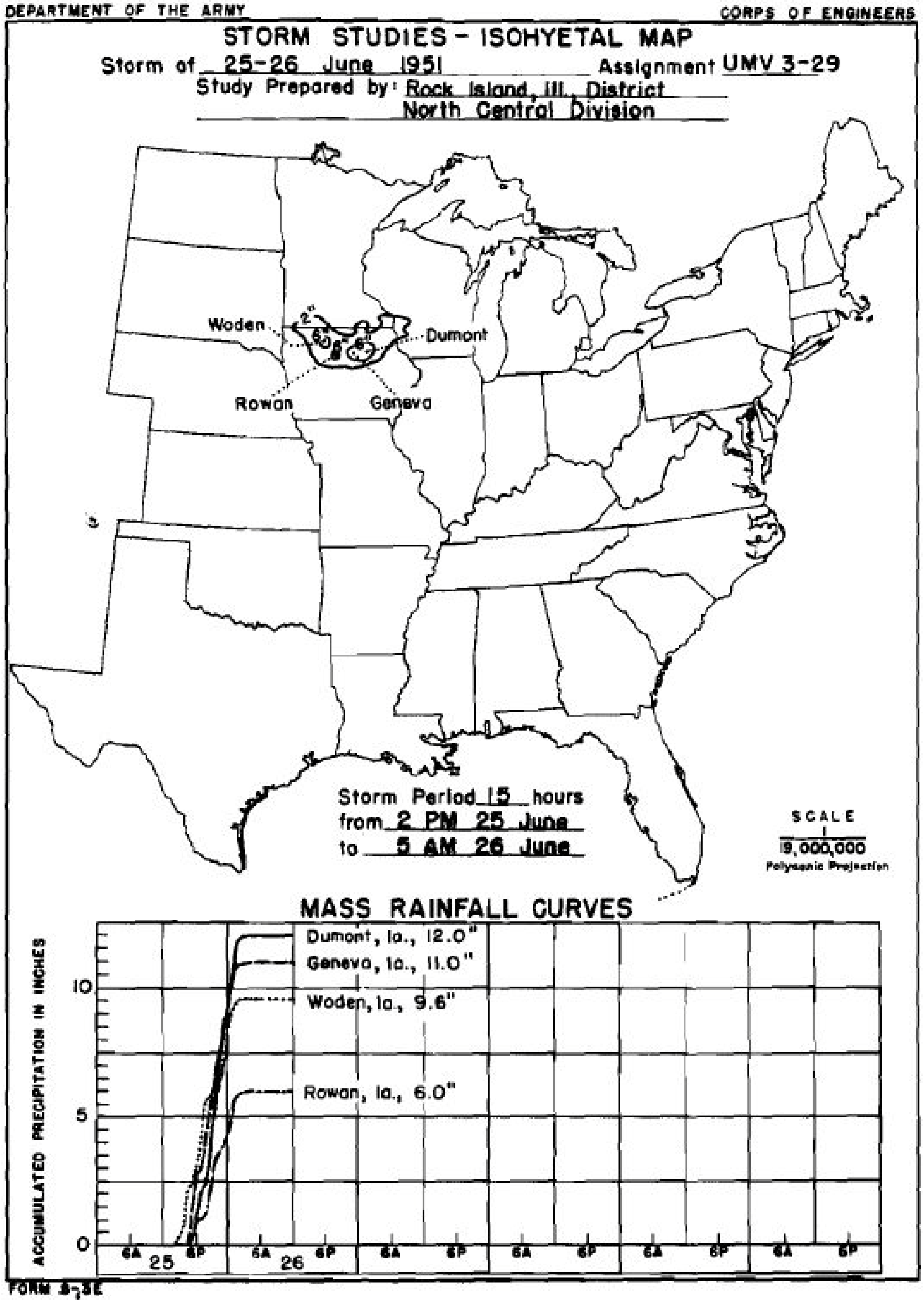
Data and computation sheets:	
Form S-10 (Data from mass rainfall curves)	5
Form S-11 (Depth-area data from isohyetal map)	1
Form S-12 (Maximum depth-duration data)	5
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	3	6	9	12	15						
Max.Station	6.8	9.4	11.6	12.0	12.0						
10	5.8	9.2	11.6	12.0	12.0						
100	4.4	7.7	9.7	10.0	10.0						
200	4.1	7.1	8.6	8.9	8.9						
500	3.6	6.1	7.3	7.5	7.6						
1000	3.2	5.3	6.4	6.6	6.6						
2000	2.7	4.5	5.4	5.6	5.7						
5000	2.1	3.5	4.2	4.4	4.5						
10000	1.6	2.7	3.3	3.5	3.6						
20000	1.2	1.9	2.3	2.5	2.6						

Form S-2

Attachment 3 Table 15: Depth-area-duration values for Dumont, IA June 1951



Attachment 3 Figure 23 and Attachment 3 Figure 24: Isohyetal map and Mass curve chart for Dumont, IA June 1951

Storm Name:	**SPAS -1034-Enid, OK**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**10-Oct-1973**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date **25-Sep**

	Lat	Long
Storm Center Location	**36.38 N**	**97.87 W**
Storm Rep Dew Point Location	**33.35 N**	**96.55 W**
Transposition Dew Point Locati	**42.30 N**	**92.36 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSE @ 225**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,250**	feet
Storm Analysis Duration	**12**	hours

The storm representative dew point is	**75.0 F**	with total precipitable water above sea level of			**2.85**	inches.
The in-place maximum dew point is	**76.5 F**	with total precipitable water above sea level of			**3.07**	inches.
The transpositioned maximum dew point is	**74.0 F**	with total precipitable water above sea level of			**2.73**	inches.
The in-place storm elevation is	**1,250**	which subtracts	**0.31**	inches of precipitable water at	**75.0 F**	
The in-place storm elevation is	**1,250**	which subtracts	**0.33**	inches of precipitable water at	**76.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.23**	inches of precipitable water at	**74.0 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.23**	inches of precipitable water at	**74.0 F**	

The in-place maximization factor is	**1.08**
The transposition factor is	**0.91**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**0.98**

Notes: DAD values taken from SPAS 1034. 12hr average taken from KDFW and WACO from 2100CDT 10-9-73 to 0900CDT10-10-73

Observed Storm Depth-Area-Duration

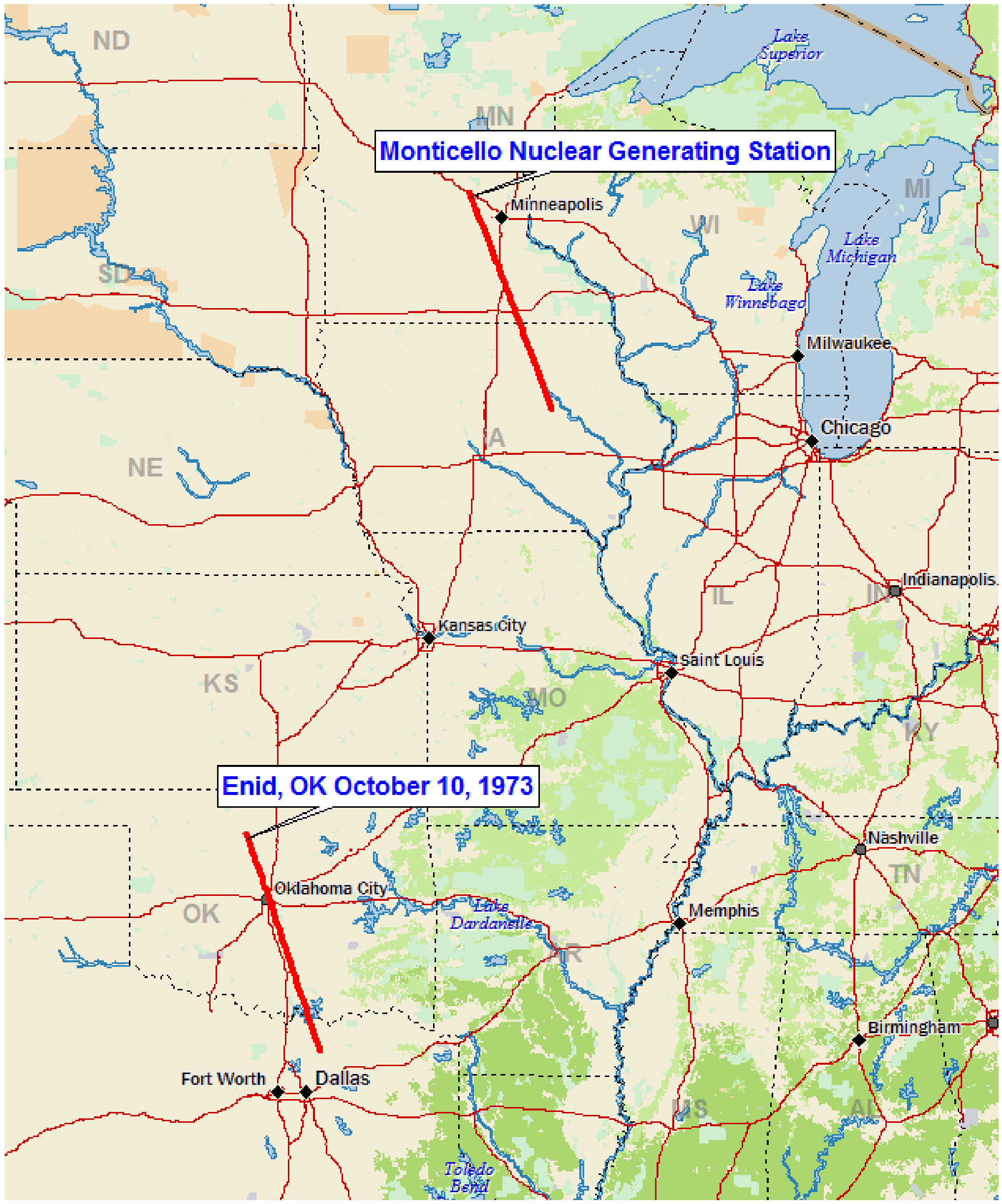
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**11.2**	**17.1**	**19.0**	**19.0**	-	**19.0**	**19.2**	-	**19.4**
10 sq miles	**10.7**	**16.3**	**18.1**	**18.1**	-	**18.1**	**18.3**	-	**18.5**
100 sq miles	**9.7**	**14.6**	**16.2**	**16.2**	-	**16.2**	**16.4**	-	**16.6**
200 sq miles	**9.1**	**13.7**	**15.2**	**15.2**	-	**15.2**	**15.3**	-	**15.5**
500 sq miles	**7.9**	**11.3**	**12.7**	**12.7**	-	**12.7**	**12.9**	-	**12.9**
1000 sq miles	**6.7**	**9.5**	**10.5**	**10.5**	-	**10.5**	**10.6**	-	**10.6**
5000 sq miles	**3.9**	**5.2**	**5.6**	**5.6**	-	**5.6**	**5.7**	-	**5.7**
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**11.0**	**16.8**	**18.7**	**18.7**	-	**18.7**	**18.9**	-	**19.1**
10 sq miles	**10.6**	**16.1**	**17.8**	**17.8**	-	**17.8**	**18.0**	-	**18.2**
100 sq miles	**9.5**	**14.4**	**15.9**	**15.9**	-	**15.9**	**16.1**	-	**16.3**
200 sq miles	**8.9**	**13.5**	**15.0**	**15.0**	-	**15.0**	**15.1**	-	**15.3**
500 sq miles	**7.8**	**11.1**	**12.5**	**12.5**	-	**12.5**	**12.7**	-	**12.7**
1000 sq miles	**6.6**	**9.3**	**10.4**	**10.4**	-	**10.4**	**10.4**	-	**10.5**
5000 sq miles	**3.8**	**5.1**	**5.5**	**5.5**	-	**5.5**	**5.6**	-	**5.6**
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**SPAS -1034-Enid, OK**			
Storm Date(s)	10-Oct-1973			
Storm Type	MCC			
Storm Location	36.38 N	97.87 W		
Storm Center Elevation	1,250			
Precipitation Total & Duration	20.00 Inches 15-hours NCDC Storm Data report			
Storm Representative Dew Point	75.0 F	12		
Storm Representative Dew Point Location	33.35 N	96.55 W		
Maximum Dew Point	76.5 F			
Moisture Inflow Vector	SSE @ 225			
In-place Maximization Factor	**1.08**			
Temporal Transposition Date	25-Sep		Sep	Oct
Transposition Dew Point Location	42.30 N	92.36 W	75.5	71.37
Transposition Maximum Dew Point	74.0 F			
Transposition Adjustment Factor	**0.91**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**0.98**			

Attachment 3 Table 16: Storm spreadsheet for Enid, OK October 1973



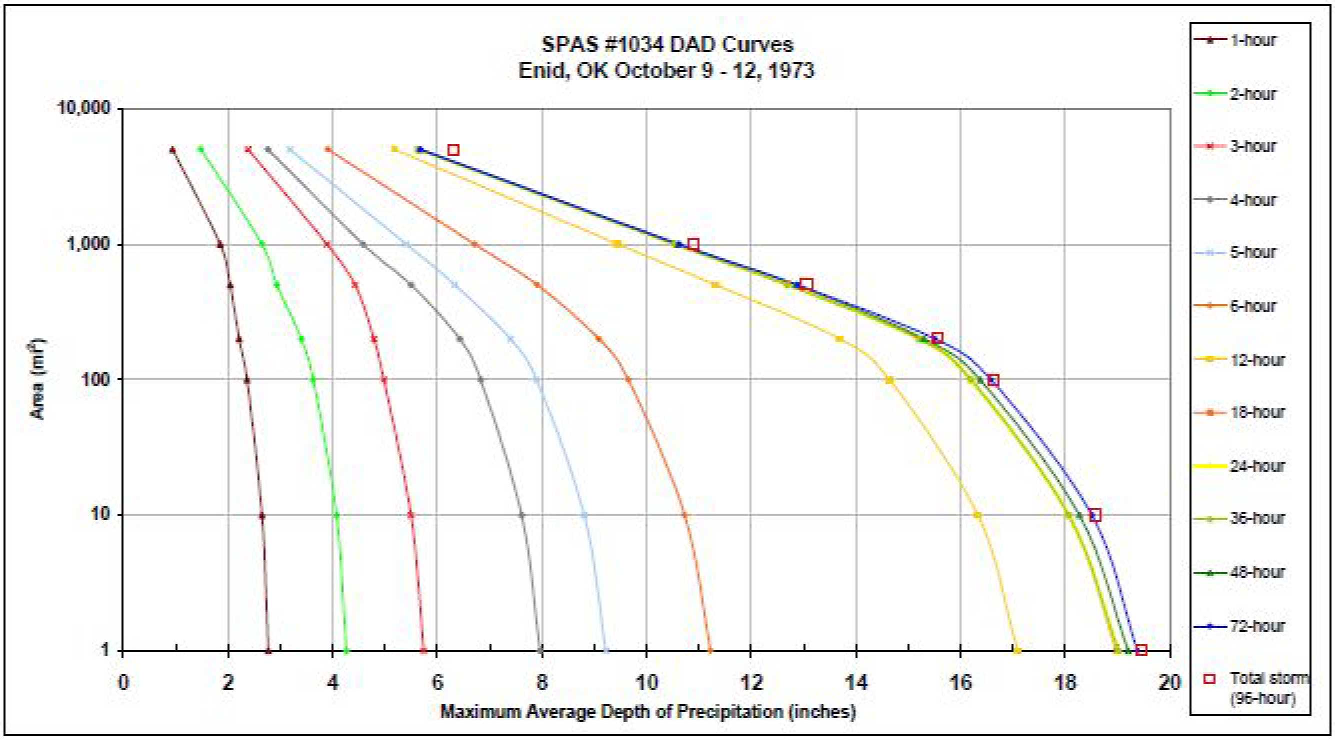
Attachment 3 Figure 25: Moisture inflow map for Enid, OK October 1973

Storm 1034 - Enid OK, October 9 - 12, 1973

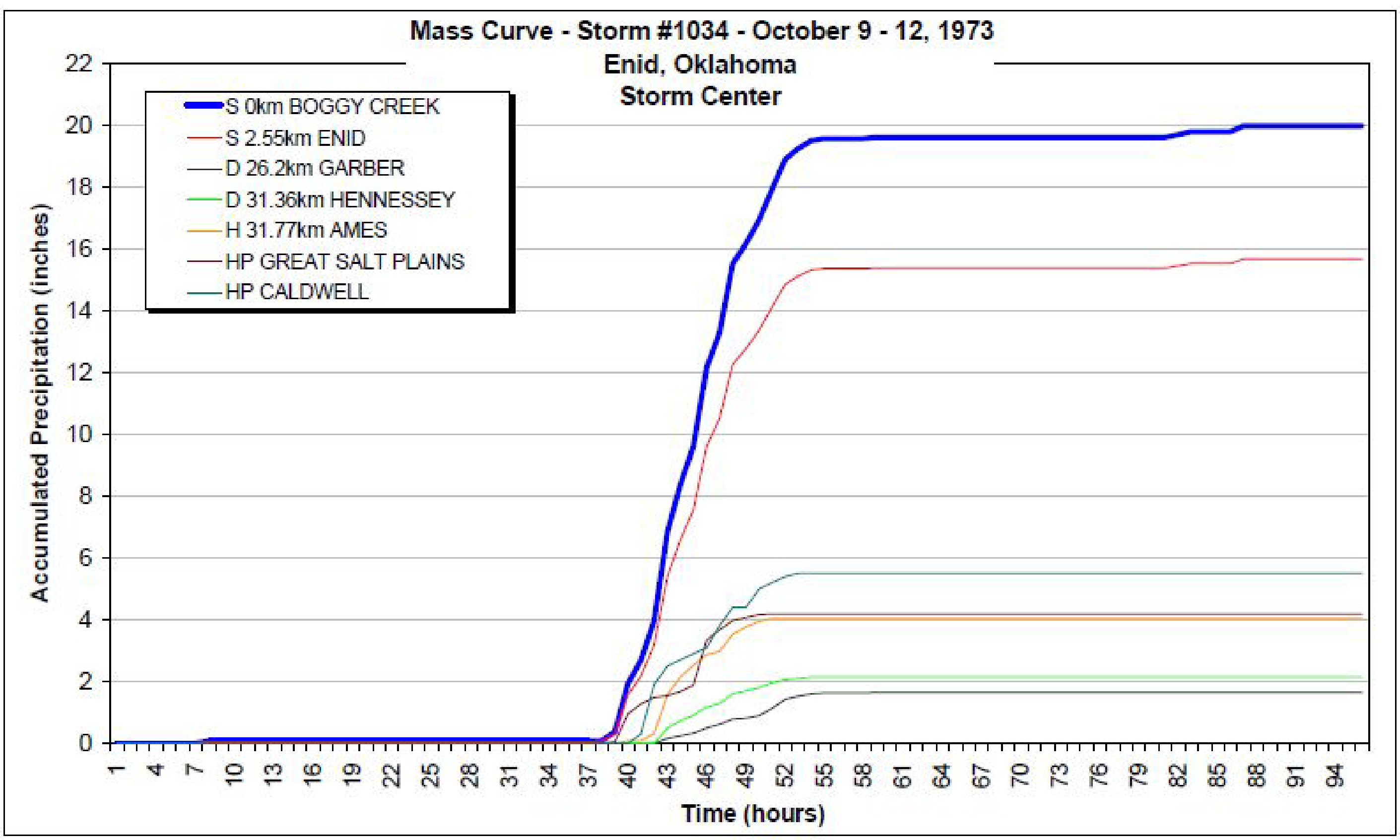
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

Area (mi²)	Duration (hours)													
	1	2	3	4	5	6	12	18	24	36	48	72	96	total
1	2.77	4.26	5.74	7.96	9.22	11.22	17.09	18.98	19.02	19.02	19.20	19.38	19.45	19.45
10	2.65	4.07	5.50	7.61	8.81	10.73	16.33	18.07	18.07	18.07	18.27	18.51	18.58	18.58
100	2.36	3.63	4.98	6.83	7.90	9.65	14.64	16.19	16.20	16.20	16.37	16.58	16.64	16.64
200	2.21	3.40	4.79	6.43	7.40	9.09	13.69	15.19	15.21	15.21	15.30	15.51	15.57	15.57
500	2.04	2.93	4.43	5.50	6.33	7.91	11.32	12.69	12.69	12.69	12.86	12.89	13.06	13.06
1,000	1.85	2.65	3.89	4.58	5.40	6.71	9.45	10.53	10.53	10.53	10.60	10.63	10.89	10.89
5,000	0.94	1.48	2.38	2.76	3.18	3.91	5.18	5.63	5.63	5.63	5.67	5.68	6.32	6.32

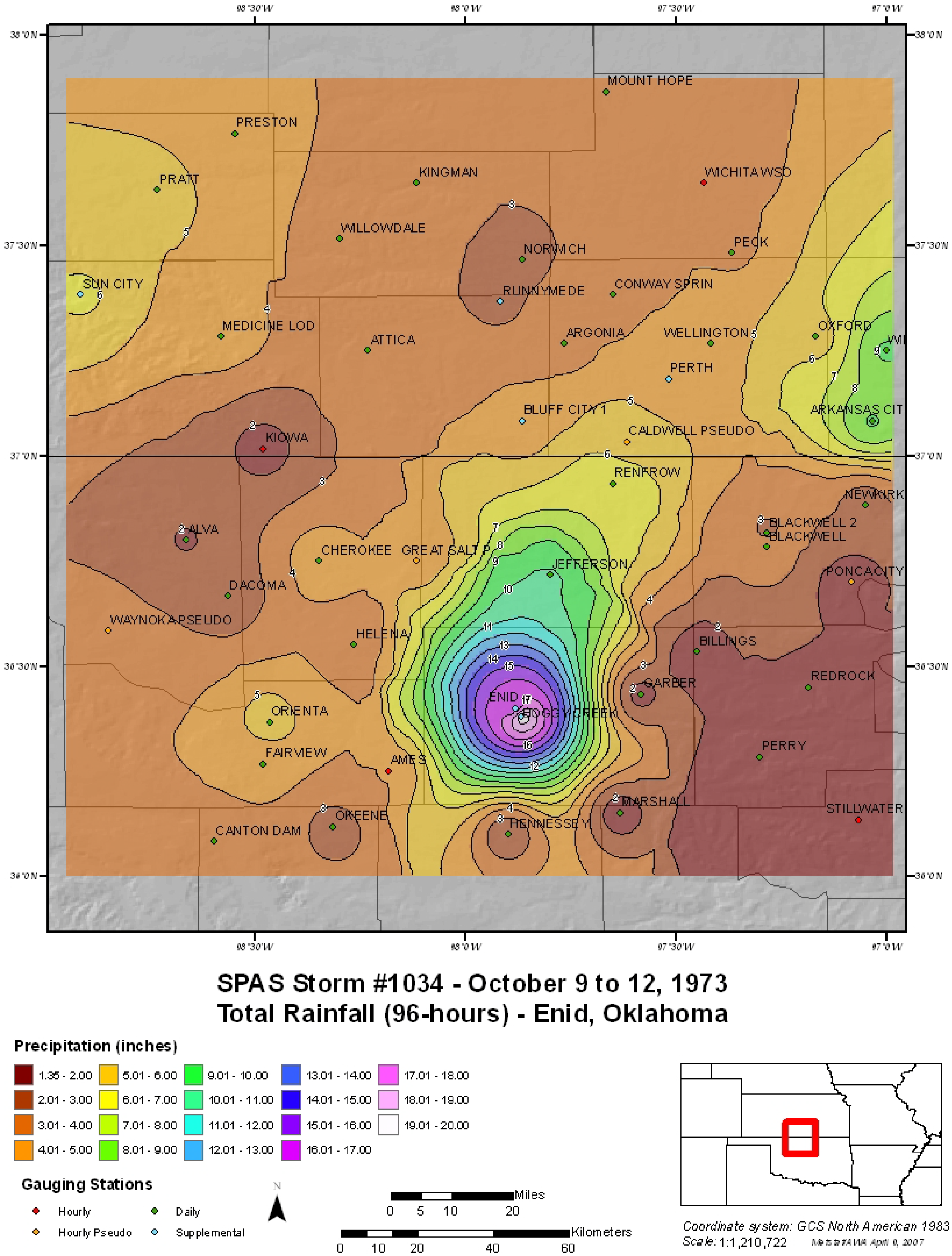
Attachment 3 Table 17: Depth-area-duration values for Enid, OK October 1973



Attachment 3 Figure 26: Depth-area-duration chart for Enid, OK October 1973



Attachment 3 Figure 27: Mass curve chart for Enid, OK October 1973



Attachment 3 Figure 28: Total storm isohyetal analysis for Enid, OK October 1973

Storm Name:	**SPAS 1228 Fall River, KS**	
Storm Date:	**6/28/2007 - 7/2/2007**	**Storm Adjustment for Monticello-LIP**
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	**37.63 N**	**96.05 W**
Storm Rep Dew Point Location	**31.00 N**	**95.50 W**
Transposition Dew Point Locati	**38.70 N**	**93.24 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**S @ 460**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**900**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**76.5 F**	with total precipitable water above sea level of			**3.07**	inches.
The in-place maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The transpositioned maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The in-place storm elevation is	**900**	which subtracts	**0.21**	inches of precipitable water at	**76.5 F**	
The in-place storm elevation is	**900**	which subtracts	**0.27**	inches of precipitable water at	**80.0 F**	
The transposition storm elevation at	**950**	which subtracts	**0.28**	inches of precipitable water at	**80.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.28**	inches of precipitable water at	**80.5 F**	

The in-place maximization factor is	**1.17**
The transposition factor is	**1.02**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.19**

Notes: DAD values taken from SPAS 1228. Storm representative dew point value was based on maximum 24-hr Td values between June 27-28, 2007 at KDKR and KUTS.

Observed Storm Depth-Area-Duration

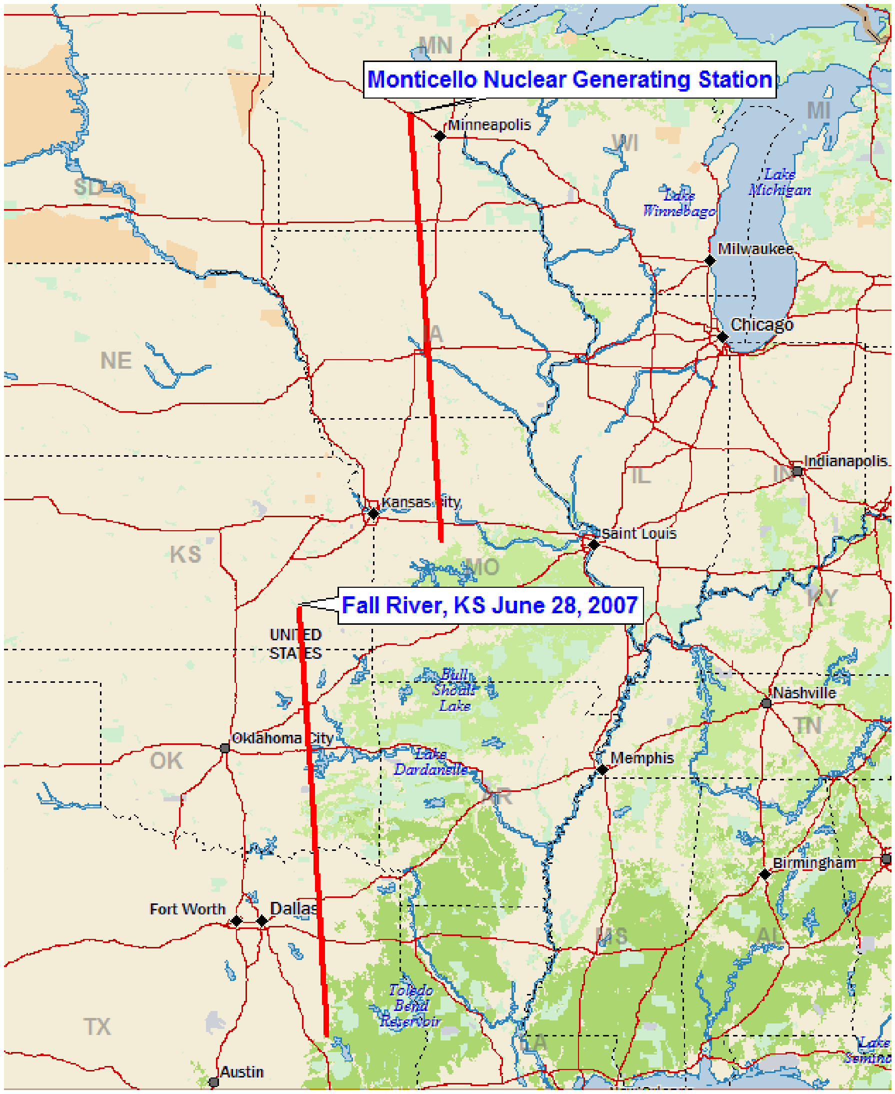
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.6**	**6.4**	**8.9**	**11.0**	**14.4**	**14.5**	**17.2**	**22.1**	**24.8**
10 sq miles	**4.2**	**6.3**	**8.8**	**10.7**	**13.8**	**13.9**	**17.1**	**21.9**	**24.8**
100 sq miles	**3.1**	**5.1**	**7.6**	**10.2**	**12.7**	**13.0**	**15.7**	**18.1**	**21.7**
200 sq miles	**2.8**	**4.7**	**7.0**	**9.6**	**11.8**	**11.9**	**14.8**	**17.1**	**20.7**
500 sq miles	**2.2**	**3.5**	**5.9**	**8.4**	**10.4**	**10.7**	**13.2**	**15.5**	**19.2**
1000 sq miles	**1.6**	**3.3**	**4.8**	**7.2**	**9.0**	**10.0**	**12.1**	**14.2**	**18.1**
2000 sq miles	**1.1**	**2.4**	**3.9**	**6.0**	**7.8**	**9.0**	**10.8**	**12.6**	**16.0**
5000 sq miles	**0.7**	**1.8**	**2.9**	**4.7**	**6.3**	**6.4**	**9.0**	**10.4**	**13.7**
10000 sq miles	**0.4**	**1.4**	**2.2**	**3.7**	**5.1**	**6.0**	**7.5**	**8.7**	**11.1**
20000 sq miles	**0.3**	**0.6**	**1.5**	**2.7**	**3.8**	**4.6**	**5.7**	**7.0**	**9.2**

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**5.4**	**7.6**	**10.5**	**13.1**	**17.1**	**17.2**	**20.5**	**26.3**	**29.6**
10 sq miles	**5.0**	**7.5**	**10.5**	**12.7**	**16.4**	**16.5**	**20.3**	**26.0**	**29.6**
100 sq miles	**3.7**	**6.1**	**9.1**	**12.2**	**15.2**	**15.5**	**18.7**	**21.6**	**25.9**
200 sq miles	**3.3**	**5.5**	**8.3**	**11.4**	**14.0**	**14.2**	**17.6**	**20.3**	**24.6**
500 sq miles	**2.6**	**4.2**	**7.0**	**10.0**	**12.3**	**12.7**	**15.8**	**18.5**	**22.9**
1000 sq miles	**1.9**	**3.9**	**5.7**	**8.5**	**10.7**	**12.0**	**14.4**	**16.9**	**21.6**
2000 sq miles	**1.4**	**2.8**	**4.7**	**7.2**	**9.3**	**10.7**	**12.9**	**15.0**	**19.1**
5000 sq miles	**0.8**	**2.2**	**3.5**	**5.6**	**7.5**	**7.6**	**10.7**	**12.4**	**16.3**
10000 sq miles	**0.5**	**1.7**	**2.6**	**4.5**	**6.1**	**7.2**	**8.9**	**10.4**	**13.2**
20000 sq miles	**0.3**	**0.8**	**1.8**	**3.3**	**4.5**	**5.4**	**6.8**	**8.3**	**10.9**

Storm or Storm Center Name	**SPAS 1228 Fall River, KS**	
Storm Date(s)	6/28/2007 - 7/2/2007	
Storm Type	Synoptic	
Storm Location	37.63 N	96.05 W
Storm Center Elevation	900	
Precipitation Total & Duration	25.50 Inches 95-hours	
Storm Representative Dew Point	76.5 F	24
Storm Representative Dew Point Location	31.00 N	95.50 W
Maximum Dew Point	80.0 F	
Moisture Inflow Vector	S @ 460	Miles
In-place Maximization Factor	**1.17**	
Temporal Transposition Date	15-Jul	
Transposition Dew Point Location	38.70 N	93.24 W
Transposition Maximum Dew Point	80.5 F	
Transposition Adjustment Factor	**1.02**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.19**	

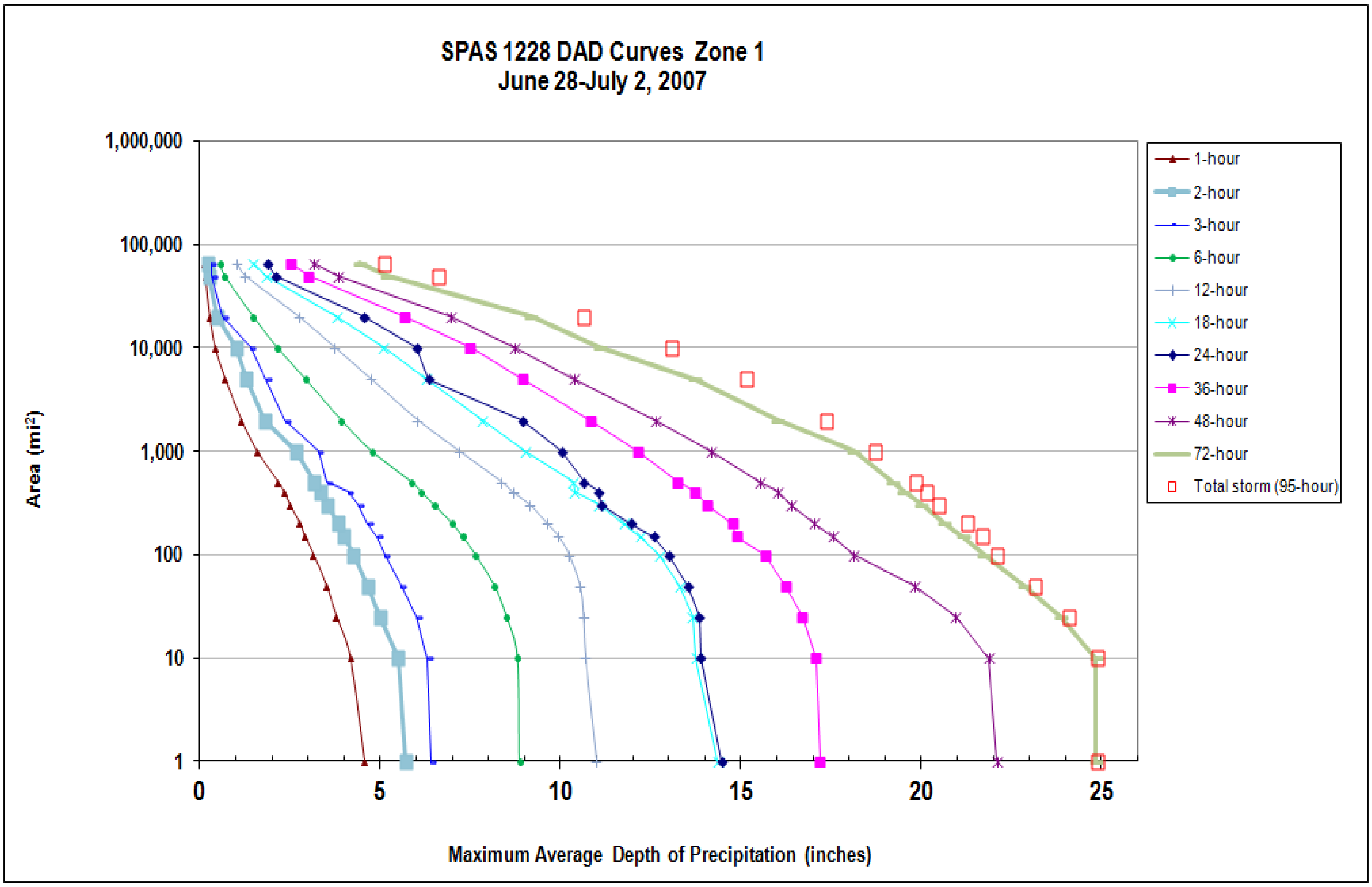
Attachment 3 Table 18: Storm spreadsheet for Fall River, KS June 2007



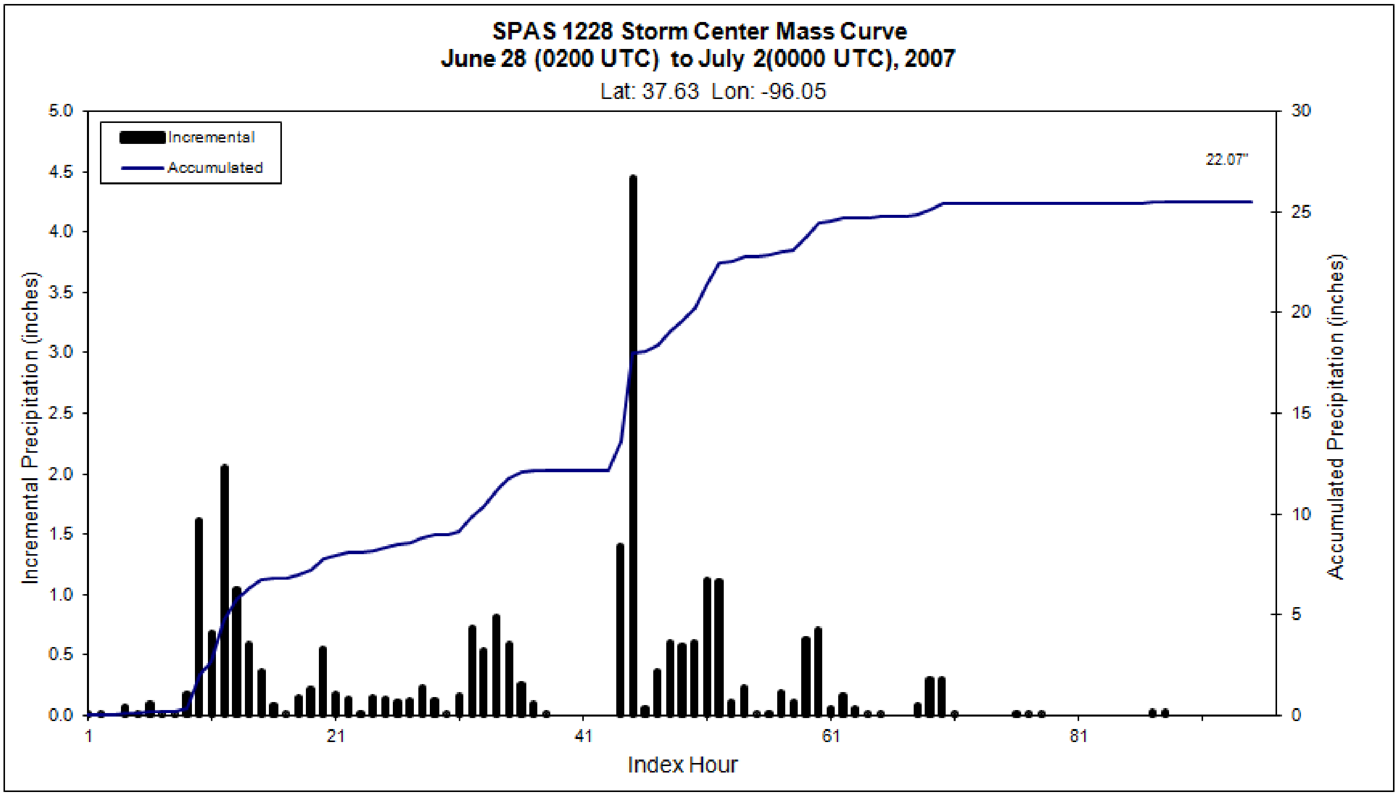
Attachment 3 Figure 29: Moisture inflow map for Fall River, KS June 2007

Storm 1228 - June 28 (0200 UTC) - July 2 (0000 UTC), 2007											
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)											
	Duration (hours)										
Area (mi^2)	1	2	3	6	12	18	24	36	48	72	Total
0.4	4.68	5.84	6.6	9.12	11.37	14.72	14.91	17.72	22.66	25.43	25.50
1	4.56	5.7	6.41	8.86	10.99	14.35	14.46	17.2	22.09	24.84	24.90
10	4.16	5.5	6.31	8.81	10.69	13.76	13.89	17.08	21.88	24.84	24.90
25	3.78	4.99	6.02	8.51	10.63	13.66	13.85	16.71	20.96	23.86	24.10
50	3.5	4.66	5.58	8.17	10.53	13.31	13.53	16.24	19.81	22.86	23.18
100	3.14	4.26	5.12	7.64	10.22	12.73	13.01	15.68	18.13	21.74	22.11
150	2.9	4	4.91	7.28	9.93	12.22	12.58	14.89	17.55	21.16	21.69
200	2.76	3.83	4.65	6.99	9.61	11.77	11.94	14.76	17.05	20.65	21.28
300	2.49	3.54	4.4	6.5	9.14	11.07	11.13	14.05	16.39	20.02	20.49
400	2.33	3.35	4.11	6.15	8.67	10.39	11.07	13.73	16.03	19.53	20.17
500	2.16	3.18	3.52	5.87	8.36	10.36	10.65	13.24	15.53	19.21	19.84
1,000	1.57	2.66	3.29	4.76	7.18	9.02	10.04	12.13	14.17	18.13	18.71
2,000	1.14	1.79	2.37	3.92	6.03	7.83	8.95	10.82	12.62	16.03	17.37
5,000	0.69	1.29	1.83	2.92	4.73	6.29	6.35	8.96	10.39	13.73	15.17
10,000	0.41	1	1.4	2.15	3.74	5.09	6.01	7.5	8.72	11.08	13.09
20,000	0.26	0.48	0.63	1.48	2.73	3.79	4.55	5.68	6.95	9.18	10.66
50,000	0.14	0.25	0.34	0.68	1.24	1.84	2.11	3.02	3.82	5.21	6.63
65,761	0.12	0.23	0.31	0.55	1.03	1.48	1.87	2.51	3.15	4.44	5.10

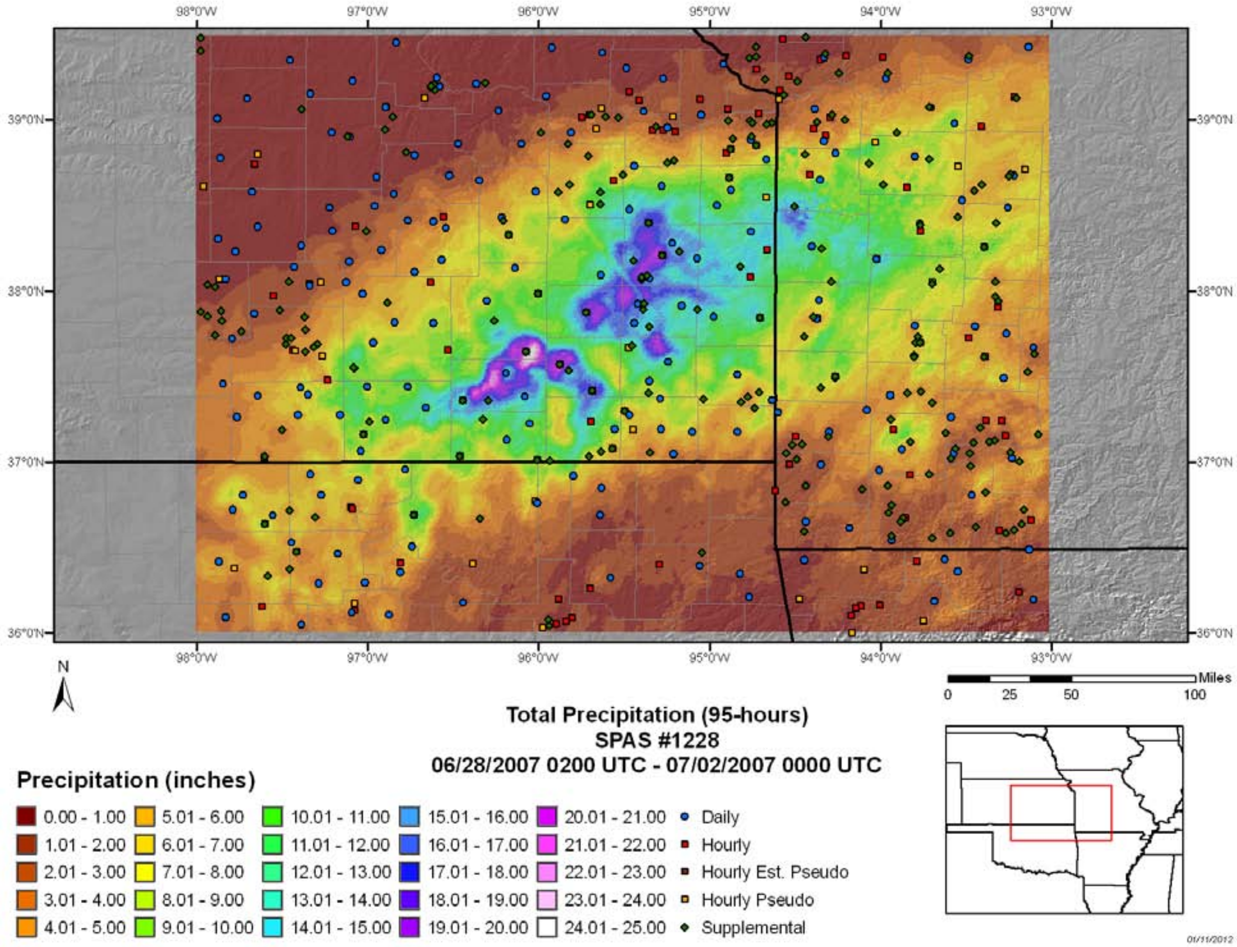
Attachment 3 Table 19: Depth-area-duration values for Fall River, KS June 2007



Attachment 3 Figure 30: Depth-area-duration chart for Fall River, KS June 2007



Attachment 3 Figure 31: Mass curve chart for Fall River, KS June 2007



Attachment 3 Figure 32: Total storm isohyetal analysis for Fall River, KS June 2007

Storm Name:	SPAS 1035-Forest City, MN	**Storm Adjustment for Monticello-LIP**
Storm Date:	21-Jun-1983	
AWA Analysis Date:	8/25/2014	

Temporal Transposition Date	6-Jul	
	Lat	Long
Storm Center Location	45.24 N	94.54 W
Storm Rep Dew Point Location	44.02 N	92.94 W
Transposition Dew Point Locati	44.11 N	92.25 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	SE @ 115	miles
Basin Average Elevation	950	feet
Storm Center Elevation	1,100	feet
Storm Analysis Duration	12	hours

The storm representative dew point is	72.0 F	with total precipitable water above sea level of			2.47	inches.
The in-place maximum dew point is	79.5 F	with total precipitable water above sea level of			3.52	inches.
The transpositioned maximum dew point is	79.5 F	with total precipitable water above sea level of			3.52	inches.
The in-place storm elevation is	1,100	which subtracts	0.25	inches of precipitable water at	72.0 F	
The in-place storm elevation is	1,100	which subtracts	0.34	inches of precipitable water at	79.5 F	
The transposition storm elevation at	950	which subtracts	0.28	inches of precipitable water at	79.5 F	
The moisture inflow barrier height is	950	which subtracts	0.28	inches of precipitable water at	79.5 F	

The in-place maximization factor is	1.43
The transposition factor is	1.02
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.46

Notes: DAD values taken from SPAS 1035. 12hr average Td taken from KRST, MCW, and KMSP 9hr ave from 06-20-83 22Z to 06-21-83 06Z

Observed Storm Depth-Area-Duration

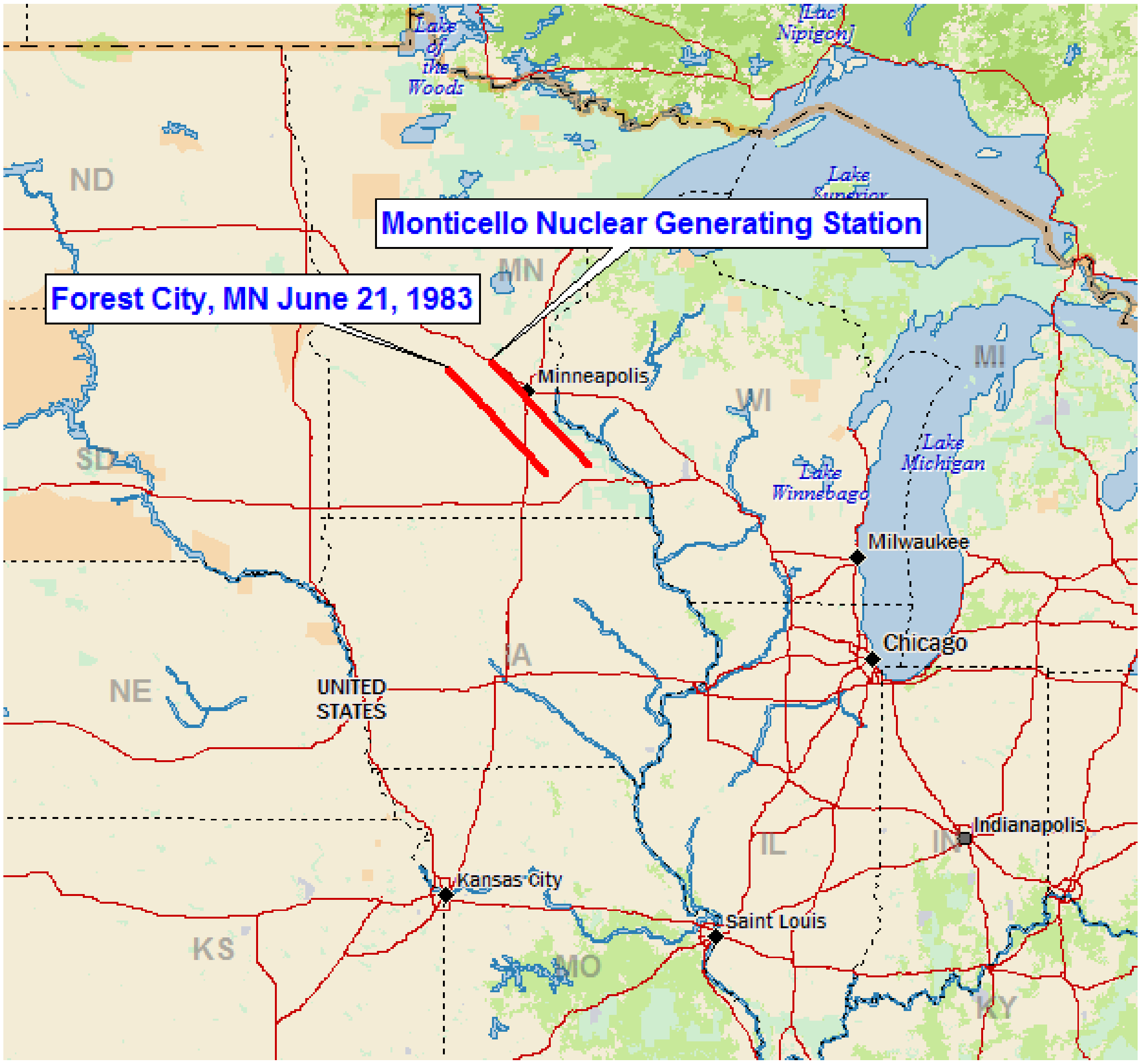
	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	3.7	8.4	13.8	13.9	13.9	-	16.5	16.5	-	16.5
10 sq miles	3.3	7.7	12.7	12.7	12.7	-	15.3	15.3	-	15.3
100 sq miles	2.6	6.2	10.2	10.2	10.2	-	12.8	12.8	-	12.8
200 sq miles	2.4	5.8	9.4	9.5	9.5	-	12.0	12.0	-	12.0
500 sq miles	2.2	5.0	7.9	8.0	8.0	-	9.9	9.9	-	10.0
1000 sq miles	2.0	4.5	6.5	6.6	6.6	-	7.9	7.9	-	7.9
5000 sq miles	1.1	2.4	3.4	3.4	3.4	-	4.0	4.0	-	4.0
10000 sq miles	-	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hours	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	5.3	12.2	20.2	20.3	20.3	-	24.1	24.1	-	24.1
10 sq miles	4.8	11.3	18.6	18.6	18.6	-	22.4	22.4	-	22.4
100 sq miles	3.8	9.1	14.9	14.9	14.9	-	18.7	18.7	-	18.7
200 sq miles	3.5	8.4	13.7	13.8	13.8	-	17.5	17.5	-	17.5
500 sq miles	3.2	7.3	11.6	11.6	11.6	-	14.4	14.4	-	14.6
1000 sq miles	3.0	6.5	9.5	9.6	9.6	-	11.5	11.5	-	11.5
5000 sq miles	1.6	3.5	4.9	4.9	4.9	-	5.8	5.8	-	5.8
10000 sq miles	-	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**SPAS 1035-Forest City, MN**			
Storm Date(s)	21-Jun-1983			
Storm Type	MCC-Thunderstorm Complex			
Storm Location	45.24 N	94.54 W		
Storm Center Elevation	1,100			
Precipitation Total & Duration	17.00 Inches 12-hours NCDC Storm Data report			
Storm Representative Dew Point	72.0 F	12		
Storm Representative Dew Point Location	44.02 N	92.94 W		
Maximum Dew Point	79.5 F			
Moisture Inflow Vector	SE @ 115			
In-place Maximization Factor	**1.43**			
Temporal Transposition Date	6-Jul			
Transposition Dew Point Location	44.11 N	92.25 W	June	July
Transposition Maximum Dew Point	79.5 F		77.15	80.27
Transposition Adjustment Factor	**1.02**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.46**			

Attachment 3 Table 20: Storm spreadsheet for Forest City, MN June 1983

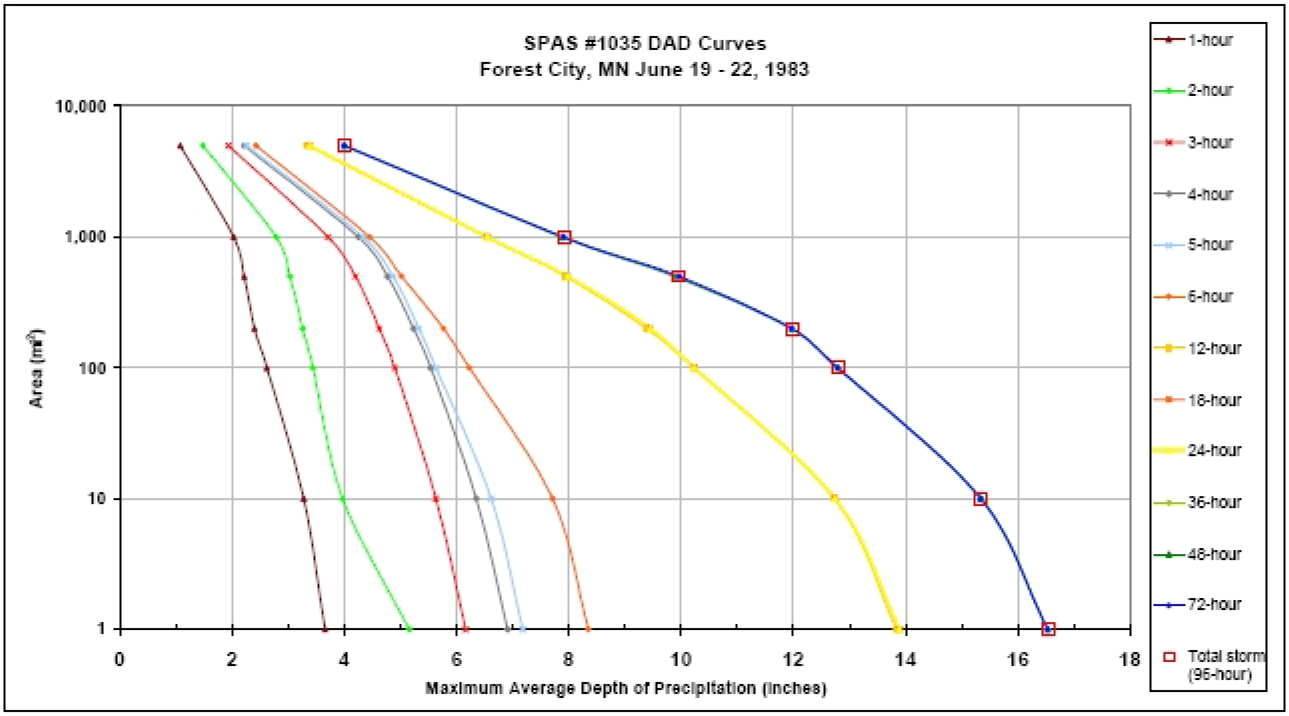


Attachment 3 Figure 33: Moisture inflow map for Forest City, MN June 1983

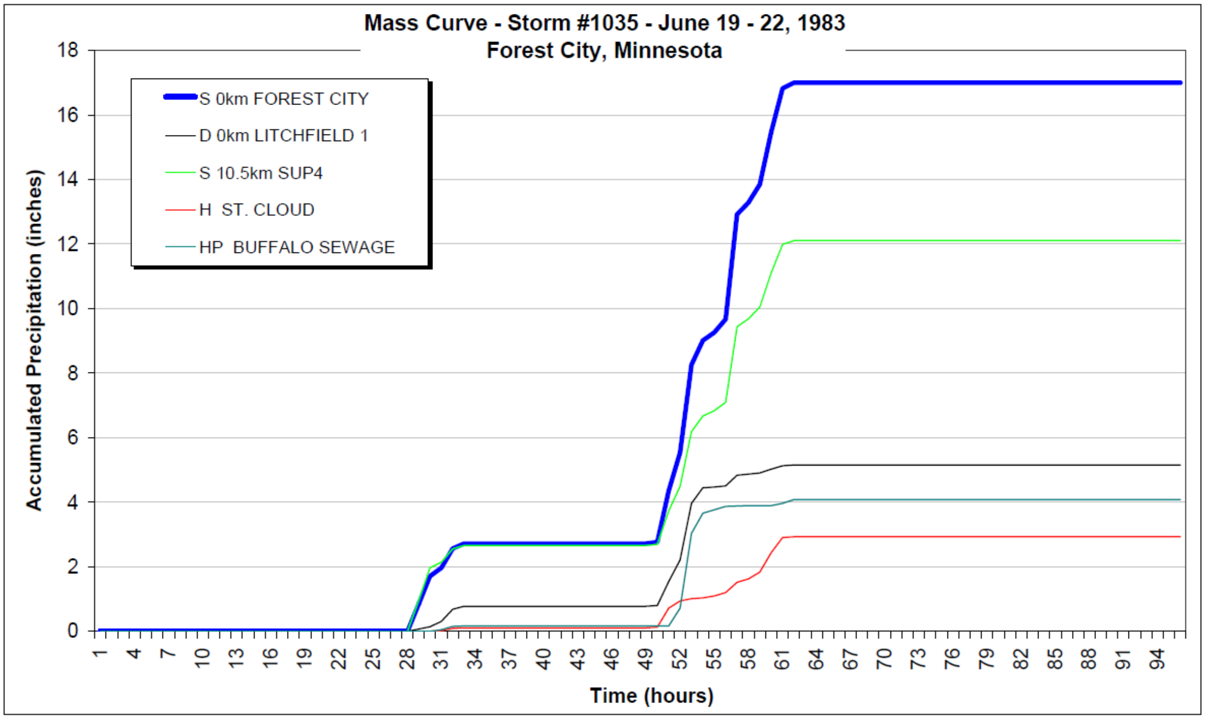
Storm 1035 - Forest City, MN June 19 - 22, 1983

MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

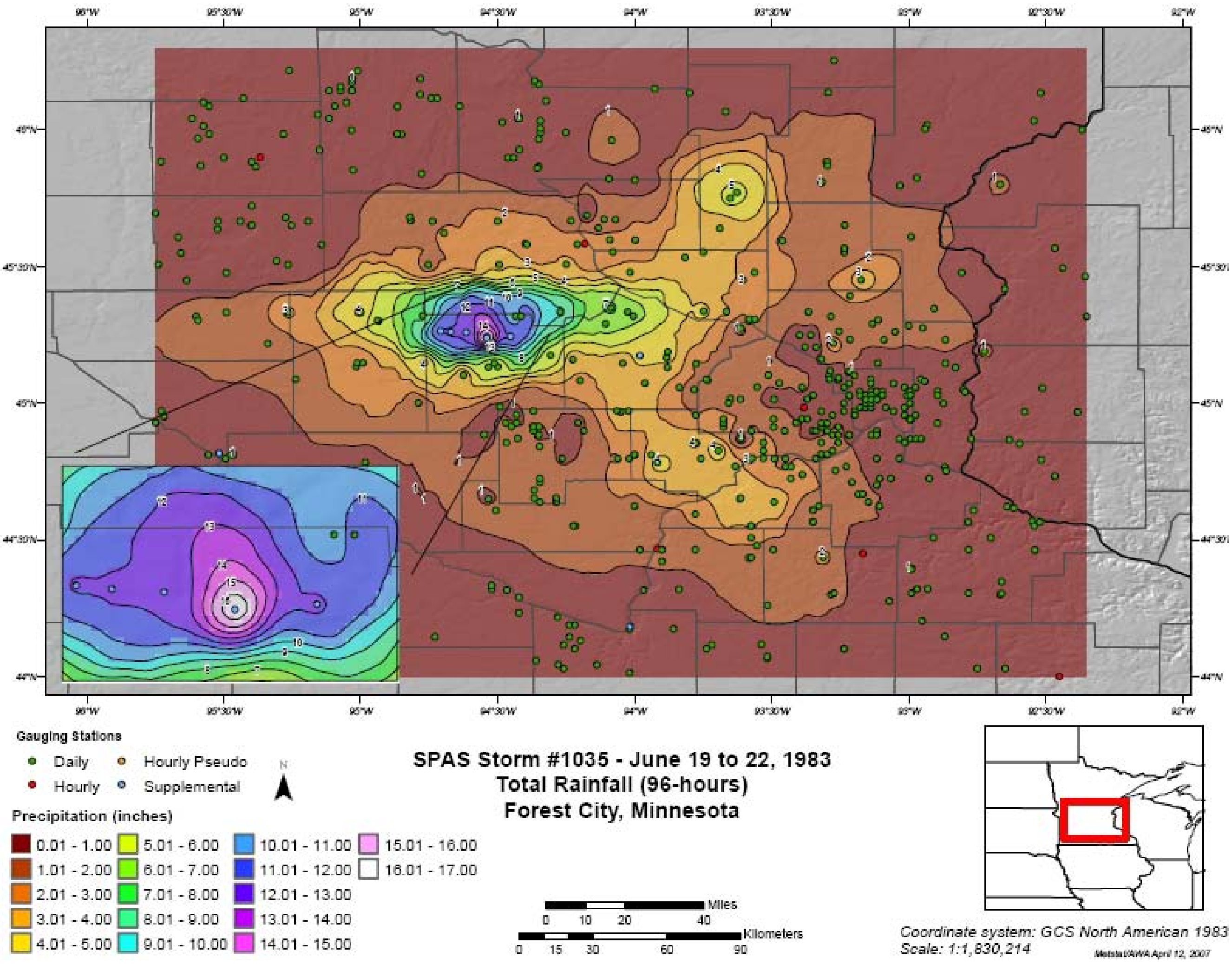
Area (mi^2)	Duration (hours)													
	1	2	3	4	5	6	12	18	24	36	48	72	96	total
1	3.66	5.16	6.16	6.91	7.18	8.35	13.84	13.89	13.89	16.53	16.53	16.53	16.53	16.53
10	3.28	3.97	5.63	6.35	6.62	7.71	12.73	12.74	12.74	15.34	15.34	15.34	15.34	15.34
100	2.62	3.44	4.90	5.54	5.63	6.23	10.23	10.23	10.23	12.79	12.79	12.79	12.79	12.79
200	2.40	3.26	4.62	5.23	5.33	5.77	9.38	9.45	9.45	11.97	11.97	11.97	11.97	11.97
500	2.22	3.03	4.20	4.77	4.87	5.02	7.94	7.98	7.98	9.90	9.90	9.97	9.97	9.97
1,000	2.03	2.79	3.71	4.25	4.33	4.45	6.54	6.55	6.55	7.89	7.89	7.91	7.91	7.91
5,000	1.08	1.48	1.94	2.22	2.26	2.43	3.35	3.38	3.38	4.00	4.00	4.00	4.01	4.01



Attachment 3 Table 21 and Attachment 3 Figure 34: Depth-area-duration values and Depth-area-duration chart for Forest City, MN June 1983



Attachment 3 Figure 35: Mass curve chart for Forest City, MN June 1983



Attachment 3 Figure 36: Total storm isohyetal analysis for Forest City, MN June 1983

Storm Name:	**USACE MR 4-5-Grant Township, NE**	**Storm Adjustment for Monticello-LIP**	
Storm Date:	**June 3, 1940**		
AWA Analysis Date:	**8/25/2014**		

Temporal Transposition Date	**18-Jun**	
	Lat	**Long**
Storm Center Location	**42.24 N**	**96.59 W**
Storm Rep Dew Point Location	**40.51 N**	**96.59 W**
Transposition Dew Point Locati	**43.60 N**	**93.85 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**S @ 120**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,400**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**74.0 F**	with total precipitable water above sea level of			**2.73**	inches.
The in-place maximum dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The transpositioned maximum dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The in-place storm elevation is	**1,400**	which subtracts	**0.34**	inches of precipitable water at	**74.0 F**	
The in-place storm elevation is	**1,400**	which subtracts	**0.39**	inches of precipitable water at	**79.0 F**	
The transposition storm elevation at	**950**	which subtracts	**0.27**	inches of precipitable water at	**79.0 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.27**	inches of precipitable water at	**79.0 F**	

The in-place maximization factor is	**1.28**
The transposition factor is	**1.04**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.33**

Notes: DAD values taken from USACE Storm Studies MR 4-5. Storm representative dew point value was based on adding 7° to the USACE analysis following previous PMP studies.

Observed Storm Depth-Area-Duration

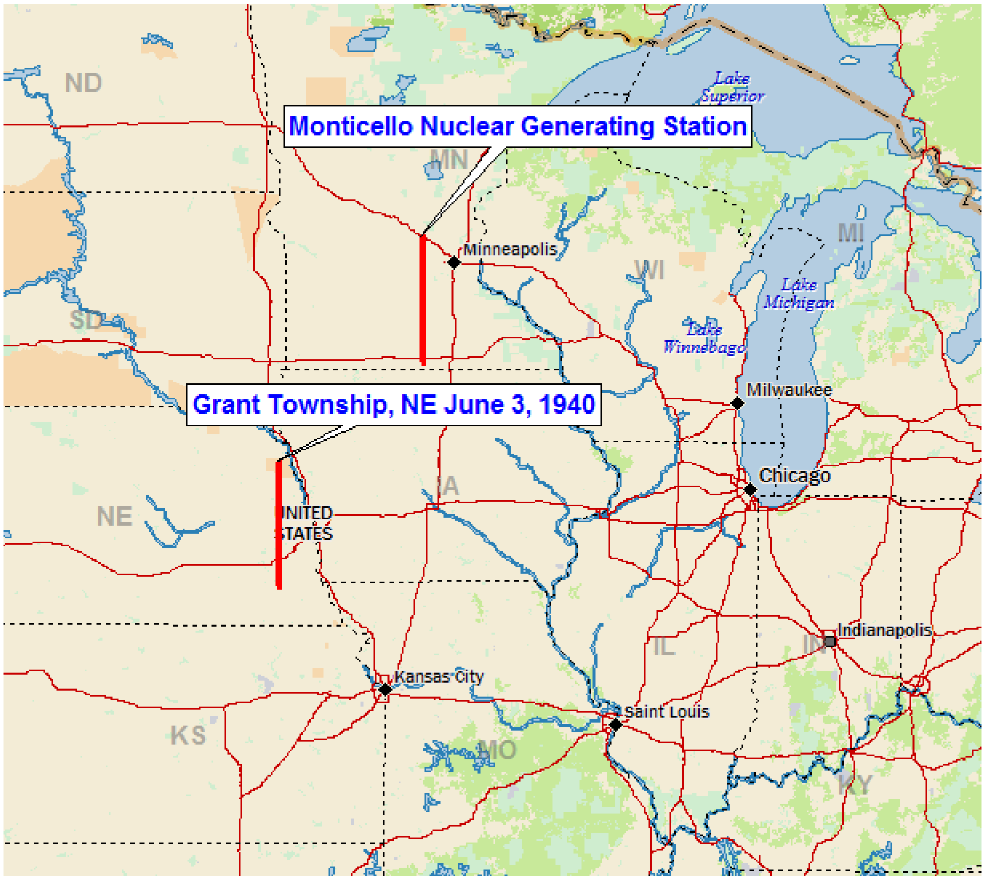
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	-	-	-	-	-	-	-	-	-
10 sq miles	**13.0**	**13.0**	**13.0**	-	-	-	-	-	-
100 sq miles	**10.6**	**11.7**	**11.7**	-	-	-	-	-	-
200 sq miles	**9.6**	**11.2**	**11.2**	-	-	-	-	-	-
500 sq miles	**8.3**	**10.2**	**10.3**	-	-	-	-	-	-
1000 sq miles	**7.2**	**8.9**	**9.0**	-	-	-	-	-	-
2000 sq miles	**6.0**	**7.5**	**7.6**	-	-	-	-	-	-
5000 sq miles	**4.2**	**5.5**	**5.7**	-	-	-	-	-	-
10000 sq miles	**3.1**	**4.4**	**4.6**	-	-	-	-	-	-
20000 sq miles	**2.1**	**3.3**	**3.5**	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	-	-	-	-	-	-	-	-	-
10 sq miles	**17.2**	**17.2**	**17.2**	-	-	-	-	-	-
100 sq miles	**14.1**	**15.5**	**15.5**	-	-	-	-	-	-
200 sq miles	**12.7**	**14.9**	**14.9**	-	-	-	-	-	-
500 sq miles	**11.0**	**13.5**	**13.7**	-	-	-	-	-	-
1000 sq miles	**9.5**	**11.8**	**11.9**	-	-	-	-	-	-
2000 sq miles	**8.0**	**9.9**	**10.1**	-	-	-	-	-	-
5000 sq miles	**5.6**	**7.3**	**7.6**	-	-	-	-	-	-
10000 sq miles	**4.1**	**5.8**	**6.1**	-	-	-	-	-	-
20000 sq miles	**2.8**	**4.4**	**4.6**	-	-	-	-	-	-

Storm or Storm Center Name	**USACE MR 4-5-Grant Township, NE**			
Storm Date(s)	3-Jun-1940			
Storm Type	MCC			
Storm Location	42.24 N	96.59 W		
Storm Center Elevation	1,400			
Precipitation Total & Duration	13.00 Inches 6-hours USACE Storm Studies MR 4-5			
Storm Representative Dew Point	74.0 F	6		
Storm Representative Dew Point Location	40.51 N	96.59 W		
Maximum Dew Point	79.0 F			
Moisture Inflow Vector	S @ 120			
In-place Maximization Factor	**1.28**			
Temporal Transposition Date	18-Jun			
Transposition Dew Point Location	43.60 N	93.85 W	Jun	Jul
Transposition Maximum Dew Point	79.0 F		78.48	81.45
Transposition Adjustment Factor	**1.04**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.33**			

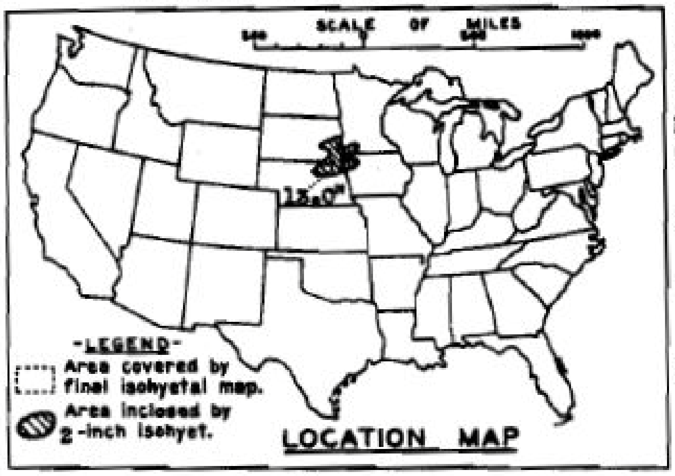
Attachment 3 Table 22: Storm spreadsheet for Grant Township, NE June 1940



Attachment 3 Figure 37: Moisture inflow map for Grant Township, NE June 1940

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 3-4 June 1940
Assignment MR 4-5
Location Nebr., Ia., Minn.
Study Prepared by:
Missouri River Division
Omaha District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 11/15/50
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 12/11/52
Remarks: Center at Grant Township, Nebr.
Dewpt. 63°F - Ref. Pt. 120 S. Grid D-15

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 1,000,000

Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 9
- Form 5001-B (24-hour " ") ---------- -
- Form 5001-D (" " " ") ---------- 8
- Miscl. precip. records, meteorological data, etc. ---------- 12
- Form 5002 (Mass rainfall curves) ---------- 24

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000

Data and computation sheets:

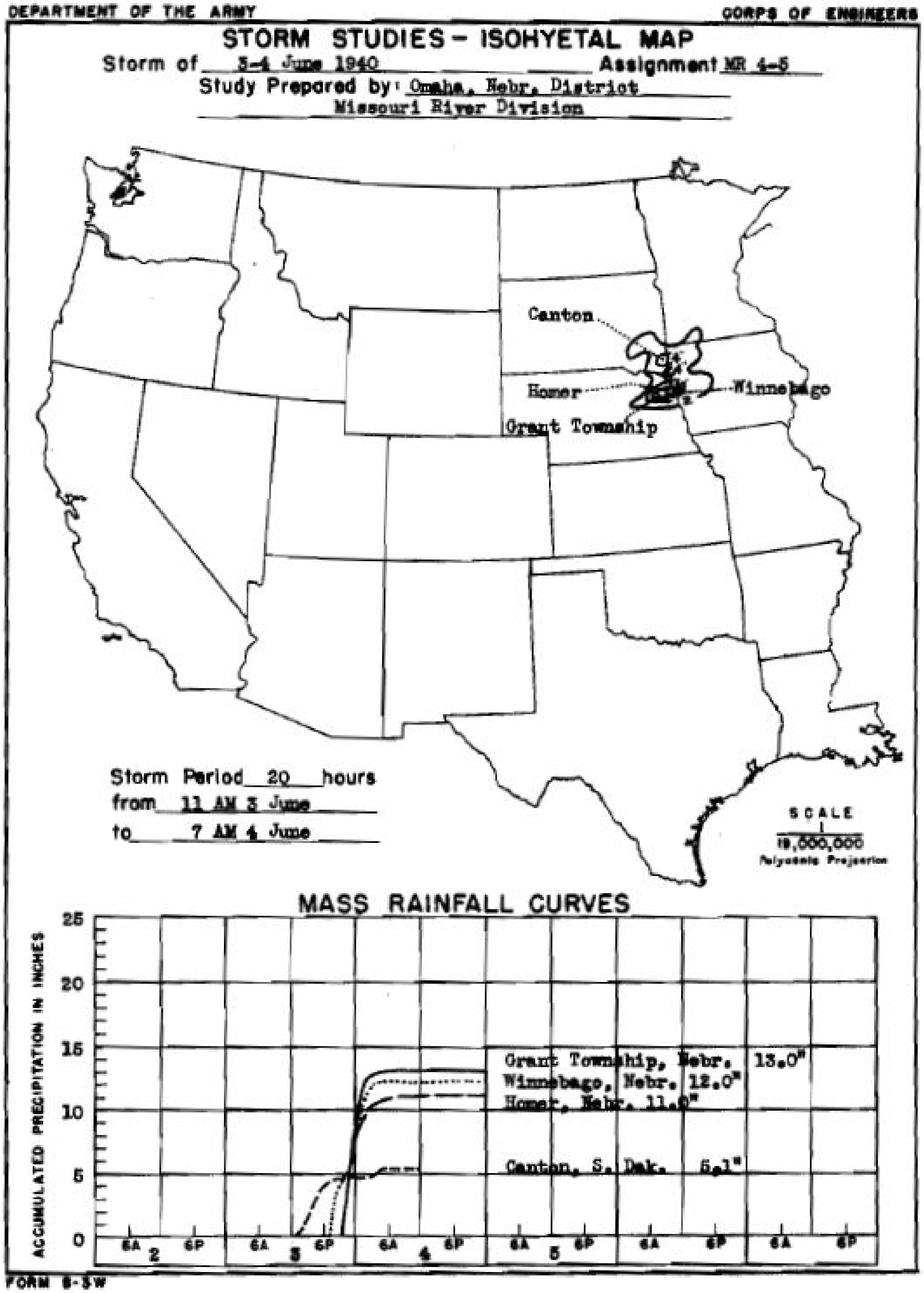
- Form S-10 (Data from mass rainfall curves) ---------- 3
- Form S-11 (Depth-area data from isohyetal map) ---------- 1
- Form S-12 (Maximum depth-duration data) ---------- 7
- Maximum duration-depth-area curves ---------- 1
- Data relating to periods of maximum rainfall ---------- 7

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	3	6	9	12	15	18	20				
10	8.3	13.0	13.0	13.0	13.0	13.0	13.0				
100	6.4	10.6	11.7	11.7	11.7	11.7	11.7				
200	5.5	9.6	11.1	11.2	11.2	11.2	11.2				
500	4.5	8.3	10.0	10.2	10.3	10.3	10.3				
1,000	3.8	7.2	8.8	8.9	9.0	9.0	9.0				
2,000	3.2	6.0	7.3	7.5	7.6	7.6	7.6				
5,000	2.4	4.2	5.3	5.5	5.7	5.7	5.7				
10,000	1.8	3.1	4.0	4.4	4.6	4.6	4.6				
20,000	1.2	2.1	2.8	3.3	3.5	3.5	3.5				

Form S-2

Attachment 3 Table 23: Depth-area-duration values for Grant Township, NE June 1940



Attachment 3 Figure 38 and Attachment 3 Figure 39: Isohyetal map and Mass curve chart for Grant Township, NE June 1940

Storm Name:	**USACE MR 8-20-Holt, MO**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**6/18-22/1947**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**5-Jul**	
	Lat	**Long**
Storm Center Location	**39.45 N**	**94.34 W**
Storm Rep Dew Point Location	**36.18 N**	**95.25 W**
Transposition Dew Point Locati	**42.06 N**	**94.84 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSW @ 230**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,000**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The in-place maximum dew point is	**81.5 F**	with total precipitable water above sea level of			**3.84**	inches.
The transpositioned maximum dew point is	**81.0 F**	with total precipitable water above sea level of			**3.76**	inches.
The in-place storm elevation is	**1,000**	which subtracts	**0.28**	inches of precipitable water at	**79.0 F**	
The in-place storm elevation is	**1,000**	which subtracts	**0.30**	inches of precipitable water at	**81.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.29**	inches of precipitable water at	**81.0 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.29**	inches of precipitable water at	**81.0 F**	

The in-place maximization factor is	**1.12**
The transposition factor is	**0.98**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.10**

Notes: DAD values taken from USACE MR 8-20, 1sqmi amount taken from Holt, MO world record rainfall within the overall storm. Storm representative Td value was based on maximum 6-hr Td values between June 22-23, 1947 at KHRO and KTUL.

Observed Storm Depth-Area-Duration

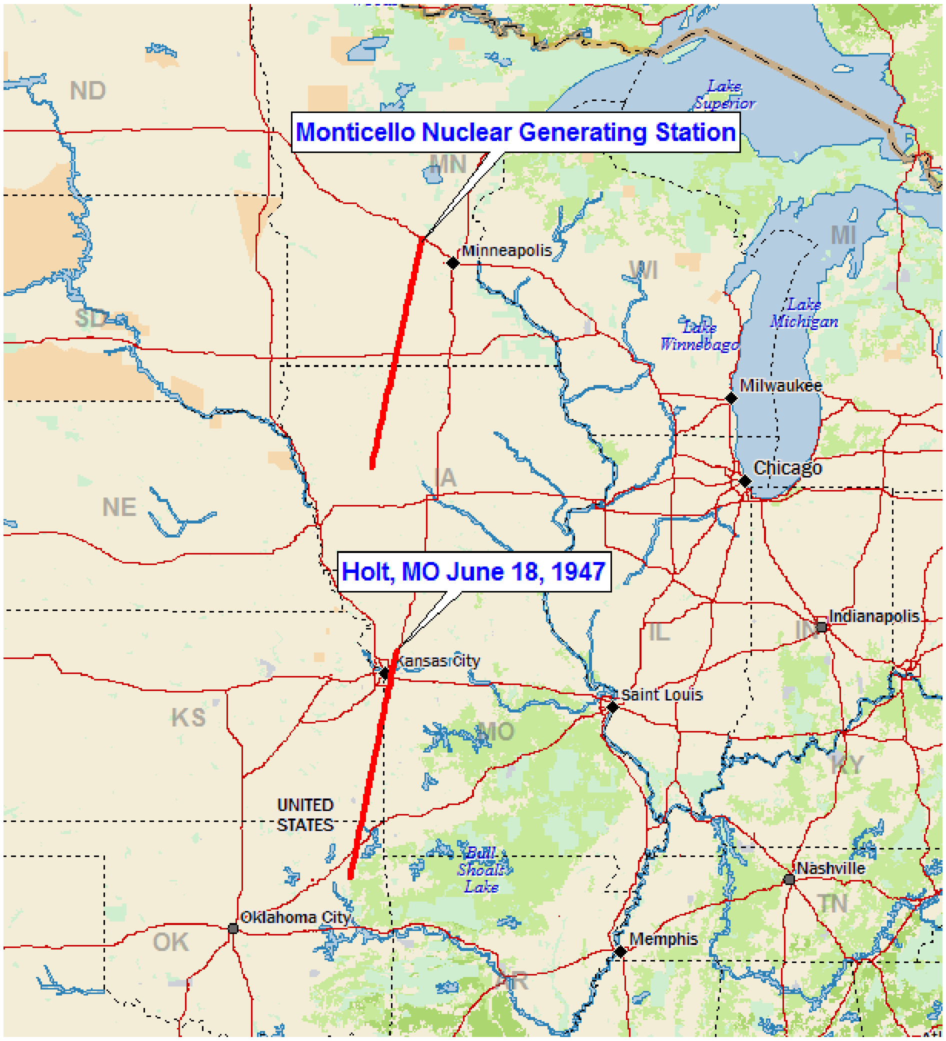
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**12.0**	**12.0**	**12.0**	**12.0**	-	**12.0**	**14.4**	-	**16.6**
10 sq miles	**11.5**	**11.5**	**11.5**	**11.5**	-	**11.5**	**12.6**	-	**15.8**
100 sq miles	**7.9**	**7.9**	**7.9**	**7.9**	-	**7.9**	**9.3**	-	**12.9**
200 sq miles	**7.1**	**7.1**	**7.1**	**7.1**	-	**7.1**	**8.4**	-	**11.9**
500 sq miles	**6.3**	**6.3**	**6.3**	**6.3**	-	**6.3**	**7.4**	-	**10.6**
1000 sq miles	**5.6**	**5.6**	**5.6**	**5.6**	-	**5.6**	**6.6**	-	**9.6**
5000 sq miles	**3.5**	**3.7**	**3.7**	**3.7**	-	**3.7**	**4.6**	-	**6.7**
10000 sq miles	**2.6**	**2.9**	**3.0**	**3.0**	-	**3.0**	**3.7**	-	**5.4**
20000 sq miles	**1.8**	**2.1**	**2.2**	**2.2**	-	**2.2**	**3.1**	-	**4.4**

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**13.2**	**13.2**	**13.2**	**13.2**	-	**13.2**	**15.8**	-	**18.2**
10 sq miles	**12.6**	**12.6**	**12.6**	**12.6**	-	**12.6**	**13.8**	-	**17.4**
100 sq miles	**8.7**	**8.7**	**8.7**	**8.7**	-	**8.7**	**10.2**	-	**14.2**
200 sq miles	**7.8**	**7.8**	**7.8**	**7.8**	-	**7.8**	**9.2**	-	**13.1**
500 sq miles	**6.9**	**6.9**	**6.9**	**6.9**	-	**6.9**	**8.1**	-	**11.6**
1000 sq miles	**6.1**	**6.1**	**6.1**	**6.1**	-	**6.1**	**7.2**	-	**10.5**
5000 sq miles	**3.8**	**4.1**	**4.1**	**4.1**	-	**4.1**	**5.1**	-	**7.4**
10000 sq miles	**2.9**	**3.2**	**3.3**	**3.3**	-	**3.3**	**4.1**	-	**5.9**
20000 sq miles	**2.0**	**2.3**	**2.4**	**2.4**	-	**2.4**	**3.4**	-	**4.8**

Storm or Storm Center Name	**USACE MR 8-20-Holt, MO**			
Storm Date(s)	6/18-22/1947			
Storm Type	MCC			
Storm Location	39.45 N	94.34 W		
Storm Center Elevation	1,000			
Precipitation Total & Duration	17.6 Inches 6-hours USACE MR 8-20			
Storm Representative Dew Point	79.0 F	6		
Storm Representative Dew Point Location	36.18 N	95.25 W		
Maximum Dew Point	81.5 F			
Moisture Inflow Vector	SSW @ 230	Miles		
In-place Maximization Factor	**1.12**			
Temporal Transposition Date	5-Jul			
Transposition Dew Point Location	42.06 N	94.84 W	June	July
Transposition Maximum Dew Point	81.0 F		78.88	82.12
Transposition Adjustment Factor	**0.98**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.10**			

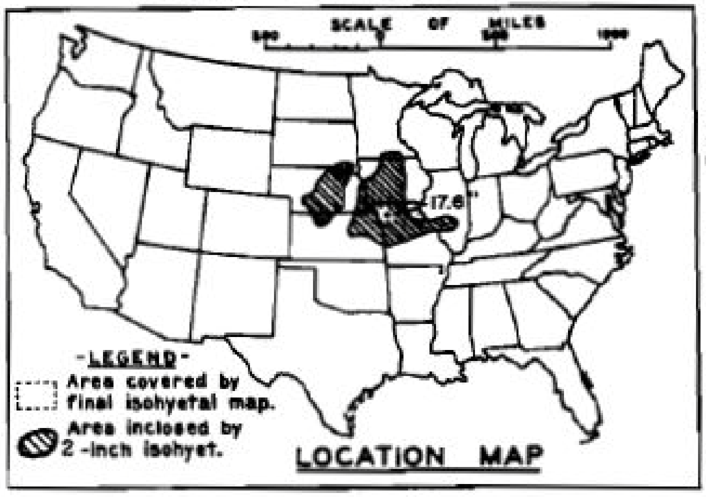
Attachment 3 Table 24: Storm spreadsheet for Holt, MO June 1947



Attachment 3 Figure 40: Moisture inflow map for Holt, MO June 1947

DEPARTMENT OF THE ARMY | CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 18-23 June 1947
Assignment MR 8-20
Location Ill, Ia, Kans, Minn. Mo, Nebr, & S.Dak.
Study Prepared by:
Missouri River Division
Omaha District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 12/17/52
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 9/10/54
Remarks:

Center near Holt, Mo.
Dewpoint 75°, Ref. Pt. 140 S

DATA AND COMPUTATIONS COMPILED

Grid E-14

PART I

Preliminary isohyetal map, in sheet, scale
Precipitation data and mass curves: (Number of Sheets)
Form 5001-C (Hourly precip. data)--
Form 5001-B (24-hour " ")--------
Form 5001-D (" " " ")--------
Miscl. precip. records, meteorological data, etc.
Form 5002 (Mass rainfall curves)-----------------------

NOTE: This study was computed by the Regional Method which does not employ the Part I and Part II phases in their entirety.

PART II

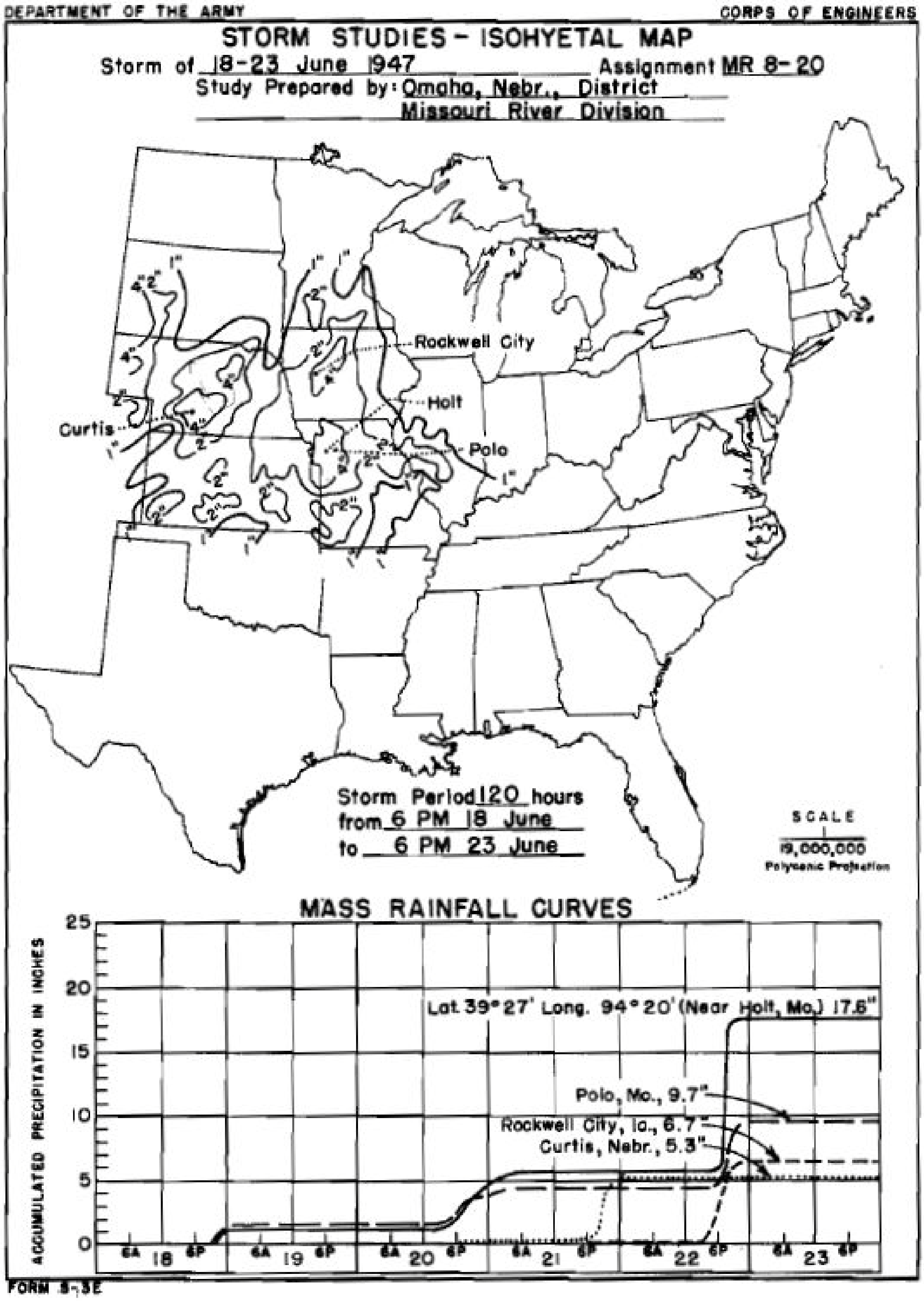
Final isohyetal maps, in 1 sheet, scale 1:1,000,000
Data and computation sheets:
Form S-10 (Data from mass rainfall curves)-------------- 9
Form S-11 (Depth-area data from isohyetal map)----------- 4
Form S-12 (Maximum depth-duration data)----------------- 7
Maximum duration-depth-area curves------------------- 1
Data relating to periods of maximum rainfall-------------

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	36	48	72	96	120		
Max. Station	~~12.0~~	~~12.0~~	~~12.0~~	~~12.0~~	~~12.0~~	~~14.4~~	~~16.8~~	~~16.8~~	~~17.6~~		
10	11.5	11.5	11.5	11.5	11.5	12.6	15.8	15.8	16.9		
100	7.9	7.9	7.9	7.9	7.9	9.3	12.9	12.9	14.1		
200	7.1	7.1	7.1	7.1	7.1	8.4	11.9	11.9	13.0		
500	6.3	6.3	6.3	6.3	6.3	7.4	10.6	10.6	11.6		
1000	5.6	5.6	5.6	5.5	5.6	6.6	9.6	9.6	10.5		
2000	4.9	4.9	4.9	4.9	4.9	5.7	8.4	8.4	9.3		
5000	3.5	3.7	3.7	3.7	3.7	4.6	6.7	6.7	7.3		
10000	2.6	2.9	3.0	3.0	3.0	3.7	5.4	5.4	5.9		
20000	1.8	2.1	2.2	2.2	2.2	3.1	4.4	4.6	4.9		
50000	1.2	1.4	1.5	1.6	1.9	2.5	3.2	3.5	3.6		
100000	0.8	1.0	1.2	1.4	1.6	2.1	2.7	2.9	3.0		
200000	0.5	0.7	0.8	1.1	1.4	1.7	2.1	2.2	2.3		
300000	0.3	0.5	0.6	0.7	0.9	1.2	1.5	1.6	1.8		

Form S-2

Attachment 3 Table 25: Depth-area-duration values for Holt, MO June 1947



Attachment 3 Figure 41 and Attachment 3 Figure 42: Isohyetal map and Mass curve chart for Holt, MO June 1947

Storm Name:	USACE UMV 3-30-Kelso, MO
Storm Date:	11-Aug-1952
AWA Analysis Date:	8/24/2014

Storm Adjustment for Monticello-LIP

Temporal Transposition Date	25-Jul	
	Lat	Long
Storm Center Location	37.19 N	89.55 W
Storm Rep Dew Point Location	35.17 N	89.50 W
Transposition Dew Point Locati	43.31 N	93.79 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	S @ 140	miles
Basin Average Elevation	950	feet
Storm Center Elevation	500	feet
Storm Analysis Duration	6	hours

The storm representative dew point is	76.5 F	with total precipitable water above sea level of		3.07	inches.
The in-place maximum dew point is	81.0 F	with total precipitable water above sea level of		3.75	inches.
The transpositioned maximum dew point is	81.0 F	with total precipitable water above sea level of		3.75	inches.
The in-place storm elevation is	500	which subtracts	0.14	inches of precipitable water at	76.5 F
The in-place storm elevation is	500	which subtracts	0.15	inches of precipitable water at	81.0 F
The transposition storm elevation at	950	which subtracts	0.26	inches of precipitable water at	81.0 F
The moisture inflow barrier height is	950	which subtracts	0.26	inches of precipitable water at	81.0 F

The in-place maximization factor is	1.23
The transposition factor is	0.97
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.19

Notes: DAD values taken from USACE UMV 3-30. Storm representative Td value was based on maximum 6-hr Td values between August 11, 1952 at KMEM, KNQA, KMKL, and KDYR.

Observed Storm Depth-Area-Duration

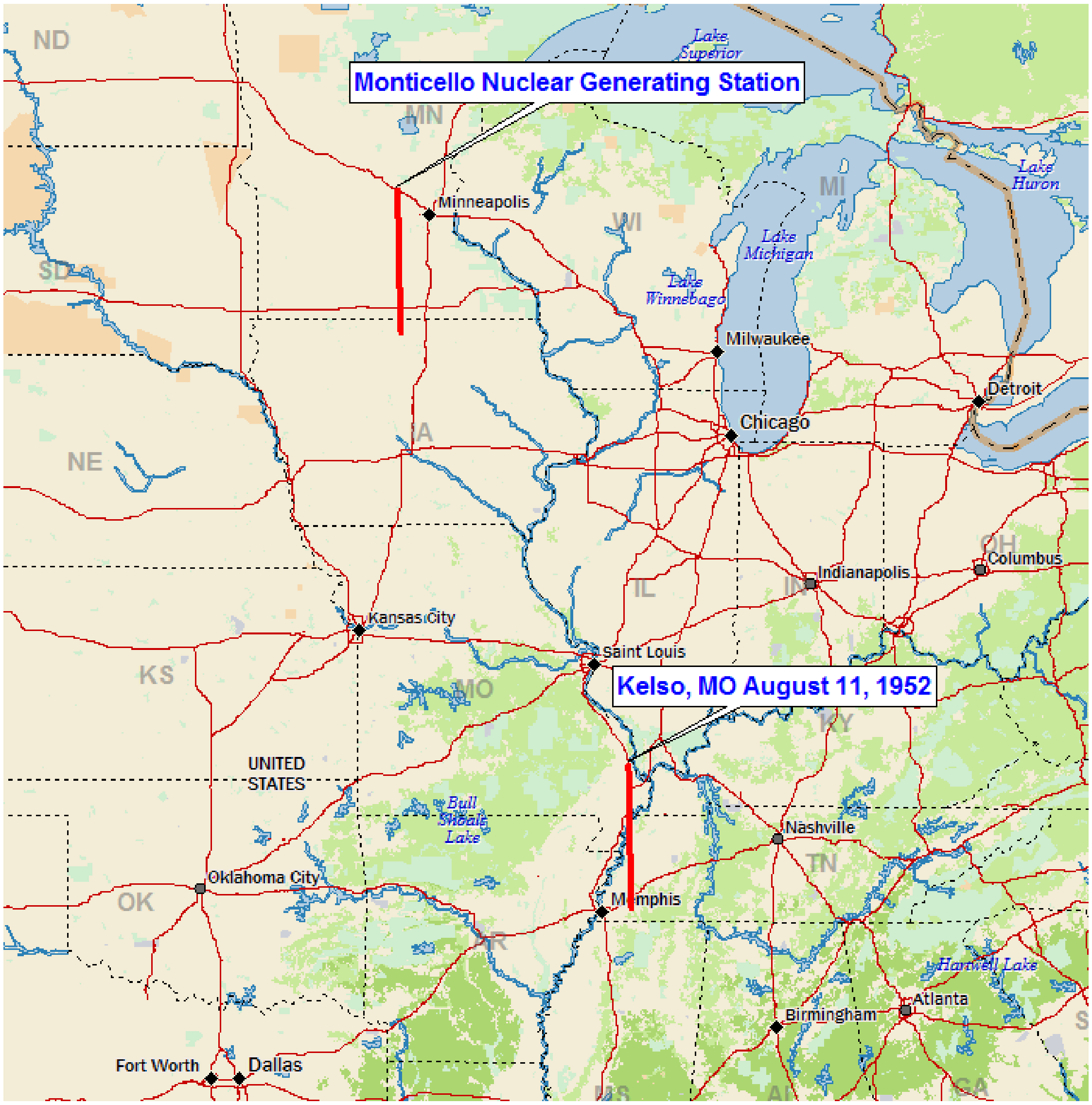
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
10 sq miles	5.5	11.5	13.0	-	-	-	-	-	-
100 sq miles	4.2	10.4	11.9	-	-	-	-	-	-
200 sq miles	0.0	0.0	0.0	-	-	-	-	-	-
500 sq miles	2.9	7.4	8.7	-	-	-	-	-	-
1000 sq miles	2.3	5.7	6.9	-	-	-	-	-	-
5000 sq miles	-	-	-	-	-	-	-	-	-
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
10 sq miles	6.6	13.7	15.5	-	-	-	-	-	-
100 sq miles	5.0	12.4	14.2	-	-	-	-	-	-
200 sq miles	0.0	0.0	0.0	-	-	-	-	-	-
500 sq miles	3.5	8.8	10.4	-	-	-	-	-	-
1000 sq miles	2.7	6.8	8.2	-	-	-	-	-	-
5000 sq miles	-	-	-	-	-	-	-	-	-
10000 sq miles	-	-	-	-	-	-	-	-	-
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**USACE UMV 3-30-Kelso, MO**			
Storm Date(s)	11-Aug-1952			
Storm Type	MCC			
Storm Location	37.19 N	89.55 W		
Storm Center Elevation	500			
Precipitation Total & Duration	13.00 Inches 6-hours USACE UMV 3-30			
Storm Representative Dew Point	76.5 F	6		
Storm Representative Dew Point Location	35.17 N	89.50 W		
Maximum Dew Point	81.0 F			
Moisture Inflow Vector	S @ 140	Miles		
In-place Maximization Factor	**1.23**			
Temporal Transposition Date	25-Jul			
Transposition Dew Point Location	43.31 N	93.79 W	July	August
Transposition Maximum Dew Point	81.0 F		81.5	80.5
Transposition Adjustment Factor	**0.97**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.19**			

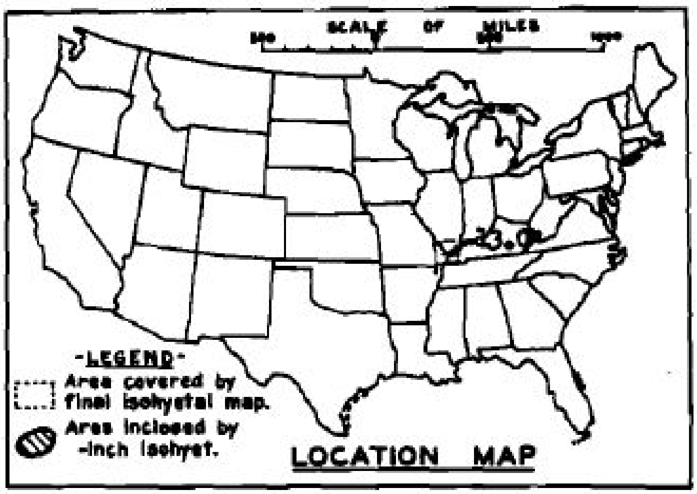
Attachment 3 Table 26: Storm spreadsheet for Kelso, MO August 1952



Attachment 3 Figure 43: Moisture inflow map for Kelso, MO August 1952

DEPARTMENT OF THE ARMY | CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 11-12 August 1952
Assignment UMV 3-30
Location SE Mo. and SW Ill.
Study Prepared by:
Lower Mississippi Valley Division
St. Louis District

Part I Reviewed by H. M. Sec. of Weather Bureau, 9/29/60
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 5/10/63
Remarks: Center at Kelso, Missouri. Dewpoint 75°F, 135 SSW.
Grid F-12

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1:500,000

Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	13
Form 5001-B (24-hour " ")	0
Form 5001-D (" " " ")	2
Miscl. precip. records, meteorological data, etc.	9
Form 5002 (Mass rainfall curves)	5

PART II

Final isohyetal maps, in 1 sheet, scale 1:500,000

Data and computation sheets:

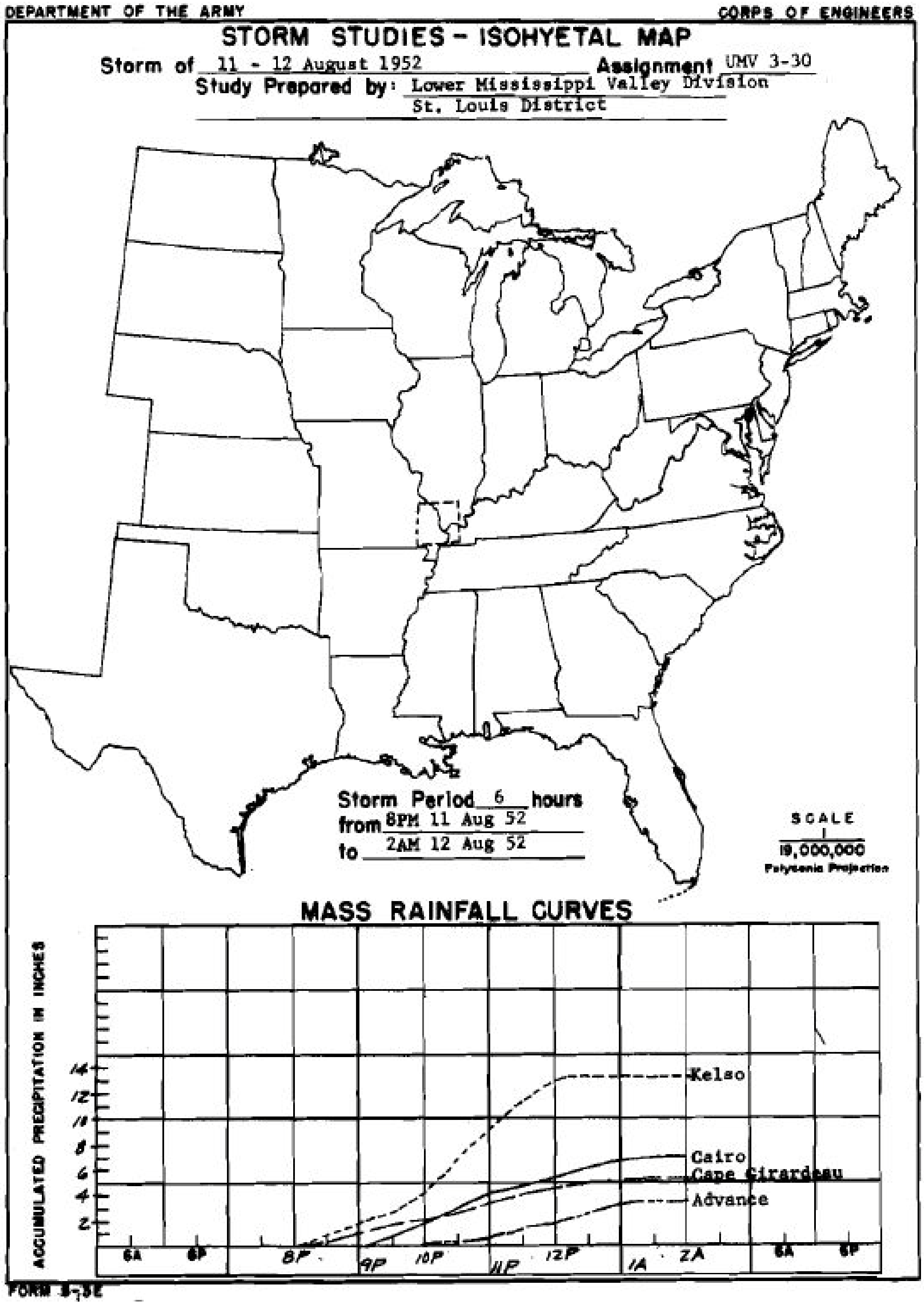
Form S-10 (Data from mass rainfall curves)	1
Form S-11 (Depth-area data from isohyetal map)	1
Form S-12 (Maximum depth-duration data)	5
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	1	2	3	4	5	6				
10	5.5	9.1	11.5	12.9	13.0	13.0				
100	4.2	8.0	10.4	11.7	11.9	11.9				
500	2.9	5.5	7.4	8.0	8.6	8.7				
1,000	2.3	4.1	5.7	6.2	6.8	6.9				
1,730	1.7	3.1	4.3	4.9	5.4	5.5				

Form S-2

Attachment 3 Table 27: Depth-area-duration values for Kelso, MO August 1952



Attachment 3 Figure 44 and Attachment 3 Figure 45: Isohyetal map and Mass curve chart for Kelso, MO August 1952

Storm Name:	**USACE MR 4-2-Larrabee, IA**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**6/23/1891**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**10-Jul**	
	Lat	**Long**
Storm Center Location	**42.86 N**	**95.55 W**
Storm Rep Dew Point Location	**39.96 N**	**95.55 W**
Transposition Dew Point Locati	**42.43 N**	**93.85 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**S @ 200**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,400**	feet
Storm Analysis Duration	**12**	hours

The storm representative dew point is	**79.0 F**	with total precipitable water above sea level of			**3.44**	inches.
The in-place maximum dew point is	**81.0 F**	with total precipitable water above sea level of			**3.75**	inches.
The transpositioned maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The in-place storm elevation is	**1,400**	which subtracts	**0.39**	inches of precipitable water at	**79.0 F**	
The in-place storm elevation is	**1,400**	which subtracts	**0.43**	inches of precipitable water at	**81.0 F**	
The transposition storm elevation at	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**	

The in-place maximization factor is	**1.09**
The transposition factor is	**1.02**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.11**

Notes: DAD values taken from USACE MR 4-2. Storm representative dew point value was based on adding 7° to the USACE analyzed storm rep based on previous PMP studies.

Observed Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**10.4**	**11.7**	**11.7**	**12.9**	**12.9**	**12.9**	**12.9**	**12.9**	**12.9**
10 sq miles	**9.0**	**11.1**	**11.6**	**12.8**	**12.8**	**12.8**	**12.8**	**12.8**	**12.8**
100 sq miles	**7.5**	**10.0**	**11.1**	**12.2**	**12.2**	**12.2**	**12.2**	**12.2**	**12.2**
200 sq miles	**7.0**	**9.5**	**10.5**	**11.5**	**11.6**	**11.6**	**11.6**	**11.6**	**11.6**
500 sq miles	**6.1**	**8.6**	**9.6**	**10.3**	**10.5**	**10.5**	**10.5**	**10.5**	**10.5**
1000 sq miles	**5.3**	**7.7**	**8.7**	**9.3**	**9.5**	**9.5**	**9.5**	**9.5**	**9.5**
2000 sq miles	**4.5**	**6.6**	**7.7**	**8.2**	**8.3**	**8.3**	**8.3**	**8.3**	**8.3**
5000 sq miles	**3.4**	**5.0**	**5.8**	**6.5**	**6.6**	**6.6**	**6.6**	**6.6**	**6.6**
10000 sq miles	**2.5**	**3.7**	**4.4**	**5.2**	**5.3**	**5.3**	**5.3**	**5.3**	**5.3**
20000 sq miles	**1.6**	**2.5**	**2.9**	**3.6**	**3.9**	**4.2**	**4.2**	**4.4**	**4.6**

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**11.6**	**13.0**	**13.0**	**14.3**	**14.3**	**14.3**	**14.3**	**14.3**	**14.3**
10 sq miles	**10.0**	**12.3**	**12.9**	**14.2**	**14.2**	**14.2**	**14.2**	**14.2**	**14.2**
100 sq miles	**8.3**	**11.1**	**12.3**	**13.6**	**13.6**	**13.6**	**13.6**	**13.6**	**13.6**
200 sq miles	**7.8**	**10.6**	**11.7**	**12.8**	**12.9**	**12.9**	**12.9**	**12.9**	**12.9**
500 sq miles	**6.8**	**9.6**	**10.7**	**11.5**	**11.7**	**11.7**	**11.7**	**11.7**	**11.7**
1000 sq miles	**5.9**	**8.6**	**9.7**	**10.3**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**
2000 sq miles	**5.0**	**7.3**	**8.6**	**9.1**	**9.2**	**9.2**	**9.2**	**9.2**	**9.2**
5000 sq miles	**3.8**	**5.6**	**6.4**	**7.2**	**7.3**	**7.3**	**7.3**	**7.3**	**7.3**
10000 sq miles	**2.8**	**4.1**	**4.9**	**5.8**	**5.9**	**5.9**	**5.9**	**5.9**	**5.9**
20000 sq miles	**1.8**	**2.8**	**3.2**	**4.0**	**4.3**	**4.7**	**4.7**	**4.9**	**5.1**

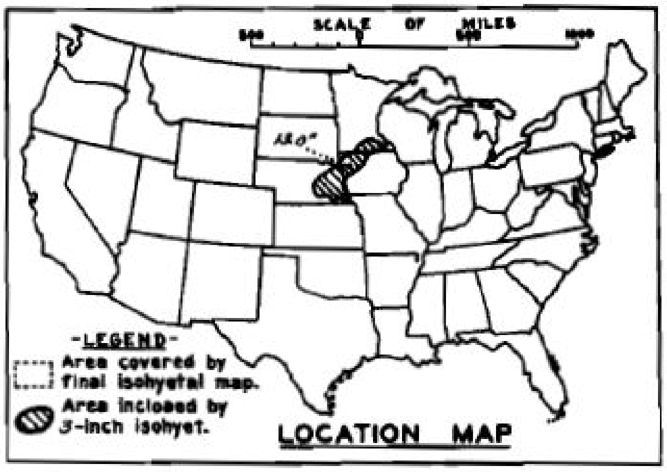
Storm or Storm Center Name	**USACE MR 4-2-Larrabee, IA**			
Storm Date(s)	6/23/1891			
Storm Type	MCC-Thunderstorm Complex			
Storm Location	42.86 N	95.55 W		
Storm Center Elevation	1,400			
Precipitation Total & Duration	12.90 Inches 24-hours			
Storm Representative Dew Point	79.0 F	12		
Storm Representative Dew Point Location	39.96 N	95.55 W	June	July
Maximum Dew Point	81.0 F		80	81.5
Moisture Inflow Vector	S @ 200			
In-place Maximization Factor	**1.09**			
Temporal Transposition Date	10-Jul			
Transposition Dew Point Location	42.43 N	93.85 W	June	July
Transposition Maximum Dew Point	80.5 F		78.1	81
Transposition Adjustment Factor	**1.02**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.11**			

Attachment 3 Table 28: Storm spreadsheet for Larrabee, IA June 1891

Attachment 3 Figure 46: Moisture inflow map for Larrabee, IA June 1891

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 23-27 June 1891
Assignment MR 4-2
Location Iowa-Nebr-Minn,
Study Prepared by:
Missouri River Division
Omaha, District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 10/29/47
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 10/14/48
Remarks: Center at Larrabee, Ia.
Dewpt. 72° - Ref. Pt. 200 S
Grid D-15

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 2,500,000
Precipitation data and mass curves: (Number of Sheets)

- Form 5001-C (Hourly precip. data) ---------- 6
- Form 5001-B (24-hour " ") ---------- 0
- Form 5001-D (" " " ") ---------- 3
- Miscl. precip. records, meteorological data, etc. ---------- 12
- Form 5002 (Mass rainfall curves) ---------- 9

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000
Data and computation sheets:

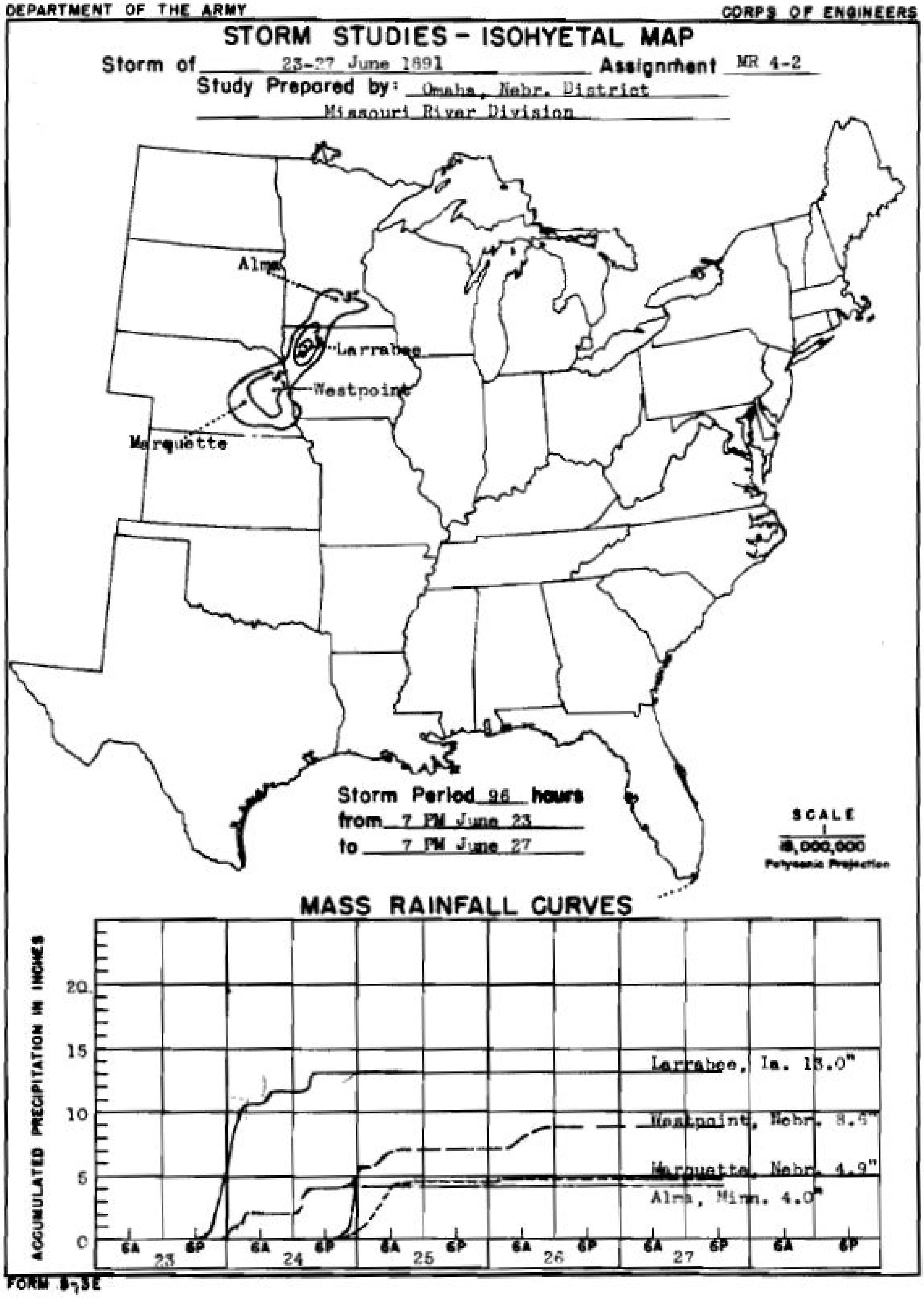
- Form S-10 (Data from mass rainfall curves) ---------- 1
- Form S-11 (Depth-area data from isohyetal map) ---------- 1
- Form S-12 (Maximum depth-duration data) ---------- 7
- Maximum duration-depth-area curves ---------- 1
- Data relating to periods of maximum rainfall ---------- 3

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	96
Max. Station	10.4	11.7	11.7	12.9	12.9	12.9	12.9	13.0	13.0	13.0
10	9.0	11.1	11.6	12.8	12.8	12.8	12.8	12.8	12.8	12.8
100	7.5	10.0	11.1	12.2	12.2	12.2	12.2	12.2	12.2	12.2
200	7.0	9.5	10.5	11.5	11.6	11.6	11.6	11.6	11.6	11.6
500	6.1	8.6	9.6	10.3	10.5	10.5	10.5	10.5	10.5	10.5
1,000	5.3	7.7	8.7	9.3	9.5	9.5	9.5	9.5	9.5	9.5
2,000	4.5	6.6	7.7	8.2	8.3	8.3	8.3	8.3	8.3	8.3
5,000	3.4	5.0	5.8	6.5	6.6	6.6	6.6	6.6	6.6	6.6
10,000	2.5	3.7	4.4	5.2	5.3	5.3	5.3	5.3	5.3	5.3
20,000	1.6	2.5	2.9	3.6	3.9	4.2	4.2	4.4	4.6	4.7
30,000	1.1	1.7	2.0	2.4	3.1	3.7	3.8	4.2	4.5	4.6

Form S-2

Attachment 3 Table 29: Depth-area-duration values for Larrabee, IA June 1891



Attachment 3 Figure 47 and Attachment 3 Figure 48: Isohyetal map and Mass curve chart for Larrabee, IA June 1891

Storm Name:	**Minneapolis, MN SPAS 1210**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**July 23-24, 1987**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**15-Jul**					
	Lat	**Long**	**Moisture Inflow Direction**	**WSW @ 90**	miles	
Storm Center Location	**44.89 N**	**93.40 W**	**Basin Average Elevation**	**950**	feet	
Storm Rep Dew Point Location	**44.54 N**	**95.16 W**	**Storm Center Elevation**	**900**	feet	
Transposition Dew Point Locati	**44.98 N**	**95.62 W**	**Storm Analysis Duration**	**6**	hours	
Basin Location	**45.33 N**	**93.85 W**				

The storm representative dew point is	**78.0 F**	with total precipitable water above sea level of			**3.29**	inches.
The in-place maximum dew point is	**81.5 F**	with total precipitable water above sea level of			**3.83**	inches.
The transpositioned maximum dew point is	**81.5 F**	with total precipitable water above sea level of			**3.83**	inches.
The in-place storm elevation is	**900**	which subtracts	**0.25**	inches of precipitable water at	**78.0 F**	
The in-place storm elevation is	**900**	which subtracts	**0.29**	inches of precipitable water at	**81.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.30**	inches of precipitable water at	**81.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.30**	inches of precipitable water at	**81.5 F**	

The in-place maximization factor is	**1.16**
The transposition factor is	**1.00**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.16**

Notes: Storm representative dew point value was based on maximum 6-hr Td values July 23, 1987 at Redwood Falls, MN. This was fromt eh EPRI analysis. The Td climatology maps produced during the Nebraska statewide PMP study were used to maximized this event.

Observed Storm Depth-Area-Duration

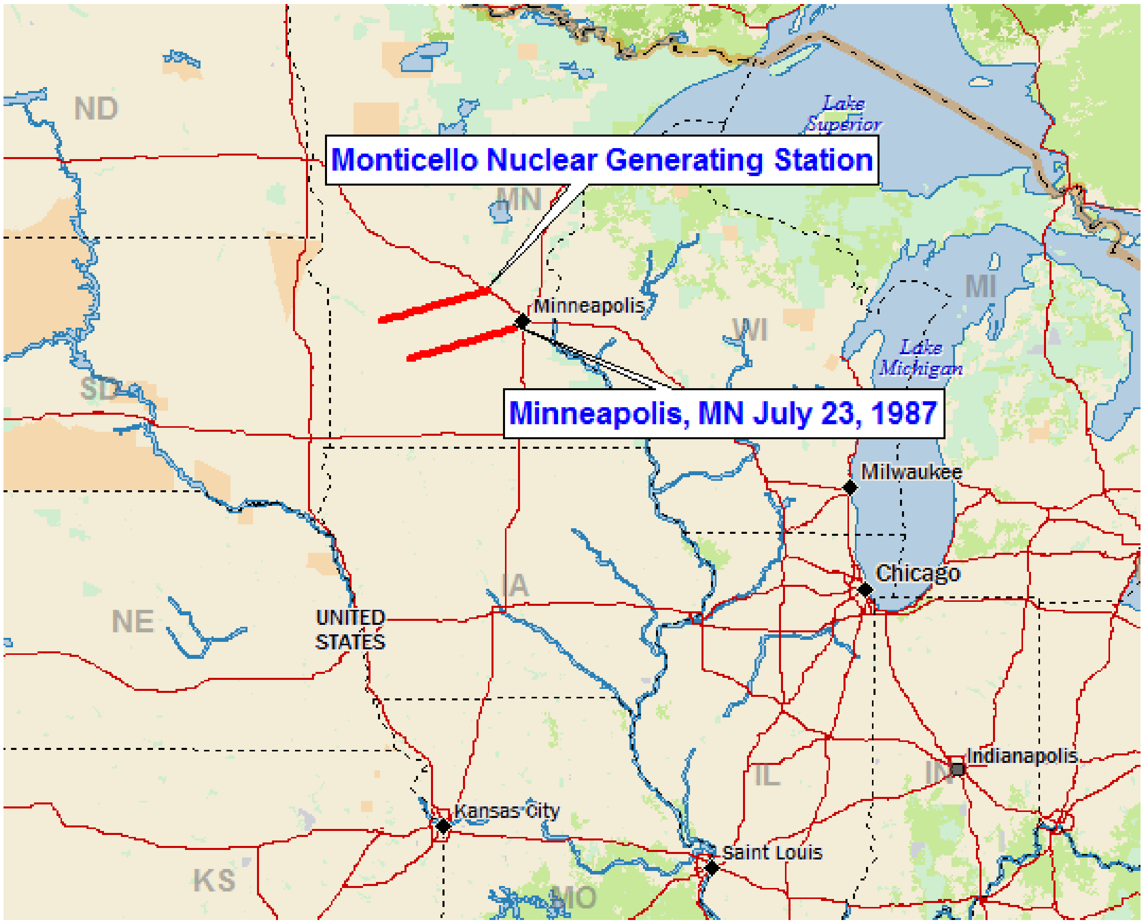
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**5.0**	**9.8**	**11.1**	**11.3**	**11.4**	**11.4**	**11.4**	**11.4**	**12.0**
10 sq miles	**4.3**	**8.7**	**10.7**	**11.2**	**11.3**	**11.3**	**11.3**	**11.3**	**11.9**
100 sq miles	**3.0**	**7.3**	**9.4**	**10.1**	**10.2**	**10.2**	**10.2**	**10.2**	**10.9**
200 sq miles	**2.6**	**6.6**	**8.5**	**9.3**	**9.3**	**9.4**	**9.4**	**9.4**	**10.0**
500 sq miles	**2.1**	**5.3**	**7.0**	**7.6**	**7.9**	**8.0**	**8.0**	**8.0**	**8.6**
1000 sq miles	**1.6**	**4.1**	**5.8**	**6.6**	**6.7**	**6.8**	**6.8**	**6.8**	**7.3**
2000 sq miles	**1.1**	**2.9**	**4.5**	**5.5**	**5.5**	**5.6**	**5.6**	**5.6**	**5.9**
5000 sq miles	**0.7**	**1.5**	**2.7**	**3.6**	**3.6**	**3.8**	**3.8**	**3.8**	**4.1**
10000 sq miles	**0.4**	**0.9**	**1.9**	**2.5**	**2.6**	**2.6**	**2.6**	**2.6**	**2.8**
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**5.8**	**11.3**	**12.9**	**13.2**	**13.3**	**13.3**	**13.3**	**13.3**	**13.9**
10 sq miles	**4.9**	**10.1**	**12.4**	**13.1**	**13.1**	**13.1**	**13.1**	**13.1**	**13.8**
100 sq miles	**3.5**	**8.5**	**10.9**	**11.7**	**11.8**	**11.8**	**11.9**	**11.9**	**12.6**
200 sq miles	**3.0**	**7.6**	**9.8**	**10.7**	**10.8**	**10.9**	**10.9**	**10.9**	**11.7**
500 sq miles	**2.4**	**6.2**	**8.2**	**8.9**	**9.2**	**9.3**	**9.3**	**9.3**	**10.0**
1000 sq miles	**1.8**	**4.8**	**6.8**	**7.7**	**7.8**	**7.9**	**7.9**	**7.9**	**8.5**
2000 sq miles	**1.3**	**3.4**	**5.2**	**6.4**	**6.4**	**6.5**	**6.5**	**6.5**	**6.9**
5000 sq miles	**0.8**	**1.8**	**3.2**	**4.2**	**4.2**	**4.4**	**4.4**	**4.4**	**4.7**
10000 sq miles	**0.4**	**1.1**	**2.1**	**3.0**	**3.0**	**3.0**	**3.1**	**3.1**	**3.2**
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**Minneapolis, MN SPAS 1210**	
Storm Date(s)	July 23-24, 1987	
Storm Type	MCC	
Storm Location	44.89 N	93.40 W
Storm Center Elevation	900	
Precipitation Total & Duration	12.13 Inches 72-hours	
Storm Representative Dew Point	78.0 F	6
Storm Representative Dew Point Location	44.54 N	95.16 W
Maximum Dew Point	81.5 F	
Moisture Inflow Vector	WSW @ 90	
In-place Maximization Factor	**1.16**	
Temporal Transposition Date	15-Jul	
Transposition Dew Point Location	44.98 N	95.62 W
Transposition Maximum Dew Point	81.5 F	
Transposition Adjustment Factor	**1.00**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.16**	

Attachment 3 Table 30: Storm spreadsheet for Minneapolis, MN July 1987



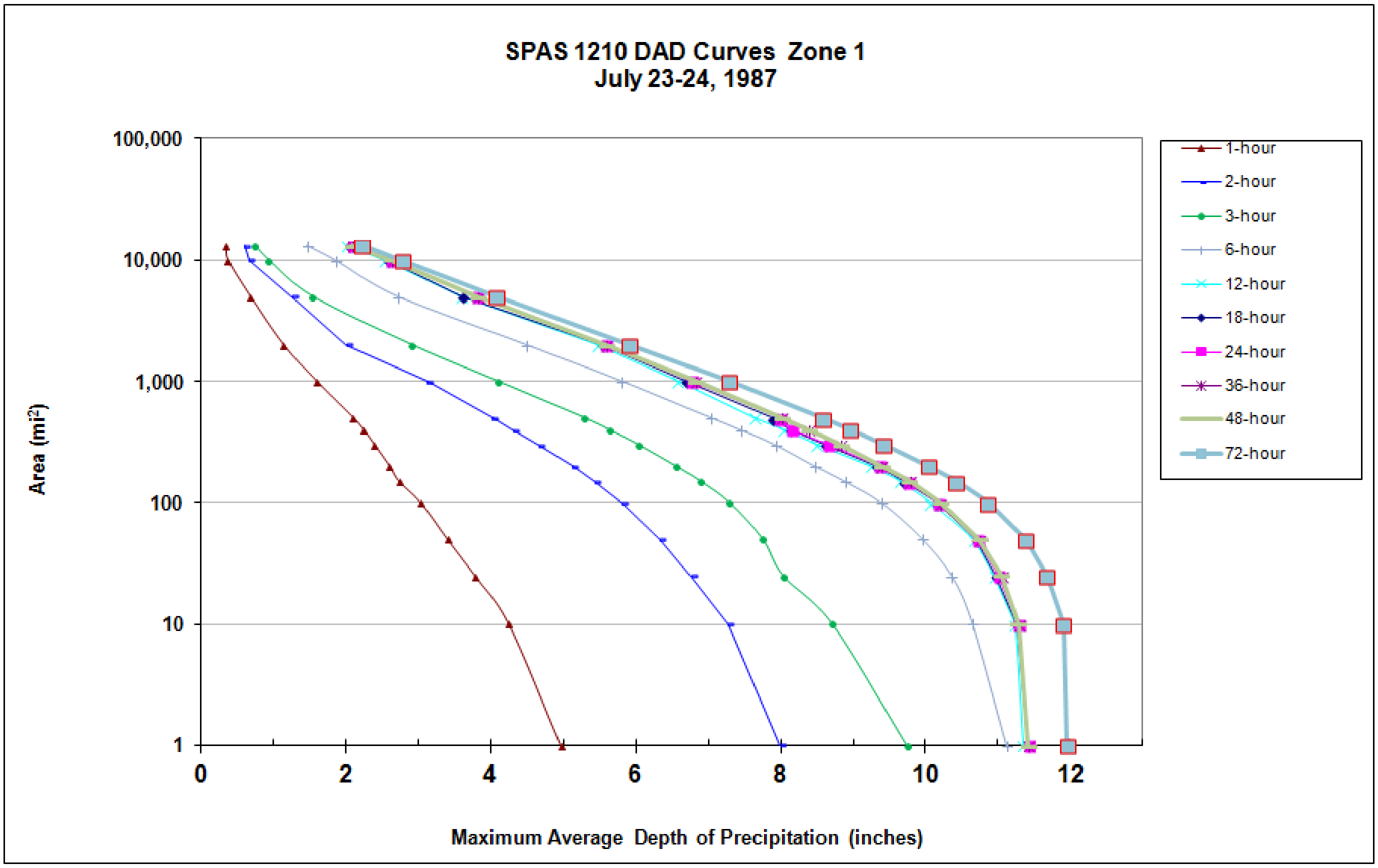
Attachment 3 Figure 49: Moisture inflow map for Minneapolis, MN July 1987

Storm 1210 - July 23 (0700 UTC) - July 24 (1800 UTC),1987

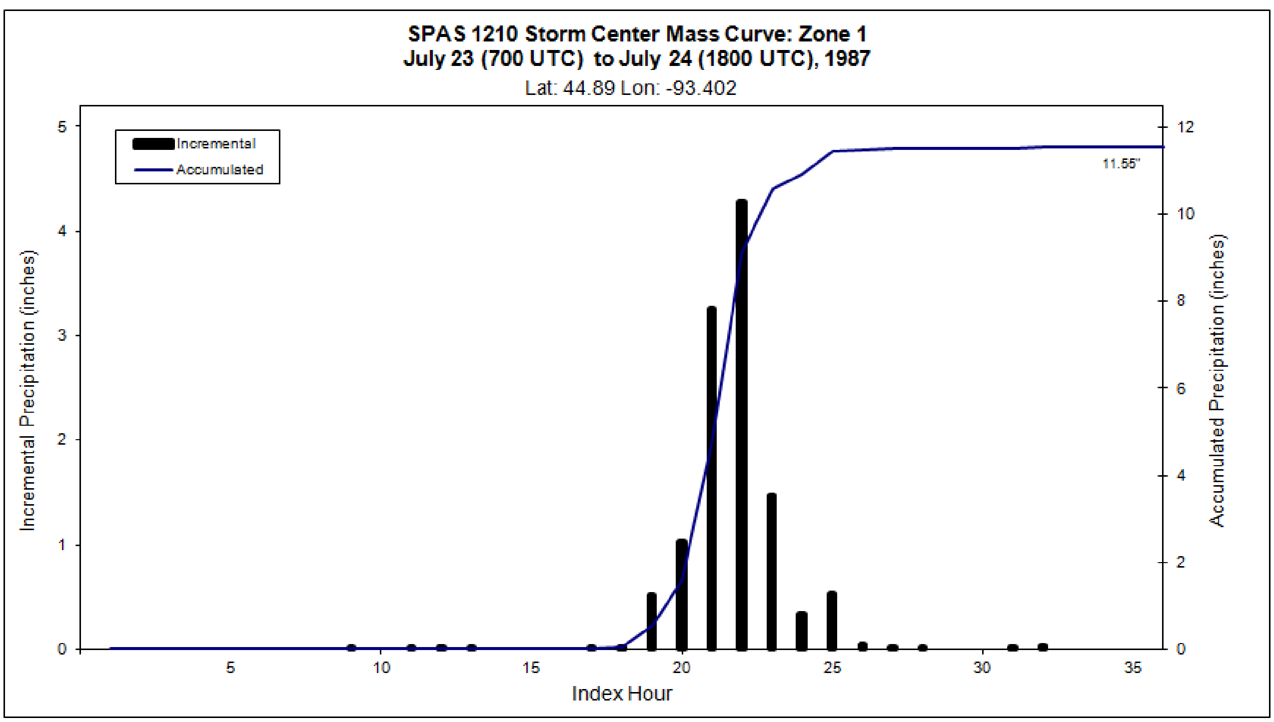
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)										
Area (mi^2)	1	2	3	6	12	18	24	36	48	72	Total
0	5.16	8.19	10	11.24	11.5	11.54	11.55	11.55	11.55	12.13	12.13
1	4.97	7.99	9.75	11.12	11.34	11.41	11.42	11.42	11.42	11.96	11.96
10	4.25	7.27	8.72	10.65	11.24	11.27	11.28	11.28	11.28	11.91	11.91
25	3.78	6.76	8.04	10.36	10.96	10.98	11.01	11.05	11.05	11.68	11.68
50	3.4	6.33	7.76	9.96	10.67	10.7	10.73	10.75	10.75	11.39	11.39
100	3.03	5.8	7.3	9.39	10.07	10.16	10.17	10.21	10.21	10.87	10.87
150	2.73	5.43	6.9	8.88	9.66	9.7	9.75	9.78	9.78	10.43	10.43
200	2.6	5.12	6.56	8.47	9.25	9.33	9.37	9.39	9.39	10.04	10.04
300	2.39	4.65	6.04	7.92	8.51	8.62	8.65	8.83	8.83	9.43	9.43
400	2.24	4.3	5.64	7.44	8.05	8.13	8.15	8.39	8.39	8.97	8.97
500	2.1	4.02	5.3	7.04	7.64	7.89	7.98	8.01	8.01	8.58	8.58
1,000	1.59	3.12	4.1	5.81	6.59	6.69	6.77	6.83	6.83	7.29	7.29
2,000	1.13	2	2.91	4.49	5.48	5.54	5.59	5.59	5.59	5.92	5.92
5,000	0.67	1.25	1.54	2.72	3.6	3.6	3.82	3.82	3.82	4.08	4.08
10,000	0.36	0.66	0.93	1.85	2.54	2.58	2.62	2.63	2.63	2.78	2.78
13,158	0.34	0.59	0.74	1.46	2.02	2.05	2.09	2.09	2.09	2.22	2.22

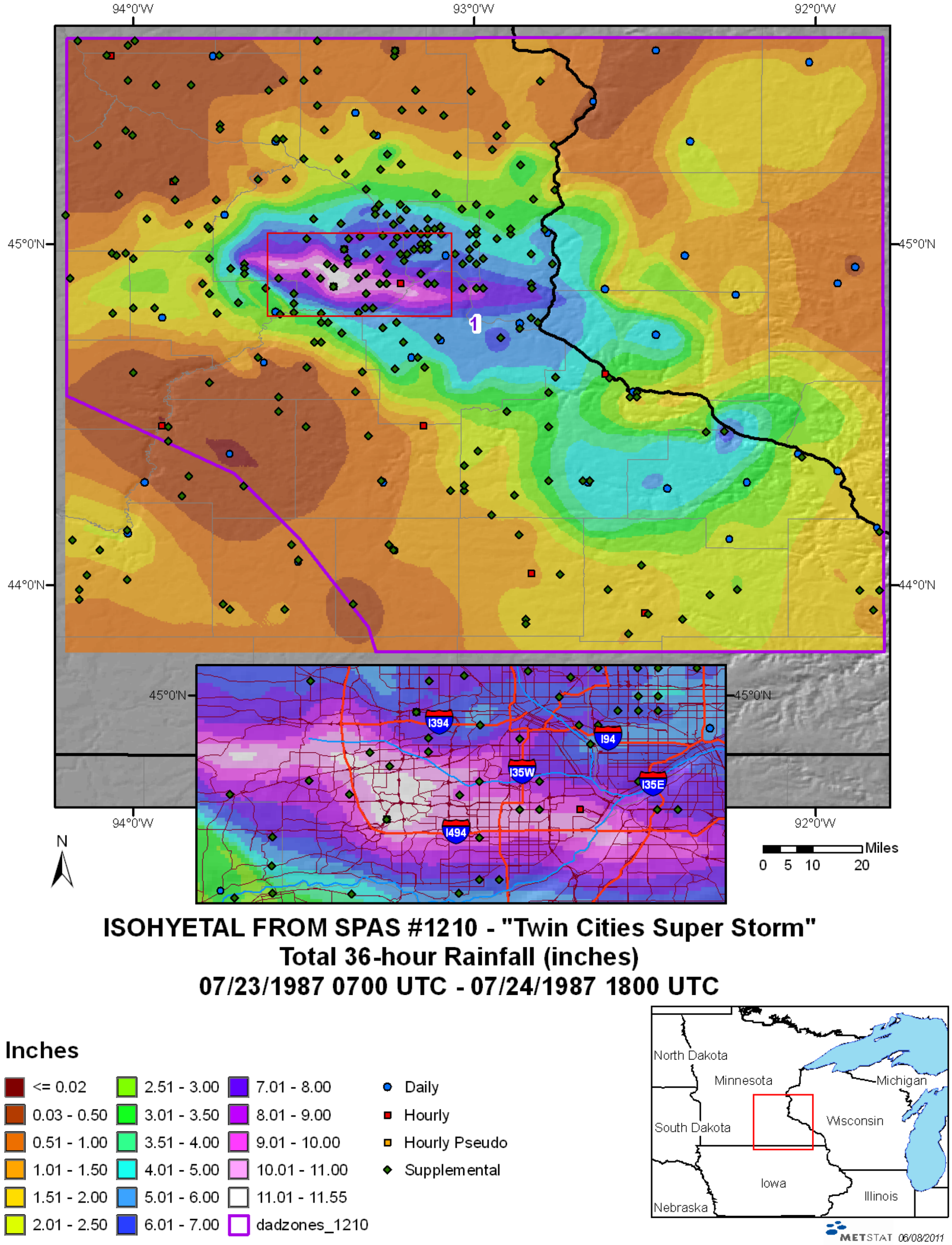
Attachment 3 Table 31: Depth-area-duration values for Minneapolis, MN July 1987



Attachment 3 Figure 50: Depth-area-duration chart for Minneapolis, MN July 1987



Attachment 3 Figure 51: Mass curve chart for Minneapolis, MN July 1987



Attachment 3 Figure 52: Total storm isohyetal analysis for Minneapolis, MN July 1987

Storm Name:	**SW 2-21-Mounds, OK**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**5/15-20/1943**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**1-Jun**	
	Lat	**Long**
Storm Center Location	**35.88 N**	**96.06 W**
Storm Rep Dew Point Location	**33.84 N**	**96.98 W**
Transposition Dew Point Locati	**43.29 N**	**94.90 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSW @ 150**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**750**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**73.0 F**	with total precipitable water above sea level of			**2.60**	inches.
The in-place maximum dew point is	**78.5 F**	with total precipitable water above sea level of			**3.37**	inches.
The transpositioned maximum dew point is	**76.0 F**	with total precipitable water above sea level of			**2.99**	inches.
The in-place storm elevation is	**750**	which subtracts	**0.18**	inches of precipitable water at	**73.0 F**	
The in-place storm elevation is	**750**	which subtracts	**0.22**	inches of precipitable water at	**78.5 F**	
The transposition storm elevation at	**950**	which subtracts	**0.25**	inches of precipitable water at	**76.0 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.25**	inches of precipitable water at	**76.0 F**	

The in-place maximization factor is	**1.30**
The transposition factor is	**0.87**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.13**

Notes: Storm rep Td re-analyzed using hourly surface observations. KADM, KFWH, and KGVT used to derive the 6 hour average storm rep Td.

Observed Storm Depth-Area-Duration

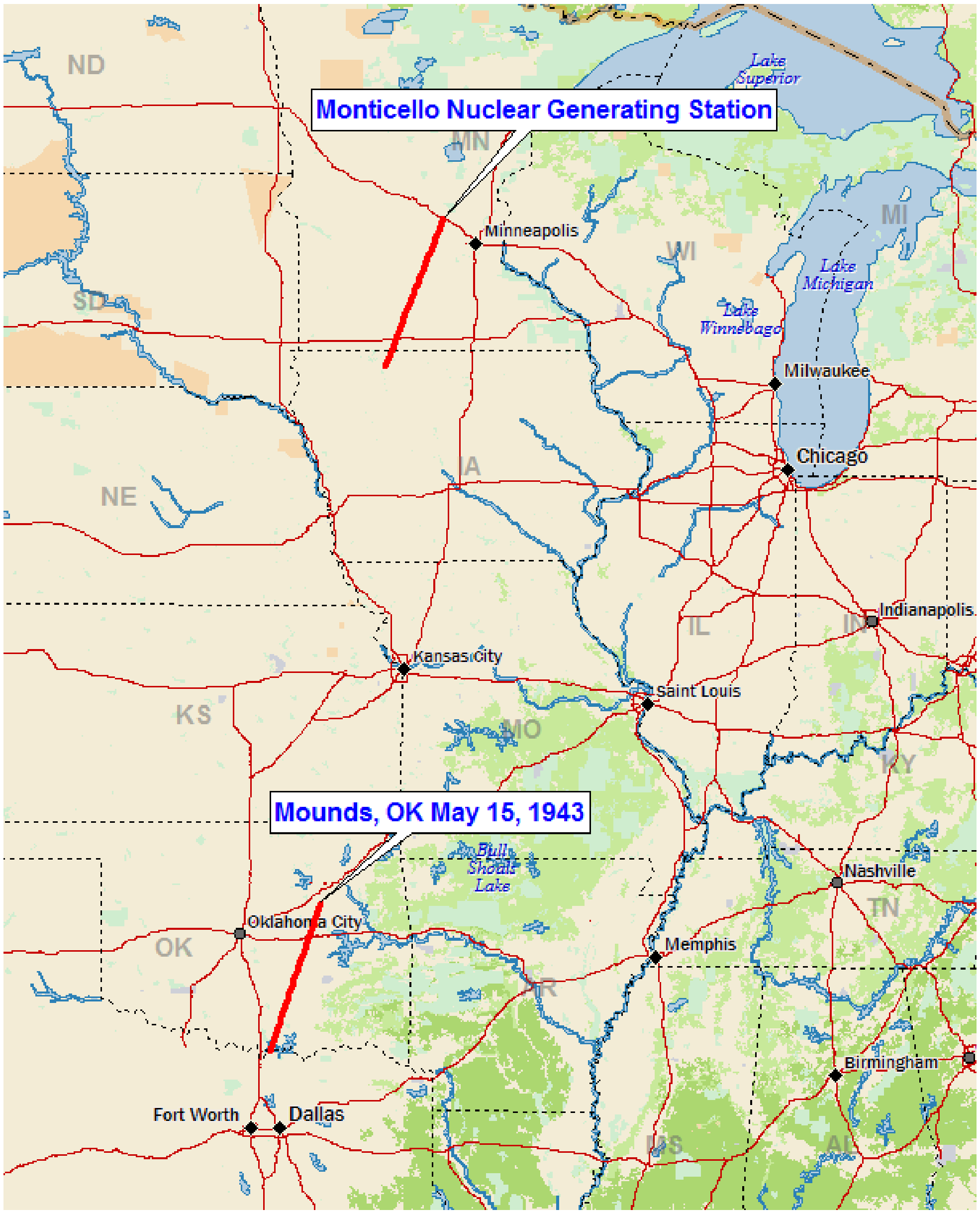
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**15.9**	**16.7**	**16.7**	**16.7**	-	**16.7**	**16.7**	**16.7**	**16.7**
100 sq miles	**14.2**	**14.8**	**14.9**	**14.9**	-	**14.9**	**14.9**	**15.0**	**15.4**
200 sq miles	**13.0**	**13.5**	**13.9**	**13.9**	-	**13.9**	**13.9**	**13.9**	**14.4**
500 sq miles	**9.2**	**10.6**	**11.1**	**11.1**	-	**11.5**	**12.0**	**13.7**	**14.4**
1000 sq miles	**6.2**	**7.9**	**8.4**	**8.5**	-	**10.0**	**10.8**	**13.2**	**13.8**
2000 sq miles	**4.0**	**5.3**	**6.3**	**6.6**	-	**9.2**	**10.0**	**12.6**	**13.2**
5000 sq miles	**3.0**	**3.6**	**4.9**	**5.4**	-	**8.3**	**8.9**	**11.5**	**12.1**
10000 sq miles	**2.6**	**3.1**	**4.2**	**4.8**	-	**7.3**	**8.0**	**10.2**	**10.7**
20000 sq miles	**2.1**	**2.6**	**3.5**	**4.2**	-	**6.2**	**6.9**	**8.6**	**9.1**

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	**18.0**	**18.9**	**18.9**	**18.9**	-	**18.9**	**18.9**	**18.9**	**18.9**
100 sq miles	**16.1**	**16.8**	**16.9**	**16.9**	-	**16.9**	**16.9**	**17.0**	**17.5**
200 sq miles	**14.7**	**15.3**	**15.8**	**15.8**	-	**15.8**	**15.8**	**15.8**	**16.3**
500 sq miles	**10.4**	**12.0**	**12.6**	**12.6**	-	**13.0**	**13.6**	**15.5**	**16.3**
1000 sq miles	**7.0**	**9.0**	**9.5**	**9.6**	-	**11.3**	**12.3**	**15.0**	**15.7**
2000 sq miles	**4.5**	**6.0**	**7.1**	**7.5**	-	**10.4**	**11.3**	**14.3**	**15.0**
5000 sq miles	**3.4**	**4.1**	**5.6**	**6.1**	-	**9.4**	**10.1**	**13.0**	**13.7**
10000 sq miles	**2.9**	**3.5**	**4.8**	**5.4**	-	**8.3**	**9.1**	**11.6**	**12.1**
20000 sq miles	**2.4**	**2.9**	**4.0**	**4.8**	-	**7.0**	**7.8**	**9.8**	**10.3**

Storm or Storm Center Name	**SW 2-21-Mounds, OK**			
Storm Date(s)	5/15-20/1943			
Storm Type	MCC			
Storm Location	35.88 N	96.06 W		
Storm Center Elevation	750			
Precipitation Total & Duration	17.0 inches in 12 hours			
Storm Representative Dew Point	73.0 F	6		
Storm Representative Dew Point Location	33.84 N	96.98 W	May	June
Maximum Dew Point	78.5 F		77	79
Moisture Inflow Vector	SSW @ 150			
In-place Maximization Factor	**1.30**			
Temporal Transposition Date	1-Jun			
Transposition Dew Point Location	43.29 N	94.90 W	May	June
Transposition Maximum Dew Point	76.0 F		72.68	78.6
Transposition Adjustment Factor	**0.87**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.13**			

Attachment 3 Table 32: Storm spreadsheet for Mounds, OK May 1943



Attachment 3 Figure 53: Moisture inflow map for Mounds, OK May 1943

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET

Storm of 12-20 May 1943
Assignment SW 2-21
Location Oklahoma to Great Lakes
Study Prepared by:
Southwestern Division
Tulsa District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 10/9/46
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 8/15/49
Remarks: Center near Mounds, Okla.
Dewpt. 71° - Ref. Pt. 60 ESE
Grid G-15

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1: 1,000,000

Precipitation data and mass curves:	(Number of Sheets)
Form 5001-C (Hourly precip. data)	531
Form 5001-B (24-hour " ")	--
Form 5001-D (" " " ")	147
Miscl. precip. records, meteorological data, etc.	10
Form 5002 (Mass rainfall curves)	251

PART II

Final isohyetal maps, in 1 sheet, scale 1: 1,000,000

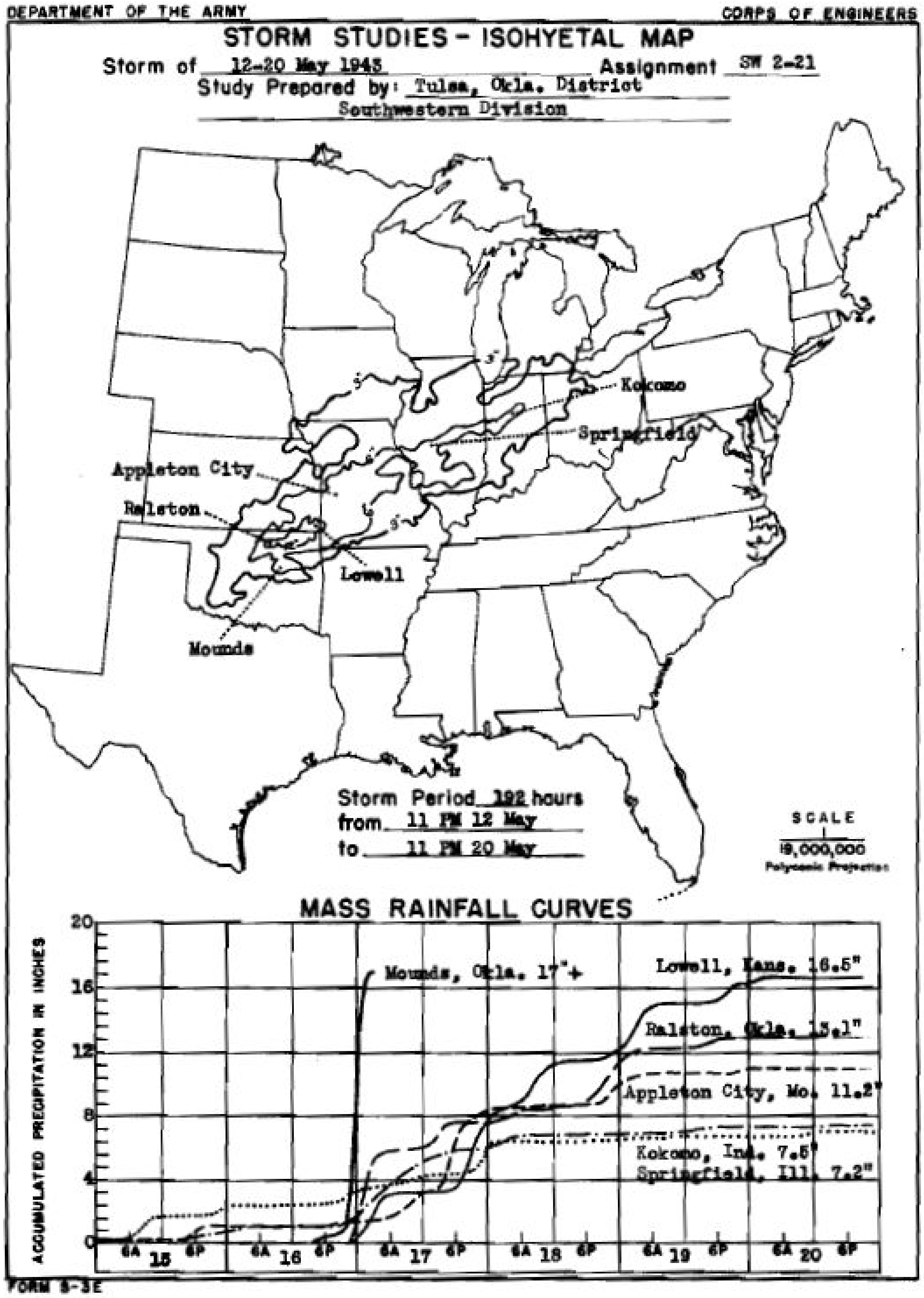
Data and computation sheets:	
Form S-10 (Data from mass rainfall curves)	44
Form S-11 (Depth-area data from isohyetal map)	8
Form S-12 (Maximum depth-duration data)	12
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	1

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										144/
	6	12	18	24	36	48	60	72	96	120	192
Max. Station	16.2	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
10	15.9	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.8	16.9	16.9
100	14.2	14.8	14.9	14.9	14.9	14.9	15.0	15.4	15.6	15.9	15.9
200	13.0	13.5	13.9	13.9	13.9	13.9	13.9	14.4	15.0	15.5	15.5
500	9.2	10.6	11.1	11.1	11.5	12.0	13.7	14.4	14.6	14.9	14.9
1,000	6.2	7.9	8.4	8.5	10.0	10.8	13.2	13.8	14.1	14.9	14.9
2,000	4.0	5.3	6.3	6.6	9.2	10.0	12.6	13.2	13.5	13.7	13.7
5,000	3.0	3.6	4.9	5.4	8.3	8.9	11.5	12.1	12.4	12.5	12.6
10,000	2.6	3.1	4.2	4.8	7.3	8.0	10.2	10.7	11.0	11.3	11.4
20,000	2.1	2.6	3.5	4.2	6.2	6.9	8.6	9.1	9.4	9.8	10.1
50,000	1.6	2.0	2.6	3.4	4.6	5.3	6.6	7.0	7.4	7.8	8.2
100,000	1.1	1.5	2.0	2.6	3.5	4.1	5.0	5.4	5.8	6.4	6.8
200,000	0.7	1.0	1.3	1.7	2.3	2.7	3.5	3.8	4.3	4.9	5.2

Form S-2

Attachment 3 Table 33: Depth-area-duration values for Mounds, OK May 1943



Attachment 3 Figure 54 and Attachment 3 Figure 55: Isohyetal map and Mass curve chart for Mounds, OK May 1943

Storm Name:	**USACE SW 2-1-Neosho Falls, KS**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**11-Sep-1926**	
AWA Analysis Date:	**8/25/2014**	

Temporal Transposition Date	**25-Aug**	
	Lat	**Long**
Storm Center Location	**38.08 N**	**95.70 W**
Storm Rep Dew Point Location	**31.35 N**	**93.80 W**
Transposition Dew Point Locati	**38.60 N**	**91.78 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSE @ 475**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,000**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**75.0 F**	with total precipitable water above sea level of		**2.85**	inches.
The in-place maximum dew point is	**80.5 F**	with total precipitable water above sea level of		**3.68**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of		**3.60**	inches.
The in-place storm elevation is	**1,000**	which subtracts **0.25**	inches of precipitable water at	**75.0 F**	
The in-place storm elevation is	**1,000**	which subtracts **0.29**	inches of precipitable water at	**80.5 F**	
The transposition storm elevation at	**950**	which subtracts **0.28**	inches of precipitable water at	**80.0 F**	
The moisture inflow barrier height is	**950**	which subtracts **0.28**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.30**
The transposition factor is	**0.98**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.28**

Notes: DAD values taken from USACE SW 2-1. Storm representative dew point value was based on maximum 6-hr Td values between September 1, 1926 at WBAN 93936 and 12945.

Observed Storm Depth-Area-Duration

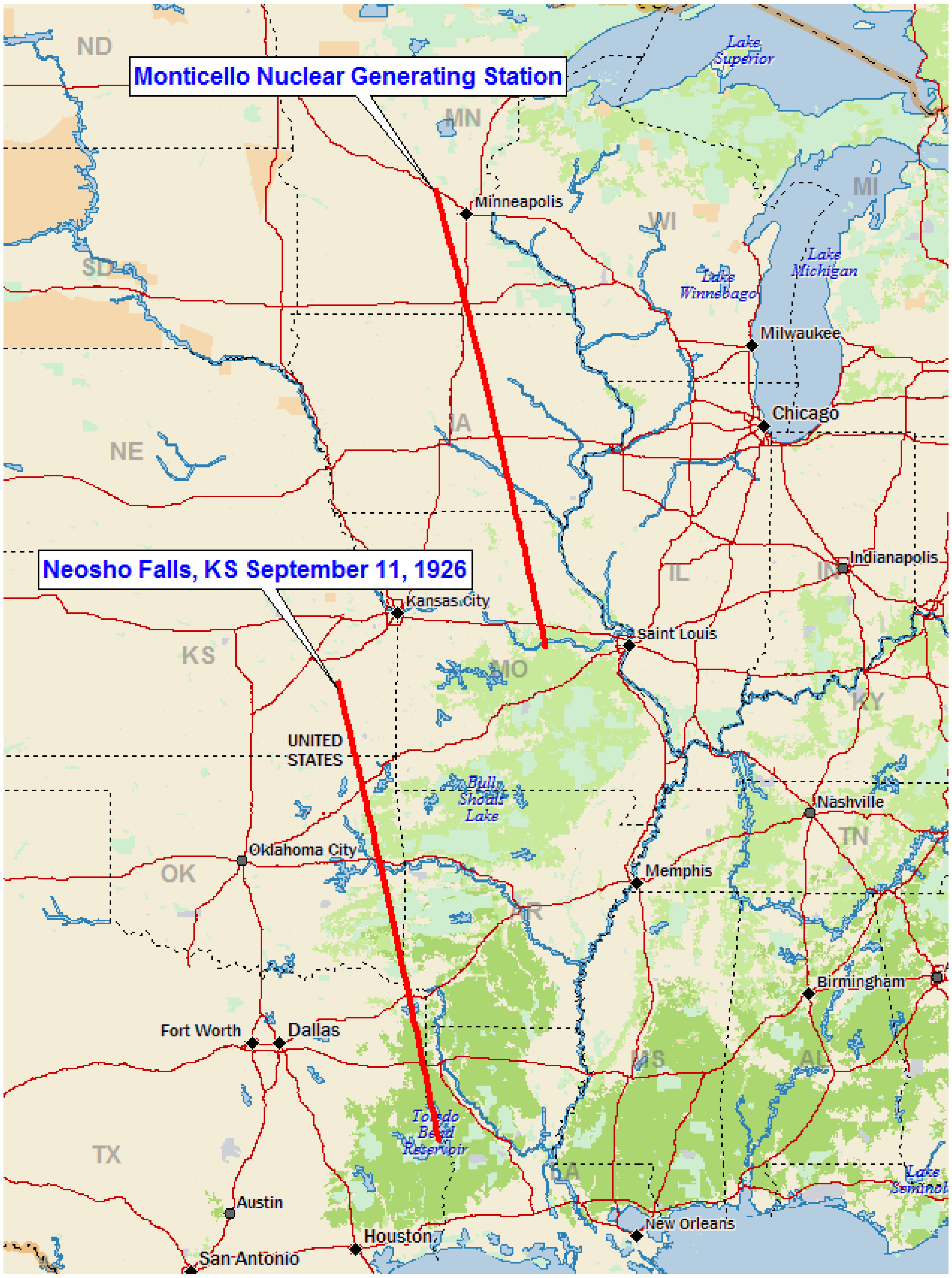
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	13.6	13.8	14.0	14.0	14.0	14.0	14.0	14.0	14.0
10 sq miles	13.4	13.7	13.9	13.9	13.9	13.9	13.9	13.9	13.9
100 sq miles	12.2	12.5	12.7	12.7	12.7	12.7	12.7	12.7	12.7
200 sq miles	11.4	11.7	11.9	12.0	12.0	12.0	12.0	12.0	12.0
500 sq miles	9.5	10.0	10.2	10.2	10.2	10.2	10.2	10.2	10.2
1000 sq miles	7.9	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8
2000 sq miles	6.4	7.1	7.3	7.3	7.3	7.3	7.3	7.3	7.3
5000 sq miles	4.3	5.1	5.3	5.3	5.3	5.3	5.3	5.5	5.5
10000 sq miles	2.9	3.8	3.9	4.0	4.0	4.0	4.2	4.3	4.4
20000 sq miles	1.7	2.6	2.7	2.8	2.8	2.8	2.9	3.3	3.5

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	17.4	17.6	17.9	17.9	17.9	17.9	17.9	17.9	17.9
10 sq miles	17.1	17.5	17.7	17.7	17.7	17.7	17.7	17.7	17.7
100 sq miles	15.6	16.0	16.2	16.2	16.2	16.2	16.2	16.2	16.2
200 sq miles	14.6	14.9	15.2	15.3	15.3	15.3	15.3	15.3	15.3
500 sq miles	12.1	12.8	13.0	13.0	13.0	13.0	13.0	13.0	13.0
1000 sq miles	10.1	10.9	11.2	11.2	11.2	11.2	11.2	11.2	11.2
2000 sq miles	8.2	9.1	9.3	9.3	9.3	9.3	9.3	9.3	9.3
5000 sq miles	5.5	6.5	6.8	6.8	6.8	6.8	6.8	7.0	7.0
10000 sq miles	3.7	4.9	5.0	5.1	5.1	5.1	5.4	5.5	5.6
20000 sq miles	2.2	3.3	3.4	3.6	3.6	3.6	3.7	4.2	4.5

Storm or Storm Center Name	**USACE SW 2-1-Neosho Falls, KS**			
Storm Date(s)	11-Sep-1926			
Storm Type	MCC-Thunderstorm Complex			
Storm Location	38.08 N	95.70 W		
Storm Center Elevation	1,000			
Precipitation Total & Duration	14.00 Inches 18-hours			
Storm Representative Dew Point	75.0 F	6		
Storm Representative Dew Point Location	31.35 N	93.80 W	Aug	Sep
Maximum Dew Point	80.5 F		81.5	78
Moisture Inflow Vector	SSE @ 475			
In-place Maximization Factor	**1.30**			
Temporal Transposition Date	25-Aug			
Transposition Dew Point Location	38.60 N	91.78 W	Aug	Sep
Transposition Maximum Dew Point	80.0 F		81.16	76.96
Transposition Adjustment Factor	**0.98**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.28**			

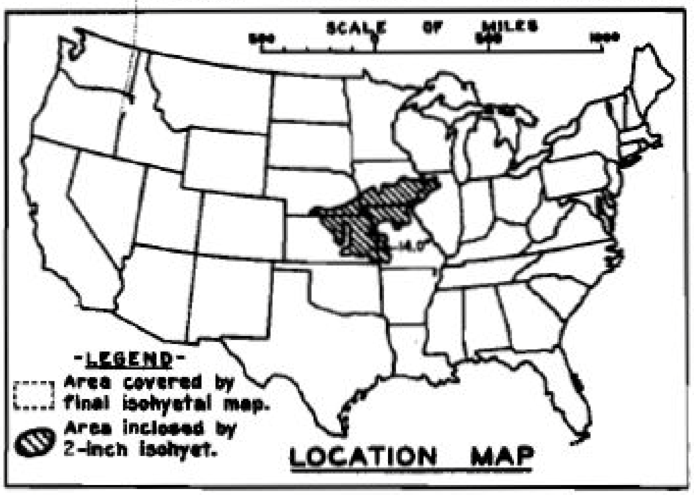
Attachment 3 Table 34: Storm spreadsheet for Neosho Falls, KS September 1926



Attachment 3 Figure 56: Moisture inflow map for Neosho Falls, KS September 1926

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES - PERTINENT DATA SHEET



Storm of September 11-16, 1926
Assignment S W 2 - 1
Location Kans. Nebr. Iowa Mo.
Study Prepared by:
Southwestern Division
Tulsa District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 1/31/41
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 6/5/45
Remarks: Center near Neosho Falls, Kans.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1 : 2,500,000

Precipitation data and mass curves:	(Number of Sheets)
Form 5001-C (Hourly precip. data)	8
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	6
Miscl. precip. records, meteorological data, etc.	2
Form 5002 (Mass rainfall curves)	17

PART II

Final isohyetal maps, in 1 sheet, scale 1 : 1,000,000

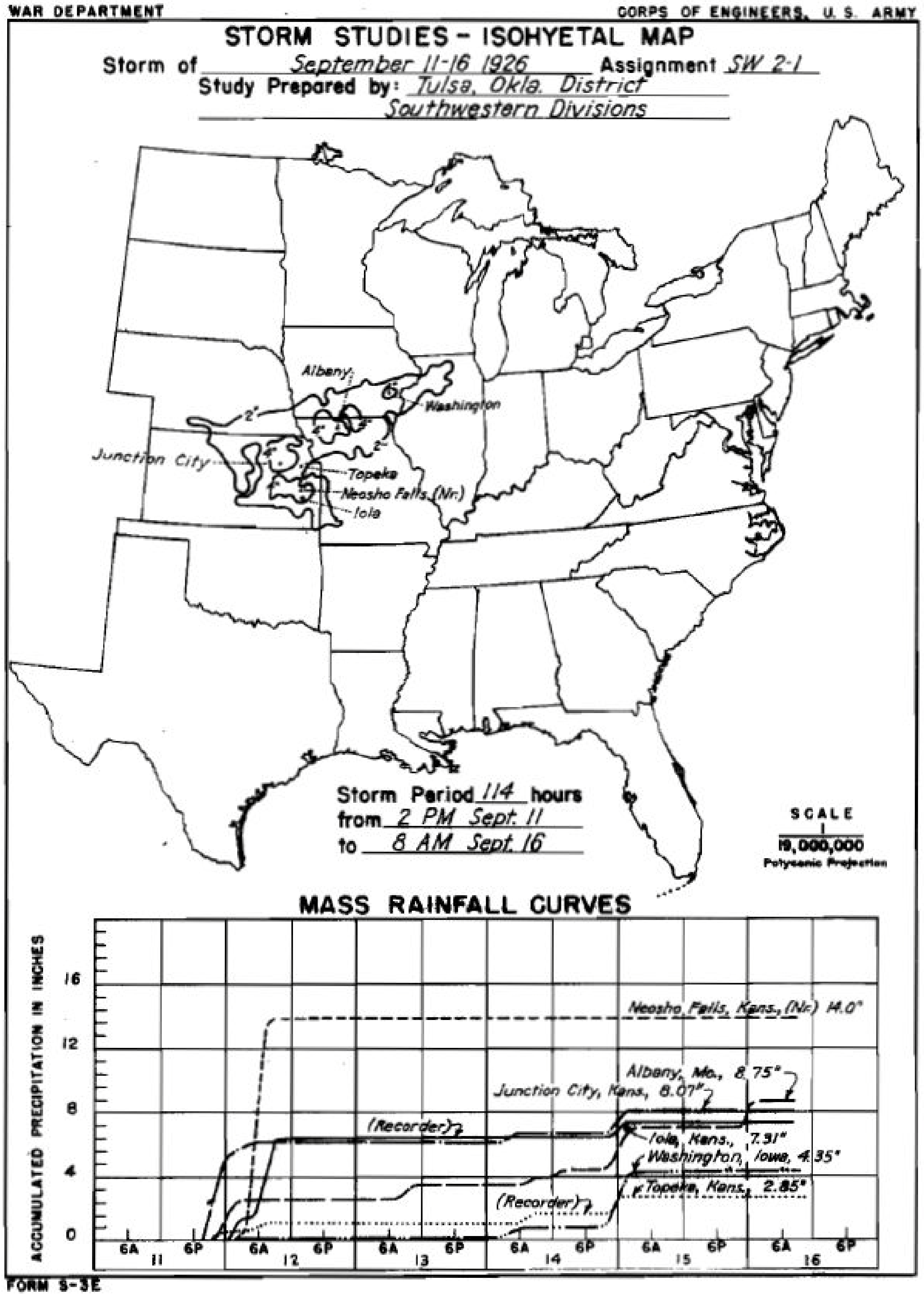
Data and computation sheets:	
Form S-10 (Data from mass rainfall curves)	10
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	6
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours										
	6	12	18	24	30	36	48	60	72	96	114
Max. Station	13.6	13.8	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
10	13.4	13.7	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
100	12.2	12.5	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
200	11.4	11.7	11.9	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
500	9.5	10.0	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.4	10.4
1,000	7.9	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8	9.0	9.0
2,000	6.4	7.1	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.6	7.6
5,000	4.3	5.1	5.3	5.3	5.3	5.3	5.3	5.5	5.5	5.8	5.8
10,000	2.9	3.8	3.9	4.0	4.0	4.0	4.2	4.3	4.4	5.0	5.0
20,000	1.7	2.6	2.7	2.8	2.8	2.8	2.9	3.3	3.5	4.4	4.5
30,000	1.2	2.0	2.1	2.2	2.2	2.2	2.3	2.8	3.0	4.1	4.2

Form S-2

Attachment 3 Table 35: Depth-area-duration values for Neosho Falls, KS September 1926



Attachment 3 Figure 57 and Attachment 3 Figure 58: Isohyetal map and Mass curve chart for Neosho Falls, KS September 1926

Storm Name:	**USACE MR-6-15-Stanton, NE**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**6/10-11/1944**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**25-Jun**	
	Lat	**Long**
Storm Center Location	**41.87 N**	**97.05 W**
Storm Rep Dew Point Location	**34.40 N**	**99.50 W**
Transposition Dew Point Locati	**37.86 N**	**96.40 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SSW @ 530**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,700**	feet
Storm Analysis Duration	**6**	hours

The storm representative dew point is	**76.0 F**	with total precipitable water above sea level of			**2.99**	inches.
The in-place maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The transpositioned maximum dew point is	**80.5 F**	with total precipitable water above sea level of			**3.68**	inches.
The in-place storm elevation is	**1,700**	which subtracts	**0.43**	inches of precipitable water at	**76.0 F**	
The in-place storm elevation is	**1,700**	which subtracts	**0.48**	inches of precipitable water at	**80.0 F**	
The transposition storm elevation at	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.29**	inches of precipitable water at	**80.5 F**	

The in-place maximization factor is	**1.22**
The transposition factor is	**1.09**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.32**

Notes: DAD values taken from USACE Storm Studies MR 6-15. Storm representative Td value was based on maximum 6-hr Td values between June 10, 1944 at mid-point of KCDS, KLTS and KFDR.

Observed Storm Depth-Area-Duration

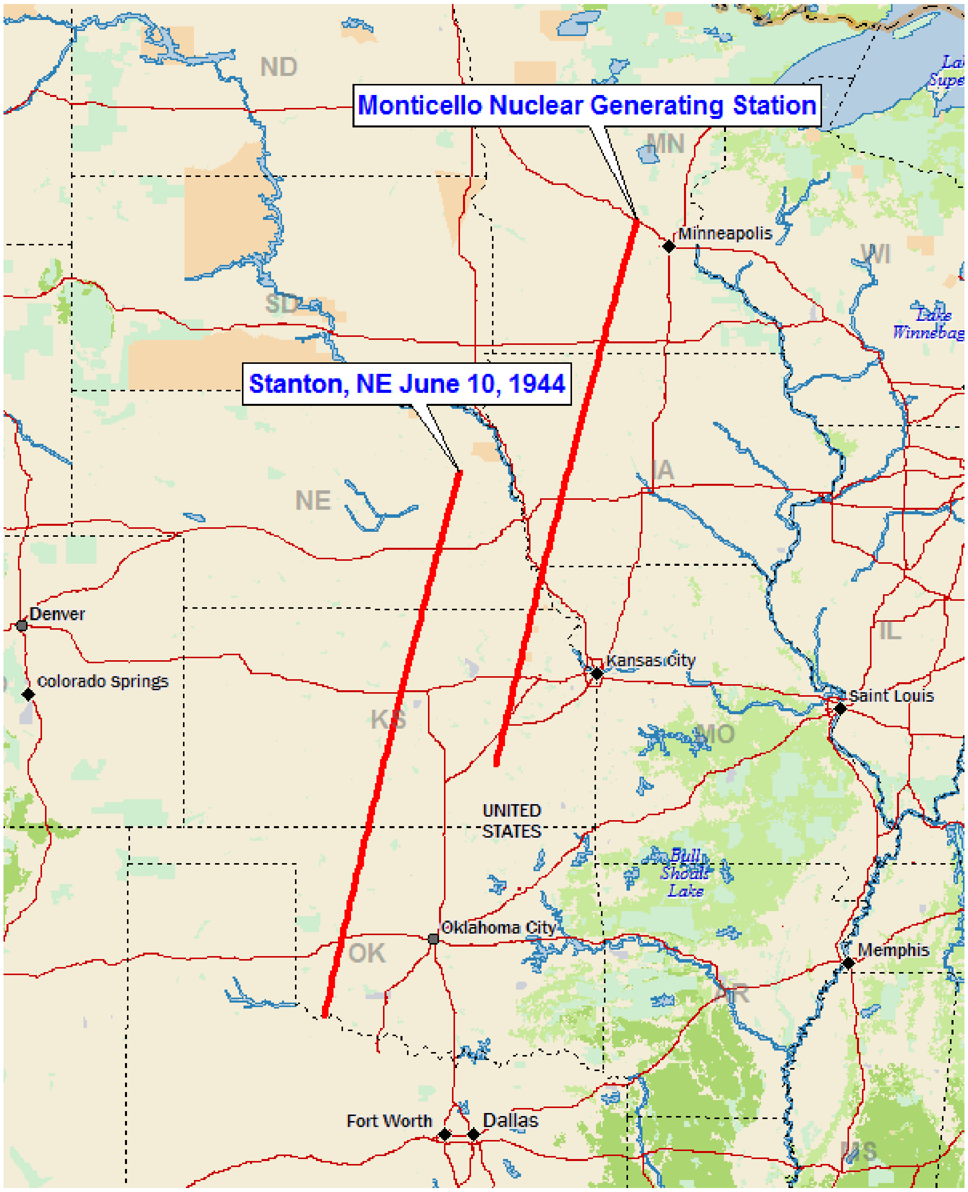
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**15.5**	**15.8**	**15.8**	**15.8**	**15.8**	**15.8**	**16.8**	**17.3**	**17.3**
10 sq miles	**13.4**	**15.3**	**15.3**	**15.3**	**15.3**	**15.3**	**16.2**	**16.4**	**16.7**
100 sq miles	**11.7**	**13.6**	**13.6**	**13.6**	**13.6**	**13.7**	**14.8**	**14.9**	**15.1**
200 sq miles	**11.1**	**12.9**	**12.9**	**12.9**	**12.9**	**13.1**	**14.1**	**14.3**	**14.4**
500 sq miles	**9.8**	**11.3**	**11.5**	**11.5**	**11.5**	**11.6**	**12.5**	**12.7**	**12.8**
1000 sq miles	**7.8**	**9.0**	**9.3**	**9.3**	**9.3**	**9.4**	**10.1**	**10.4**	**10.4**
2000 sq miles	**5.9**	**6.9**	**7.1**	**7.1**	**7.2**	**7.3**	**7.8**	**8.1**	**8.1**
5000 sq miles	**3.4**	**4.0**	**4.2**	**4.6**	**4.7**	**4.9**	**5.3**	**5.5**	**5.7**
10000 sq miles	**2.2**	**2.5**	**2.7**	**3.5**	**3.9**	**4.1**	**4.5**	**4.7**	**4.9**
20000 sq miles	-	-	-	-	-	-	-	-	-

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
1 sq miles	**20.5**	**20.9**	**20.9**	**20.9**	**20.9**	**20.9**	**22.2**	**22.9**	**22.9**
10 sq miles	**17.7**	**20.3**	**20.3**	**20.3**	**20.3**	**20.3**	**21.4**	**21.7**	**22.1**
100 sq miles	**15.5**	**18.0**	**18.0**	**18.0**	**18.0**	**18.1**	**19.6**	**19.7**	**20.0**
200 sq miles	**14.7**	**17.1**	**17.1**	**17.1**	**17.1**	**17.3**	**18.7**	**18.9**	**19.1**
500 sq miles	**13.0**	**15.0**	**15.2**	**15.2**	**15.2**	**15.4**	**16.5**	**16.8**	**16.9**
1000 sq miles	**10.3**	**11.9**	**12.3**	**12.3**	**12.3**	**12.4**	**13.4**	**13.8**	**13.8**
2000 sq miles	**7.8**	**9.1**	**9.4**	**9.4**	**9.5**	**9.7**	**10.3**	**10.7**	**10.7**
5000 sq miles	**4.5**	**5.3**	**5.6**	**6.1**	**6.2**	**6.5**	**7.0**	**7.3**	**7.5**
10000 sq miles	**2.9**	**3.3**	**3.6**	**4.6**	**5.2**	**5.4**	**6.0**	**6.2**	**6.5**
20000 sq miles	-	-	-	-	-	-	-	-	-

Storm or Storm Center Name	**USACE MR-6-15-Stanton, NE**			
Storm Date(s)	6/10-11/1944			
Storm Type	MCC			
Storm Location	41.87 N	97.05 W		
Storm Center Elevation	1,700			
Precipitation Total & Duration	17.3 Inches 60-hours USACE Storm Studies MR 6-15			
Storm Representative Dew Point	76.0 F	6		
Storm Representative Dew Point Location	34.40 N	99.50 W		
Maximum Dew Point	80.0 F			
Moisture Inflow Vector	SSW @ 530			
In-place Maximization Factor	**1.22**			
Temporal Transposition Date	25-Jun			
Transposition Dew Point Location	37.86 N	96.40 W	June	July
Transposition Maximum Dew Point	80.5 F		79.4	82.35
Transposition Adjustment Factor	**1.09**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.32**			

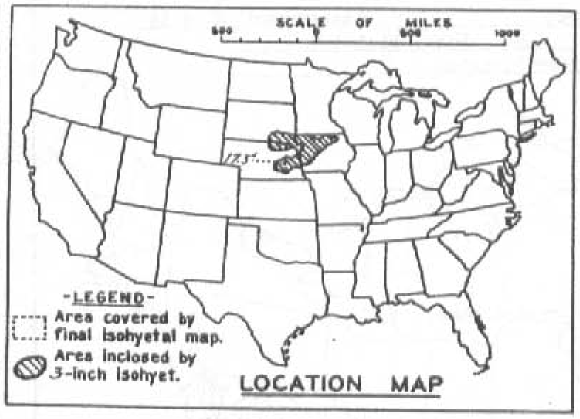
Attachment 3 Table 36: Storm spreadsheet for Stanton, NE June 1944



Attachment 3 Figure 59: Moisture inflow map for Stanton, NE June 1944

DEPARTMENT OF THE ARMY CORPS OF ENGINEERS

STORM STUDIES - PERTINENT DATA SHEET



Storm of 10-13 June 1944
Assignment MR 6-15
Location Ia., Nebr., S. Dak.
Study Prepared by:
Missouri River Division
Omaha District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 8/7/46
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 2/10/48
Remarks: Center near Stanton, Nebr.
Dewpt. 70°- Ref. Pt. 125 SSE
Grid D-16

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 2 sheets, scale 1:500,000
Precipitation data and mass curves: (Number of Sheets)

Form 5001-C (Hourly precip. data)	56
Form 5001-B (24-hour " ")	-
Form 5001-D (" " " ")	19
Miscl. precip. records, meteorological data, etc.	11
Form 5002 (Mass rainfall curves)	34

PART II

Final isohyetal maps, in 1 sheet , scale 500,000
Data and computation sheets:

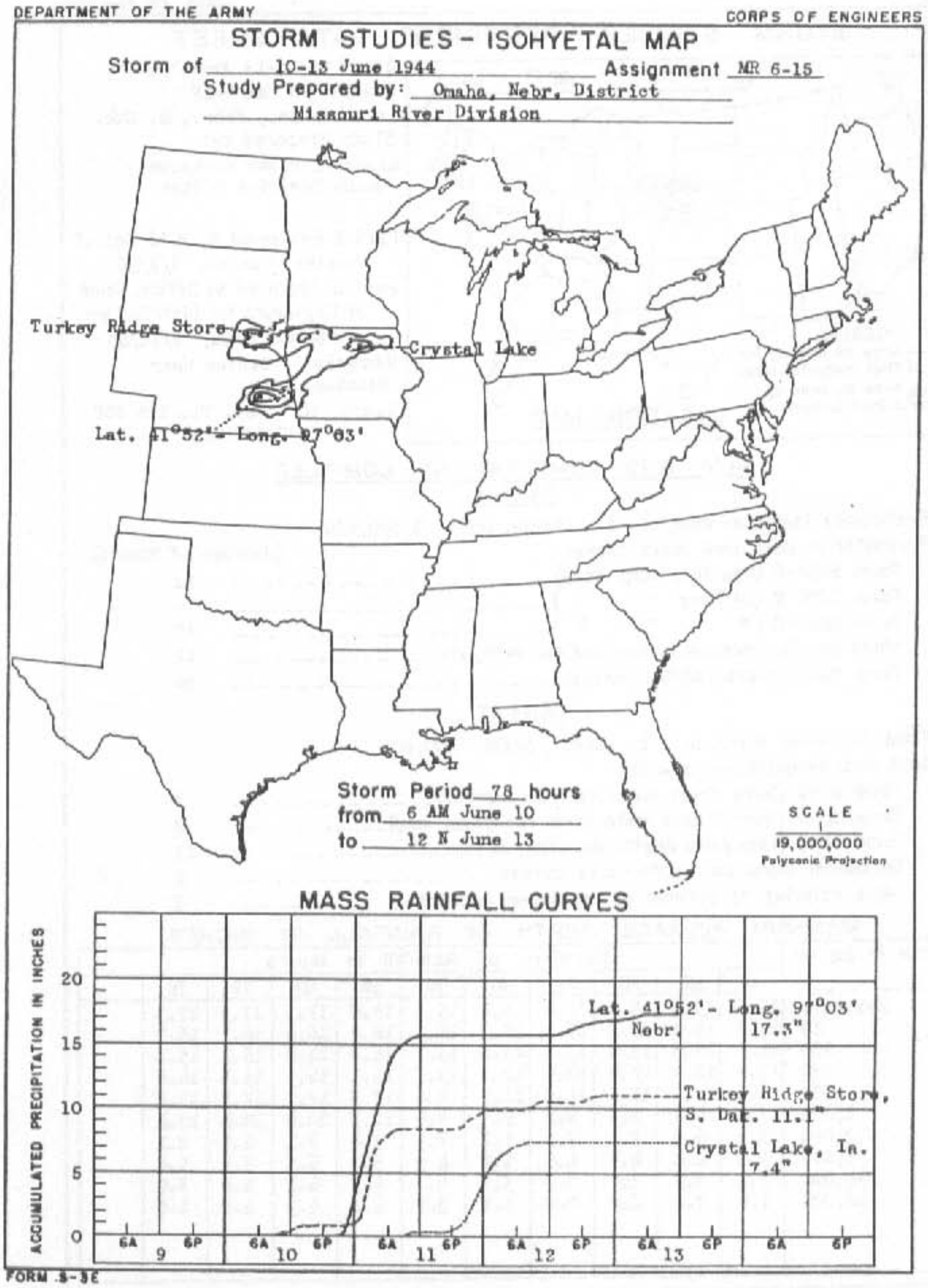
Form S-10 (Data from mass rainfall curves)	3
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	13
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	5

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	78
Max.Sta.	15.5	15.8	15.8	15.8	15.8	15.8	16.8	17.3	17.3	17.3
10	13.4	15.3	15.3	15.3	15.3	15.3	16.2	16.4	16.7	16.7
100	11.7	13.6	13.6	13.6	13.6	13.7	14.8	14.9	15.1	15.1
200	11.1	12.9	12.9	12.9	12.9	13.1	14.1	14.3	14.4	14.4
500	9.8	11.3	11.5	11.5	11.5	11.6	12.5	12.7	12.8	12.8
1,000	7.8	9.0	9.3	9.3	9.3	9.4	10.1	10.4	10.4	10.4
2,000	5.9	6.9	7.1	7.1	7.2	7.3	7.8	8.1	8.1	8.1
5,000	3.4	4.0	4.2	4.6	4.7	4.9	5.3	5.5	5.7	5.8
10,000	2.2	2.5	2.7	3.5	3.9	4.1	4.5	4.7	4.9	5.0
16,000	1.8	2.0	2.2	2.9	3.5	3.7	4.1	4.3	4.5	4.6

Form S-2

Attachment3 Table 37: Depth-area-duration values for Stanton, NE June 1944



Attachment 3 Figure 60 and Attachment 3 Figure 61: Isohyetal map and Mass curve chart for Stanton, NE June 1944

Storm Name:	MR 1-10-Woodburn, IA
Storm Date:	24-Aug-1903
AWA Analysis Date:	8/24/2014

Storm Adjustment for Monticello-LIP

Temporal Transposition Date	5-Aug	
	Lat	Long
Storm Center Location	41.01 N	93.60 W
Storm Rep Dew Point Location	38.52 N	91.81 W
Transposition Dew Point Locati	42.84 N	91.94 W
Basin Location	45.33 N	93.85 W

Moisture Inflow Direction	SSE @ 195	miles
Basin Average Elevation	950	feet
Storm Center Elevation	1,150	feet
Storm Analysis Duration	24	hours

The storm representative dew point is	75.0 F	with total precipitable water above sea level of			2.85	inches.
The in-place maximum dew point is	80.5 F	with total precipitable water above sea level of			3.68	inches.
The transpositioned maximum dew point is	80.0 F	with total precipitable water above sea level of			3.60	inches.
The in-place storm elevation is	1,150	which subtracts	0.30	inches of precipitable water at	75.0 F	
The in-place storm elevation is	1,150	which subtracts	0.34	inches of precipitable water at	80.5 F	
The transposition storm elevation at	950	which subtracts	0.28	inches of precipitable water at	80.0 F	
The moisture inflow barrier height is	950	which subtracts	0.28	inches of precipitable water at	80.0 F	

The in-place maximization factor is	1.31
The transposition factor is	0.99
The elevation/barrier adjustment factor is	1.00
The total adjustment factor is	1.30

Notes: DAD values taken from USACE MR 1-10. 2° added to the storm rep based on EPRI and Nebraska analyses to adjust 12-hr persisting Td to 24-hr average Td.

Observed Storm Depth-Area-Duration

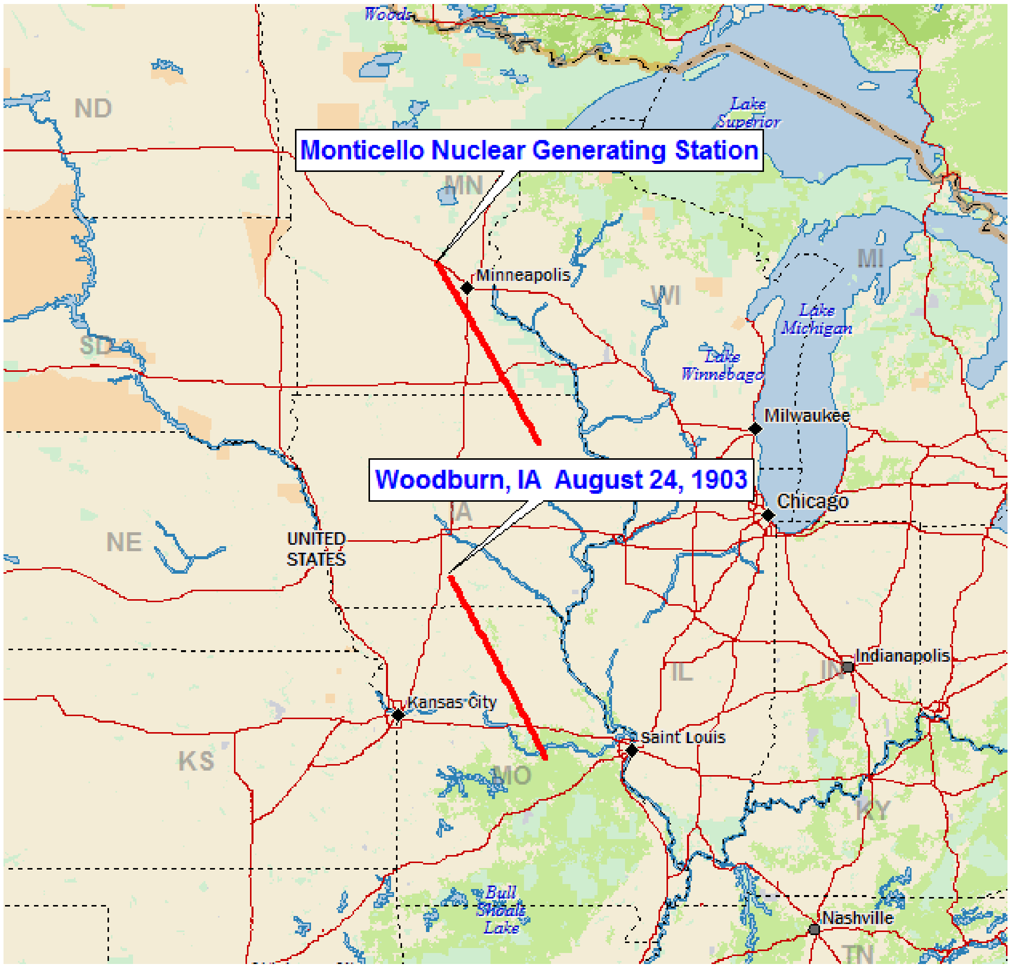
	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	6.9	11.5	11.9	14.7	14.7	14.7	15.4	15.5	15.5
100 sq miles	6.6	10.3	11.4	12.8	13.8	13.8	13.9	14.4	14.6
200 sq miles	6.3	9.9	11.0	12.2	13.2	13.2	13.2	13.8	13.9
500 sq miles	5.7	9.3	10.3	11.2	12.2	12.2	12.6	12.8	12.8
1000 sq miles	5.2	8.7	9.5	10.3	11.1	11.2	11.2	11.5	11.7
2000 sq miles	4.6	7.8	8.6	9.2	10.0	10.1	10.2	10.4	10.6
5000 sq miles	3.7	6.4	7.3	7.7	8.4	8.7	8.8	8.8	9.0
10000 sq miles	3.0	5.2	6.3	6.5	7.1	7.3	7.5	7.5	7.7
20000 sq miles	2.3	4.0	5.0	5.2	5.6	5.9	6.1	6.1	6.3

Adjusted Storm Depth-Area-Duration

	6 Hours	12 Hours	18 Hours	24 Hours	30 Hours	36 Hours	48 Hours	60 Hours	72 Hours
10 sq miles	9.0	14.9	15.5	19.1	19.1	19.1	20.0	20.1	20.1
100 sq miles	8.6	13.4	14.8	16.6	17.9	17.9	18.1	18.7	19.0
200 sq miles	8.2	12.9	14.3	15.9	17.2	17.2	17.2	17.9	18.1
500 sq miles	7.4	12.1	13.4	14.6	15.9	15.9	16.4	16.6	16.6
1000 sq miles	6.8	11.3	12.3	13.4	14.4	14.6	14.6	14.9	15.2
2000 sq miles	6.0	10.1	11.2	12.0	13.0	13.1	13.3	13.5	13.8
5000 sq miles	4.8	8.3	9.5	10.0	10.9	11.3	11.4	11.4	11.7
10000 sq miles	3.9	6.8	8.2	8.4	9.2	9.5	9.7	9.7	10.0
20000 sq miles	3.0	5.2	6.5	6.8	7.3	7.7	7.9	7.9	8.2

Storm or Storm Center Name	**MR 1-10-Woodburn, IA**			
Storm Date(s)	24-Aug-1903			
Storm Type	MCC			
Storm Location	41.01 N	93.60 W		
Storm Center Elevation	1,150			
Precipitation Total & Duration	14.70 Inches 24-hours USACE MR 1-10			
Storm Representative Dew Point	75.0 F	24		
Storm Representative Dew Point Location	38.52 N	91.81 W		
Maximum Dew Point	80.5 F			
Moisture Inflow Vector	SSE @ 195			
In-place Maximization Factor	**1.31**			
Temporal Transposition Date	5-Aug			
Transposition Dew Point Location	42.84 N	91.94 W	July	Aug
Transposition Maximum Dew Point	80.0 F		80.2	79.6
Transposition Adjustment Factor	**0.99**			
Average Basin Elevation	950			
Highest Elevation in Basin	950			
Inflow Barrier Height	950			
Elevation Adjustment Factor	**1.00**			
Total Adjustment Factor	**1.30**			

Attachment 3 Table 38: Storm spreadsheet for Woodburn, IA August 1903



Attachment 3 Figure 62: Moisture inflow map for Woodburn, IA August 1903

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

STORM STUDIES - PERTINENT DATA SHEET

Storm of August 24 - 28, 1903
Assignment MR 1 - 10
Location Iowa
Study Prepared by:
Missouri River Division
Kansas City District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 6/6/39
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 11/4/44
Remarks: Centers at Woodburn, Ia., and Council Bluffs, Ia.

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1 : 2,500,000

Precipitation data and mass curves:	(Number of Sheets)
Form 5001-C (Hourly precip. data)	5
Form 5001-B (24-hour " ")	21
Form 5001-D (" " " ")	-
Miscl. precip. records, meteorological data, etc.	-
Form 5002 (Mass rainfall curves)	11

PART II

Final isohyetal maps, in 1 sheet, scale 1 : 1,000,000

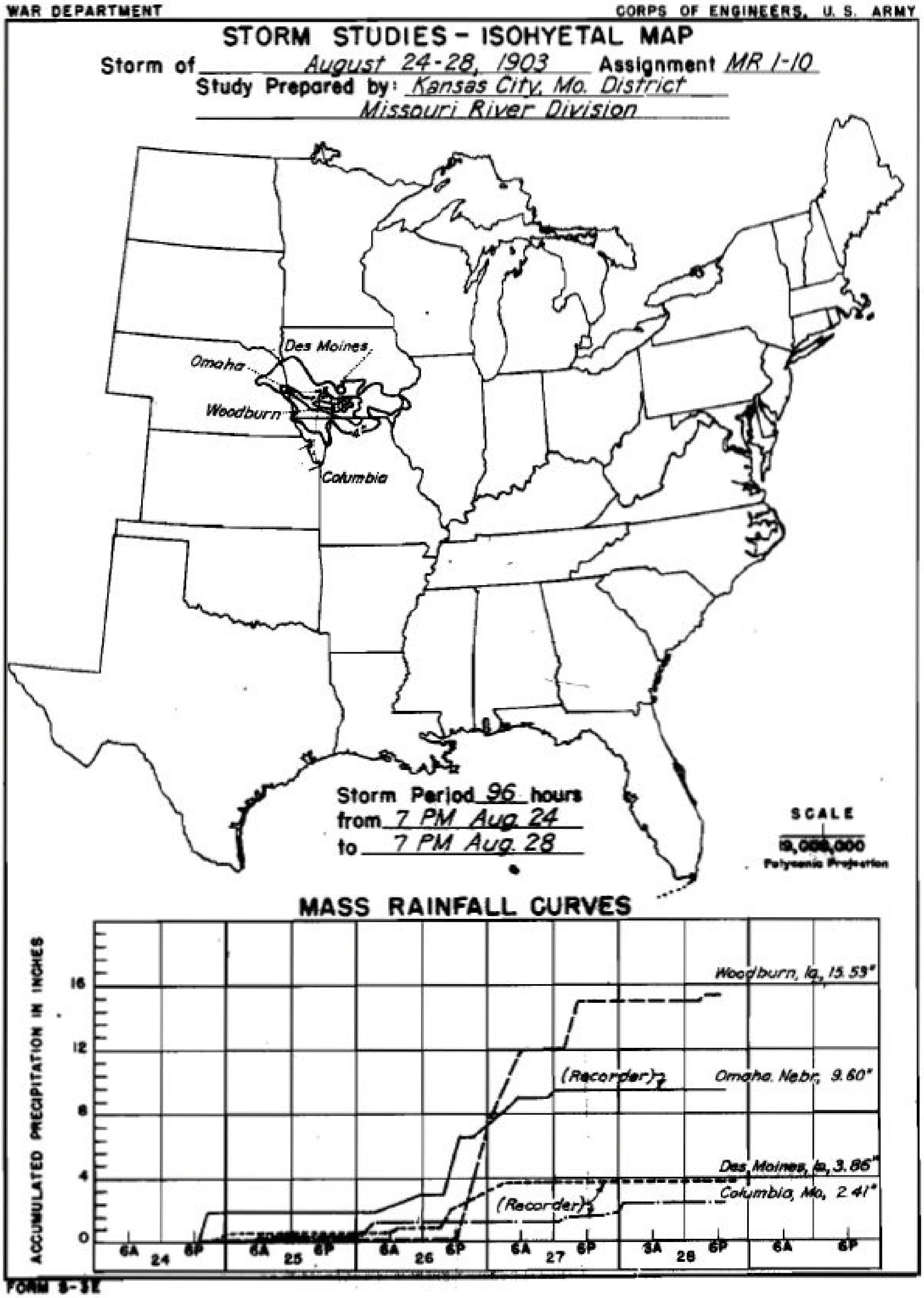
Data and computation sheets:	
Form S-10 (Data from mass rainfall curves)	4
Form S-11 (Depth-area data from isohyetal map)	2
Form S-12 (Maximum depth-duration data)	6
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	2

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	96
10	6.9	11.5	11.9	14.7	14.7	14.7	15.4	15.5	15.5	15.5
100	6.6	10.3	11.4	12.8	13.8	13.8	13.9	14.4	14.6	14.6
200	6.3	9.9	11.0	12.2	13.2	13.2	13.2	13.8	13.9	13.9
500	5.7	9.3	10.3	11.2	12.2	12.2	12.2	12.6	12.8	12.8
1,000	5.2	8.7	9.5	10.3	11.1	11.2	11.2	11.5	11.7	11.7
2,000	4.6	7.8	8.6	9.2	10.0	10.1	10.2	10.4	10.6	10.7
5,000	3.7	6.4	7.3	7.7	8.4	8.7	8.8	8.8	9.0	9.2
10,000	3.0	5.2	6.3	6.5	7.1	7.3	7.5	7.5	7.7	7.9
20,000	2.3	4.0	5.0	5.2	5.6	5.9	6.1	6.1	6.3	6.5
50,000	1.3	2.4	3.1	3.2	3.5	4.0	4.2	4.3	4.4	4.7
59,000	1.1	2.1	2.8	2.9	3.2	3.6	3.9	4.0	4.1	4.4

Form S-2

Attachment 3 Table 39: Depth-area-duration values for Woodburn, IA August 1903



Attachment 3 Figure 63 and Attachment 3 Figure 64: Isohyetal map and Mass curve chart for Woodburn, IA August 1903

Storm Name:	**Wooster, OH SPAS 1209**	**Storm Adjustment for Monticello-LIP**
Storm Date:	**7/4-7/1969**	
AWA Analysis Date:	**8/24/2014**	

Temporal Transposition Date	**15-Jul**	
	Lat	**Long**
Storm Center Location	**40.91 N**	**81.97 W**
Storm Rep Dew Point Location	**39.43 N**	**83.80 W**
Transposition Dew Point Locati	**43.85 N**	**95.81 W**
Basin Location	**45.33 N**	**93.85 W**

Moisture Inflow Direction	**SW @ 140**	miles
Basin Average Elevation	**950**	feet
Storm Center Elevation	**1,150**	feet
Storm Analysis Duration	**24**	hours

The storm representative dew point is	**76.0 F**	with total precipitable water above sea level of			**2.99**	inches.
The in-place maximum dew point is	**78.0 F**	with total precipitable water above sea level of			**3.29**	inches.
The transpositioned maximum dew point is	**80.0 F**	with total precipitable water above sea level of			**3.60**	inches.
The in-place storm elevation is	**1,150**	which subtracts	**0.30**	inches of precipitable water at	**76.0 F**	
The in-place storm elevation is	**1,150**	which subtracts	**0.32**	inches of precipitable water at	**78.0 F**	
The transposition storm elevation at	**950**	which subtracts	**0.28**	inches of precipitable water at	**80.0 F**	
The moisture inflow barrier height is	**950**	which subtracts	**0.28**	inches of precipitable water at	**80.0 F**	

The in-place maximization factor is	**1.10**
The transposition factor is	**1.12**
The elevation/barrier adjustment factor is	**1.00**
The total adjustment factor is	**1.23**

Notes: DAD values taken from SPAS 1209. Storm representative dew point value was based on maximum 24-hr Td values between July 4-5, 1969 at KILN, KFFO, and KCVG.

Observed Storm Depth-Area-Duration

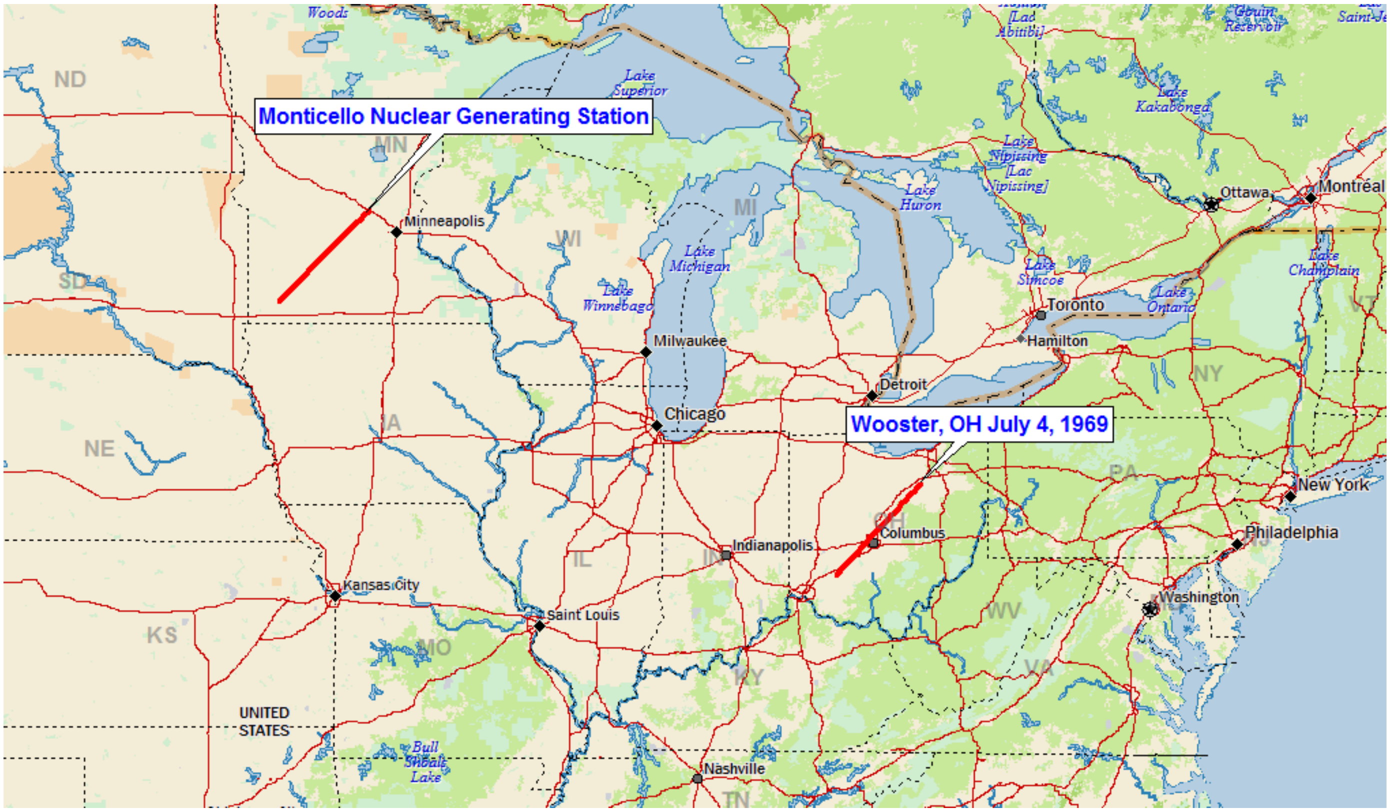
	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**4.6**	**6.2**	**8.8**	**12.7**	**14.3**	**14.4**	**14.5**	**14.6**	**14.7**
10 sq miles	**4.2**	**6.0**	**8.7**	**12.3**	**13.7**	**13.7**	**13.8**	**14.0**	**14.0**
100 sq miles	**2.9**	**5.7**	**8.0**	**10.7**	**12.0**	**12.1**	**12.1**	**12.6**	**12.8**
200 sq miles	**2.5**	**5.5**	**7.7**	**10.4**	**11.6**	**11.6**	**11.7**	**12.2**	**12.4**
500 sq miles	**2.1**	**4.8**	**7.3**	**9.9**	**11.0**	**11.0**	**11.2**	**11.6**	**11.8**
1000 sq miles	**1.7**	**4.2**	**6.9**	**9.3**	**10.3**	**10.5**	**10.7**	**11.0**	**11.3**
2000 sq miles	**1.5**	**3.7**	**6.2**	**8.5**	**9.4**	**9.7**	**9.8**	**10.2**	**10.4**
5000 sq miles	**1.0**	**2.6**	**4.5**	**6.3**	**7.0**	**7.1**	**7.4**	**7.6**	**7.9**
10000 sq miles	**0.5**	**1.6**	**2.7**	**4.4**	**4.7**	**4.8**	**5.4**	**5.5**	**5.8**
20000 sq miles	**0.3**	**1.0**	**1.8**	**2.6**	**3.4**	**3.5**	**3.7**	**3.8**	**4.0**

Adjusted Storm Depth-Area-Duration

	1 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	36 Hours	48 Hours	72 Hours
1 sq miles	**5.7**	**7.7**	**10.9**	**15.6**	**17.6**	**17.8**	**17.8**	**18.0**	**18.1**
10 sq miles	**5.2**	**7.4**	**10.7**	**15.1**	**16.8**	**16.9**	**17.0**	**17.2**	**17.3**
100 sq miles	**3.6**	**7.0**	**9.8**	**13.2**	**14.8**	**14.9**	**15.0**	**15.5**	**15.8**
200 sq miles	**3.1**	**6.7**	**9.5**	**12.8**	**14.2**	**14.3**	**14.4**	**15.0**	**15.3**
500 sq miles	**2.6**	**6.0**	**9.0**	**12.2**	**13.5**	**13.5**	**13.7**	**14.3**	**14.6**
1000 sq miles	**2.1**	**5.1**	**8.5**	**11.4**	**12.7**	**13.0**	**13.1**	**13.6**	**13.9**
2000 sq miles	**1.8**	**4.6**	**7.7**	**10.4**	**11.6**	**11.9**	**12.1**	**12.5**	**12.8**
5000 sq miles	**1.2**	**3.3**	**5.5**	**7.7**	**8.6**	**8.7**	**9.1**	**9.4**	**9.7**
10000 sq miles	**0.7**	**1.9**	**3.3**	**5.4**	**5.8**	**6.0**	**6.7**	**6.8**	**7.2**
20000 sq miles	**0.4**	**1.2**	**2.2**	**3.3**	**4.2**	**4.3**	**4.5**	**4.7**	**4.9**

Storm or Storm Center Name	**Wooster, OH SPAS 1209**	
Storm Date(s)	7/4-7/1969	
Storm Type	Synoptic	
Storm Location	40.91 N	81.97 W
Storm Center Elevation	1,150	
Precipitation Total & Duration	14.73 Inches 72-hours	
Storm Representative Dew Point	76.0 F	24
Storm Representative Dew Point Location	39.43 N	83.80 W
Maximum Dew Point	78.0 F	
Moisture Inflow Vector	SW @ 140	Miles
In-place Maximization Factor	**1.10**	
Temporal Transposition Date	15-Jul	
Transposition Dew Point Location	43.85 N	95.81 W
Transposition Maximum Dew Point	80.0 F	
Transposition Adjustment Factor	**1.12**	
Average Basin Elevation	950	
Highest Elevation in Basin	950	
Inflow Barrier Height	950	
Elevation Adjustment Factor	**1.00**	
Total Adjustment Factor	**1.23**	

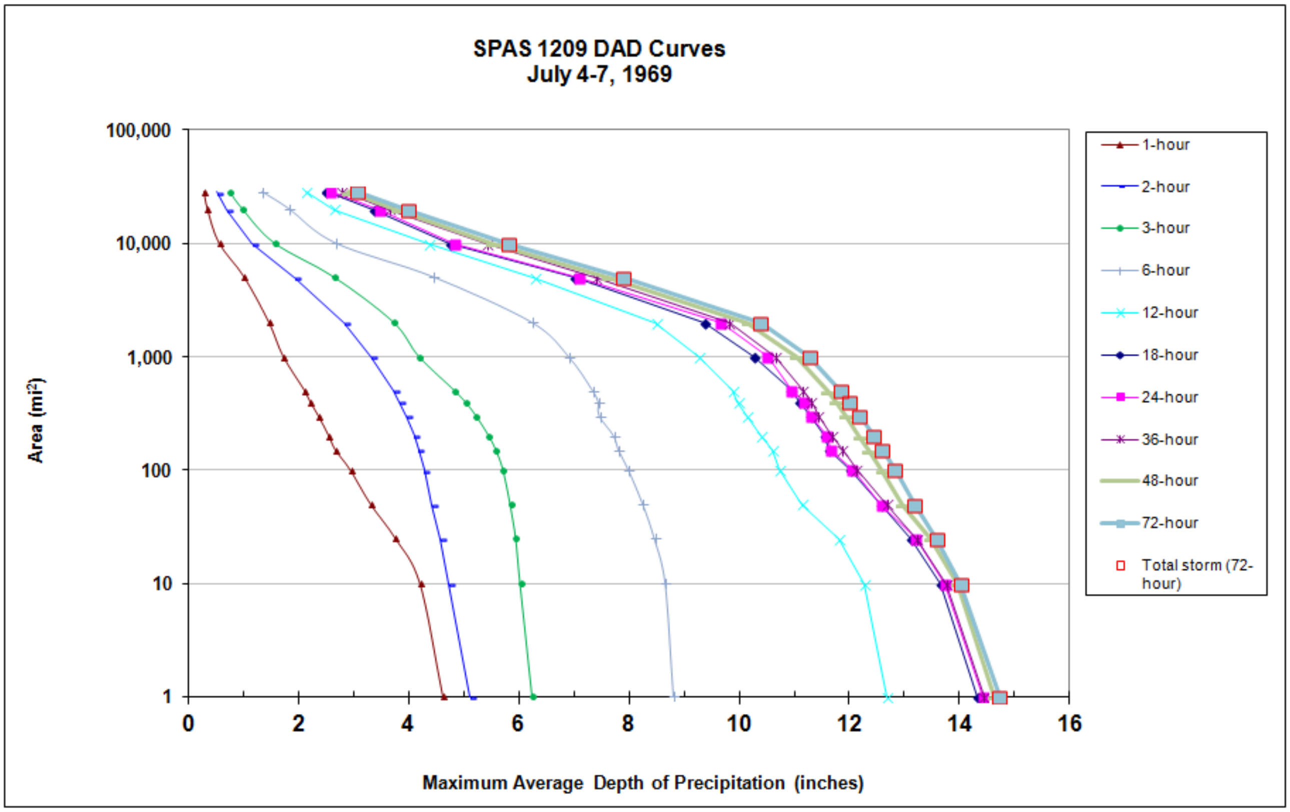
Attachment 3 Table 40: Storm spreadsheet for Wooster, OH July 1969



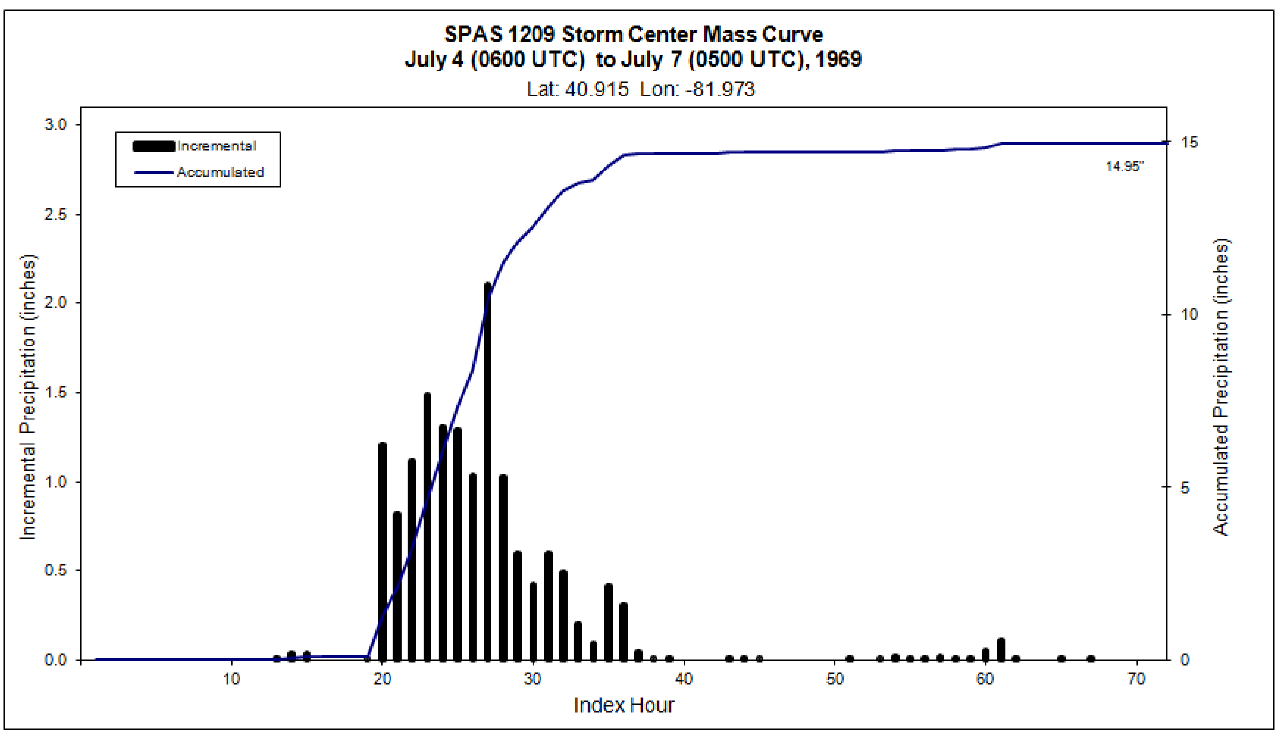
Attachment 3 Figure 65: Moisture inflow map for Wooster, OH July 1969

Storm 1209 - July 4 (0600 UTC) - July 7 (0500 UTC),1969											
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)											
	Duration (hours)										
Area (mi^2)	1	2	3	6	12	18	24	36	48	72	Total
0.3	4.82	5.33	6.41	8.95	13.02	14.58	14.67	14.69	14.94	14.95	14.95
1	4.62	5.11	6.24	8.81	12.67	14.32	14.44	14.45	14.63	14.73	14.73
10	4.2	4.72	6.02	8.66	12.26	13.66	13.74	13.77	13.97	14.02	14.02
25	3.75	4.56	5.94	8.46	11.81	13.13	13.21	13.23	13.47	13.58	13.58
50	3.3	4.42	5.84	8.25	11.14	12.57	12.59	12.69	12.97	13.19	13.19
100	2.93	4.27	5.71	7.99	10.72	12.02	12.06	12.14	12.59	12.83	12.83
150	2.66	4.17	5.58	7.81	10.59	11.63	11.66	11.88	12.35	12.6	12.60
200	2.54	4.09	5.45	7.72	10.4	11.56	11.6	11.69	12.18	12.44	12.44
300	2.35	3.96	5.22	7.46	10.14	11.3	11.3	11.44	11.94	12.19	12.19
400	2.2	3.83	5.02	7.44	9.97	11.1	11.18	11.31	11.75	12	12.00
500	2.1	3.72	4.83	7.34	9.88	10.95	10.96	11.16	11.61	11.84	11.84
1,000	1.71	3.31	4.18	6.9	9.27	10.28	10.52	10.66	11.04	11.27	11.27
2,000	1.45	2.82	3.72	6.23	8.48	9.38	9.67	9.83	10.15	10.39	10.39
5,000	1	1.93	2.64	4.45	6.27	7.02	7.09	7.4	7.62	7.9	7.90
10,000	0.54	1.14	1.55	2.66	4.35	4.74	4.83	5.42	5.52	5.81	5.81
20,000	0.33	0.69	0.97	1.82	2.64	3.37	3.47	3.65	3.78	3.98	3.98
28,279	0.27	0.51	0.74	1.33	2.13	2.5	2.59	2.79	2.89	3.06	3.06

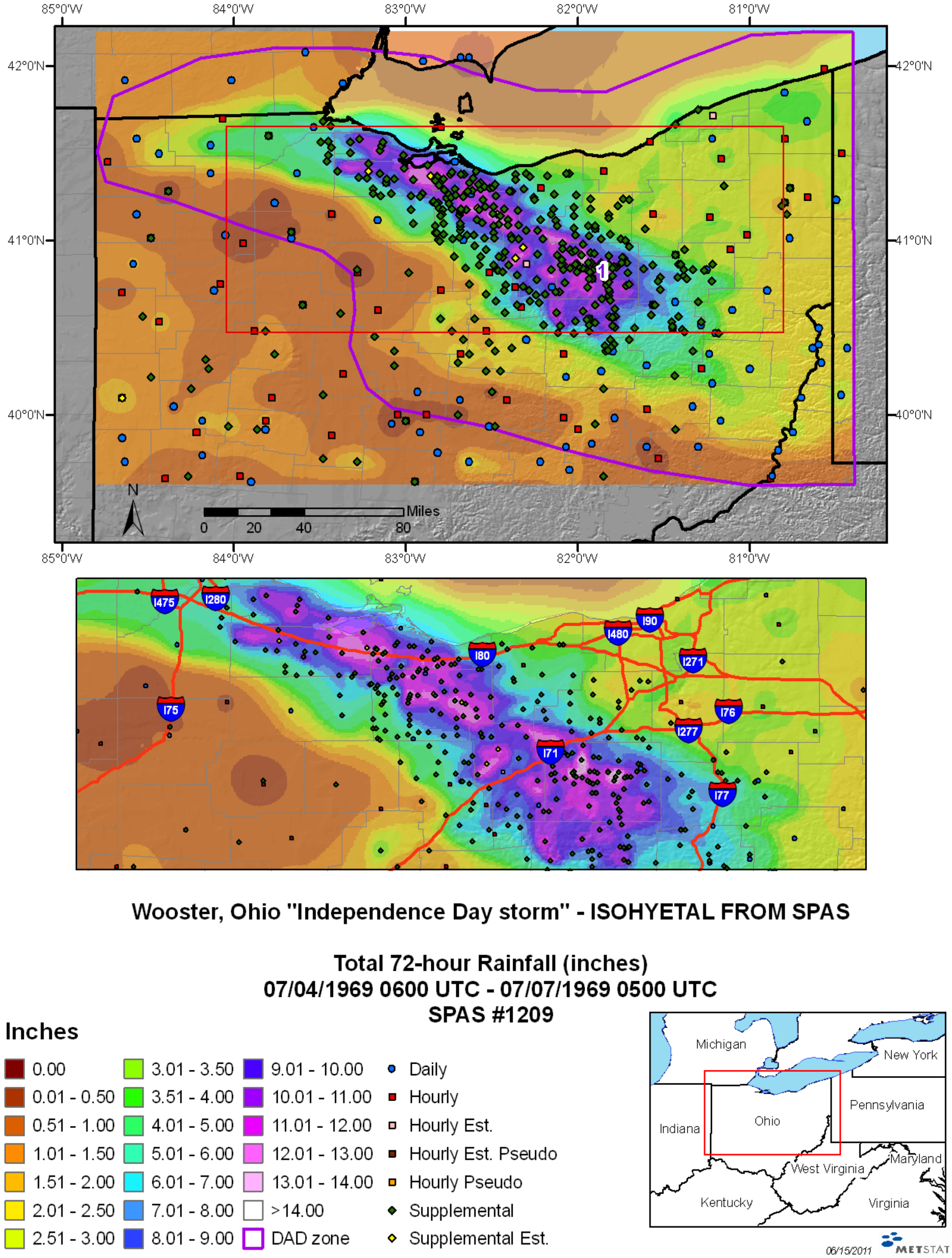
Attachment 3 Table 41: Depth-area-duration values for Wooster, OH July 1969



Attachment 3 Figure 66: Depth-area-duration chart for Wooster, OH July 1969

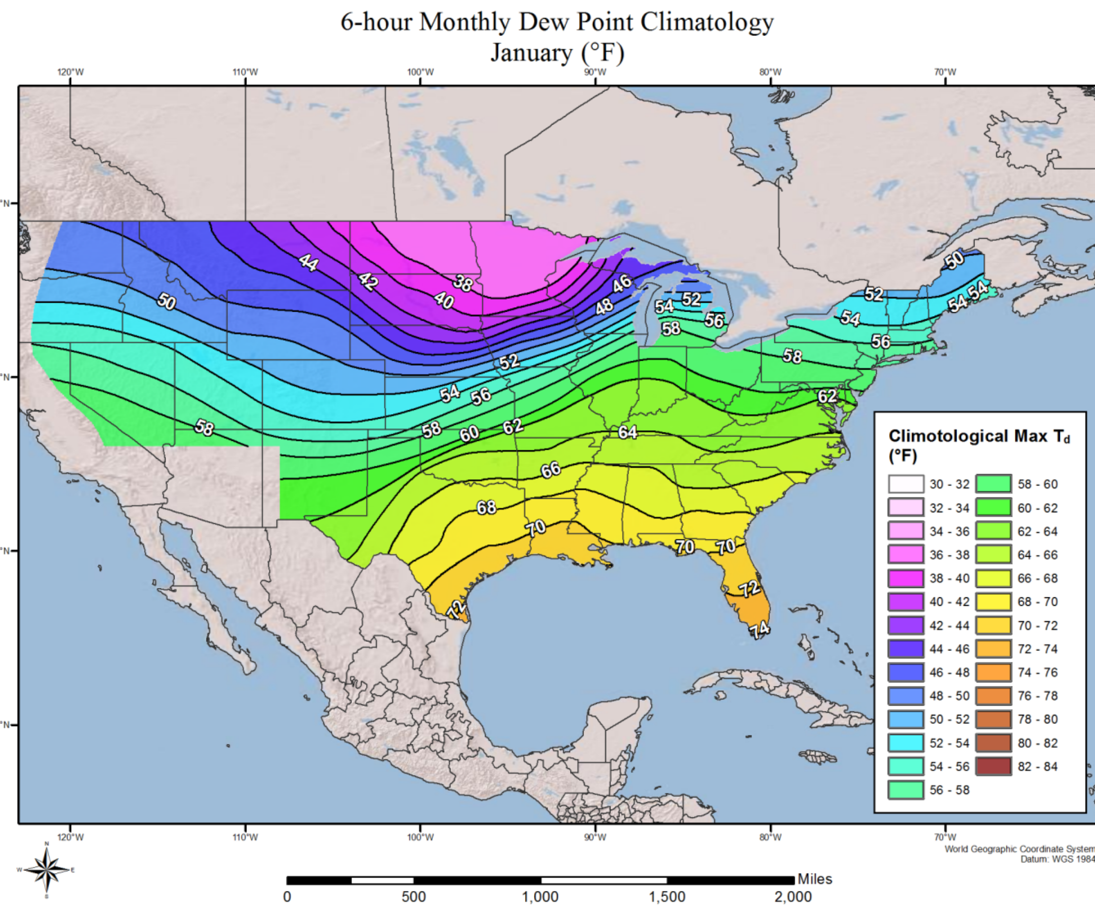


Attachment 3 Figure 67: Mass curve chart for Wooster, OH July 1969

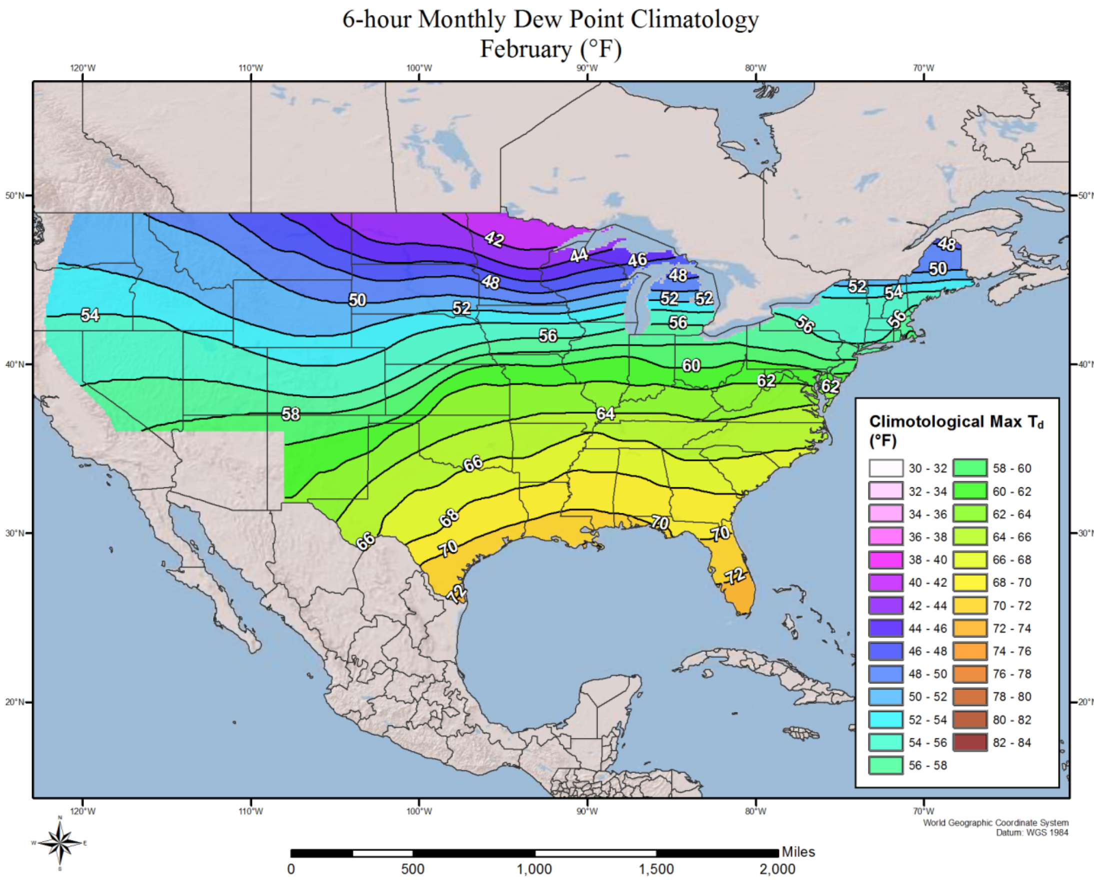


Attachment 3 Figure 68: Total storm isohyetal analysis for Wooster, OH July 1969

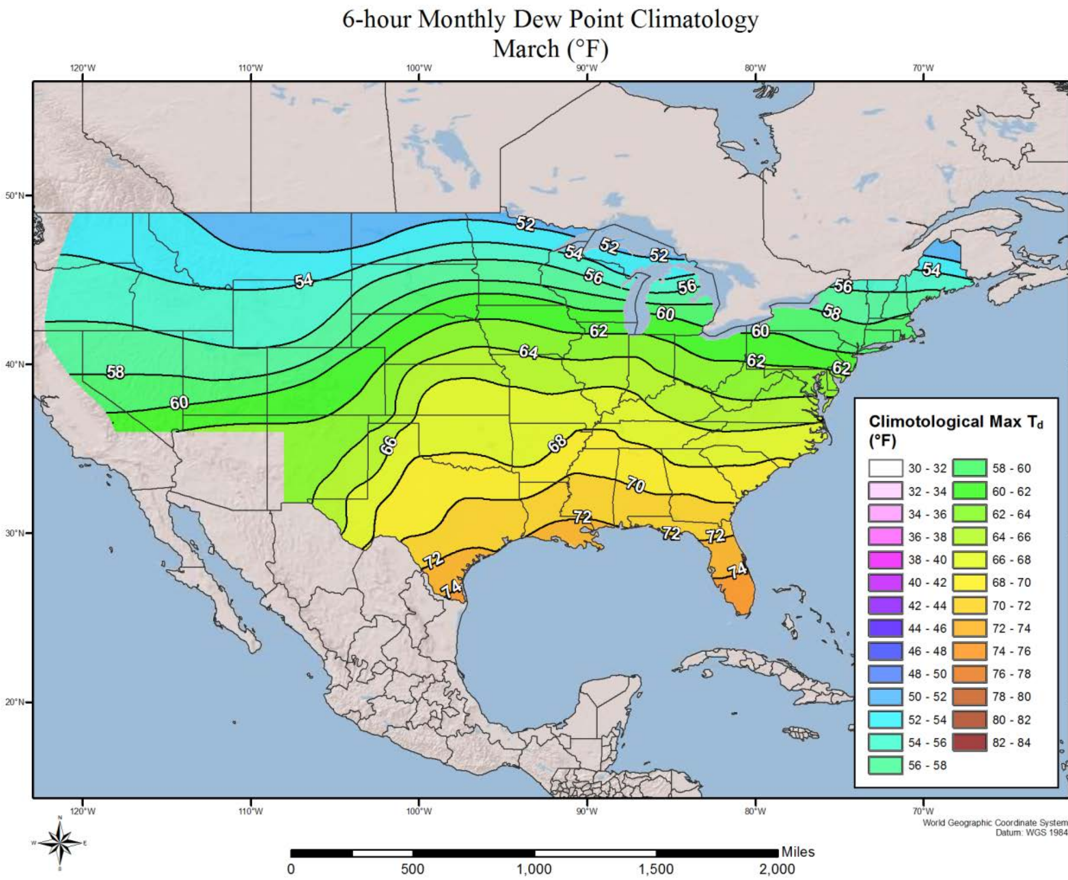
ATTACHMENT 4: 100-year Return Frequency Average Dew Point Climatology Maps Used in the Storm Maximization and Transposition Calculations



Attachment 4 Figure 1: January 6-hour 100-year maximum dew point climatology

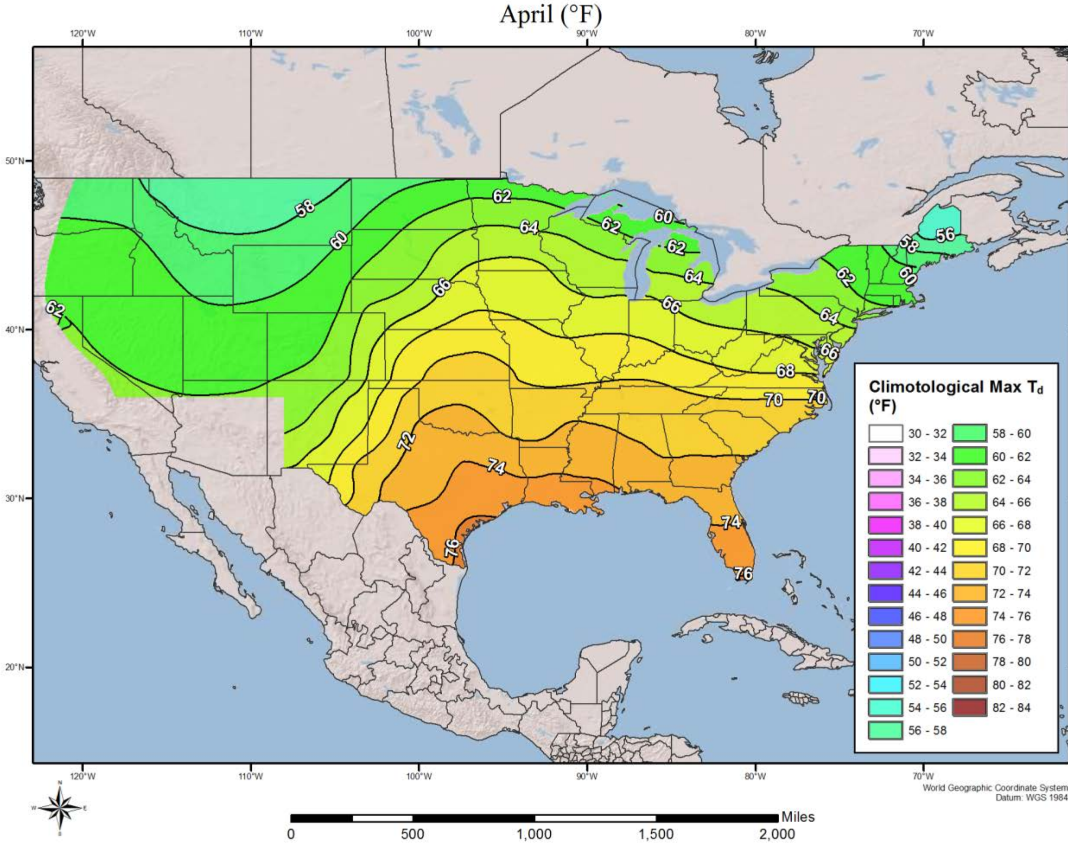


Attachment 4 Figure 2: February 6-hour 100-year maximum dew point climatology

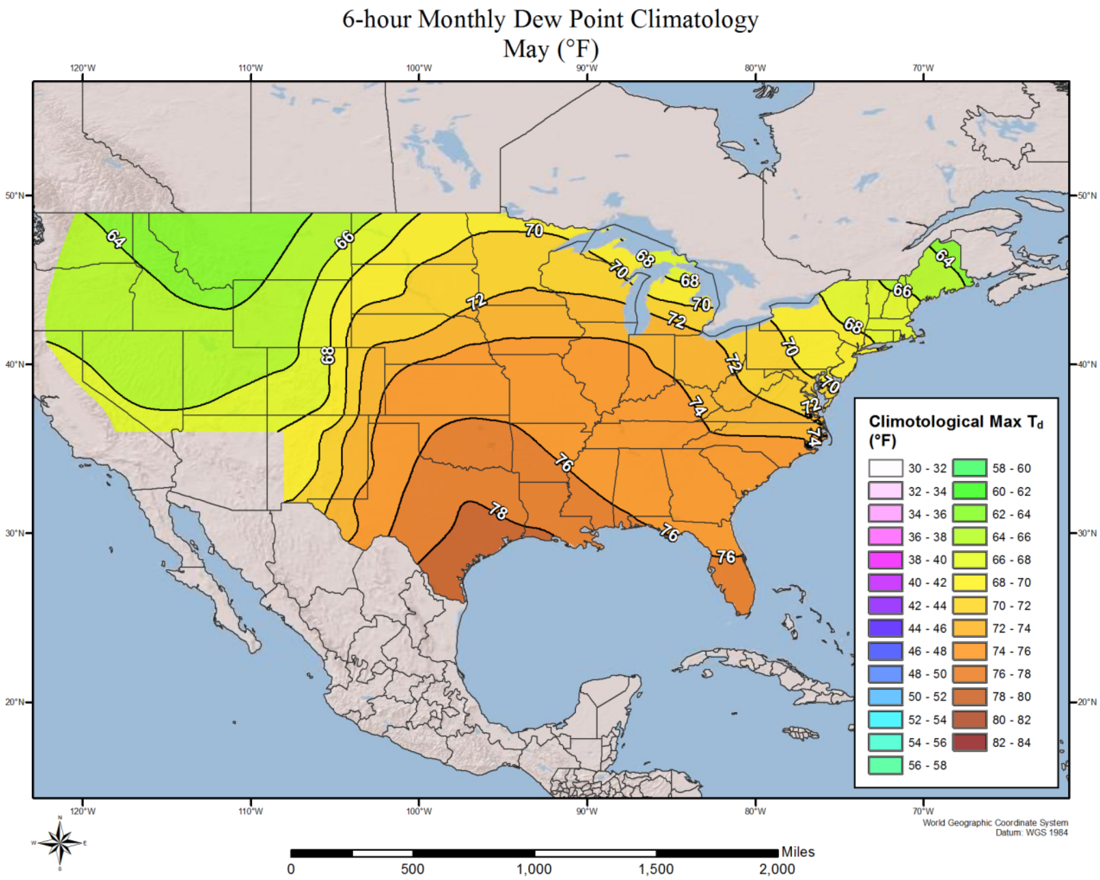


Attachment 4 Figure 3: March 6-hour 100-year maximum dew point climatology

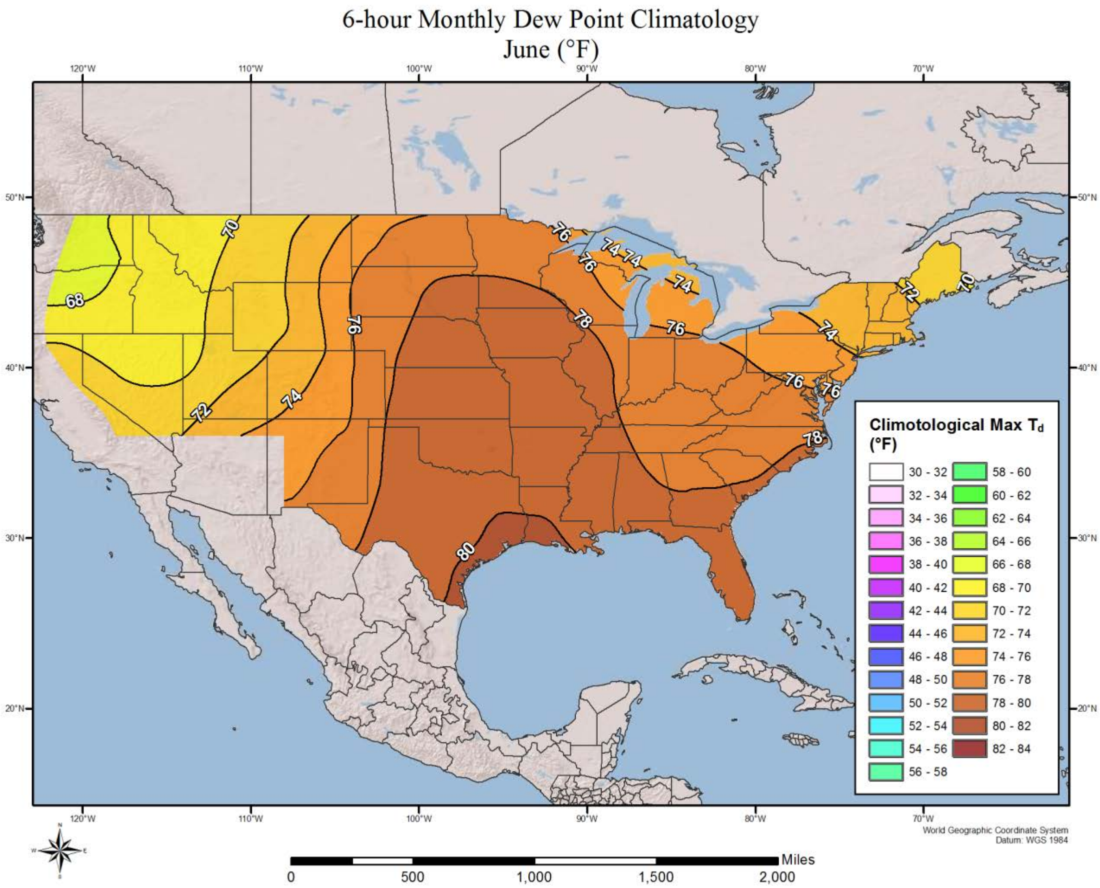
6-hour Monthly Dew Point Climatology
April (°F)



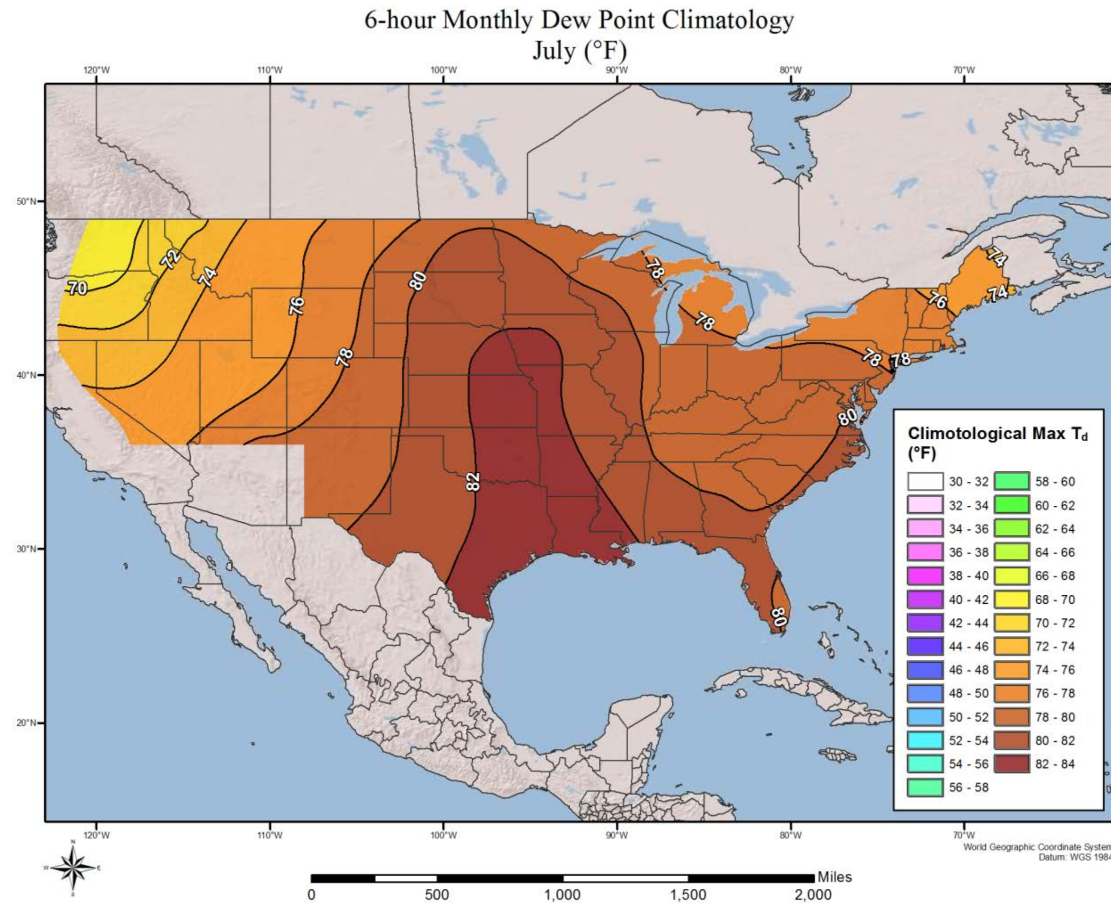
Attachment 4 Figure 4: April 6-hour 100-year maximum dew point climatology



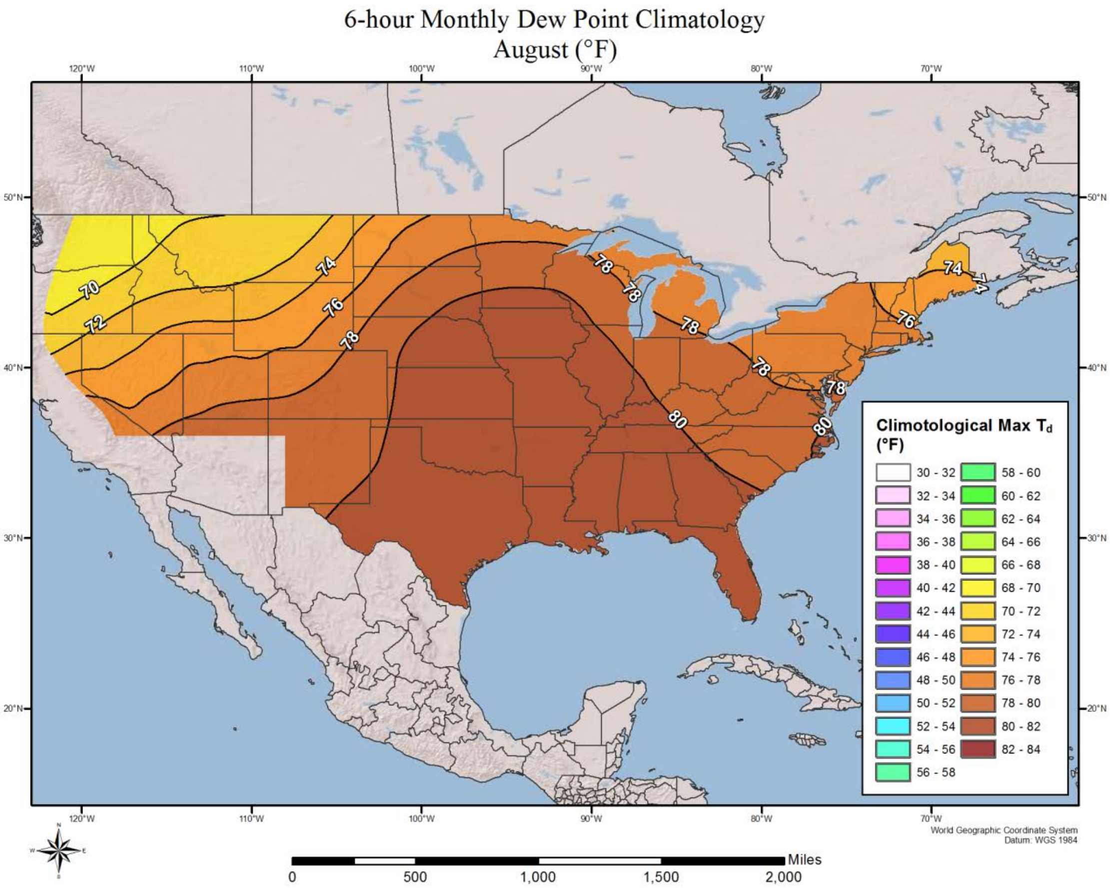
Attachment 4 Figure 5: May 6-hour 100-year maximum dew point climatology



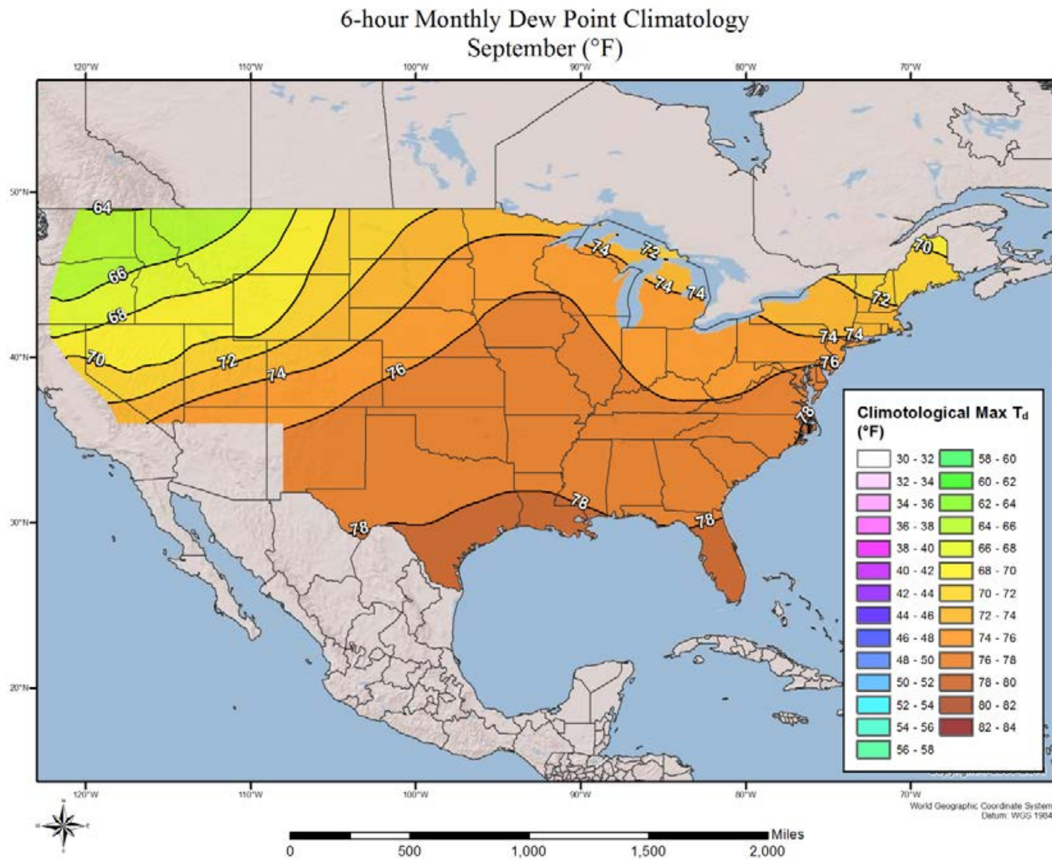
Attachment 4 Figure 6: June 6-hour 100-year maximum dew point climatology



Attachment 4 Figure 7: July 6-hour 100-year maximum dew point climatology

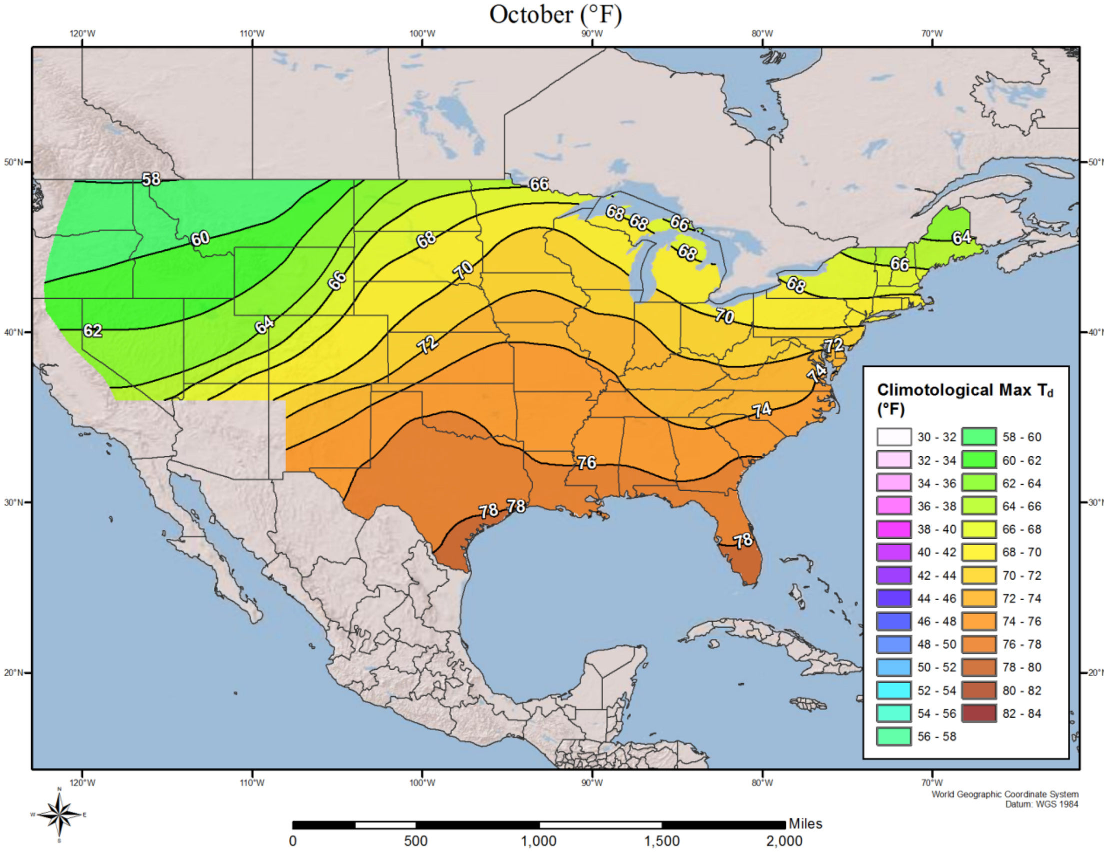


Attachment 4 Figure 8: August 6-hour 100-year maximum dew point climatology

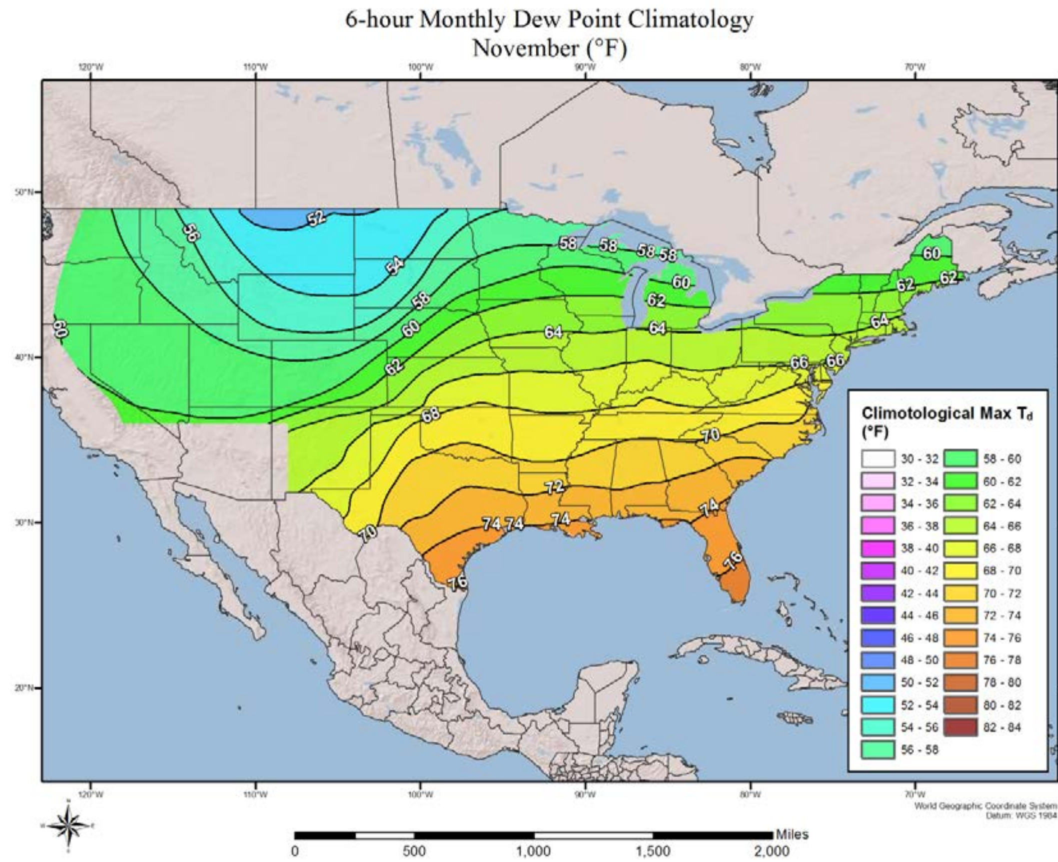


Attachment 4 Figure 9: September 6-hour 100-year maximum dew point climatology

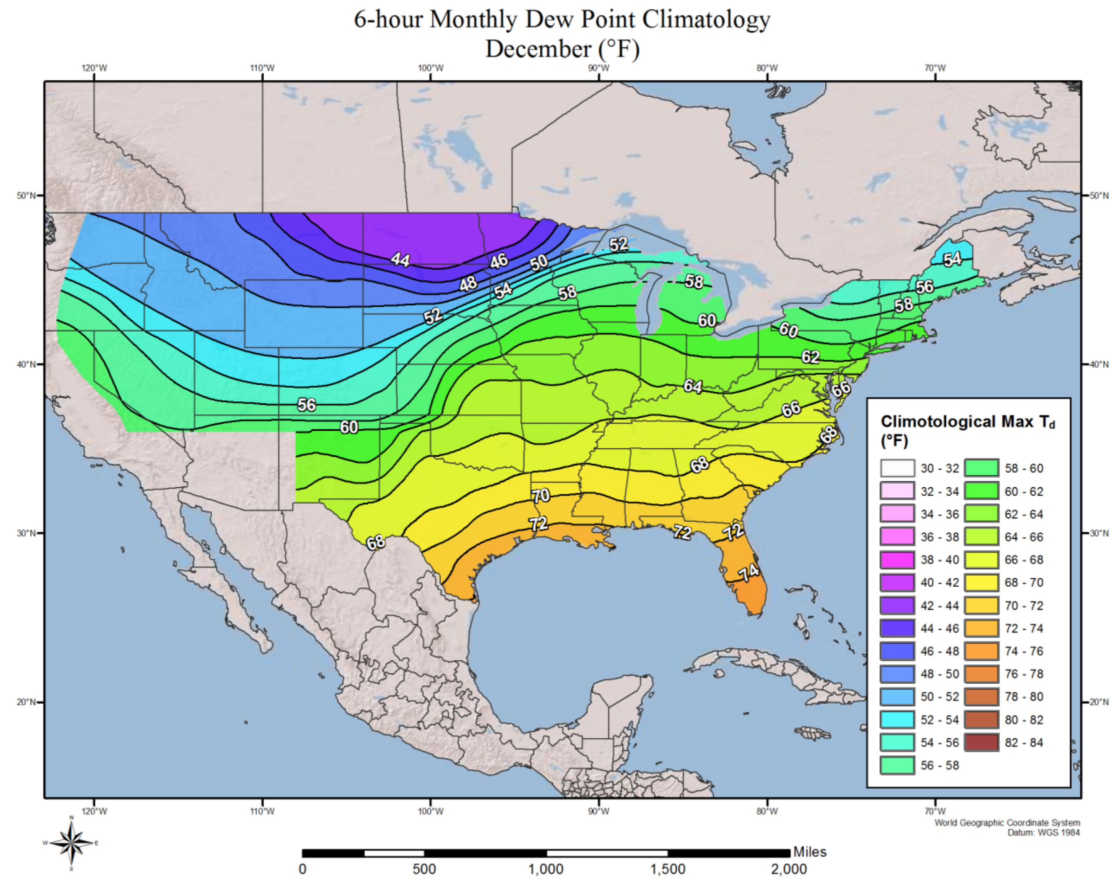
6-hour Monthly Dew Point Climatology
October (°F)



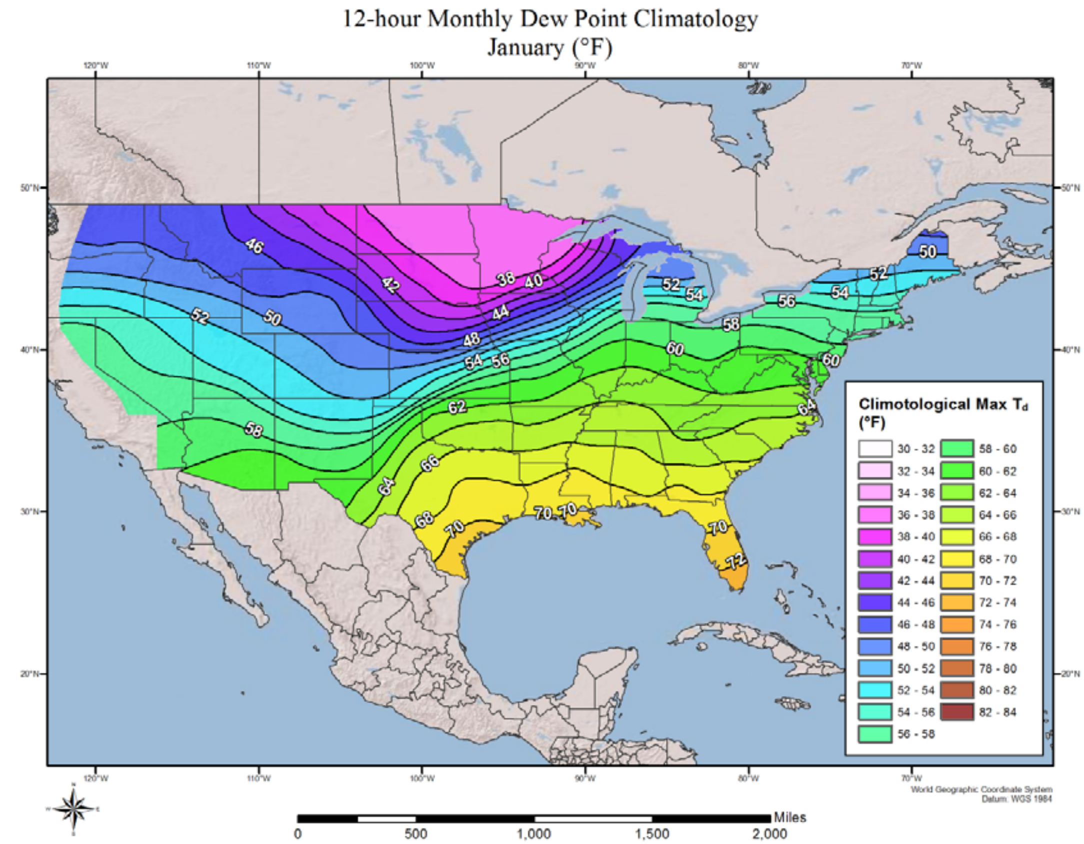
Attachment 4 Figure 10: October 6-hour 100-year maximum dew point climatology



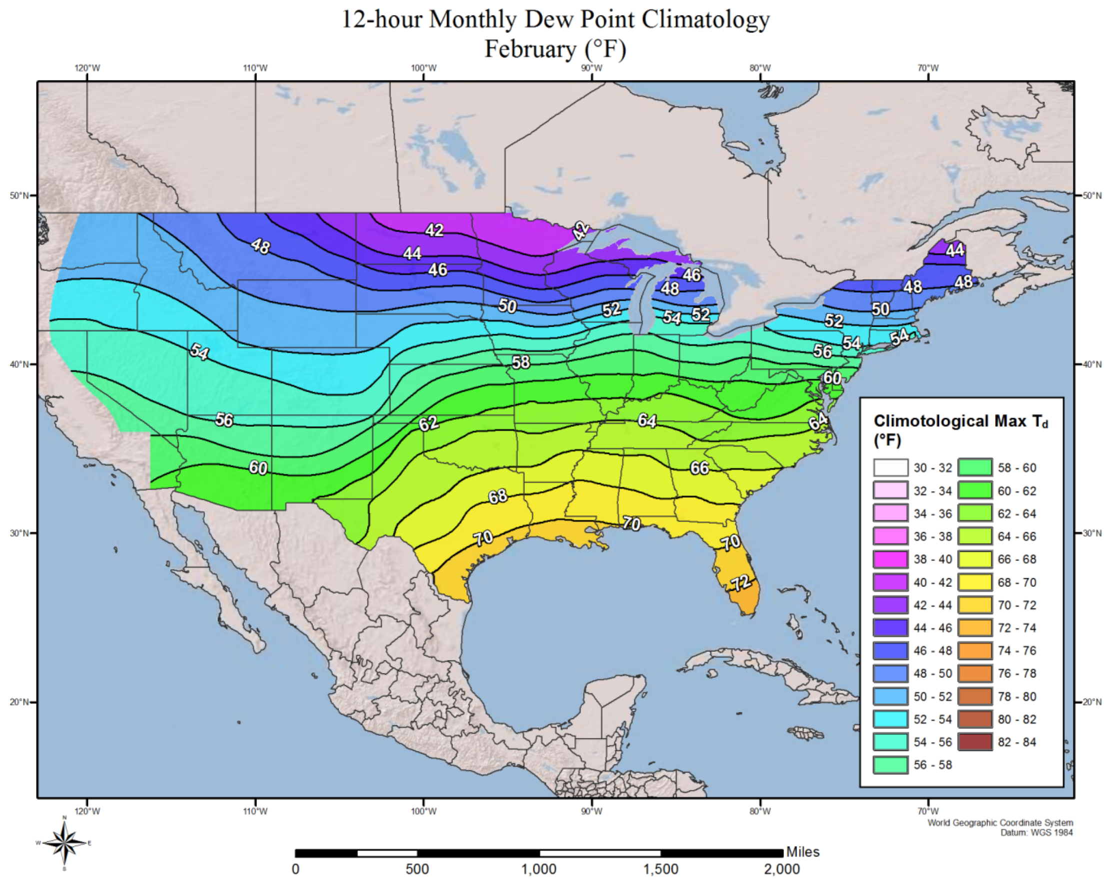
Attachment 4 Figure 11: November 6-hour 100-year maximum dew point climatology



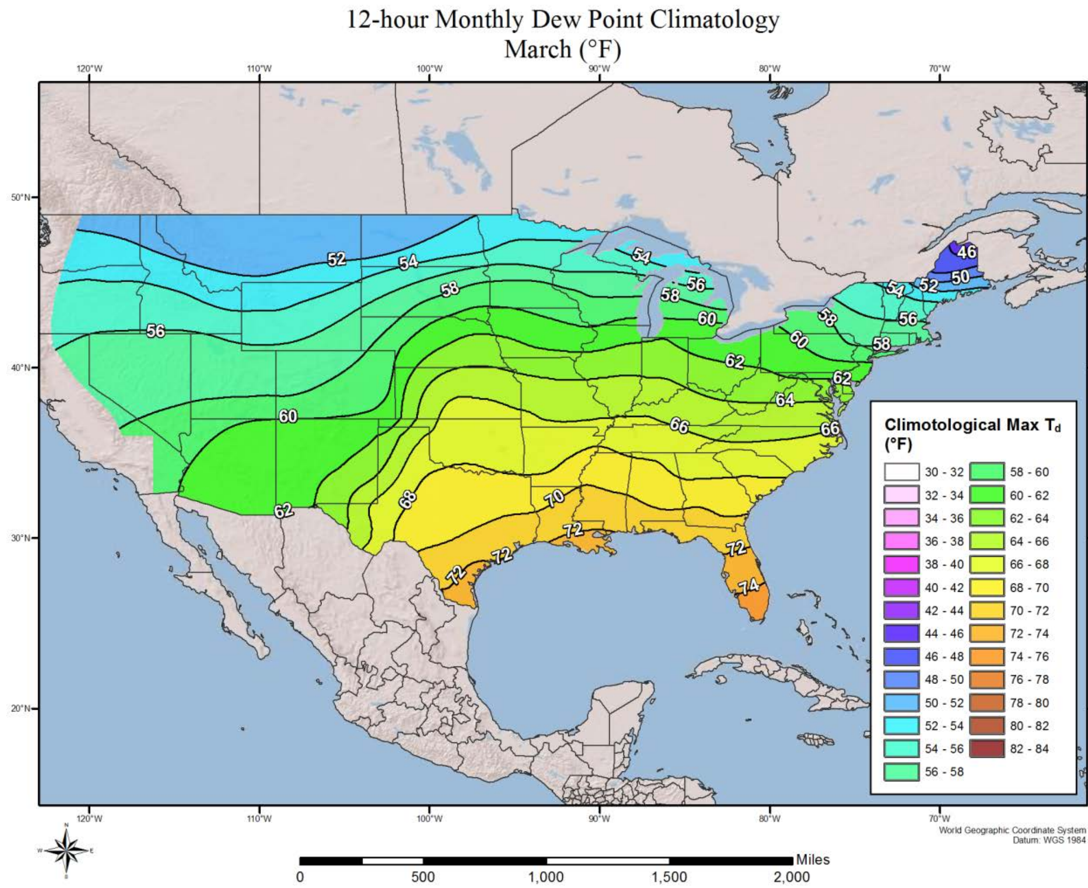
Attachment 4 Figure 12: December 6-hour 100-year maximum dew point climatology



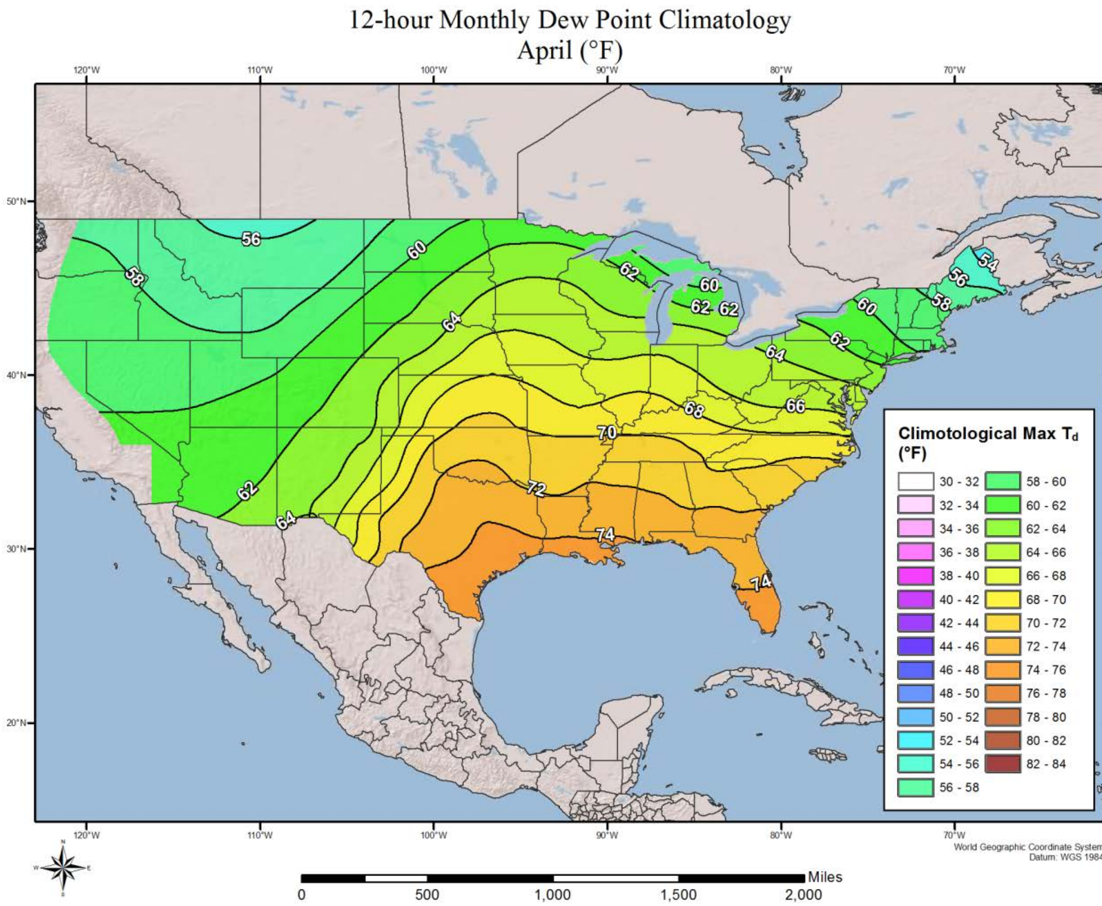
Attachment 4 Figure 13: January 12-hour 100-year maximum dew point climatology



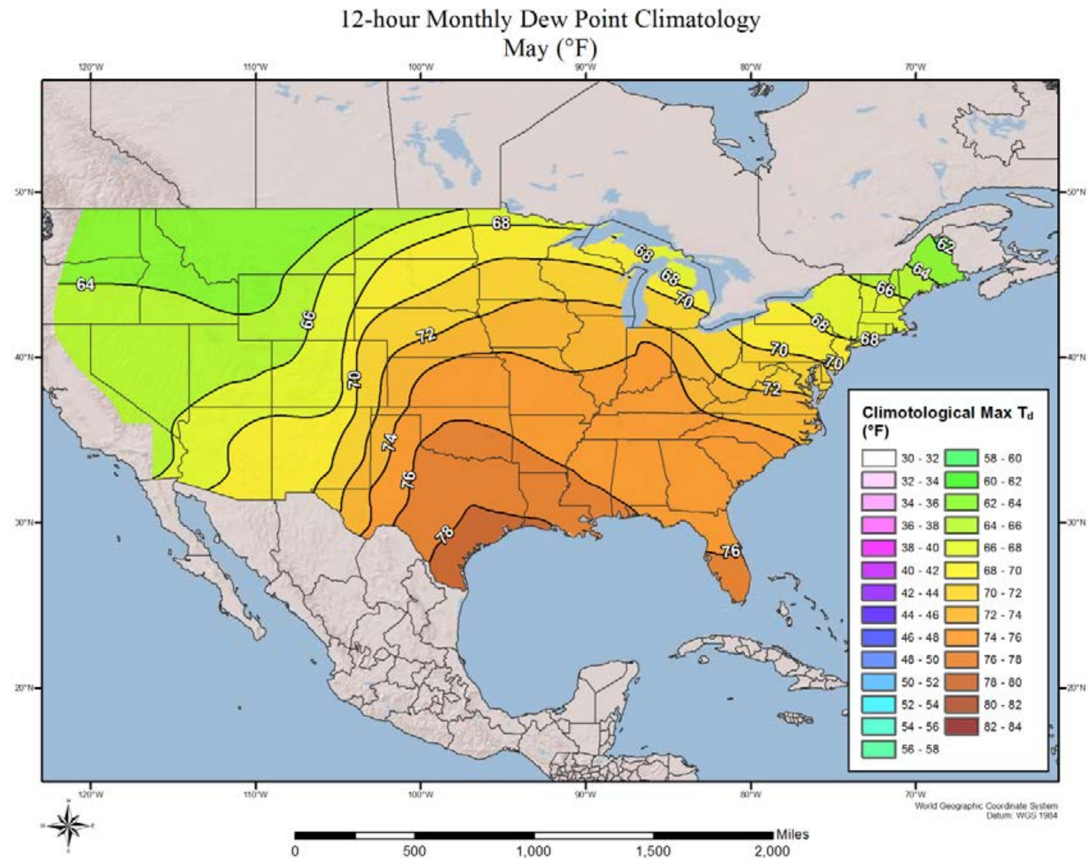
Attachment 4 Figure 14: February 12-hour 100-year maximum dew point climatology



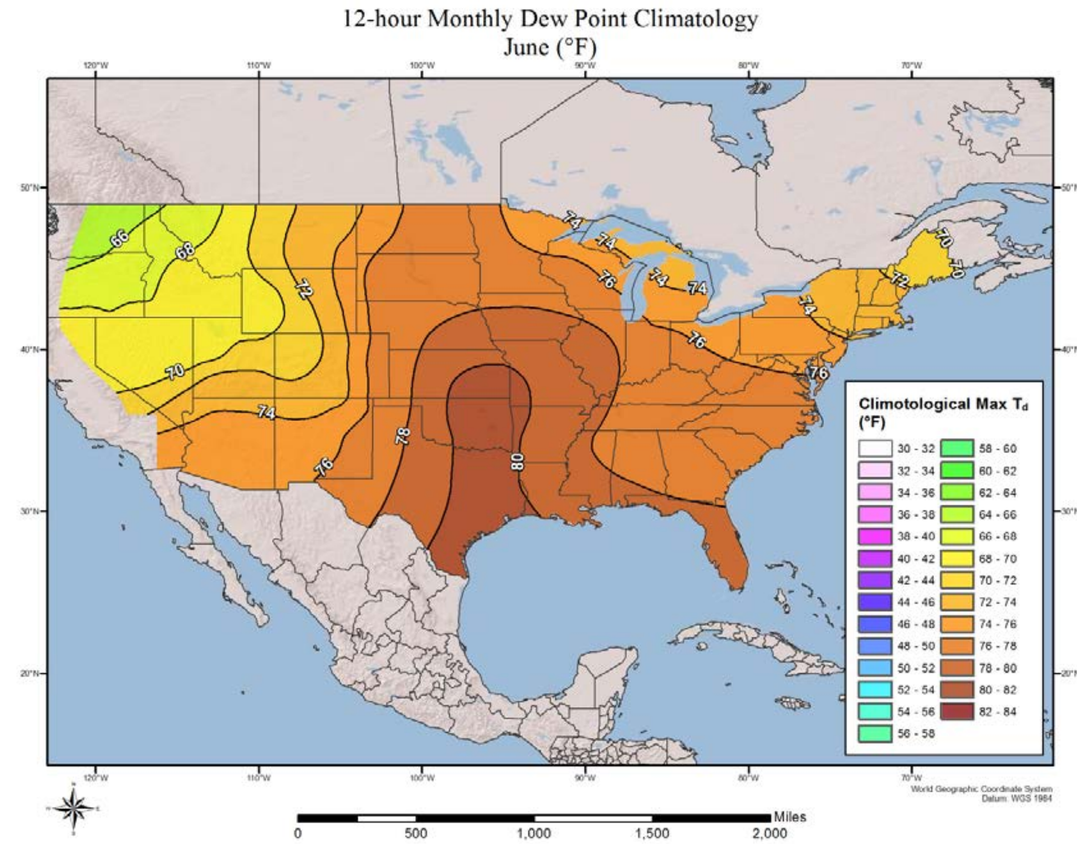
Attachment 4 Figure 15: March 12-hour 100-year maximum dew point climatology



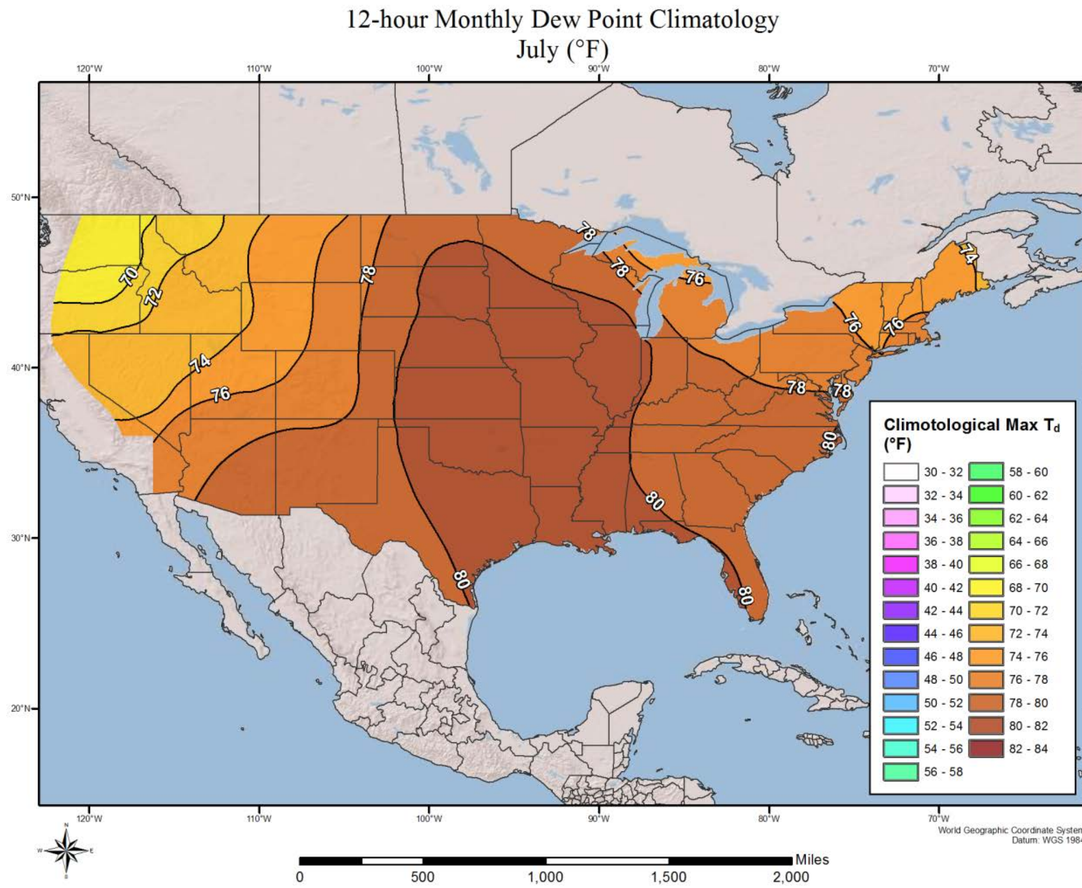
Attachment 4 Figure 16: April 12-hour 100-year maximum dew point climatology



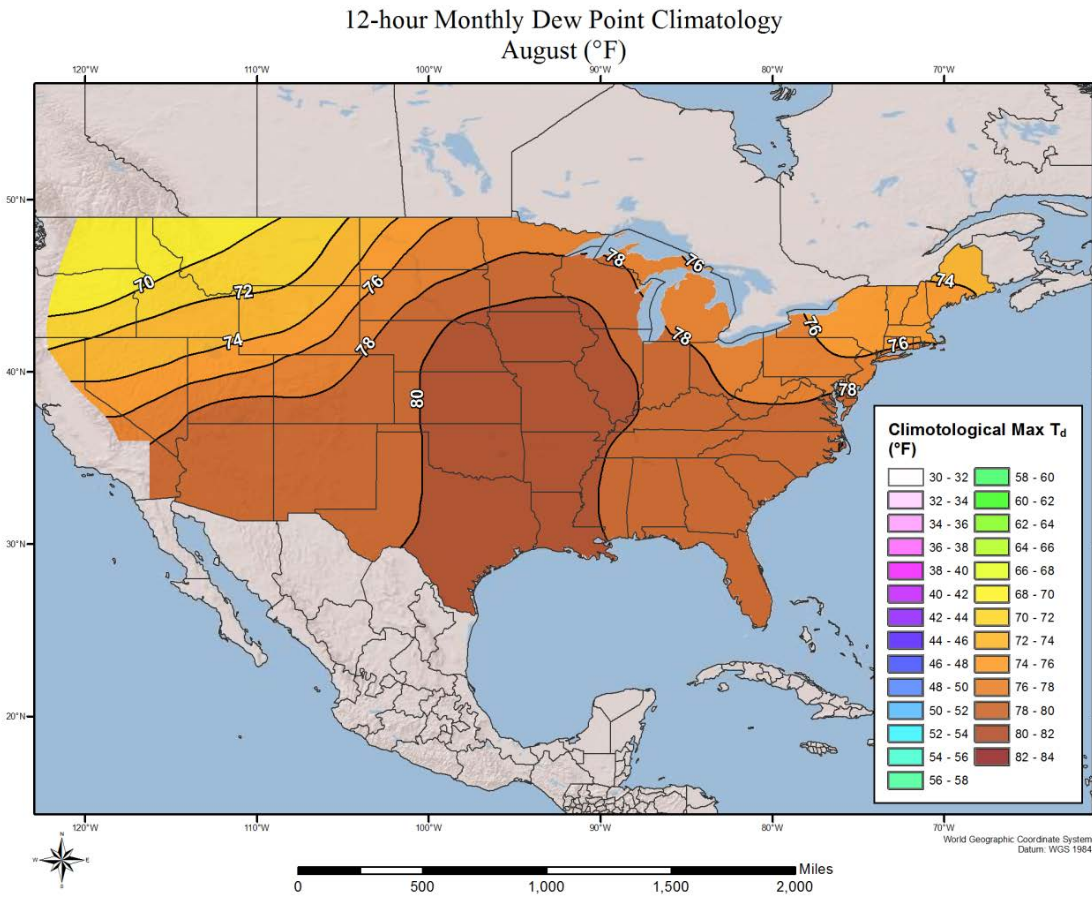
Attachment 4 Figure 17: May 12-hour 100-year maximum dew point climatology



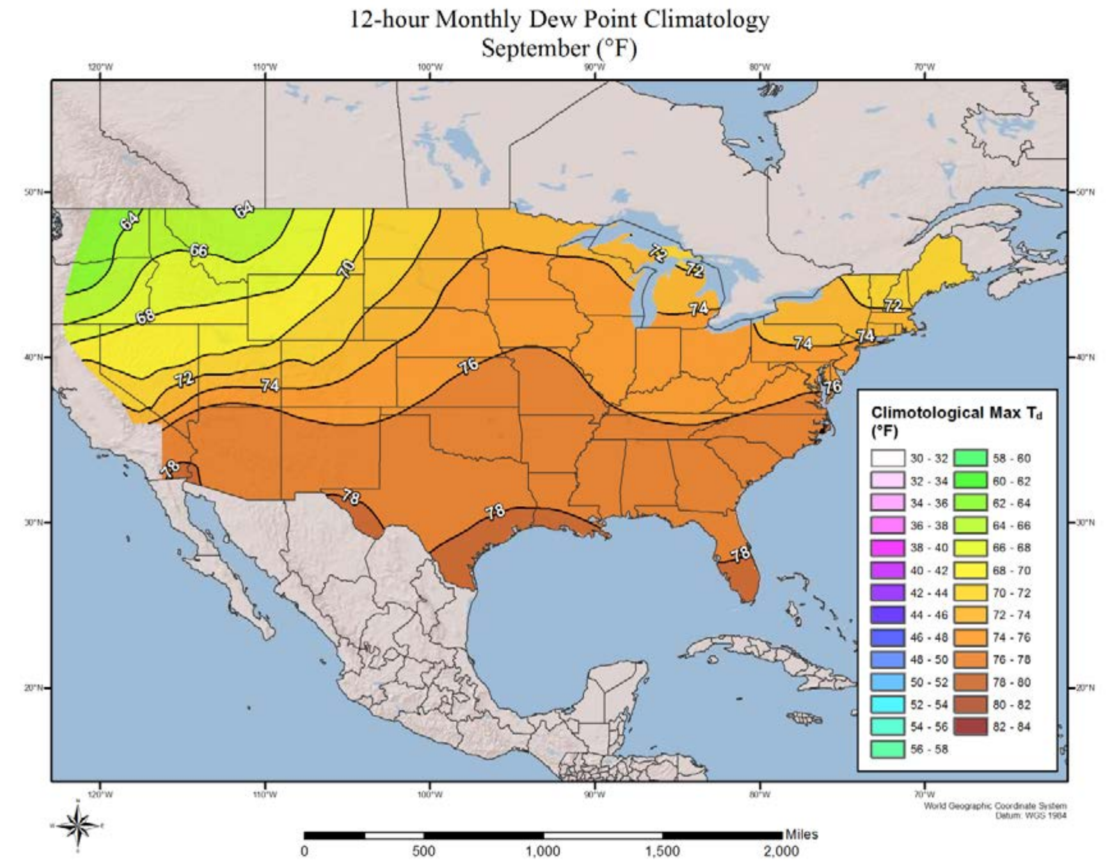
Attachment 4 Figure 18: June 12-hour 100-year maximum dew point climatology



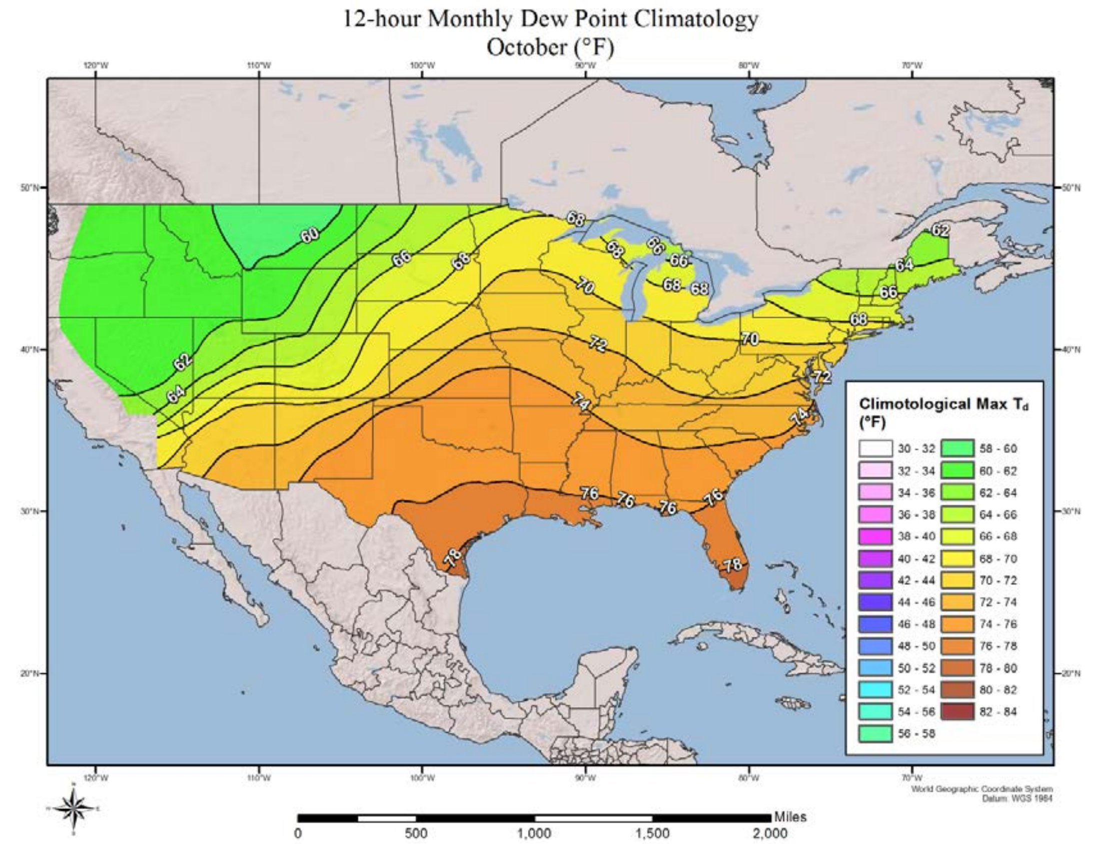
Attachment 4 Figure 19: July 12-hour 100-year maximum dew point climatology



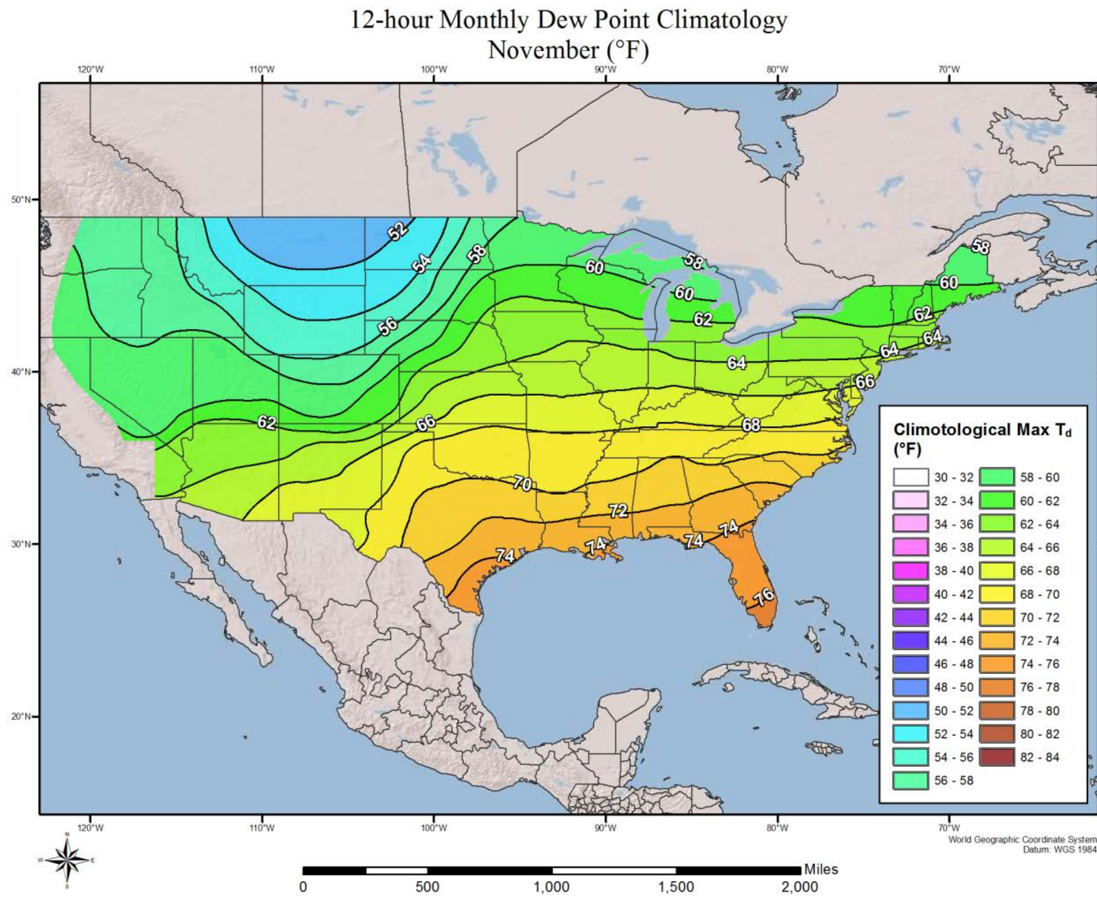
Attachment 4 Figure 20: August 12-hour 100-year maximum dew point climatology



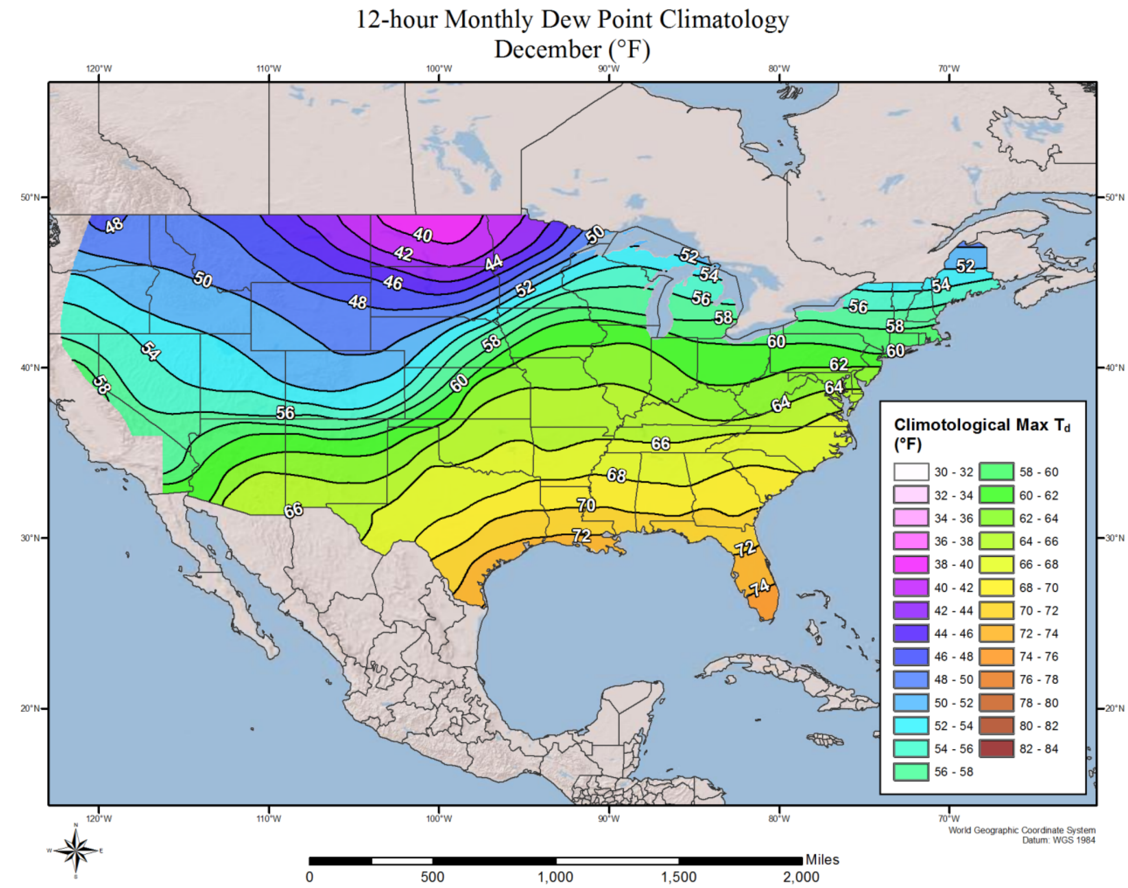
Attachment 4 Figure 21: September 12-hour 100-year maximum dew point climatology



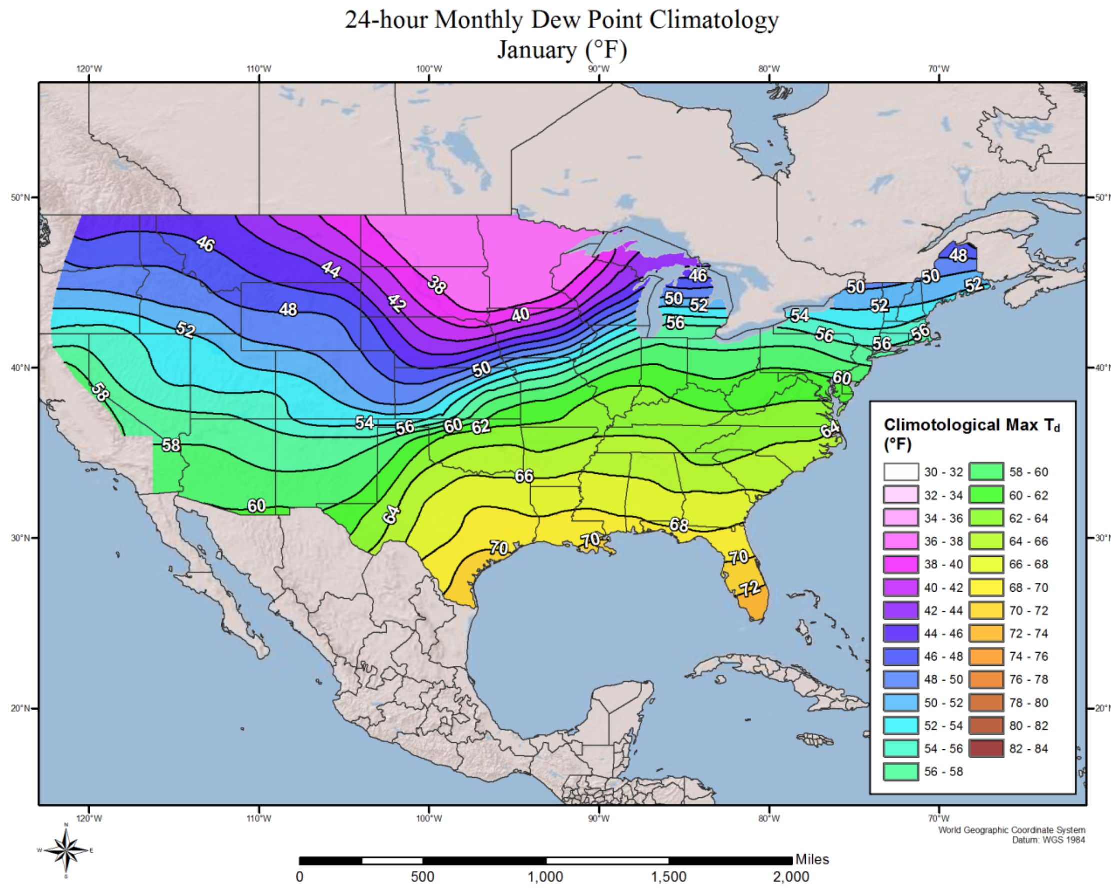
Attachment 4 Figure 22: October 12-hour 100-year maximum dew point climatology



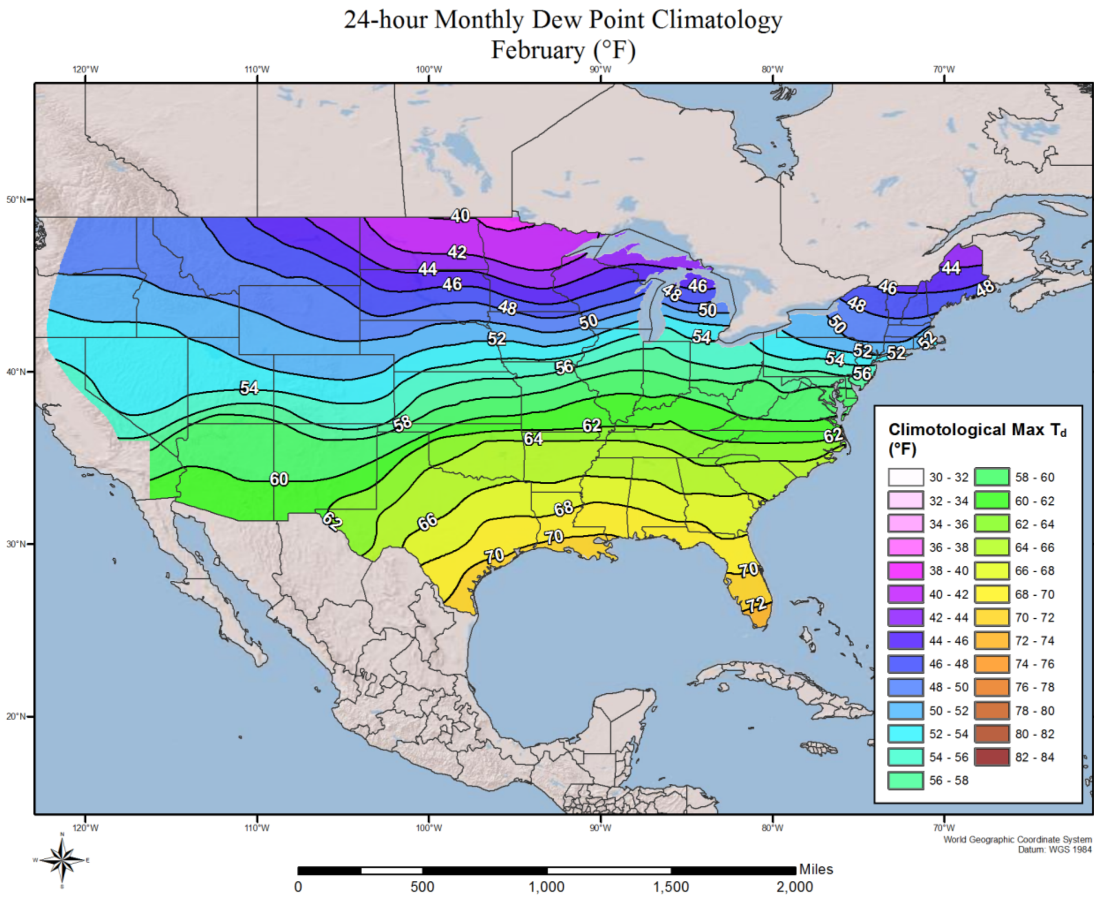
Attachment 4 Figure 23: November 12-hour 100-year maximum dew point climatology



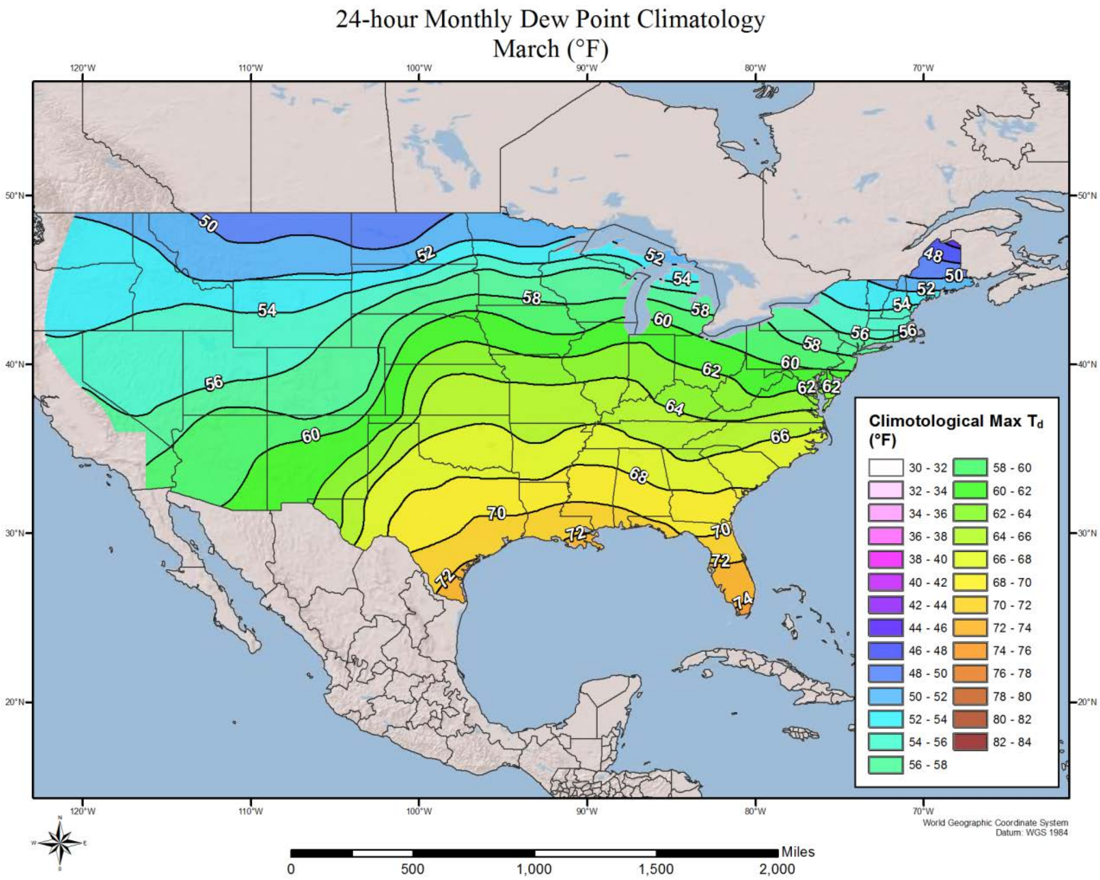
Attachment 4 Figure 24: December 12-hour 100-year maximum dew point climatology



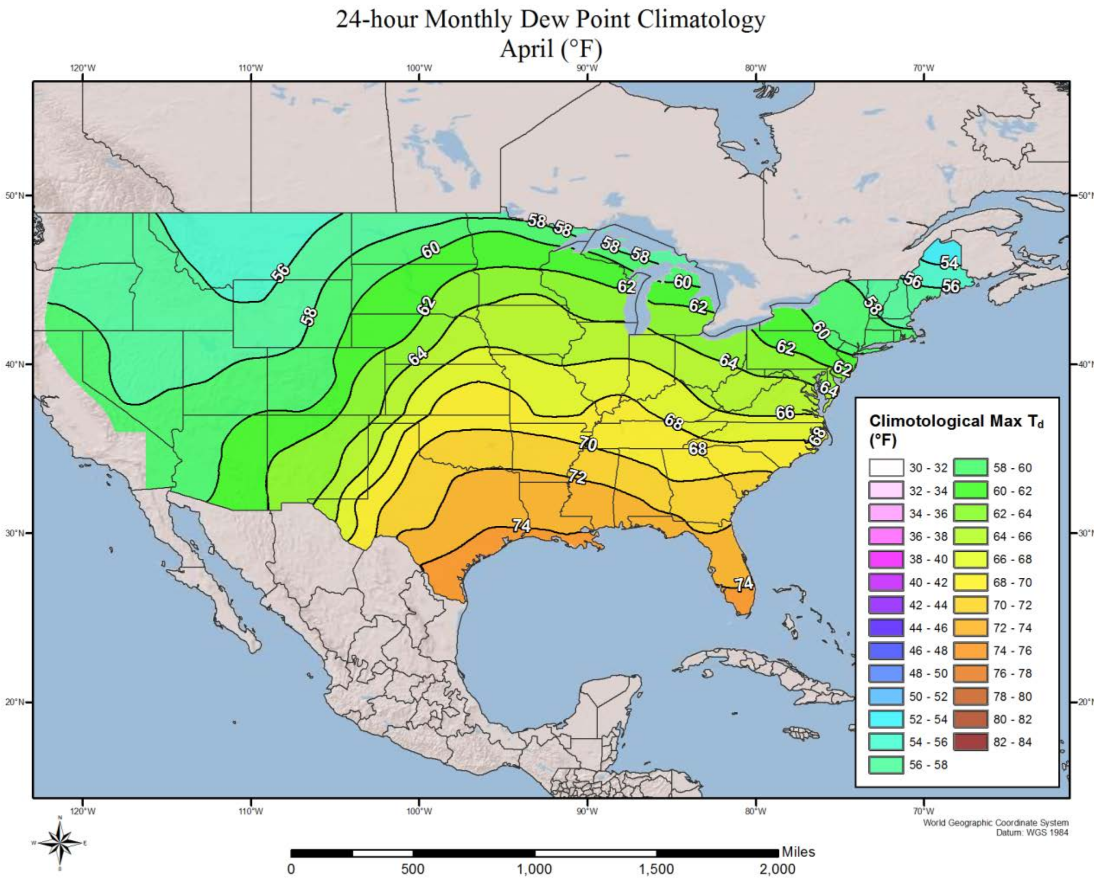
Attachment 4 Figure 25: January 24-hour 100-year maximum dew point climatology



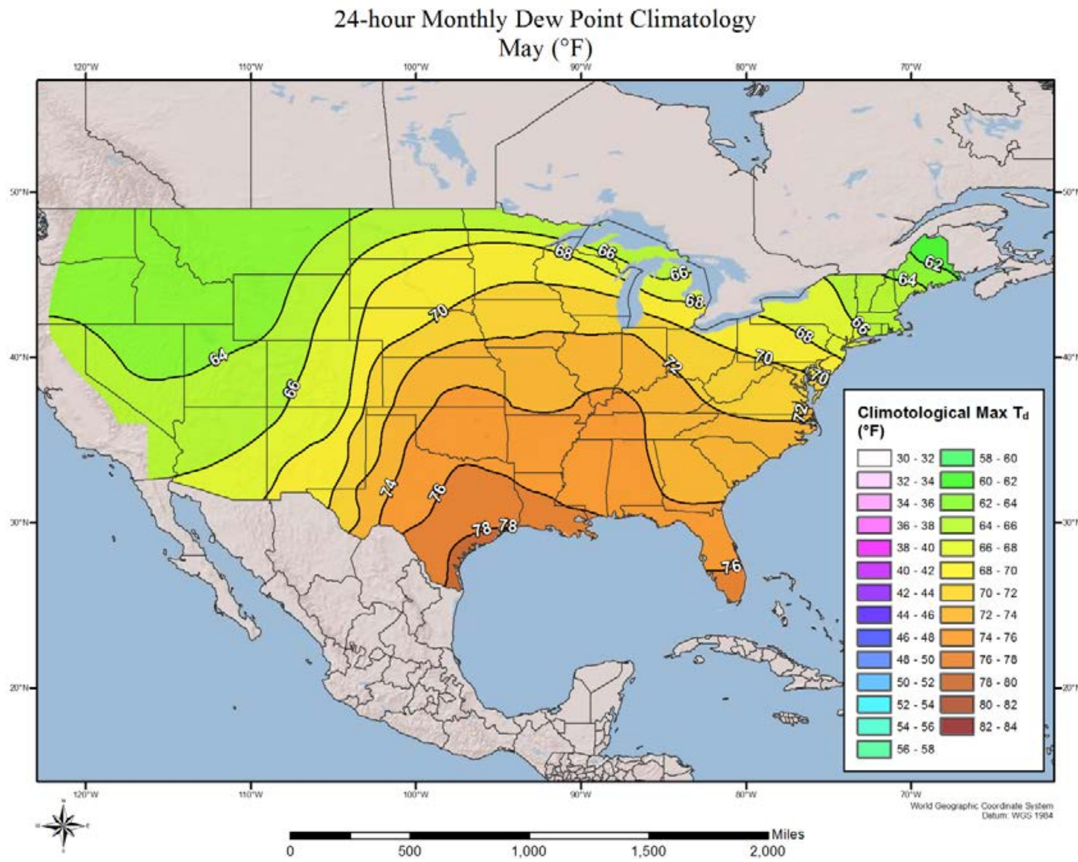
Attachment 4 Figure 26: February 24-hour 100-year maximum dew point climatology



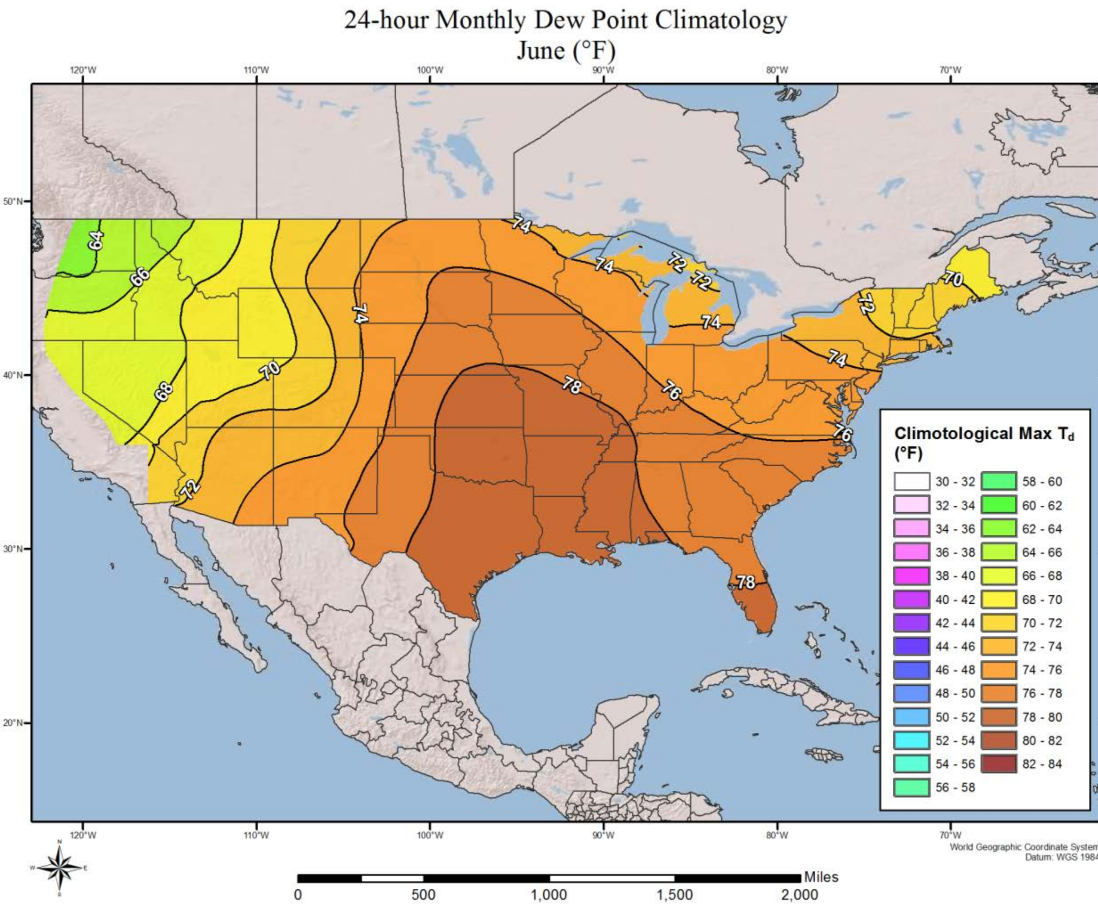
Attachment 4 Figure 27: March 24-hour 100-year maximum dew point climatology



Attachment 4 Figure 28: April 24-hour 100-year maximum dew point climatology

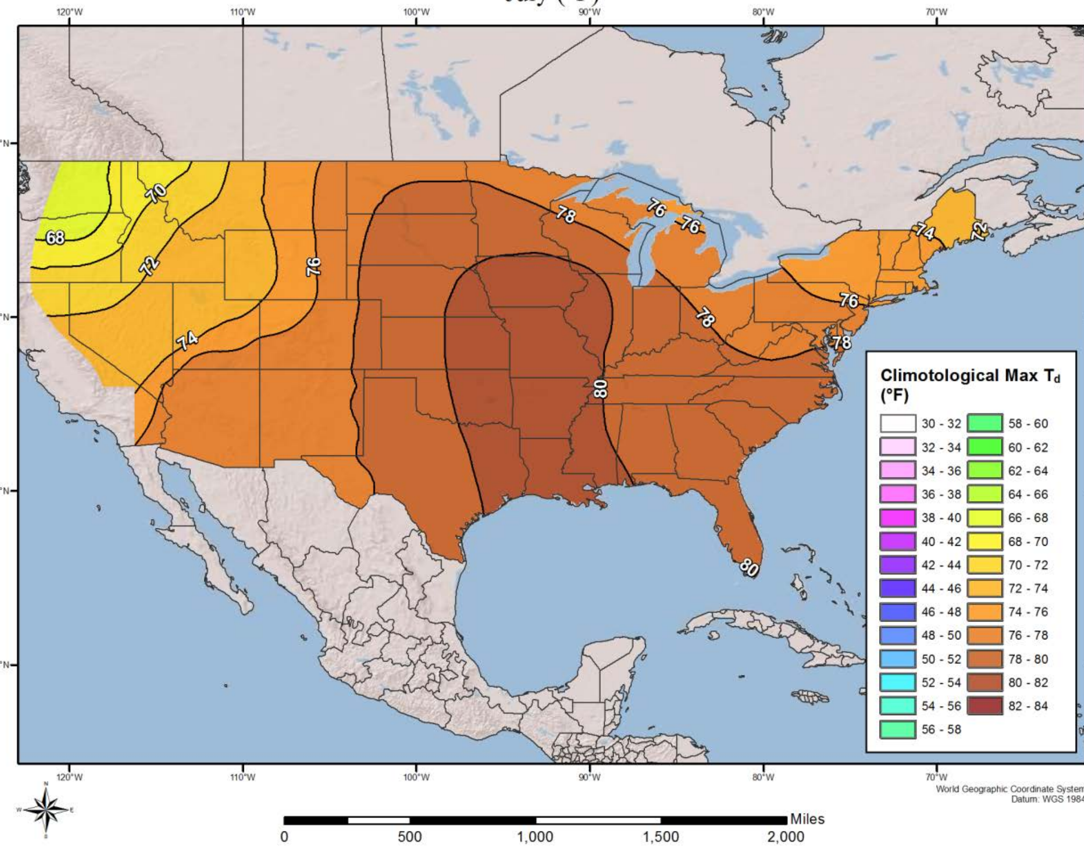


Attachment 4 Figure 29: May 24-hour 100-year maximum dew point climatology



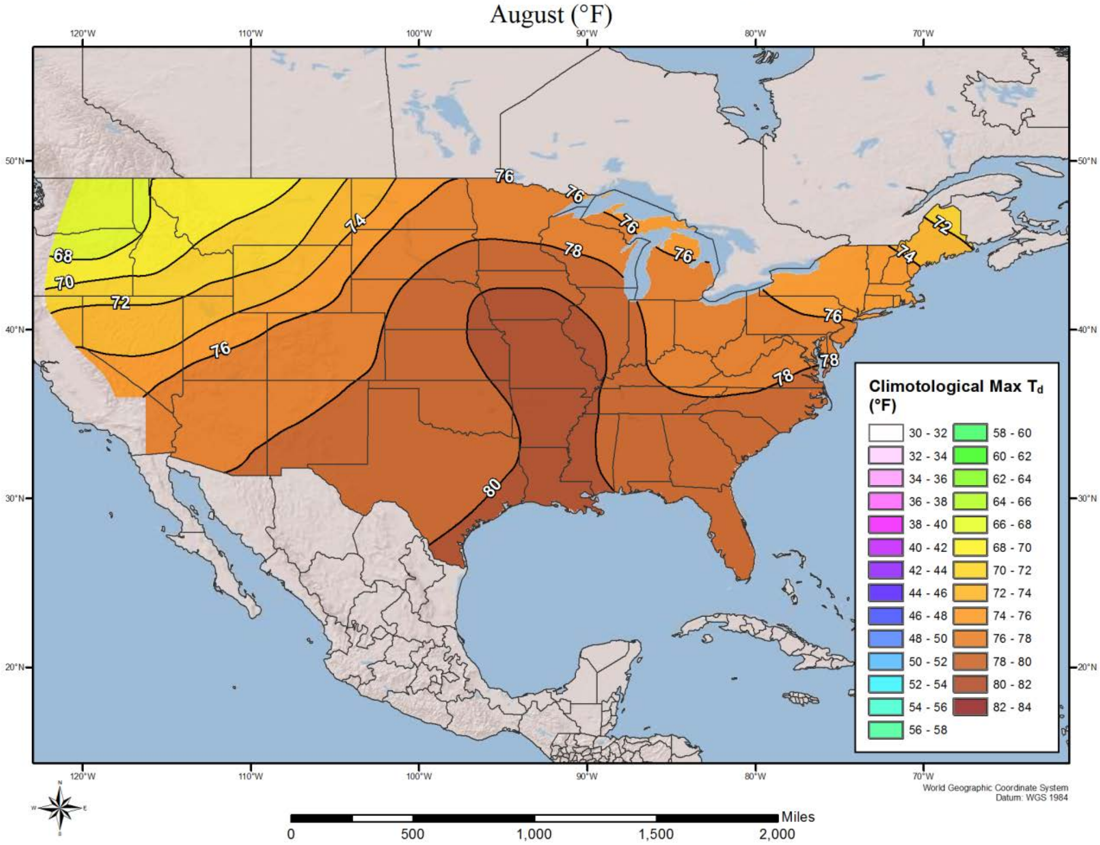
Attachment 4 Figure 30: June 24-hour 100-year maximum dew point climatology

24-hour Monthly Dew Point Climatology
July (°F)

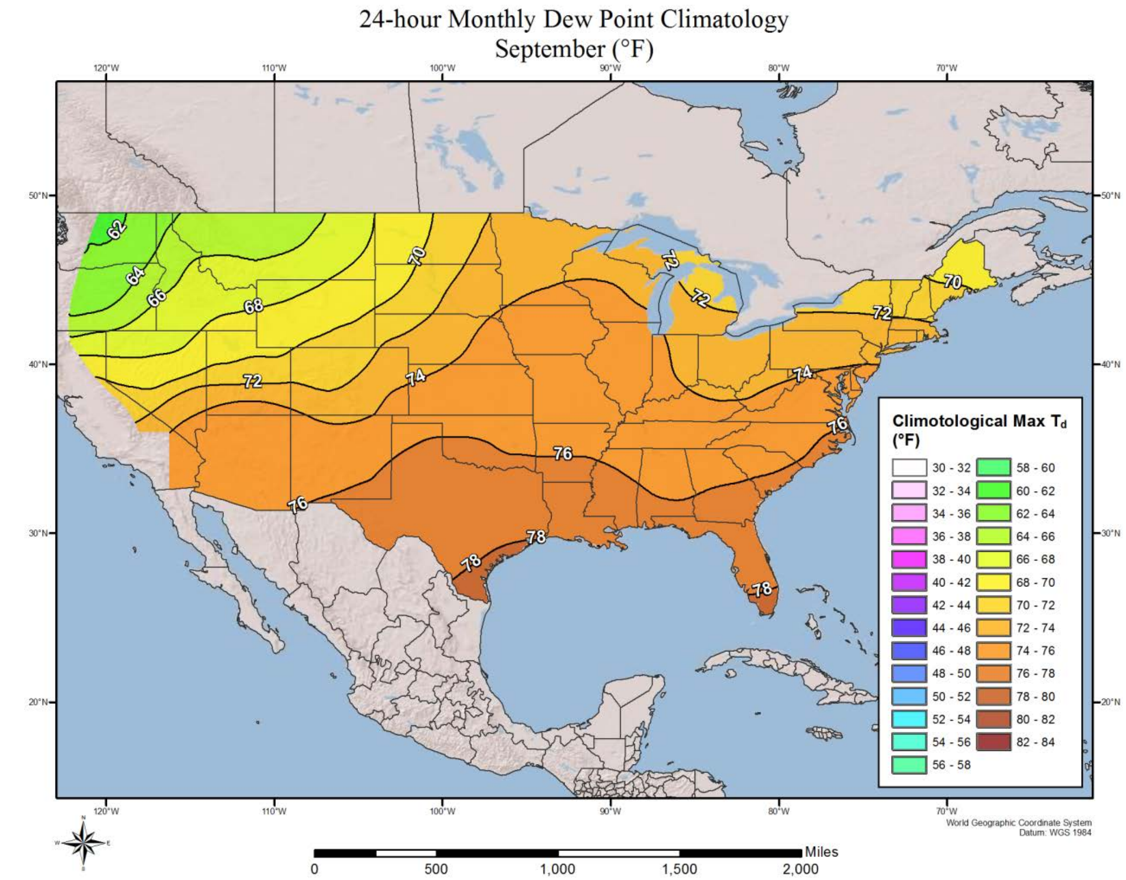


Attachment 4 Figure 31: July 24-hour 100-year maximum dew point climatology

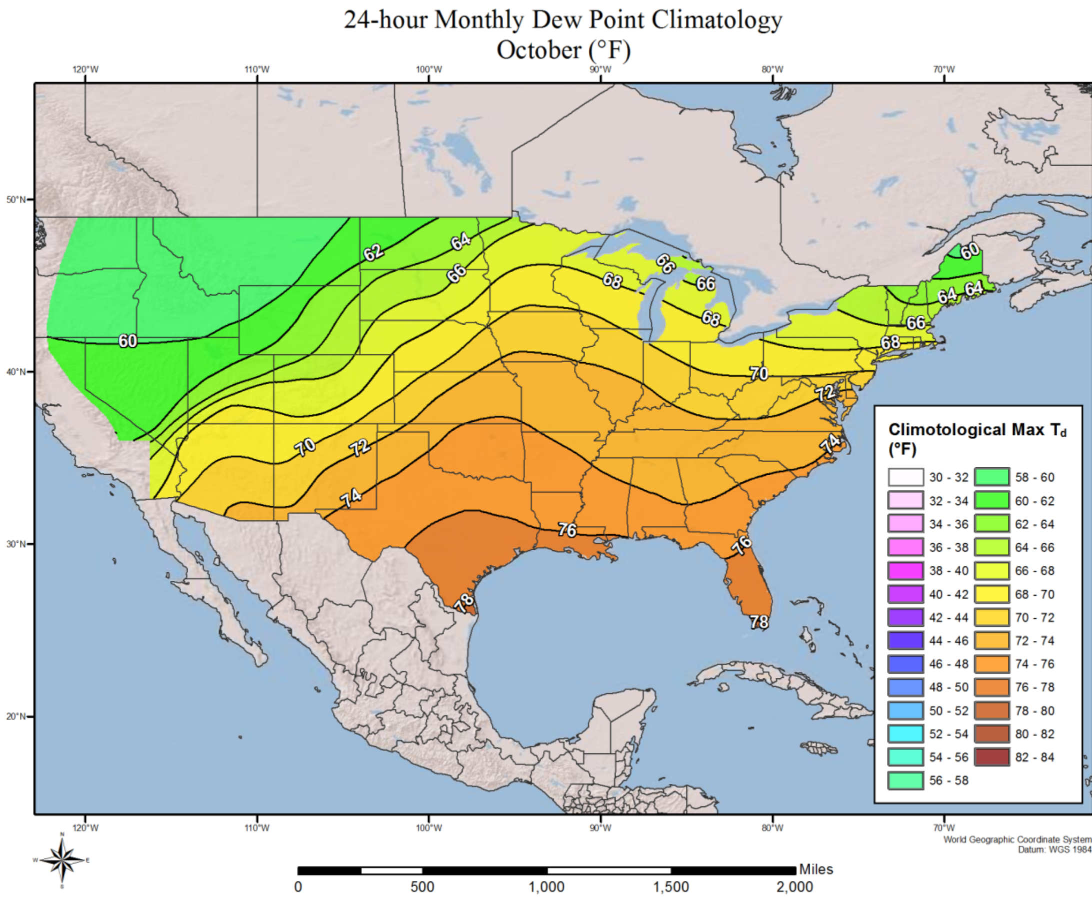
24-hour Monthly Dew Point Climatology
August (°F)



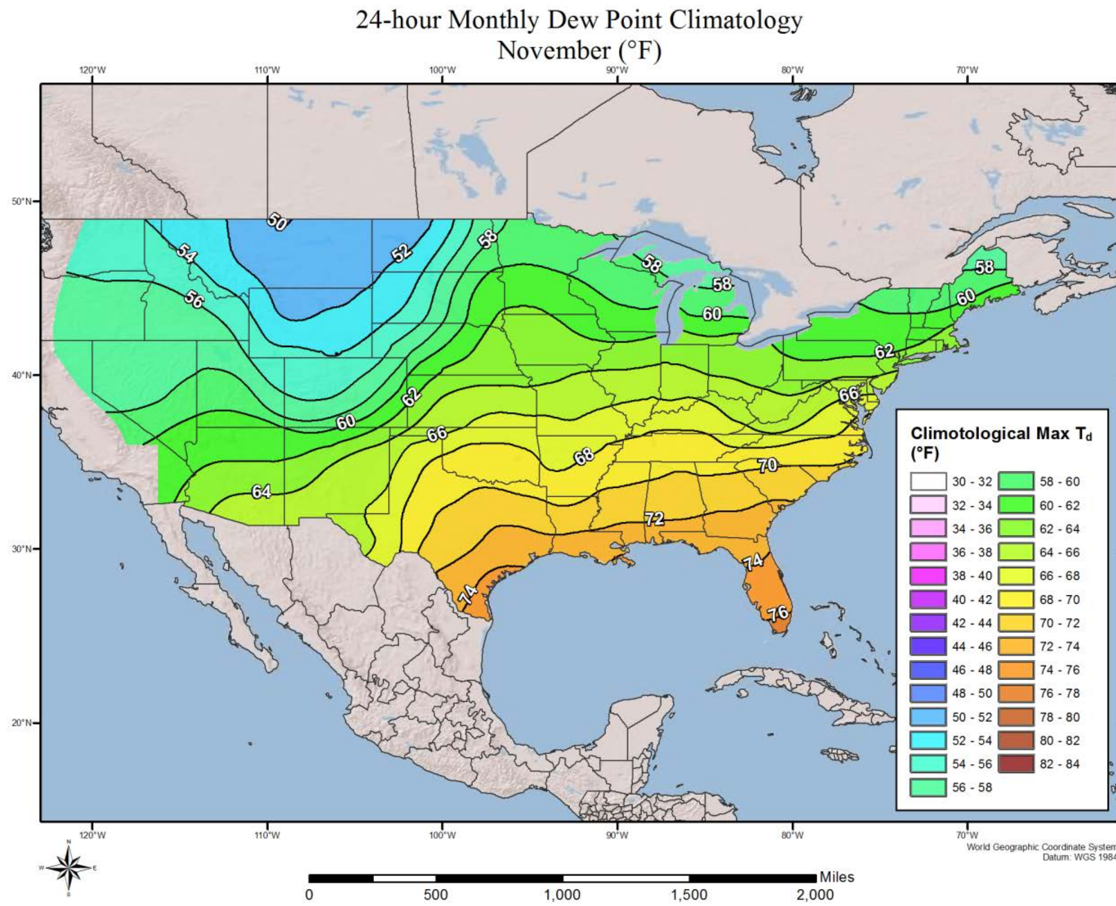
Attachment 4 Figure 32: August 24-hour 100-year maximum dew point climatology



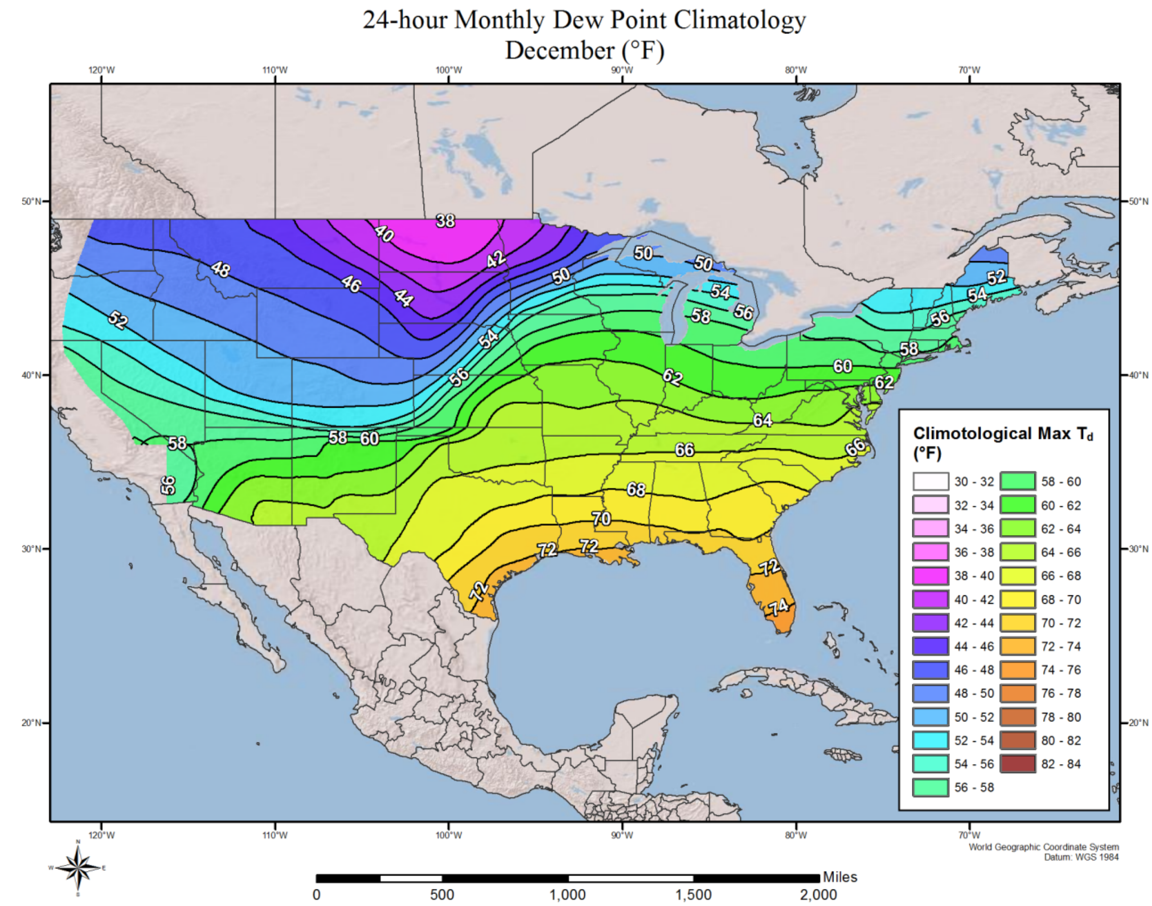
Attachment 4 Figure 33: September 24-hour 100-year maximum dew point climatology



Attachment 4 Figure 34: October 24-hour 100-year maximum dew point climatology



Attachment 4 Figure 35: November 24-hour 100-year maximum dew point climatology



Attachment 4 Figure 36: December 24-hour 100-year maximum dew point climatology

ATTACHMENT 5: Procedure for using Dew Point Temperatures for Storm Maximization and Transposition

Maximum dew point temperatures (hereafter referred to as dew points) have historically been used for two primary purposes in the PMP computation process:

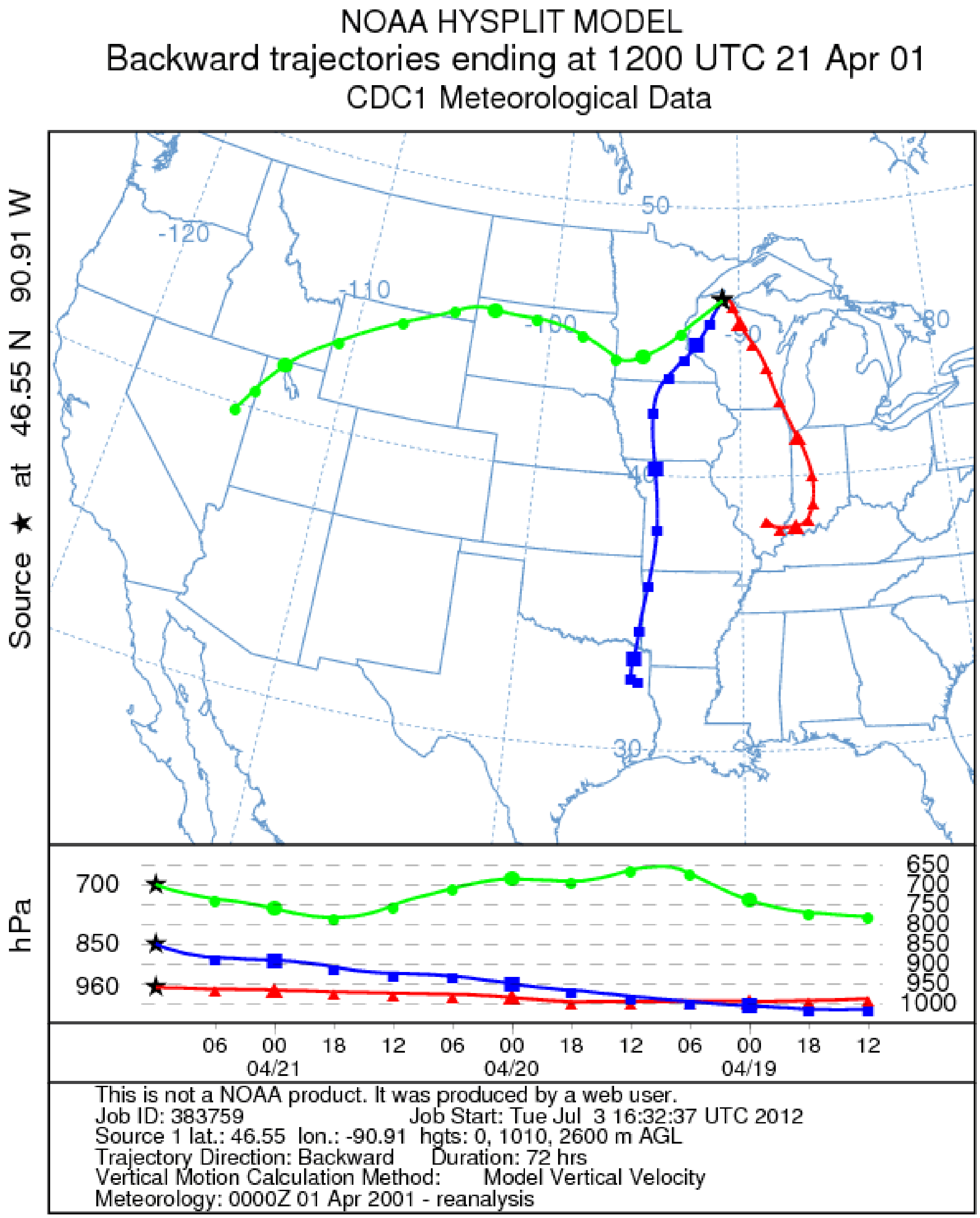
1. Increase the observed rainfall amounts to a maximum value based on a potential increase in atmospheric moisture available to the storm.
2. Adjust the available atmospheric moisture to account for any increases or decreases associated with the maximized storm potentially occurring at another location within the transposition limits for that storm.

HMR and WMO procedures for storm maximization use a representative storm dew point as the parameter to represent available moisture to a storm. Prior to the mid-1980s, maps of maximum dew point values from the *Climatic Atlas of the United States*, Environmental Data Services, Department of Commerce, were the source for maximum dew point values. HMR 55 published in 1984 updated maximum dew point values for a portion of the United States from the Continental Divide eastward into the central plains. A regional PMP study for Michigan and Wisconsin produced return frequency maps using the L-moments method. The Review Committee for that study included representatives from NWS, FERC, Bureau of Reclamation, and others. They agreed that the 50-year return frequency values were appropriate for use in PMP calculations. HMR 57 was published in 1994 and HMR 59 in 1999. These latest NWS publications also update the maximum dew point climatology but use maximum observed dew points instead of return frequency values. For this study, the 100-year return frequency dew point climatology maps were appropriate because this added a layer of conservatism and the extra 17 years of data available since the EPRI and Nebraska studies allow the 100-year return frequency to be more reliable. Storm precipitation amounts are maximized using the ratio of precipitable water for the maximum observed dew point to precipitable water for the storm representative dew point, assuming a vertically saturated atmosphere. This procedure was followed in this study using the updated maximum dew point climatology developed in Appendix 4.

The procedure for determining a storm representative dew point begins with the determination of the inflow wind vector (direction and magnitude) for the air mass that contains the atmospheric moisture available to the storm. Beginning and ending times of the rainfall event at locations of the most extreme rainfall amounts are determined using rainfall mass curves from those locations.

The storm inflow wind vector is determined using available wind data. The inflow wind vector has historically been determined using winds reported by weather stations, together with upper air winds, when available. Recently, re-analyzed weather and weather model data representing various atmospheric parameters including wind direction and speed in the atmosphere have become available for use from the HYSPLIT trajectory model and the North American Reanalysis Project. These analyses are

available back to 1948. Use of these wind fields in the lower portion of the atmosphere provides much improved reliability in the determination of the storm inflow wind vectors. The program is available through an online interface through the Air Resources Laboratory section of NOAA. Users are able to enter in specific parameters that then produce a trajectory from a starting point going backwards (or forwards) for a specified amount of time. Users can define variables such as the starting point (using latitude and longitude or a map interface), the date and time to start the trajectory, the length of time to run the trajectory, and the pressure level at which to delineate the inflow vector. Attachment 5 Figure 1 shows an example inflow vectors generated by HYSPLIT at three levels: 700mb, 850mb, and surface. The data generated from the HYSPLIT runs is then used in conjunction with standard methods to help delineate the source region of the air mass responsible for the storm precipitation. Also, this serves as another tool to determine from which weather stations to derive hourly dew point data for storm representative dew point analysis.



Attachment 5 Figure 1: HYSPLIT trajectory model results for Ashland, WI April 2001

The inflow wind vector is followed upwind until a location is reached that is outside of the storm rainfall. The nearest weather stations that report dew point values are identified. At least two stations are desired but a single station with reliable dew points observations can be used. The time period used to identify the appropriate dew point values is determined by computing the time required for the air mass to be transported from the location of the weather station to the location of maximum rainfall.

The start time of the extreme rainfall is then adjusted back in time to account for transit time from the dew point observing station to the maximum rainfall location.

For example, consider the following case:

1. Rainfall begins at 11:00am and ends at 6:00pm the following day at the location of maximum rainfall,
2. The storm representative dew point location (the location of the weather stations observing the dew points) is 100 miles from the maximum rainfall location in the direction of the inflow wind vector, and
3. The inflow wind speed is 20 mph.

The transit time for the air mass from the weather stations to the maximum rainfall location is five hours (100 miles divided by 20 mph). The time to begin using the dew point observations is five hours before the rainfall began (11:00am minus 5 hours = 6:00am) and the time to stop using the dew point observations is five hours before the rainfall ended (6:00pm minus 5 hours = 1:00pm the following day). Dew point observations taken between these times are used to determine the storm representative average 24-hour 1,000mb dew point value. The storm representative dew point location can come from a single location if only one station is used or from a location between the reporting weather stations if more than one station is used. The vector connecting this location and the location of maximum rainfall becomes the wind inflow vector used for storm transpositioning.

The storm representative dew point determined from the weather dew point observations needs to be corrected to the 1000mb level. The elevation of the storm representative dew point location is used in this correction. The correction factor of 2.4^{o}F per 1,000 feet of elevation is used. This is the same correction factor used in the *Climatic Atlas of the United States*. For example, a storm representative dew point of 72^{o}F at a station location with an elevation of 800 feet above sea level is corrected with a factor of 800 X 2.7 /1,000 = 2.2^{o}F. The dew point value corrected to 1,000mb (sea level) is 72^{o}F + 2.2^{o}F = 74^{o}F after rounding.

The procedure that computes the in-place maximized rainfall for a storm provides an estimate of the maximum amount of rainfall that could have been produced by the same storm at the same location if the maximum amount of atmospheric moisture had been available. This procedure requires that a maximum value for the storm representative dew point be determined. The maximum dew point value is selected at the same location where the storm dew point was determined using a maximum dew point climatology. The maximum dew point values must be corrected to 1,000mb. The precipitable water in the atmosphere is determined using the storm representative and maximum dew point values. Precipitable water is defined in this study as the total amount of moisture in a column of the atmosphere from sea level to 30,000 feet assuming a vertically saturated atmosphere. Values of atmospheric precipitable water are determined using the moist pseudo-adiabatic assumption, i.e. assume that for the given 1,000mb dew point value, the atmosphere holds the maximum amount of moisture

possible. The ratio of the precipitable water associated with the maximum 1,000mb dew point to the precipitable water associated with the 1,000mb storm representative dew point is the maximization factor.

For example, consider the following case:

1,000mb storm representative dew point:	72°F
1,000mb maximum dew point:	76°F
Precipitable water associated with a 1,000mb dew point of 72°F:	2.47"
Precipitable water associated with a 1,000mb dew point of 76°F:	2.99"
Maximization factor: PW(76°F)/PW(72°F) = 2.99 "/2.47" =	1.21

For transpositioning, the storm inflow vector (determined by connecting the storm representative dew point location with the location of maximum rainfall) is moved to the basin location being studied. The new location of the upwind end of the vector is determined. The maximum dew point associated with that location is then selected using the same maximum dew point climatology map used for in-place maximization. The transpositioning factor is the ratio of the precipitable water associated with the maximum 1,000mb dew point value at the transpositioned location to the precipitable water associated with the maximum 1,000mb dew point for the storm representative dew point location.

An example is provided.

1,000mb maximum dew point at the storm representative dew point location:	76°F
1,000mb maximum dew point at the transpositioned location:	74°F
Precipitable water associated with a 1,000mb dew point of 76°F:	2.99 "
Precipitable water associated with a 1,000mb dew point of 74°F:	2.73 "

Transposition factor: PW(74°F)/PW(76°F) = 2.73 "/2.99" = 0.91

ATTACHMENT 6: Procedure for Deriving PMP Values from Storm Depth-Area-Duration Analyses

Although PMP rainfall amounts are theoretical values, there currently is no theoretical method for determining the values. The accepted procedure for determining PMP values begins with the identification of the largest identified historic observed rainfall amounts in the region and applies the following procedures:

1. Increase the rainfall amounts to some maximized value (in-place maximization),
2. Adjust the "maximized" rainfall amounts to the potential situation where the historic storm occurs over the basin being studied (transposition),
3. Adjust the "maximized transpositioned" rainfall amounts for elevation changes or intervening topographic barriers which could potentially affect the storm moisture and subsequently the rainfall amounts for the "maximized transpositioned" storm (barrier adjustment).

The procedure begins with the DAD analysis from the largest of the identified storms that have occurred over regions that are climatologically and topographically similar to the area being studied. Identification of the largest rainfall events is relatively straight forward and is accomplished by identifying the largest station rainfall amounts and correlating the dates among adjacent stations to identify the areal extent of the heavy rainfall and the storm period. The DAD for each storm is computed using isohyetal analyses for each hour during the storm and determining the largest rainfall totals for each duration of interest over each area size of interest. HMR 51 uses temporal periods of 6-, 12-, 24-, 48- and 72- hours. Standard area sizes of 10-, 200-, 1,000-, 5,000-, 10,000- and 20,000-square miles area used. Other durations and area sizes can also be used in the DAD analysis as desired.

The US Army Corps of Engineers, the Bureau of Reclamation and the National Weather Service have performed storm studies and produced DADs for many storms. This study reviewed additional weather station data to identify extreme rainfall storms that had not been identified and studied previously. The new storms identified primarily occurred since the publication of HMR 51, but additional storms that occurred prior to HMR 51 publication were also identified. DADs that had been previously developed are used in this report. Newly identified storms are analyzed in this study, and DADs are developed for these storms. These DADs quantify the rainfall associated with each storm event, providing the largest rainfall amounts for each of the durations and area sizes used in this study.

Identification of storms that can be transpositioned to the MNGP watershed is largely based on subjective judgments. For a storm to be transpositionable, it should have occurred over a region that is meteorologically and topographically similar to the basin being studied. Storms generally should not be transpositioned across significant topographic features or into different climate regions. Therefore, it is assumed that the

same moisture sources and dynamics that produced these events could have produced a similar storm over the basin.

Maximization of the storm DADs involves deriving the in-place and transposition factors to adjust the observed rainfall to look like it would have occurred had the storm been located over the basin. This accounts for the three factors which could affect a particular storm as it's moved from its original location to the MNGP basin centroid; the storm could have been some amount bigger in-place had more moisture been available, the storm would have had more or less moisture available versus where it originally occurred based on it being moved toward or away from its moisture source, and the storm would have occurred at a lower or higher elevation than its original location. This follows the procedures and calculations described in Attachment E.

For this study, all computations associated with historic storms are computed at the 1,000mb level (approximately sea level). The elevation of the location where the largest rainfall was observed is used as the storm elevation. An adjustment is applied to the storm moisture to account for the elevation of the storm above sea level. For example, if the maximum rainfall occurred at an elevation of 500 feet, the total atmospheric moisture (500 to 30,000 feet) is decreased by the amount of moisture associated with the storm representative dew point between sea level and 500 feet. The adjustment factor uses precipitable water contained in the moisture maximized atmosphere above the storm elevation, i.e., the moisture contained in the entire depth of the moisture maximized atmosphere, minus the moisture contained in the moisture maximized atmosphere below the storm elevation. An adjustment was made to account for the storm's elevation (either higher or lower than the basin centroid elevation) and the amount of precipitable water that would be available while taking into consideration upwind elevated barrier, more if the elevation was lower and less if the elevation was higher. This elevation adjustment factor is determined by computing the ratio of precipitable water in the moisture maximized atmosphere above the elevation to the precipitable water in the entire depth of the moisture maximized atmosphere.

The equations for the computation of the in-place maximization factor, transposition and elevation adjustment factors are as follows:

In-place maximization factor =
(storm representative maximum dew point PW – in-place storm elevation maximum dew point PW) / (storm representative dew point PW – in-place storm elevation representative dew point PW)

Transpositioned/elevation to basin factor =
(transpositioned maximum dew point PW – average basin elevation maximum dew point PW)/(storm representative maximum dew point PW – in-place storm elevation representative dew point PW)

Barrier adjustment factor =

(transpositioned maximum dew point or PW – moisture inflow barrier elevation maximum PW)/(transpositioned maximum dew point or PW – average basin elevation maximum dew point or PW)

Multiplication of these terms leads to a simplified computation where all the required adjustments are combined in a single equation.

Total adjustment factor =
(in-place max factor) * (transpositioned/elevation to basin factor) * (barrier adjustment factor)

The total adjustment factor modifies the storm DAD by a factor using two computed values:

1) The maximum atmospheric moisture available to a historic storm if it were to occur over the study basin. This air mass is assumed to contain the maximum amount of atmospheric moisture for the basin location and is adjusted for elevation upwind of the basin and within the basin.
2) The atmospheric moisture available for the historic storm at the location and elevation where it occurred.

The total adjustment factor is applied as a linear multiplier for all rainfall amounts in the storm DAD.

As an example, the DAD from a storm center is maximized, transpositioned/elevation adjusted to the MNGP basin centroid. The following are values for the parameters used in computing the adjustments:

Storm representative:	75.0° F
In-place maximum:	76.5° F
Transpositioned maximum:	75.0° F
Storm elevation:	600'
Average basin elevation:	1,000’

Total atmospheric precipitable water for 75.0° F:	2.85"
Total atmospheric precipitable water for 76.5° F:	3.07"
Total atmospheric precipitable water for 75.0° F:	2.85"

Adjustment for storm elevation, 1,000mb to 600' at 75.0°F:	0.15"
Adjustment for storm elevation, 1,000mb to 600' at 76.5°F:	0.16"
Adjustment for ave basin elevation, 1,000mb to 1,000' at 75.0°F:	0.25"
Adjustment for inflow barrier elevation, 1,000mb to 1,000' at 75.0°F:	0.25"

Total adjustment factor =
(in-place max factor) * (transpositioned/elevation to basin factor) * (barrier adjustment factor)

= ((3.07" - 0.16") / (2.85 " - 0.15")) * ((2.85" - 0.25") / (3.07" - 0.16")) * ((2.85" - 0.25") / (2.85" - 0.25")) = (1.08) * (0.90) * (1.00) = 0.96

To explicitly show how each adjustment factor (in-place maximization, transposition and barrier adjustment) affects the total adjustment, separate computation are provided.

<u>In-place maximization factor</u>

Storm representative:	75.0° F
In-place maximum:	76.5° F
Storm atmospheric precipitable water for 75.0° F:	2.85"
Maximum atmospheric precipitable water for 76.5° F:	3.07"
Adjustment for storm elevation, 1,000mb to 600' at 75.0°F:	0.15"
Adjustment for storm elevation, 1,000mb to 600' at 76.5°F:	0.16"

In-place maximization factor =
(storm representative maximum dew point PW – in place storm elevation maximum PW)/(storm representative dew point PW – in place storm elevation maximum dew point PW)

= (3.07"- 0.16) / (2.85" - 0.15")
= 2.91" / 2.70"
= 1.08

<u>Transposition factor</u>

In-place maximum:	76.5° F
Transpositioned maximum:	75.0° F
Maximum atmospheric precipitable water for 76.5° F:	3.07"
Maximum atmospheric precipitable water for 75.0° F:	2.85"
Adjustment for storm elevation, 1,000mb to 600' at 76.5°F:	0.16"
Adjustment for storm elevation, 1,000mb to 1,000' at 75.0°F:	0.25"

Transposition factor =
(transpositioned maximum dew point PW – basin elevation maximum dew point PW)/(storm representative maximum dew point PW – in place storm elevation maximum dew point PW)

= (2.85"- 0.25") / (3.07" - 0.16")
= 2.60" / 2.91"
= 0.90

<u>Moisture inflow barrier adjustment factor</u>

Transpositioned maximum dew point:	75.0° F
Basin effective barrier height:	1,000'
Precipitable water for 76.5° F:	3.07"
Adjustment for basin ave. elevation, 1,000mb to 1,000' at 76.5°F:	0.25"

Barrier adjustment for basin elevation, 76.5° F, 1,000mb to 1,000': 0.25"

Moisture inflow barrier adjustment factor =
(transpositioned maximum dew point PW – effective barrier height elevation maximum dew point PW)/(transpositioned maximum dew point PW – basin elevation maximum PW)

= (3.07"- 0.25) / (3.07" - 0.25")
= 2.82" / 2.82"
= 1.00

Total adjustment factor = (In-Place maximization) X (Transposition) X (Barrier Adjustment/Storm elevation)

= 1.084 * 0.90 * 1.00
= 0.96

This is the same total adjustment computed earlier (within round-off error) using the single equation to compute the total adjustment factor.

Since these procedures involve linear multiplication, Excel spreadsheets can be used to incorporate the storm DAD and apply the factors to compute the total adjusted DAD. Each storm spreadsheet and all the data used for the calculations are presented for each storm in Attachments 1, 2, and 3.

Once the total adjustment factors are applied to all of the storms being considered, rainfall amounts from largest storms are plotted on a log-linear plot with rainfall depth plotted on the linear scale and area size plotted on the log scale. A separate graph is constructed for each duration period, e.g. 6-hour, 12-hour, etc. The graphs provide curves of the transpositioned maximized adjusted storm rainfall amounts for all area sizes. These DA curves represent the maximum rainfall potential based on standard procedure modifications of the largest observed historic storms in the region surrounding the basins. An enveloping curve is drawn using the largest rainfall values. All of the plotted rainfall amounts either lie on the enveloping curve or below it. The exception is in the case where there is reason to suspect that a value is larger than is reasonable and that rainfall value may be undercut, i.e. the envelop curve should be drawn beneath the value. Undercutting should rarely be done and each case needs to be justified. No undercutting was done in this study. In general, the enveloping curve should provide a smooth transition among the maximum rainfall values for various area sizes. This process of enveloping DA plots provides continuity in space for the rainfall amounts among various area sizes.

After enveloping curves are completed for each of the duration periods, DD curves are plotted on a linear-linear graph, with duration on one axis and depth on the other. Since there is only a single curve for each area size from the enveloped DA plots, all of DA curves can be plotted as a family of curves on a single graph. Enveloping and smoothing of curves is completed for each area size. The curve should provide a smooth

transition among the maximum rainfall values for various durations. This procedure of enveloping DD plots provides continuity in time for the rainfall amounts among various durations.

The final envelopment curves provide the maximum rainfall amounts that represent PMP values for the MNGP basin centroid. Rainfall amounts for each area size and each duration are taken from the curves and used to construct the PMP DAD table. Enveloped rainfall values were taken from the DA plots and used to construct the DD plots. A curve was constructed for each area size, i.e., 10-; 100-; 200-; 500-; 1,000-; 5,000-; 10,000-; and 20,000-square mile area sizes. Enveloping curves were drawn with smoothing to provide smooth transitions among duration periods.

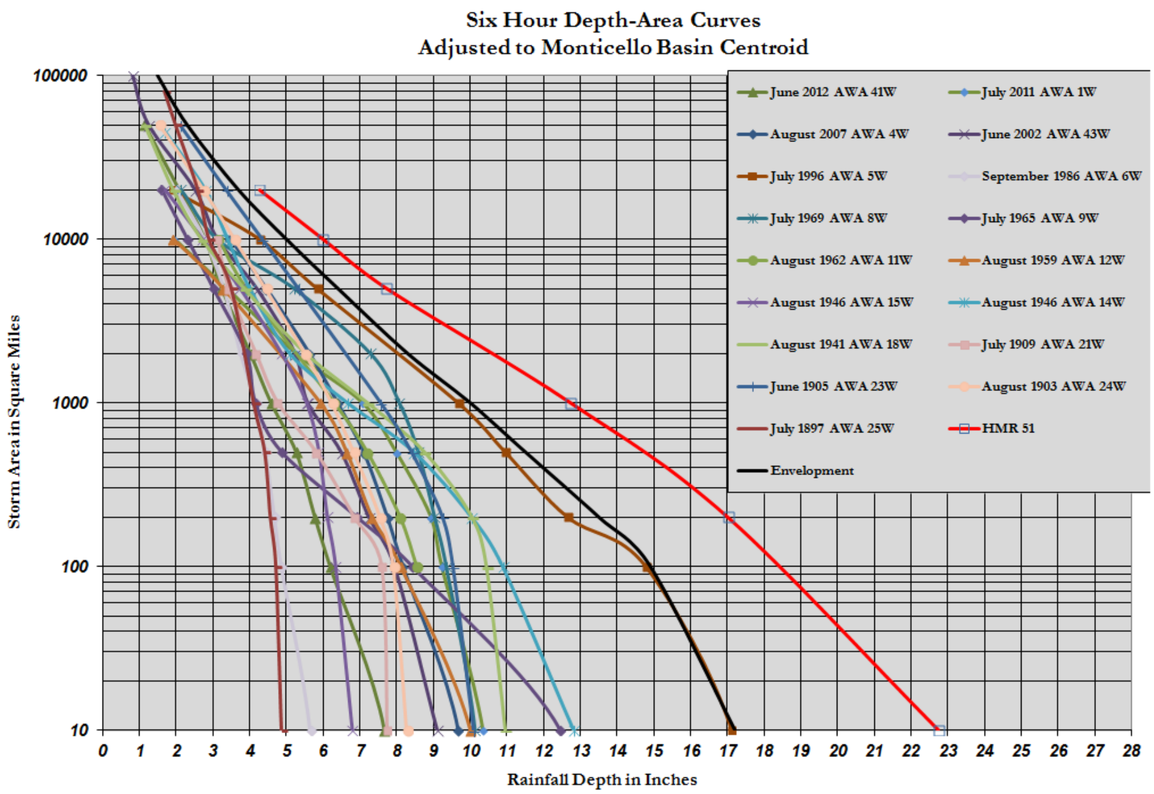
This procedure of enveloping and smoothing produces maximum rainfall amounts that have continuity in both time and space. Final plots of the DA and DD curves for the basin are provided in this Attachment 7. The final PMP values for the study were taken from the DD curves and used to derive the PMP values.

ATTACHMENT 7: Depth-Area and Depth-Duration Curves

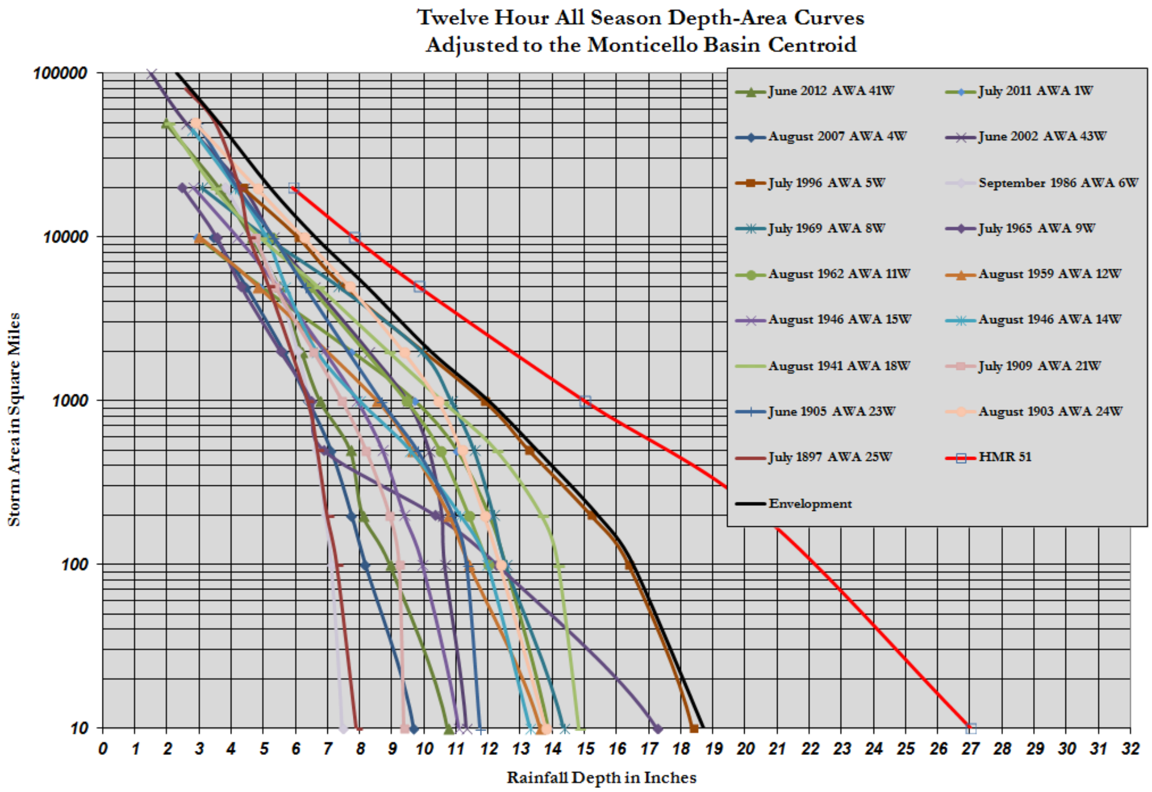
Rainfall amounts from the largest storms were plotted on DA plots. Curves were made for each duration period, i.e., 6-, 12-, 24-, 48-, and 72-hour duration periods. Enveloping curves were drawn using the maximum rainfall values and smoothing was applied to provide smooth transitions among area sizes.

Enveloped rainfall values were taken from the DA plots and used to construct the DD plots. A curve was constructed for each area size, i.e., 10-; 100-; 200-; 500-; 1,000-; 5,000-; 10,000-; 20,000-; 50,000-, and 100,000-square mile area sizes. Enveloping and smoothing was completed to provide smooth transitions among duration periods.

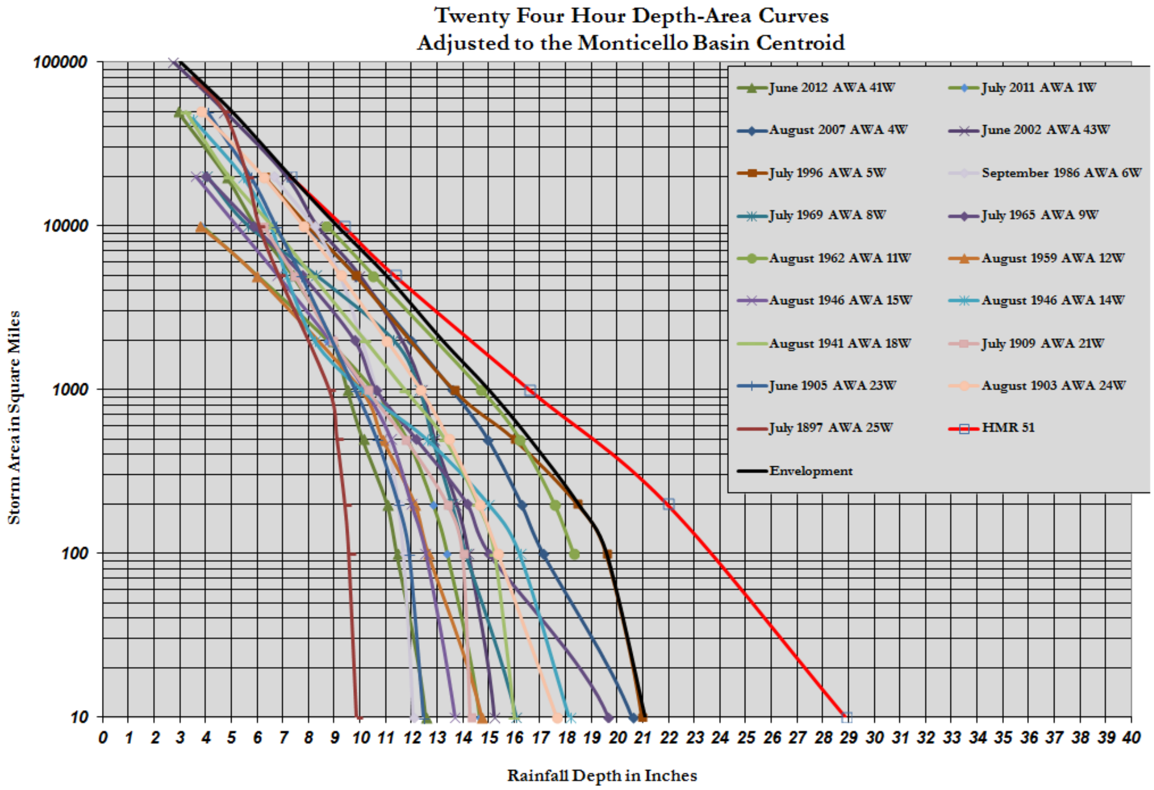
This procedure of enveloping and smoothing produces maximum rainfall amounts that have continuity in both time and space. Final plots of the DA and DD curves for the PINGP basin centroid, for both all season and cool season, are provided in this Attachment. The final PMP values for the study were taken from the DD curves and used to derive the PMP values.



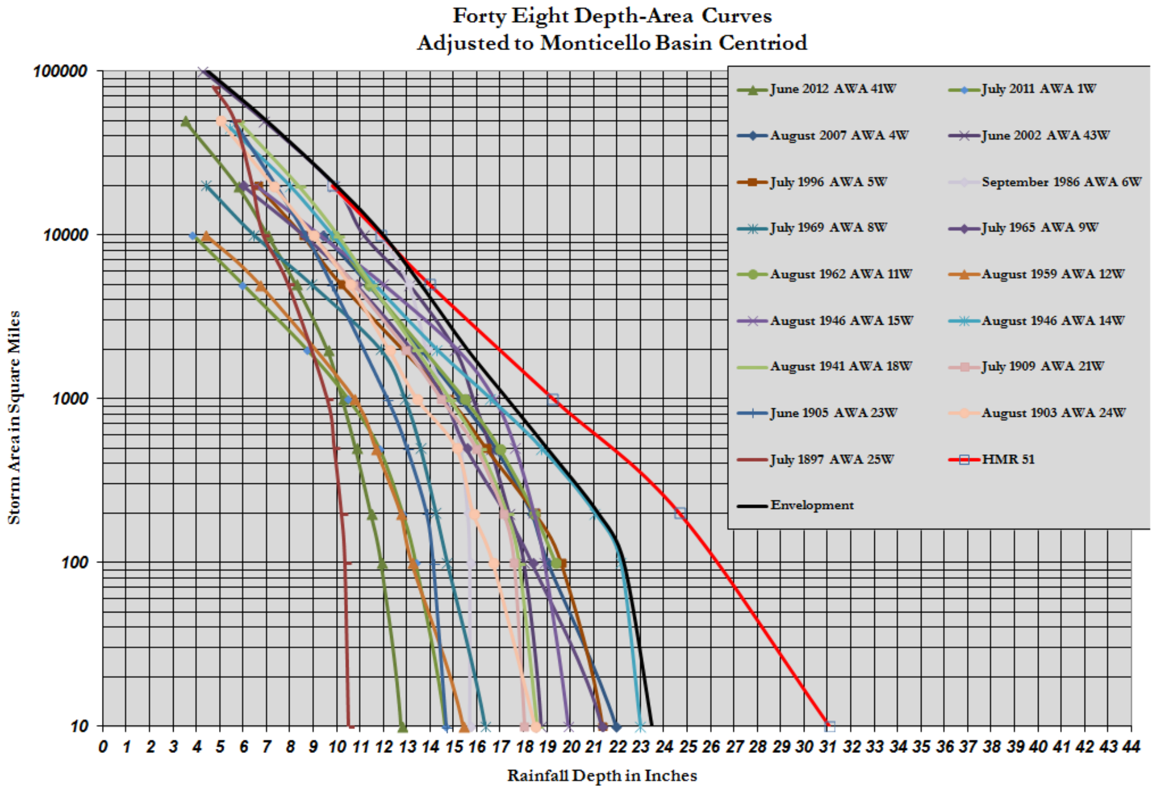
Attachment 7 Figure 1: Depth-area chart for the 6-hour duration



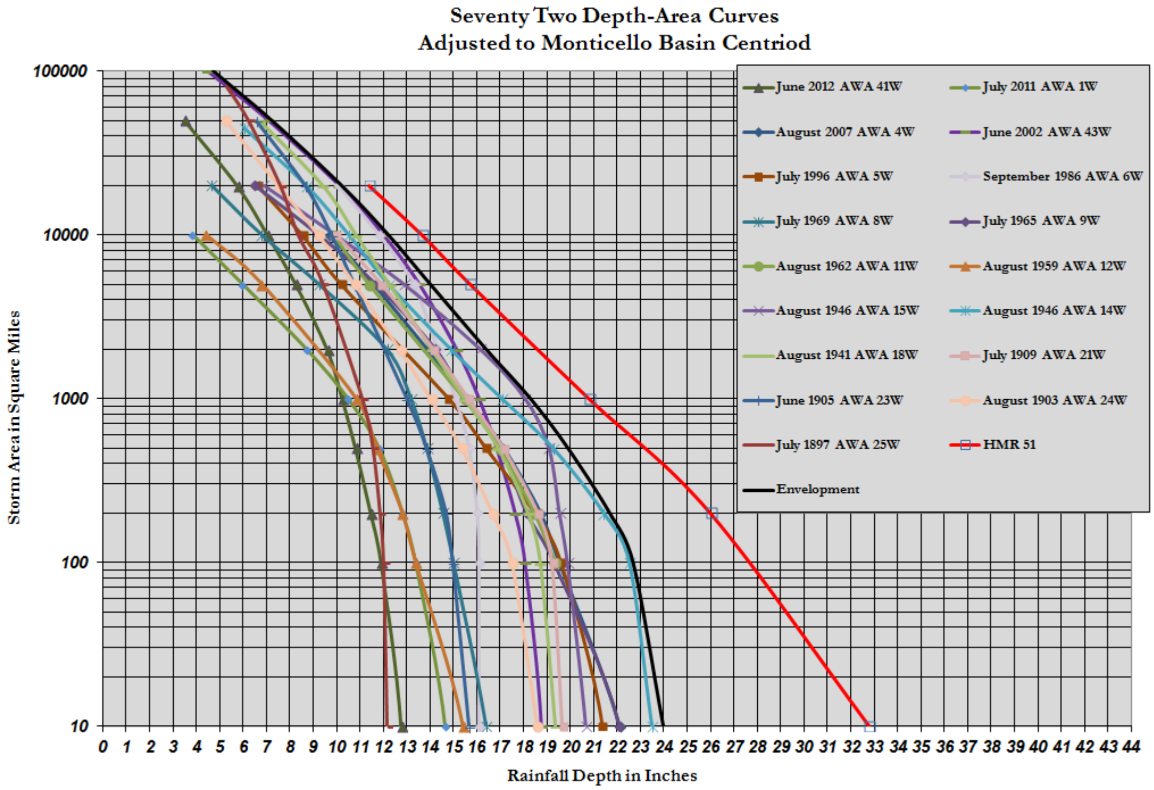
Attachment 7 Figure 2: Depth-area chart for the 12-hour duration



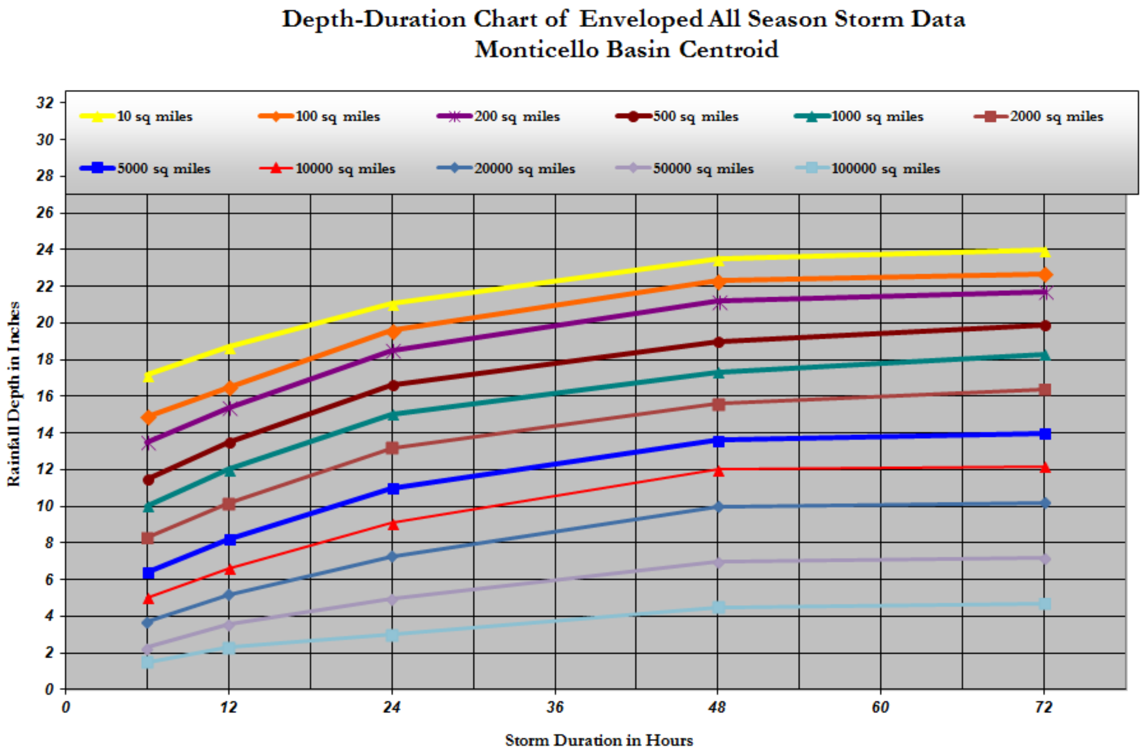
Attachment 7 Figure 3: Depth-area chart for the 24-hour duration



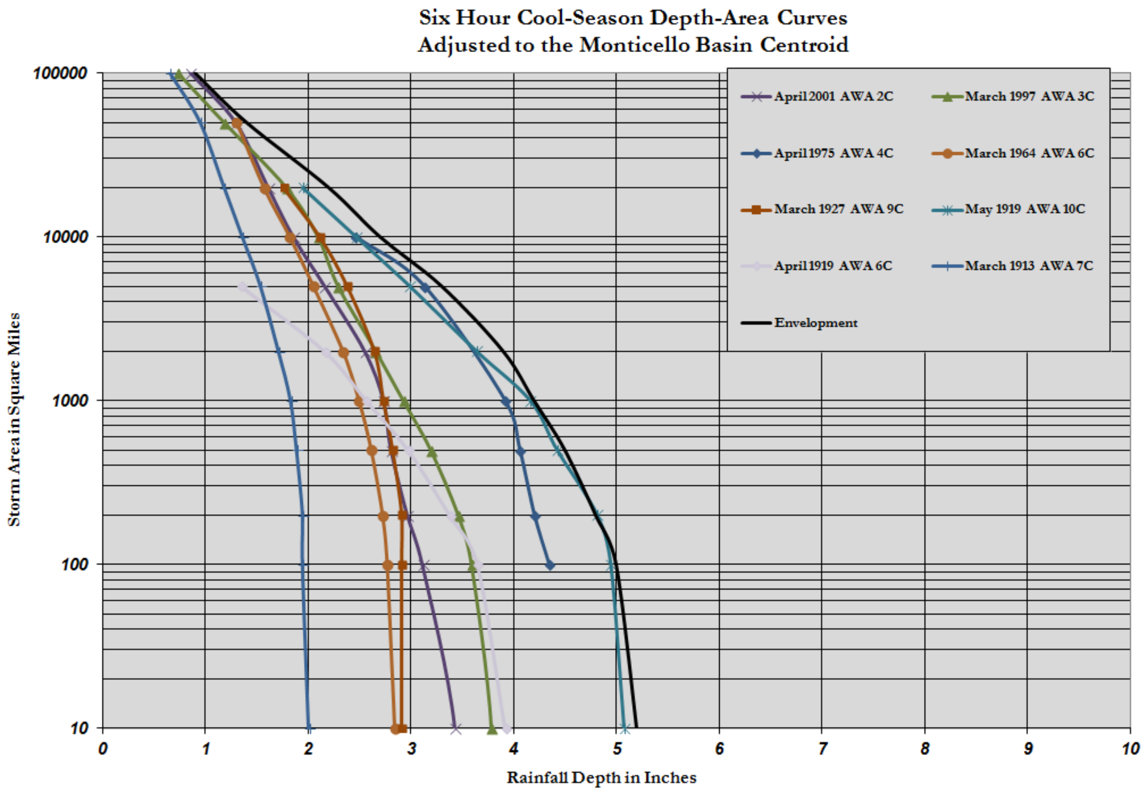
Attachment 7 Figure 4: Depth-area chart for the 48-hour duration



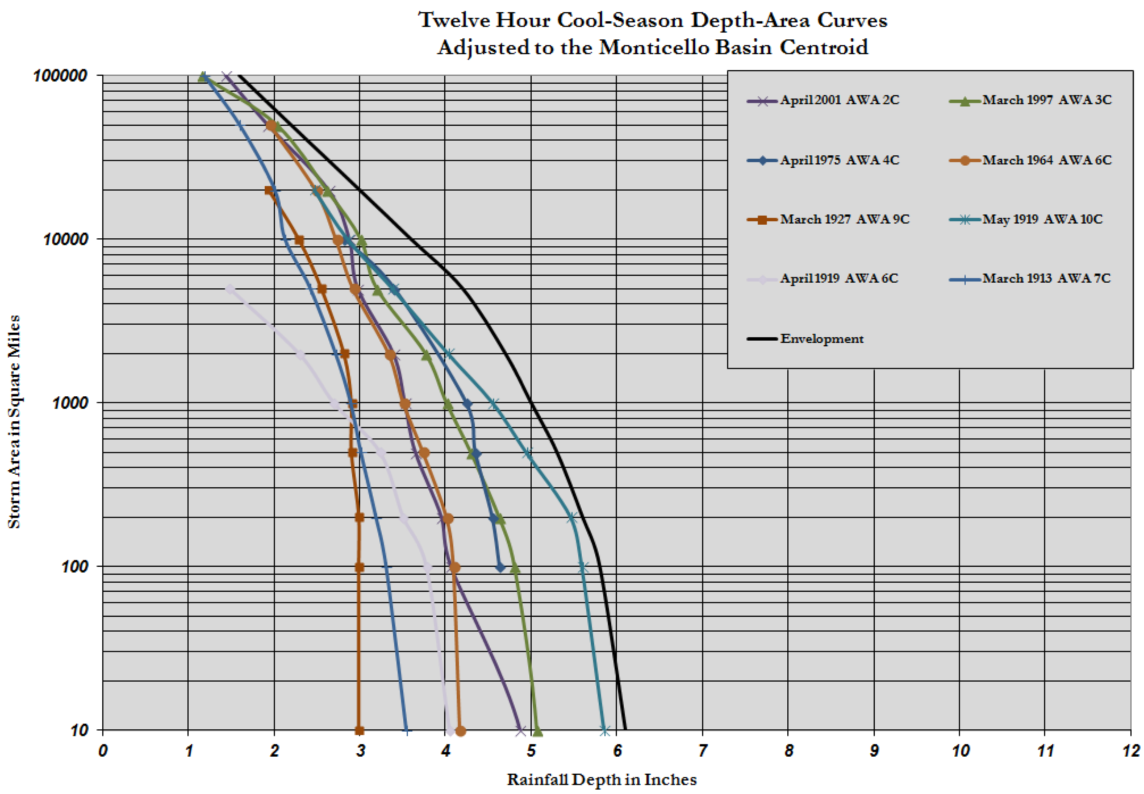
Attachment 7 Figure 5: Depth-area chart for the 72-hour duration



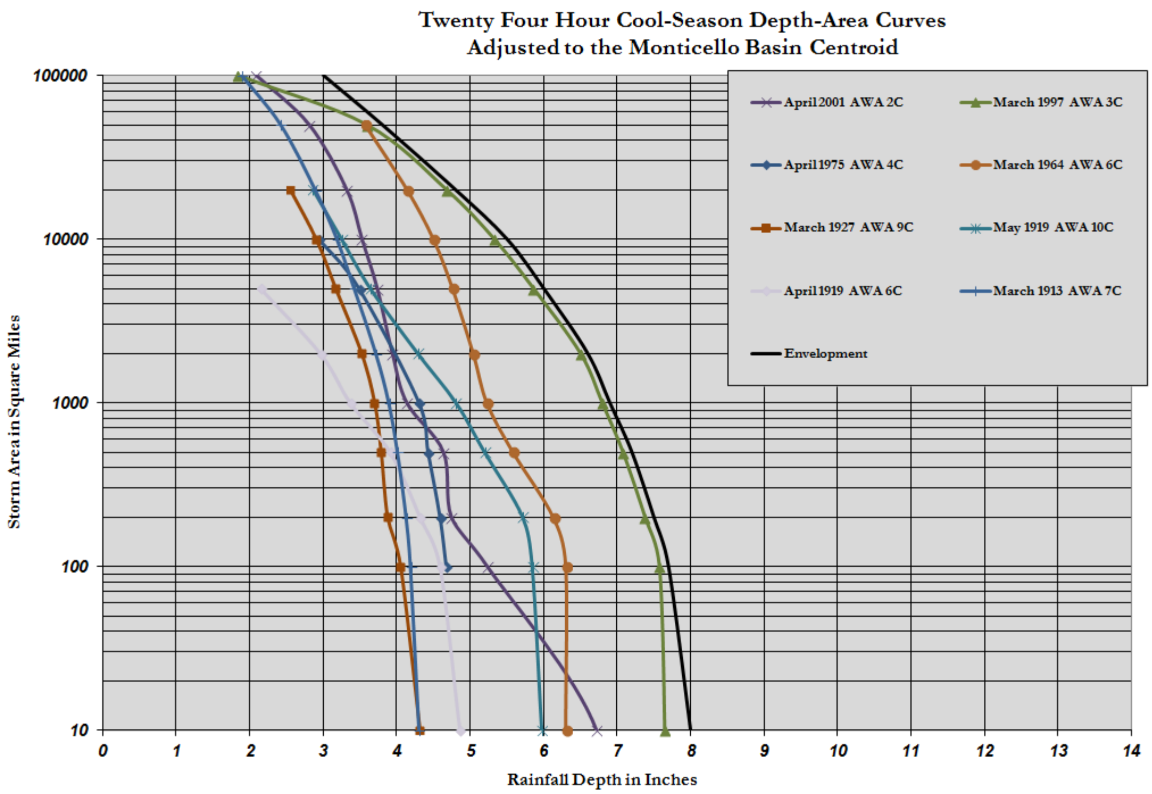
Attachment 7 Figure 6: Depth-duration chart for the all area sizes and durations



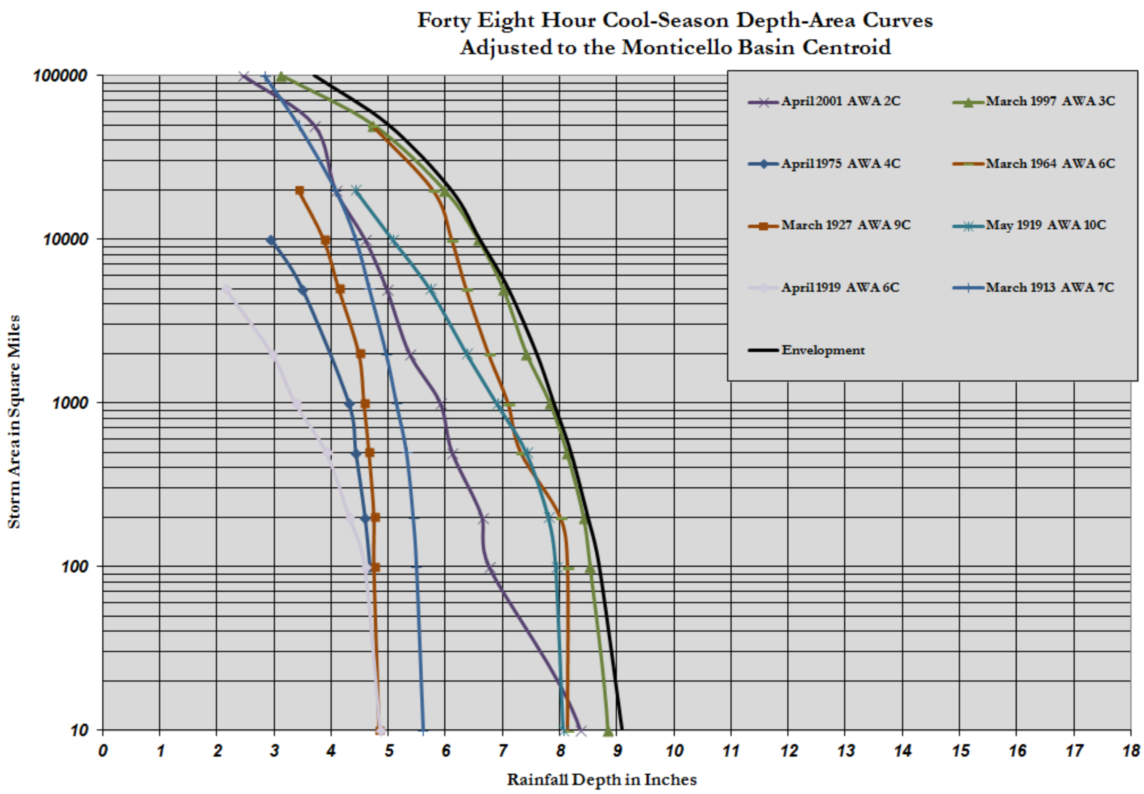
Attachment 7 Figure 7: Depth-area chart for the cool-season 6-hour duration



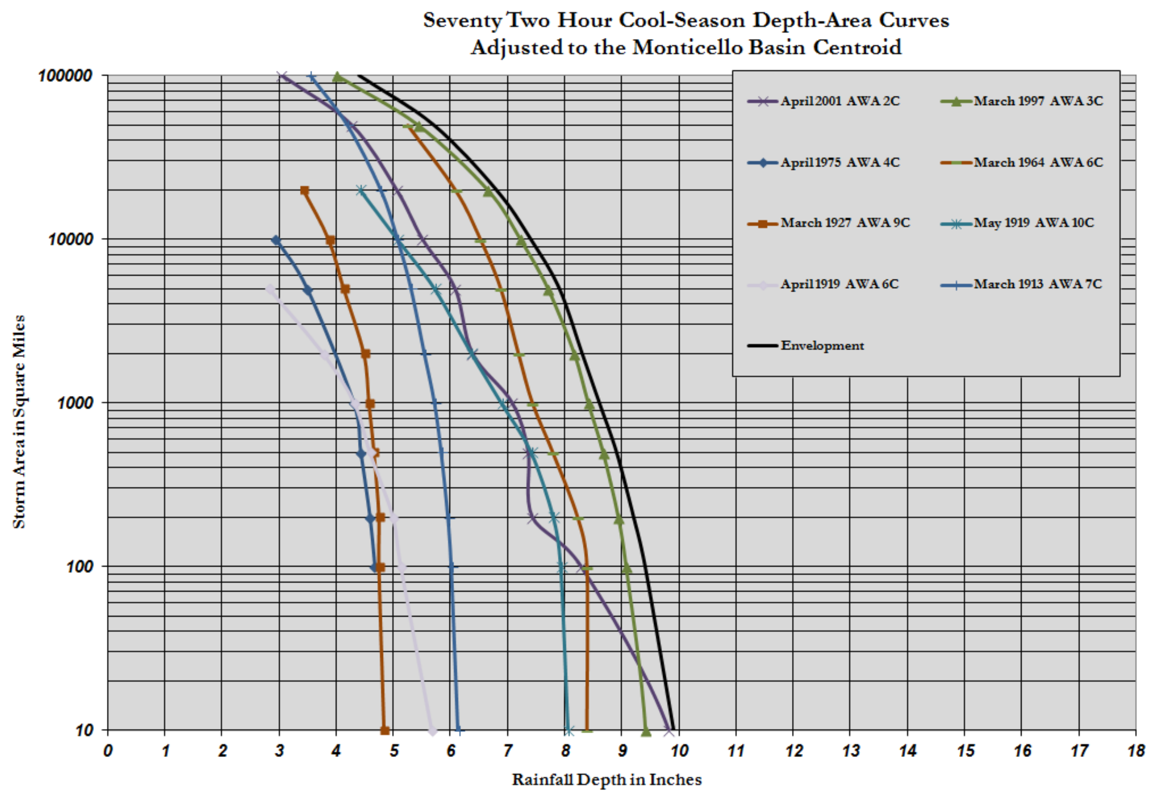
Attachment 7 Figure 8: Depth-area chart for the cool-season 12-hour duration



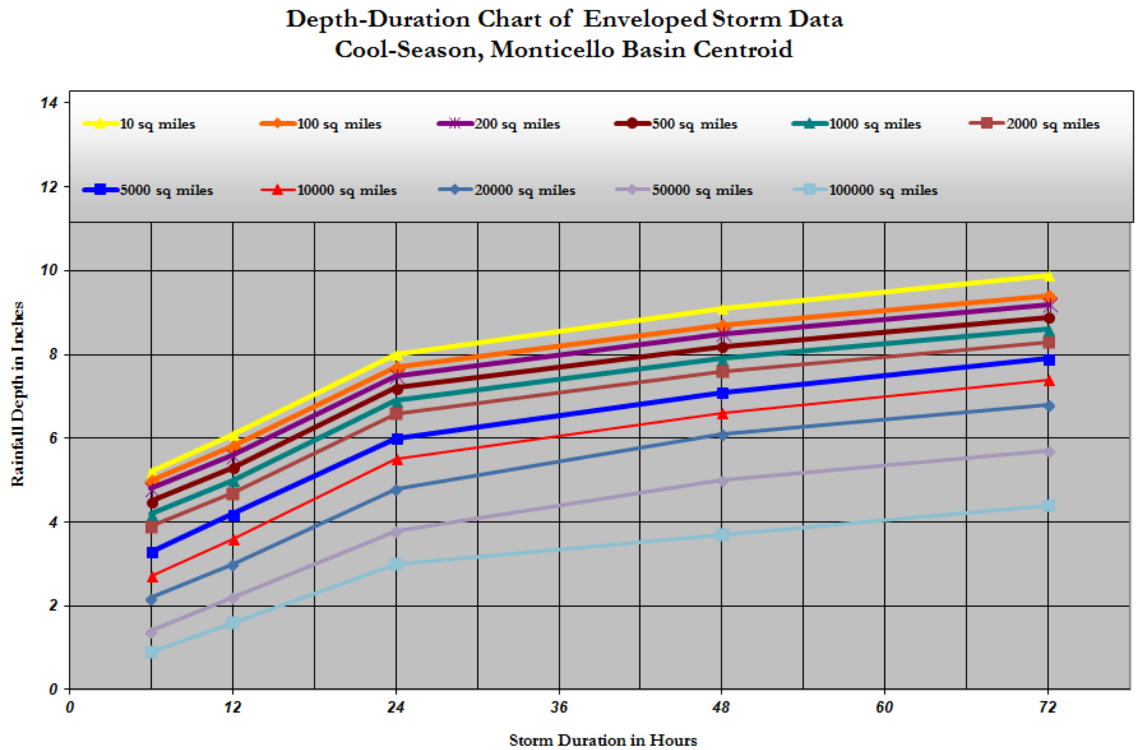
Attachment 7 Figure 9: Depth-area chart for the cool-season 24-hour duration



Attachment 7 Figure 10: Depth-area chart for the cool-season 48-hour duration



Attachment 7 Figure 11: Depth-area chart for the cool-season 72-hour duration



Attachment 7 Figure 12: Depth-duration chart cool-season