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2D Rain-on-Grid Sensitivity Testing

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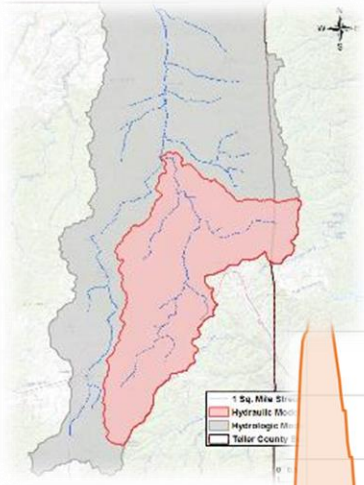
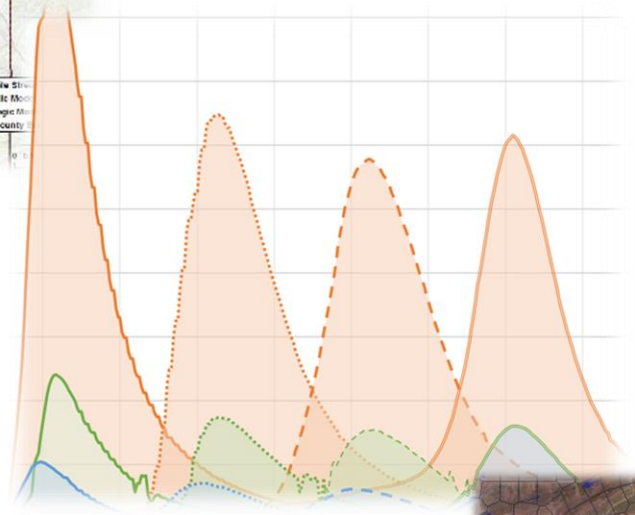
UFSMA Conference 2020

October 21, 2020

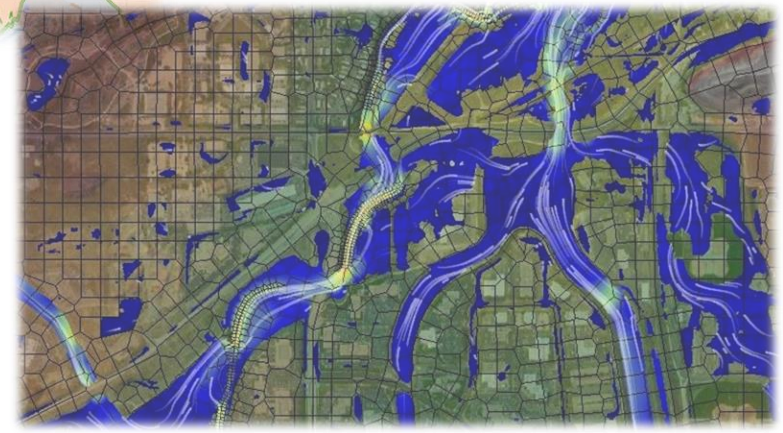
Presentation Outline



OVERVIEW:
Purpose, Study Overview



Hydrologic Variations & Sensitivity Results



Hydraulic Variations & Sensitivity Results

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Poll Question

– I have personally used the following modeling software: (select all that apply)
  - HEC-2
  - HEC-RAS 1D
  - HEC-RAS 2D (or other 2D software package)
  - HEC-2 **AND** HEC-RAS 2D
  - None of the above

Software	Release Date
HEC-2	1968
HEC-RAS 1.0	1995
HEC-RAS 5.0	2016

Goals & Purpose for Study

To assess the relative influence and impacts of various H&H parameters on rain-on-mesh results, so that we can…

– Better root future decisions in logic rather than subjectivity
– Better defend decisions made in H&H analysis
– Substantiate best practices with example data
– Quantify variability the range of results associated with input uncertainty bands

Thanks to:

FEMA

DEPARTMENT of PUBLIC SAFETY
DIVISION of EMERGENCY MANAGEMENT
UTAH

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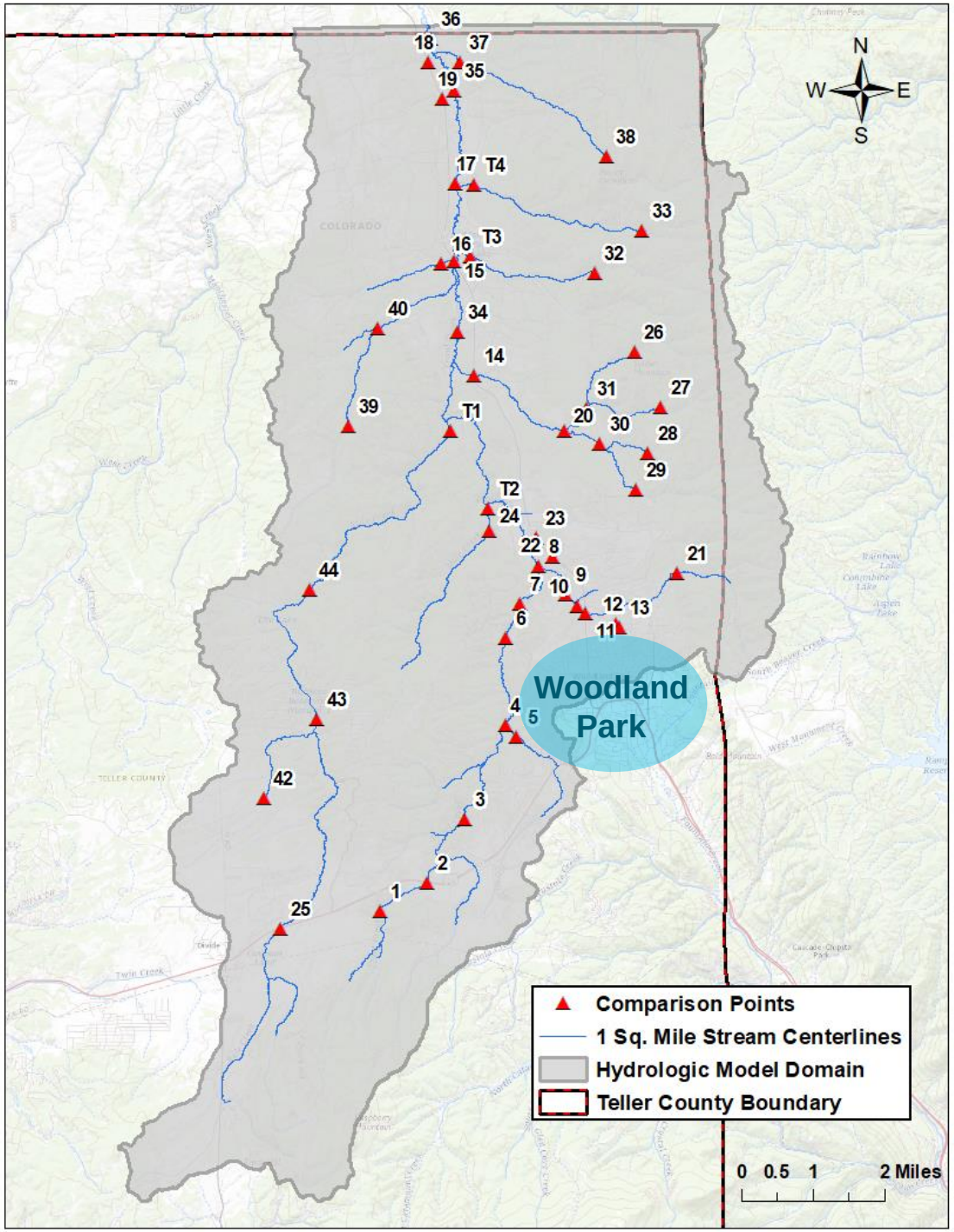
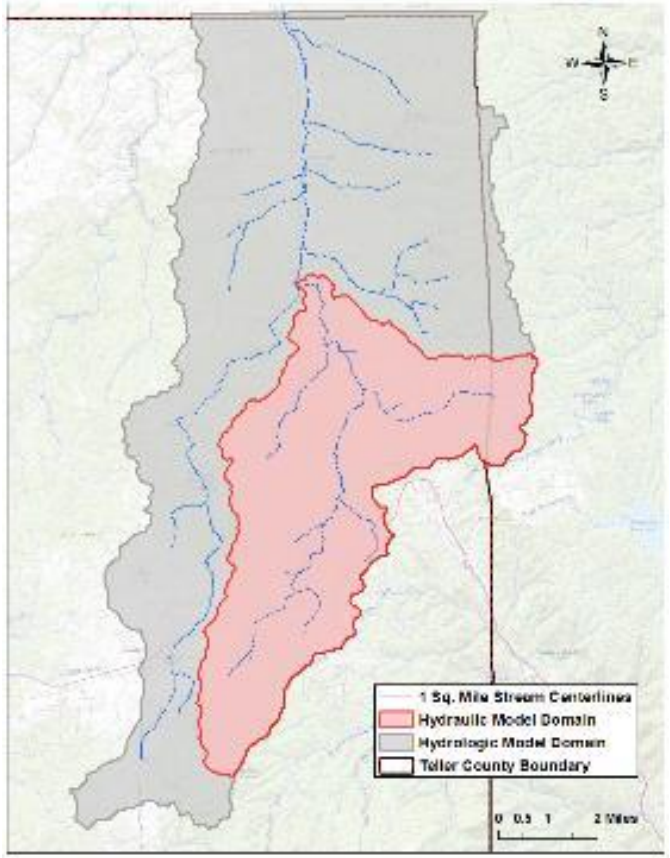
Hydrologic Study Area

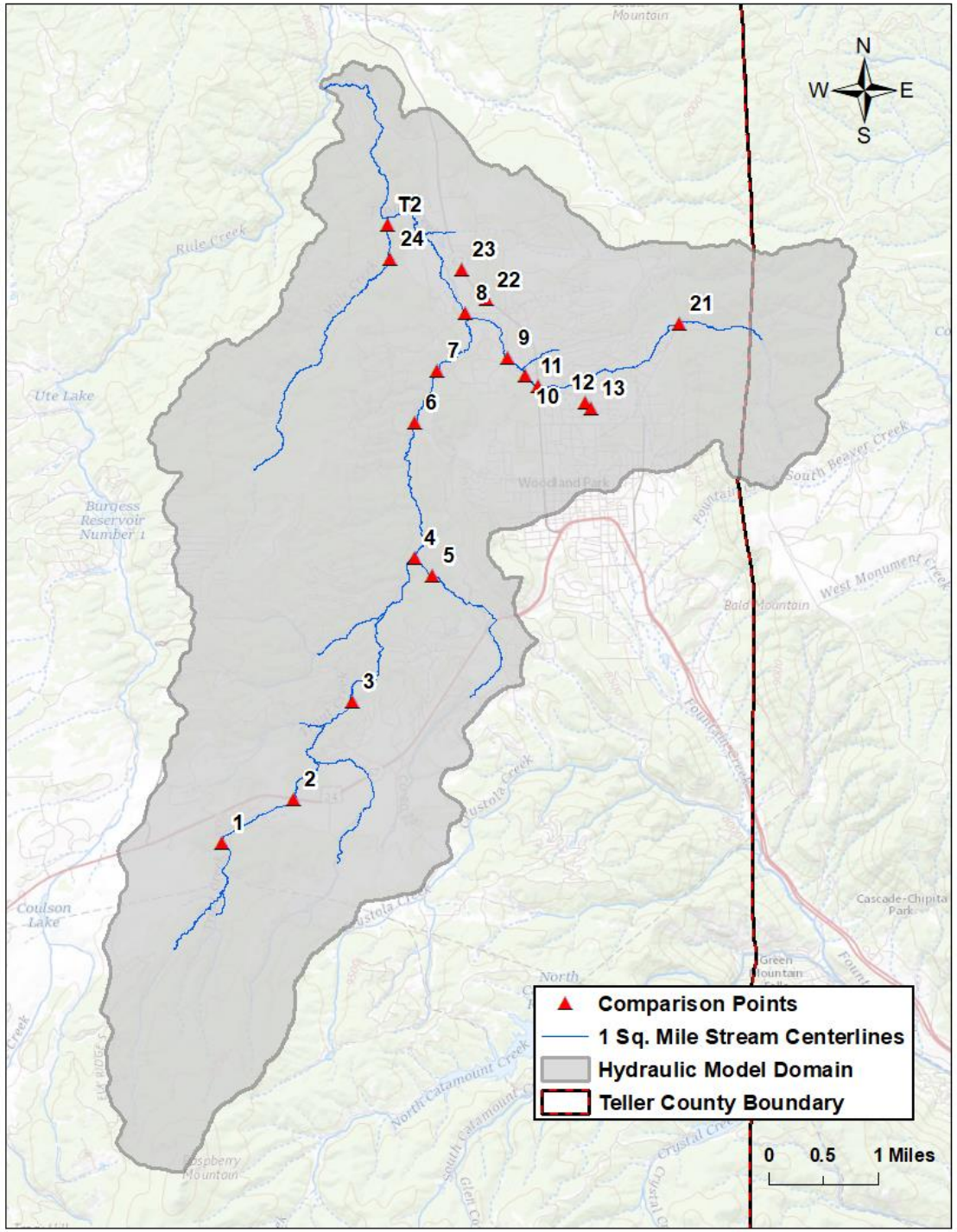
- Trout Creek Watershed in Teller County, Colorado
- ~85 sq mi with elevations ranging from 7,580 to 10,500 ft
- 47 internal model connections used as evaluation lines – DA's ranging from 0.1 to 85 sq mi
- Chosen for:
  - Variety in slopes (flat to steep)
  - Basin drainage areas
  - Relatively homogeneous land cover



Hydraulic Study Area

– Subset around ~29 sq mi
– 18 internal model connections used as evaluation lines – DA's ranging from 0.1 to 22 sq mi





Hydrologic Sensitivity

- Storm Distribution/Duration
- Depth Confidence Limits
- CN/Loss Parameters

Storm Distributions – NOAA Atlas 14

– 6 durations: 0.5, 1, 3, 6, 12, 24-hour
  - 4 Quartiles: Q1-Q4
    - 5 Deciles: D1, 3, 5, 7, 9

– Attempts to re-create actual historical events

Duration	All Cases	First quartile cases	Second quartile cases	Third quartile cases	Fourth quartile cases
6-hour	1,300	755 (58%)	271 (21%)	178 (14%)	96 (7%)
12-hour	1,356	710 (52%)	283 (21%)	215 (16%)	148 (11%)
24-hour	1,025	503 (49%)	206 (20%)	155 (15%)	161 (16%)
96-hour	1,134	542 (48%)	228 (20%)	188 (16%)	176 (16%)

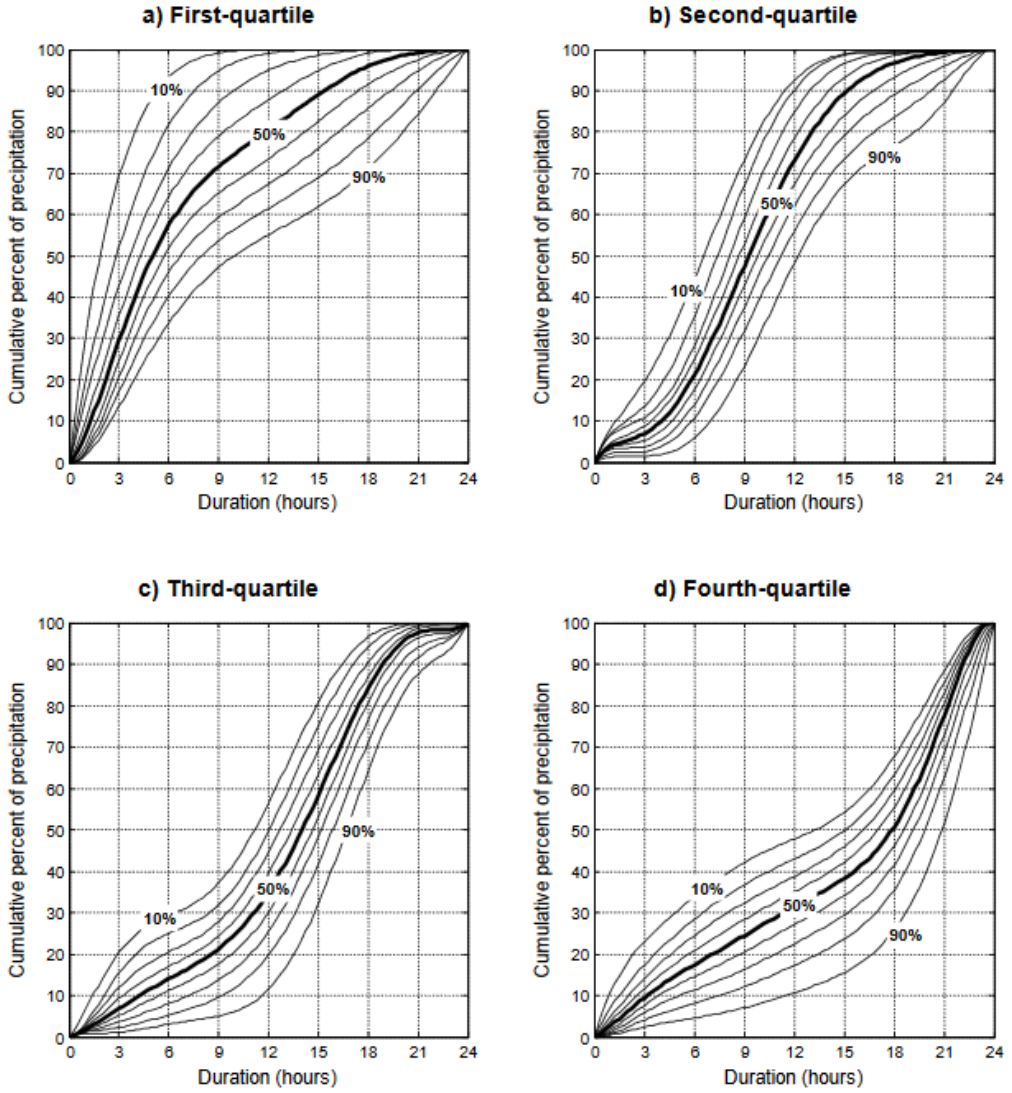


Figure A.5.4. 24-hour temporal distribution curves for the Mississippi Valley region (region 4): a) first-quartile, b) second-quartile, c) third-quartile, and d) fourth-quartile cases.

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Storm Distributions – NRCS Synthetic Rainfall Distribution

– Also known as the “Nested Distribution”
– Rainfall depths and intensities for all durations from 5-minutes to 24-hours are represented accurately

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.114** (0.096-0.141)	**0.147** (0.123-0.181)	**0.202** (0.169-0.250)	**0.253** (0.210-0.311)	**0.333** (0.270-0.411)	**0.406** (0.321-0.502)	**0.492** (0.378-0.608)	**0.591** (0.440-0.736)	**0.748** (0.531-0.941)	**0.888** (0.610-1.14)
10-min	**0.174** (0.146-0.215)	**0.223** (0.187-0.275)	**0.307** (0.256-0.380)	**0.384** (0.320-0.472)	**0.506** (0.410-0.624)	**0.618** (0.488-0.764)	**0.748** (0.576-0.925)	**0.899** (0.669-1.12)	**1.14** (0.809-1.43)	**1.35** (0.928-1.73)
15-min	**0.215** (0.180-0.266)	**0.276** (0.232-0.342)	**0.381** (0.318-0.471)	**0.477** (0.397-0.586)	**0.628** (0.509-0.774)	**0.766** (0.606-0.947)	**0.928** (0.714-1.15)	**1.12** (0.830-1.39)	**1.41** (1.00-1.78)	**1.68** (1.15-2.14)
30-min	**0.290** (0.243-0.358)	**0.371** (0.313-0.460)	**0.513** (0.428-0.634)	**0.642** (0.534-0.789)	**0.846** (0.685-1.04)	**1.03** (0.815-1.27)	**1.25** (0.961-1.55)	**1.50** (1.12-1.87)	**1.90** (1.35-2.39)	**2.26** (1.55-2.88)
60-min	**0.359** (0.300-0.443)	**0.460** (0.387-0.569)	**0.635** (0.530-0.785)	**0.794** (0.661-0.977)	**1.05** (0.848-1.29)	**1.28** (1.01-1.58)	**1.55** (1.19-1.91)	**1.86** (1.38-2.31)	**2.35** (1.67-2.96)	**2.79** (1.92-3.57)
2-hr	**0.443** (0.378-0.533)	**0.558** (0.476-0.671)	**0.746** (0.633-0.899)	**0.917** (0.770-1.10)	**1.20** (0.984-1.44)	**1.45** (1.16-1.75)	**1.75** (1.37-2.13)	**2.11** (1.59-2.58)	**2.68** (1.92-3.35)	**3.20** (2.21-4.07)
3-hr	**0.497** (0.430-0.592)	**0.624** (0.539-0.743)	**0.811** (0.697-0.966)	**0.985** (0.840-1.17)	**1.26** (1.06-1.50)	**1.50** (1.23-1.79)	**1.79** (1.43-2.15)	**2.13** (1.65-2.59)	**2.70** (2.00-3.38)	**3.22** (2.30-4.11)
6-hr	**0.653** (0.570-0.767)	**0.812** (0.711-0.956)	**1.02** (0.889-1.20)	**1.20** (1.04-1.41)	**1.46** (1.25-1.72)	**1.69** (1.42-1.99)	**1.95** (1.61-2.33)	**2.25** (1.82-2.70)	**2.78** (2.18-3.39)	**3.29** (2.51-4.15)
12-hr	**0.789** (0.705-0.901)	**0.976** (0.871-1.12)	**1.20** (1.06-1.37)	**1.39** (1.23-1.59)	**1.67** (1.45-1.91)	**1.89** (1.62-2.17)	**2.13** (1.80-2.47)	**2.40** (1.99-2.81)	**2.86** (2.31-3.41)	**3.32** (2.62-4.20)
24-hr	**0.918** (0.830-1.02)	**1.14** (1.03-1.27)	**1.41** (1.27-1.57)	**1.63** (1.47-1.82)	**1.95** (1.75-2.16)	**2.19** (1.96-2.44)	**2.46** (2.18-2.73)	**2.73** (2.41-3.03)	**3.11** (2.71-3.46)	**3.42** (2.95-4.24)

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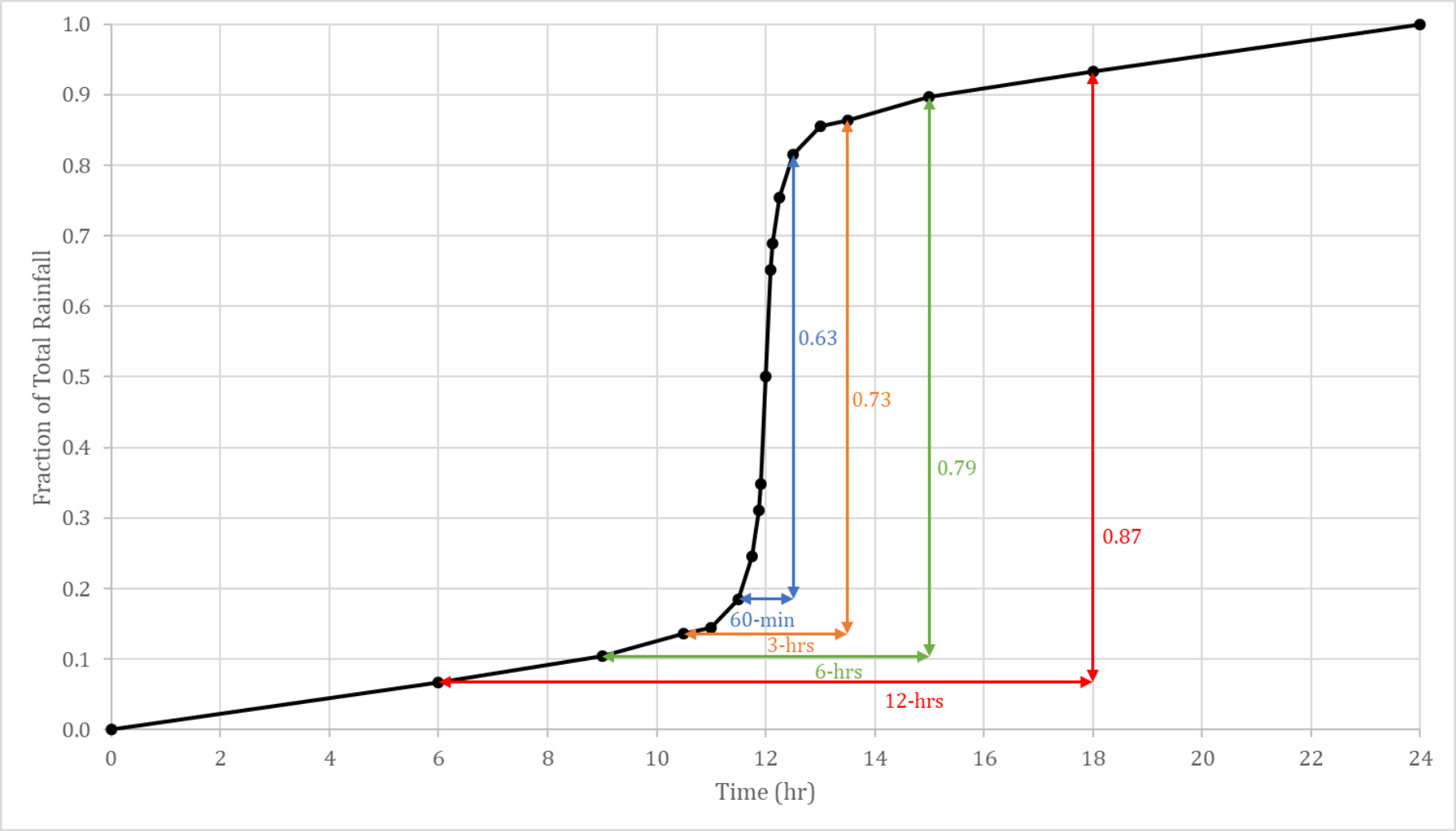
Storm Distributions – NRCS Synthetic Rainfall Distribution

Duration	Atlas 14 Precip Depth	Ratio to 24-hr
5-min	0.492	0.20
10-min	0.748	0.30
15-min	0.928	0.38
30-min	1.25	0.51
60-min	1.55	0.63
2-hr	1.75	0.71
3-hr	1.79	0.73
6-hr	1.95	0.79
12-hr	2.13	0.87
24-hr	2.46	1.00



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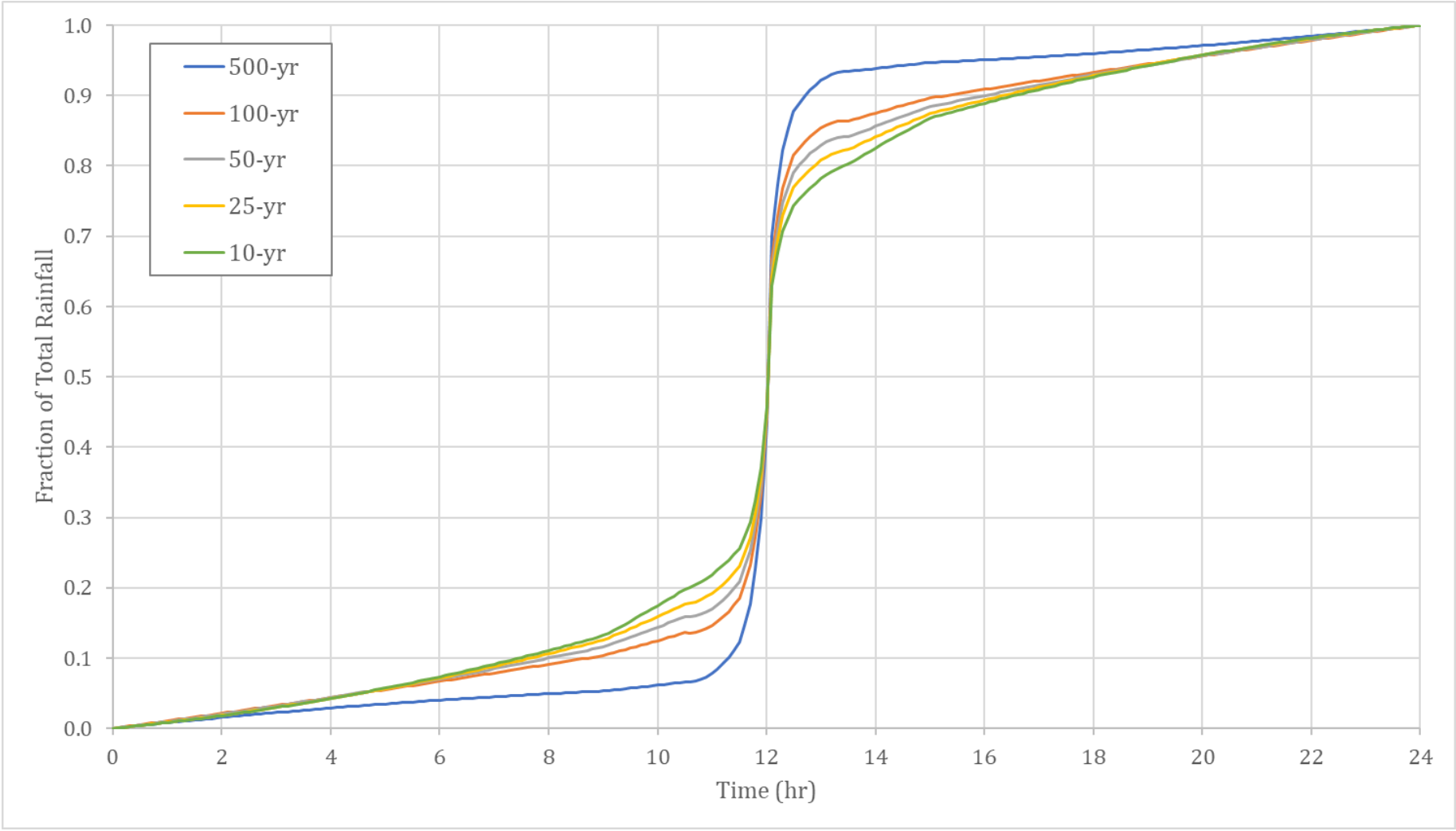
Storm Distributions – NRCS Synthetic Rainfall Distribution

Freq.	Ratio to 24-hr				
	10-yr	25-yr	50-yr	100-yr	500-yr
5-min	0.16	0.17	0.18	0.20	0.24
10-min	0.24	0.26	0.28	0.30	0.37
15-min	0.29	0.32	0.35	0.38	0.45
30-min	0.39	0.43	0.47	0.51	0.61
60-min	0.49	0.54	0.58	0.63	0.76
2-hr	0.56	0.62	0.66	0.71	0.86
3-hr	0.60	0.65	0.68	0.73	0.87
6-hr	0.74	0.75	0.77	0.79	0.89
12-hr	0.85	0.86	0.86	0.87	0.92
24-hr	1.00	1.00	1.00	1.00	1.00



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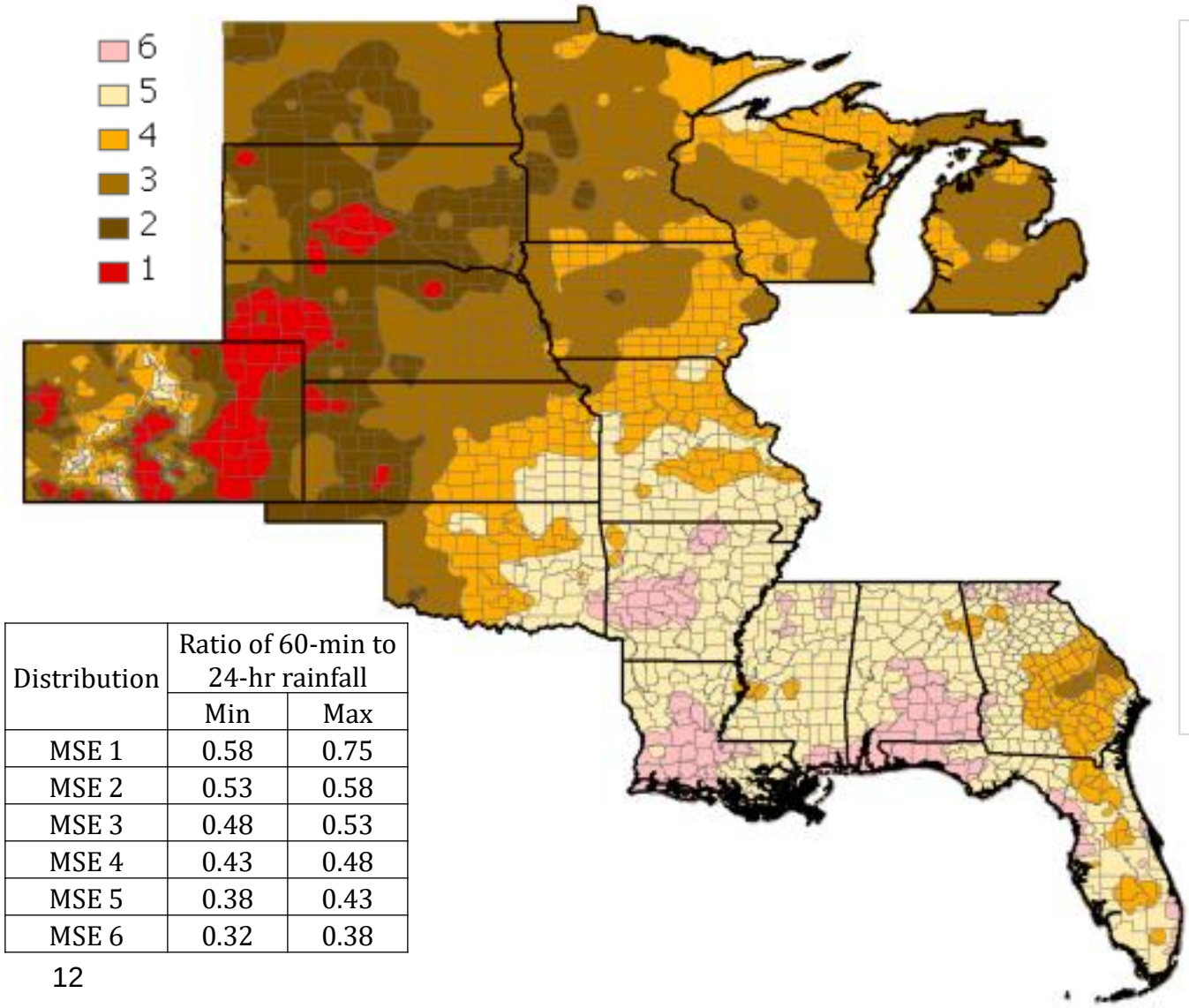
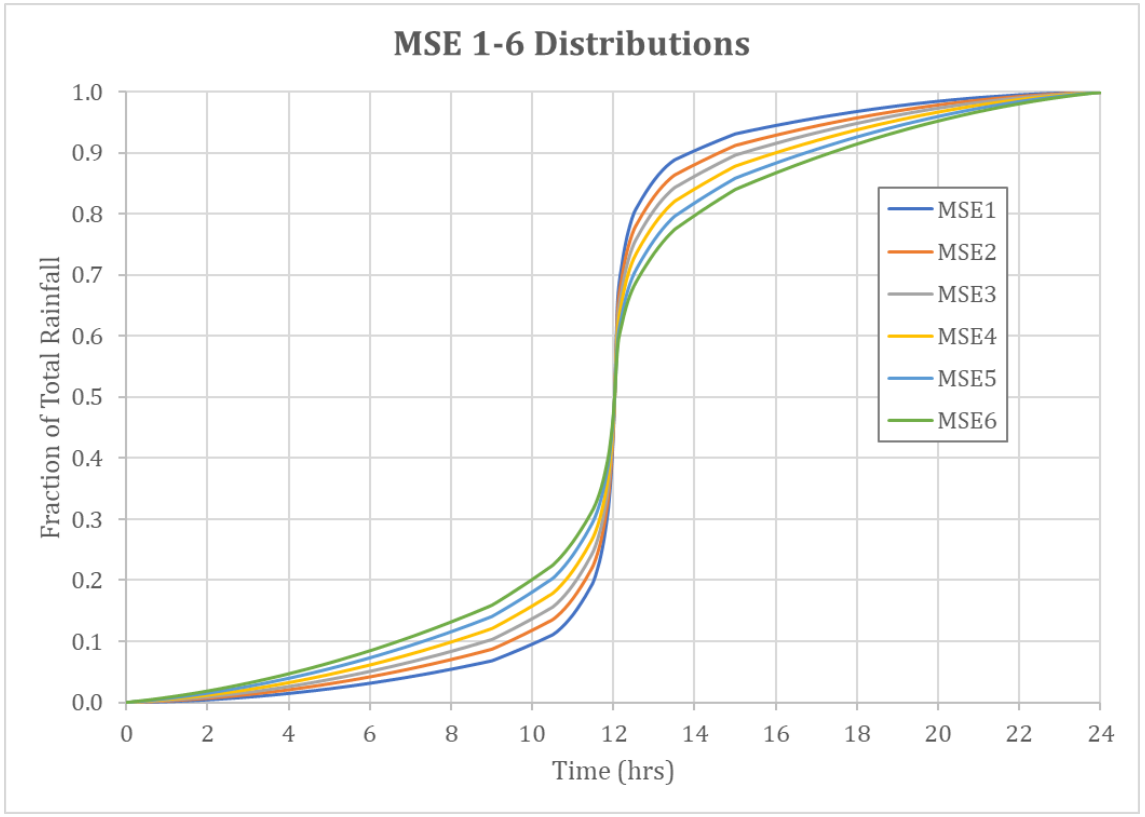
Storm Distributions – “MSE” Distributions



Distribution	Ratio of 60-min to 24-hr rainfall	
	Min	Max
MSE 1	0.58	0.75
MSE 2	0.53	0.58
MSE 3	0.48	0.53
MSE 4	0.43	0.48
MSE 5	0.38	0.43
MSE 6	0.32	0.38



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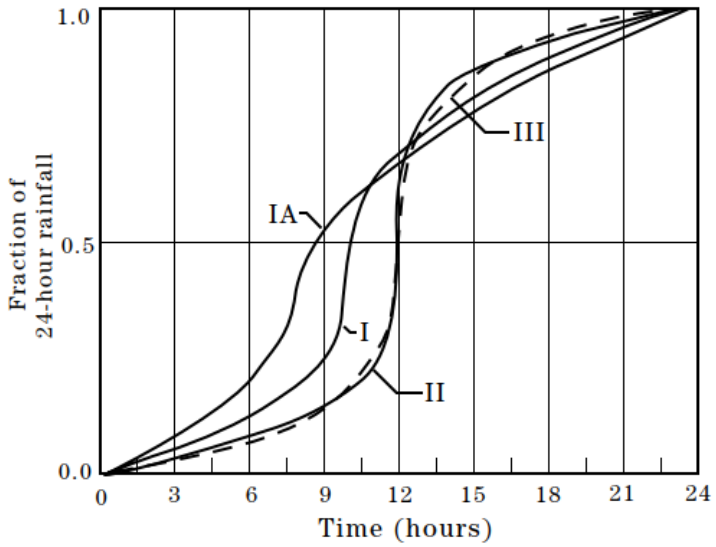
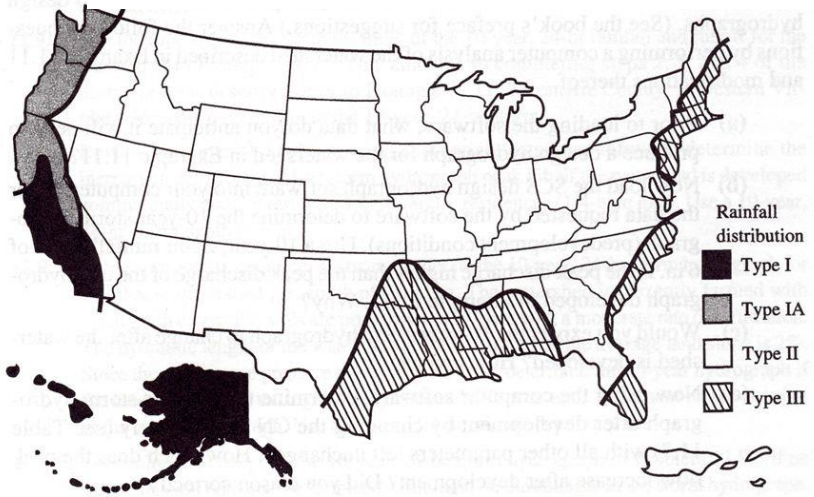
Storm Distributions – SCS Type II

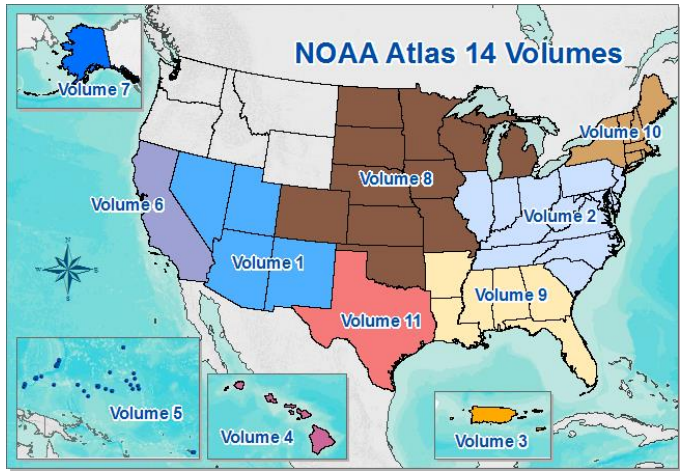
Figure B 1 SCS 24-hour rainfall distributions





" To use a Type II or other legacy rainfall distribution with the updated NOAA Atlas 14 data could introduce errors by application of inaccurate rainfall intensities during the storm... Study of available [documentation] leads to the conclusion that their use be discontinued in areas covered by NOAA Atlas 14 data. "

210-NEH Part 630 Chapter 4 Hydrology (Aug 2019) Section 630.0403 A. (8). Available at: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=43924.wba



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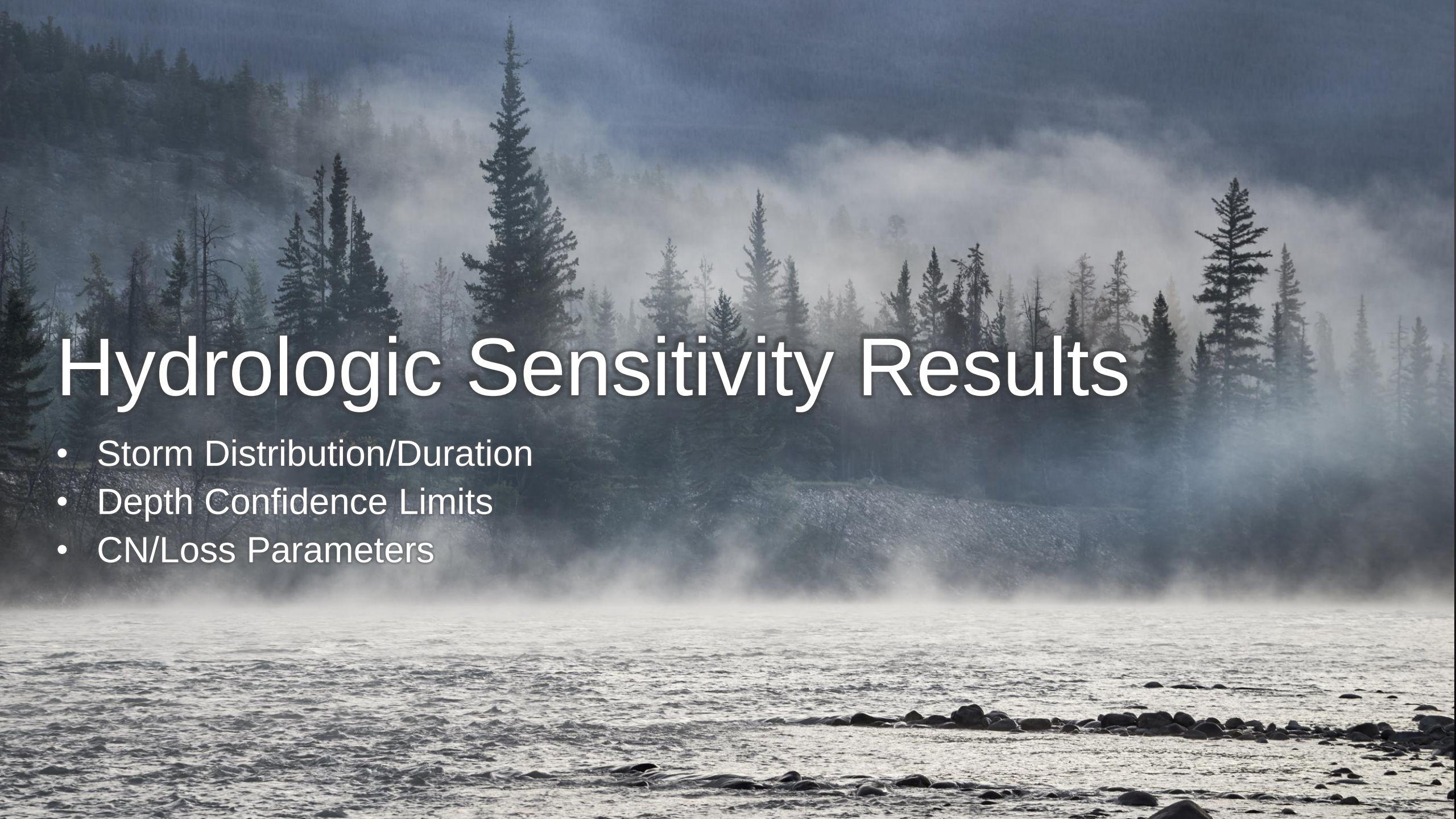


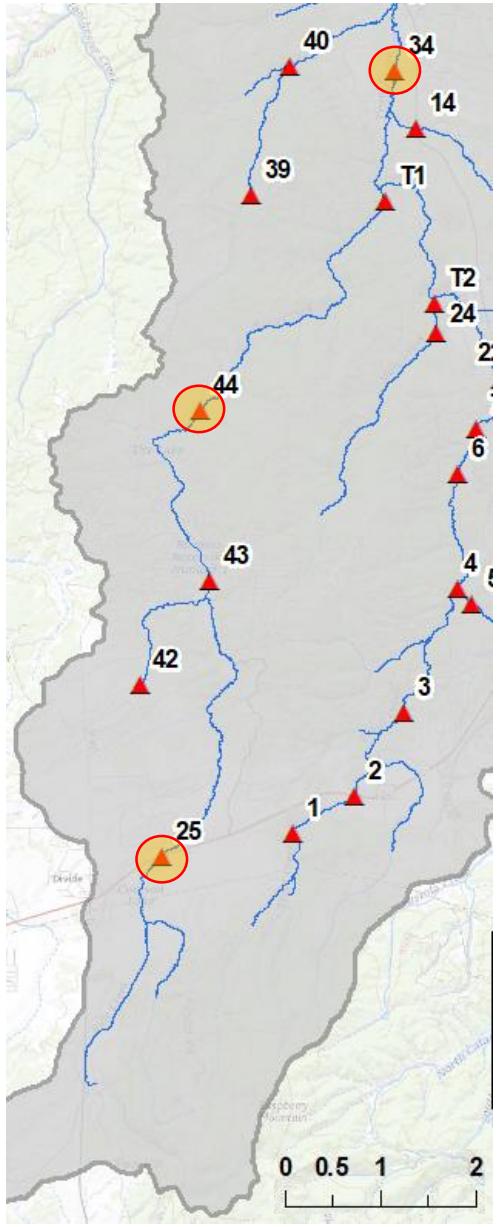
Hydrologic Sensitivity Results

- Storm Distribution/Duration
- Depth Confidence Limits
- CN/Loss Parameters

Summary of Hydrologic Variations

– 182 simulations varying
  - Distribution & duration
  - Depth confidence limit
  - CN/loss
– Fixed
  - Terrain of 8 ft cells
  - Max courant of 1.5; min timestep of 1.8 sec
  - Mesh of 200 ft cells w/50-ft along streamlines
  - Breaklines and v-notches
  - Manning's n based on NLCD 2016
– Extracted stage and flow hydrographs at each connection

Featuring results primarily at…



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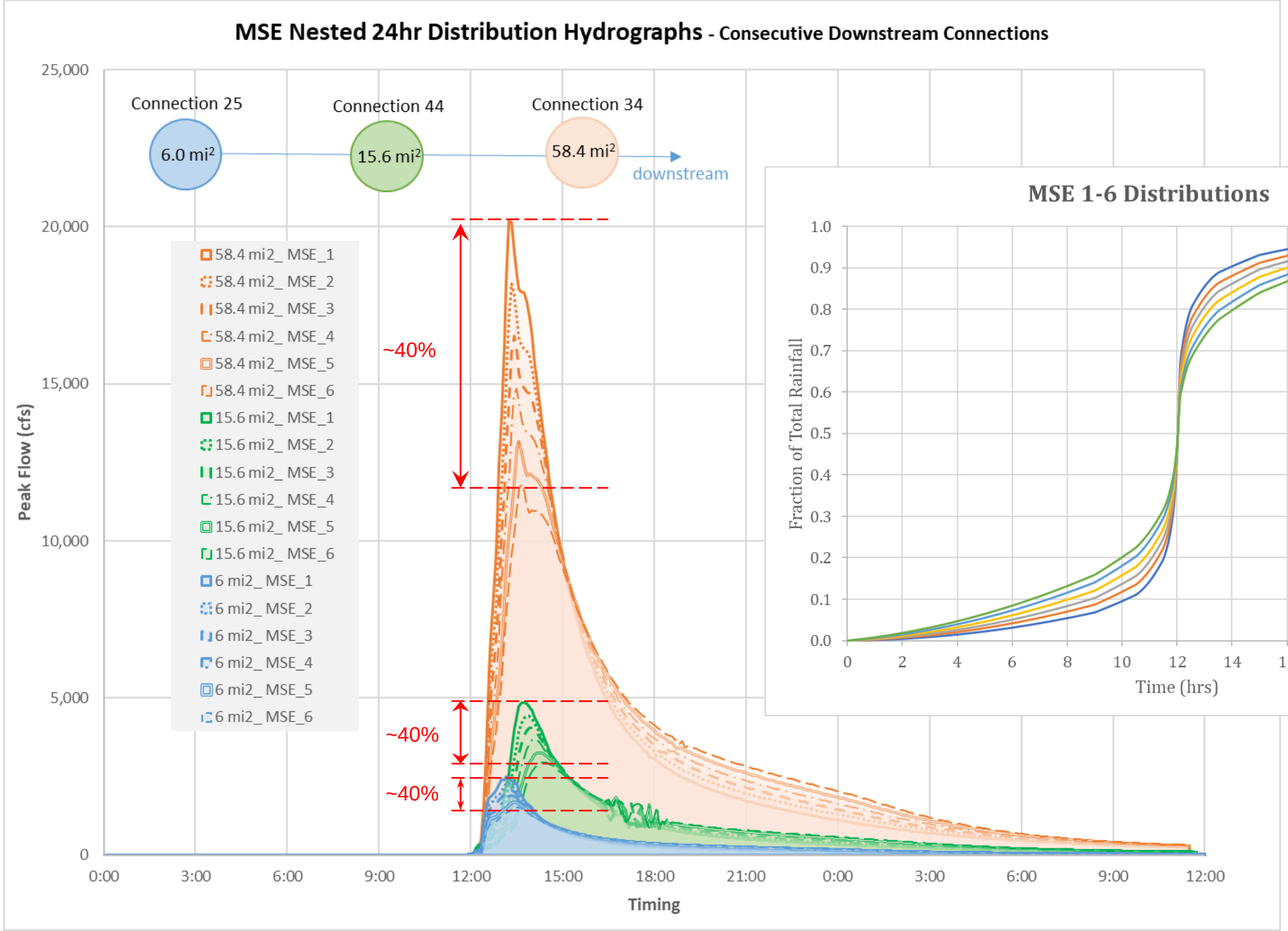
MSE Nested 24hr Distribution Hydrographs - Consecutive Downstream Connections
Connection 25
Connection 44
Connection 34
6.0 mi²
15.6 mi²
58.4 mi²
downstream
58.4 mi2_ MSE_1
58.4 mi2_ MSE_2
58.4 mi2_ MSE_3
58.4 mi2_ MSE_4
58.4 mi2_ MSE_5
58.4 mi2_ MSE_6
15.6 mi2_ MSE_1
15.6 mi2_ MSE_2
15.6 mi2_ MSE_3
15.6 mi2_ MSE_4
15.6 mi2_ MSE_5
15.6 mi2_ MSE_6
6 mi2_ MSE_1
6 mi2_ MSE_2
6 mi2_ MSE_3
6 mi2_ MSE_4
6 mi2_ MSE_5
6 mi2_ MSE_6
~40%
~40%
~40%
Peak Flow (cfs)
25,000
20,000
15,000
10,000
5,000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
3:00
6:00
9:00
12:00
Timing
MSE 1-6 Distributions
Fraction of Total Rainfall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Time (hrs)
MSE1
MSE2
MSE3
MSE4
MSE5
MSE6

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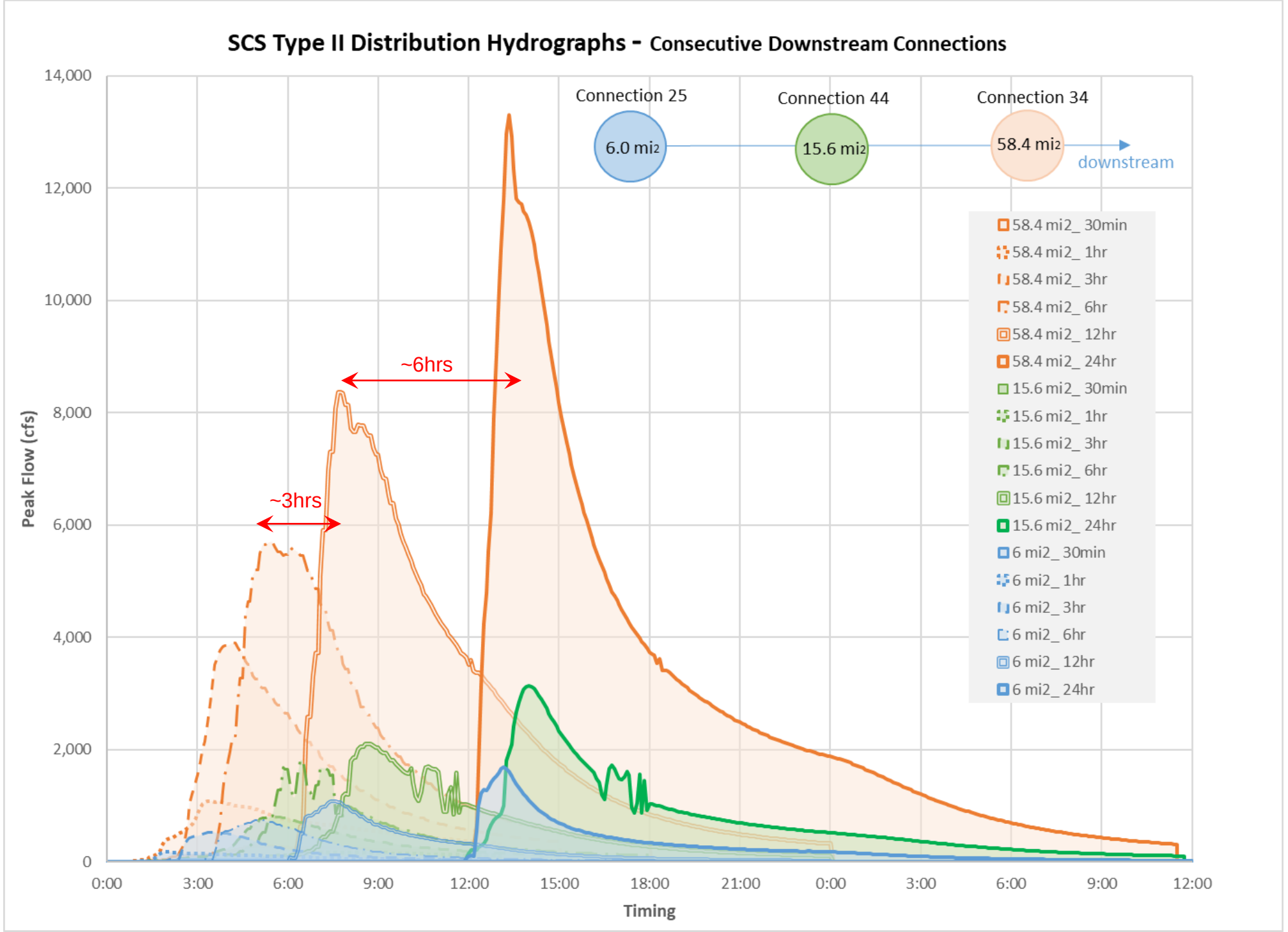
SCS Type II Distribution Hydrographs - Consecutive Downstream Connections
Connection 25
Connection 44
Connection 34
6.0 mi2
15.6 mi2
58.4 mi2
downstream
~6hrs
~3hrs
58.4 mi2_ 30min
58.4 mi2_ 1hr
58.4 mi2_ 3hr
58.4 mi2_ 6hr
58.4 mi2_ 12hr
58.4 mi2_ 24hr
15.6 mi2_ 30min
15.6 mi2_ 1hr
15.6 mi2_ 3hr
15.6 mi2_ 6hr
15.6 mi2_ 12hr
15.6 mi2_ 24hr
6 mi2_ 30min
6 mi2_ 1hr
6 mi2_ 3hr
6 mi2_ 6hr
6 mi2_ 12hr
6 mi2_ 24hr
Peak Flow (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
3:00
6:00
9:00
12:00
Timing

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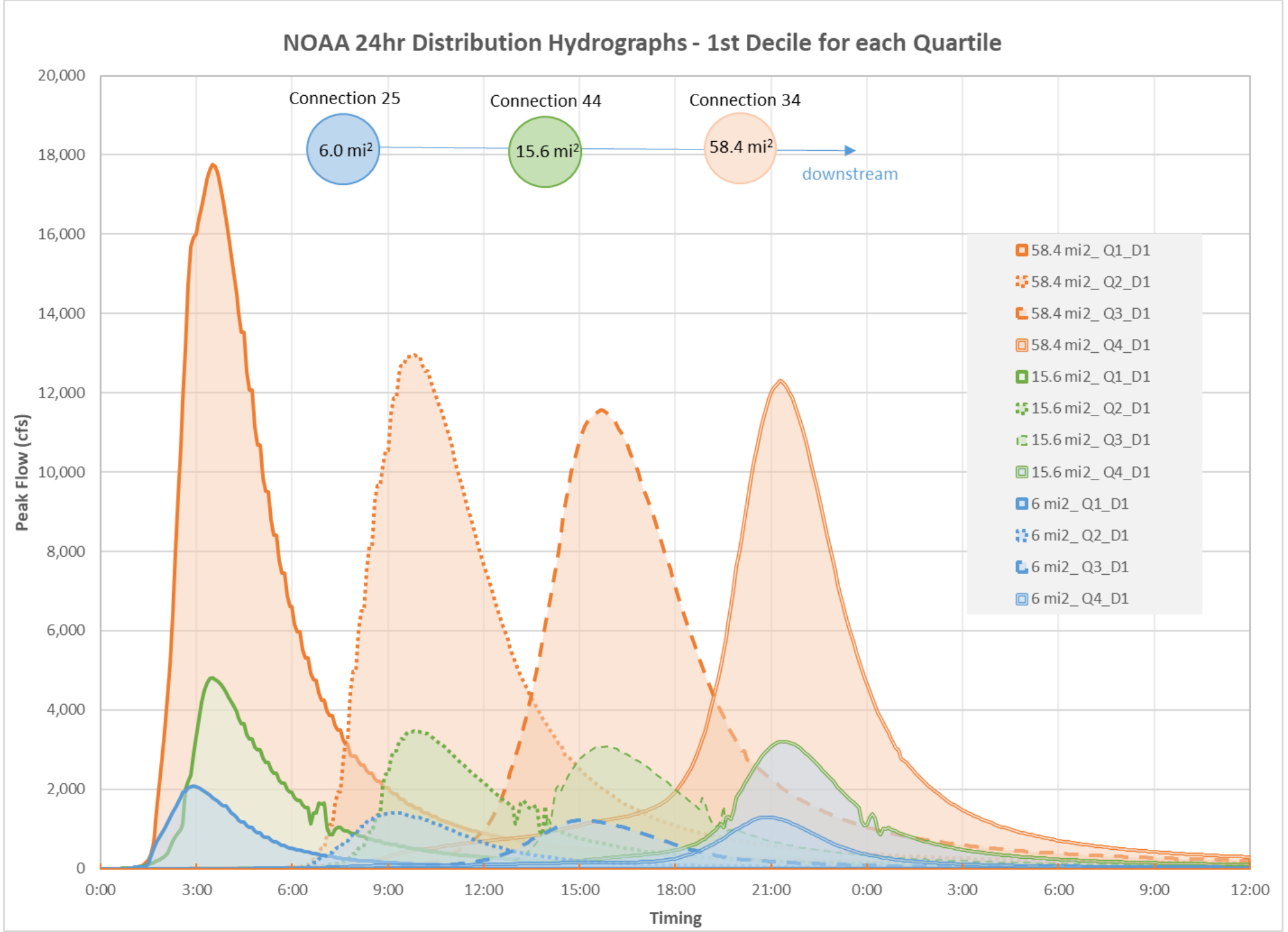
NOAA 24hr Distribution Hydrographs - 1st Decile for each Quartile
Connection 25
6.0 mi²
Connection 44
15.6 mi²
Connection 34
58.4 mi²
downstream
Peak Flow (cfs)
Timing
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
3:00
6:00
9:00
12:00
58.4 mi2_ Q1_D1
58.4 mi2_ Q2_D1
58.4 mi2_ Q3_D1
58.4 mi2_ Q4_D1
15.6 mi2_ Q1_D1
15.6 mi2_ Q2_D1
15.6 mi2_ Q3_D1
15.6 mi2_ Q4_D1
6 mi2_ Q1_D1
6 mi2_ Q2_D1
6 mi2_ Q3_D1
6 mi2_ Q4_D1

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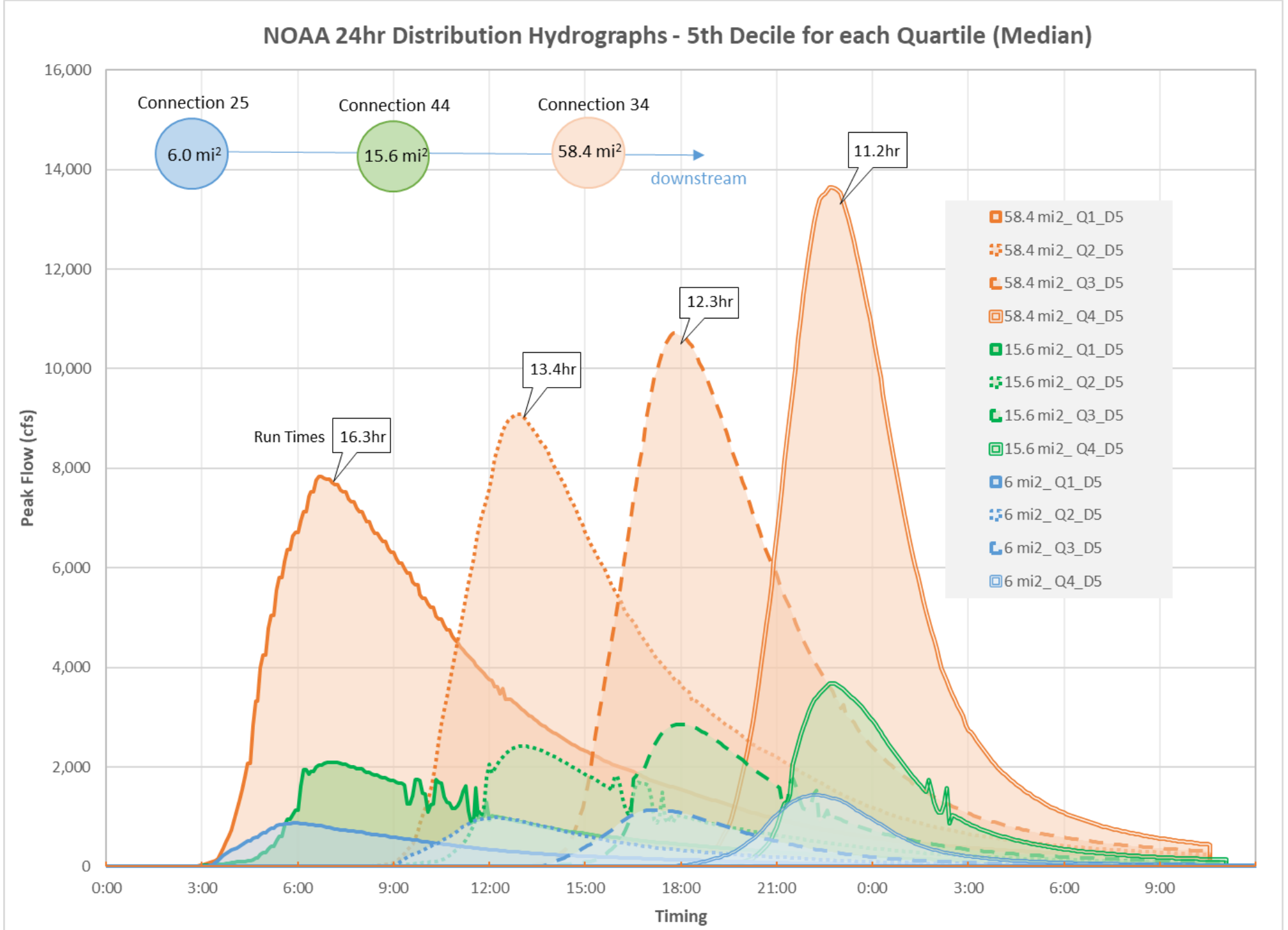
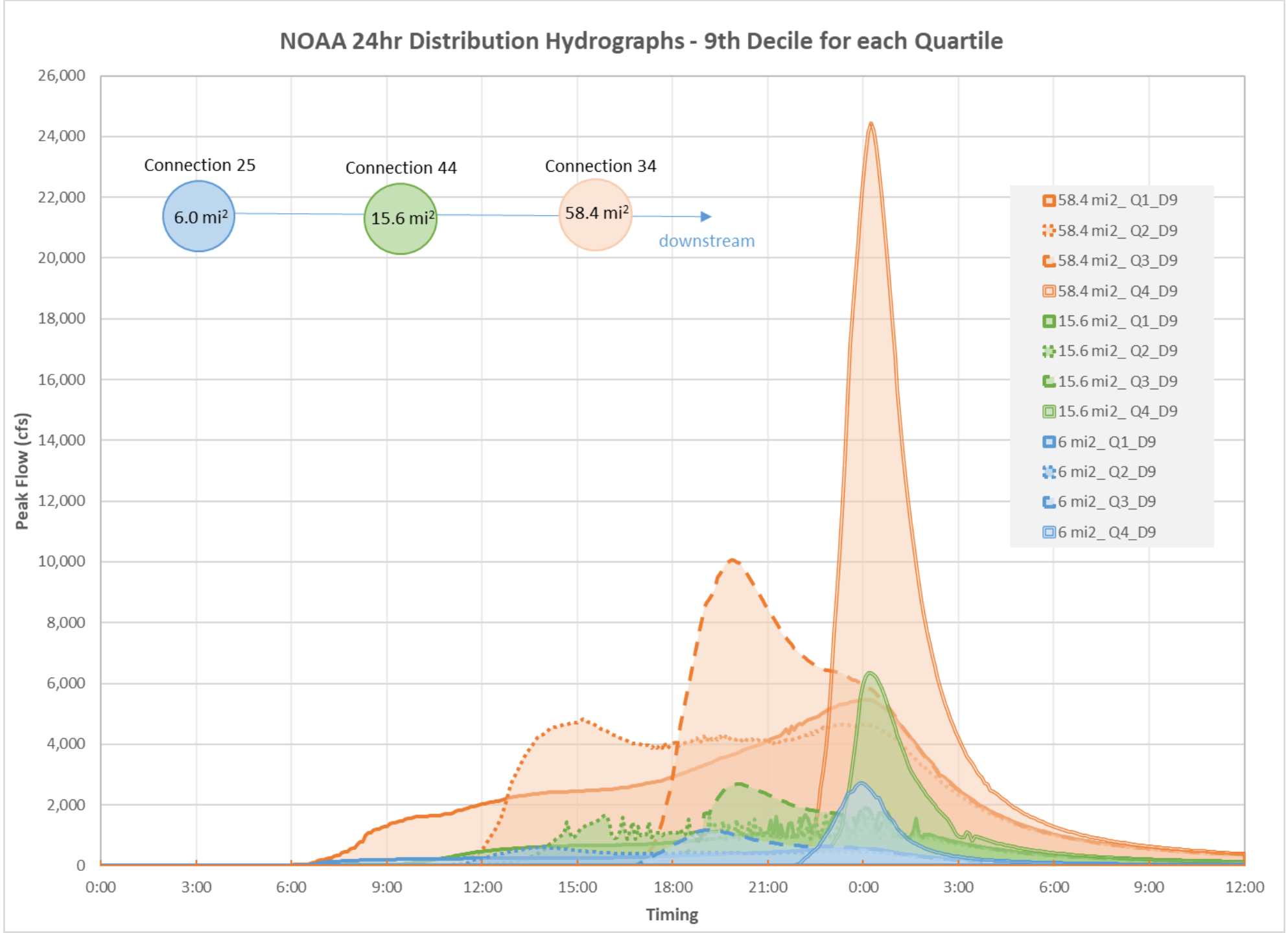

NOAA 24hr Distribution Hydrographs - 5th Decile for each Quartile (Median)
Connection 25
6.0 mi²
Connection 44
15.6 mi²
Connection 34
58.4 mi²
downstream
Run Times
16.3hr
13.4hr
12.3hr
11.2hr
58.4 mi2_ Q1_D5
58.4 mi2_ Q2_D5
58.4 mi2_ Q3_D5
58.4 mi2_ Q4_D5
15.6 mi2_ Q1_D5
15.6 mi2_ Q2_D5
15.6 mi2_ Q3_D5
15.6 mi2_ Q4_D5
6 mi2_ Q1_D5
6 mi2_ Q2_D5
6 mi2_ Q3_D5
6 mi2_ Q4_D5
Peak Flow (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
3:00
6:00
9:00
Timing

AECOM


NOAA 24hr Distribution Hydrographs - 9th Decile for each Quartile
Connection 25
6.0 mi²
Connection 44
15.6 mi²
Connection 34
58.4 mi²
downstream
58.4 mi2_ Q1_D9
58.4 mi2_ Q2_D9
58.4 mi2_ Q3_D9
58.4 mi2_ Q4_D9
15.6 mi2_ Q1_D9
15.6 mi2_ Q2_D9
15.6 mi2_ Q3_D9
15.6 mi2_ Q4_D9
6 mi2_ Q1_D9
6 mi2_ Q2_D9
6 mi2_ Q3_D9
6 mi2_ Q4_D9
Peak Flow (cfs)
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
3:00
6:00
9:00
12:00
Timing

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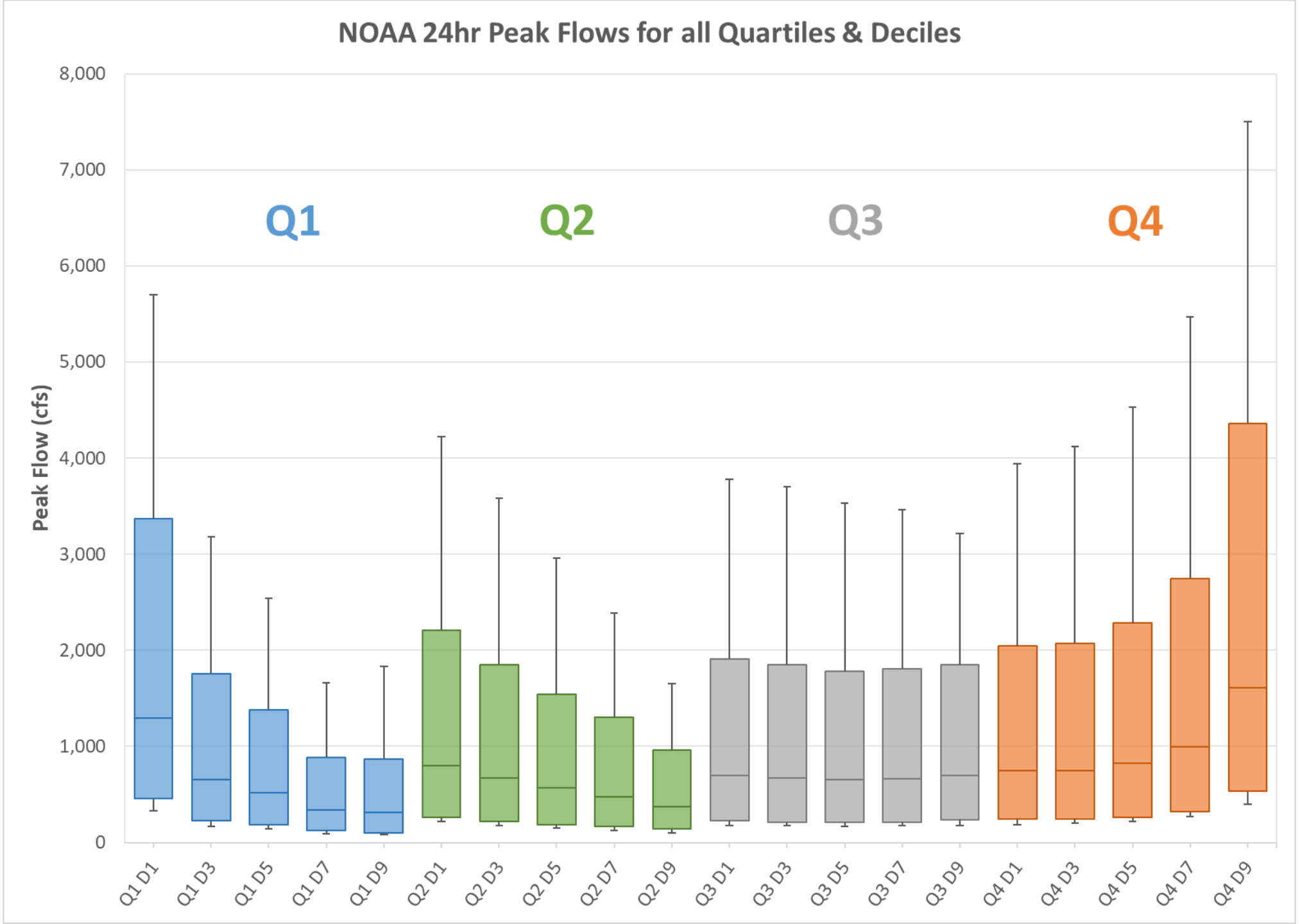
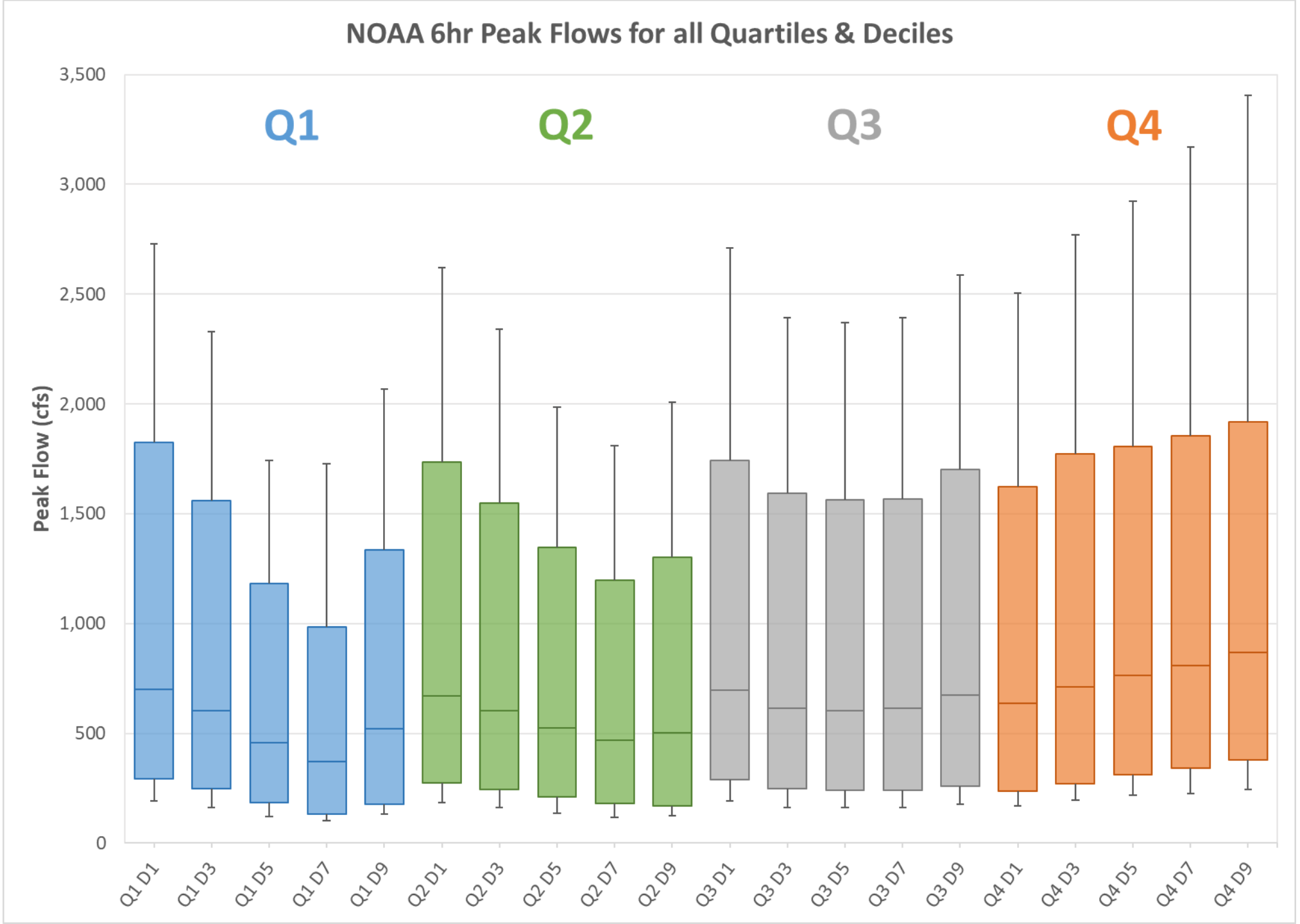
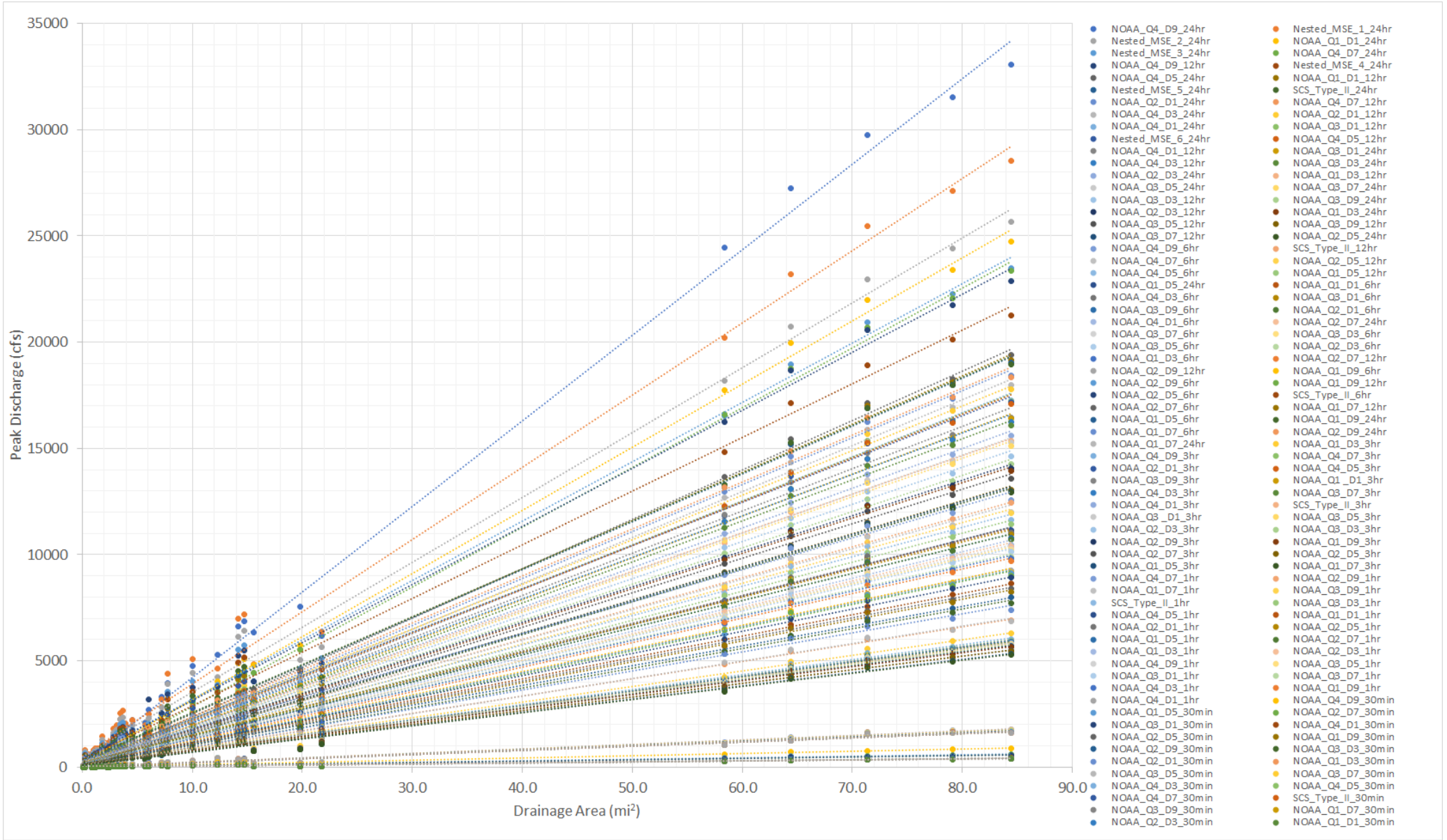

NOAA 24hr Peak Flows for all Quartiles & Deciles
Peak Flow (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Q1
Q2
Q3
Q4
Q1 D1
Q1 D3
Q1 D5
Q1 D7
Q1 D9
Q2 D1
Q2 D3
Q2 D5
Q2 D7
Q2 D9
Q3 D1
Q3 D3
Q3 D5
Q3 D7
Q3 D9
Q4 D1
Q4 D3
Q4 D5
Q4 D7
Q4 D9

AECOM


NOAA 6hr Peak Flows for all Quartiles & Deciles
Q1
Q2
Q3
Q4
Peak Flow (cfs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Q1 D1
Q1 D3
Q1 D5
Q1 D7
Q1 D9
Q2 D1
Q2 D3
Q2 D5
Q2 D7
Q2 D9
Q3 D1
Q3 D3
Q3 D5
Q3 D7
Q3 D9
Q4 D1
Q4 D3
Q4 D5
Q4 D7
Q4 D9

AECOM

All of the Data…



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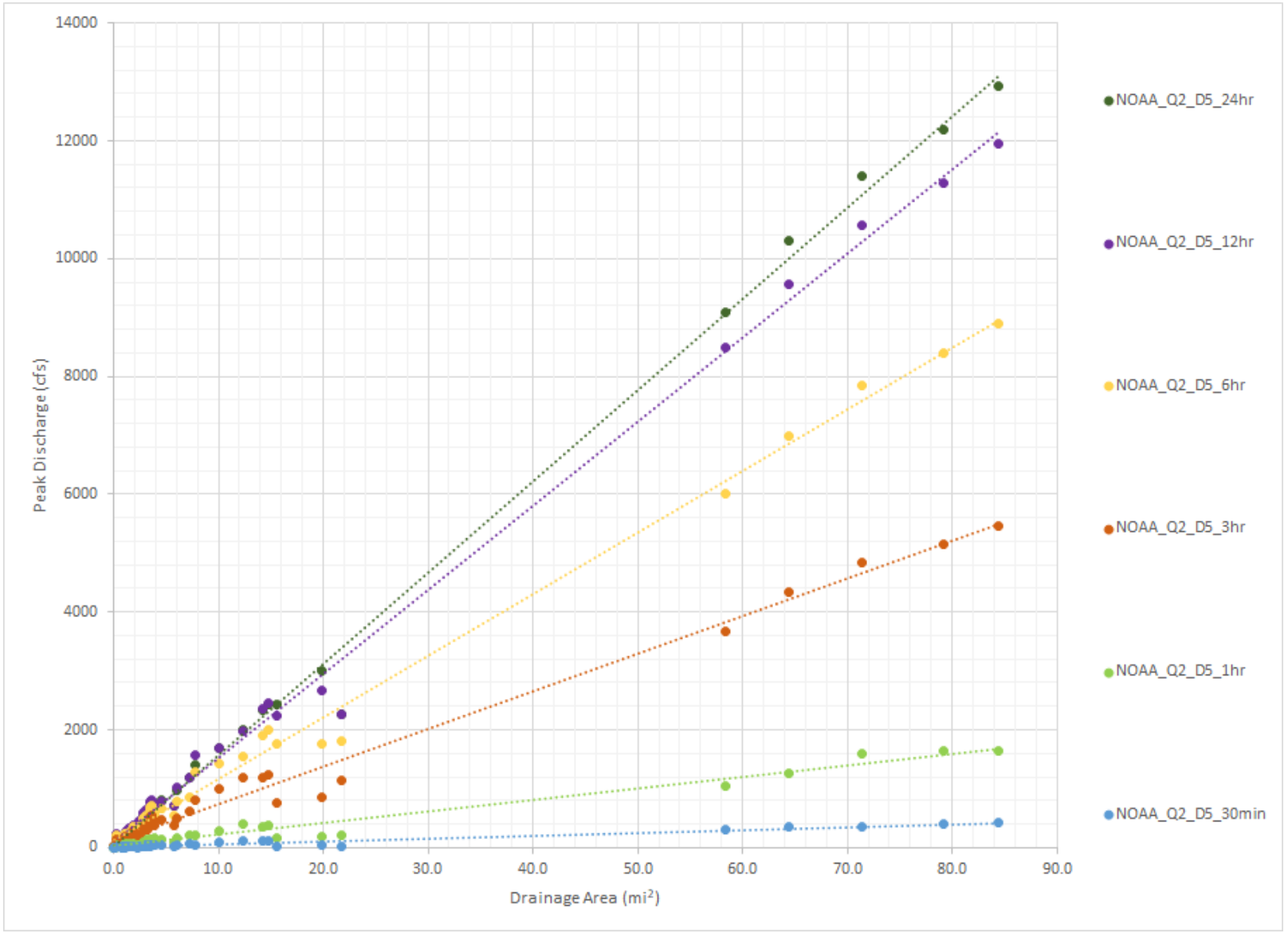
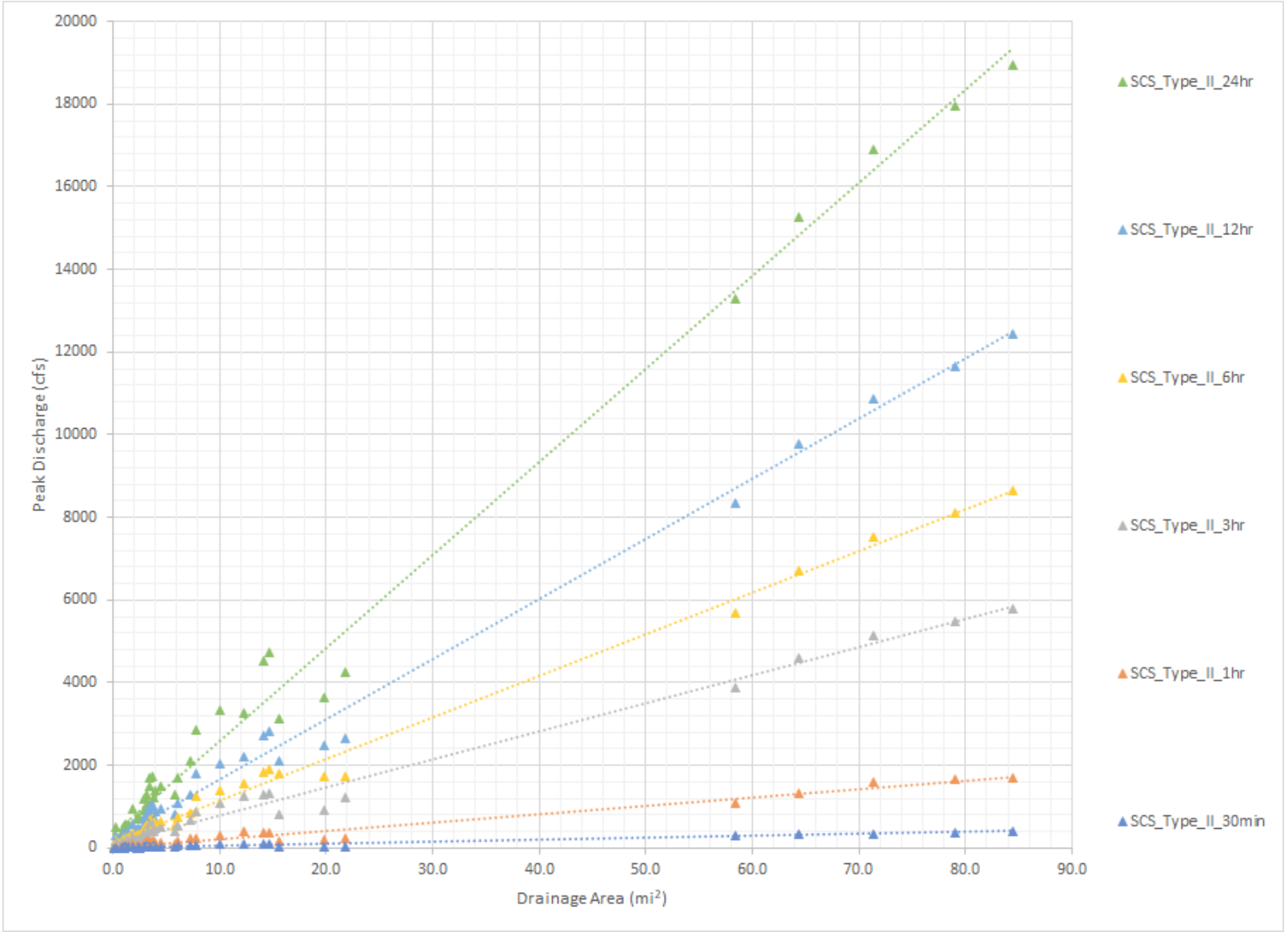
Impact of NOAA Duration on Peak Discharge (using Q2D5)



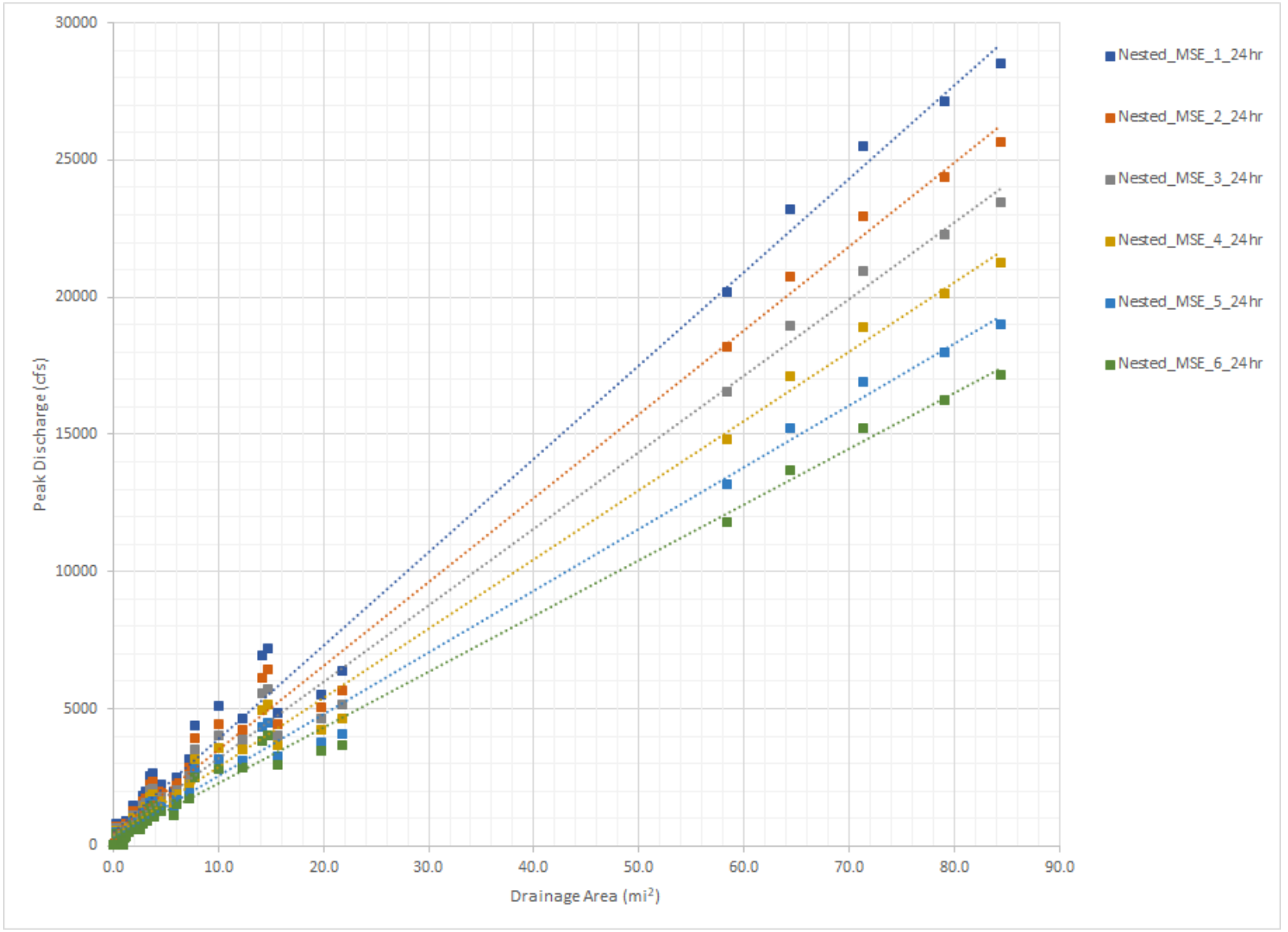
AECOM

Impact of SCS Type II Duration on Peak Discharge



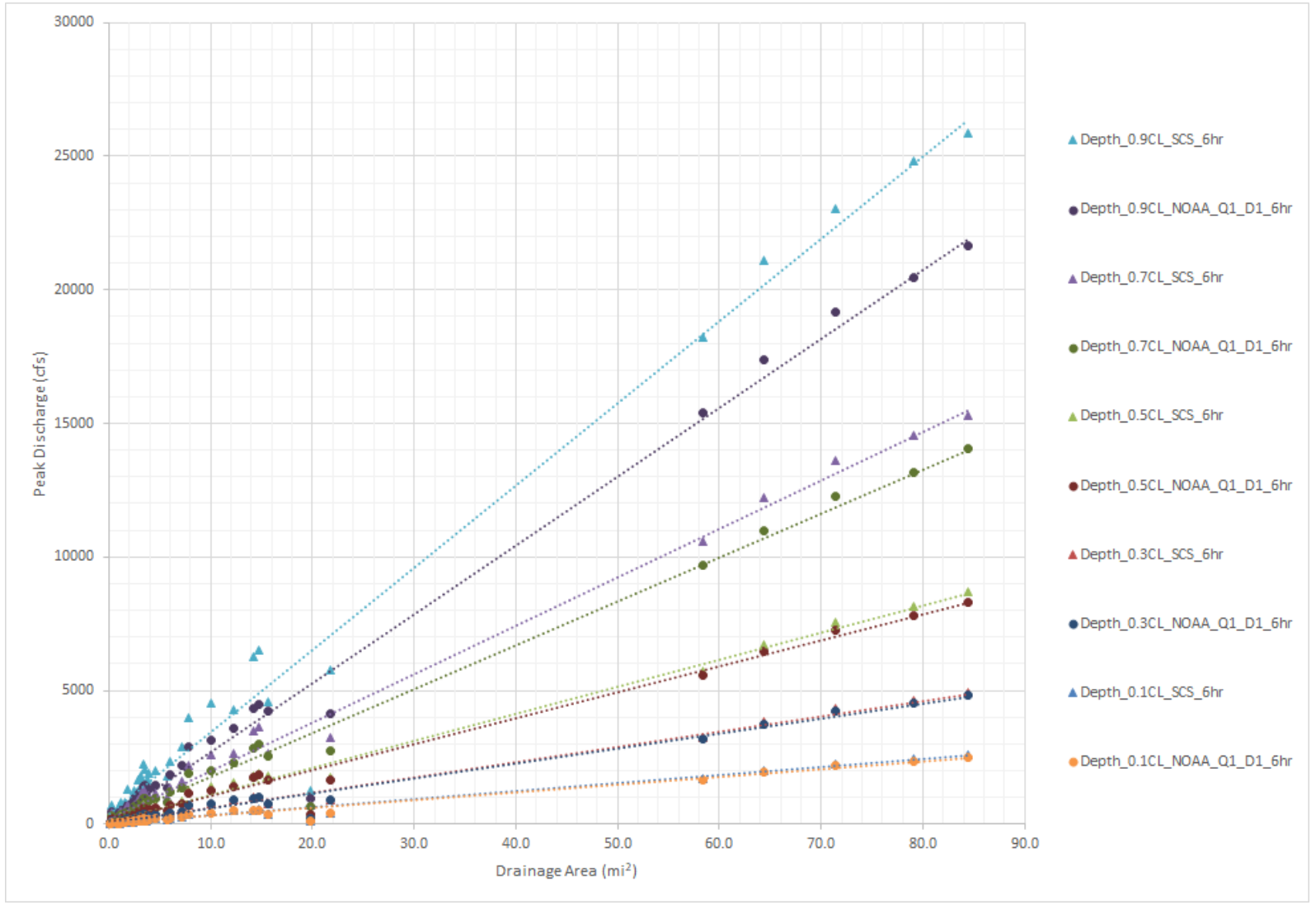
AECOM

Impact of MSE Nested Distribution Type on Peak Discharge



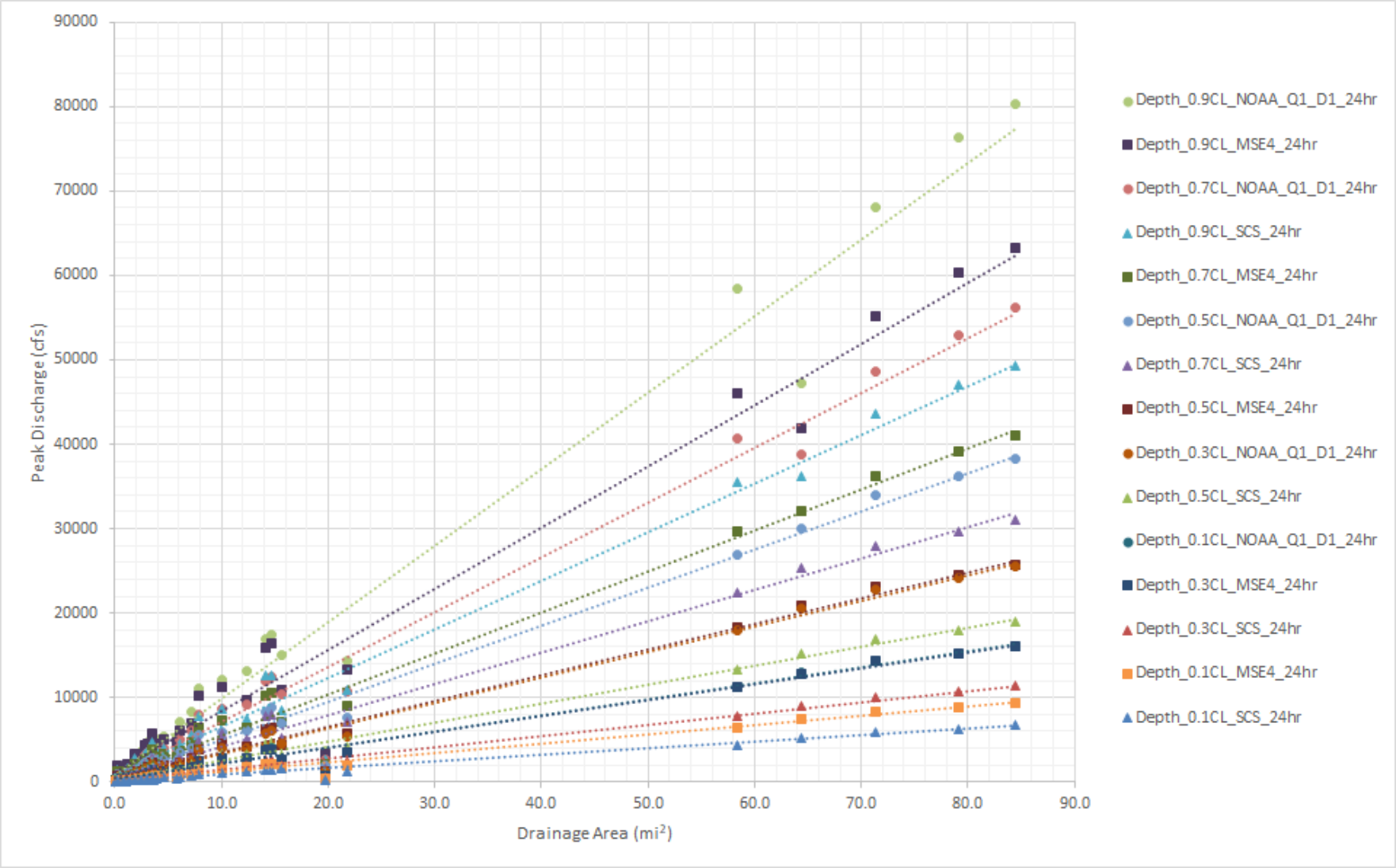
AECOM

Impact of Varied Rainfall Depths on Peak Discharge (6-hr)



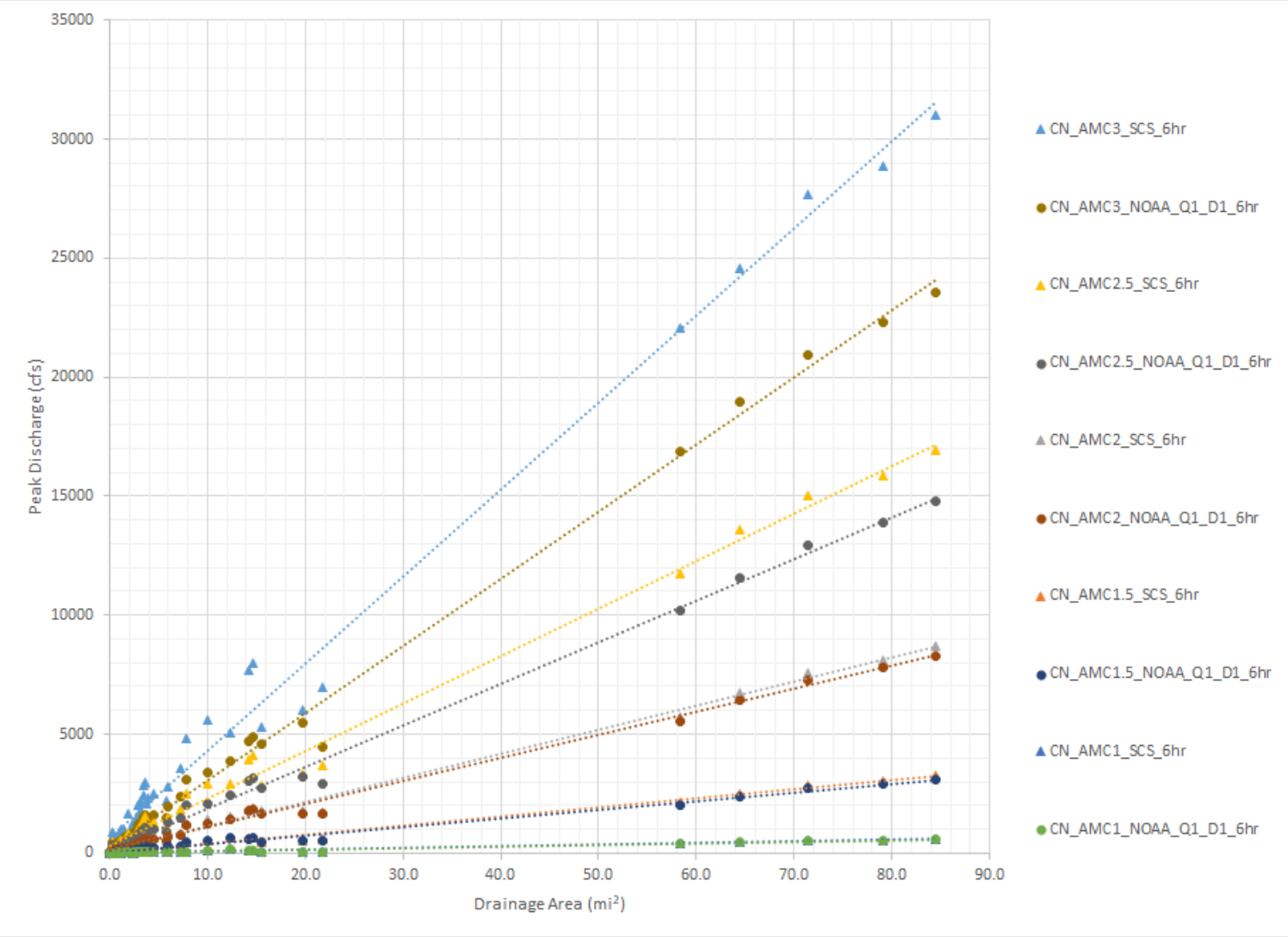
AECOM

Impact of Varied Rainfall Depths on Peak Discharge (24-hr)



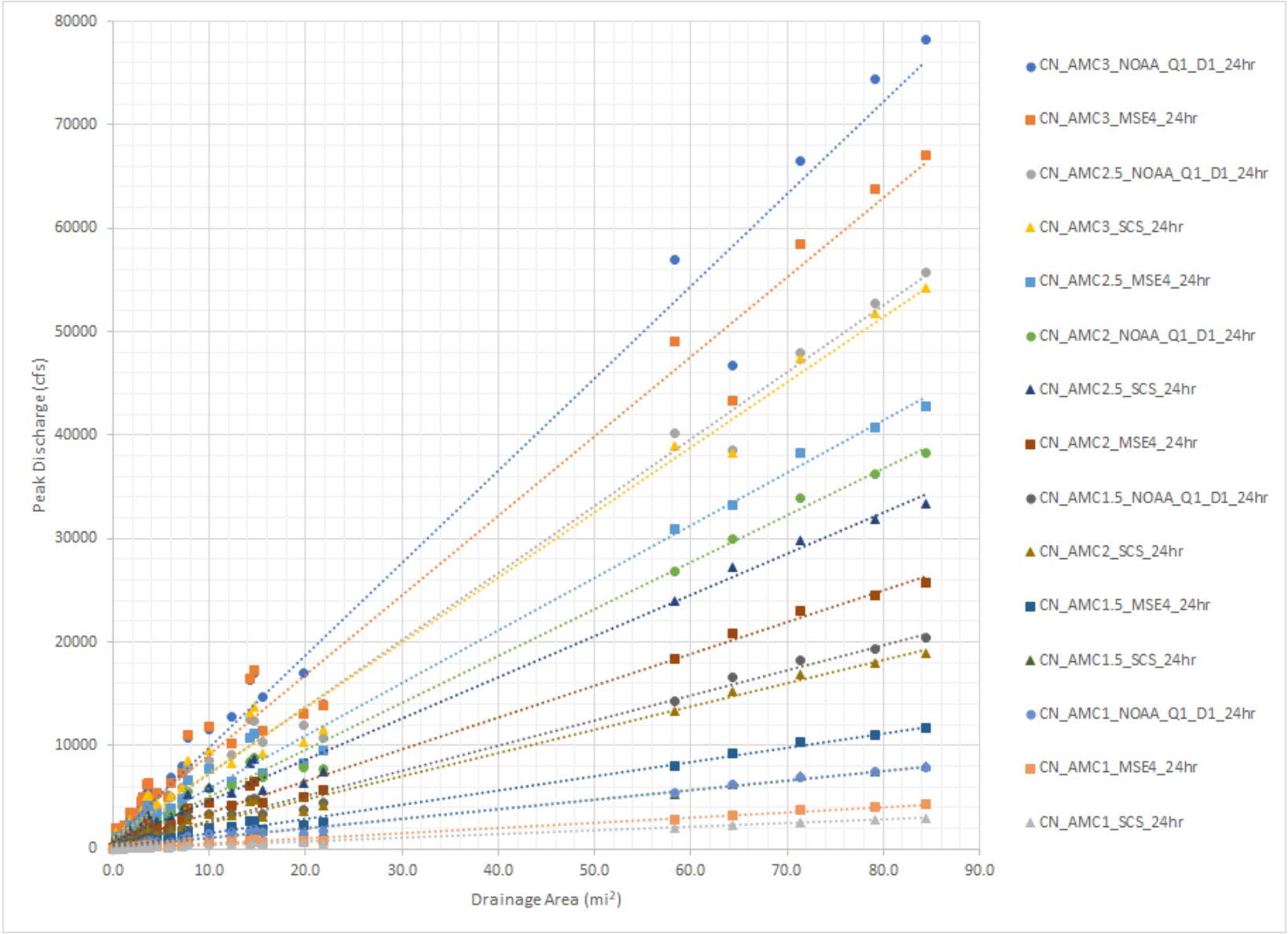
AECOM

Impact of Varied Curve Numbers on Peak Discharge (6-hr)



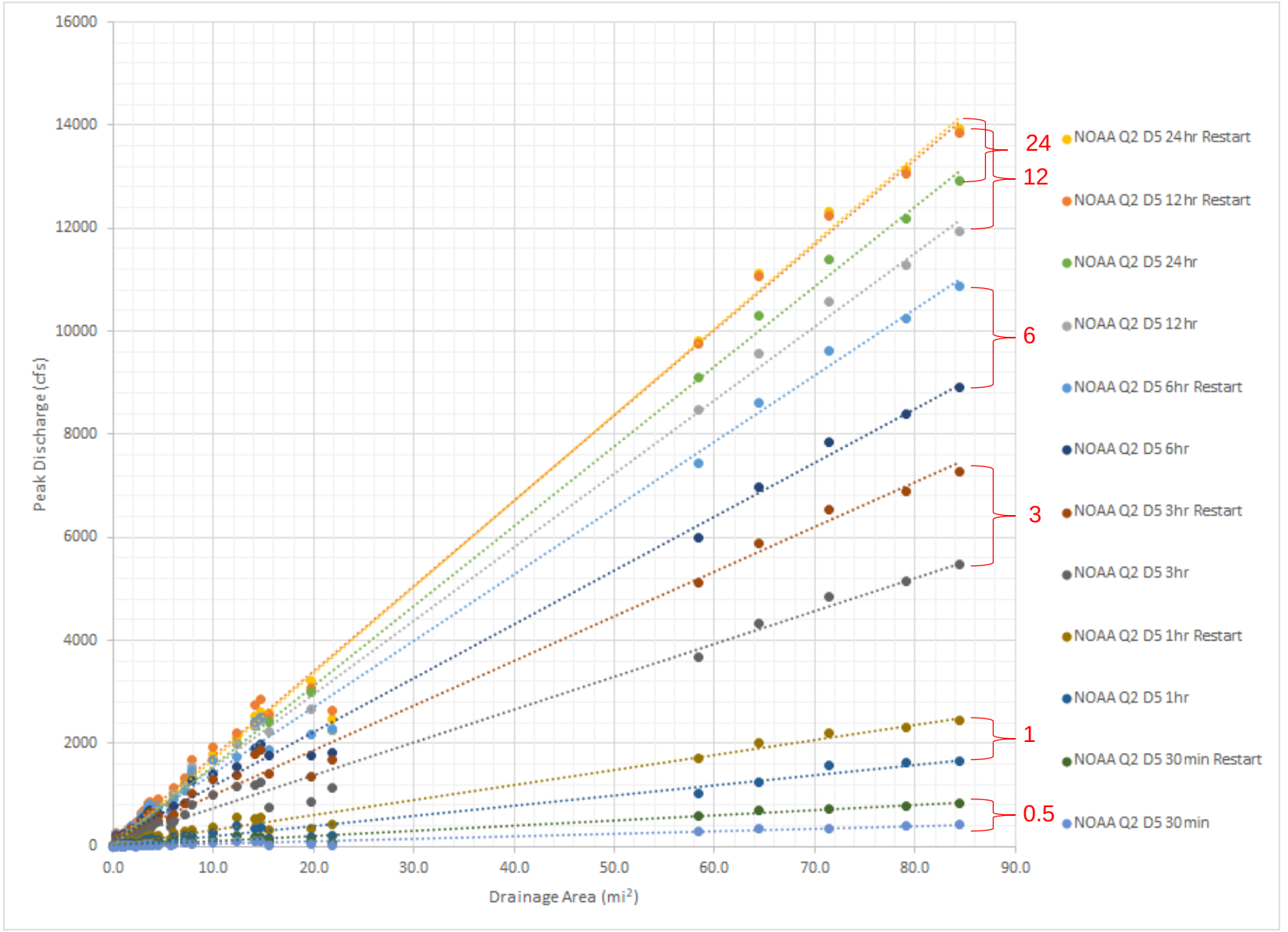
AECOM

Impact of Varied Curve Numbers on Peak Discharge (24-hr)



AECOM

Impact of Restart Files on Peak Discharge



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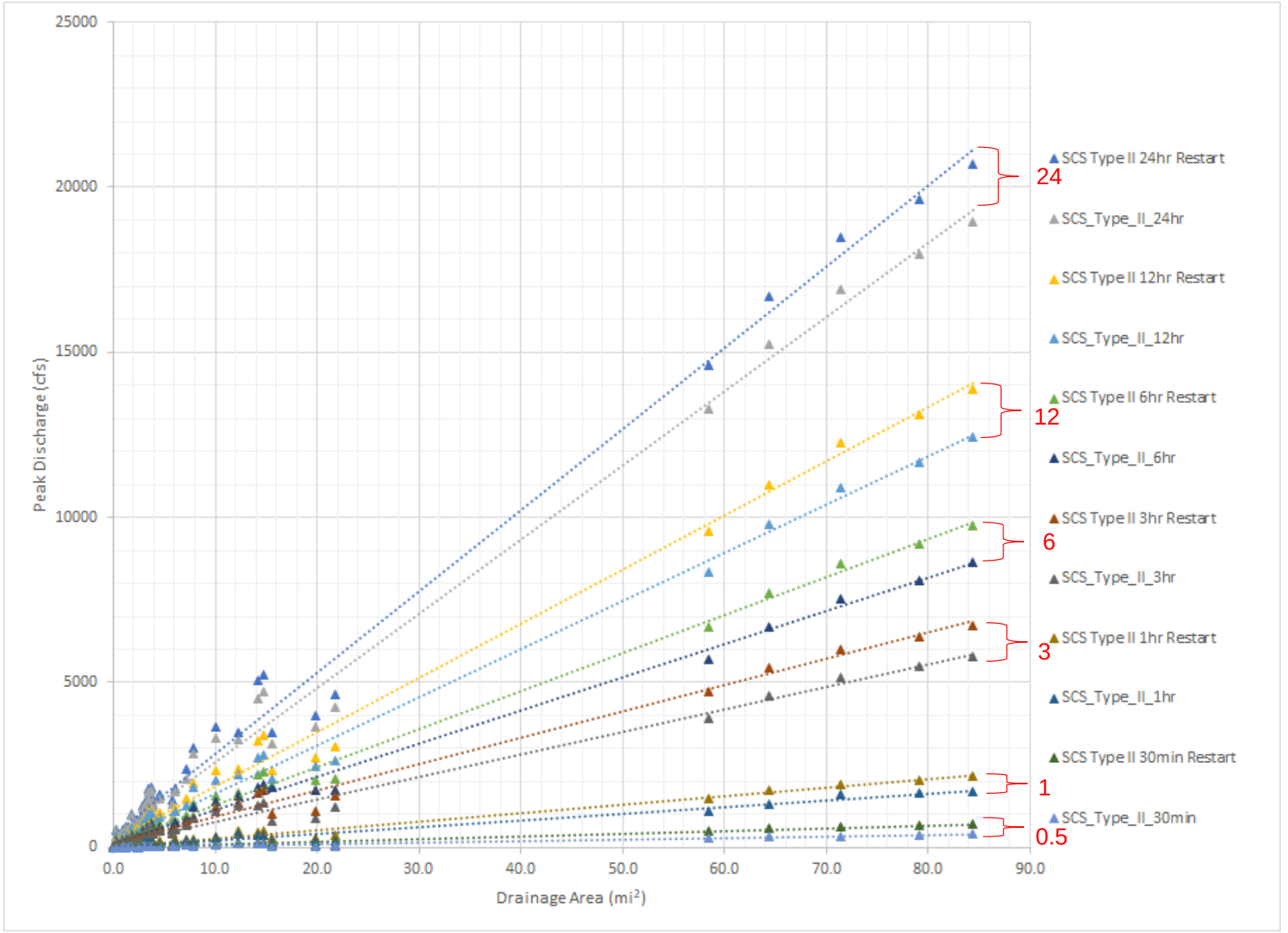
Impact of Restart Files on Peak Discharge



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Hydrologic Observation Summary

- The nested hyetograph is duration agnostic (includes intensities across all durations), whereas SCS Type II and NOAA distributions are highly influenced by the duration selected, which is often a function of the regional climate and drainage area properties
- SCS Type II and NOAA Q1,D1 have similar resemblance and tend to yield peak discharges similar to more gradual nested hyetograph (~MSE5)
- Distribution shape is very influential on results; therefore:
  - consult historic record and guidance for selection (use NRCS spatial delineations or gridded ratios)
  - delineate modeled basins by distribution when possible

Hydrologic Observation Summary

- Drainage area can increase significantly, without significantly increasing peak timing. Timing can vary considerably in smaller basins depending on basin characteristics, such as orientation, slopes, flowpaths, and manning's n
- The maximum peak discharges may result from differing durations (not always the longest) depending on drainage area, basin characteristics (Tc), and ratios between intensities by
  duration
- Some distributions are more sensitive to CN with a broader spread
- Assumed AMC can have a tremendous effect on results, with discharges varying from -75% to +200% from default (AMC II)

Poll Question

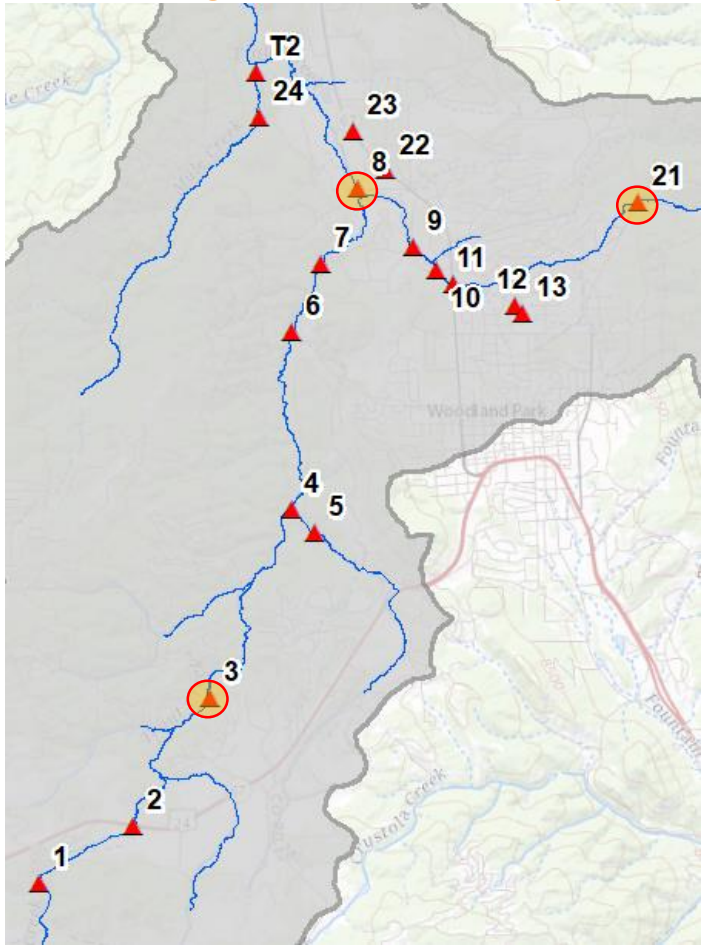
– In areas where NOAA Atlas 14 data is available, the NRCS recommends using the SCS Type II rainfall distribution.
  - True
  - False


Hydraulic Sensitivity

Summary of Hydraulic Analysis

– 21 simulations varying
  - Crossing type
  - Storage accounting
  - Cell size
  - Manning's n
  - Terrain resolution
  - Computational settings
– Fixed settings:
  - Custom nested hyetograph with 24-hr depth
  - CN based on AMC II

Featuring results primarily at…

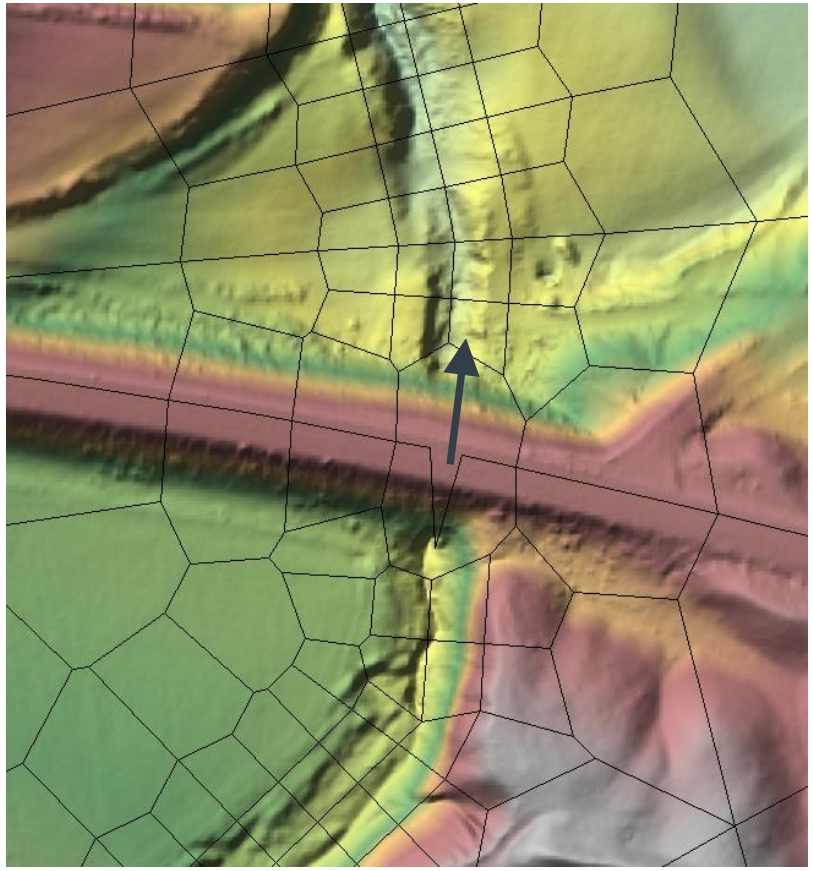


AECOM

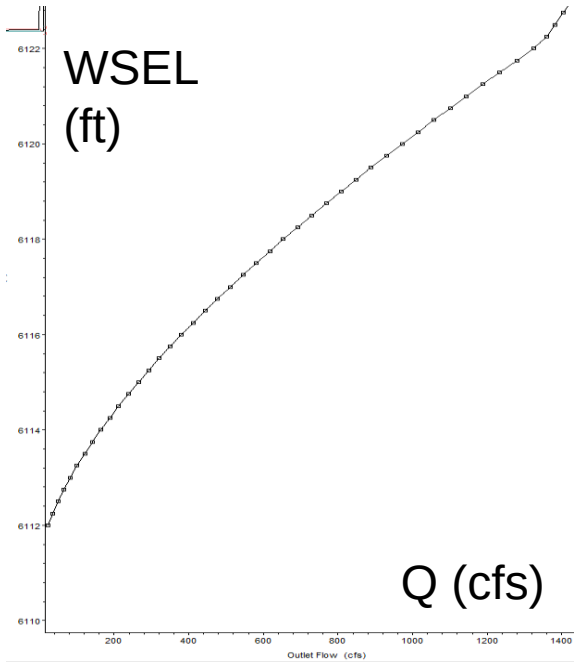
Summary of Hydraulic Variations

Crossing Type

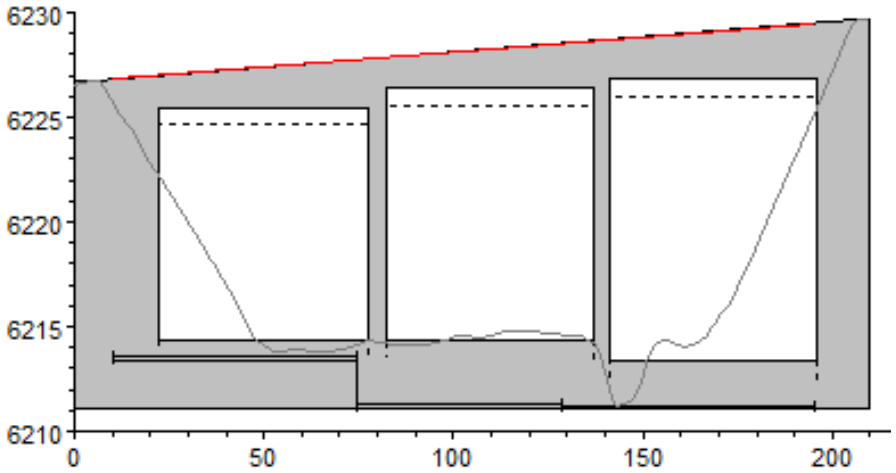
v-notch



rating curve



internal connection



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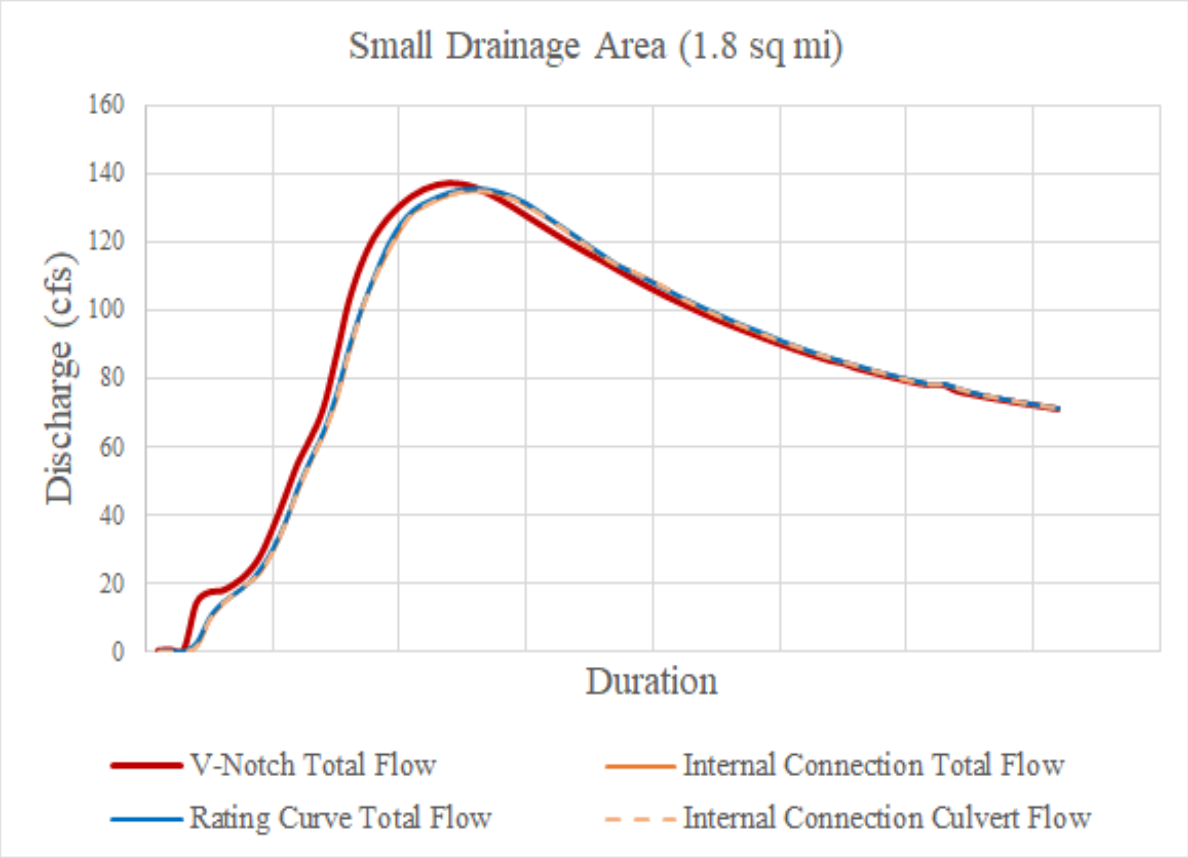
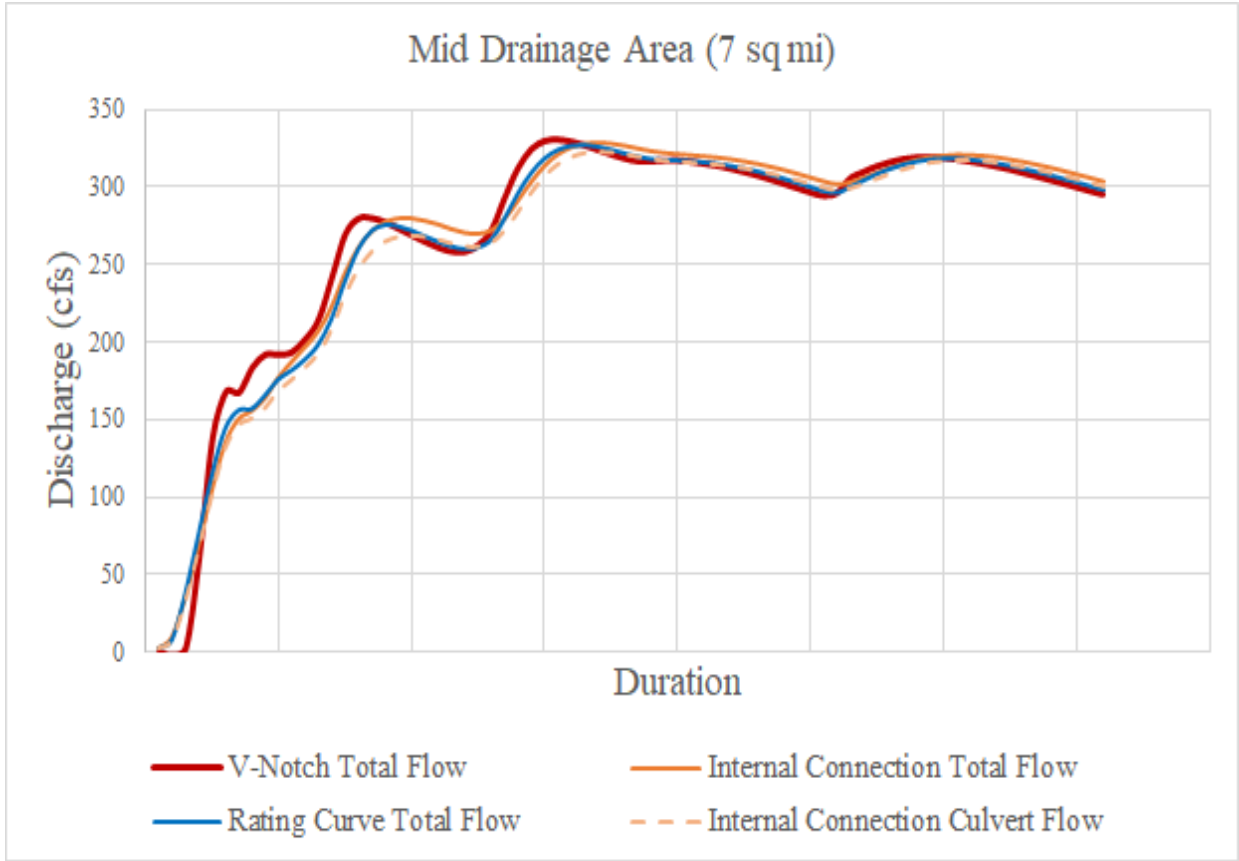
Summary of Hydraulic Variations

- 4 mesh sizes
  - Uniform (no refinements): 50, 100, and 200-foot cells
  - Refined: 200-foot nominal with 50-foot along streams
- Terrain: 8 ft vs 2 ft underlying resolution
- Settings: diffusion vs full momentum
- Manning’s n: shared land cover, but ±20% from estimated
- Breakline alignment: none, centerline as breakline, buffered centerline (banks)


Hydraulic Sensitivity Results

Crossing Type
Flow Hydrographs





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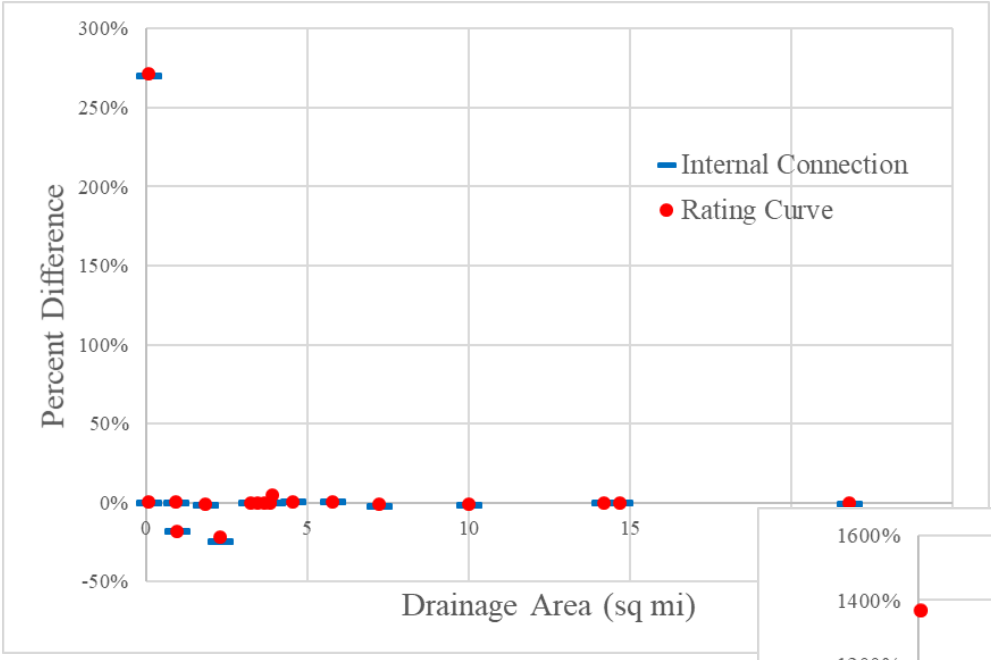
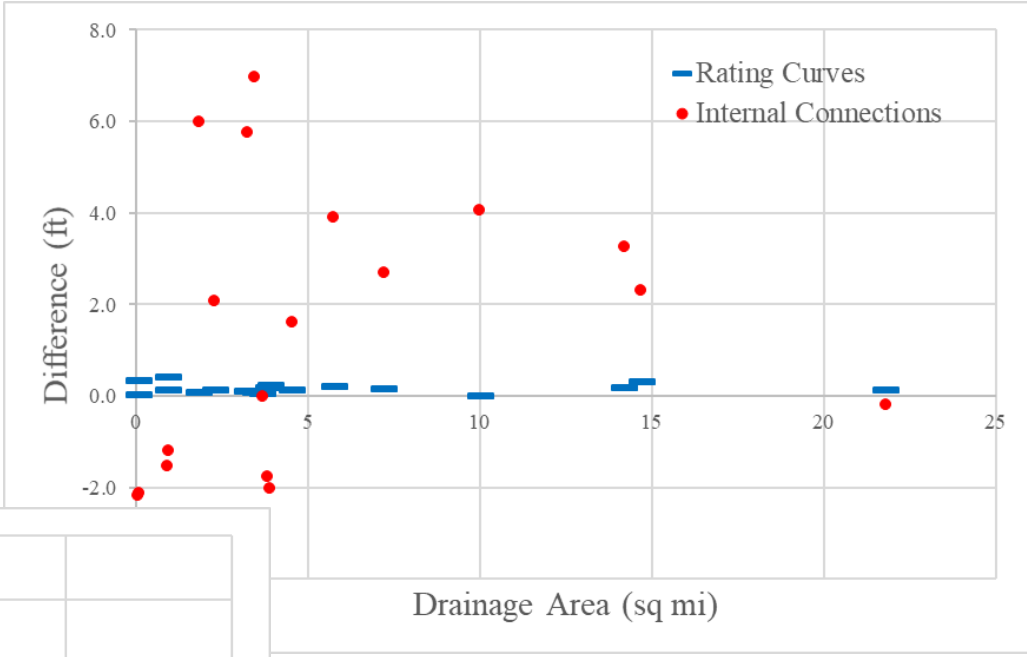
Crossing Type
% Change from V-notch

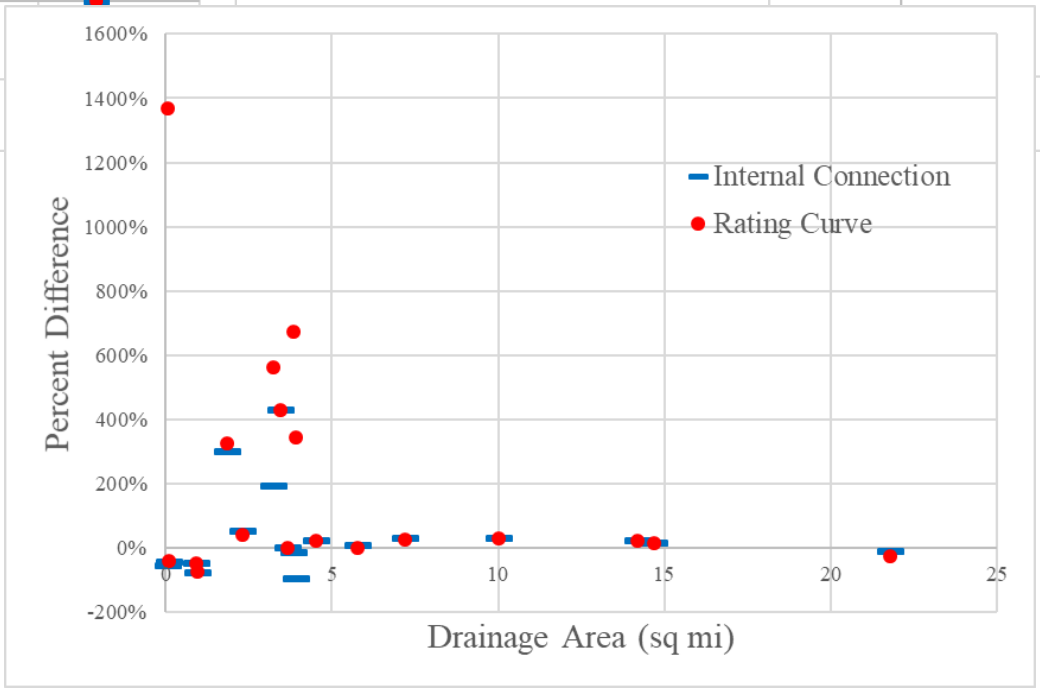
Discharge



Stage



Floodplain Width



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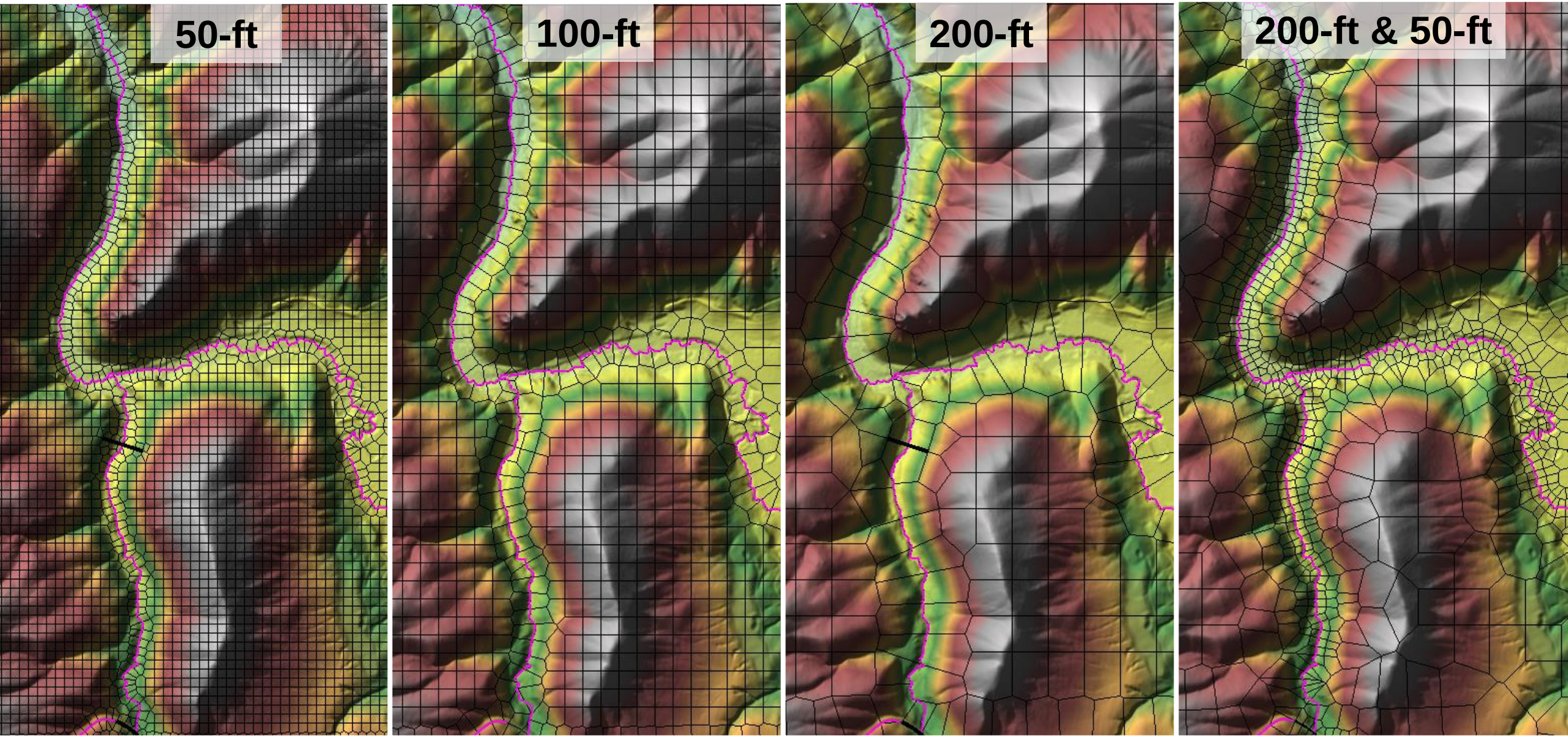
Mesh Cell Size



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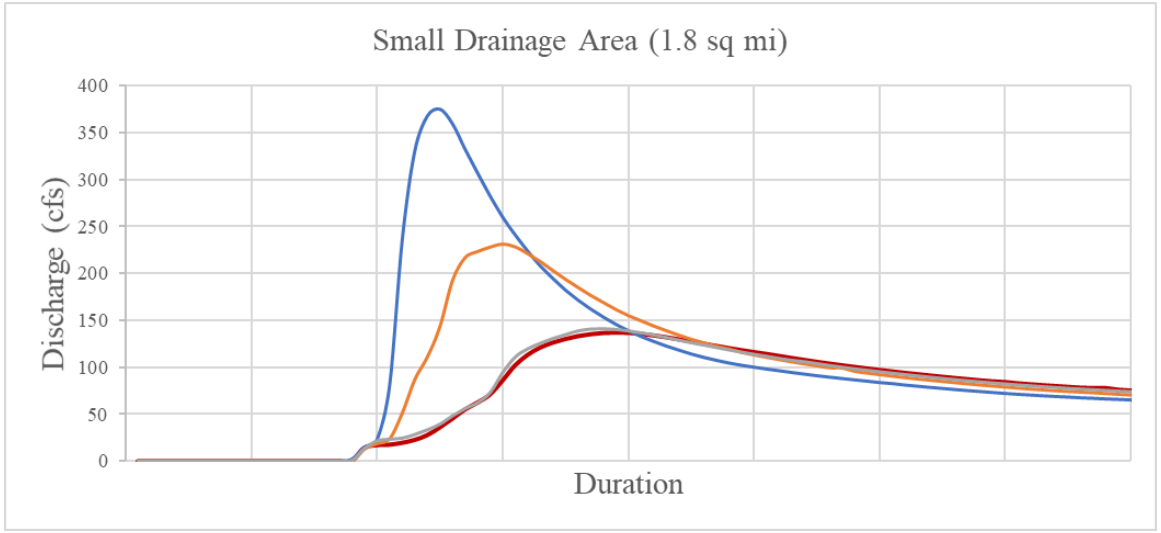
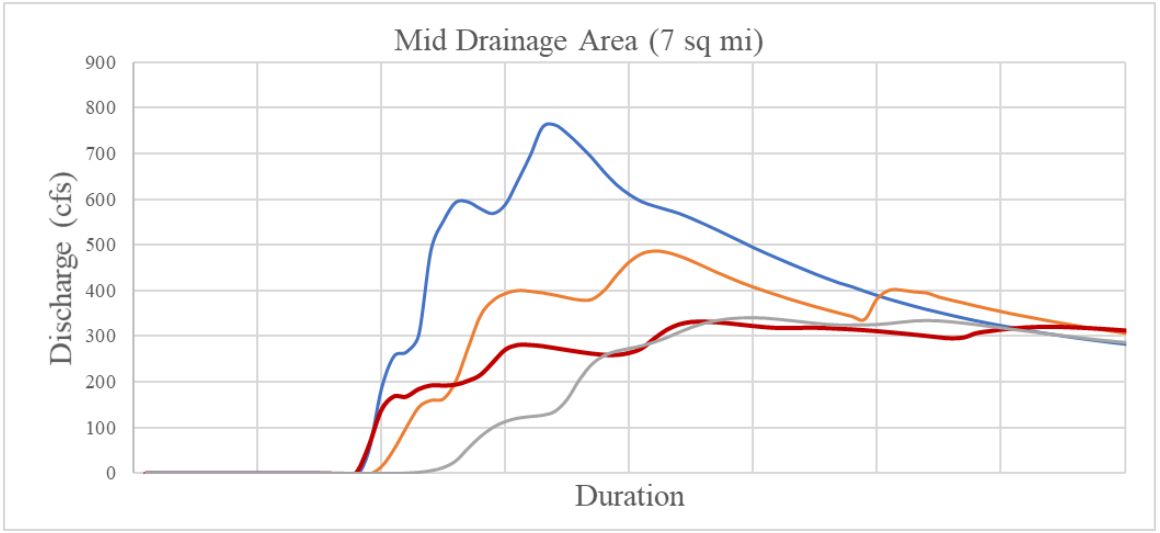
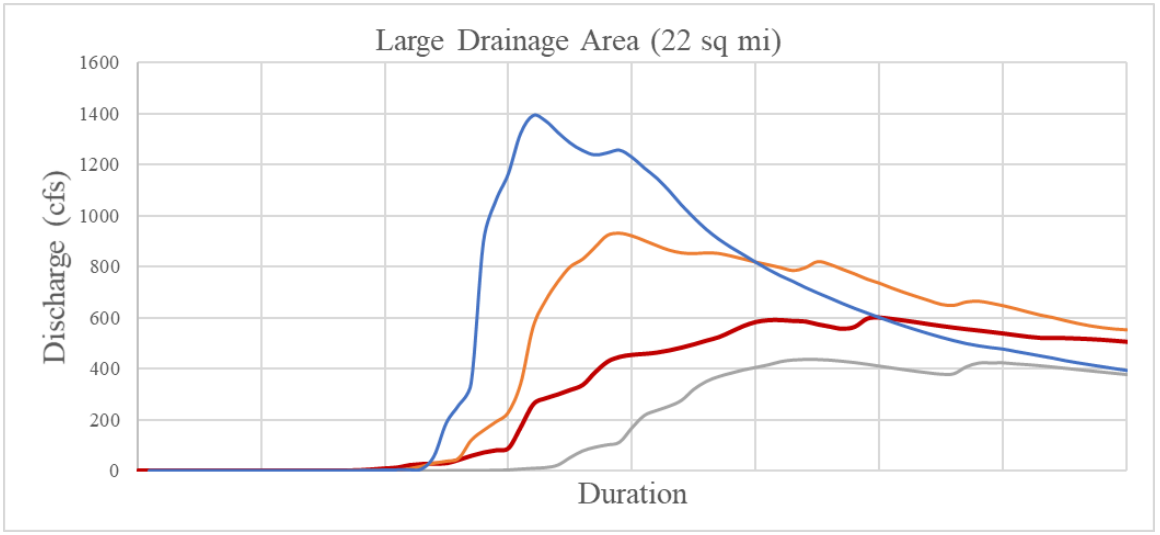
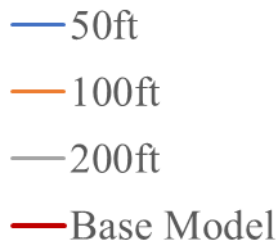
Mesh Cell Size
Flow Hydrographs









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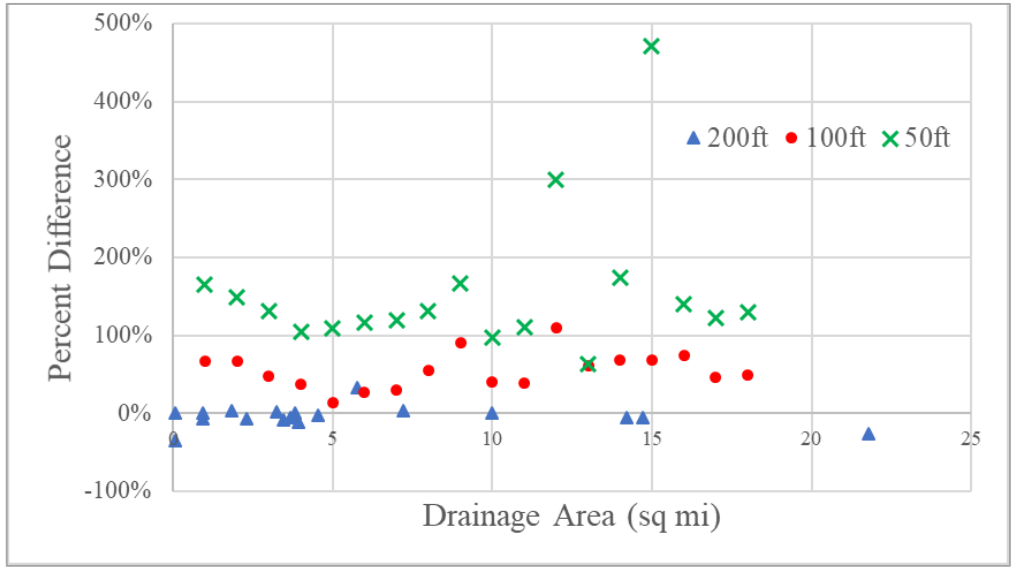
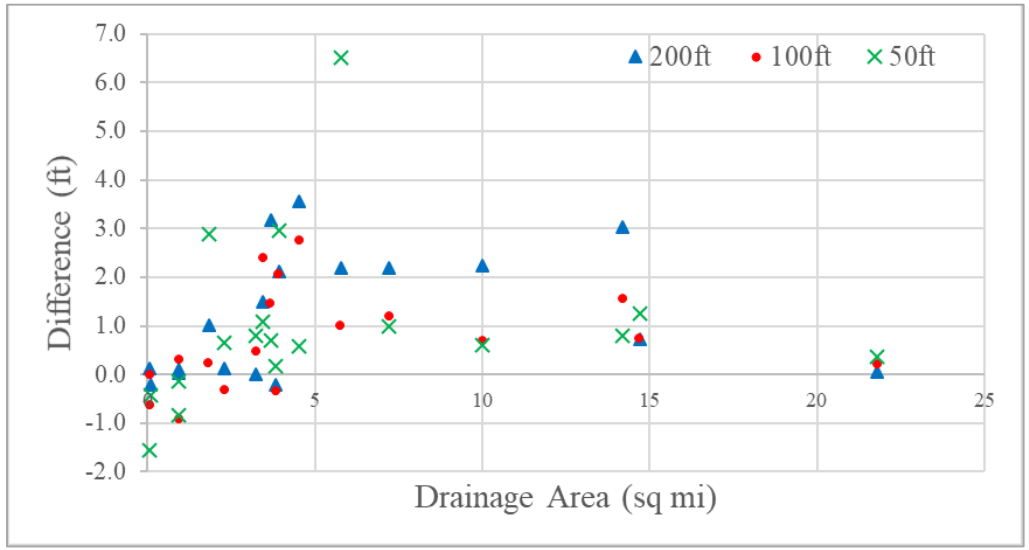
Mesh Cell Size
% Change from "Base" 200-ft w/ 50-ft Streams

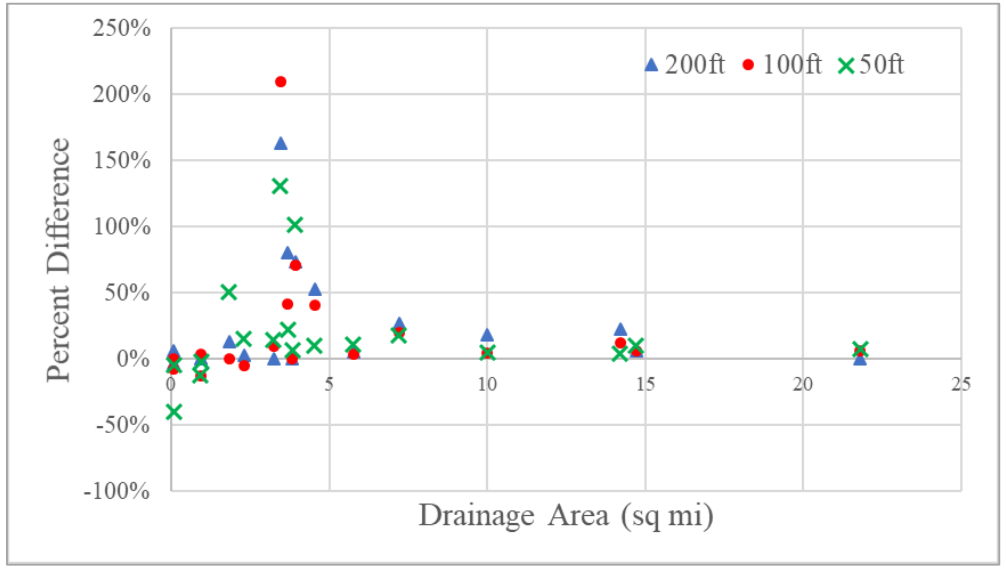
Discharge



Stage



Floodplain Width



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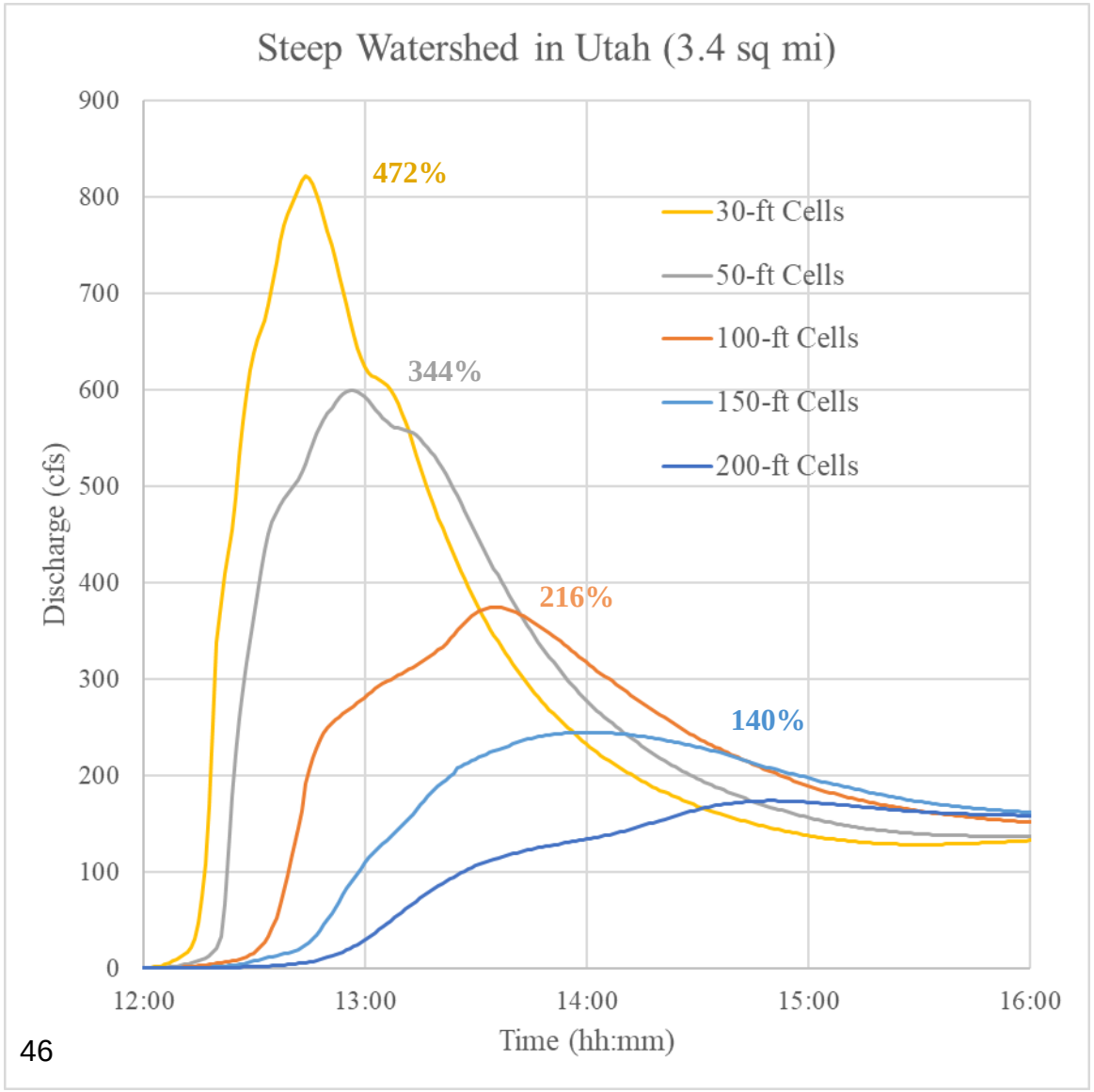
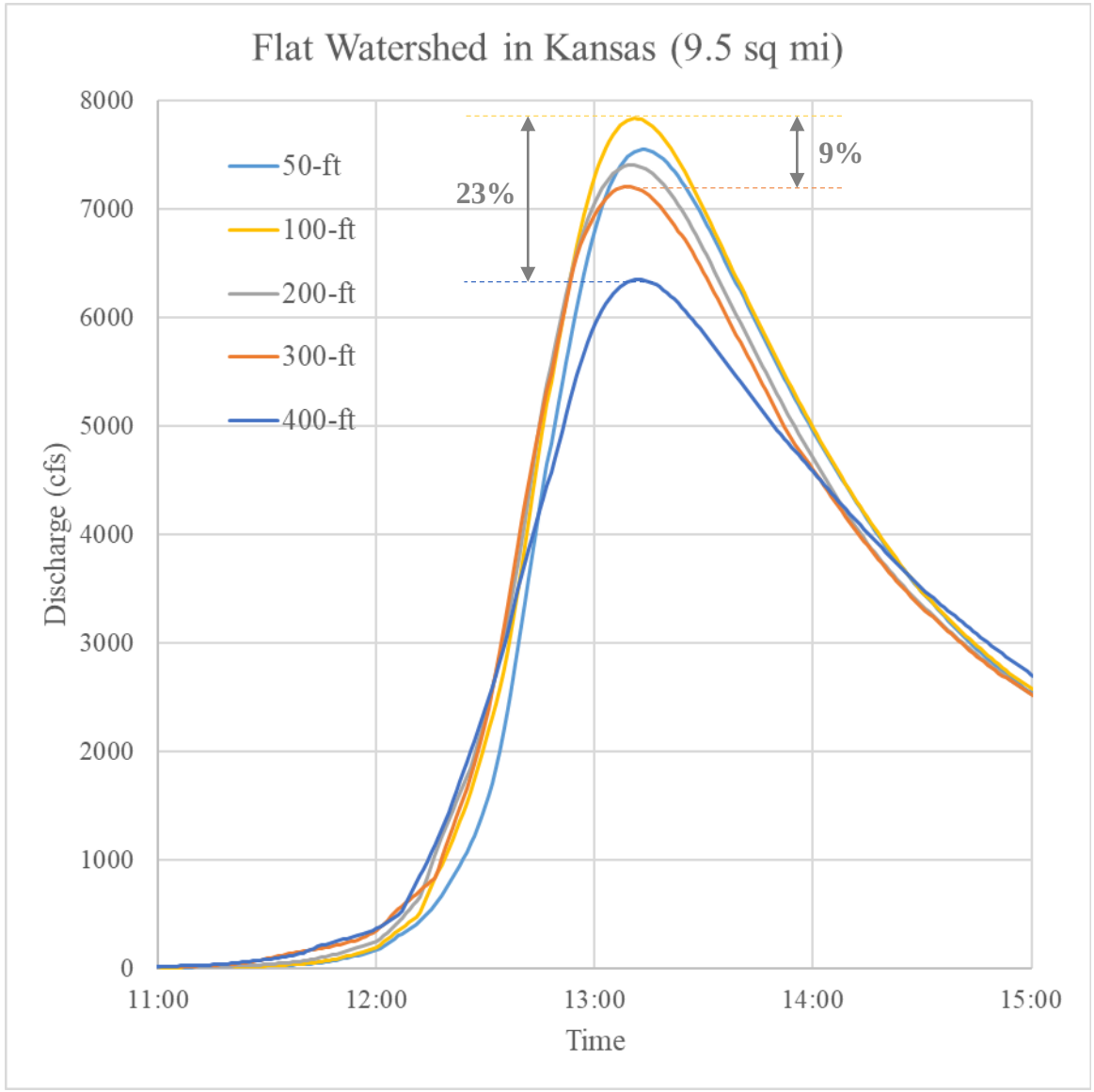
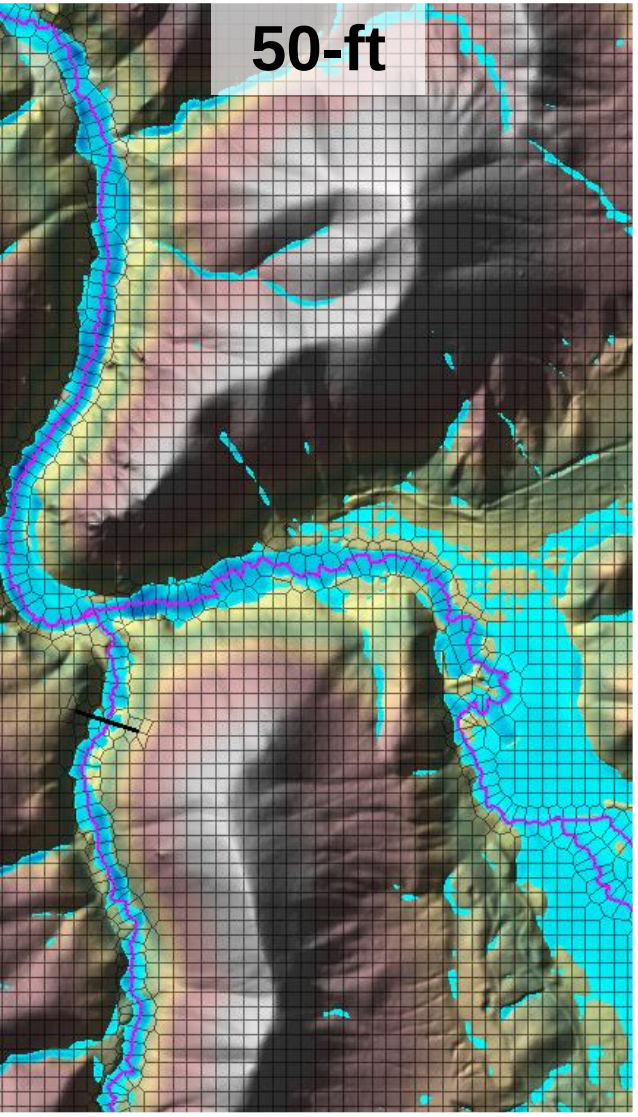
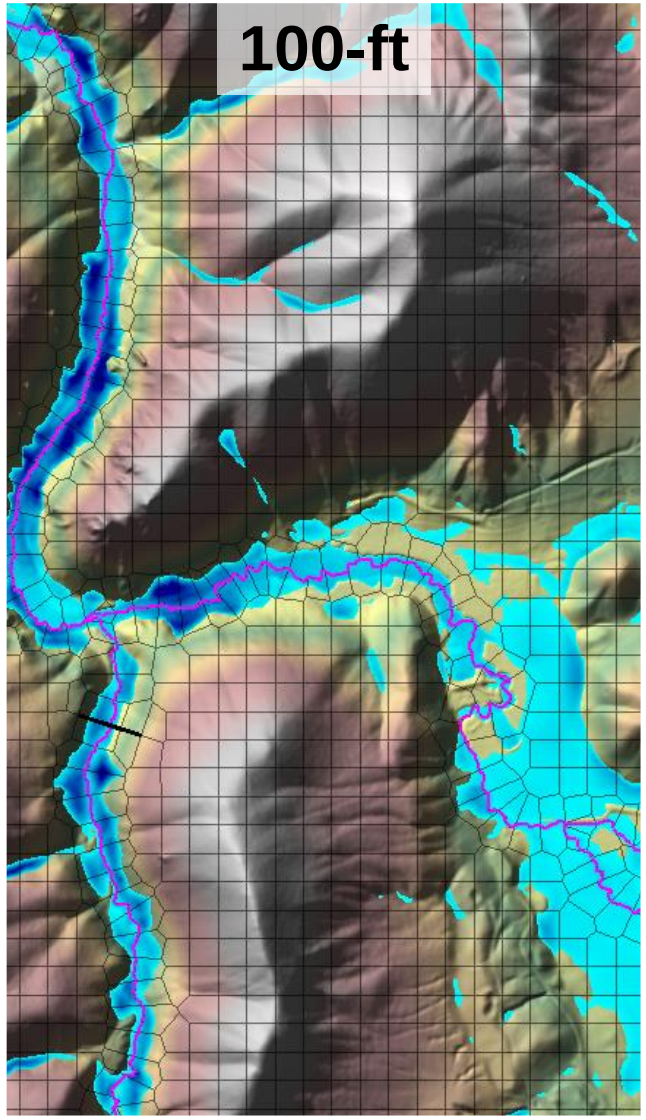
Mesh Cell Size
Other Examples

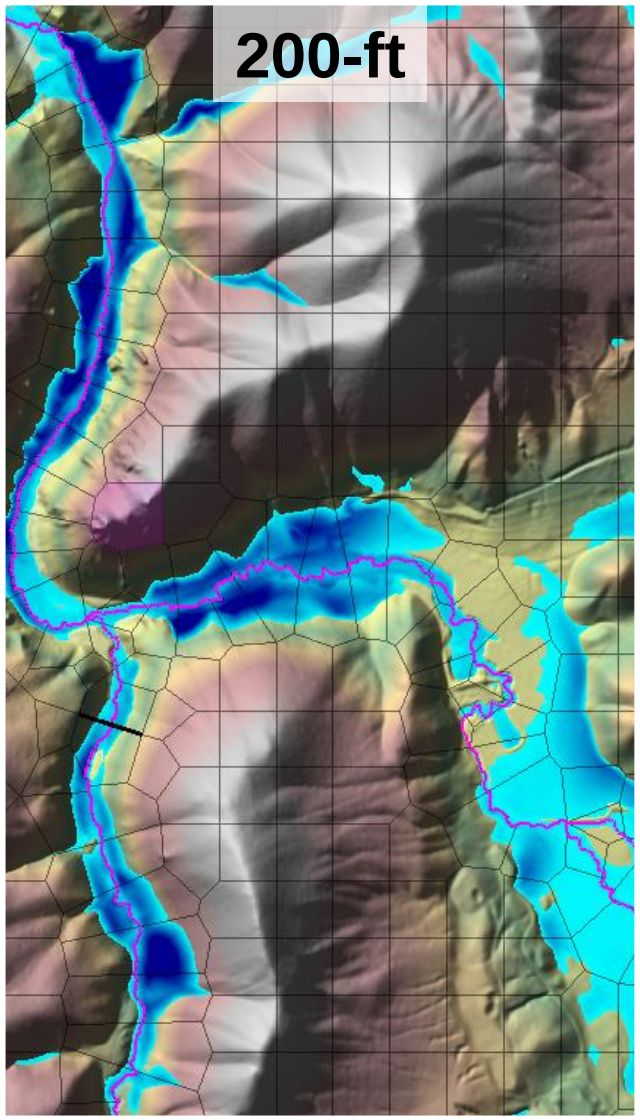


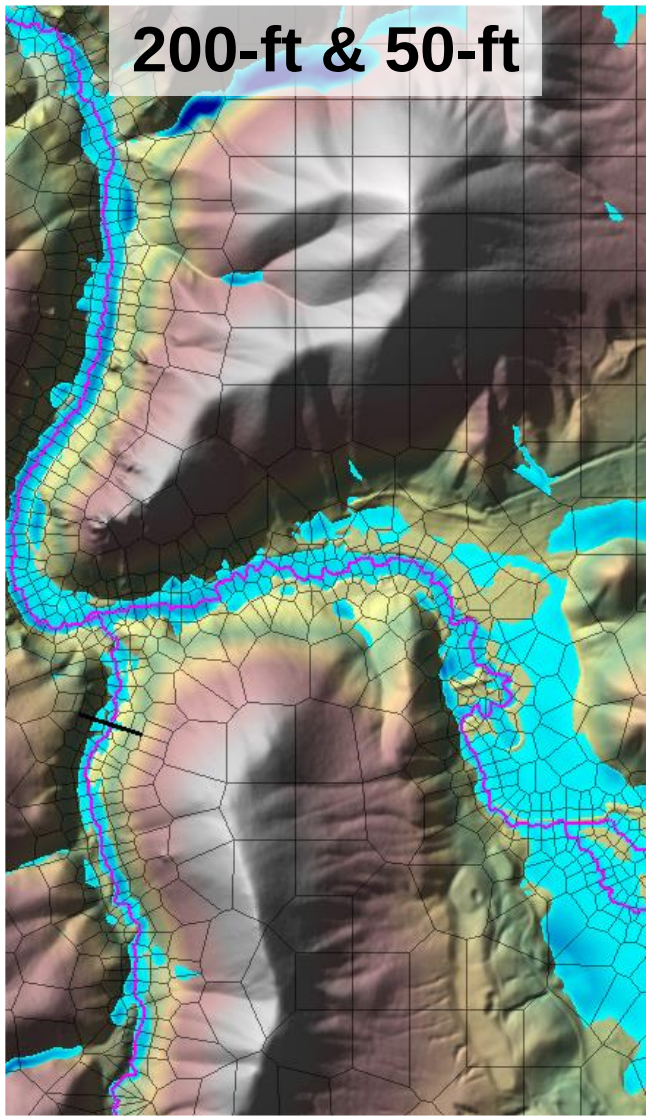


Mesh Cell Size
Mapping Differences









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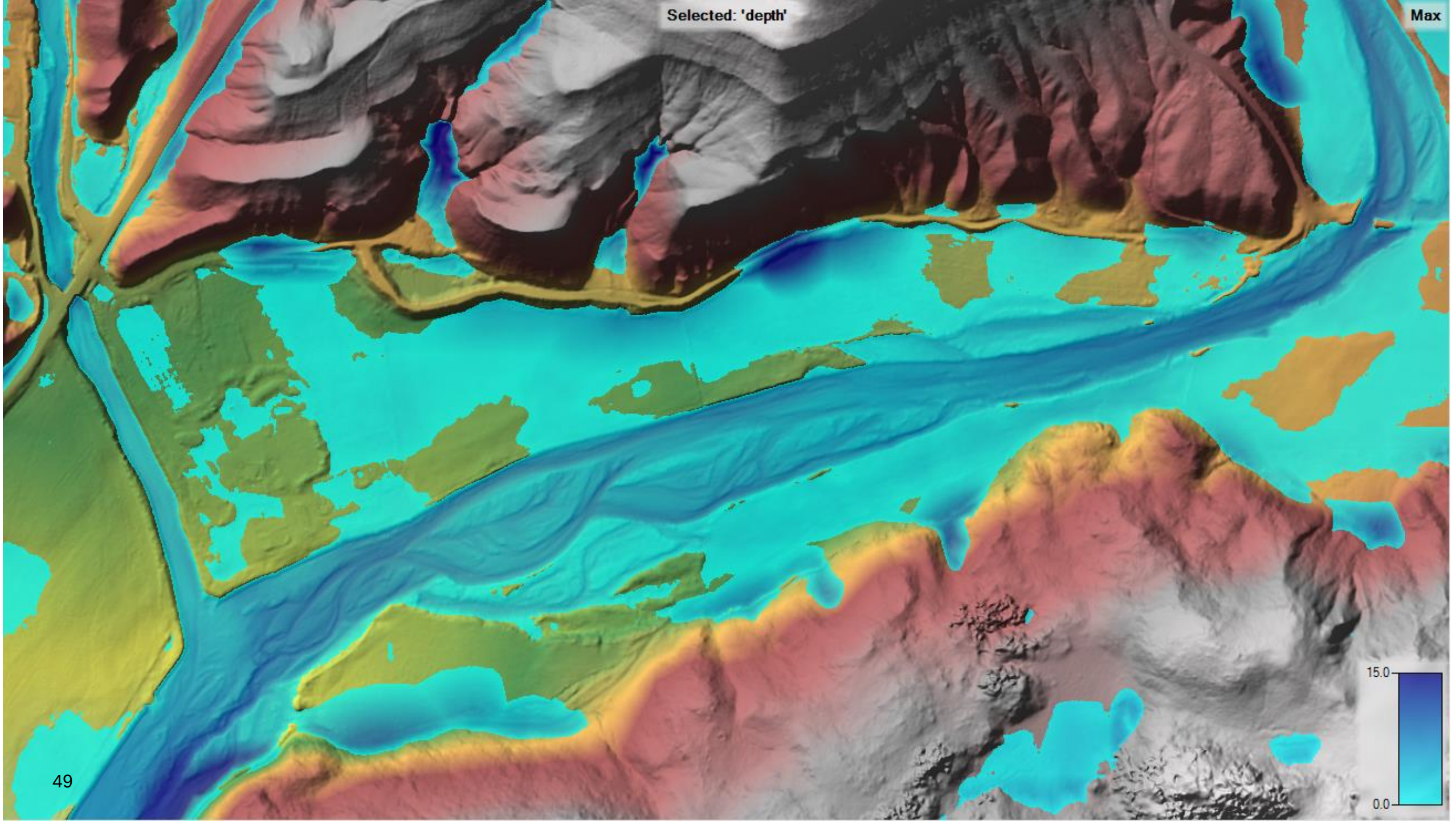
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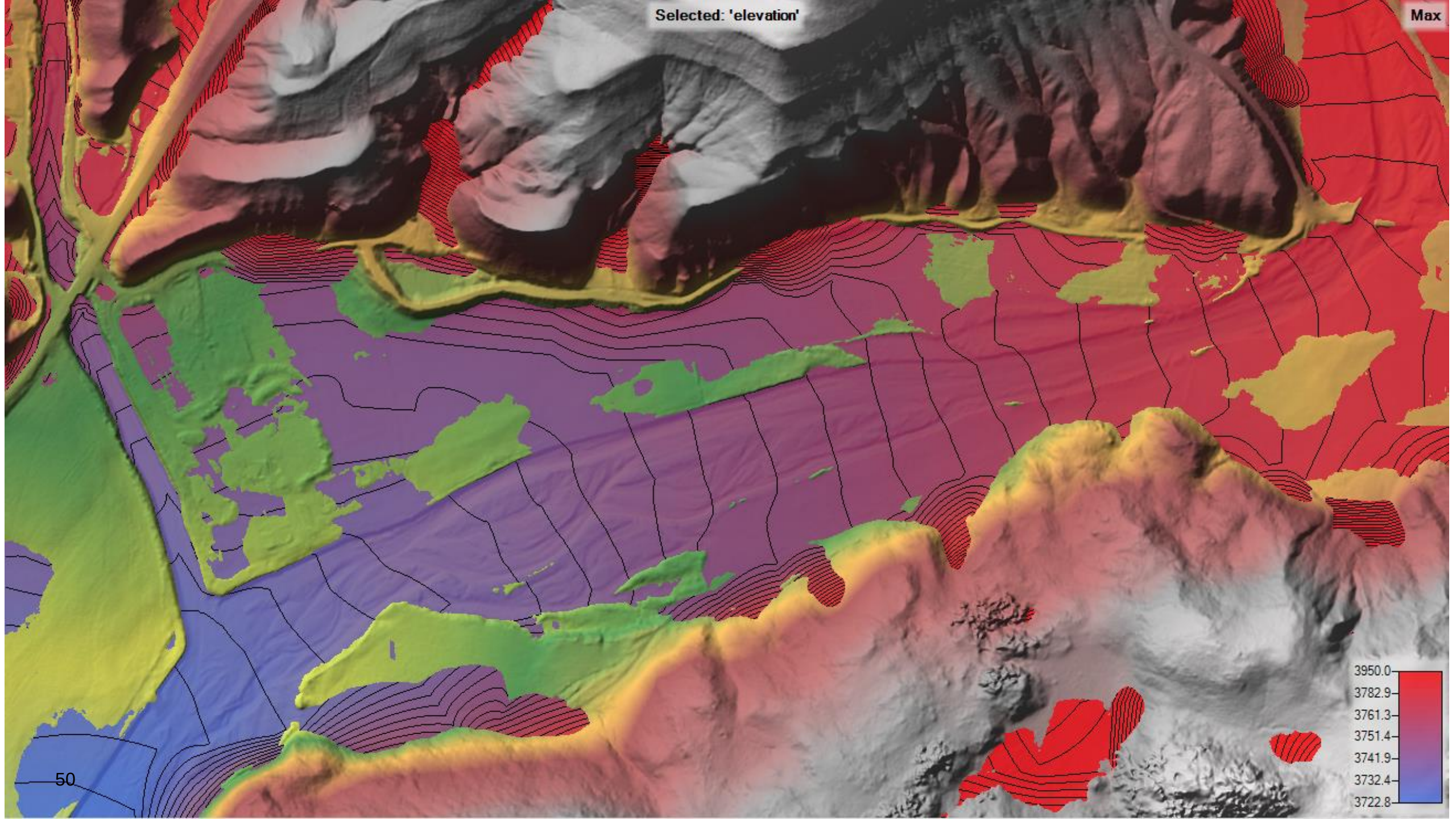
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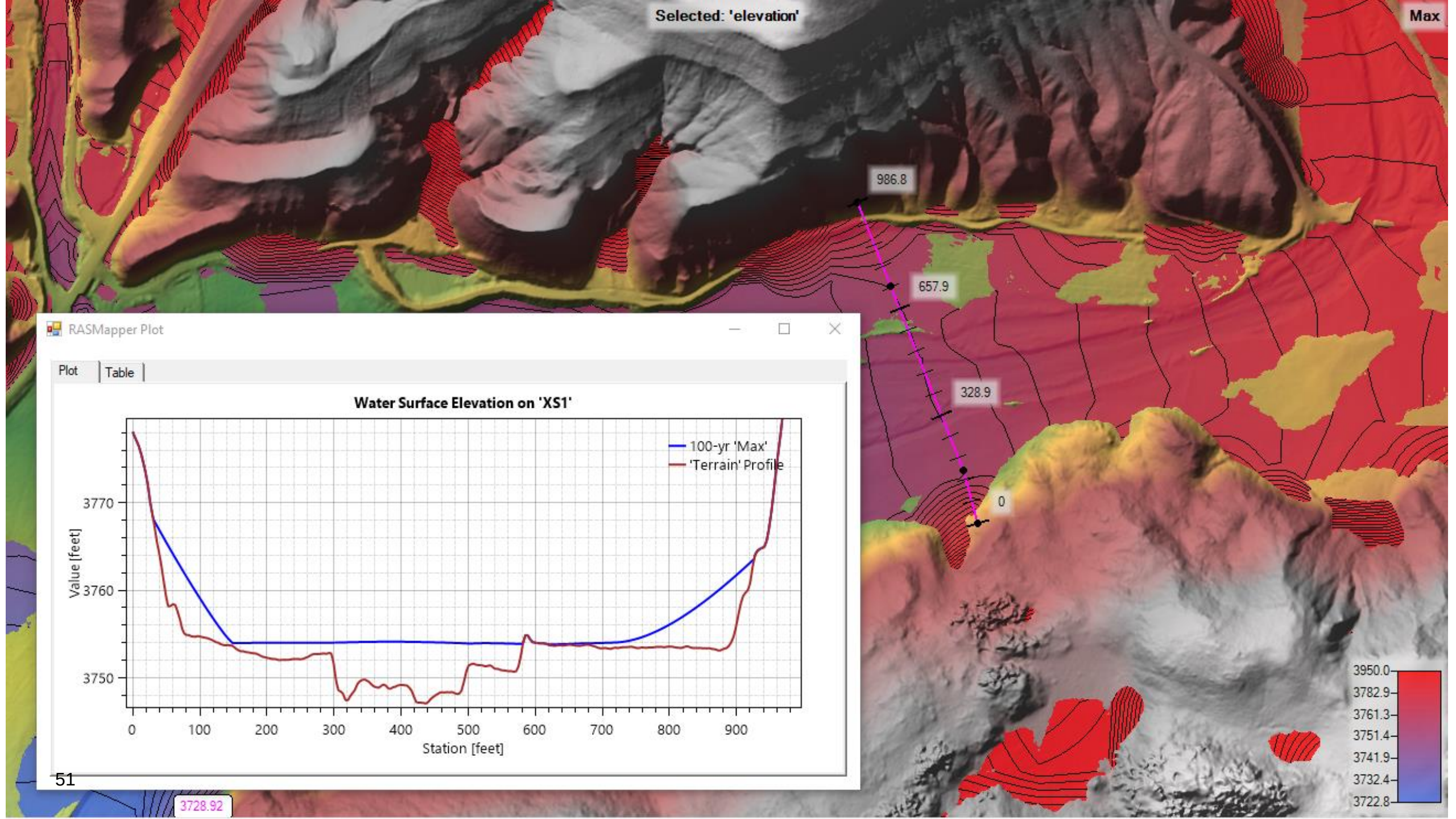
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RASMapper Plot
Plot
Table
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100-yr 'Max'
'Terrain' Profile
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3760
3750
0
100
200
300
400
500
600
700
800
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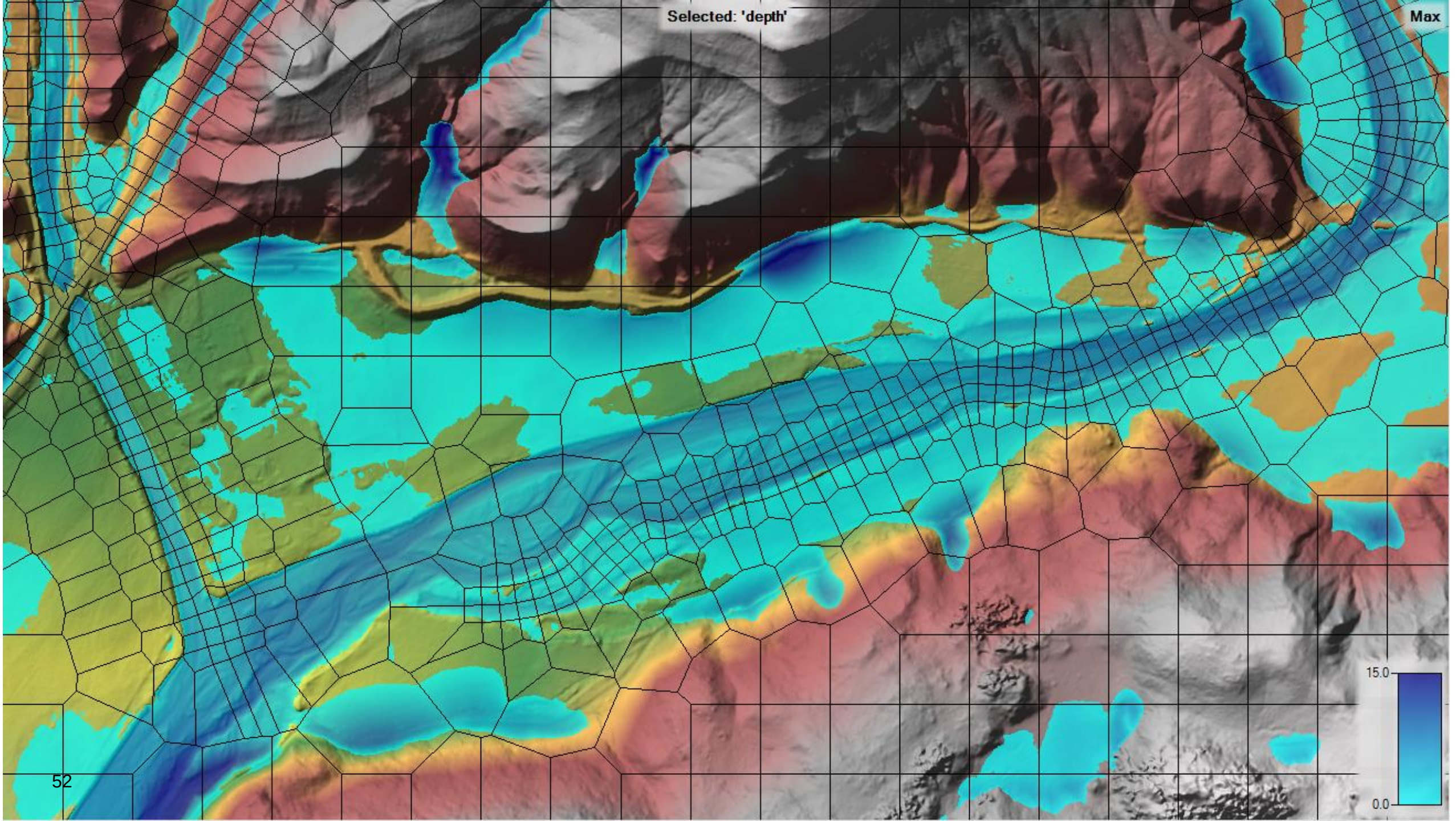
3728.92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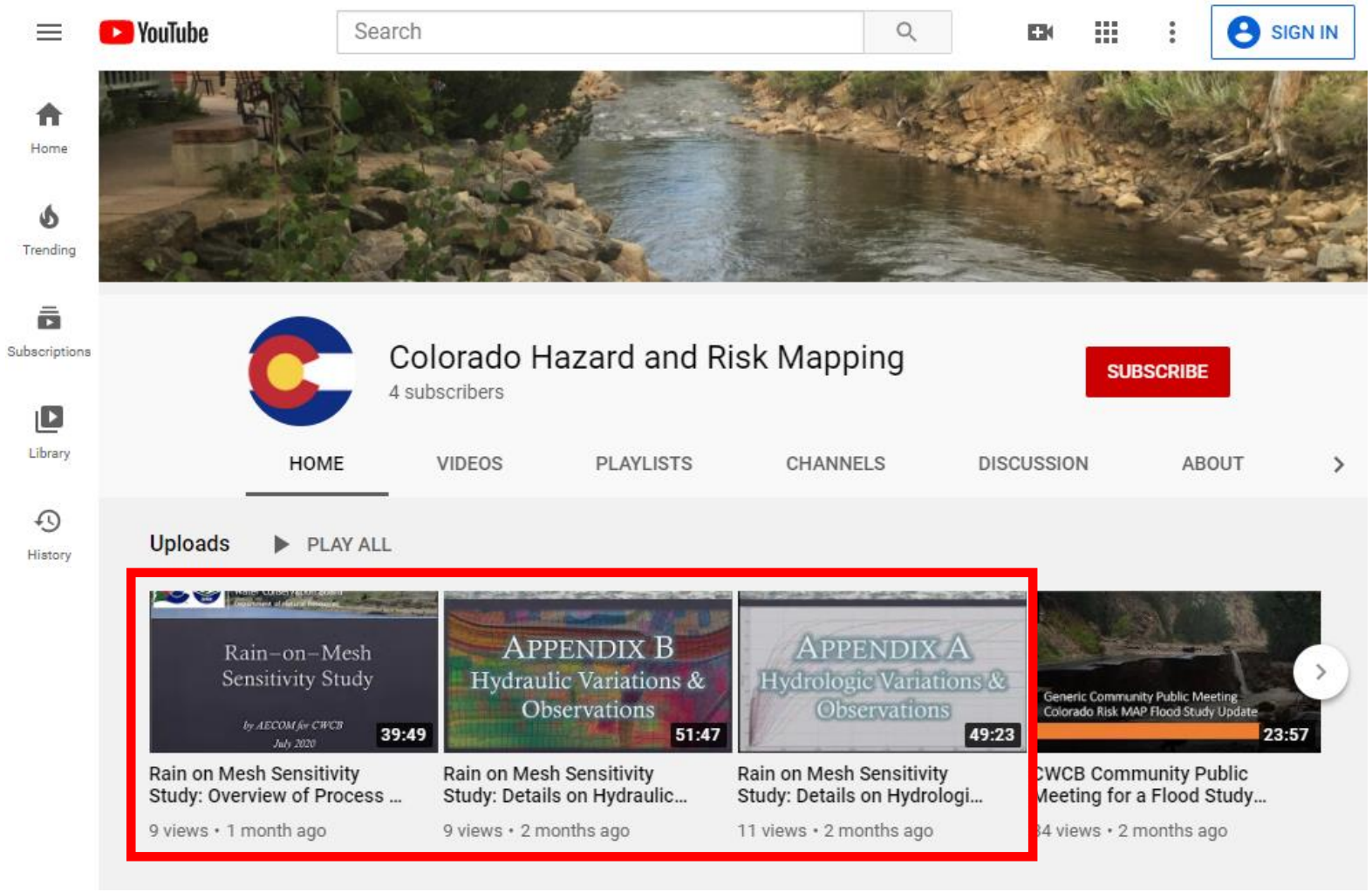
Hydraulic Observation Summary

- V-notches are simplest and often accurate enough if implemented correctly
- Decreasing cell size makes hydrograph more intense (greater & flashier)
  - Extent of effect depends on slope (not DA) - ~5 to 400%
- HEC-RAS “Sloping” render mode sometimes interpolates more than you want it to in rain-on-mesh models
  - Issue to be aware of
  - Must correct using either breaklines along toe, or in post-processing

Additional Topics Not Covered Here:

- Rainfall depth confidence limits
- CN/loss
- Manning's n
- Terrain resolution
- Watershed storage accounting
- Computational settings



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Questions?

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