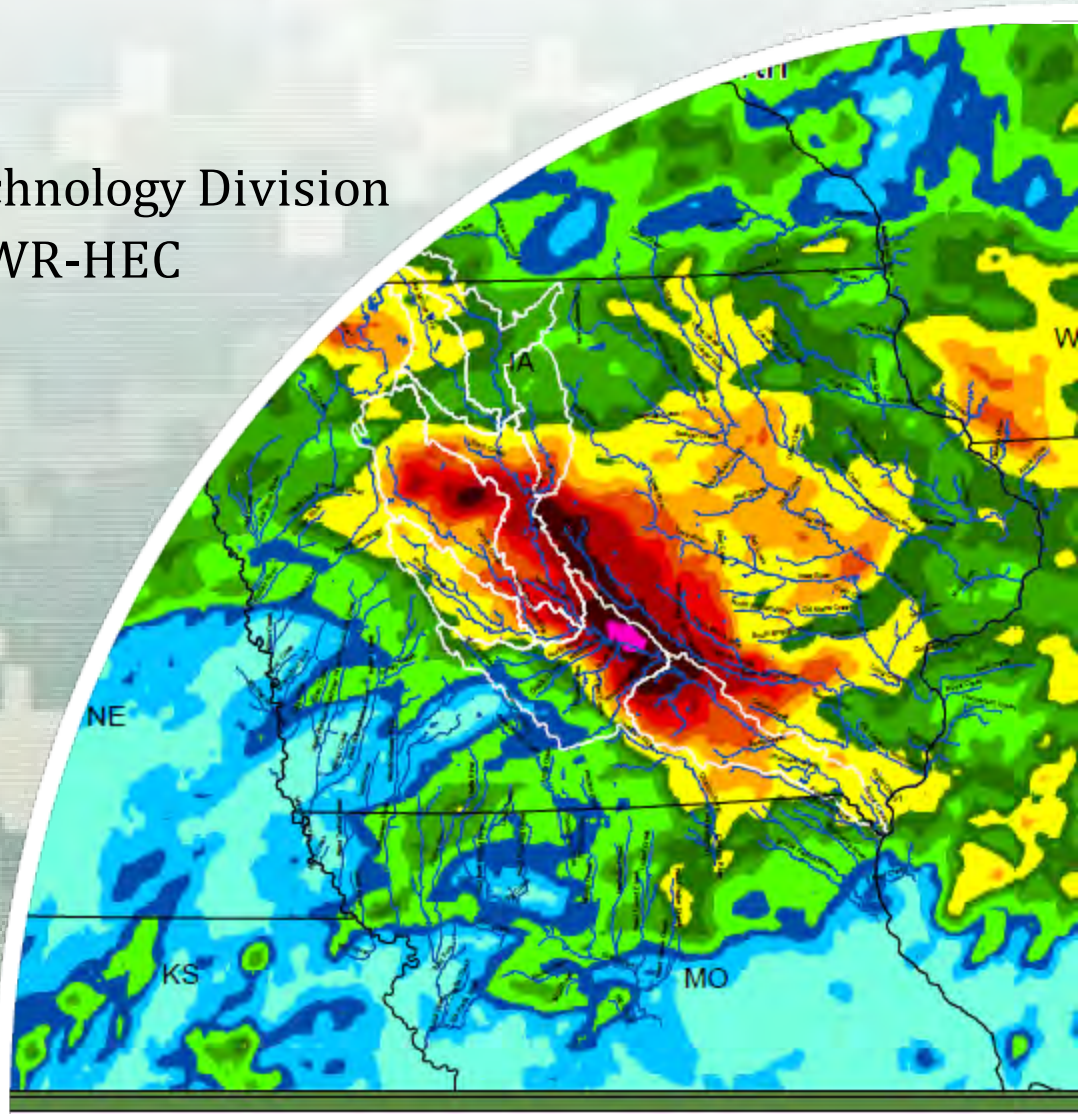
Information on Speaker Notes

There are speaker notes on some of the slides. The notes provide more information about the content of the slide. An icon, indicating there are notes for a slide, is found in the upper left hand corner of the slide. You can activate the notes window in two ways:

- Hold the cursor over the icon and the text will appear.
- Click on the icon and a text box will open. Close with a click outside the text box. The text box can be moved around if needed by clicking (in top of box) and dragging.

USACE Extreme Storm Team and Hypothetical Storm Analysis

Matthew Fleming, P. E.
Chief, Hydrology and Hydraulics Technology Division
Hydrologic Engineering Center, CEIWR-HEC
Institute for Water Resources



US Army Corps of Engineers
BUILDING STRONG®

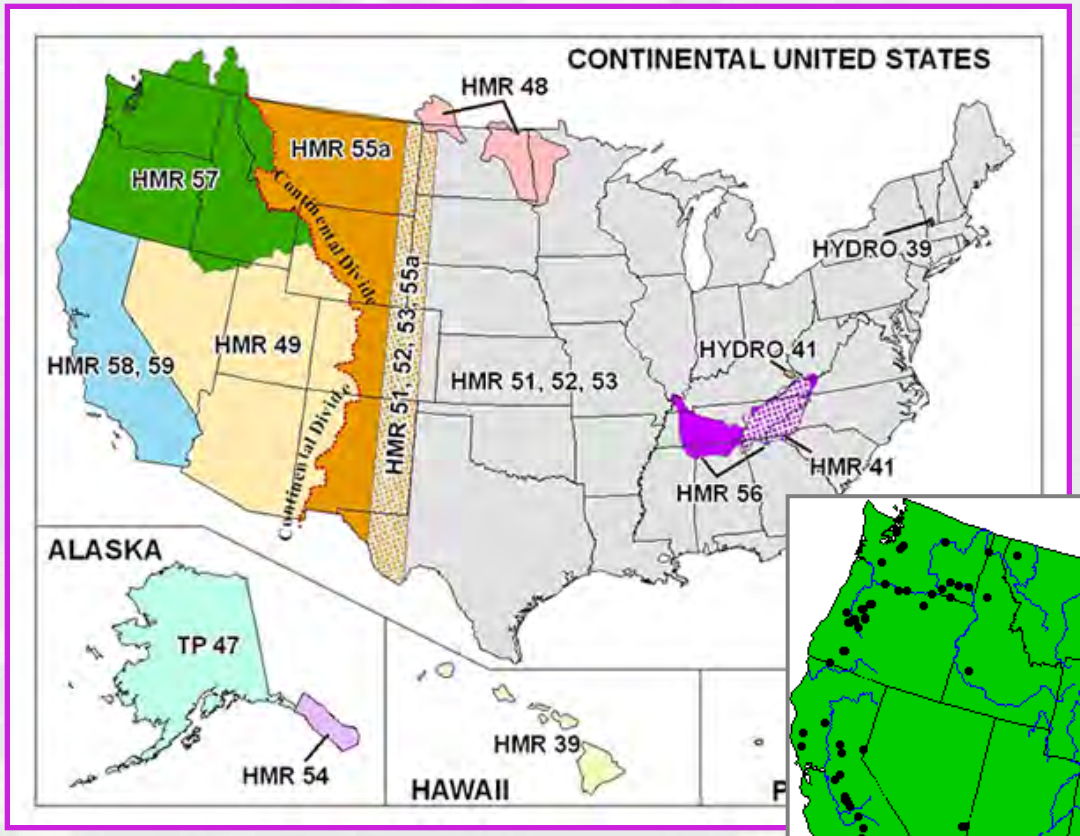
Outline

- **USACE Extreme Storm Team**
  - Catalog Historic Storms
  - Perform Site Specific PMP and Antecedent Storm Studies
  - Develop Guidance for Hypothetical Storm Analysis
- **HEC-MetVue and its Application to Cataloging Historic Storms and Applying Synthetics Storms**
- **Stochastic Hydrologic Simulations using HEC Software**
  - Monte Carlo Analyses will be Available in HEC Software
  - Knowledge Uncertainty and Natural Variability are Modeled in a Nested Monte Carlo Sampling Loop within HEC-WAT
  - Application of HEC-WAT, HMS, and ResSim to Define Flow and Reservoir Stage Frequency Curves (Beyond Observed Records) while Including Uncertainty

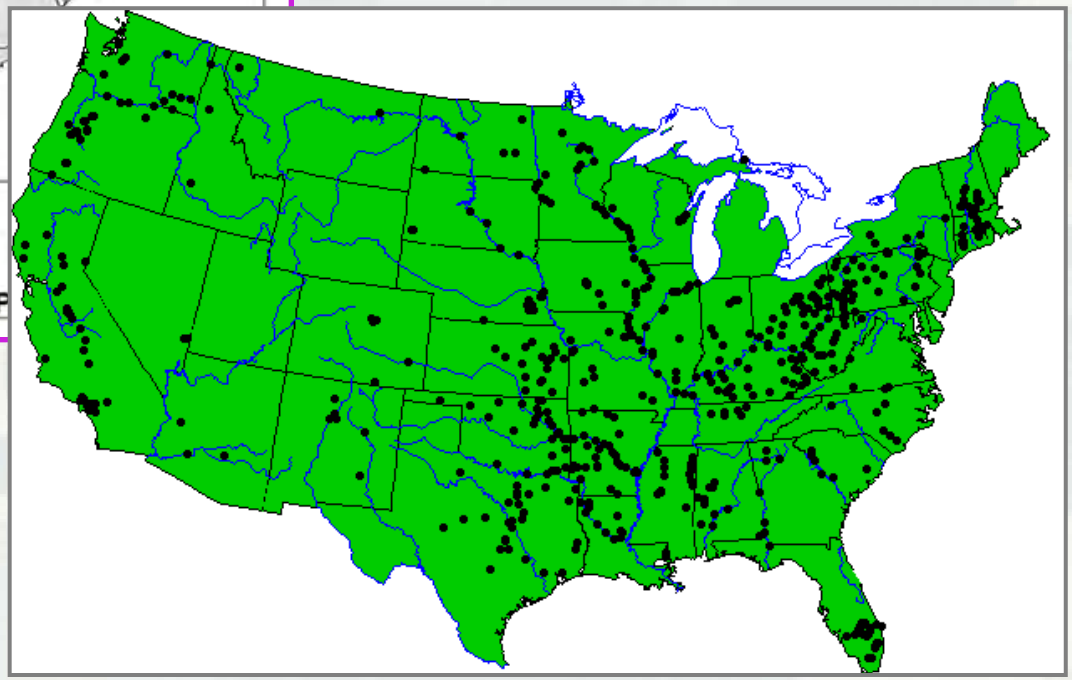
USACE Extreme Storm Data Needs

- **Dam Safety Program**
  - Site-Specific PMP and Antecedent Storm Studies
  - NOAA Hydrometeorological Reports (HMRs) updates
- **Levee Safety Program**
  - Update Standard Project Storm Criteria
  - Precipitation-Frequency (NOAA-14, TP40, NOAA II)
- **Extreme Storm Database**
  - Extreme Storm Data Archiving/Retrieval
  - Analysis of Recent Extreme Storm Events
  - Linked with HEC-HMS and HEC-MetVue
- **Computation of Areal Reduction Factors**
- **Monte Carlo Analysis for Frequency Curve Extension**
- **Atmospheric Modeling of Extreme Precipitation**

NOAA HMR Regional Coverage

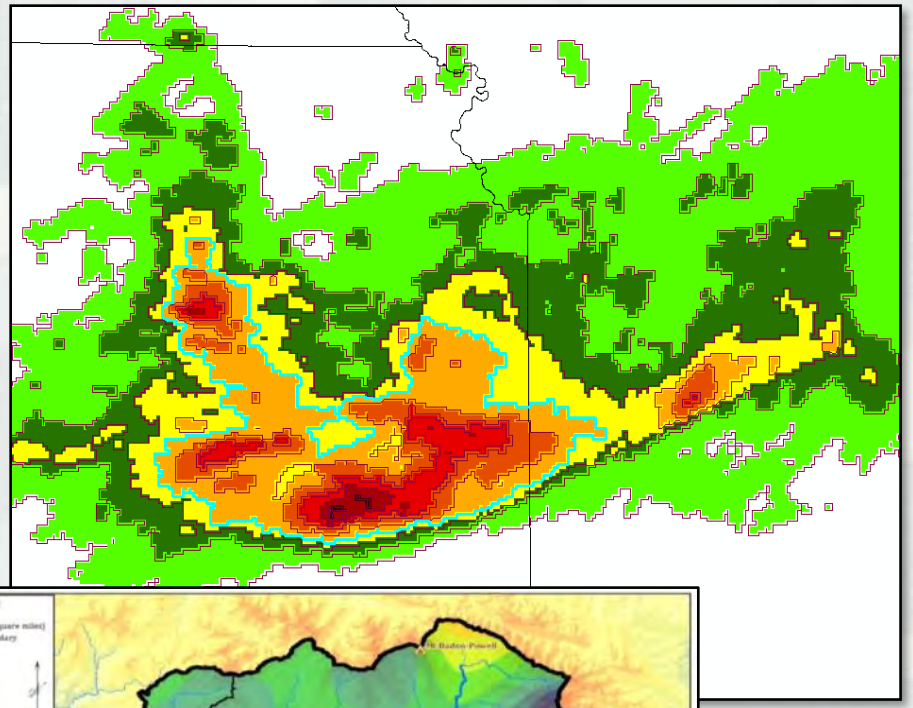


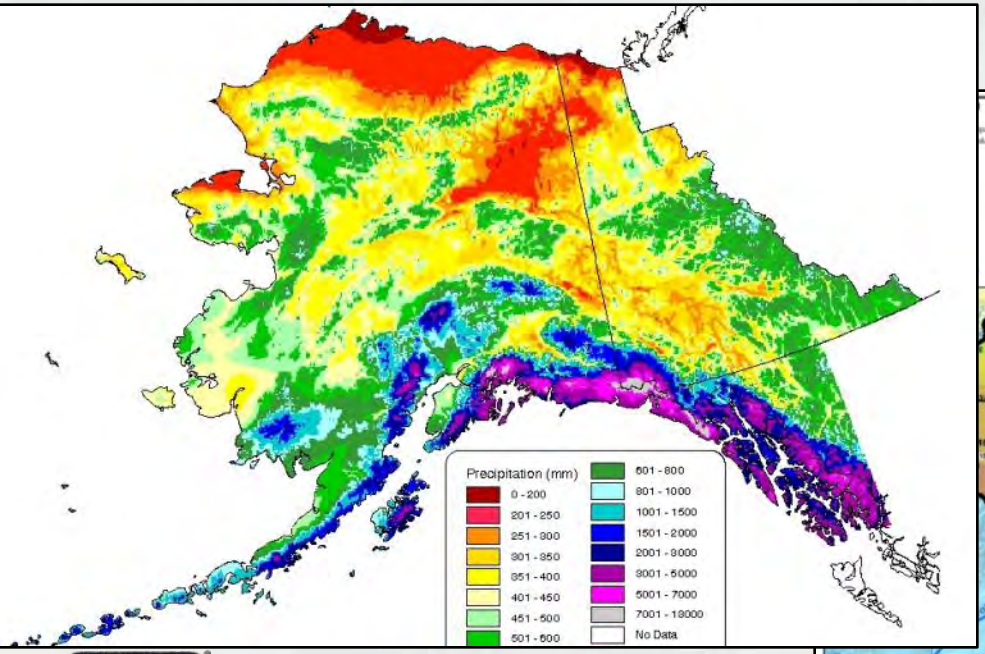
Location of USACE Dams

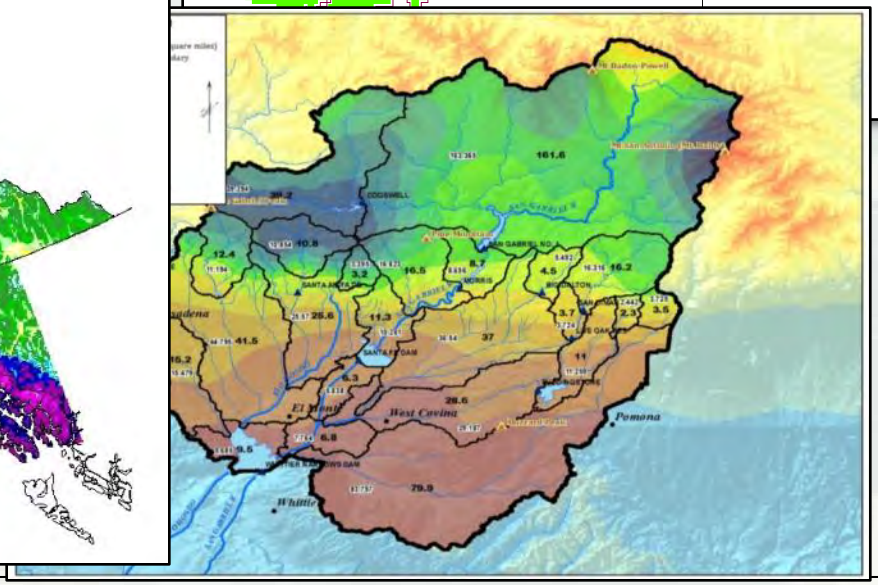


Site Specific Studies

- **Site Specific PMP Studies**
  - Completed: Moose Creek, Bluestone, Whittier Narrows
  - In progress: Martis Creek, Ft Peck, Garrison, Kajaki
- **Antecedent Storm Studies**
- **Atmospheric Modeling**







Status of NOAA HMRs

HMR	Publication Date	Latest Storm Used
49	1977	Sept. 3-7, 1970
51	June 1978	June 19-23, 1972
55A	June 1988	Aug. 1-4, 1978
57	October 1994	Dec. 24-26, 1980
59	February 1999	Feb. 14-19, 1986

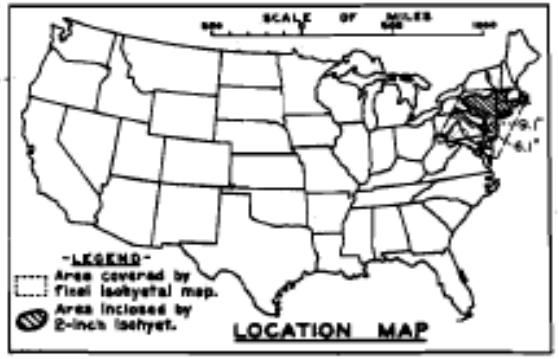
6 of the Top 10 Texas Storms Have Occurred Since HMR 55A Publication

Rank	Rainfall (inches)	Date	Location	Storm
1	43	7/24-25 1979	Alvin	TS Claudette
2	42	8/1-2 1978	Kerr County	TS Amelia
3	38.2	9/9-10 1921	Thrall	Unnamed
4	36	7/1-2 1932	Ingram	None
5	35	6/27-28 1954	Pandale	Alice
6	34	9/20 1967	Nueces River	Beulah
7	33	8/3 1978	Shackleford Co	TS Amelia
8	30	10/17-18 1998	San Marcos	None
9	28.8	6/9 2001	Houston	TS Allison
10	25	10/19 1984	Oden	Unnamed

Extreme Storm Catalog

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

STORM STUDIES – PERTINENT DATA SHEET



Storm of 26-29 July 1897
Assignment NA 1-7 (a)
Location North
Study Prepared
North Atlan
New York Di
Part I Review
Weather Bu
Part II Approv
of Engineer
of Factual
Remarks: Nor
Centers at
Elizabeth

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 1 sheet, scale 1:2,500,000
Precipitation data and mass curves: (Nu
Form 5001-C (Hourly precip. data)
Form 5001-B (24-hour " ")
Form 5001-D (" " " ")
Misc. precip. records, meteorological data, etc.
Form 5002 (Mass rainfall curves)

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)	2
Form S-12 (Maximum depth-duration data)	5
Maximum duration-depth-area curves	3
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	6.2	8.1	8.6	8.7	8.9	9.0	9.0	9.1	9.1	9.1
100	4.3	7.3	7.5	7.8	7.9	8.0	8.0	8.1	8.1	8.1
200	3.8	6.6	6.8	7.0	7.1	7.2	7.3	7.3	7.3	7.3
500	3.1	5.5	5.7	5.9	6.0	6.1	6.2	6.3	6.3	6.3
1,000	2.8	4.6	4.8	4.9	5.1	5.2	5.3	5.4	5.5	5.5
2,000	2.4	3.9	4.0	4.1	4.3	4.4	4.5	4.6	5.1	5.1
5,000	1.9	3.1	3.3	3.3	3.4	3.7	3.8	3.9	4.0	4.1
10,000	1.5	2.6	2.8	2.9	2.9	3.3	3.4	3.5	3.6	3.7
20,000	1.1	2.1	2.4	2.5	2.6	2.9	3.1	3.2	3.3	3.4
26,000	1.0	1.9	2.1	2.2	2.3	2.8	3.0	3.2	3.3	3.3

Form S-2

WAR DEPARTMENT

STORM
RAINFALL
IN THE
UNITED STATES

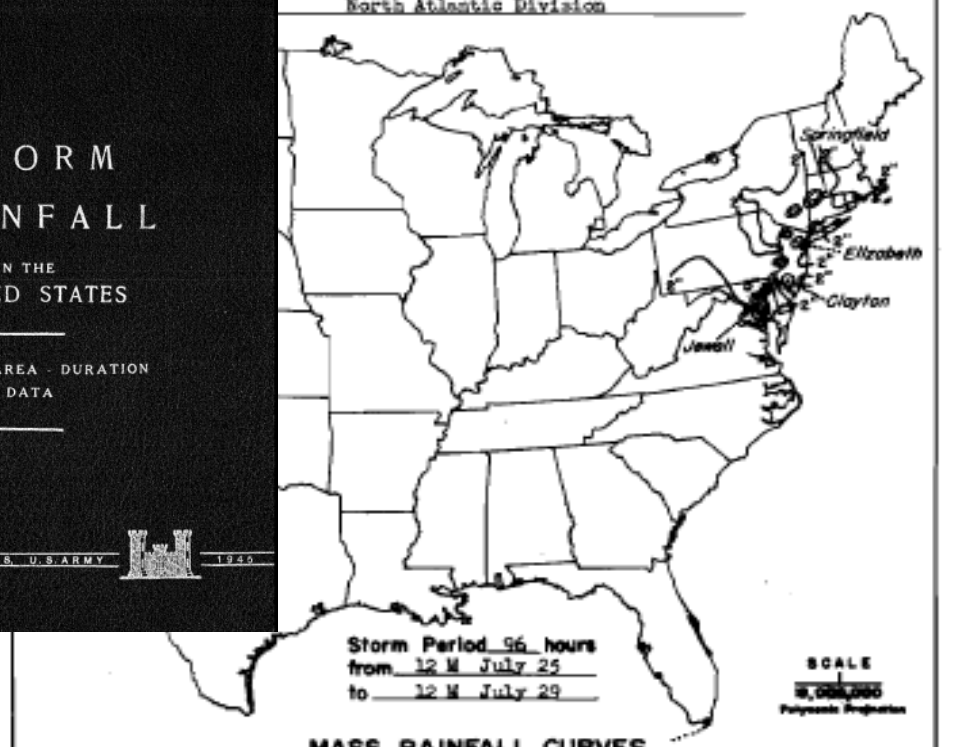
DEPTH - AREA - DURATION
DATA

CORPS OF ENGINEERS, U.S. ARMY 1945

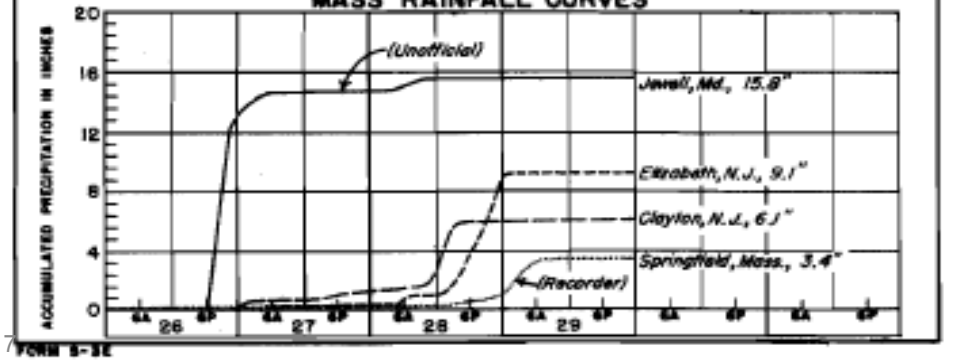
WAR DEPARTMENT — CORPS OF ENGINEERS, U.S. ARMY

STORM STUDIES – ISOHYETAL MAP

Storm of July 26-29, 1897 Assignment NA 1-7 (a)
Study Prepared by: New York, N. Y. District
North Atlantic Division



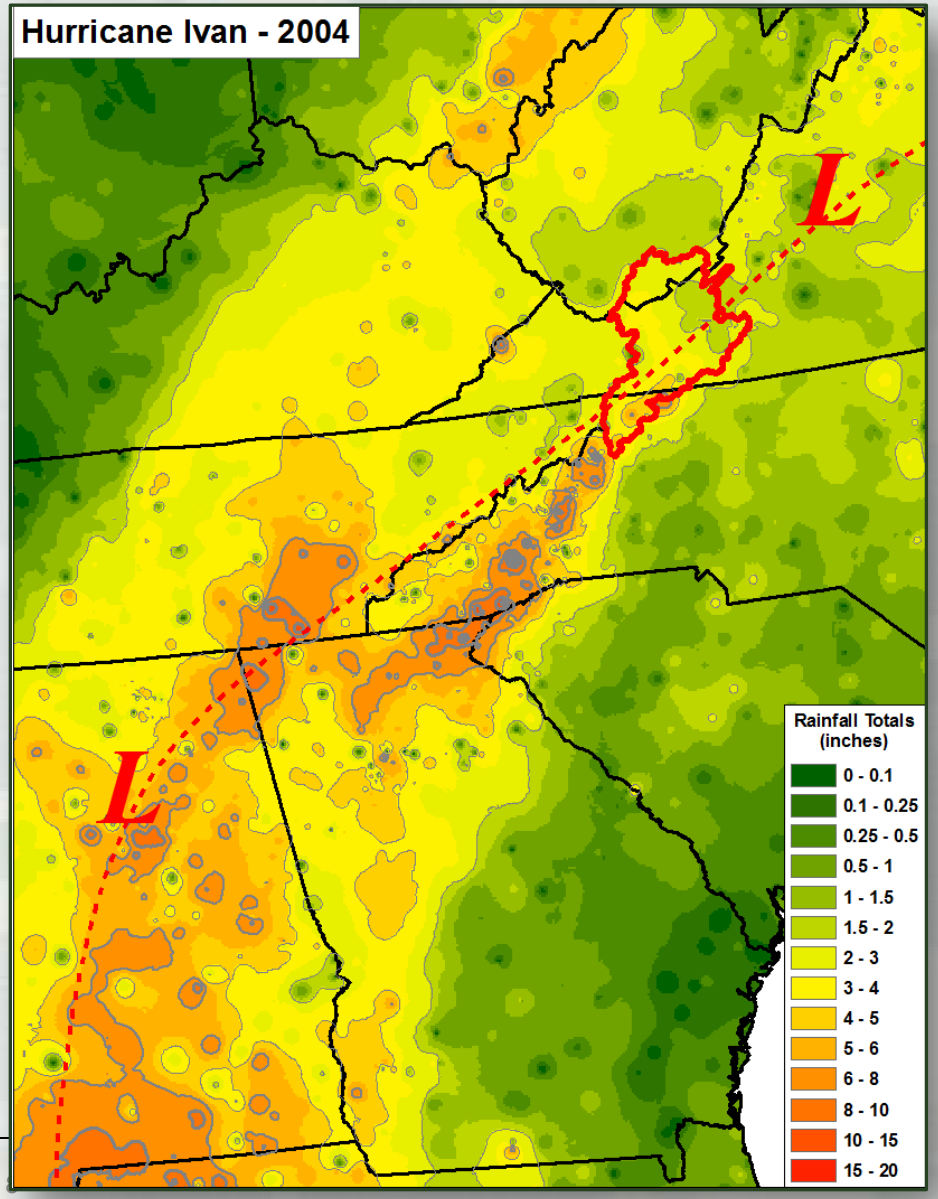
MASS RAINFALL CURVES



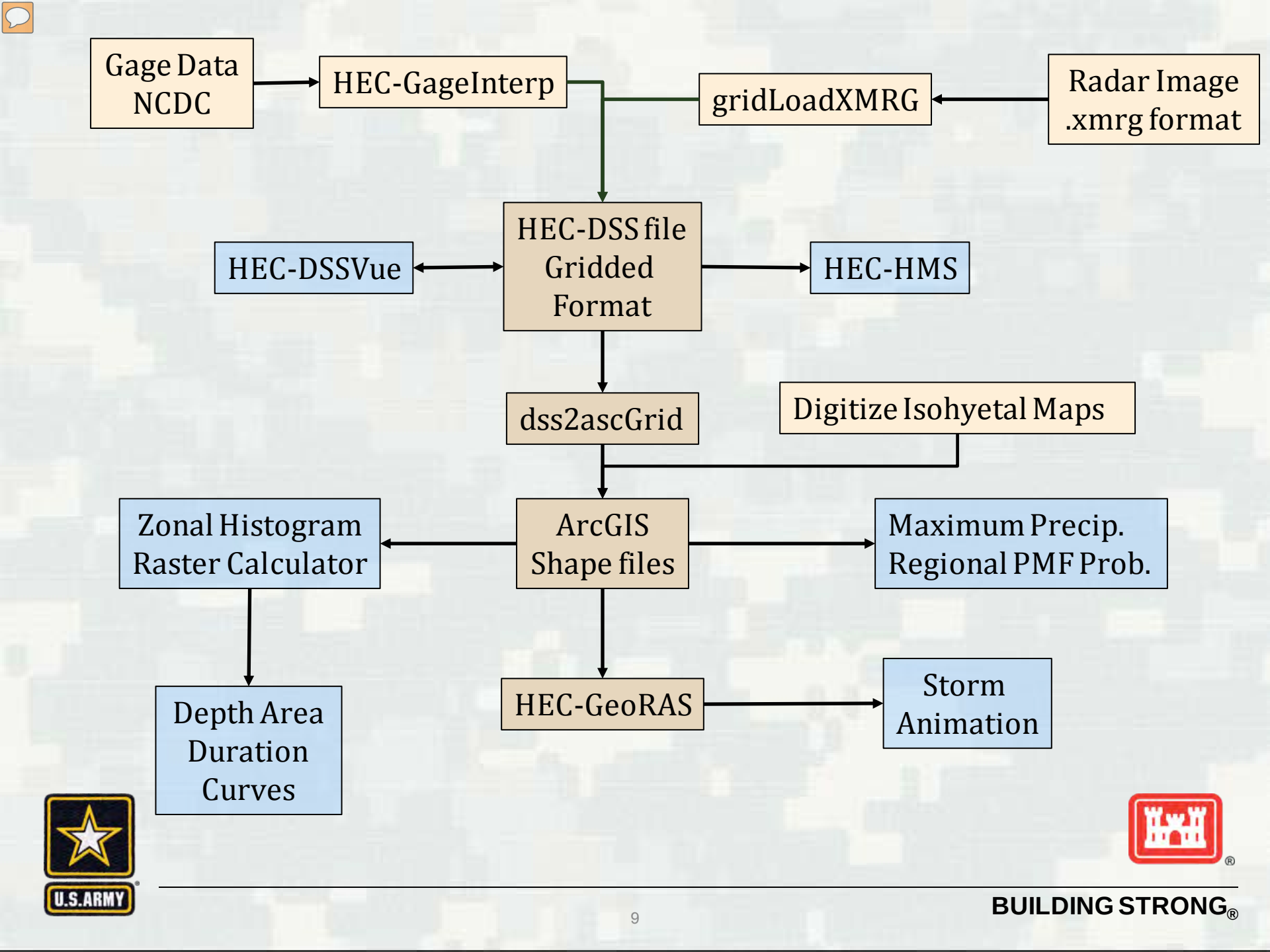
FORM S-3E

Extreme Storm Database

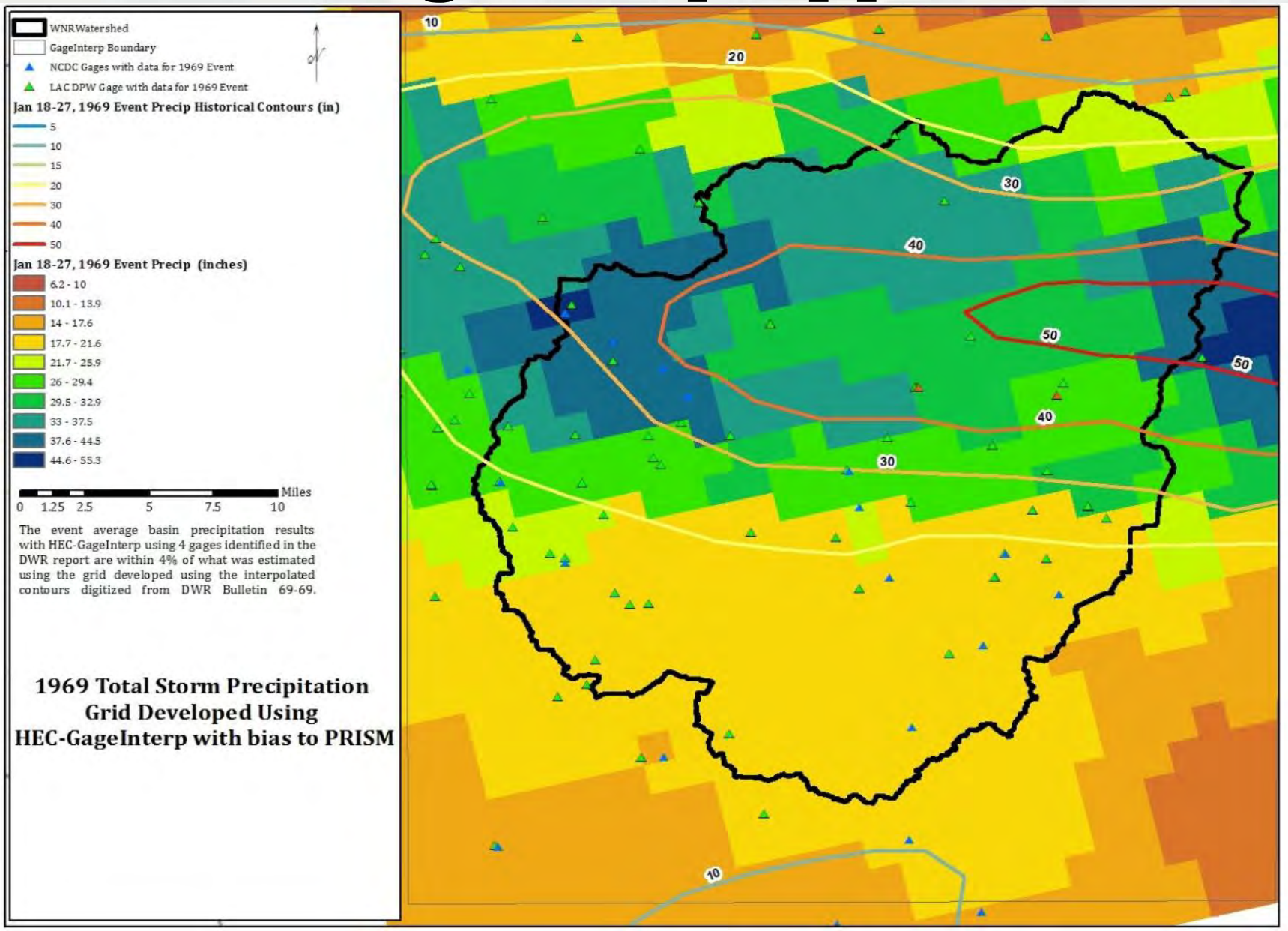
- Common Database shared with all federal and state agencies, academia, private consultants
- Historic and Synthetic Extreme Storms
- Depth Area Duration, Isohyetal maps, mass rainfall curves, meteorological characteristics
- Interfaced with Hydrologic Models, tools, etc



U.S.ARMY



HEC-GageInterp Approach



Extreme Storm Database

Select Storm by Map or by Searching Catalog

U.S.ARMY

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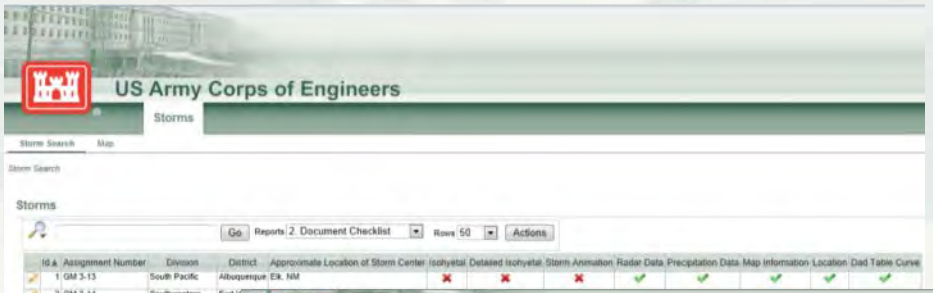
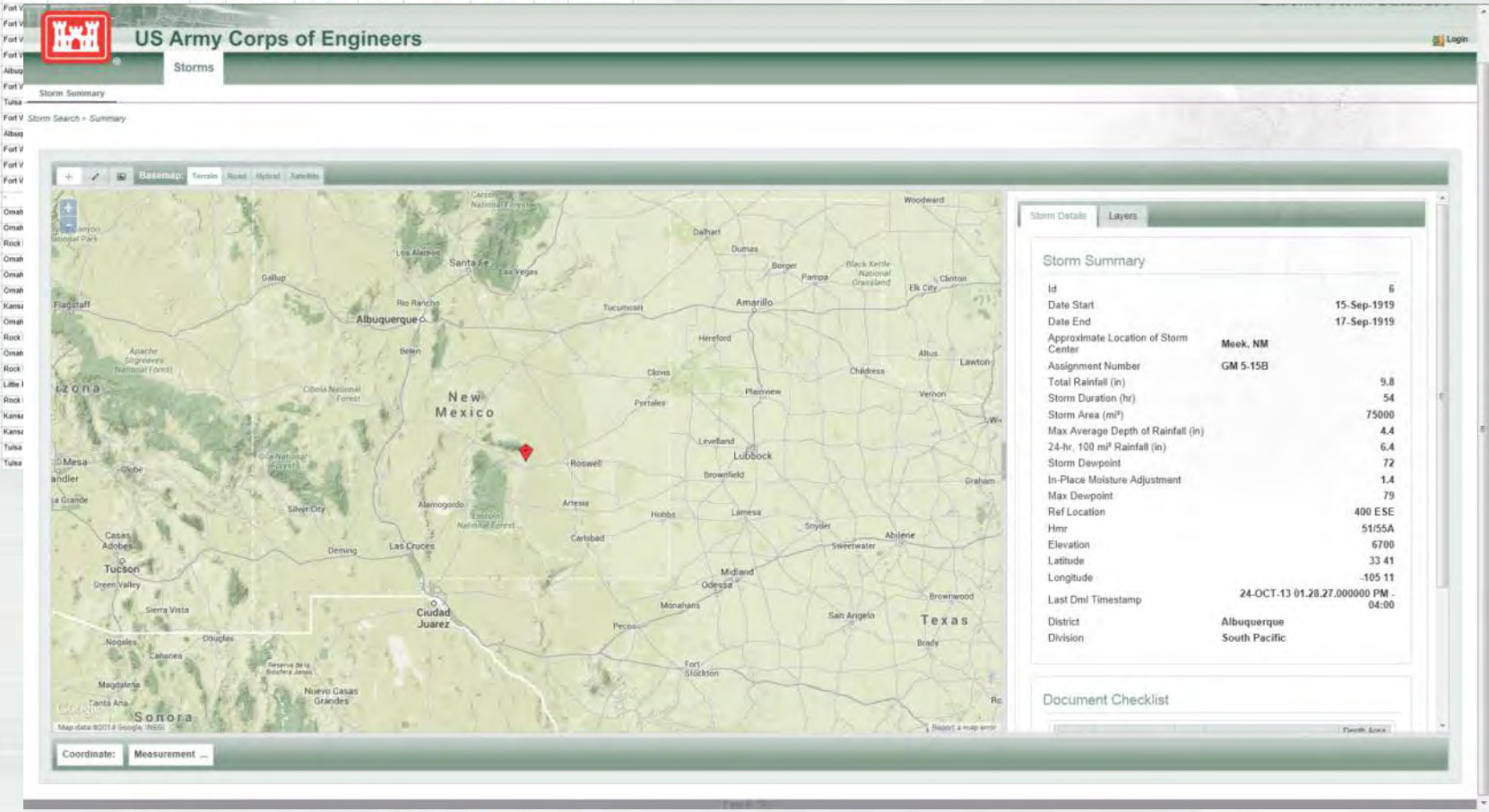
Extreme Storm Database



Obtain Storm Documents, Storm Summary, and Data



Planned Extreme Storm Database Enhancements

- **Lat/Long Search Box or by Location/Radius**
- **Field for Storm Type (ie, synoptic, convective)**
- **Access by non-Corps (read-only, edit, add rights)**
  - Field to ID who entered/edited data
- **DAD Tables**
  - Search & Interpolate any area or duration
  - Plot DAD Curves
- **Show Reference Location on Map**
- **Extract Dew Points from Map**
- **Extract PMP from Map**
  - Compute % PMP

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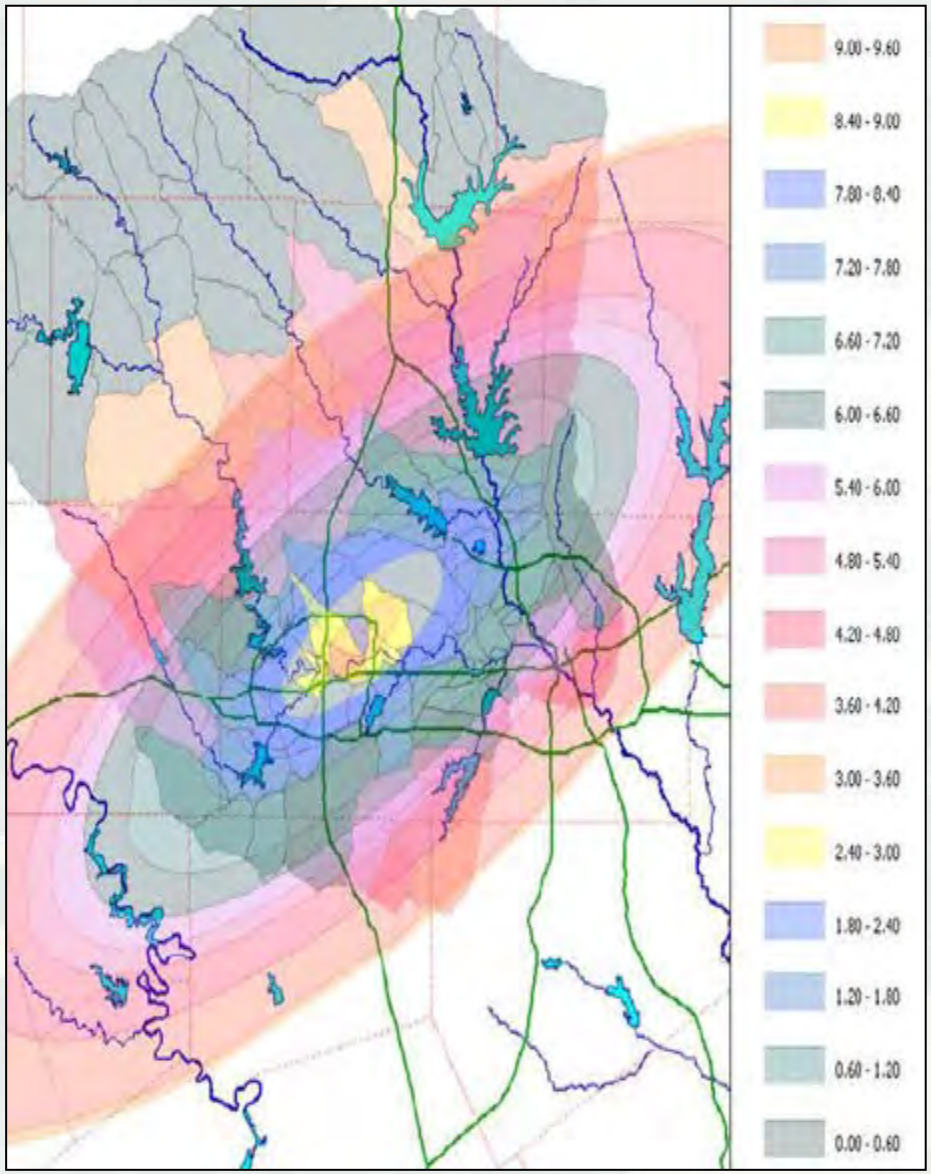
HEC-MetVue

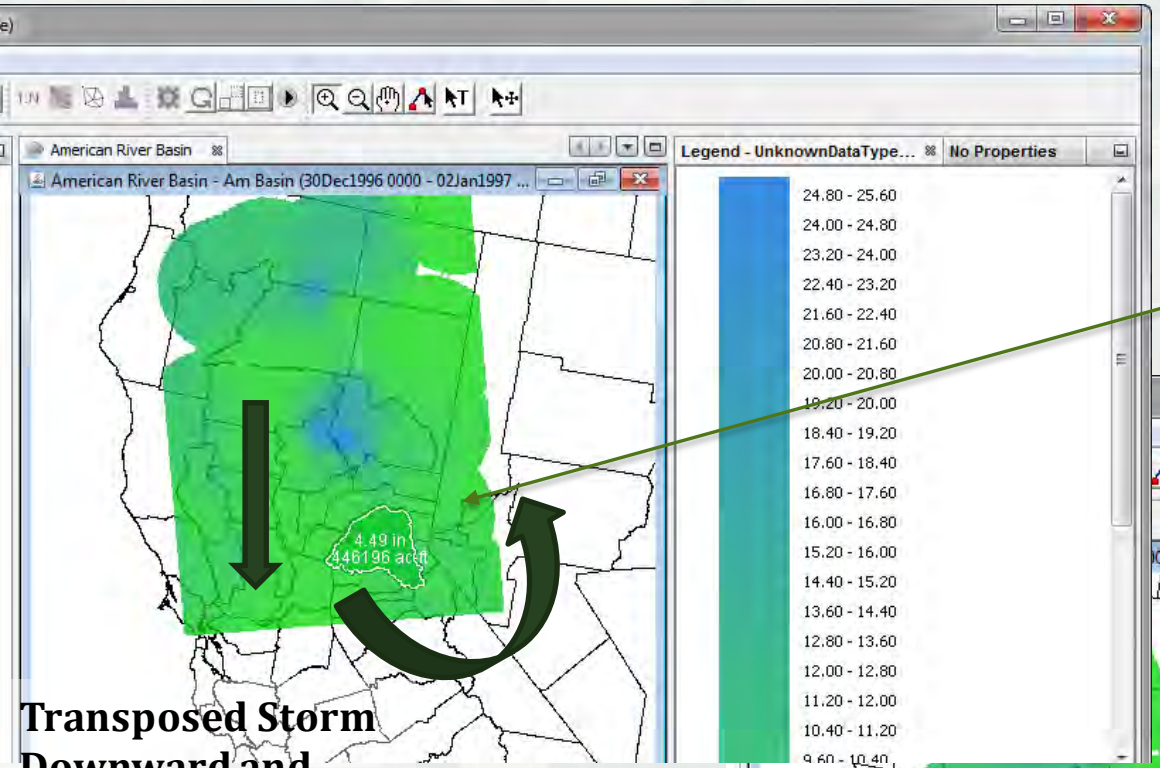
- **GIS-Based Meteorologic Model / Visualization Tool**
  - Accepts shapefiles in any coordinate system
- **Inputs**
  - QPE, QPF (XMRG, NetCDF)
  - Gage Data (ASCII, DSS)
- **Outputs**
  - Hyetographs/ Gridded Precipitation (HRAP,SHG)
- **Analyze Historic Storms**
  - Compute DAD
  - Translate, Rotate, Maximize
  - Calibrate QPE to gage data or PRISM data
  - Aggregate/Segregate Storms
- **Develop Design Storms**
  - Hypothetical Frequency Based
  - PMP (HMR51/52, HMR55A, HMR58/59)
- **Linkage with HEC-HMS/Extreme Storm Database**
- **Future work : Sample storm characteristics such as movement, centroid location, and orientation**



HEC-MetVue

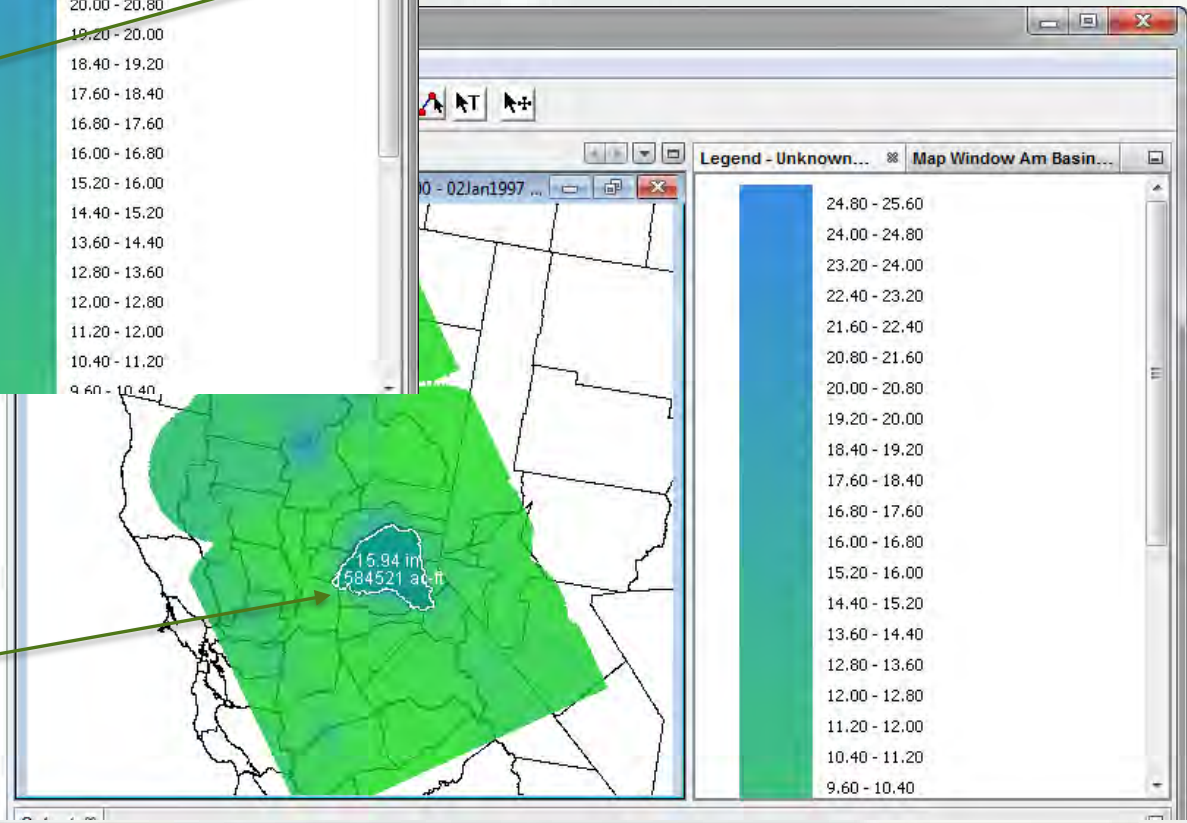
Dynamically updates basin average precipitation with transposed, reoriented storm

Basin Precipitation = 4.49 inches



Transposed Storm Downward and Rotated 20 Degrees

Basin Precipitation = 15.94 inches



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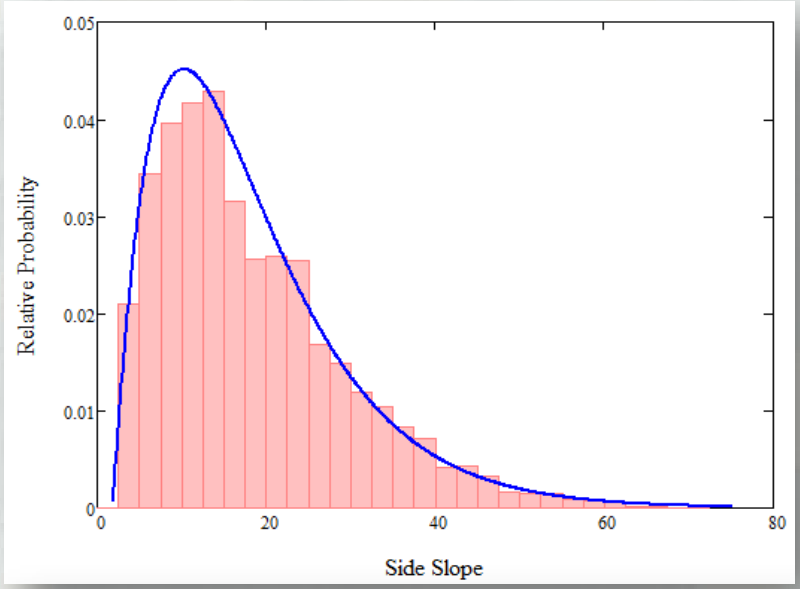
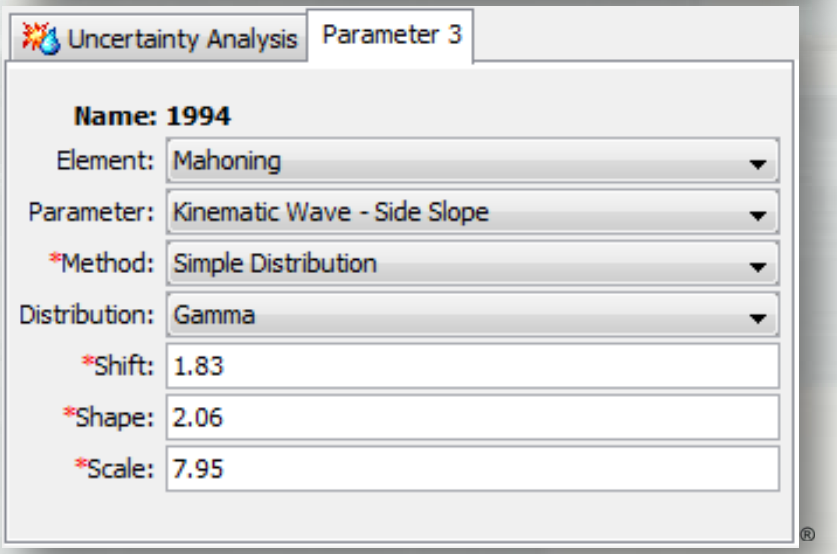
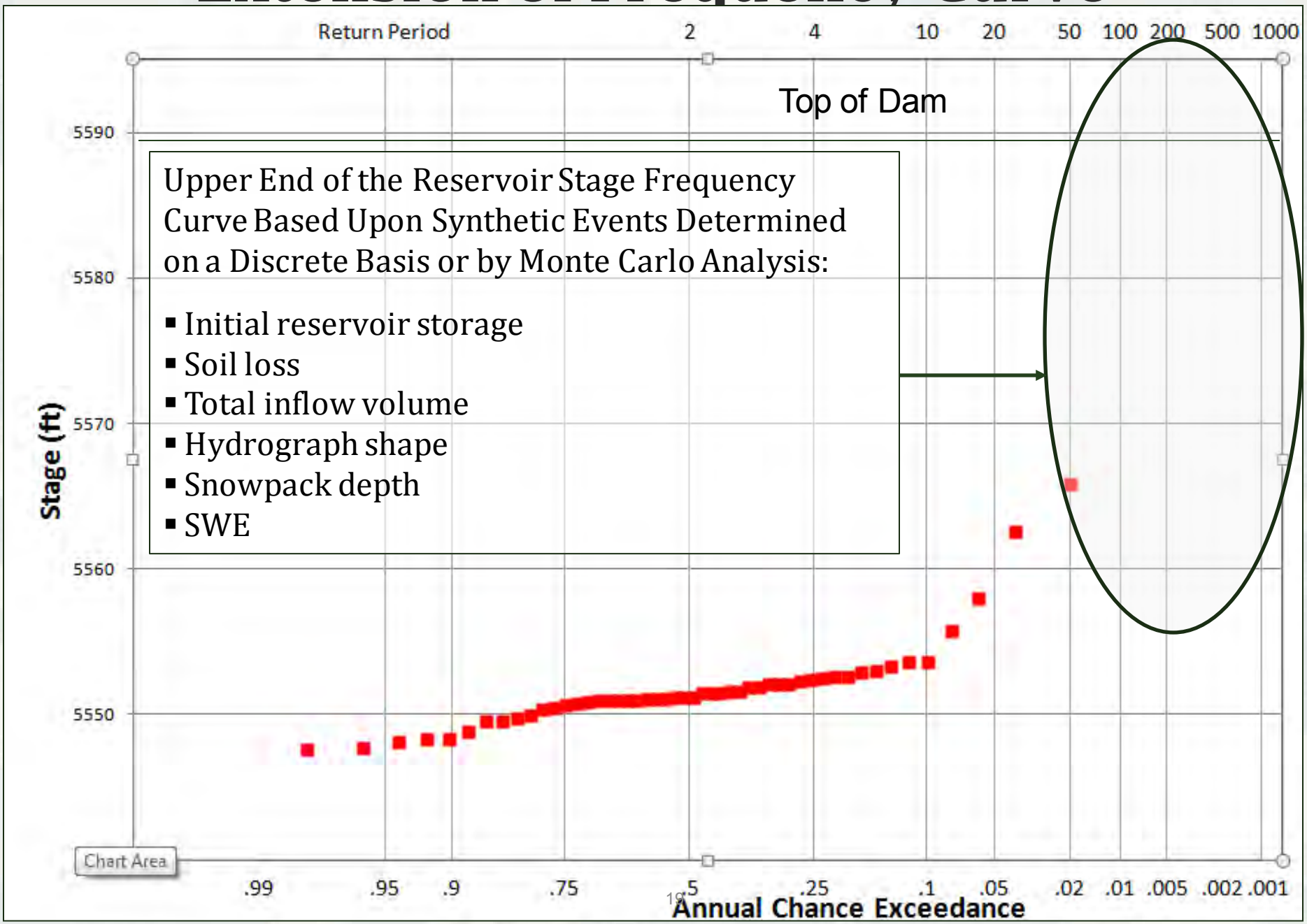
Monte Carlo Capabilities in HEC Software

- **Monte Carlo sampling capabilities are being added to HEC Software:**
  - HEC-HMS - Loss Rate, Transform, Baseflow, and Routing
  - HEC-ResSim – Initial conditions, Rules (like maximum releases), and input TS
  - HEC-RAS – Manning's n-values and dam breach parameters
  - HEC-FIA – Stage-damage information and structure elevations
- **User defines parameters for uncertainty distributions (**Beta, Exponential, Gamma, Log-Normal, Normal, Triangular, Uniform, Weibull)
- **Independent and Dependent Parameter Sampling**
- **When used within a HEC-WAT Monte Carlo simulation, HEC-WAT helps to manages sampling of model data/parameters**

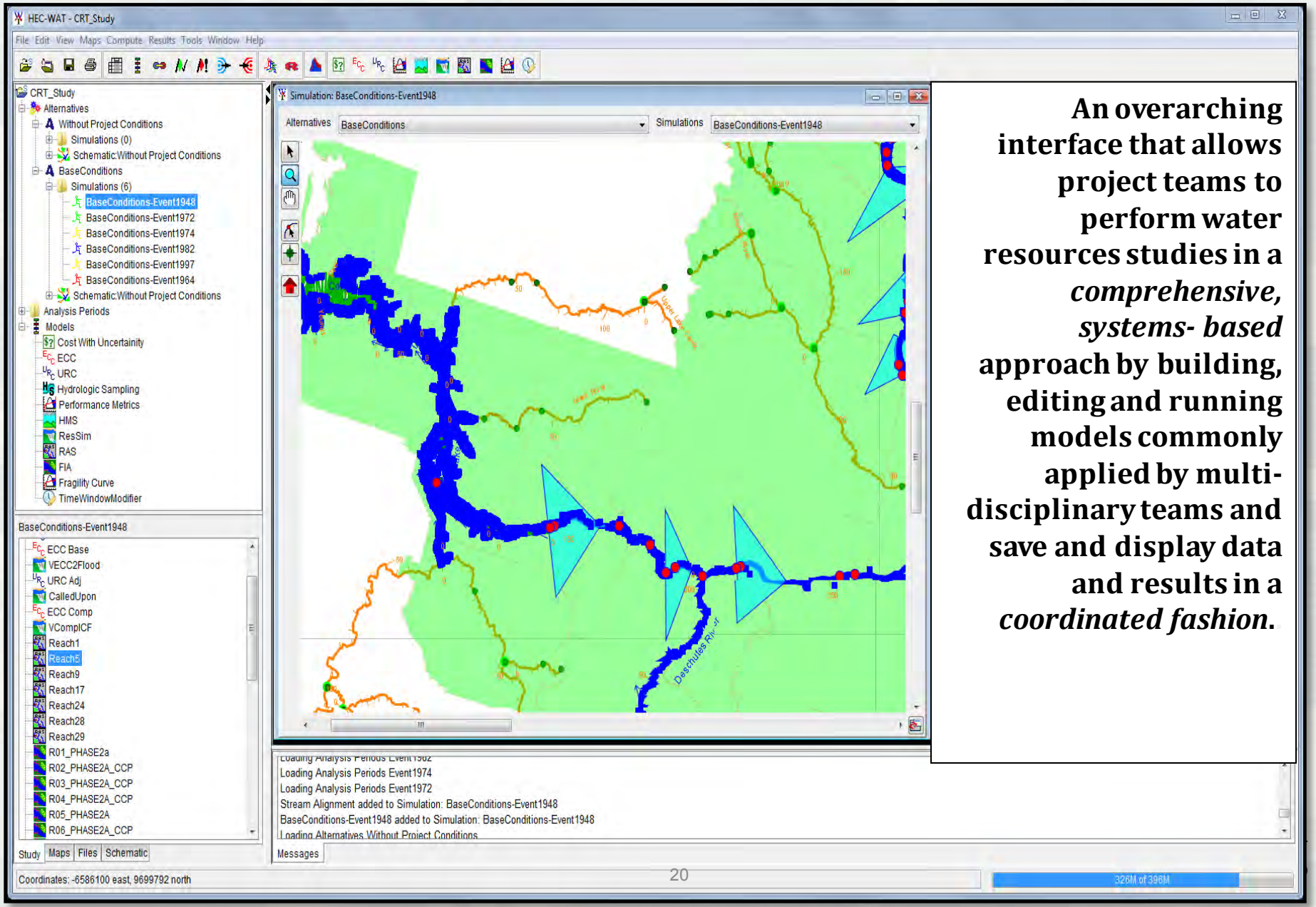




Extension of Frequency Curve



HEC-WAT



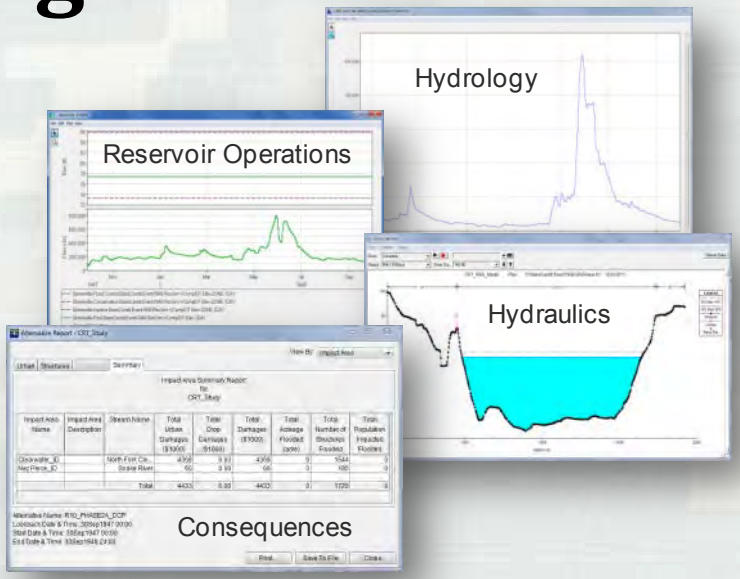
An overarching interface that allows project teams to perform water resources studies in a *comprehensive, systems- based* approach by building, editing and running models commonly applied by multi-disciplinary teams and save and display data and results in a *coordinated fashion*.

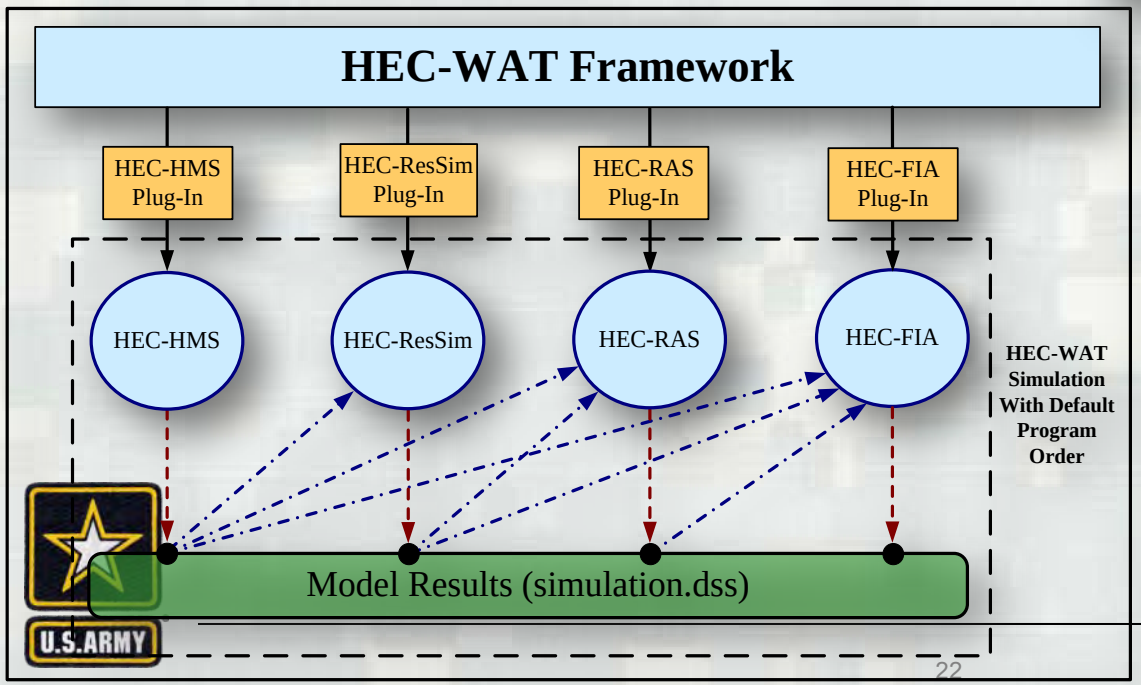
HEC-WAT for the Columbia River Watershed

- 258,000 sq. miles
- 2 countries
- 7 states
- 1,214 miles
- 125 tributaries
- Approximately 176,000 structures
- 65 projects
- 100 fragility curve locations
- 43 consequence areas
- 128 levee systems; 449 miles

HEC-WAT – Linking Models

- The initial set of models and tools to be used during the analytical process in HEC-WAT are:
  - Hydrology (HEC-HMS)
  - Reservoir Operations (HEC-ResSim)
  - Hydraulics (HEC-RAS)
  - Consequences (HEC-FIA)





- Communication between software is provided through a "plug-in."
- Data is shared through a common DSS file.

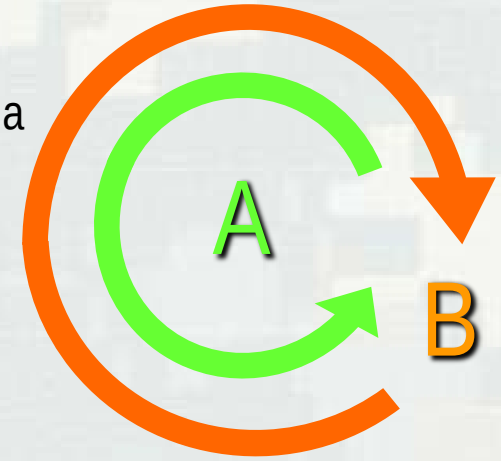
Nested Sampling Approach for Monte Carlo Simulations

Nested Monte Carlo:

A. Sample instances of **natural variability** as flood *events*, with enough events to capture the distribution of damage

B. Sample instances of **knowledge uncertainties** in model parameters to get their impact on the damage distribution

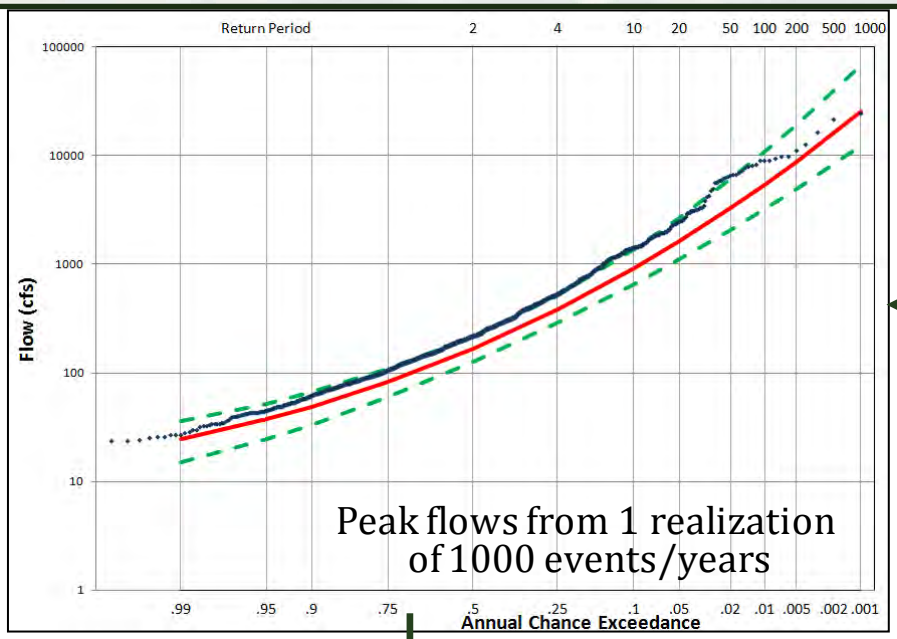
1 outer loop B = a realization

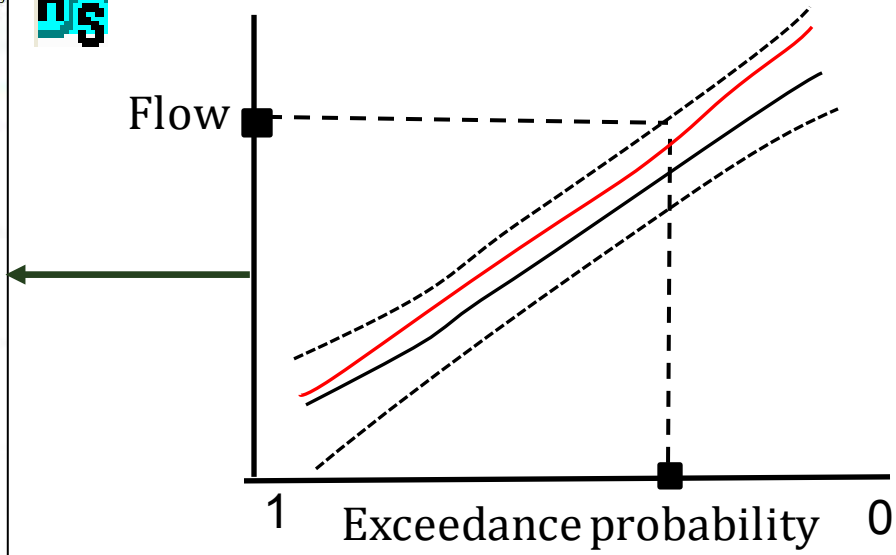


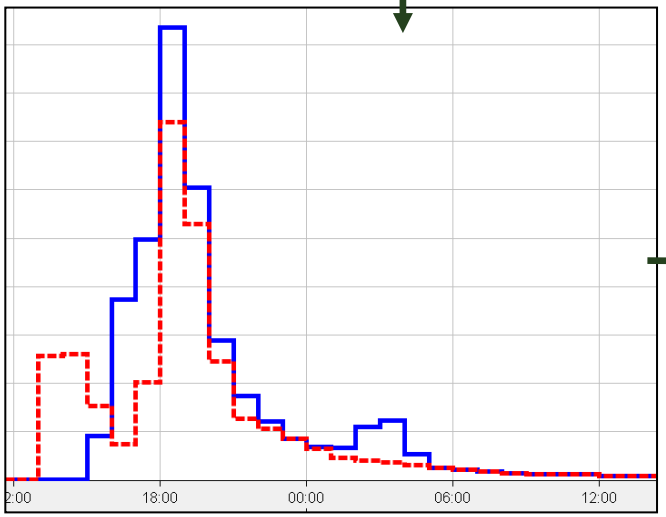
inner loop A varies natural variabilities, computes EAD

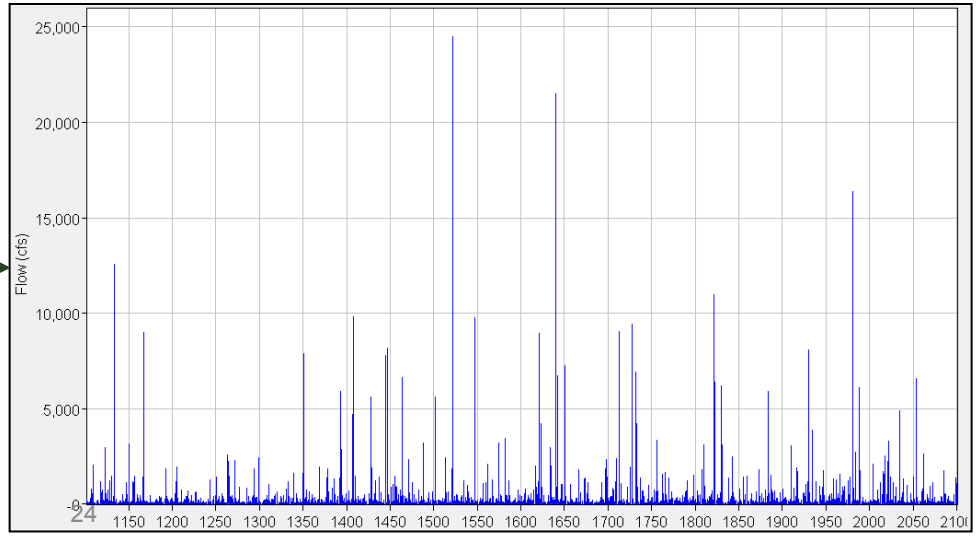
outer loop B varies knowledge uncertainty, computes EAD distribution

Nested Sampling Approach for Monte Carlo Simulations

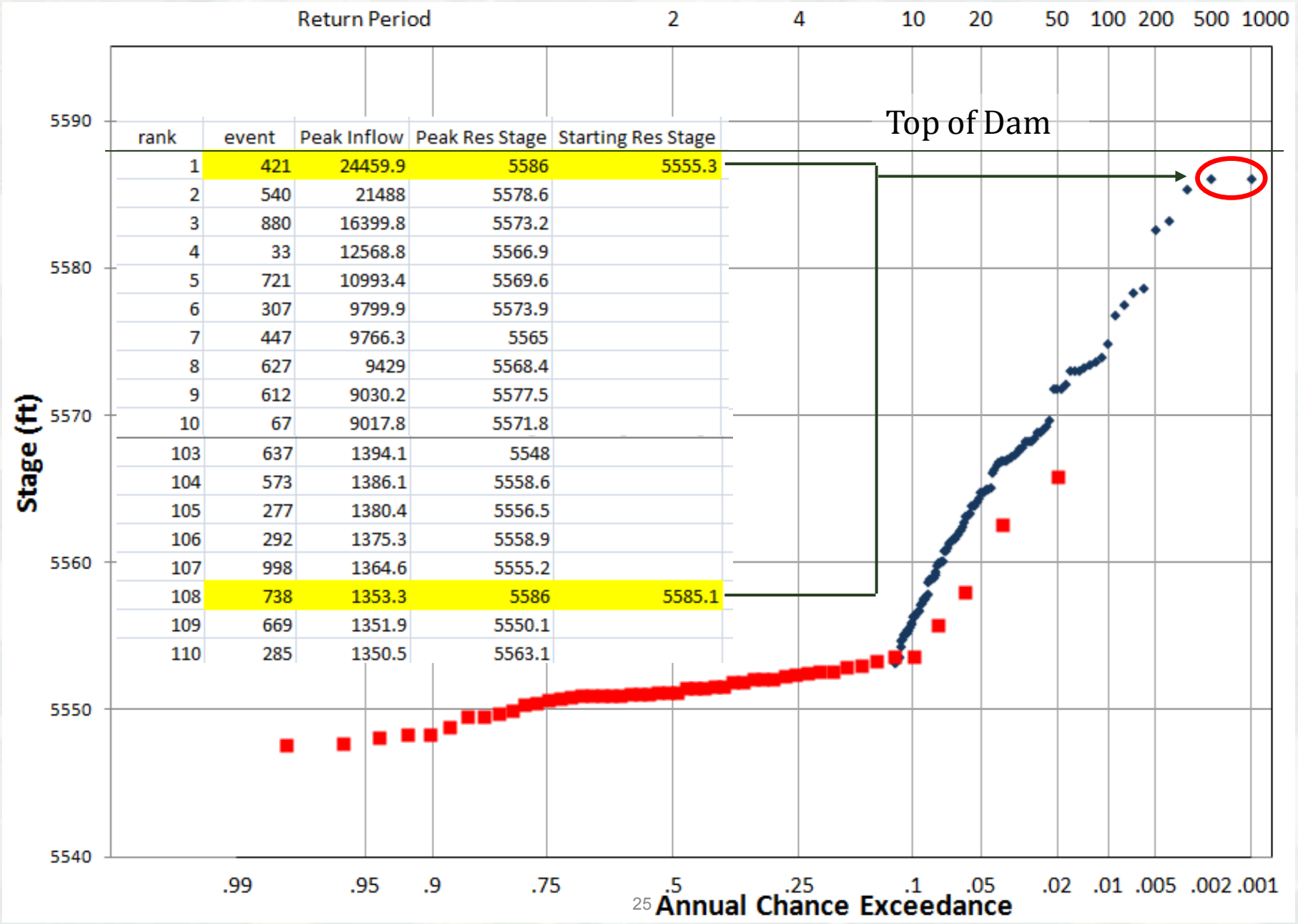






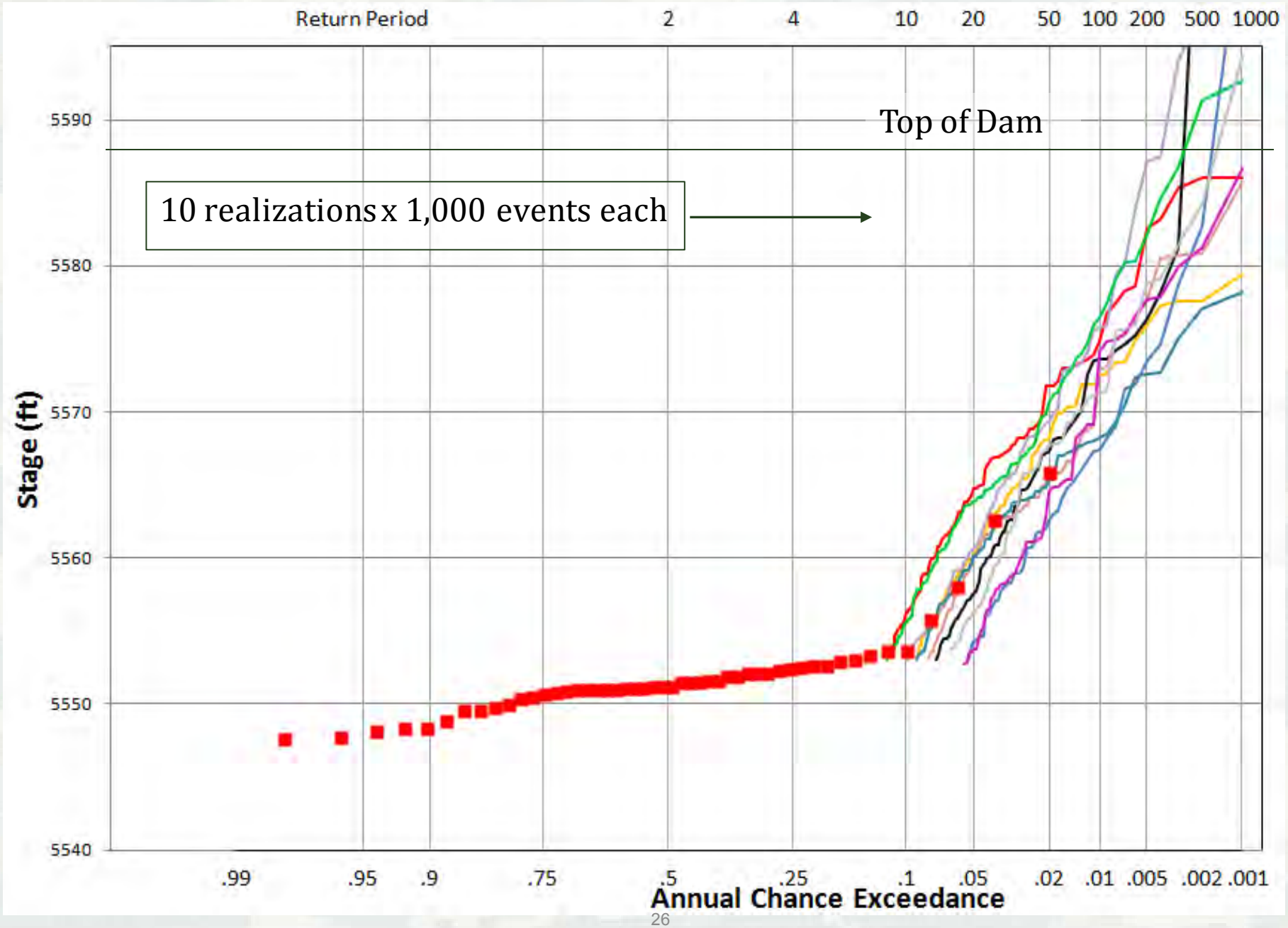


Peak Reservoir Stage from 1 Realization



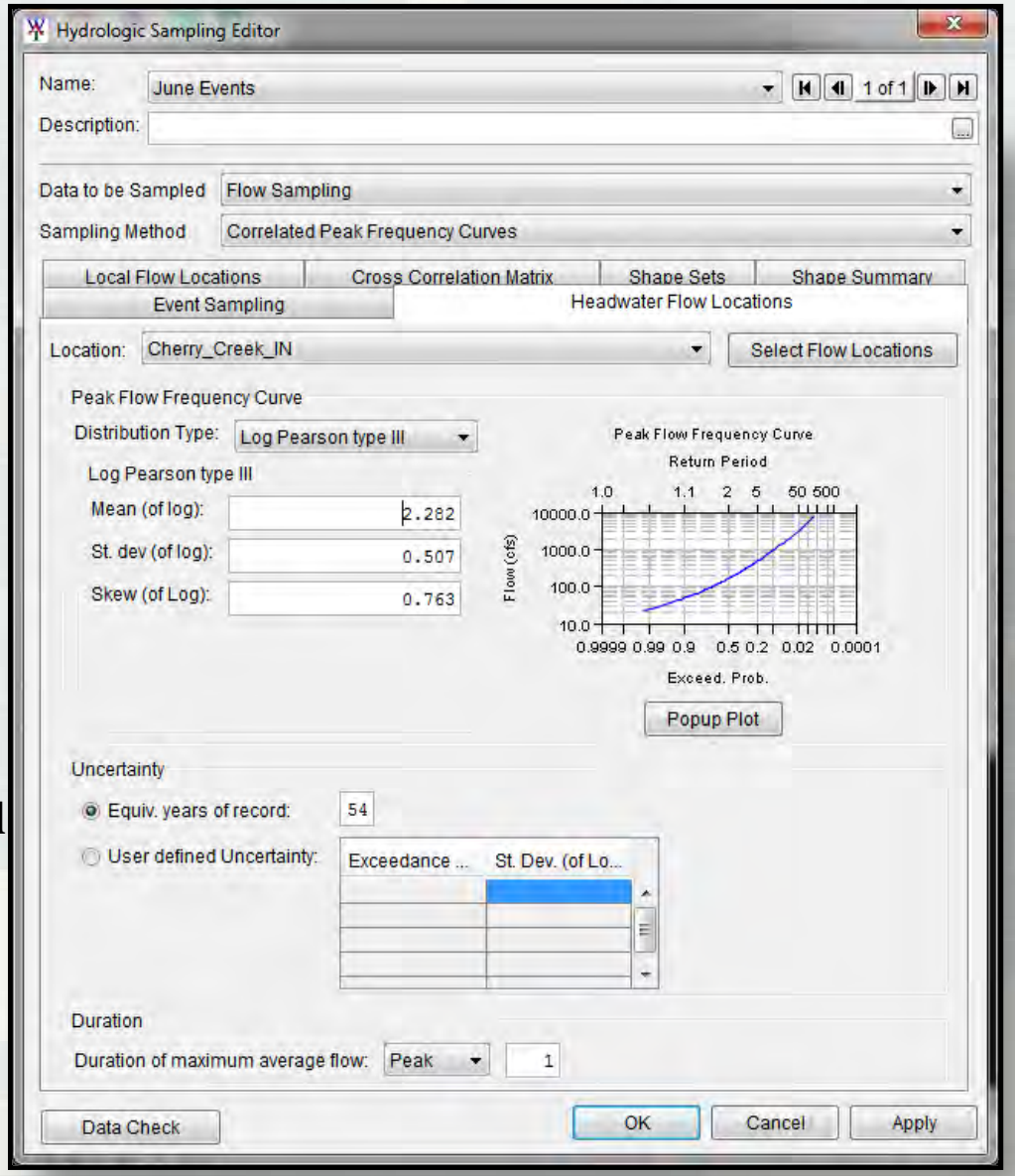
rank	event	Peak Inflow	Peak Res Stage	Starting Res Stage
1	421	24459.9	5586	5555.3
2	540	21488	5578.6	
3	880	16399.8	5573.2	
4	33	12568.8	5566.9	
5	721	10993.4	5569.6	
6	307	9799.9	5573.9	
7	447	9766.3	5565	
8	627	9429	5568.4	
9	612	9030.2	5577.5	
10	67	9017.8	5571.8	
103	637	1394.1	5548	
104	573	1386.1	5558.6	
105	277	1380.4	5556.5	
106	292	1375.3	5558.9	
107	998	1364.6	5555.2	
108	738	1353.3	5586	5585.1
109	669	1351.9	5550.1	
110	285	1350.5	5563.1	

Peak Reservoir Stage from 10 Realizations

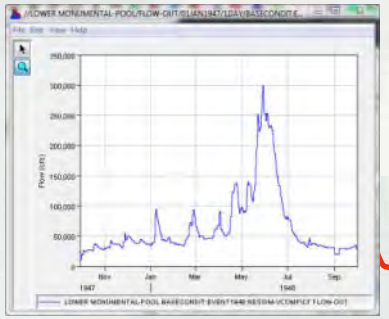


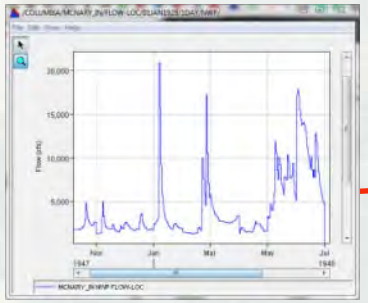
The Hydrologic Sampler

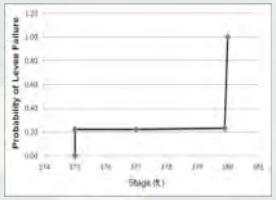
- Generate the boundary conditions for the first model in the compute sequence (initially, this has been flow)
- Two methods for generating flow data:
  - Sampling from a frequency curve (and applying a shape)
  - Sampling historic events
- New Sample precipitation depth
- Sample hyetograph shapes
- Future: Incorporating HEC-MetVue to sample storm characteristics, such as storm centroid, depth-area-duration, angle of orientation, and pass either a grid or hyetographs to HEC-HMS.

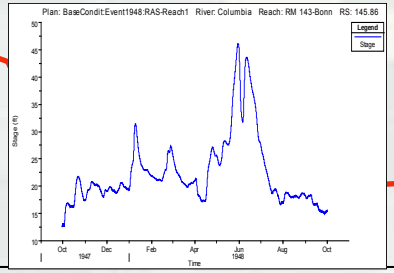


Flow Volume Sampling → Hydrographs → Integrated Routing through HEC-WAT (HEC-HMS, HEC-ResSim, HEC-RAS, HEC-FIA)→ Systems-Based Watershed Assessment









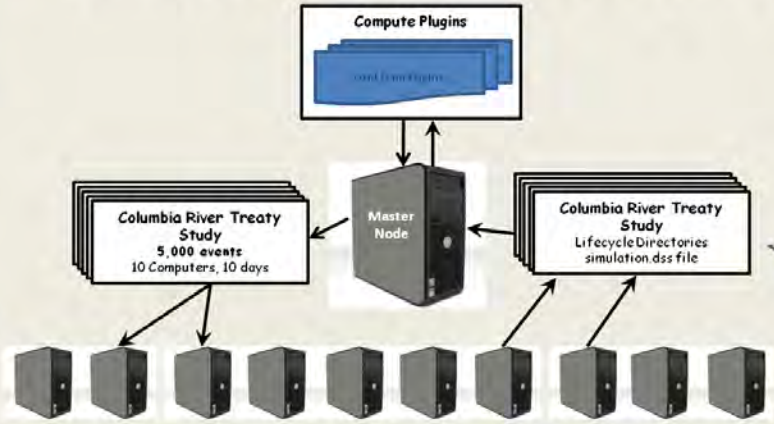
Distributed Computing

Testing Model Setup

Columbia River Treaty Study
100 lifecycles; 5,000 events
86.8 days

Compute can be run standalone on a single PC to test and calibrate the models and the linkages between models.

Local Network Compute



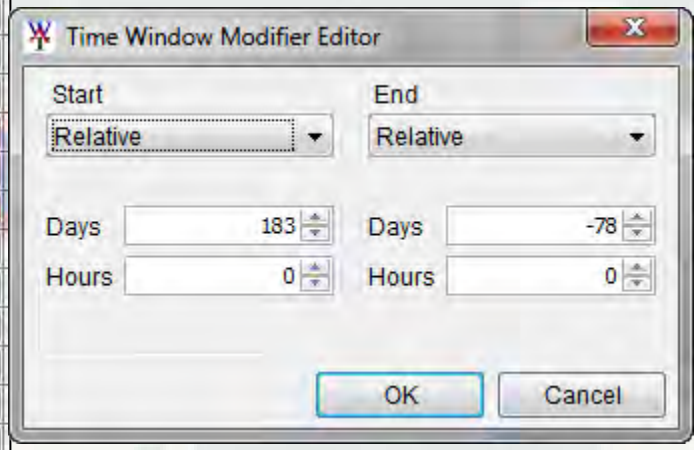
Compute can be distributed on computers on the local area network. One realization to each computer.

Time Window Modifications

Order of Time Window Modifications

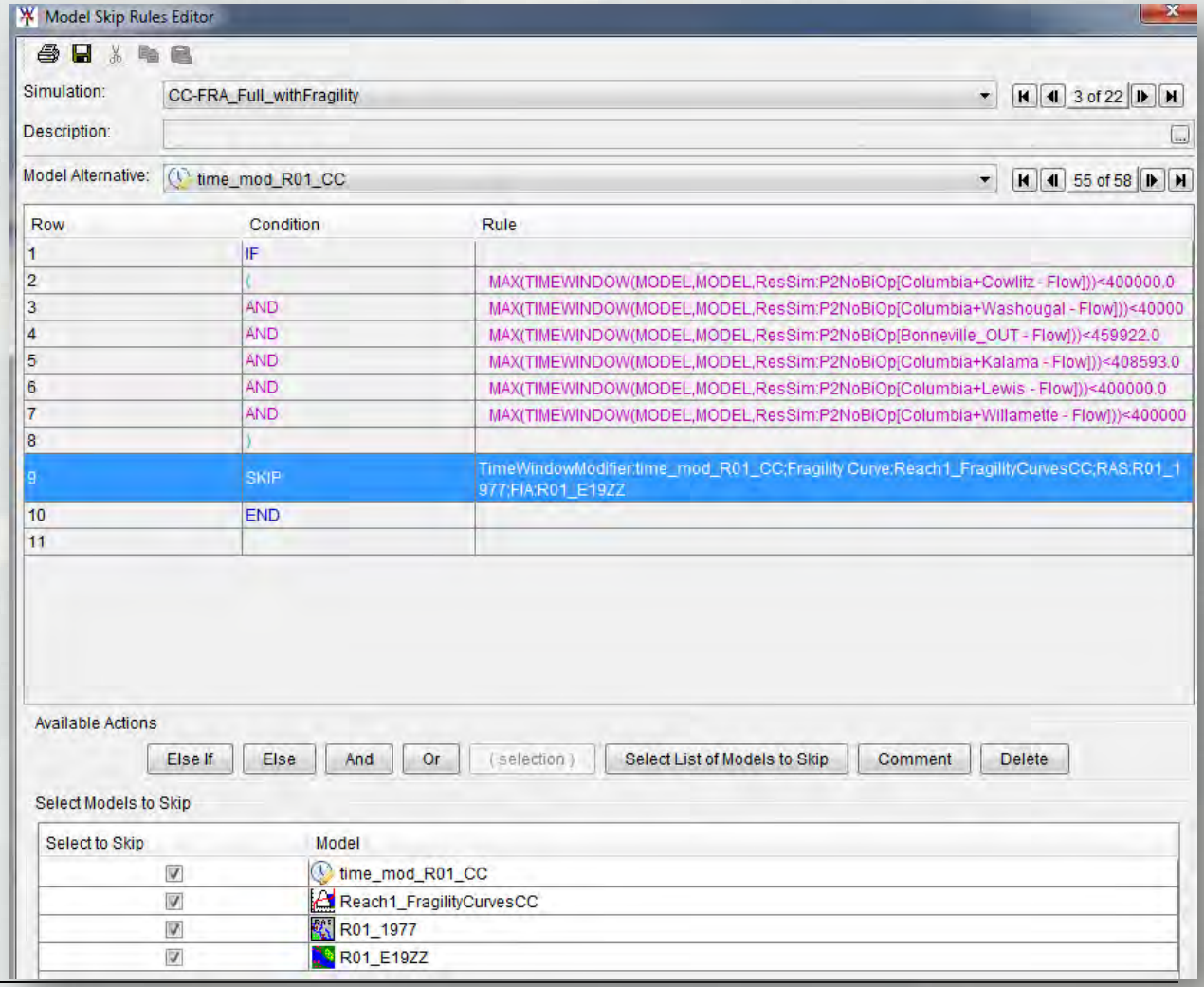
1) Simulation Window (defined by the hydrograph shapes)
2) Time Window Modification (with in the simulation)
3) Time Window Modification Alternative (simple model)
4) Scripting Option with Time Window Modification Alternative

FIA	R17_E19ZZ	Simulation Window	Edit...
TIMEWINDOWMODIFIER	time_mod_R09	Simulation Window	(+183D), (-78D)
Fragility Curve	Reach9_Fragility...	Simulation Window	Edit...
RAS	R09_1977	time_mod_R09	Edit...
FIA	R09_E19ZZ	Simulation Window	Edit...
TIMEWINDOWMODIFIER	time_mod_R05	Simulation Window	(+183D), (-78D)
Fragility Curve	Reach5_Fragility...	Simulation Window	Edit...
RAS	R05_1977	time_mod_R05	Edit...
FIA	R05_E19ZZ	Simulation Window	Edit...
TIMEWINDOWMODIFIER	time_mod_R01_...	Simulation Window	(+183D), (-78D)
Fragility Curve	Reach1_Fragility...	Simulation Window	Edit...
RAS	R01_1977	time_mod_R01_...	Edit...
FIA	R01_E19ZZ	Simulation Window	Edit...

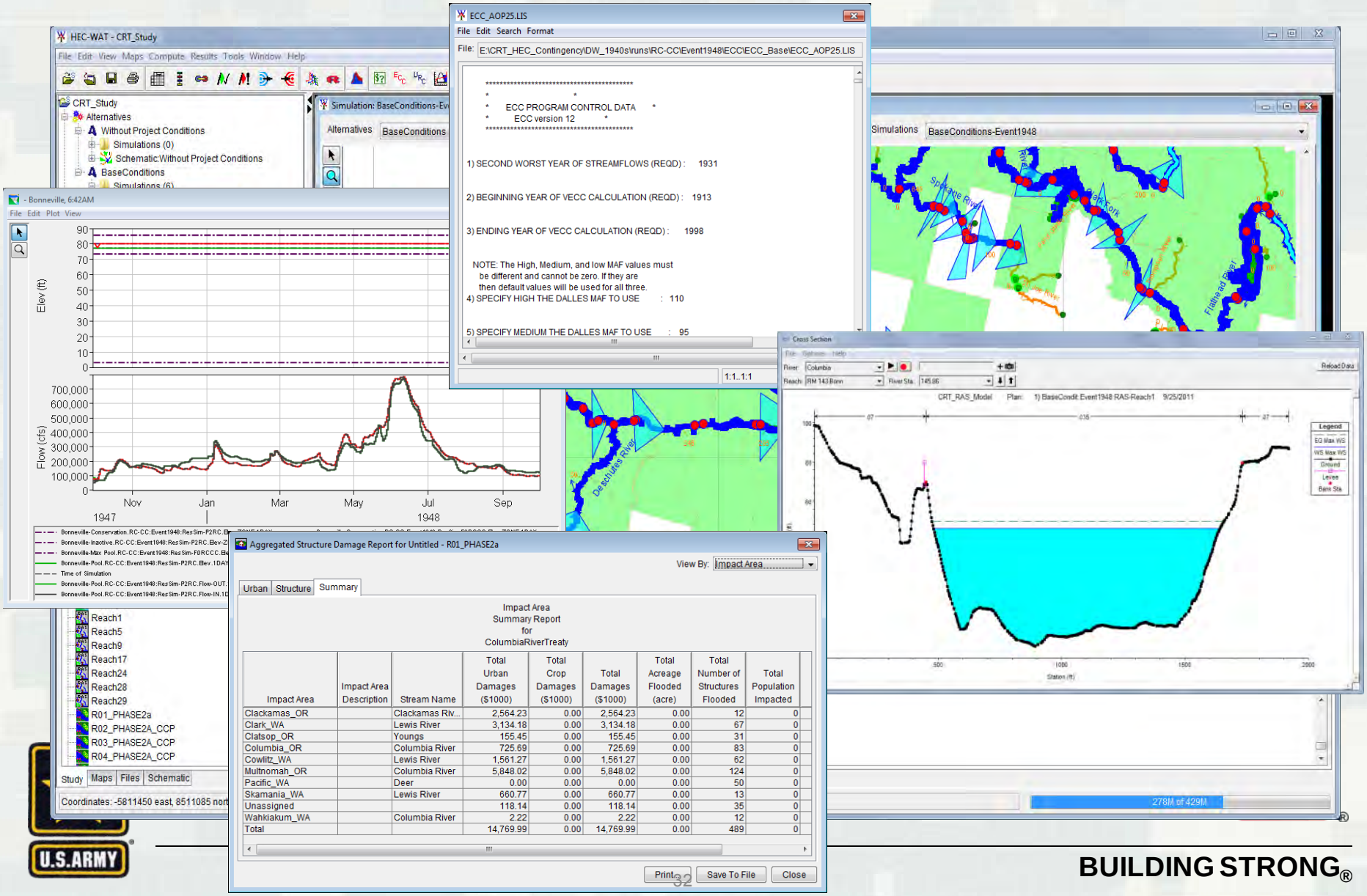


Skip Models in the Compute Sequence

- Model simulations can be skipped (might not be necessary to simulate smaller magnitude events).
- Multiple locations can be selected
  - Interface assists in defining skip logic
  - Select the models to be skipped in the compute sequence



HEC-WAT Output



Aggregated Structure Damage Report for Untitled - R01_PHASE2a

View By: Impact Area

Urban | Structure | Summary

Impact Area Summary Report for ColumbiaRiverTreaty

Impact Area	Impact Area Description	Stream Name	Total Urban Damages ($1000)	Total Crop Damages ($1000)	Total Damages ($1000)	Total Acreage Flooded (acre)	Total Number of Structures Flooded	Total Population Impacted
Clackamas_OR		Clackamas Riv...	2,564.23	0.00	2,564.23	0.00	12	0
Clark_WA		Lewis River	3,134.18	0.00	3,134.18	0.00	67	0
Clatsop_OR		Youngs	155.45	0.00	155.45	0.00	31	0
Columbia_OR		Columbia River	725.69	0.00	725.69	0.00	83	0
Cowlitz_WA		Lewis River	1,561.27	0.00	1,561.27	0.00	62	0
Multnomah_OR		Columbia River	5,848.02	0.00	5,848.02	0.00	124	0
Pacific_WA		Deer	0.00	0.00	0.00	0.00	50	0
Skamania_WA		Lewis River	660.77	0.00	660.77	0.00	13	0
Unassigned			118.14	0.00	118.14	0.00	35	0
Wahkiakum_WA		Columbia River	2.22	0.00	2.22	0.00	12	0
Total			14,769.99	0.00	14,769.99	0.00	489	0

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