Watershed level Risk Analysis with HEC-WAT

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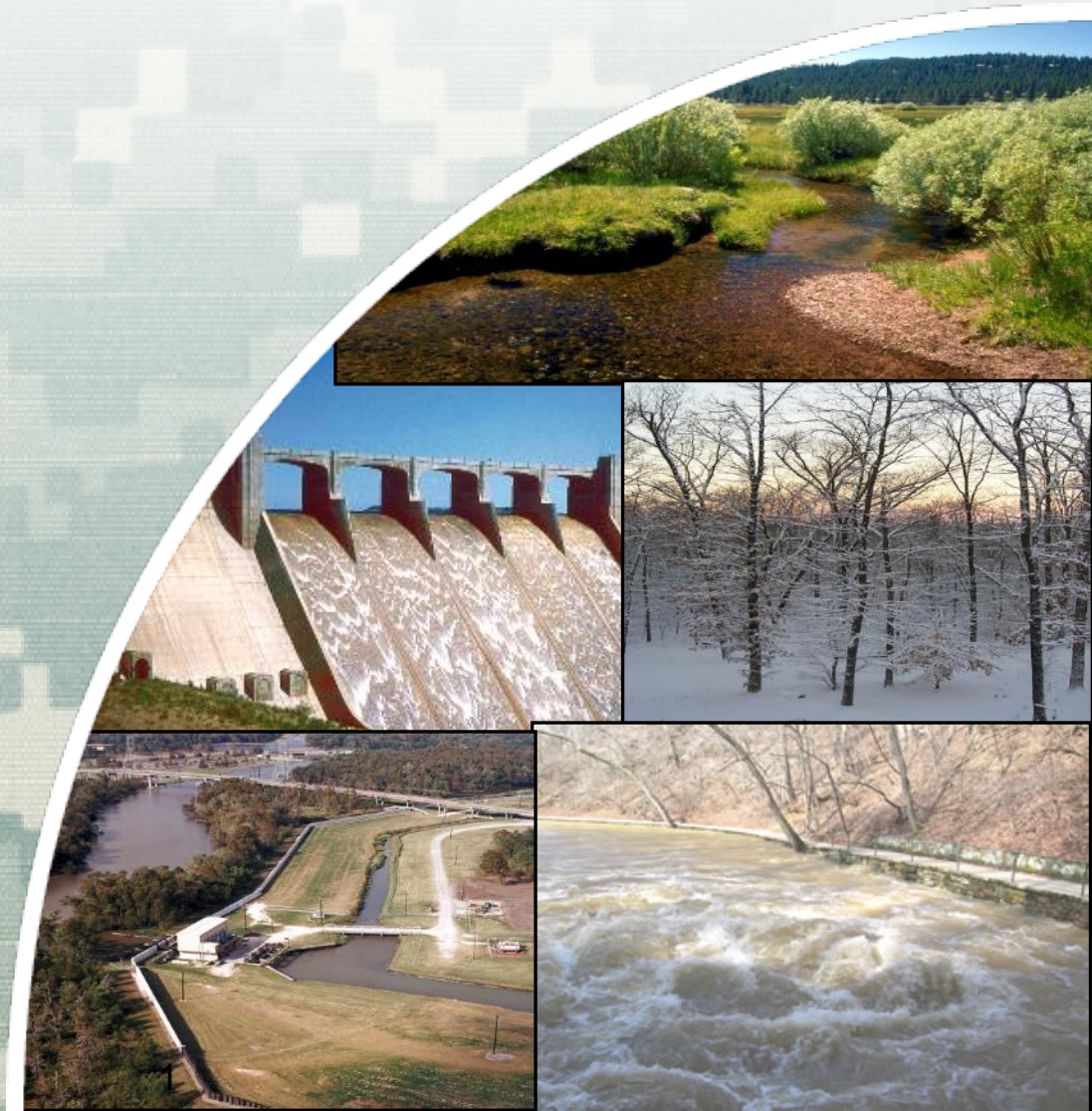
Rockville, MD



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What is HEC-WAT?

- Provides a plug-in architecture to allow other computational models to be computed in the program sequence
- Integrates HEC-HMS, HEC-ResSim, HEC-RAS and HEC-FIA models, eliminating manual data exchange.
- Supports systems and watershed-based studies.
- Supports risk and uncertainty evaluations.

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HEC- WAT INTEGRATES

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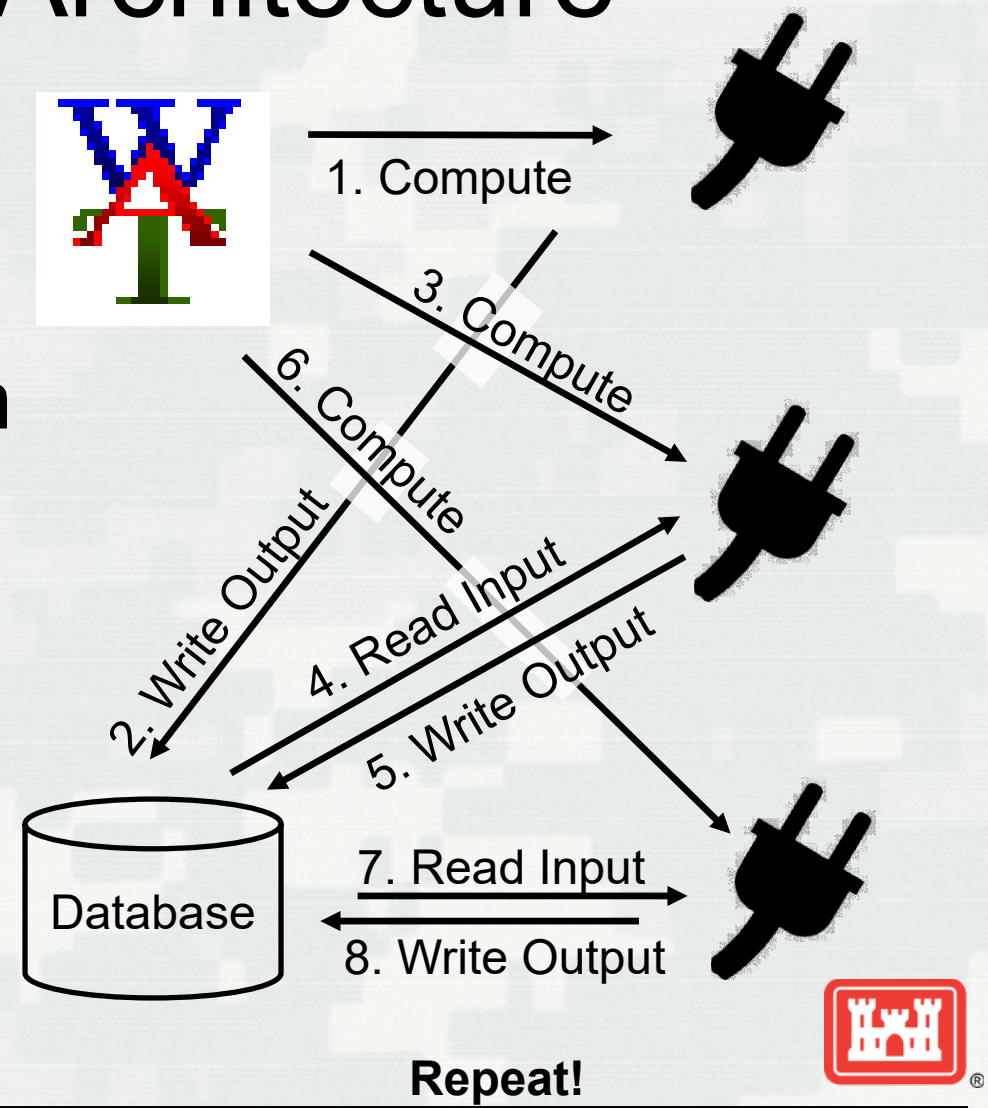
- Supports systems and watershed-based studies.
- Supports risk and uncertainty analysis

HEC- WAT Facilitates Evaluation

HEC- WAT INTEGRATES

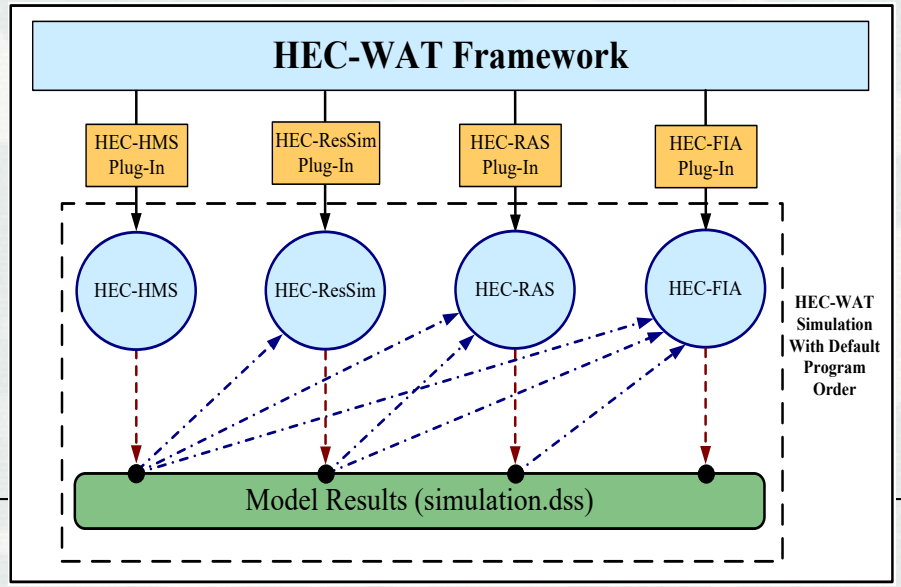
Plug-in Architecture

- HEC-WAT Manages the computes through plug-ins
- Plug-ins interact with each other through a centralized database

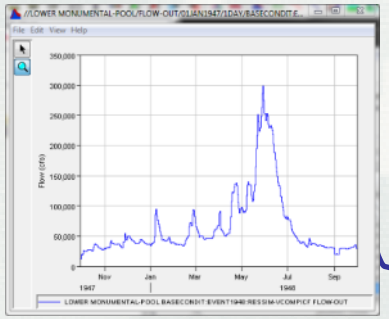


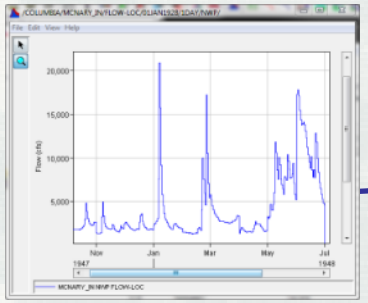
HEC-WAT Model Integration

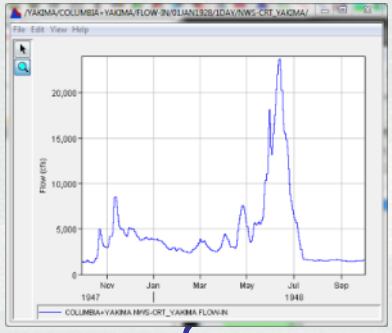
- Models and tools that implement the Plugin Interface can contribute to the computational process
  - Hydrology - *HEC-HMS*
  - Reservoirs - *HEC-ResSim*
  - Hydraulics - *HEC-RAS*
  - Economics - *HEC-FIA*
- Communication is defined by the Plugin API and facilitated by HEC-WAT
- Data is transferred through a common DSS file.

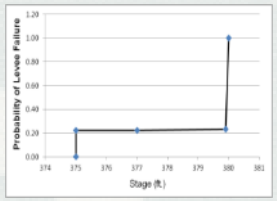


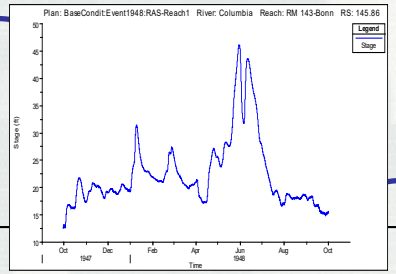
Load Distribution & Consequences











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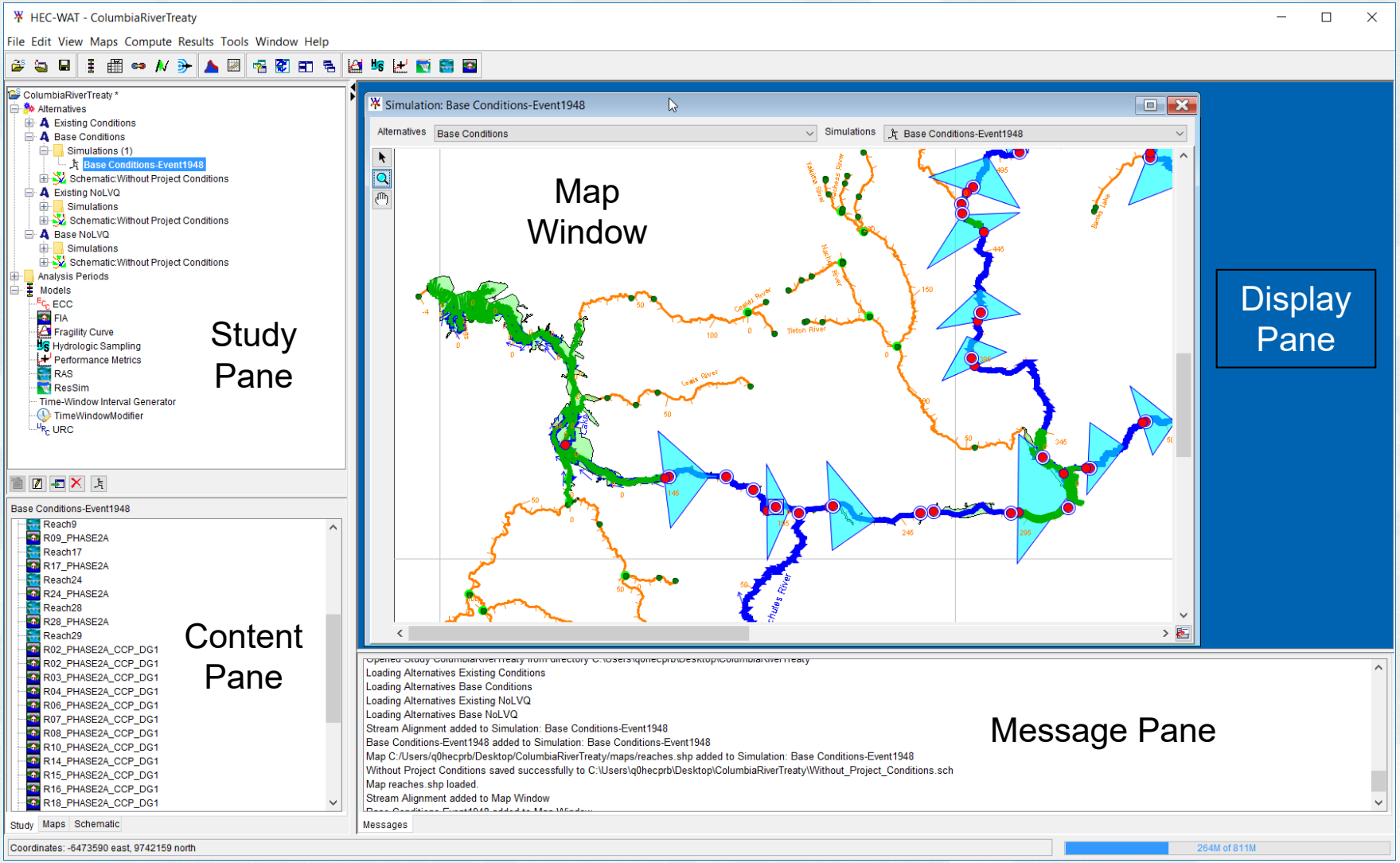
HEC- WAT Facilitates Evaluation

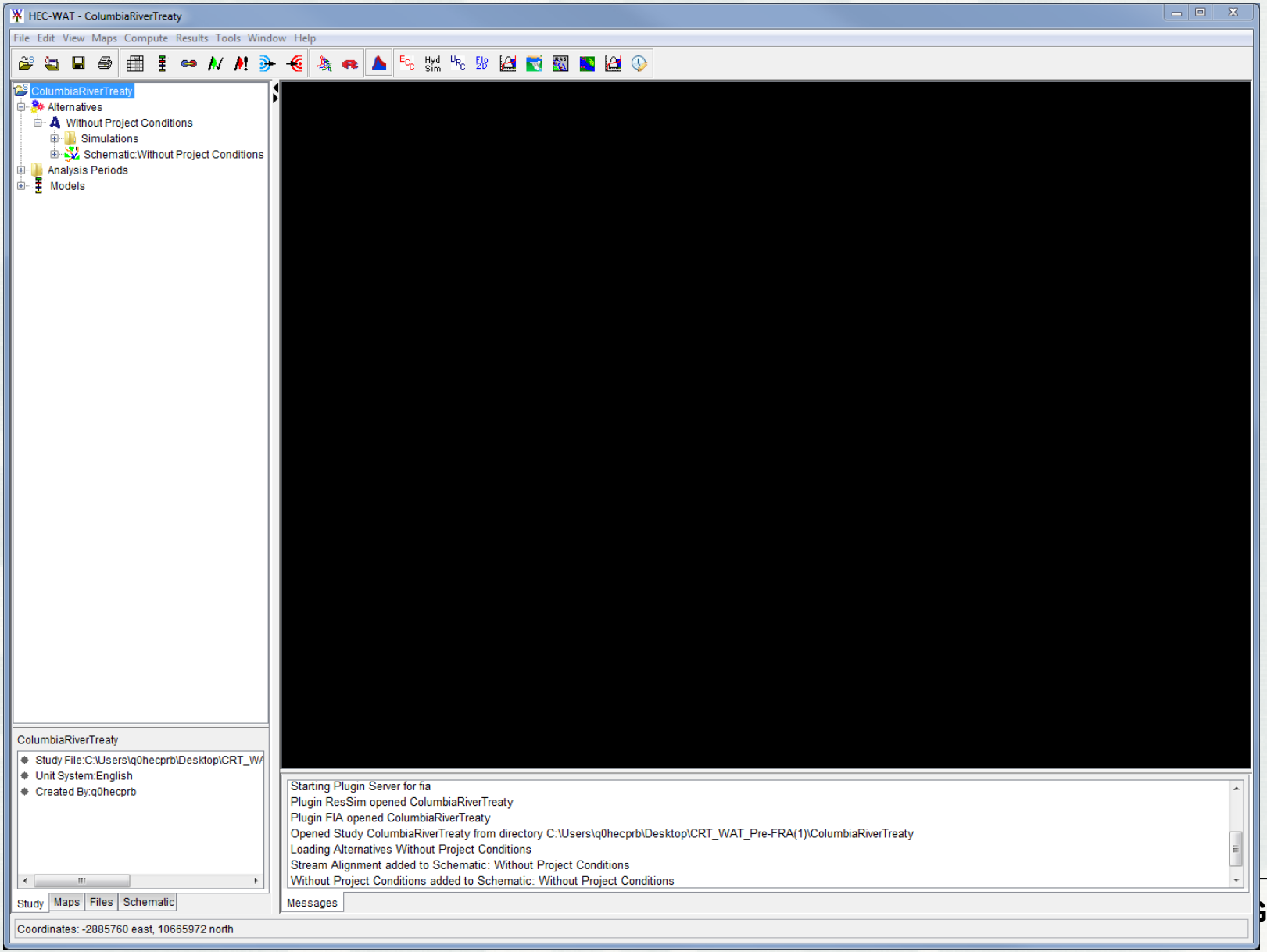
HEC-WAT Workflow

- Import existing models or develop models from within HEC-WAT
- Develop alternatives
- Organize & store data
- Edit models – accessed via plug-ins to view Native model interfaces
- Run modeling software – via plug-ins
- View and compare alternative results

HEC-WAT Interface



Development of HEC-WAT Model



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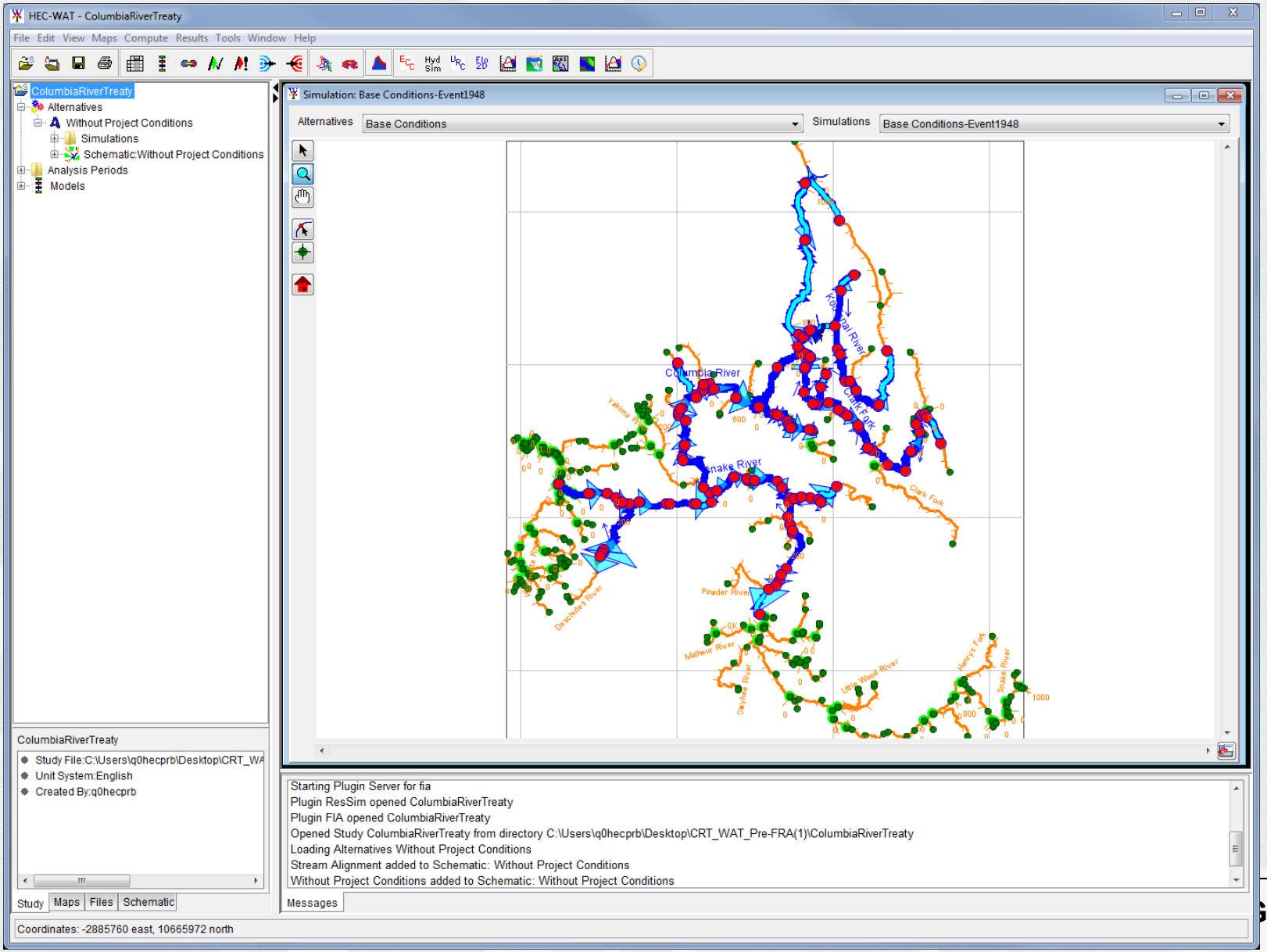
Development of HEC-WAT Model



- ResSim Models

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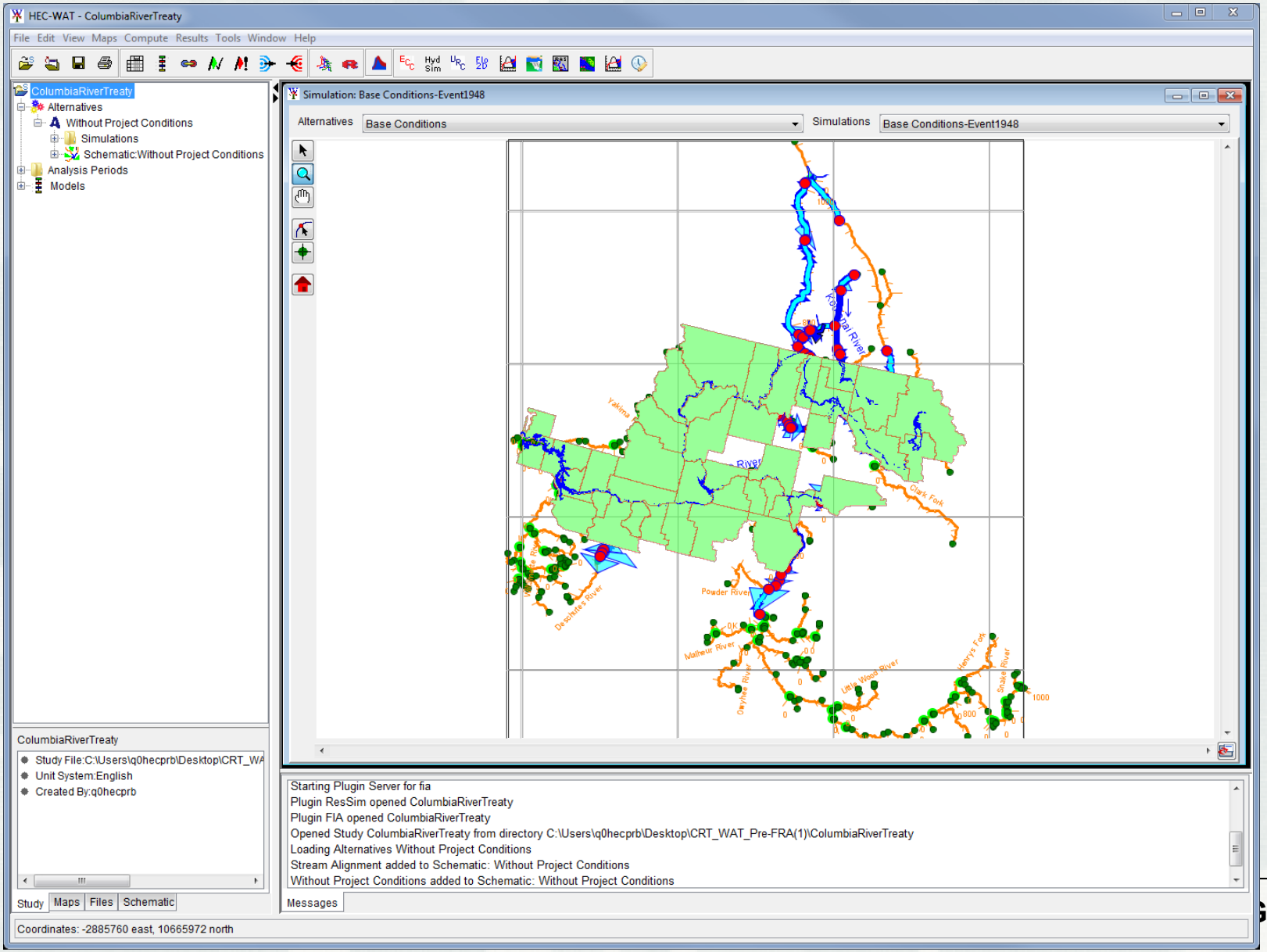
Development of HEC-WAT Model



- ResSim Models
- FIA Models

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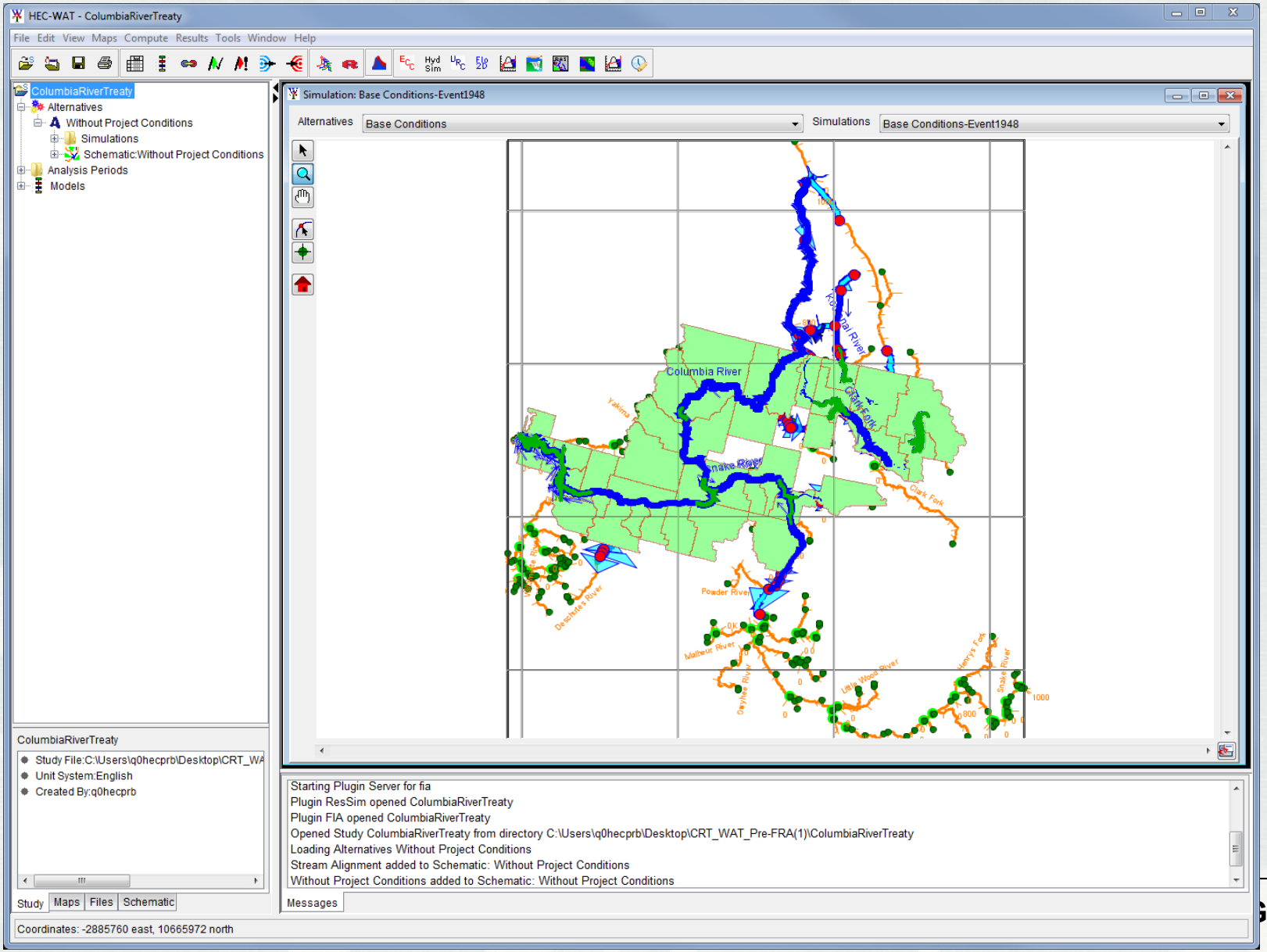
Development of HEC-WAT Model



- ResSim Models
- FIA Models
- RAS Models

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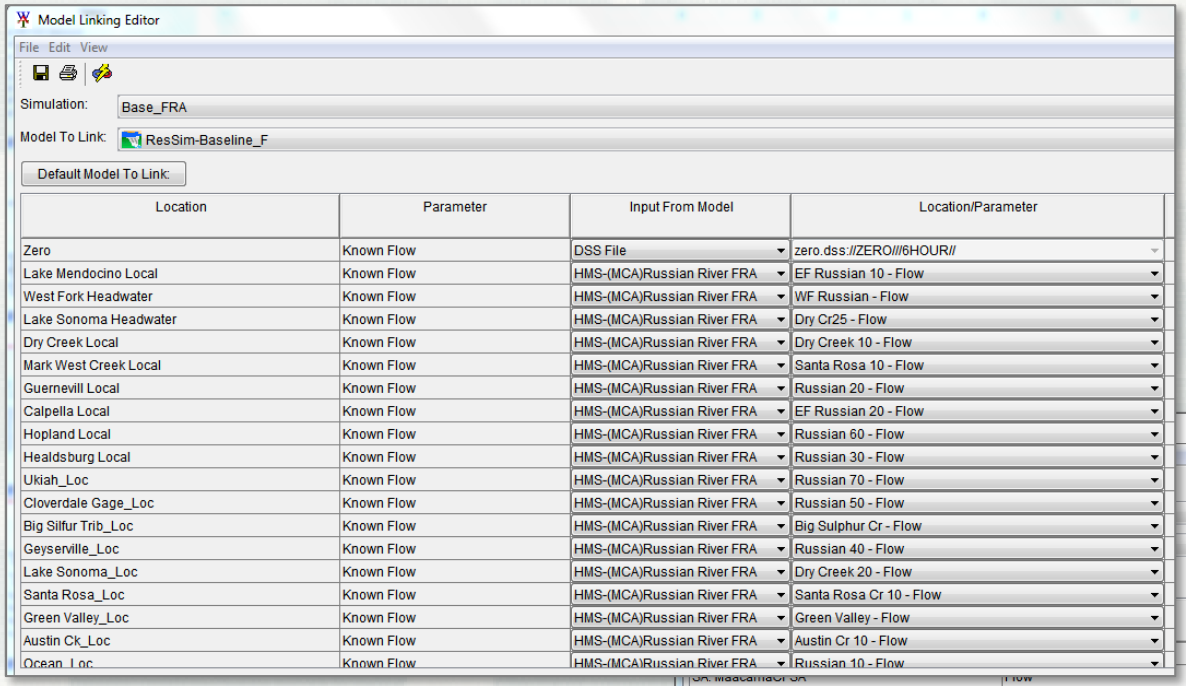
Model Linking



Location	Parameter	Input From Model	Location/Parameter
Zero	Known Flow	DSS File	zero.dss://ZERO///6HOUR//
Lake Mendocino Local	Known Flow	HMS-(MCA)Russian River FRA	EF Russian 10 - Flow
West Fork Headwater	Known Flow	HMS-(MCA)Russian River FRA	WF Russian - Flow
Lake Sonoma Headwater	Known Flow	HMS-(MCA)Russian River FRA	Dry Cr25 - Flow
Dry Creek Local	Known Flow	HMS-(MCA)Russian River FRA	Dry Creek 10 - Flow
Mark West Creek Local	Known Flow	HMS-(MCA)Russian River FRA	Santa Rosa 10 - Flow
Guernevill Local	Known Flow	HMS-(MCA)Russian River FRA	Russian 20 - Flow
Calpella Local	Known Flow	HMS-(MCA)Russian River FRA	EF Russian 20 - Flow
Hopland Local	Known Flow	HMS-(MCA)Russian River FRA	Russian 60 - Flow
Healdsburg Local	Known Flow	HMS-(MCA)Russian River FRA	Russian 30 - Flow
Ukiah_Loc	Known Flow	HMS-(MCA)Russian River FRA	Russian 70 - Flow
Cloverdale Gage_Loc	Known Flow	HMS-(MCA)Russian River FRA	Russian 50 - Flow
Big Silfur Trib_Loc	Known Flow	HMS-(MCA)Russian River FRA	Big Sulphur Cr - Flow
Geyserville_Loc	Known Flow	HMS-(MCA)Russian River FRA	Russian 40 - Flow
Lake Sonoma_Loc	Known Flow	HMS-(MCA)Russian River FRA	Dry Creek 20 - Flow
Santa Rosa_Loc	Known Flow	HMS-(MCA)Russian River FRA	Santa Rosa Cr 10 - Flow
Green Valley_Loc	Known Flow	HMS-(MCA)Russian River FRA	Green Valley - Flow
Austin Ck_Loc	Known Flow	HMS-(MCA)Russian River FRA	Austin Cr 10 - Flow
Ocean_Loc	Known Flow	HMS-(MCA)Russian River FRA	Russian 10 - Flow

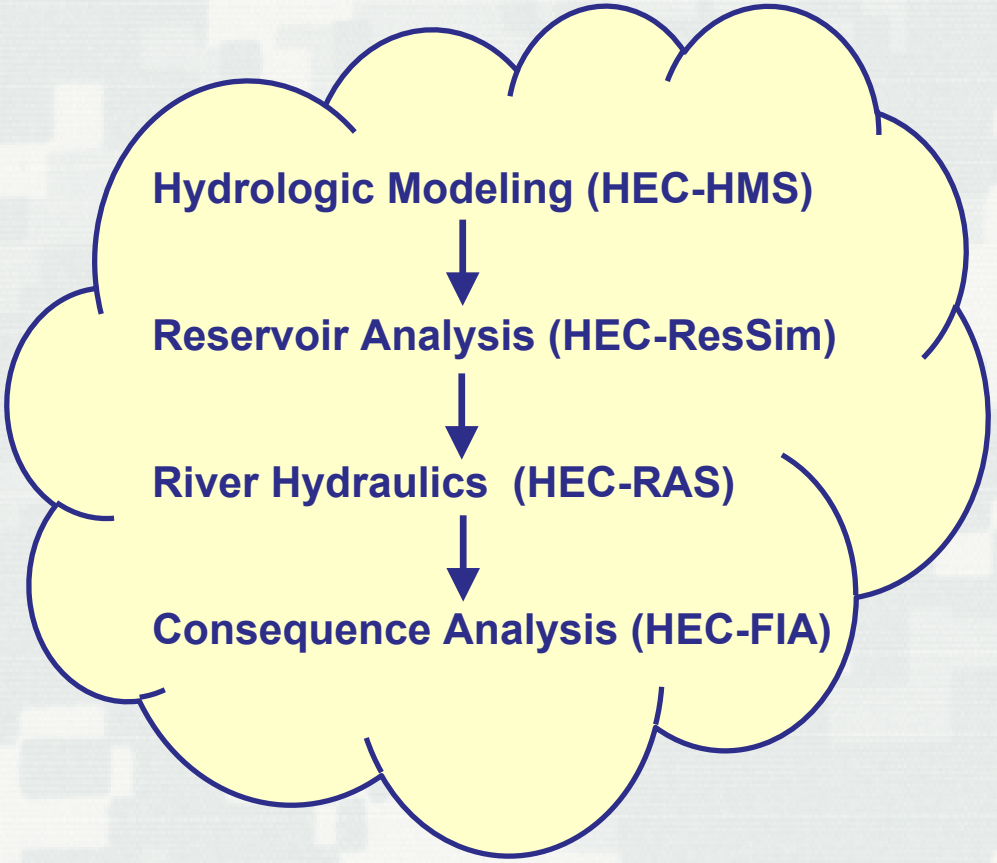
HEC-ResSim Links

HEC-RAS Links

		Input From Model	Location/Parameter
		HMS-(MCA)Russian River FRA	WF Russian - Flow
		HMS-(MCA)Russian River FRA	Russian 30 - Flow
SA: AustinCr SA	Flow	HMS-(MCA)Russian River FRA	Austin Cr - Flow
SA: GreenValleyCr SA	Flow	HMS-(MCA)Russian River FRA	Green Valley - Flow
SA: SantaRosaCr SA	Flow	HMS-(MCA)Russian River FRA	Santa Rosa 10 - Flow
DryCreek DryCreek RS 14.28 (Sonoma Outflow J)	Flow	ResSim-Baseline_F	Lake Sonoma_OUT - Flow
Russian CoyoteToDC RS 99.93 (Lk Mendocino Out)	Flow	ResSim-Baseline_F	Lake Mendocino_OUT - Flow
Russian CoyoteToDC RS 91.31	Flow	HMS-(MCA)Russian River FRA	Russian 60 - Flow
Russian CoyoteToDC RS 84.61	Flow	HMS-(MCA)Russian River FRA	Russian 50 - Flow
Russian CoyoteToDC RS 70.92 (Cloverdale)	Flow	HMS-(MCA)Russian River FRA	Russian 40 - Flow
Russian CoyoteToDC RS 54.07	Flow	HMS-(MCA)Russian River FRA	Russian 30 - Flow
Russian CoyoteToDC RS 35.42	Flow	HMS-(MCA)Russian River FRA	Russian 20 - Flow
Russian DCtoOcean RS 21.16	Flow	HMS-(MCA)Russian River FRA	Russian 10 - Flow
Russian CoyoteToDC RS 65.71	Flow	HMS-(MCA)Russian River FRA	Big Sulphur Cr - Flow
Russian DCtoOcean RS 31.47	Flow	HMS-(MCA)Russian River FRA	Russian 20 - Flow
DryCreek DryCreek RS 13.73	Flow	HMS-(MCA)Russian River FRA	Dry Creek 10 - Flow
Russian CoyoteToDC RS 99.17	Flow	HMS-(MCA)Russian River FRA	Russian 70 - Flow

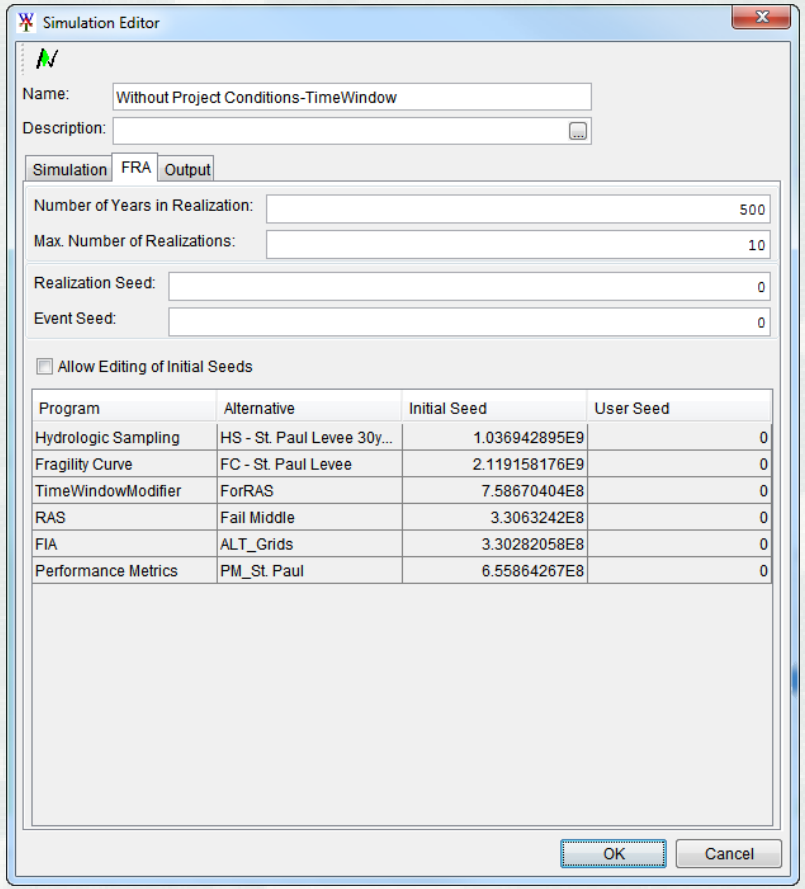
Deterministic Compute

- Single Flood Event
  - Example: 8 January 1986 to 13 January 1986
  - Simplest type of compute
  - Eliminates manual handoffs between models
- Period of Record
  - Example: 1 October 1943 to 30 September 2014
  - Slightly more complex compute



FRA Simulations

- FRA simulations uses a Monte Carlo style compute to support risk analyses.
- Individual applications sample model parameters from a range of values to capture uncertainty.
- Natural variability and knowledge uncertainty sampled separately.
- Maintains consistency between alternatives by allowing use of same initial seeds.



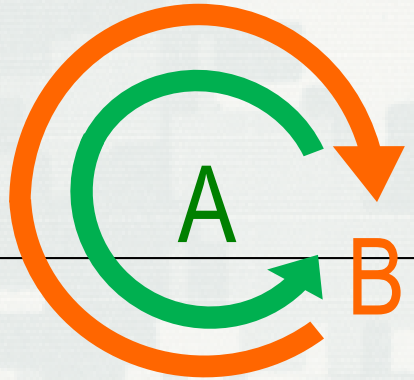
How do we capture a distribution of uncertainty in EAD?

Nested Monte Carlo: *HEC-WAT/FRA*

A. Sample instances of natural variabilities 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

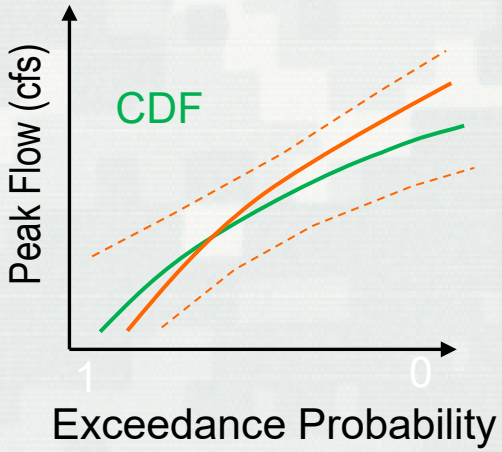
outer loop B varies knowledge uncertainty, computes EAD distribution

Sampling Variability and Uncertainty

Nested Monte Carlo Simulation

sample new frequency curve (uncertainty)

Reservoir Analysis
Channel Hydraulics
Levee Behavior
Spreading Model



sample uncertain model parameters

Inundation Mapping
Structure Inventory
Damage to Structures

Sampling Variability and Uncertainty

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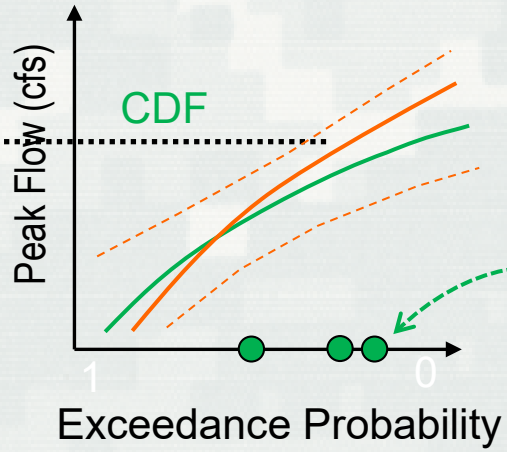
hydrographs



sample new frequency curve (uncertainty)

and then sample events (variability)

Random choice of probability ~ $U_i[0,1]$ to "generate" event

One Event: sample member i

sample uncertain model parameters
sample variabilities

stage

Inundation Mapping
Structure Inventory
Damage to Structures

damage

Damage(i)

Sampling Variability and Uncertainty

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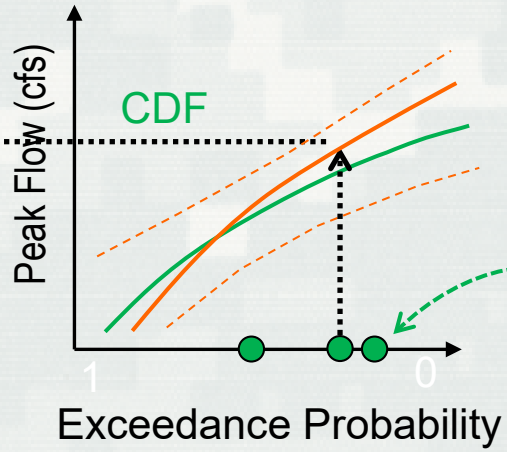

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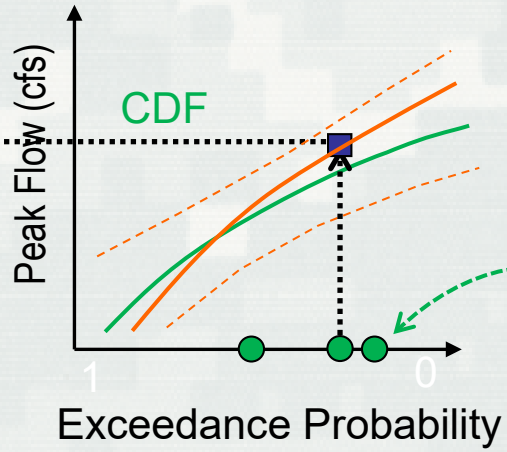

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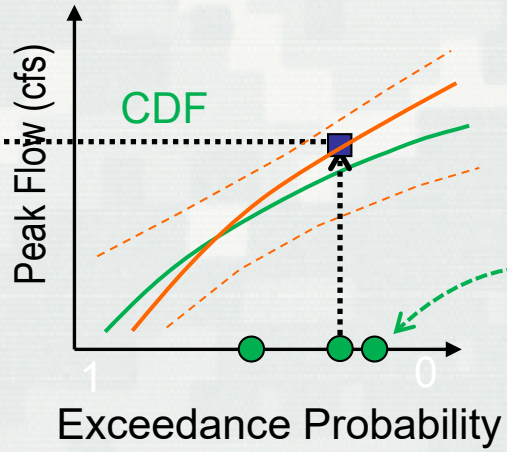

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sample uncertain model parameters

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damage

Damage(i)

…still end with a sample of damages

One Realization

For each realization, get an EAD estimate:

$$EAD = \frac{1}{N}\sum_{i=1}^{N} Damage(i)$$

Sampling Variability and Uncertainty

Nested Monte Carlo Simulation

sample new frequency curve (uncertainty)

and then sample events (variability)

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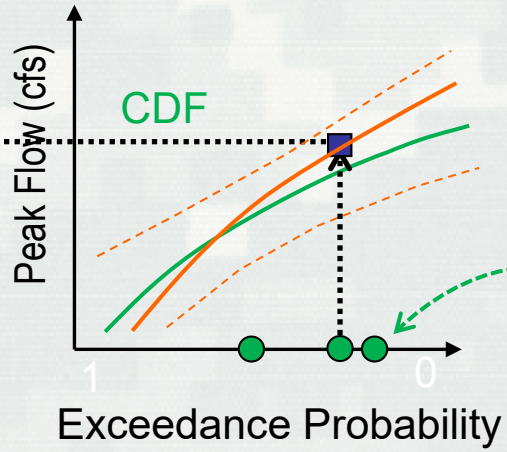

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sample uncertain model parameters

sample variabilities

stage

One Event: sample member i

Inundation Mapping
Structure Inventory
Damage to Structures

damage

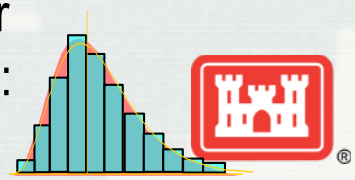
Damage(i)

…still end with a sample of damages

One Realization

For each realization, get an EAD estimate:

After repeating for many realizations:

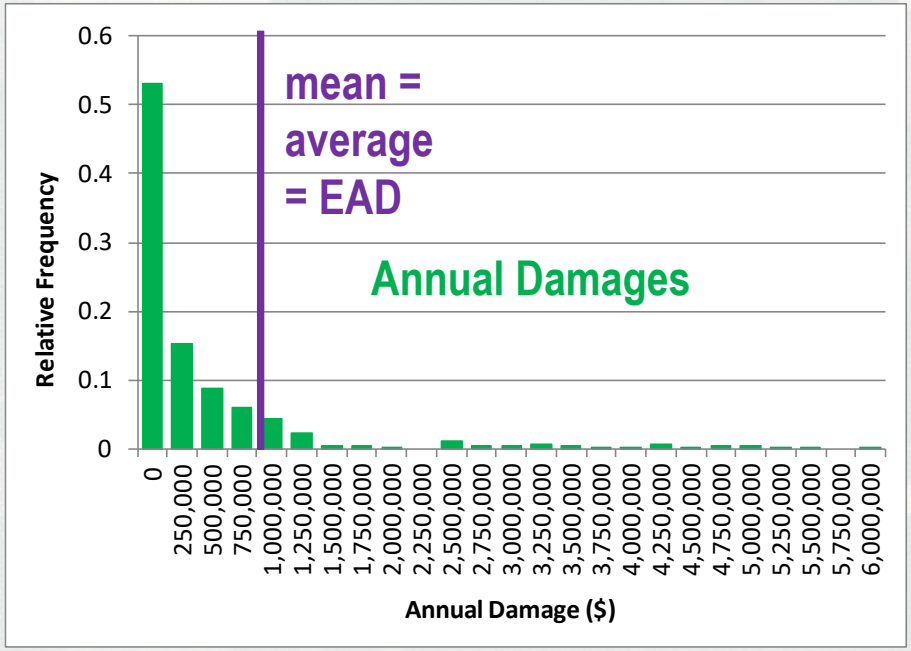


$$EAD = \frac{1}{N}\sum_{i=1}^{N} Damage(i)$$

sample of annual damage from **one realization**

(spans natural variability)

provides 1 estimate of EAD



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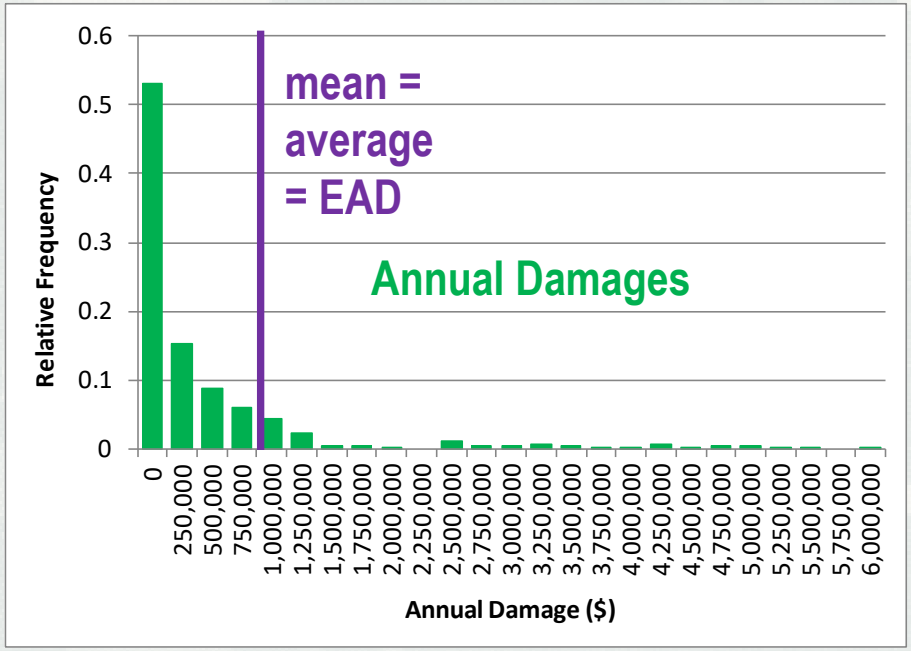
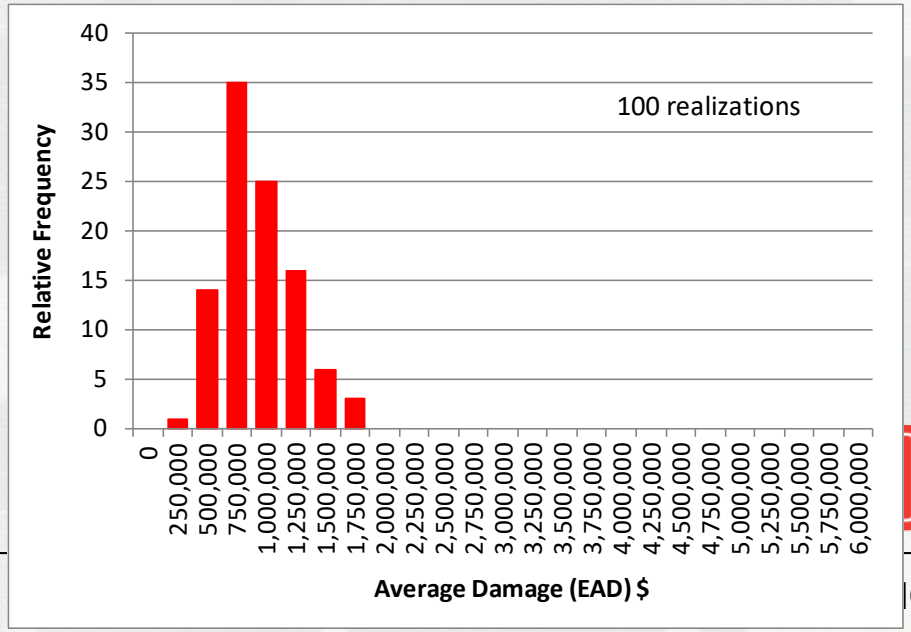




sample of annual damage from **one realization**

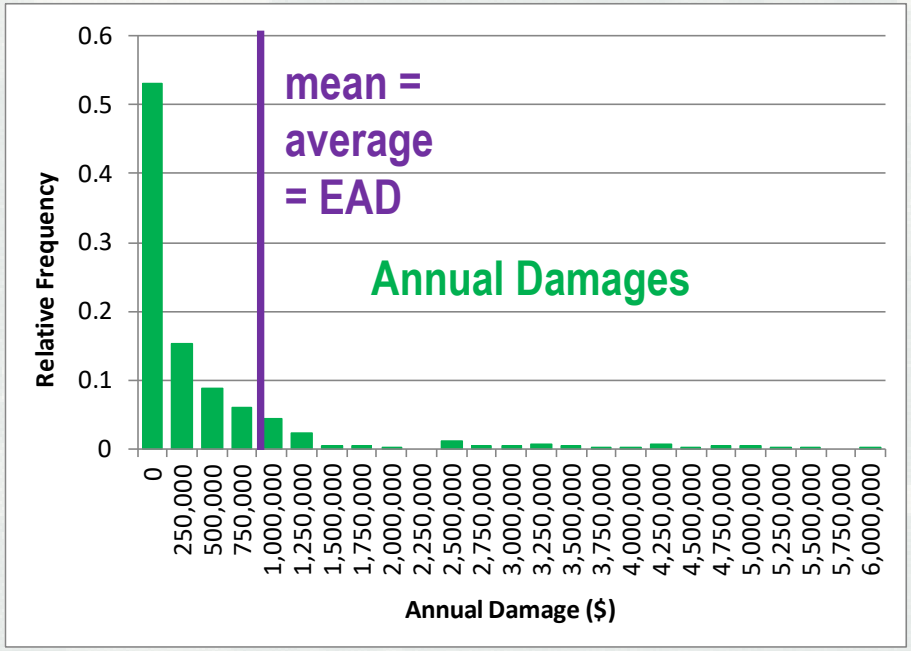
(spans natural variability)

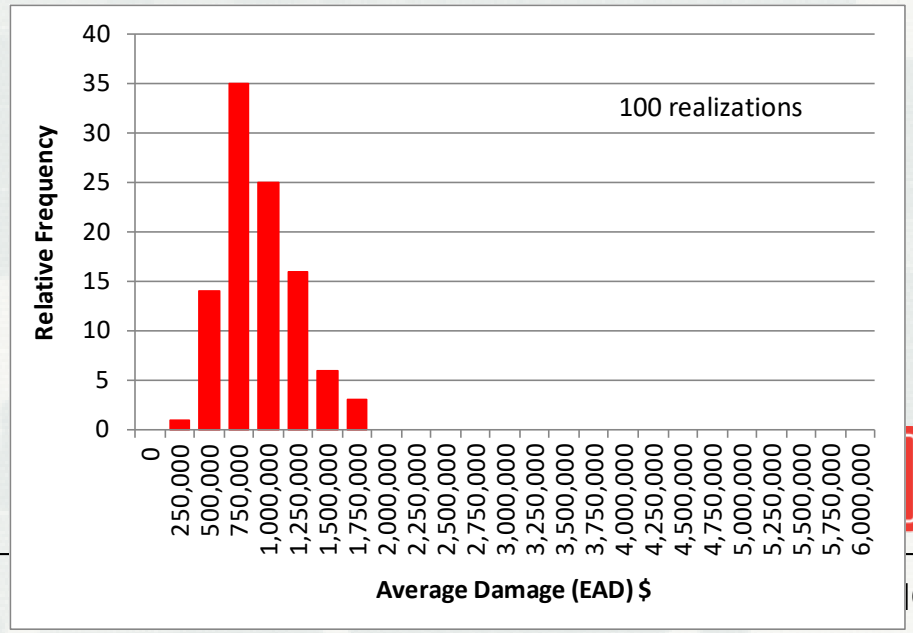
provides 1 estimate of EAD

sample of mean damage (EAD) from **all realizations**

(spans knowledge uncertainty)

provides distribution of EAD





sample of annual damage from **one realization**

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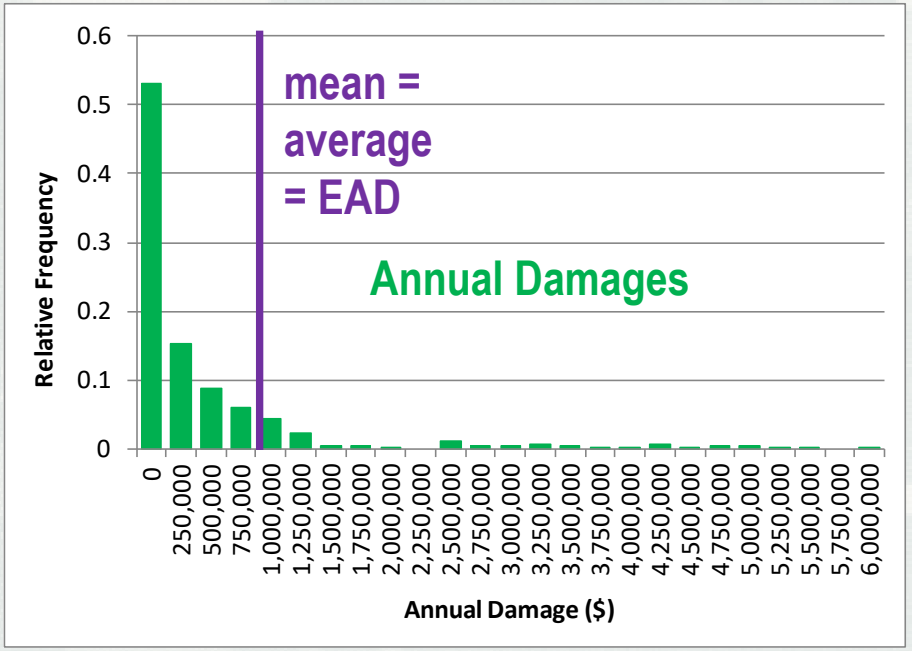
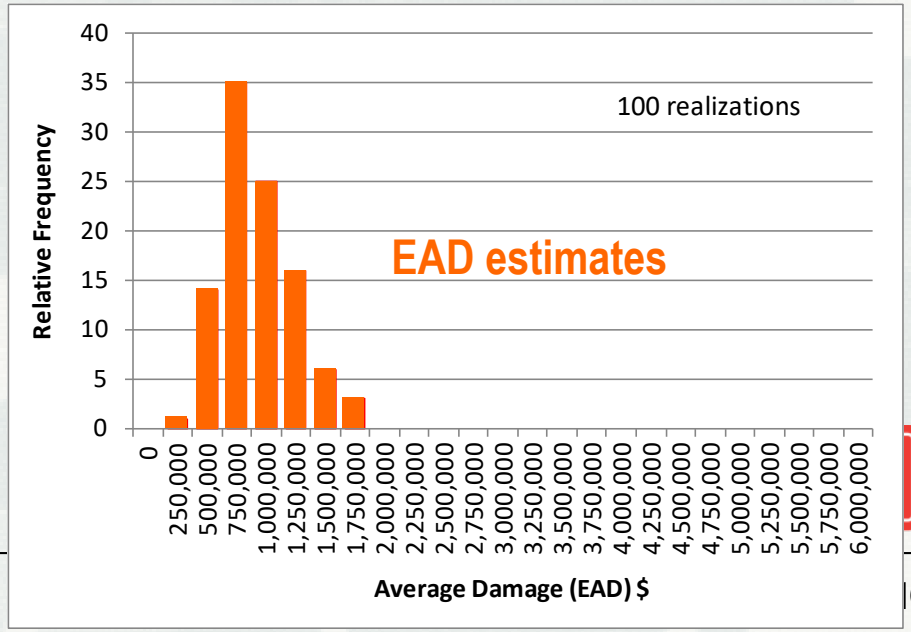


sample of mean damage (EAD) from **all realizations**

(spans knowledge uncertainty)

provides distribution of EAD



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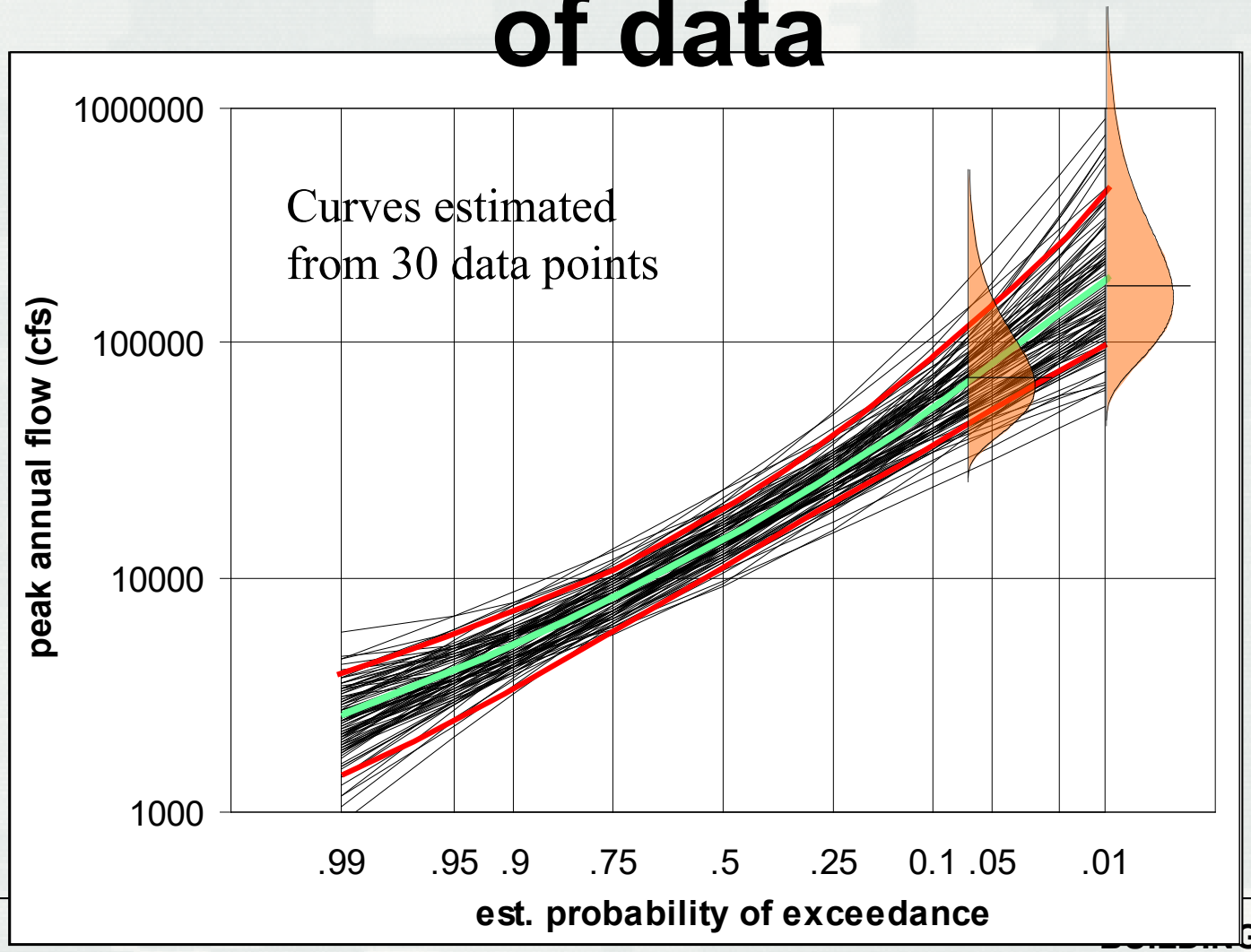
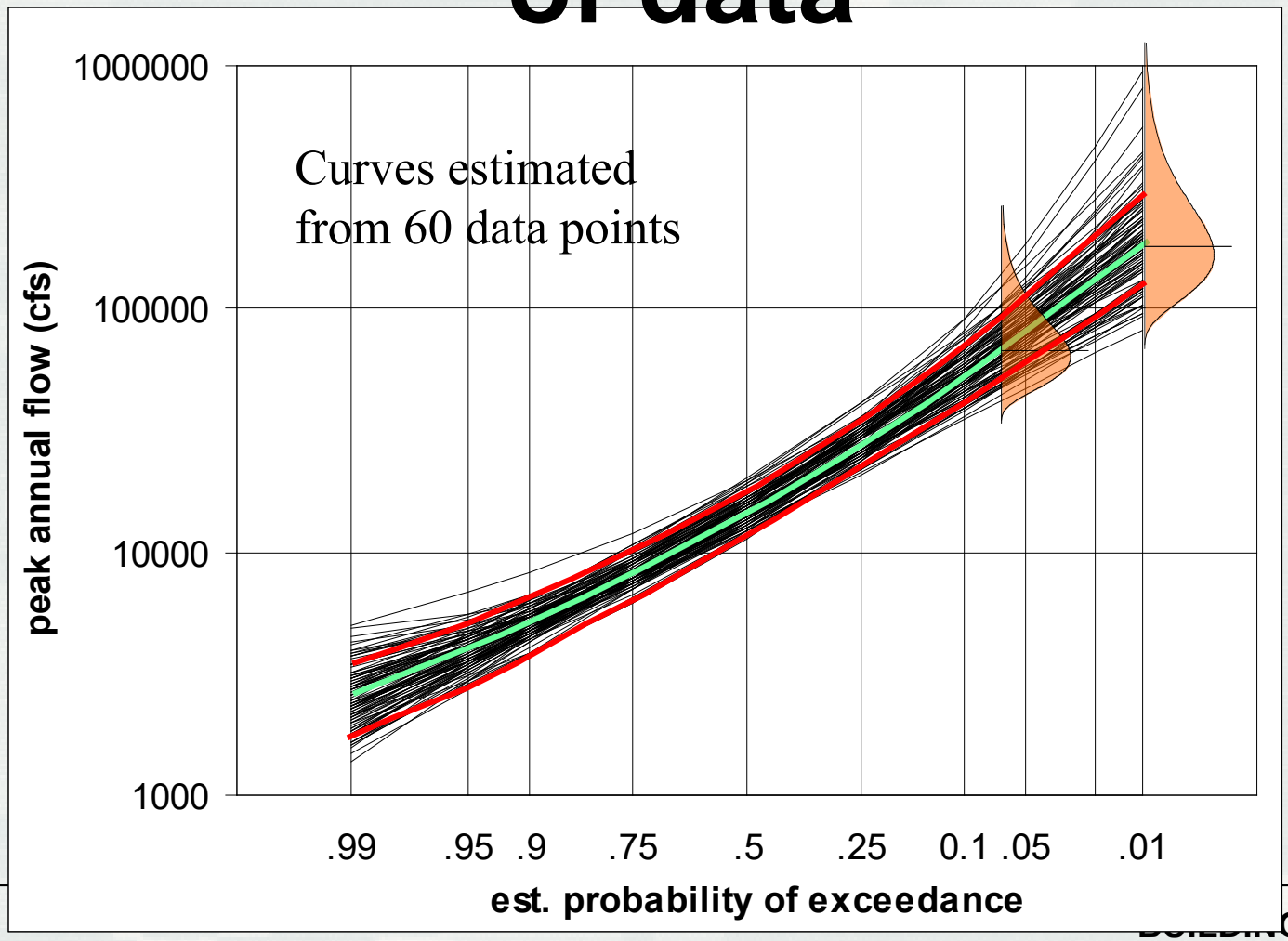
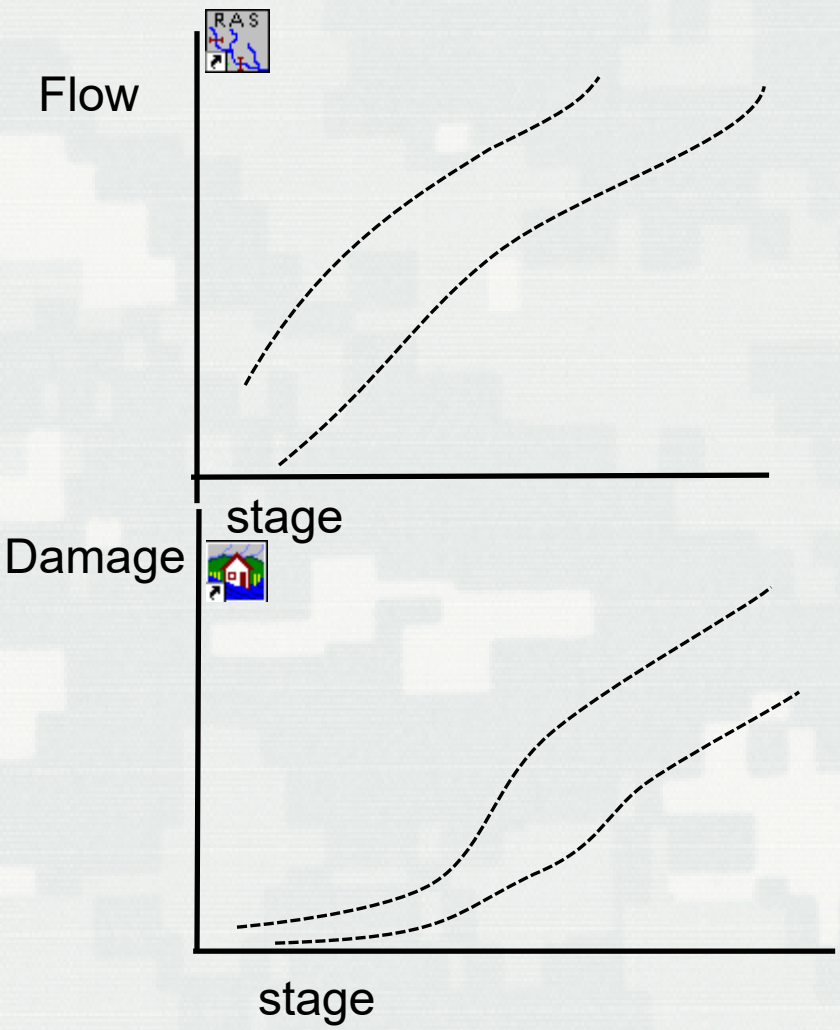
Uncertainty in a frequency curve estimated from 30 years of data

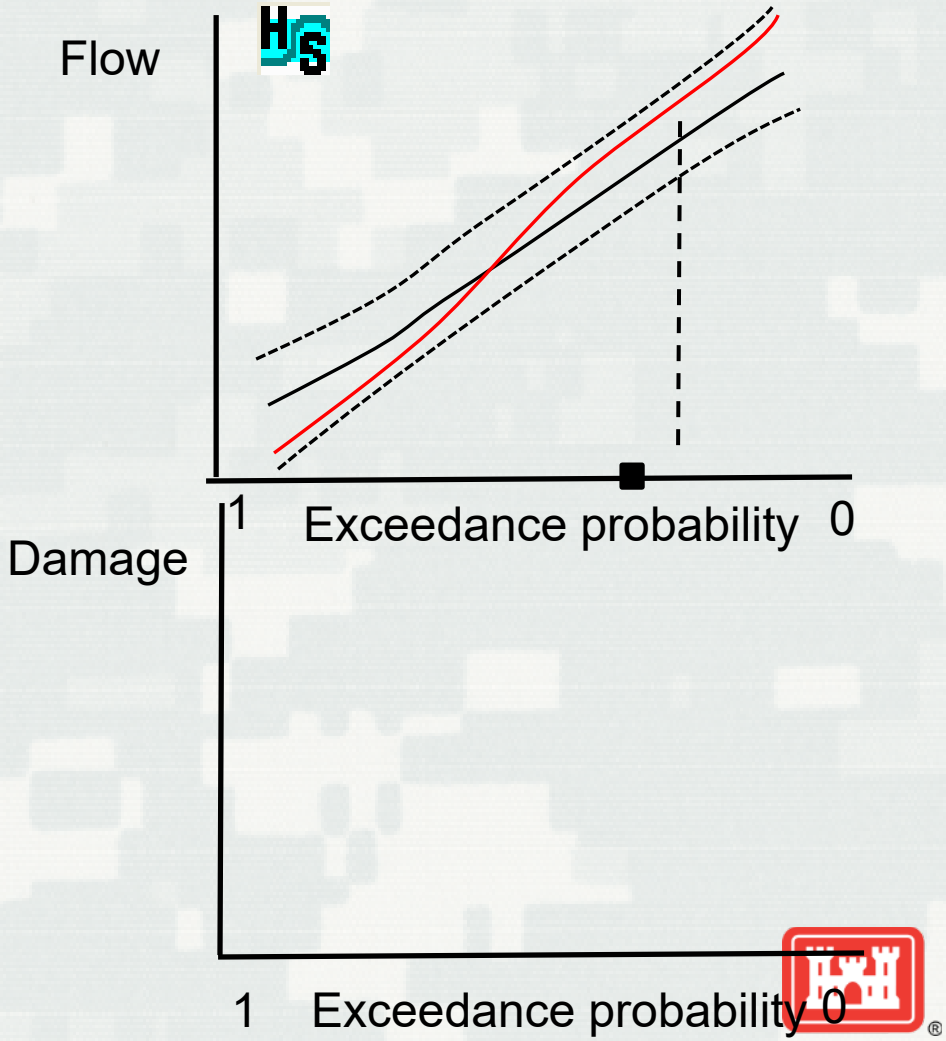


Uncertainty in a frequency curve estimated from 60 years of data



Concept behind event sampling





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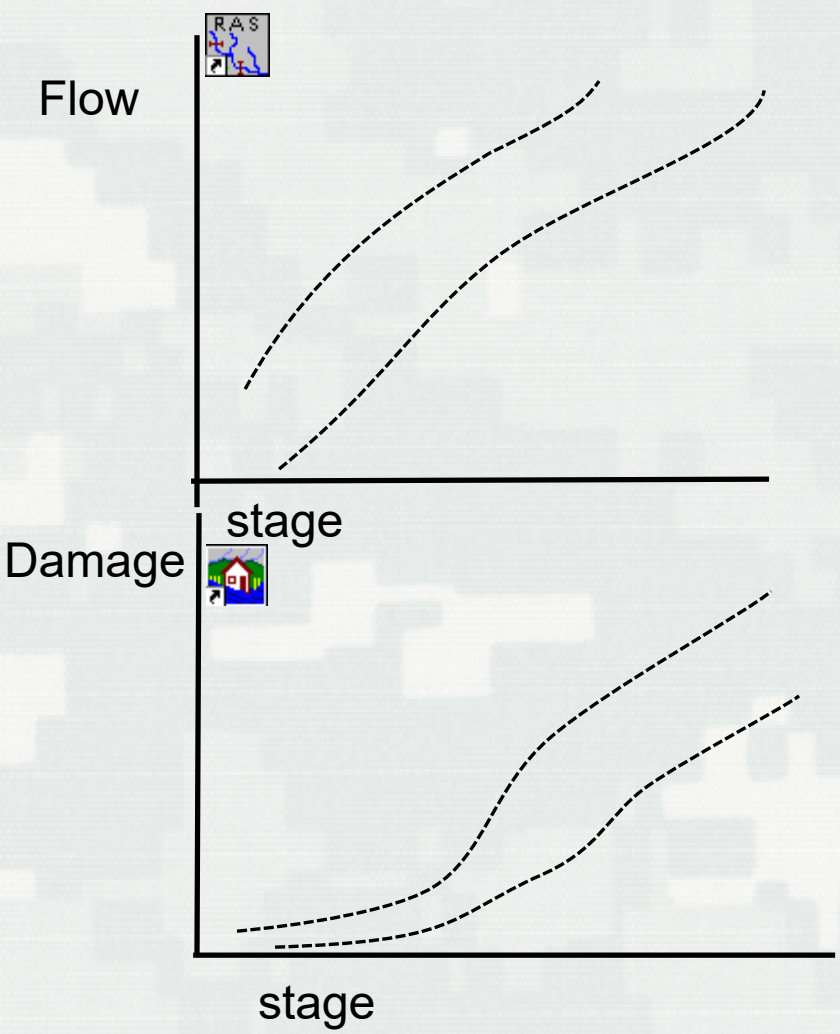

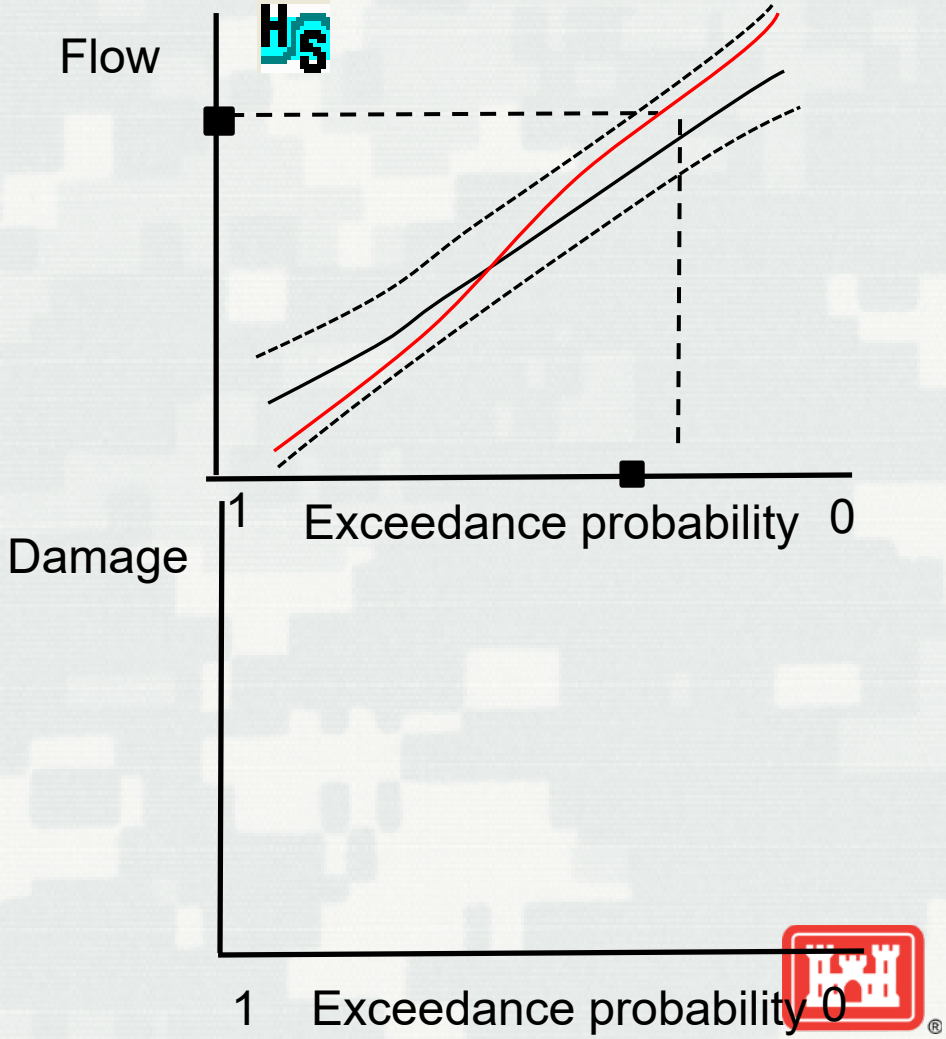

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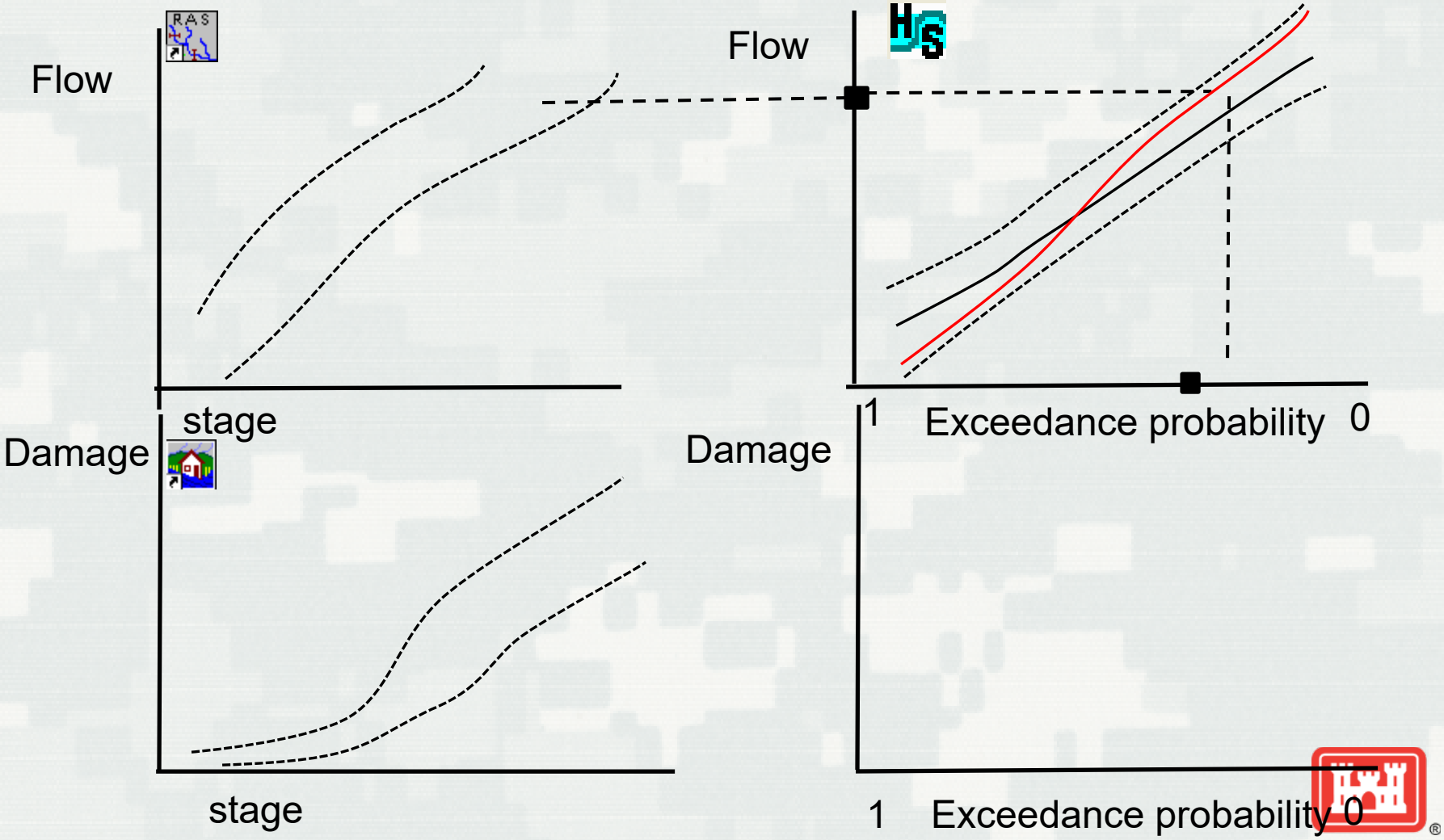
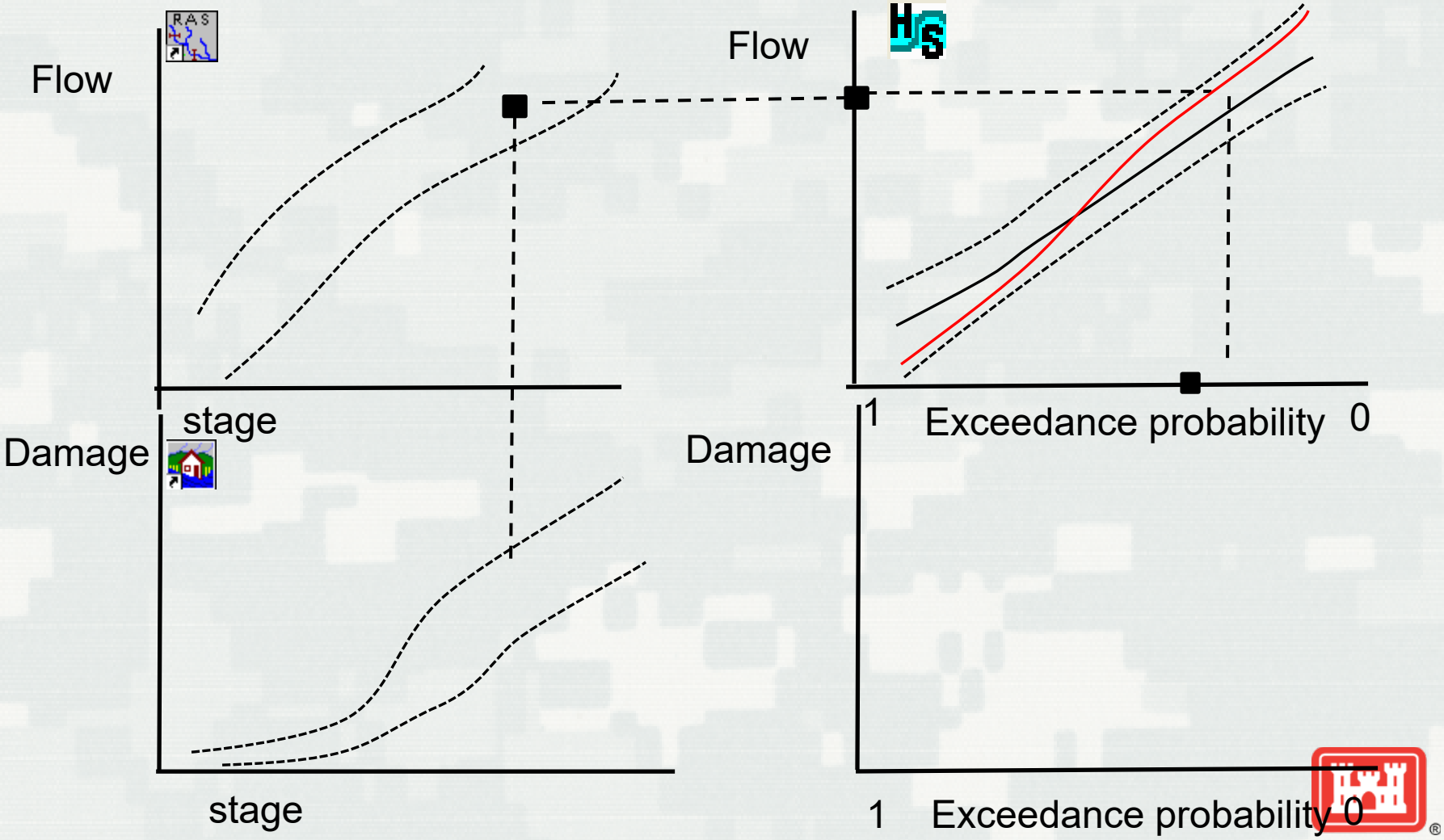
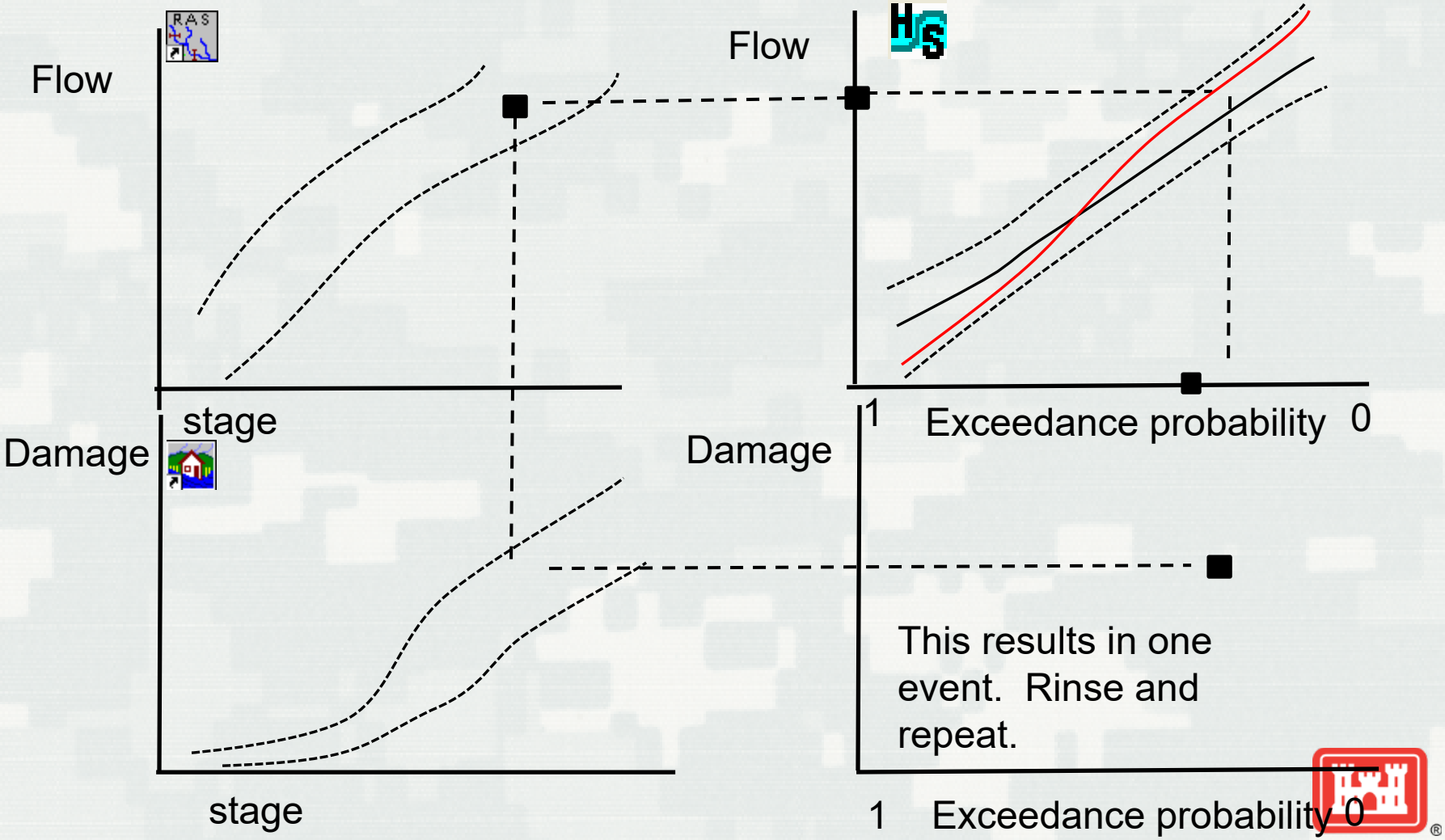


Concept behind event sampling



Concept behind event sampling



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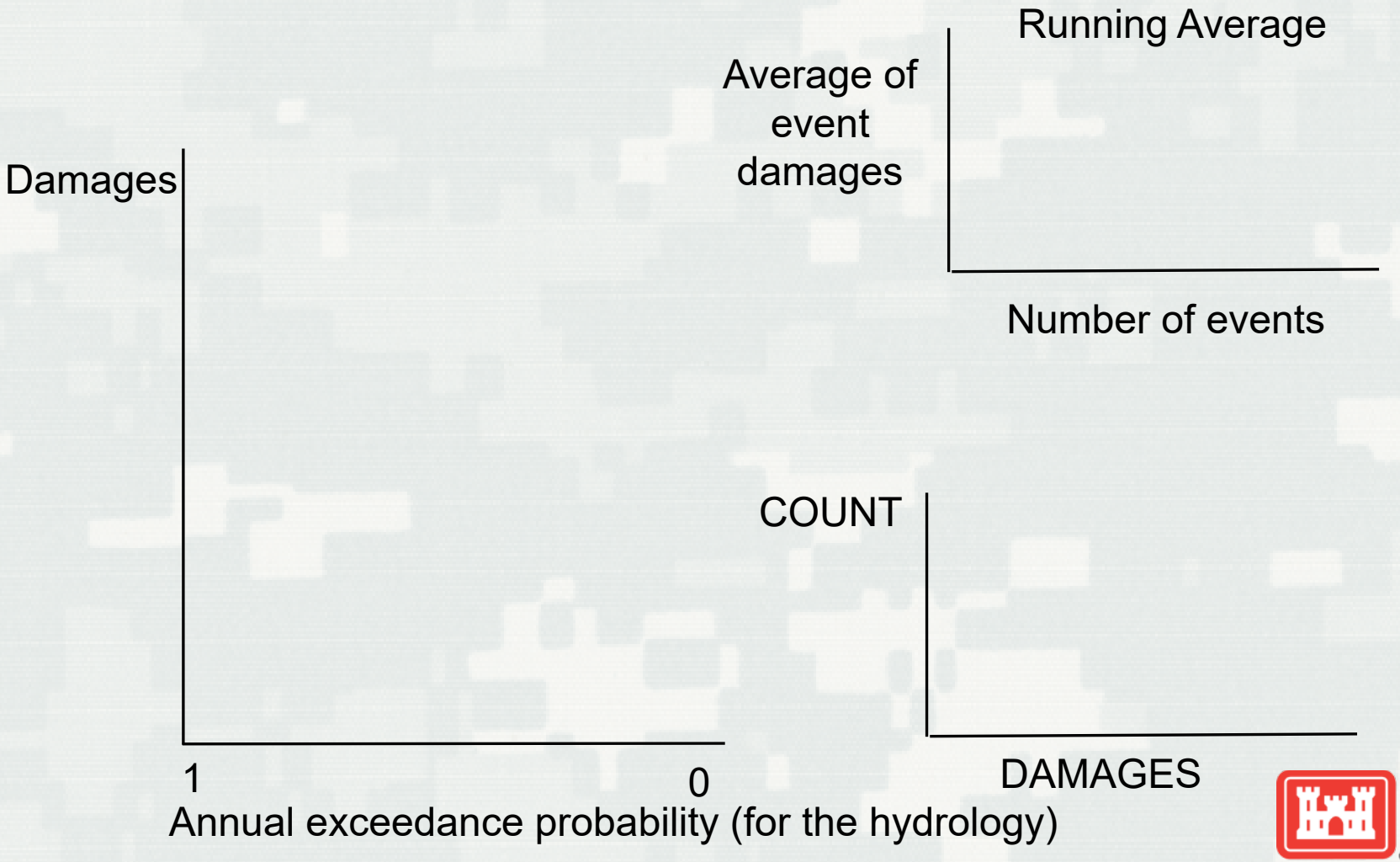

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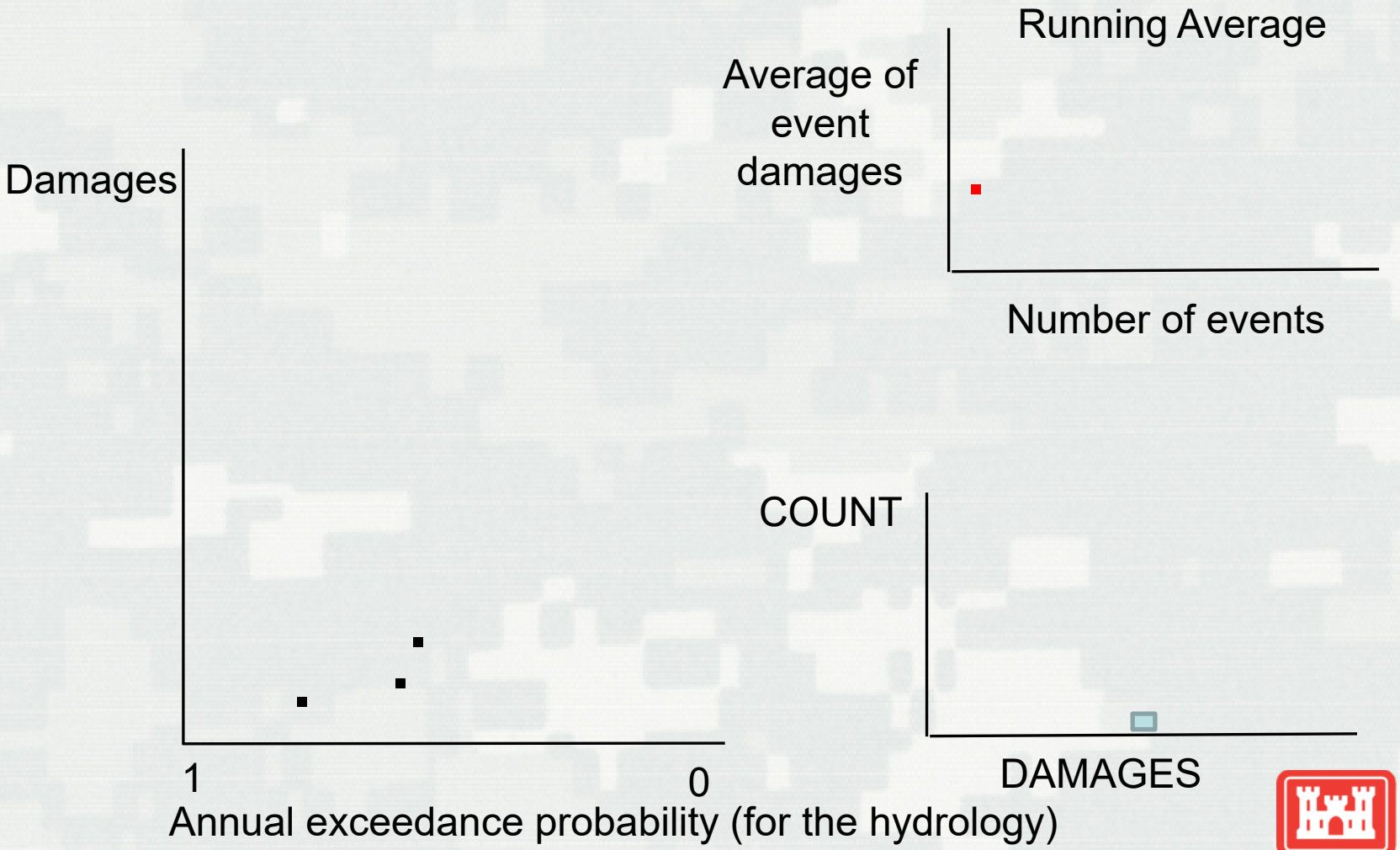

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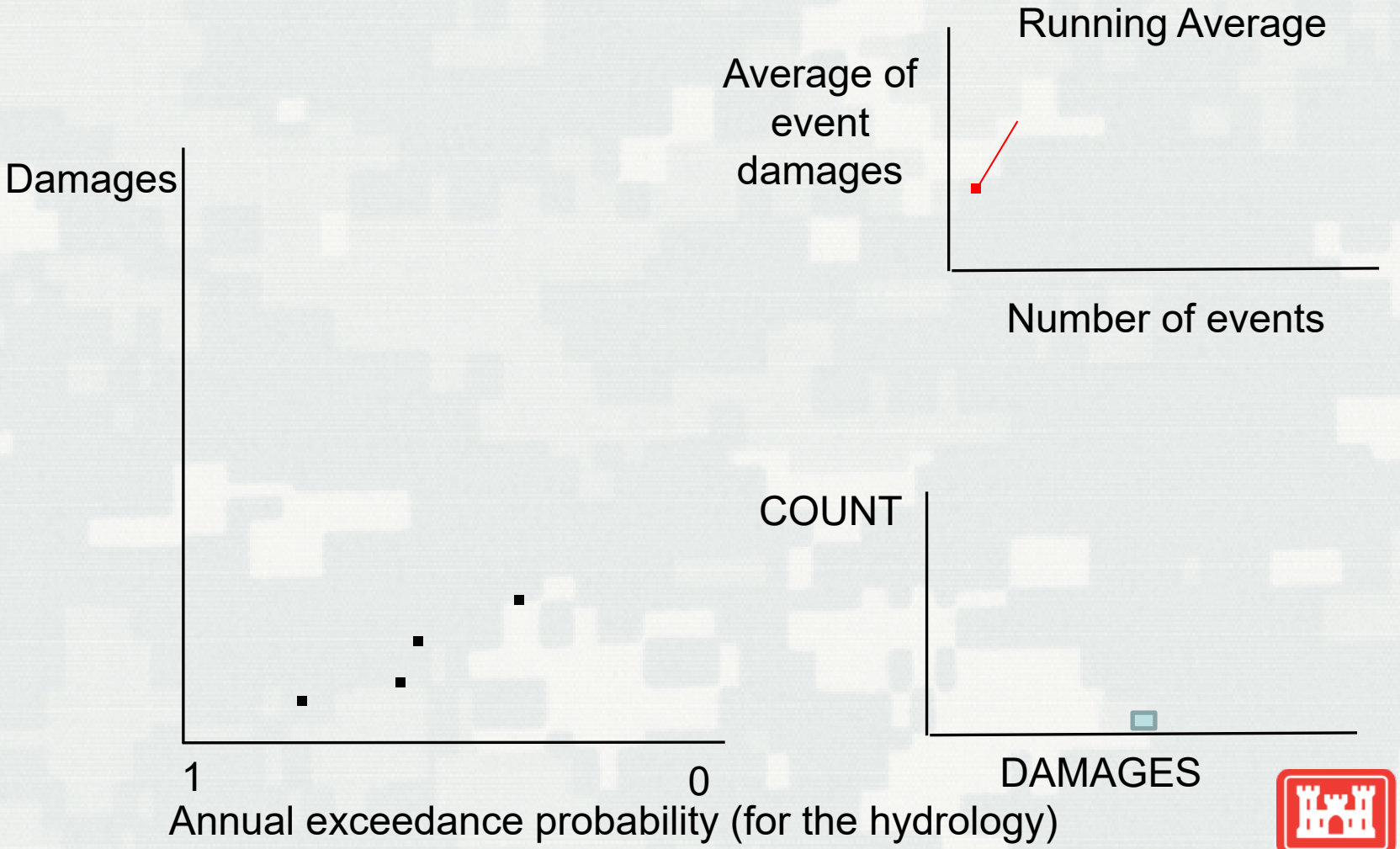

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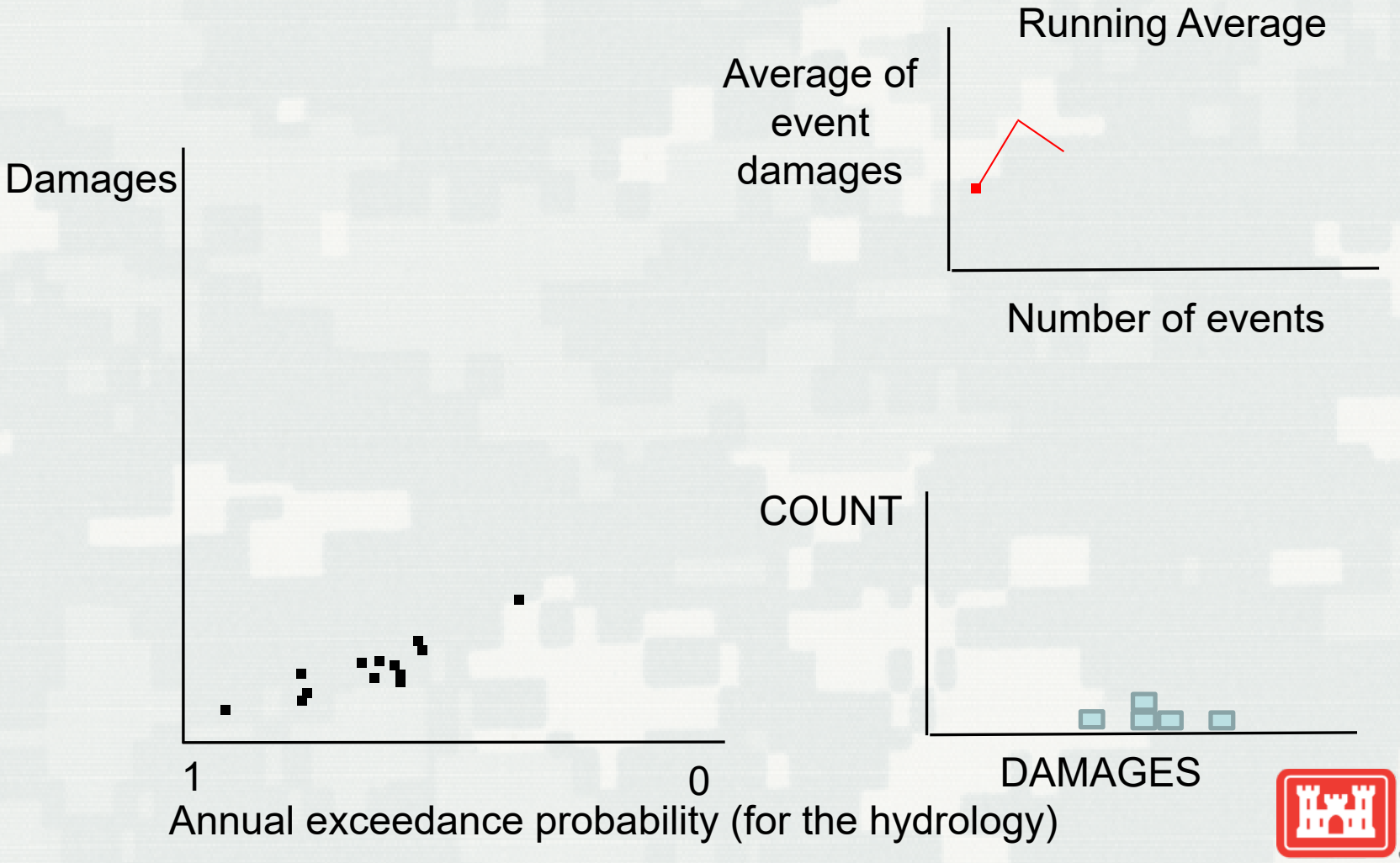

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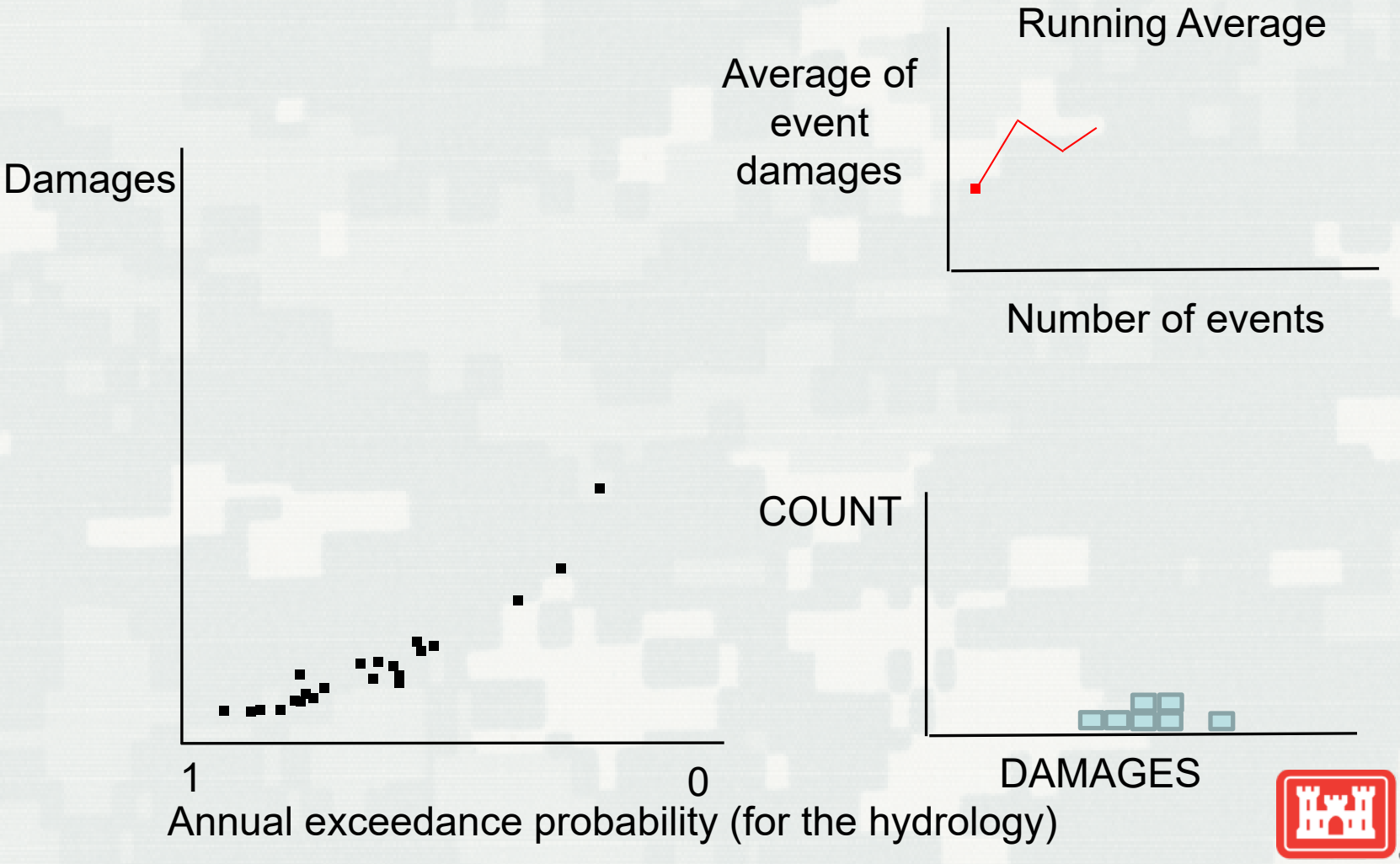

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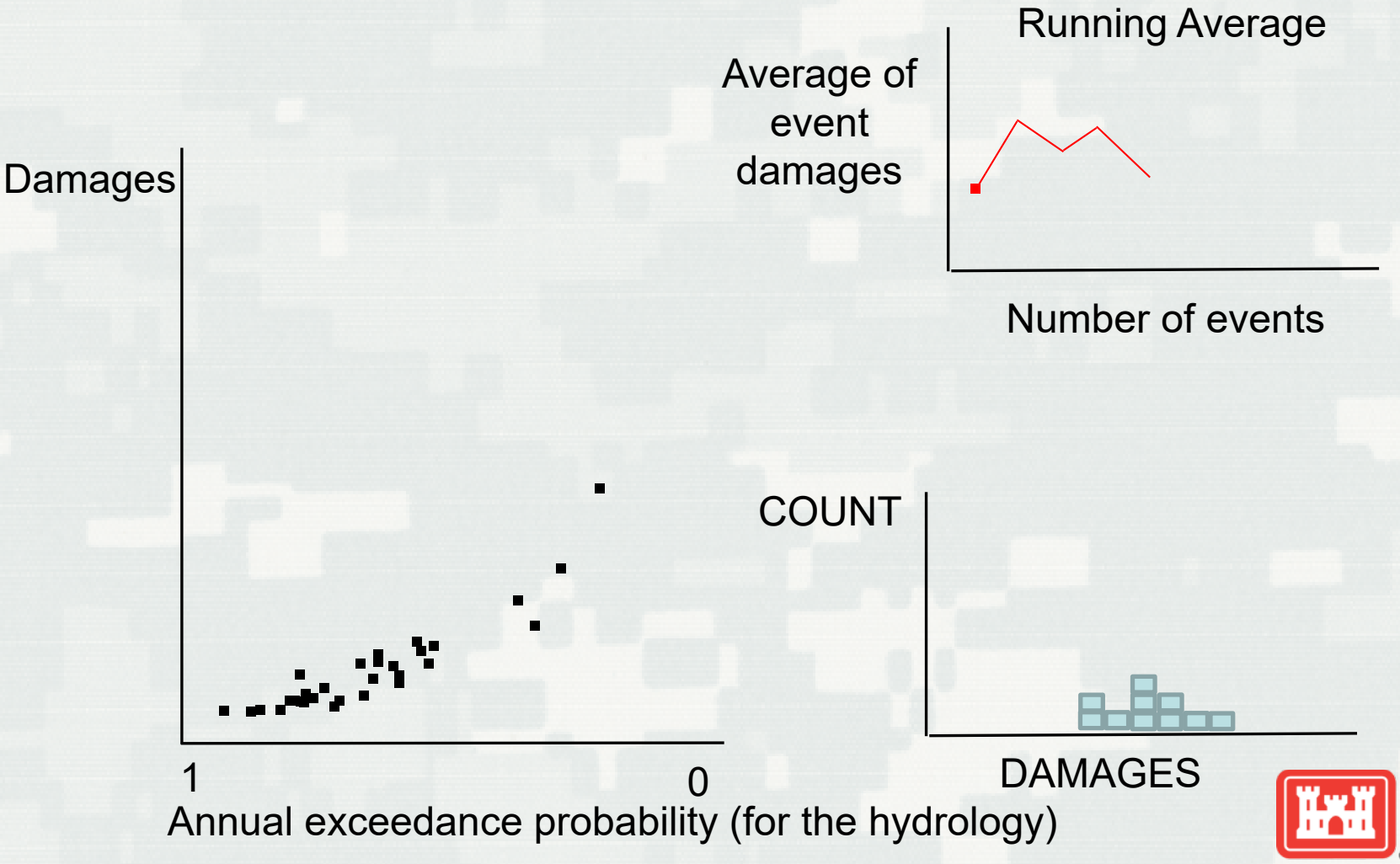

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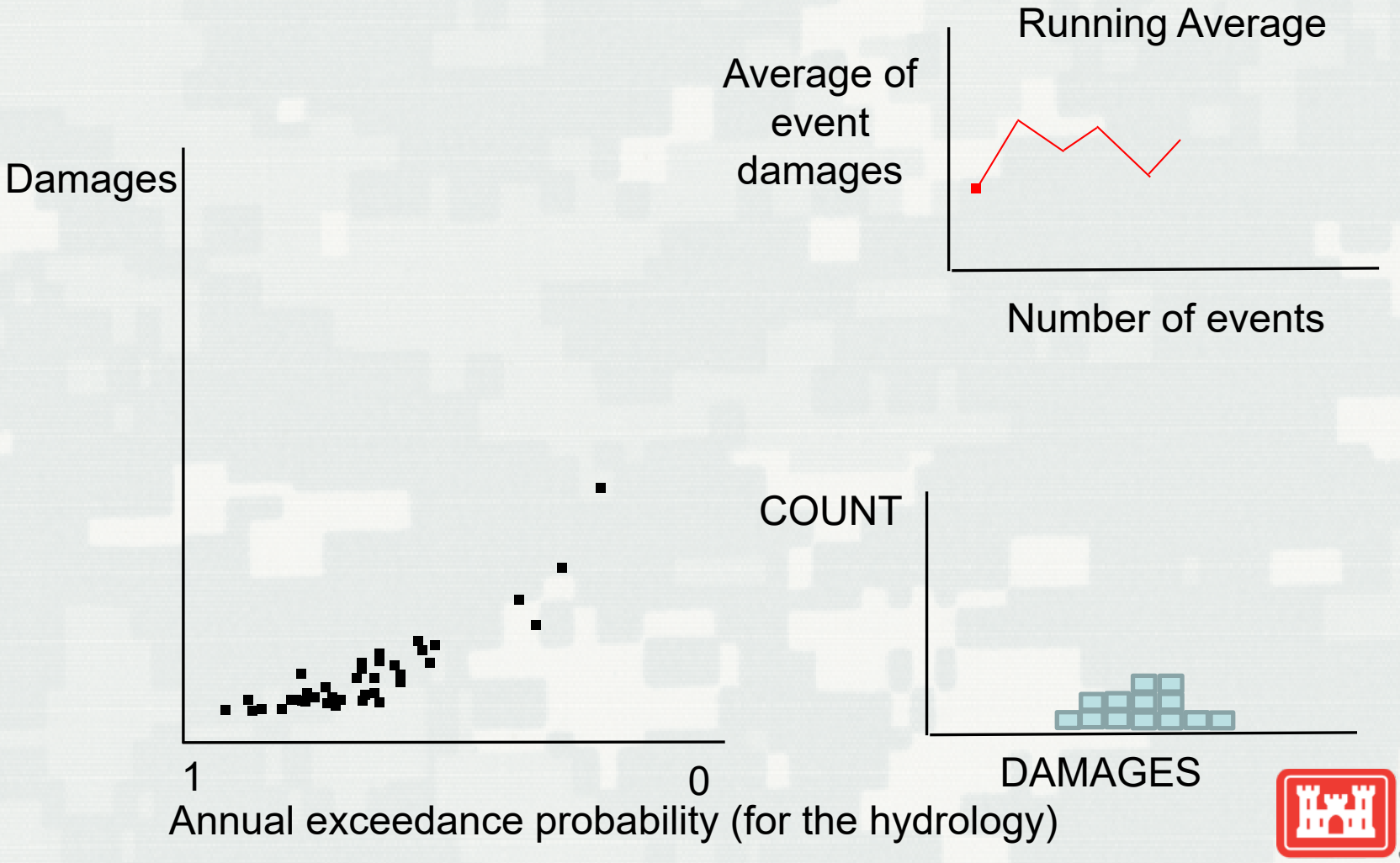

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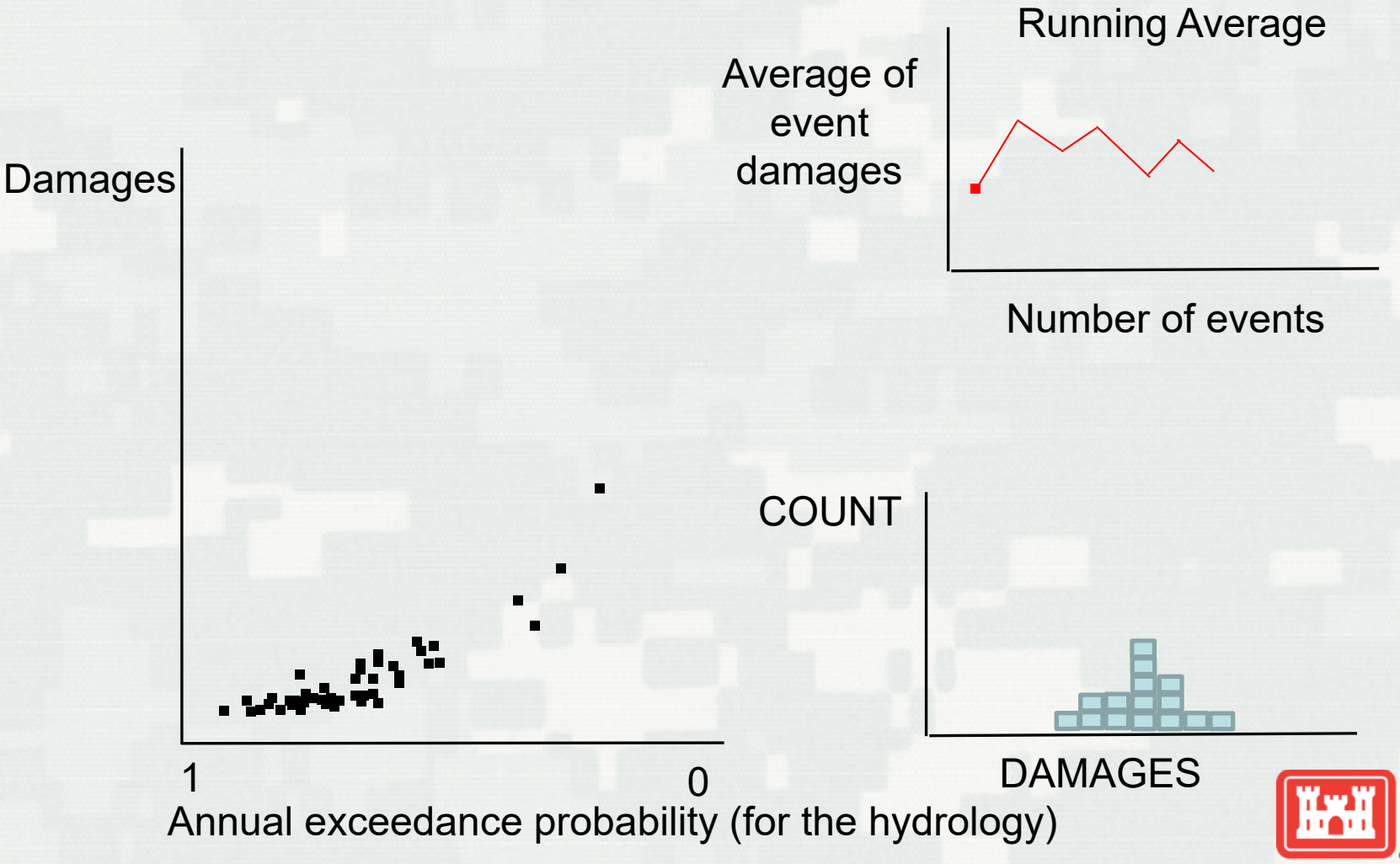

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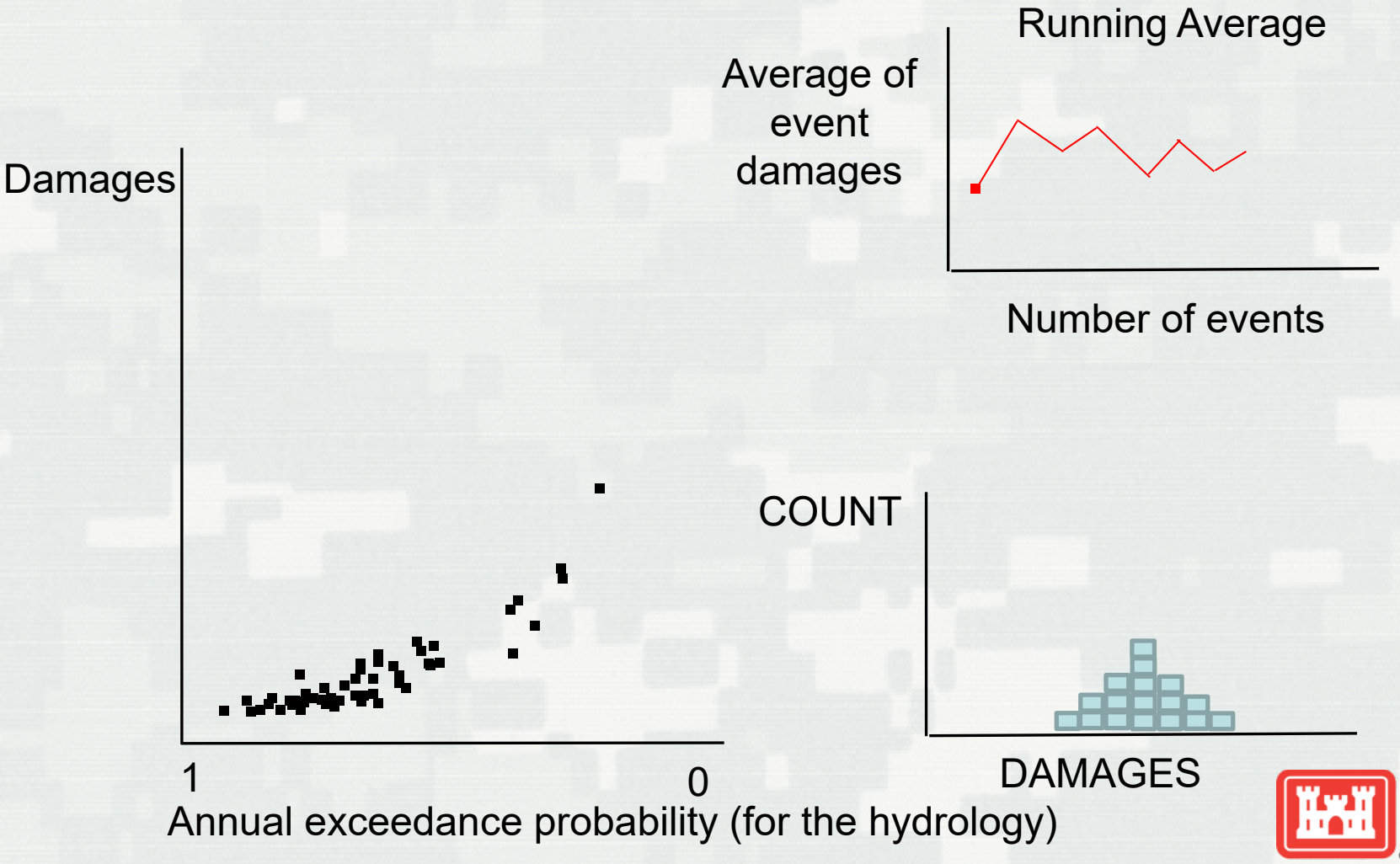

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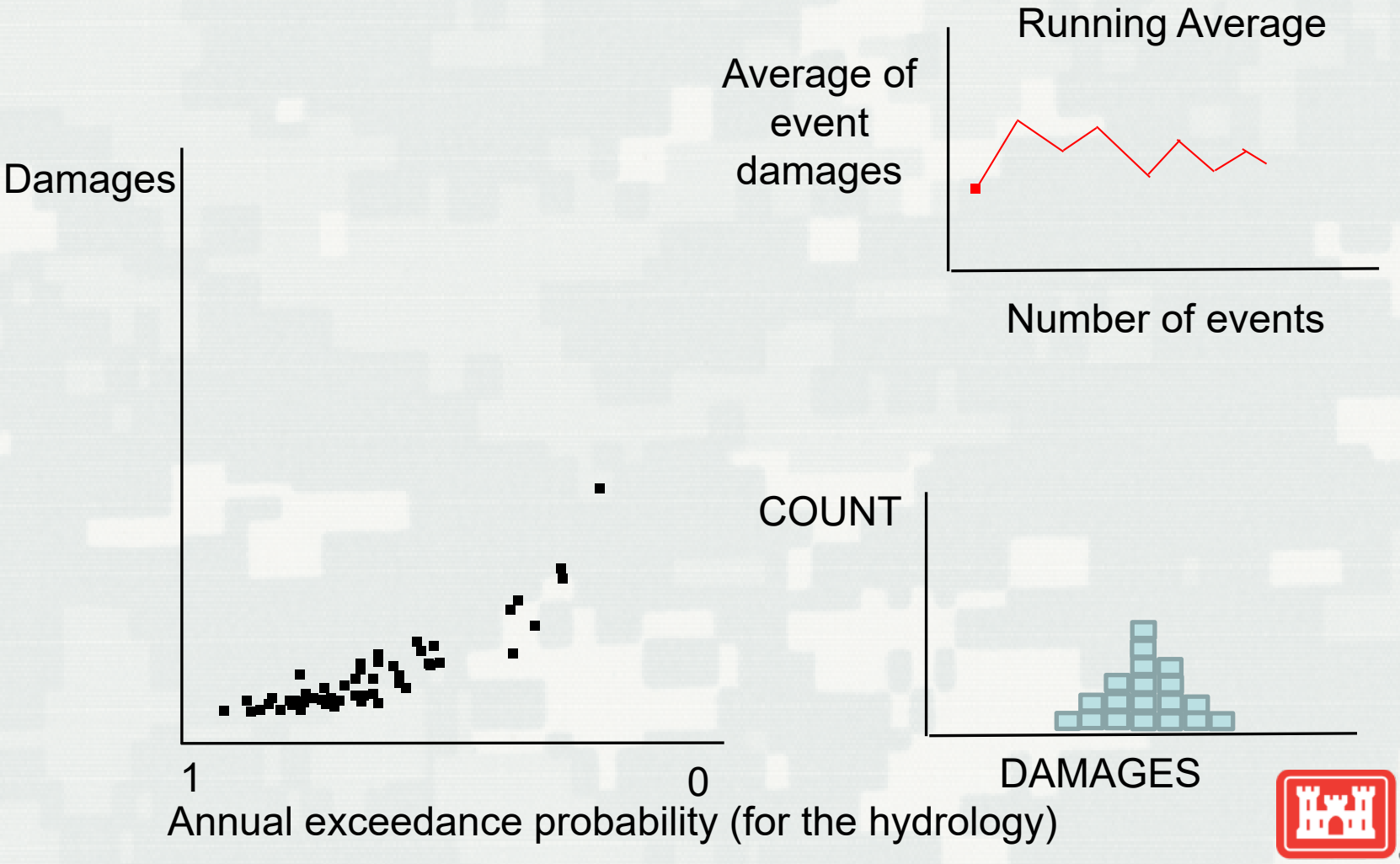

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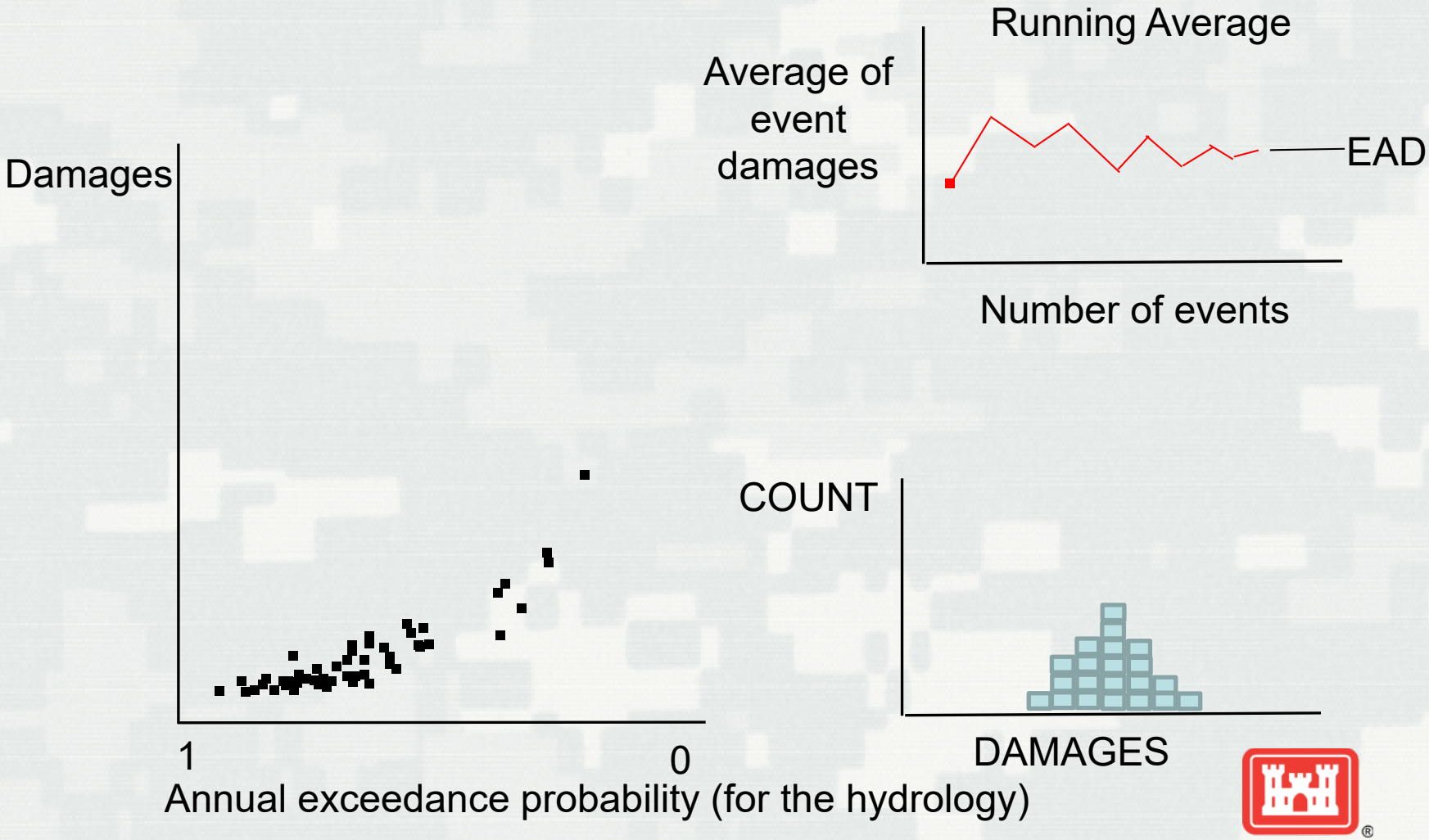

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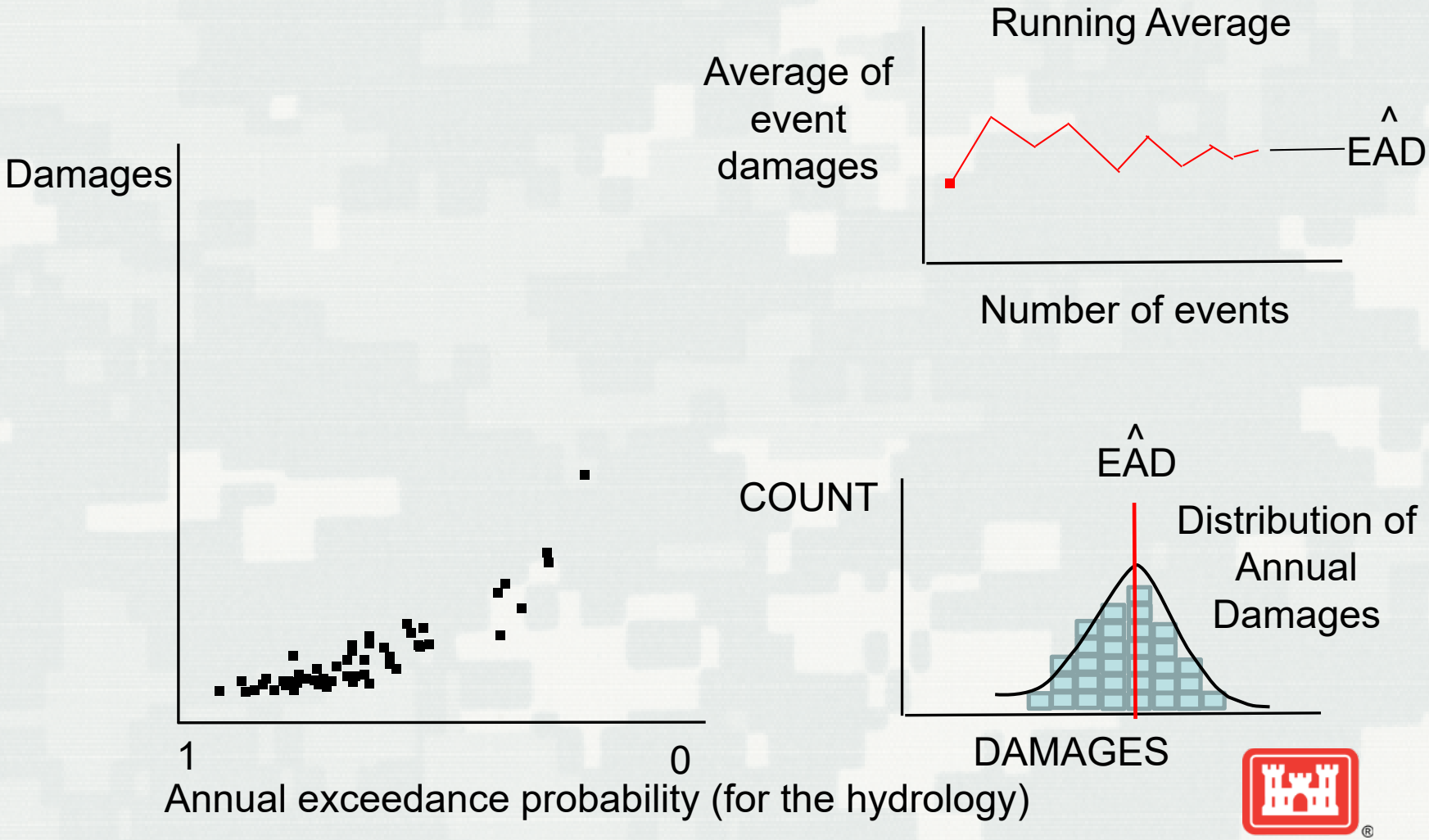
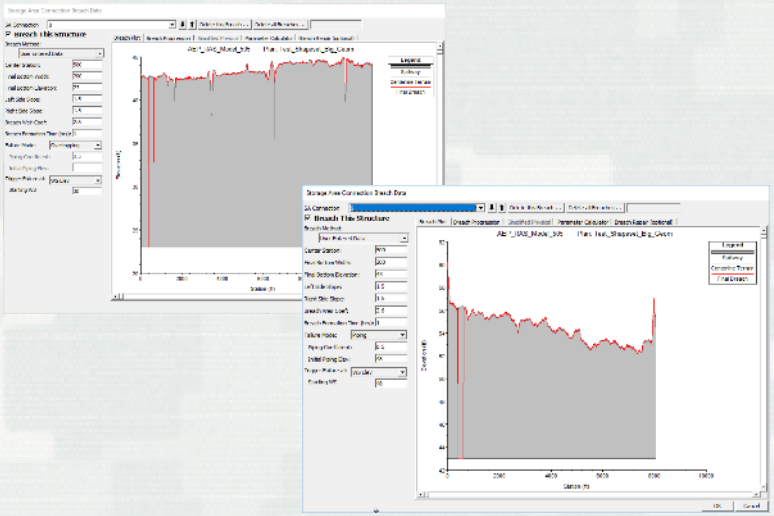
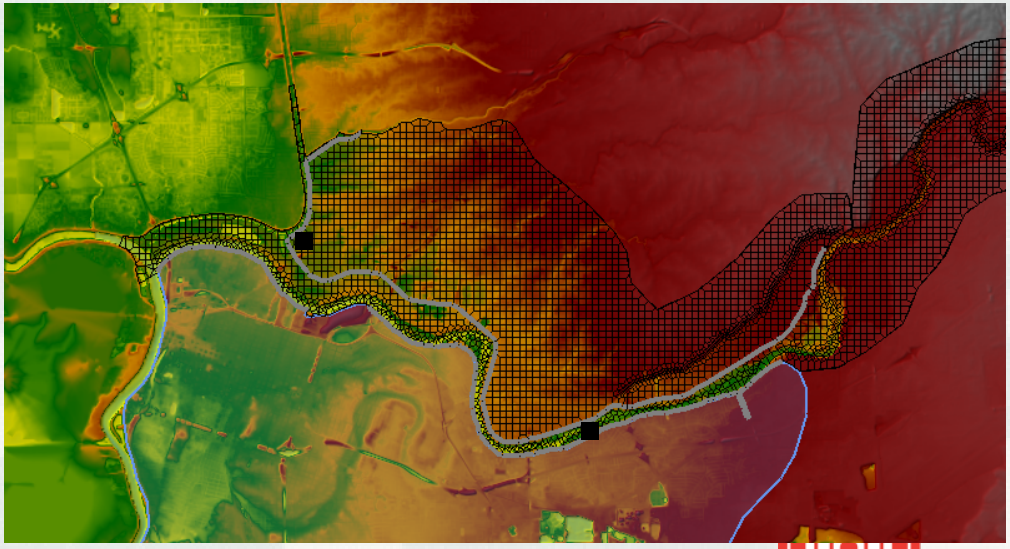


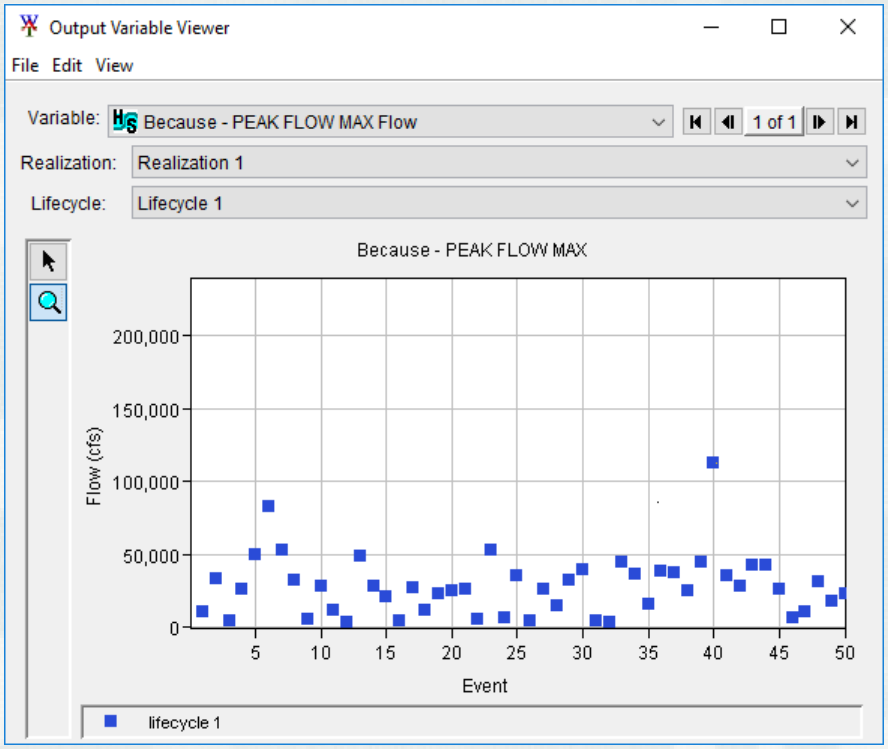
American River Insurance Study

- For stability a 2D channel was linked to a 2D overbank area through a 2D SA connection.
- Two connections were set to breach
- Model development took approximately 8 hours

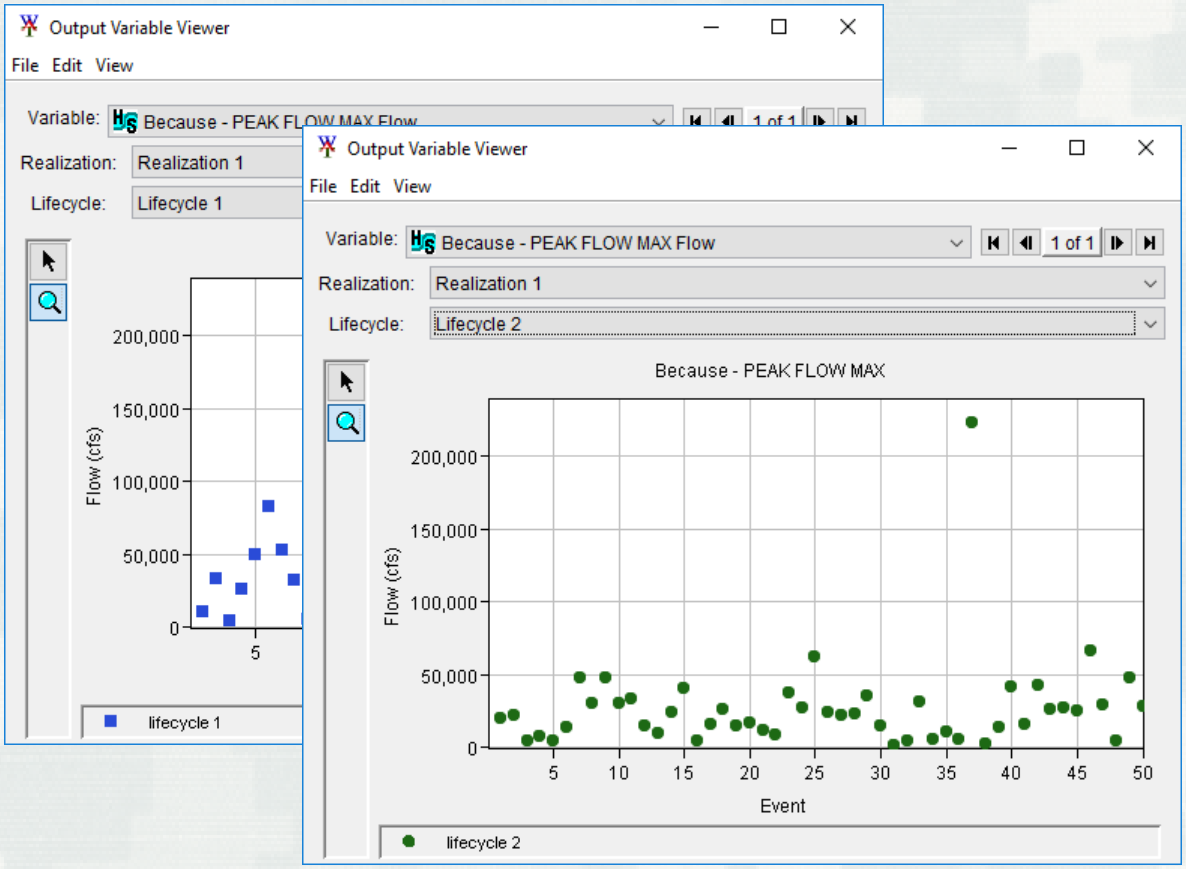




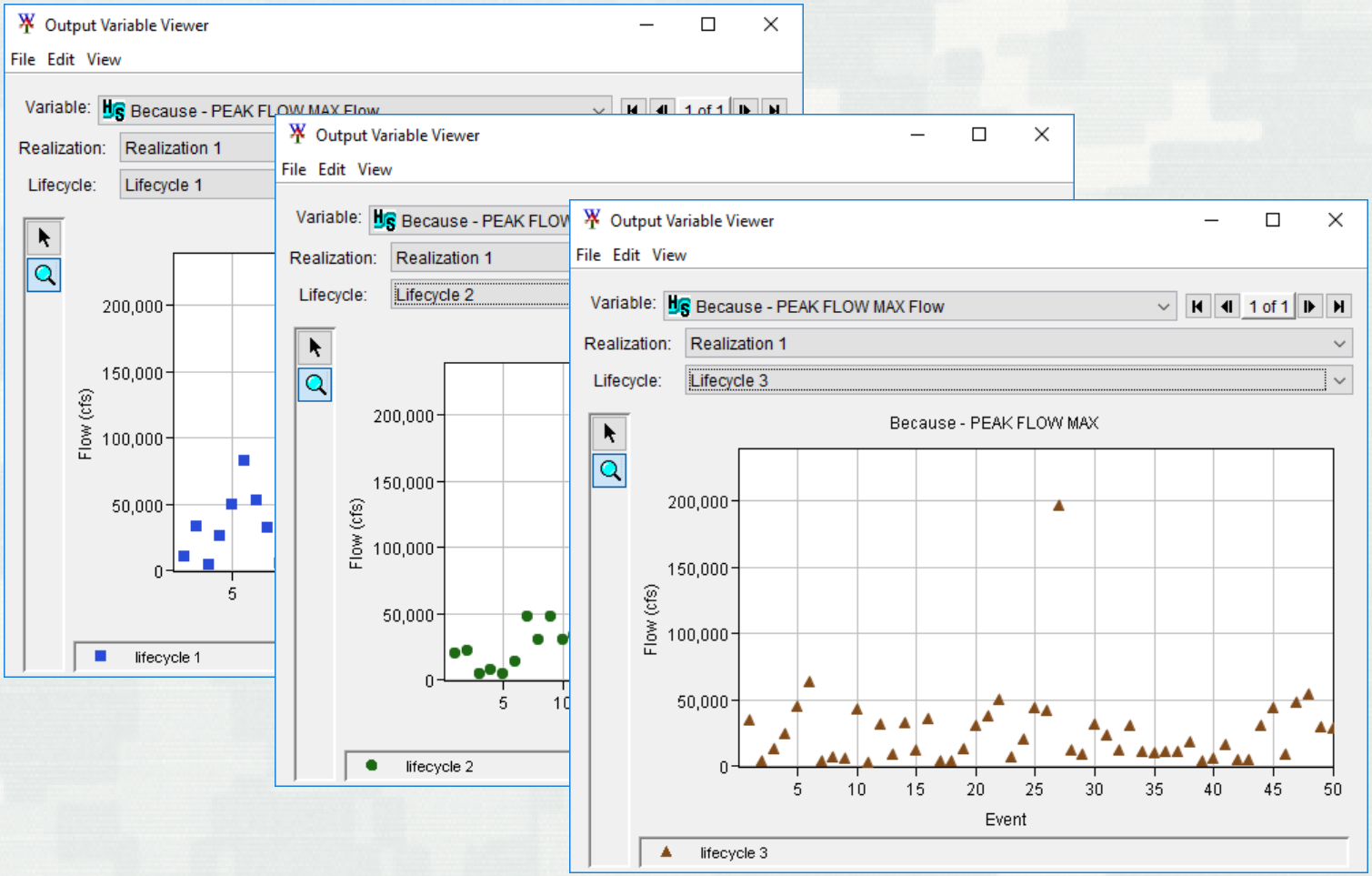
Hydrologic Sampler Events



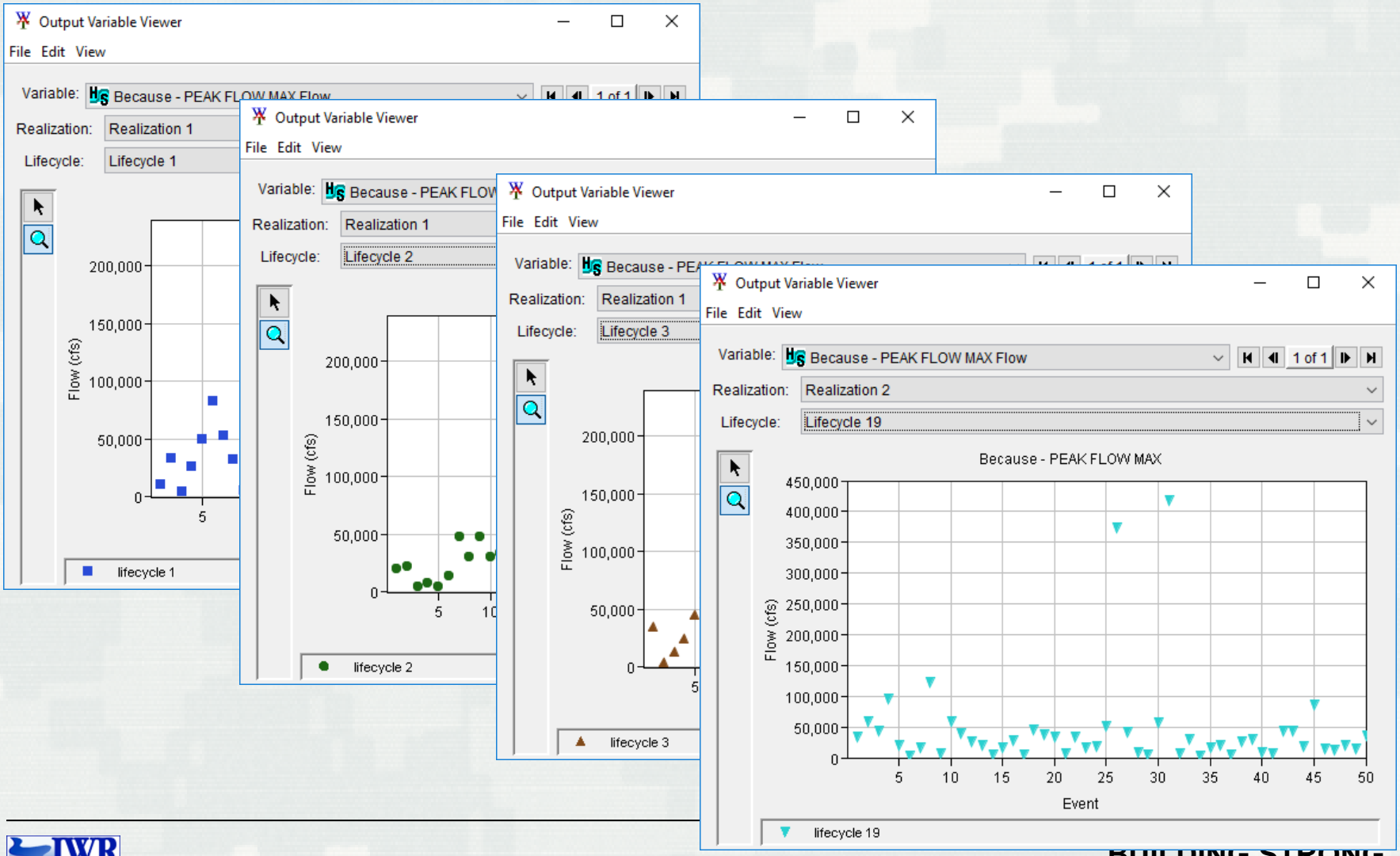
Hydrologic Sampler Events

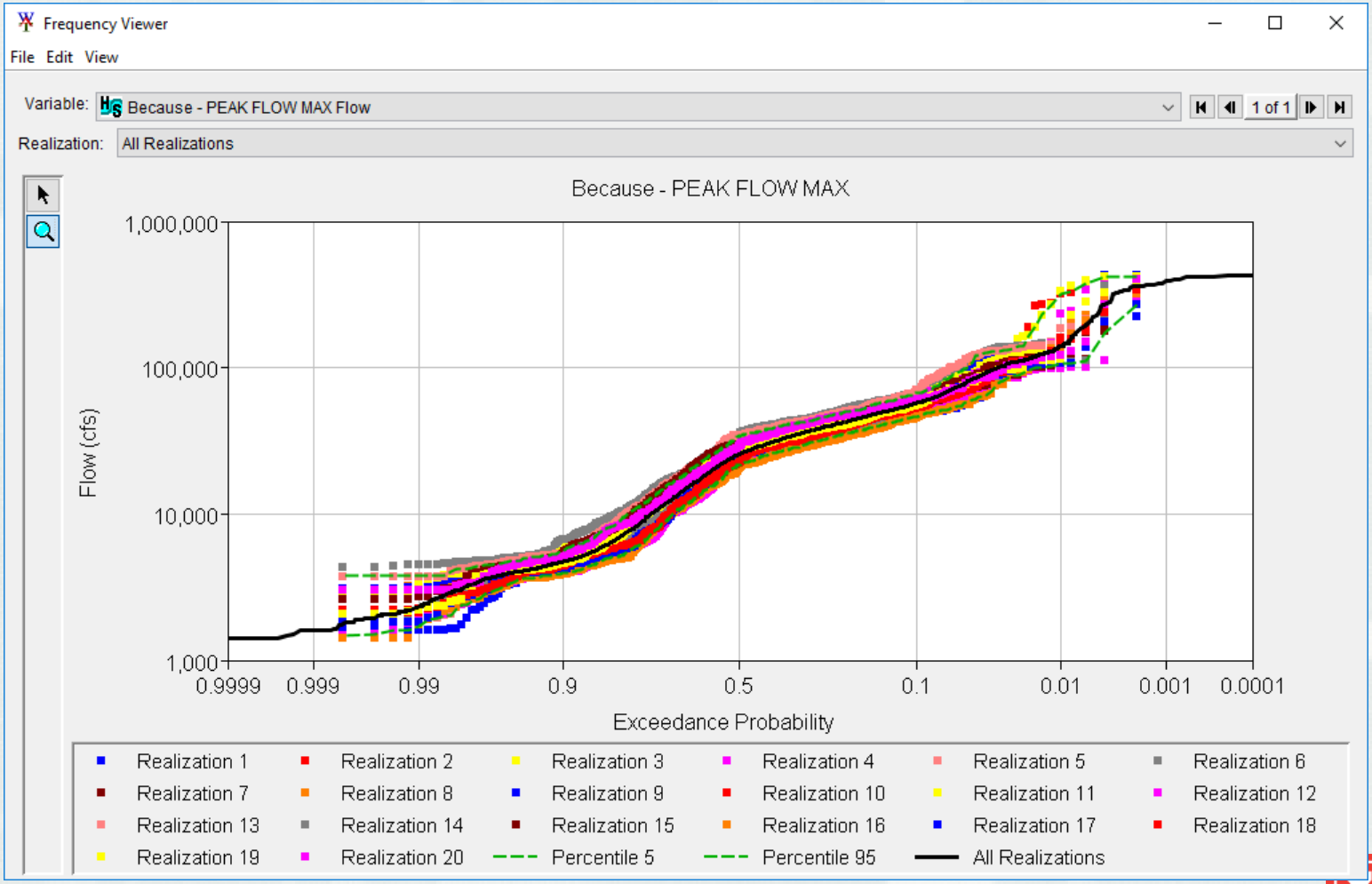


Hydrologic Sampler Events

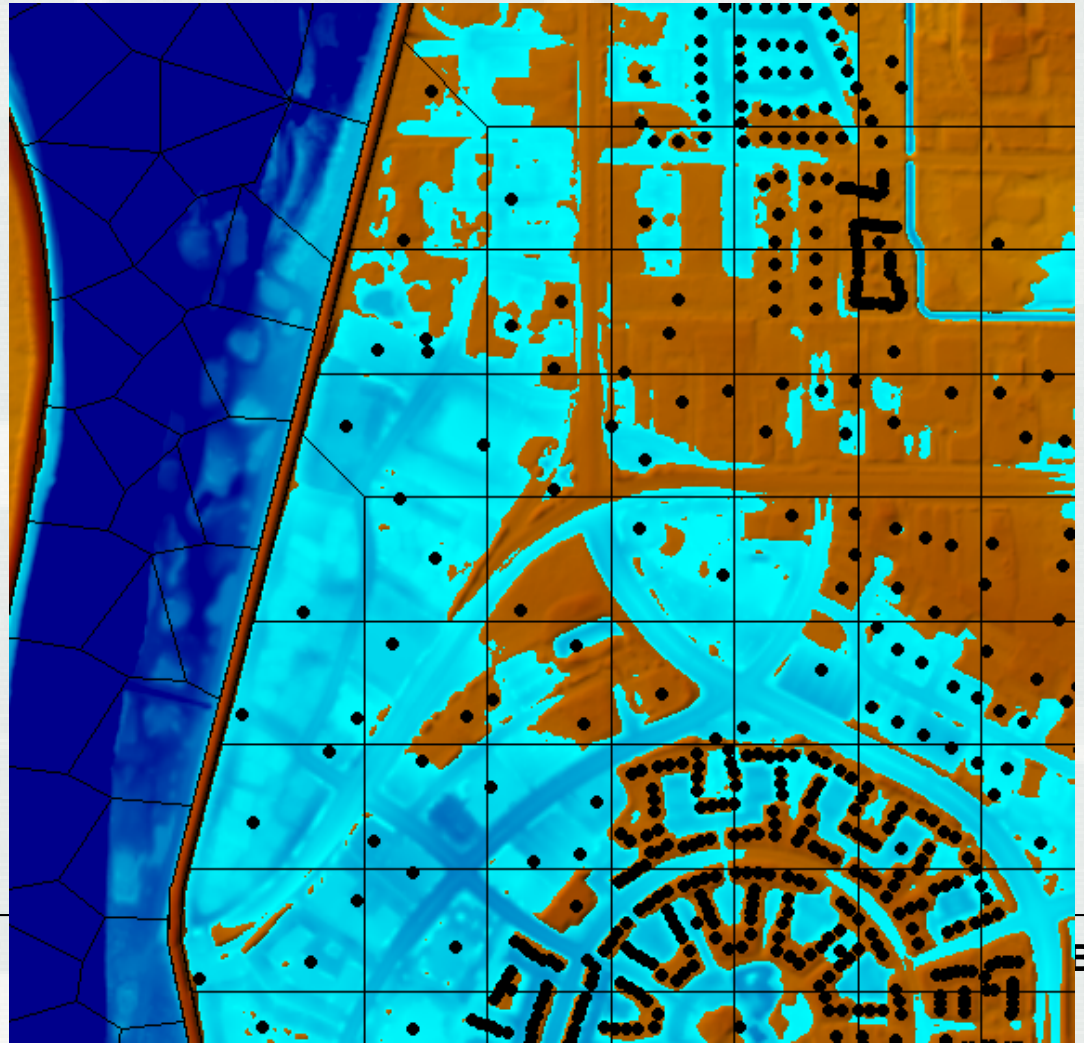


Hydrologic Sampler Events

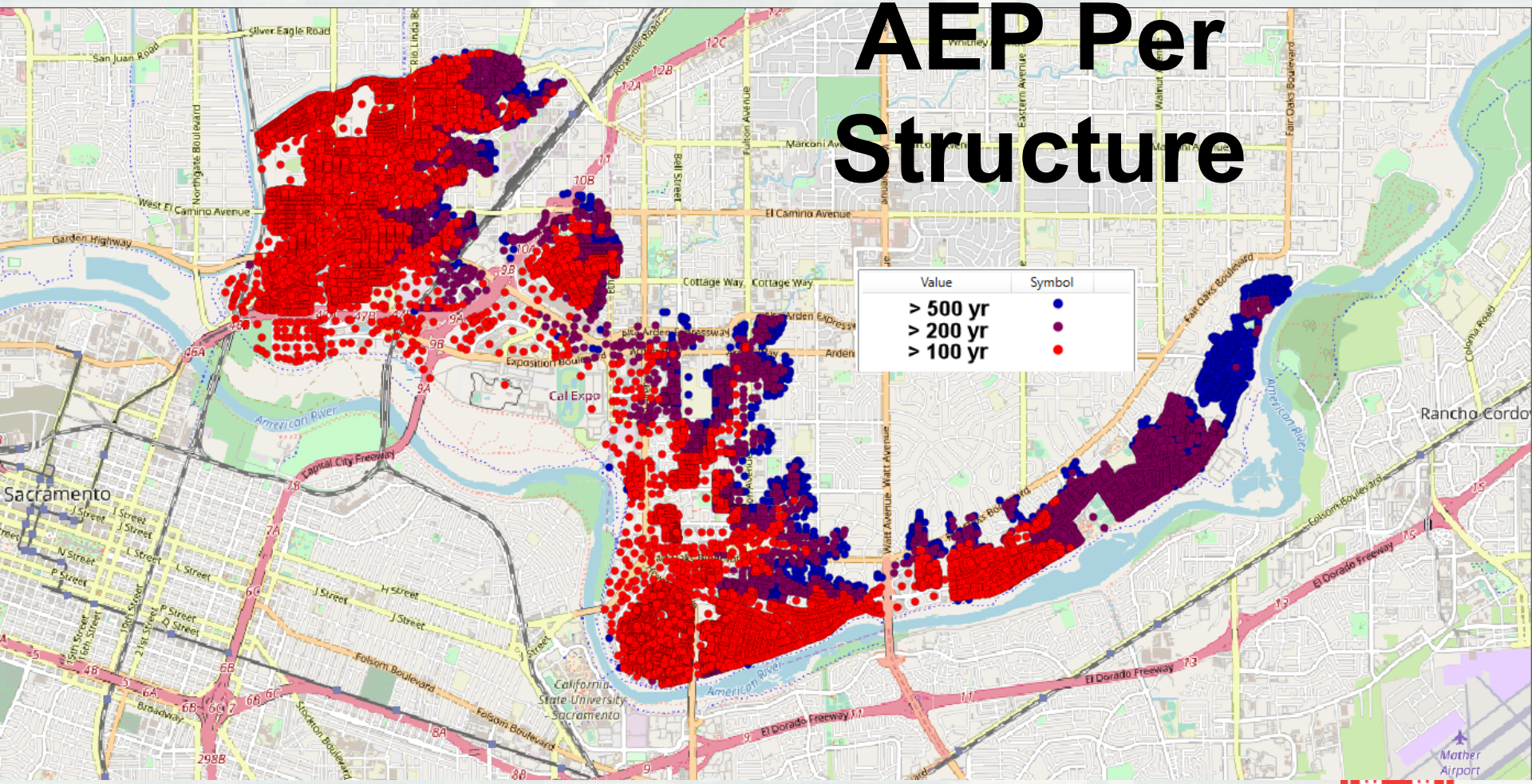



Frequency Viewer
File Edit View
Variable: Because - PEAK FLOW MAX Flow
1 of 1
Realization: All Realizations
Because - PEAK FLOW MAX
1,000,000
100,000
10,000
1,000
Flow (cfs)
0.9999
0.999
0.99
0.9
0.5
0.1
0.01
0.001
0.0001
Exceedance Probability
Realization 1
Realization 2
Realization 3
Realization 4
Realization 5
Realization 6
Realization 7
Realization 8
Realization 9
Realization 10
Realization 11
Realization 12
Realization 13
Realization 14
Realization 15
Realization 16
Realization 17
Realization 18
Realization 19
Realization 20
Percentile 5
Percentile 95
All Realizations

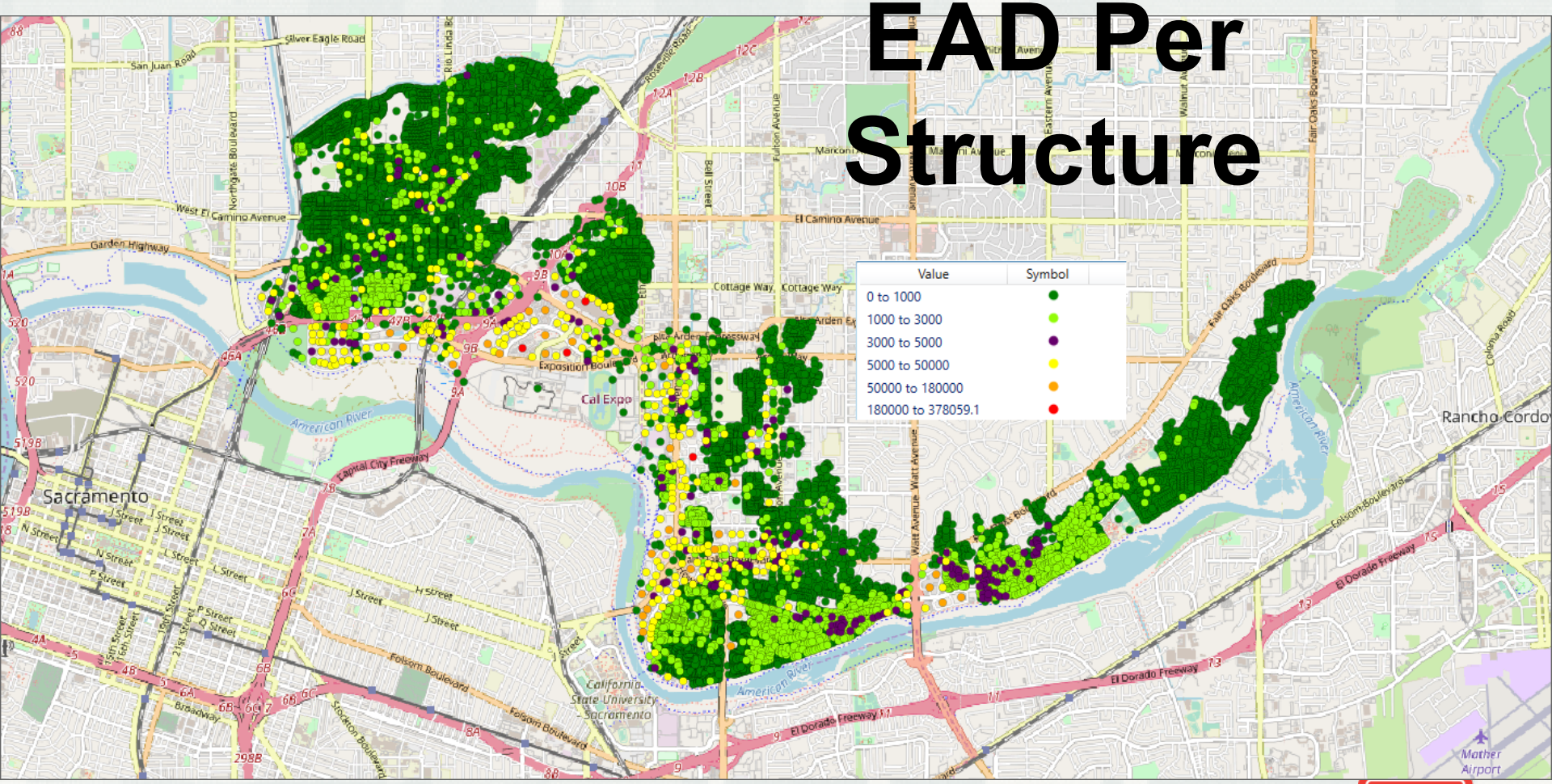
HEC-RAS output by event

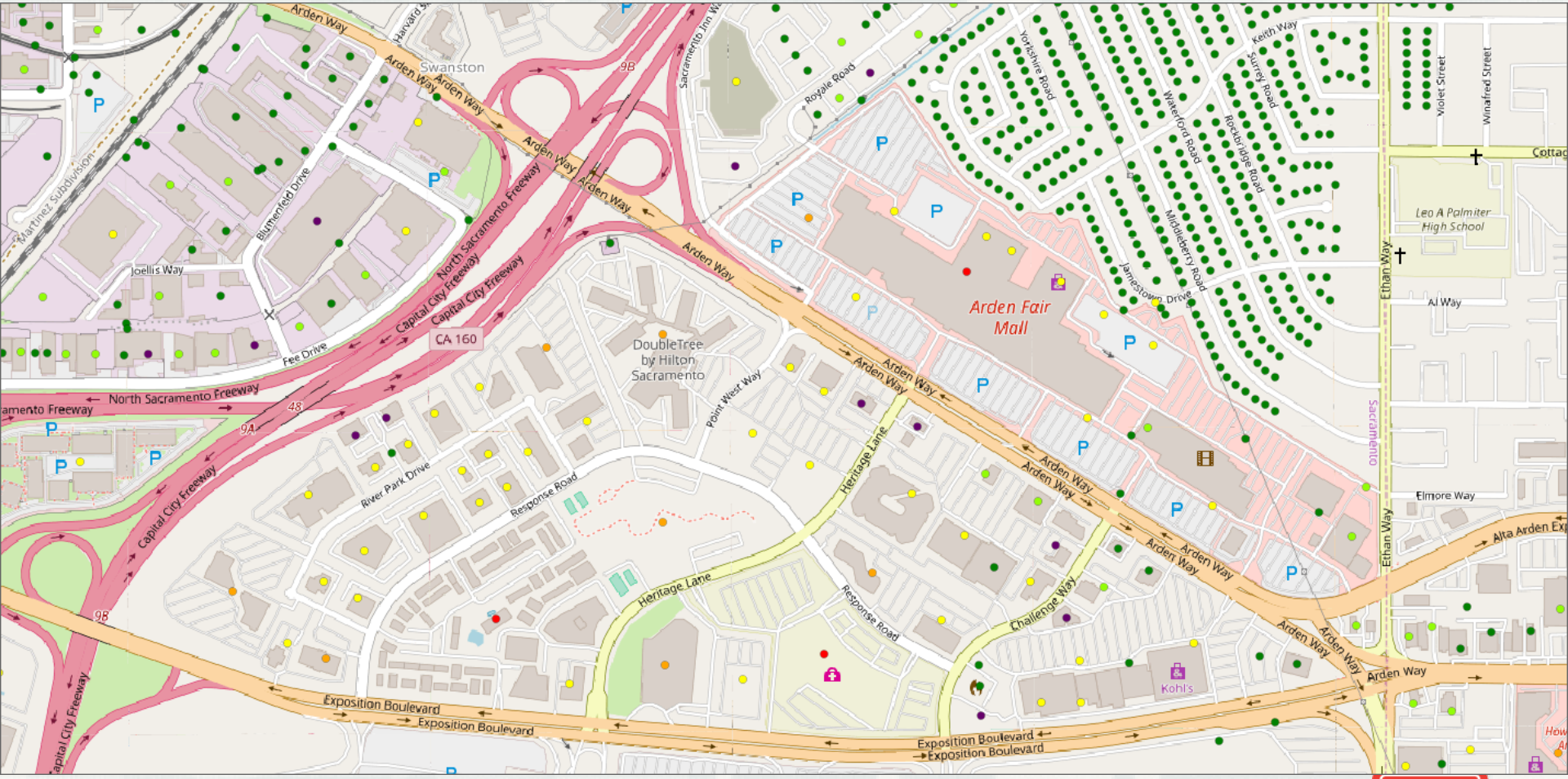


AEP Per Structure



EAD Per Structure

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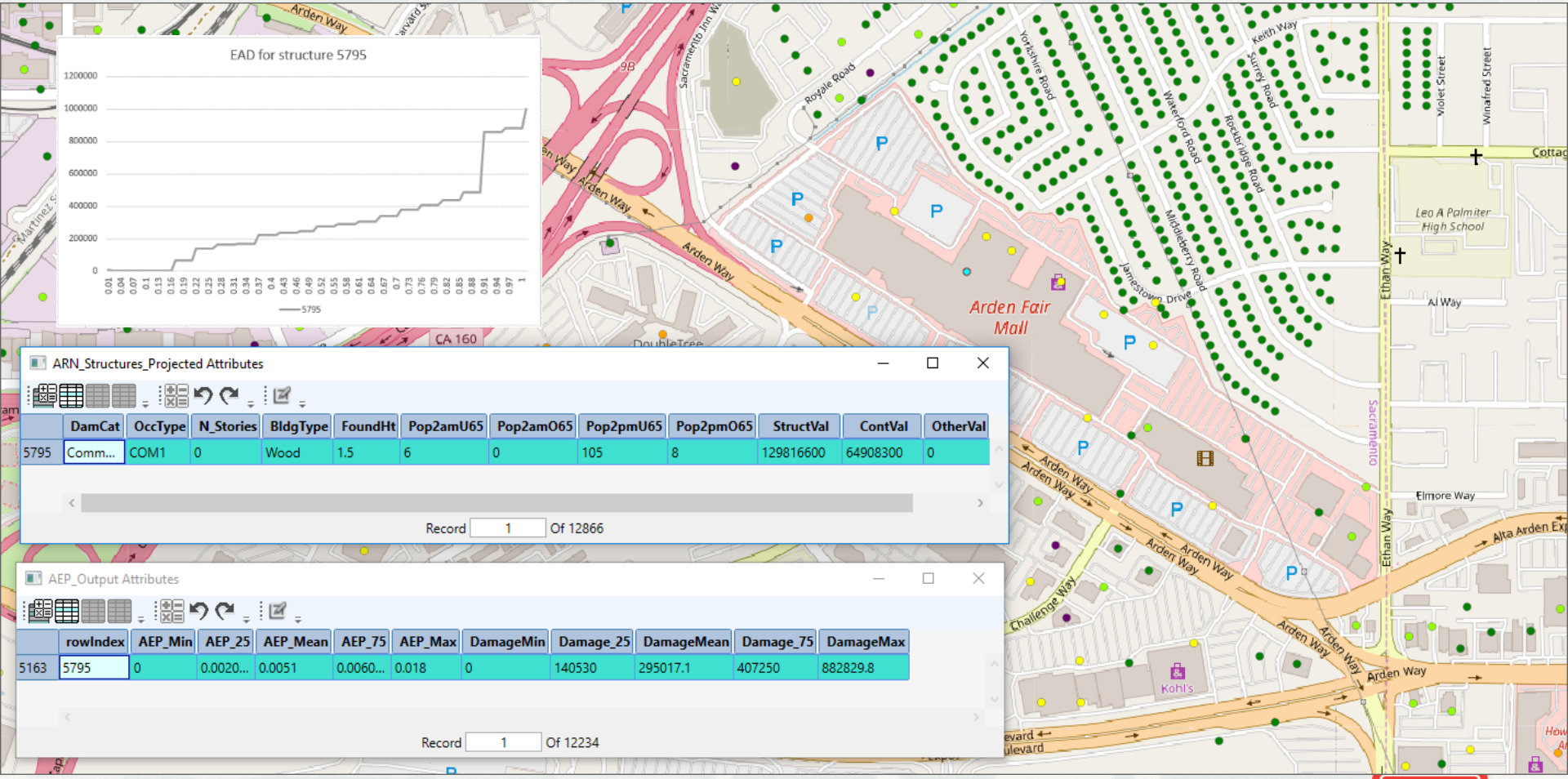
Swanston
Martinez Subdivision
Blumenfield Drive
Joellis Way
Fee Drive
North Sacramento Freeway
Capital City Freeway
CA 160
DoubleTree by Hilton Sacramento
Point West Way
River Park Drive
Response Road
Heritage Lane
Challenge Way
Arden Fair Mall
Royale Road
Yorkshire Road
Waterford Road
Surrey Road
Keith Way
Rochbridge Road
Huckleberry Road
Jamestown Drive
Violet Street
Winafred Street
Leo A Palmiter High School
Ethan Way
Al Way
Elmore Way
Alta Arden Expy
Kohl's
Exposition Boulevard
98
48
9A


EAD for structure 5795
1200000
1000000
800000
600000
400000
200000
0
5795
ARN_Structures_Projected Attributes
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5795 | Comm... | COM1 | 0 | Wood | 1.5 | 6 | 0 | 105 | 8 | 129816600 | 64908300 | 0
Record 1 Of 12866
AEP_Output Attributes
rowIndex | AEP_Min | AEP_25 | AEP_Mean | AEP_75 | AEP_Max | DamageMin | Damage_25 | DamageMean | Damage_75 | DamageMax
5163 | 5795 | 0 | 0.0020... | 0.0051 | 0.0060... | 0.018 | 0 | 140530 | 295017.1 | 407250 | 882829.8
Record 1 Of 12234
Arden Way
Arden Fair Mall
Royale Road
Yorkshire Road
Waterford Road
Keith Way
Surrey Road
Rochbridge Road
Mulberry Road
Violet Street
Winafred Street
Leo A Palmiter High School
Ethan Way
Al Way
Elmore Way
Alta Arden Expy
Challenge Way
Kohl's
Jamestown Drive
Sacramento
DoubleTree
CA 160

Conclusion

- HEC-WAT/FRA is a planning and evaluation tool that conducts risk assessments in a systems context.
- It includes systems approaches, event sampling, alternative analyses, structural and non-structural analyses, Life Loss, agricultural damage analyses.
- Is being used nationwide for dam and levee evaluations and assessments, and planning and design studies.

QUESTIONS?

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