2017 Montana Floodplain Resource Seminar: Lecture 5 HEC-RAS 5.0 Model Inputs

Eli Gruber, PE

compass

Identify Hazards, Interpret Risks, Integrate Mitigation

Lecture 5 Overview

- Overview of components
- Hydrology data development
- Boundary conditions
- Computational options and tolerances
- Model stability, run times, and accuracy
- Executing a model run

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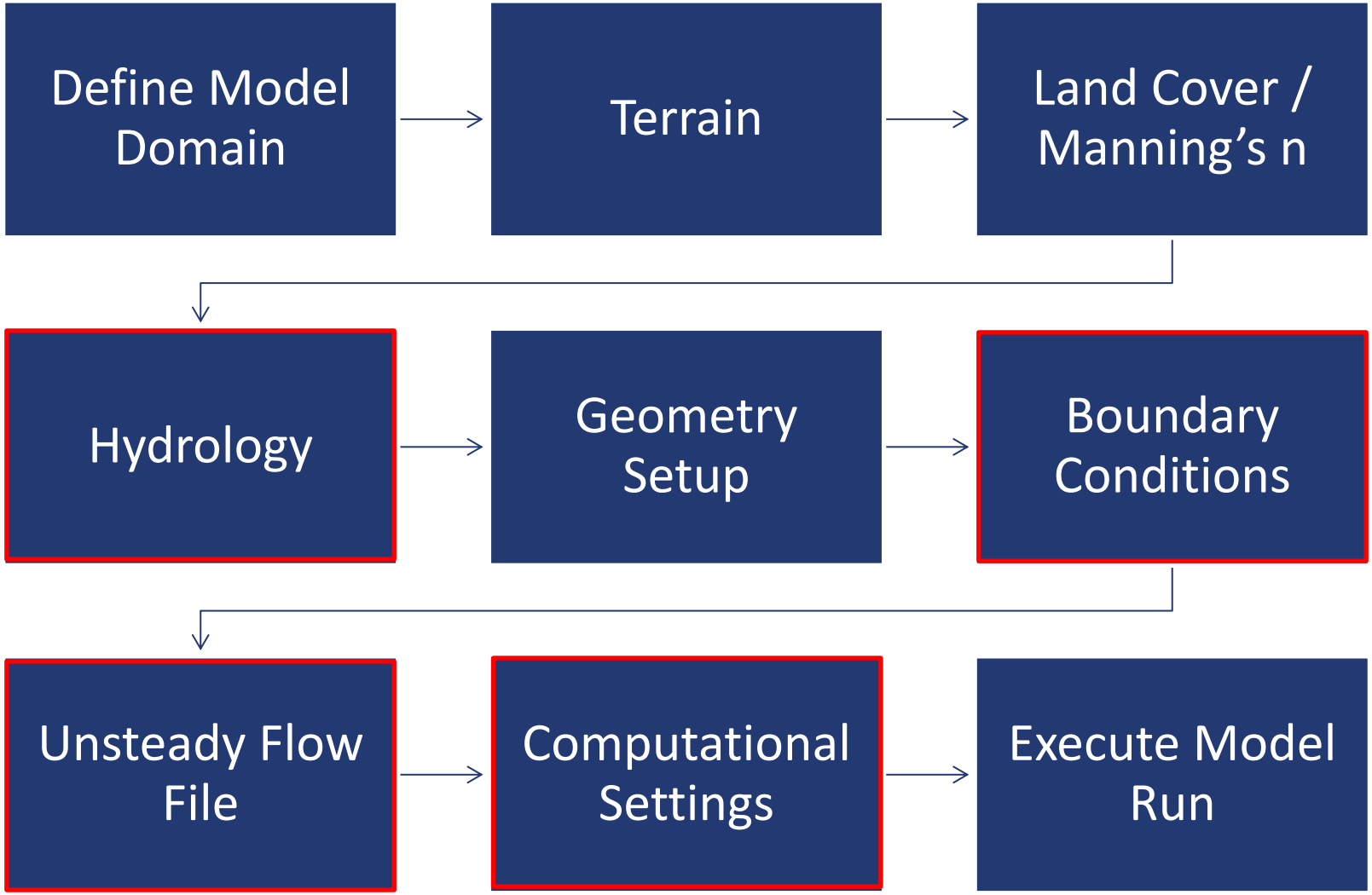
HEC-RAS 5.0 2D Process



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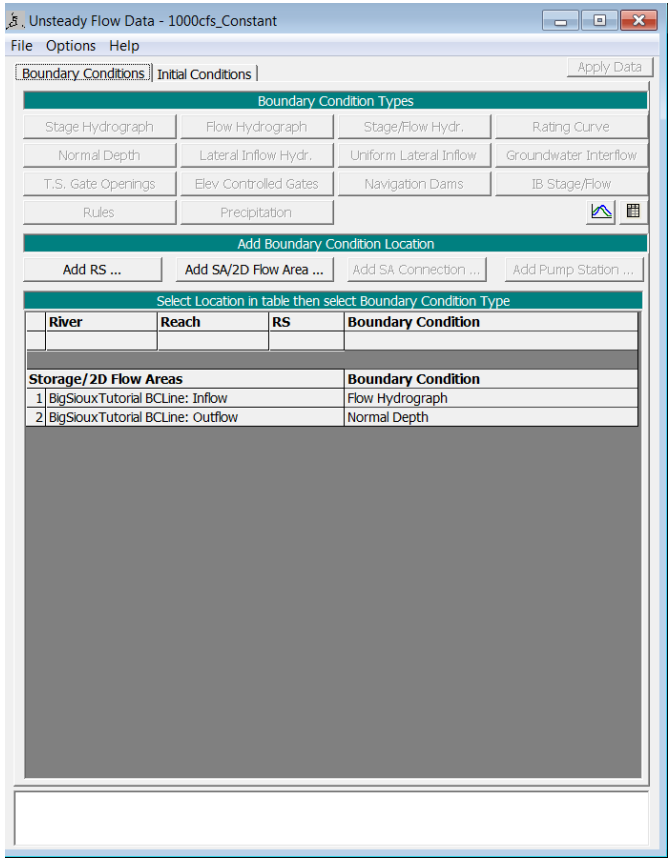
External Boundary Conditions

- Location defined in geometry
- Data input into unsteady flow
- Flow hydrograph
- Stage hydrograph (inflow/outflow)
- Normal depth (inflow/outflow)
- Rating curve (outflow)
- Precipitation
  - Applied to 2D model area



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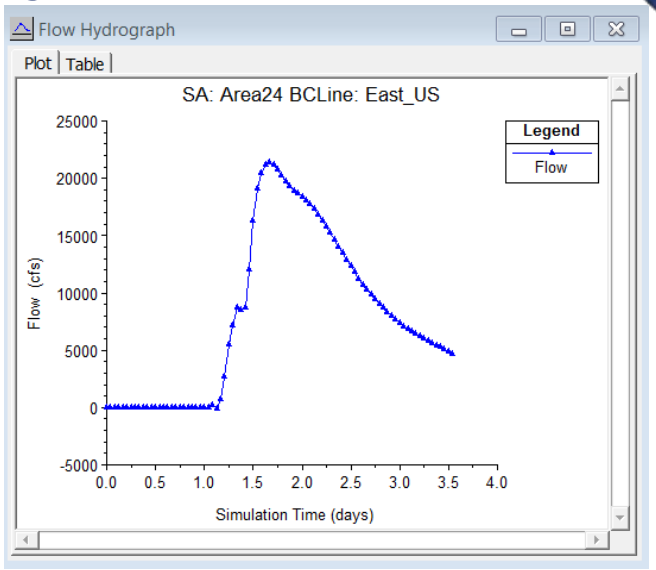
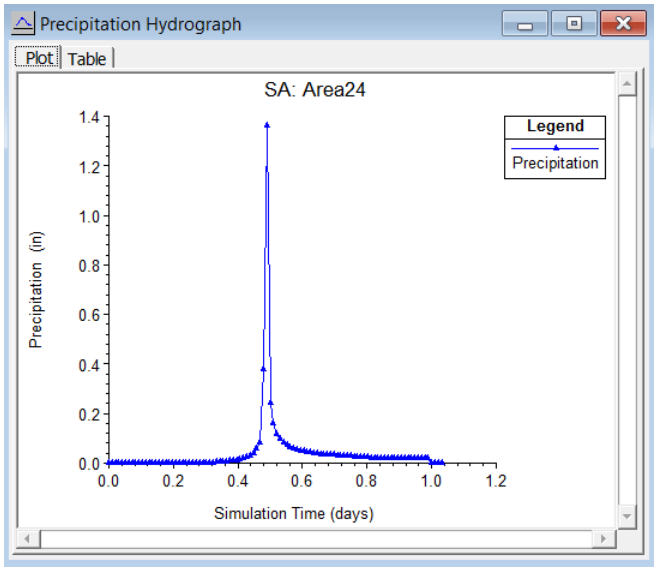
Hydrology Development

- Inflow Hydrograph
  - Developed with same methods as 1D model
- Rain-on-grid
  - Apply precipitation directly to computational mesh
  - Specific to 2D model





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Calculating Peak Flows

- Peak flow analysis → USGS Bulletin 17B
  - Gage data (USGS, state agency, USACE, etc.)
  - Greater than 25-years period of record preferred
  - PeakFQ is a great free tool
  - Leverage published data for consistency (FEMA, USGS, etc.)
  - Skew and high/low outlier values need to be adjusted specific to region

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PeakFQ

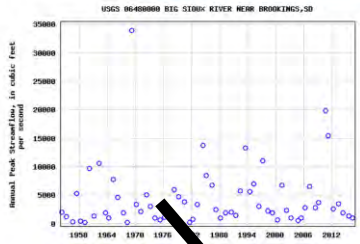
USGS 06480000 BIG SIOUX RIVER NEAR BROOKINGS,SD

Available data for this site: Surface-water Peak streamflow GO

Moody County, South Dakota
Hydrologic Unit Code 10170203
Latitude 44°10'49", Longitude 96°44'57" NAD27
Drainage area 3,338 square miles
Contributing drainage area 2,469 square miles
Gage datum 1,551.91 feet above NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- peakfq (watstore) format
- Reselect output format



ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	<-- FOR BULLETIN 17B ESTIMATES --> VARIANCE OF EST.	95% CONFIDENCE INTERVALS LOWER	UPPER
0.9950	98.8	103.6	----	53.5	158.1
0.9900	139.7	144.9	----	79.9	215.1
0.9500	348.4	353.0	----	228.0	487.8
0.9000	555.8	558.2	----	387.1	746.7
0.8000	960.9	957.7	----	712.2	1243.0
0.6667	1574.	1563.	----	1215.0	1998.0
0.5000	2593.	2572.	----	2044.0	3298.0
0.4292	3172.	3147.	----	2504.0	4064.0
0.2000	6525.	6515.	----	5036.0	8829.0
0.1000	10290.	10350.	----	7695.0	14650.0
0.0400	16380.	16680.	----	11770.0	24800.0
0.0200	21880.	22500.	----	15290.0	34510.0
0.0100	28180.	29260.	----	19190.0	46140.0
0.0050	35320.	37030.	----	23480.0	59840.0
0.0020	46100.	48960.	----	29770.0	81350.0

PeakFQ Version 7.1

File Help

Use File menu to Open PeakFQ data or PKFQWin spec file.
Update Station, Threshold and Output

PeakFQ Data File: C:\FEMA\Region_8\Montana\HydroExample\BigSiouxBrookings\PEAK
PeakFQ Spec File:

Station Specifications | Input/View | Output Options | Results

Global Analysis Option: B17B

Global PILF (LO) Test Option: le Grubbs-Bec

Station ID	Analysis Option	Beginning Year	Ending Year	Record Length	Inc Hist Peaks	Skew Option	Generalized Skew	Gen Skew Std Error	Mean Sqr Err	Low Hist Peak	PILF (LO) Threshold	PILF (LO) Test	High Sys Peak	Hi-Outlier Threshold	Gage Bas Discharge	Urban/Reg Peaks	Latitude	Longitude	Plot Name
06480000	B17B	1954	2016	63	No	Weighted	-0.4	0.55	0.3025	0	0	Single	33900	0	0		44.18028	96.74916	06480000

Run PEAKF | Save Specs | Exit

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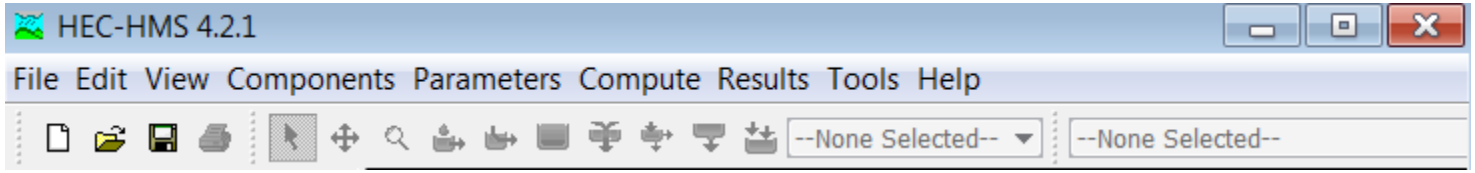
Peak Flows Continued

- Regional Regression Equations
- Rainfall-runoff hydrologic model
  - SCS or other method
  - Calibrate hydrology before hydraulic modeling



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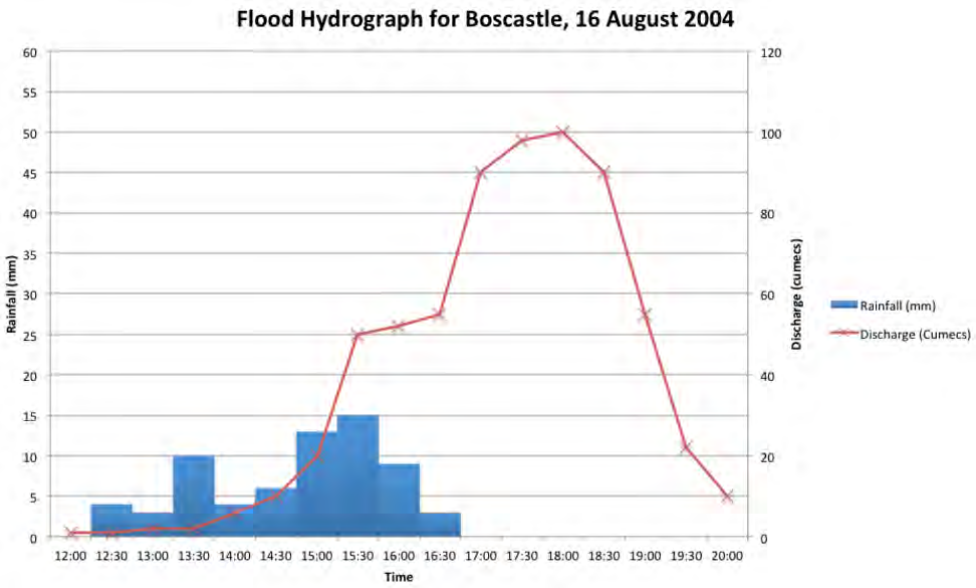
Hydrograph Shape

- Unit Hydrograph Methods
  - Based on actual gaged events
  - Instantaneous or daily data
  - Time to peak
- Synthetic Hydrograph
  - Similar watershed or regional data
- Rainfall-runoff hydrologic model
  - Shape depends on basin parameters and assumed storm distribution
  - Calibrate to historical event(s)



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Adding Boundary Conditions (BCs)

- Geometry Editor ***SA/2D Area BC Lines***
- Draw at specific model boundary locations
- Can draw as many BCs as needed
  - Two BCs can't share the same cell face, this will produce an error
- Each BC drawn in the geometry file will show up in the unsteady flow file editor

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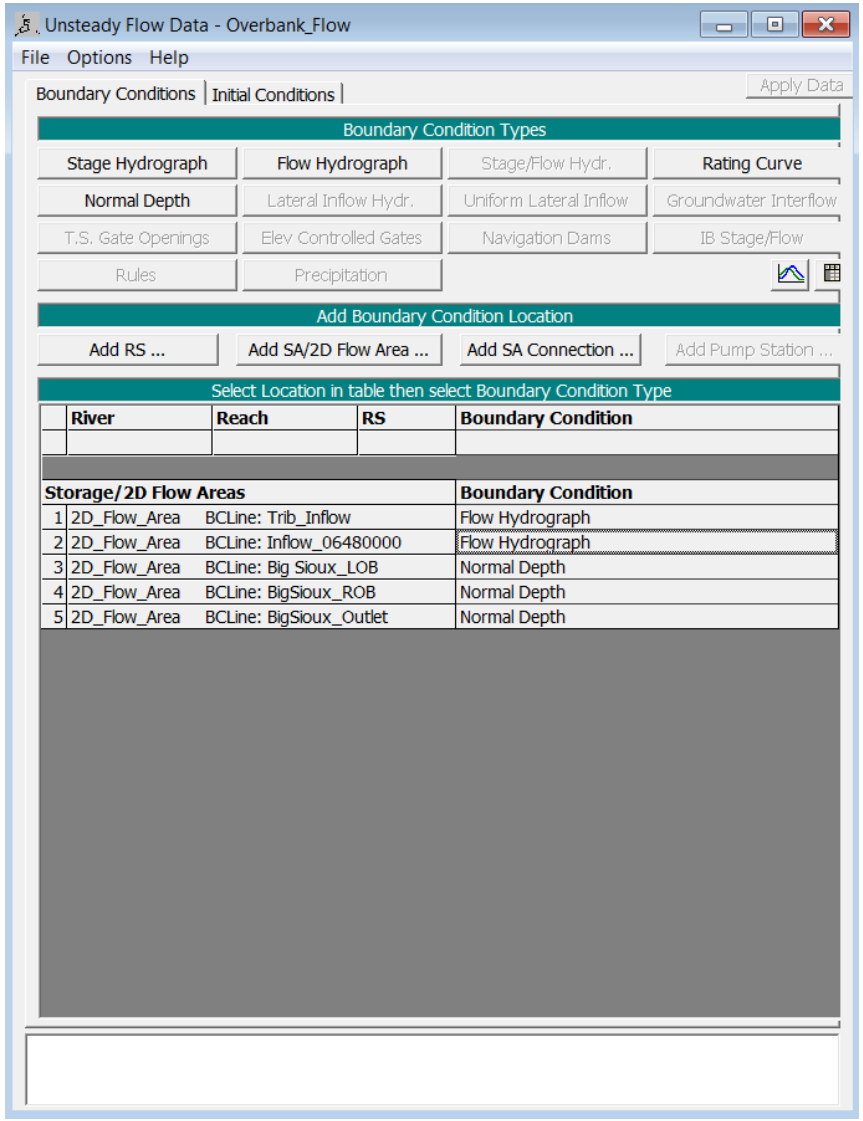
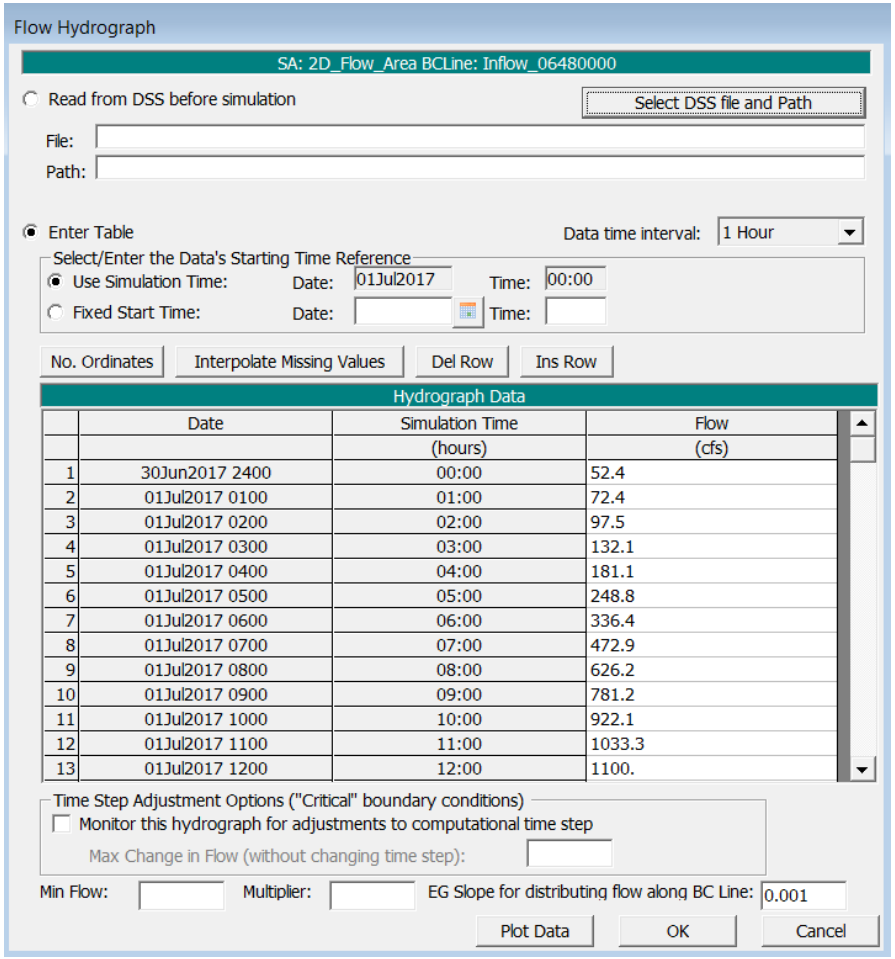
Inputting BC Data





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Precipitation (Rain-on-Grid)

- Applied to 2D computational mesh
- HEC-RAS does not account for losses
  - Develop excess precipitation hyetograph through external hydrologic model (e.g., HEC-HMS)
- Requires "watershed approach" to account for all contributing areas
- Useful for large scale model applications

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Rain-on-Grid Development

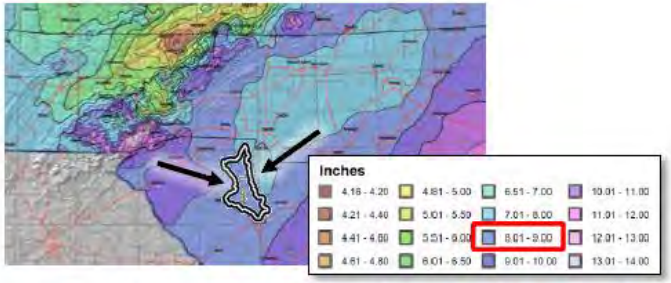
LAND USE & SOILS

- Land Use: National Land Cover Database (2011)
- Soils: NRCS Web Soil Survey
- Used as an input in all HEC-HMS models to support the calculation of Curve Numbers and Lag Times
- Also used within the 2D model to estimate roughness values

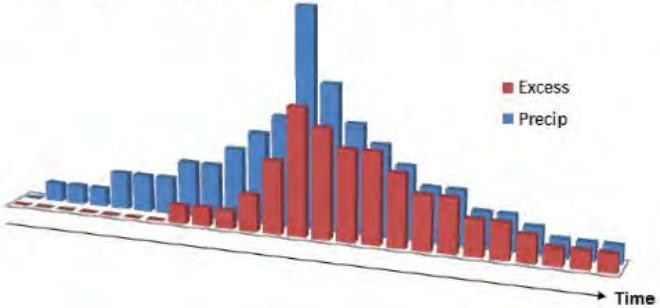
Rain-on-Grid Development

PRECIPITATION (RAIN-on-GRID)

- NOAA Precipitation Frequency Data Server or Atlas 14



- Simple HEC-HMS model developed to determine excess rainfall to apply within the 2D model (HEC-RAS 5.0)



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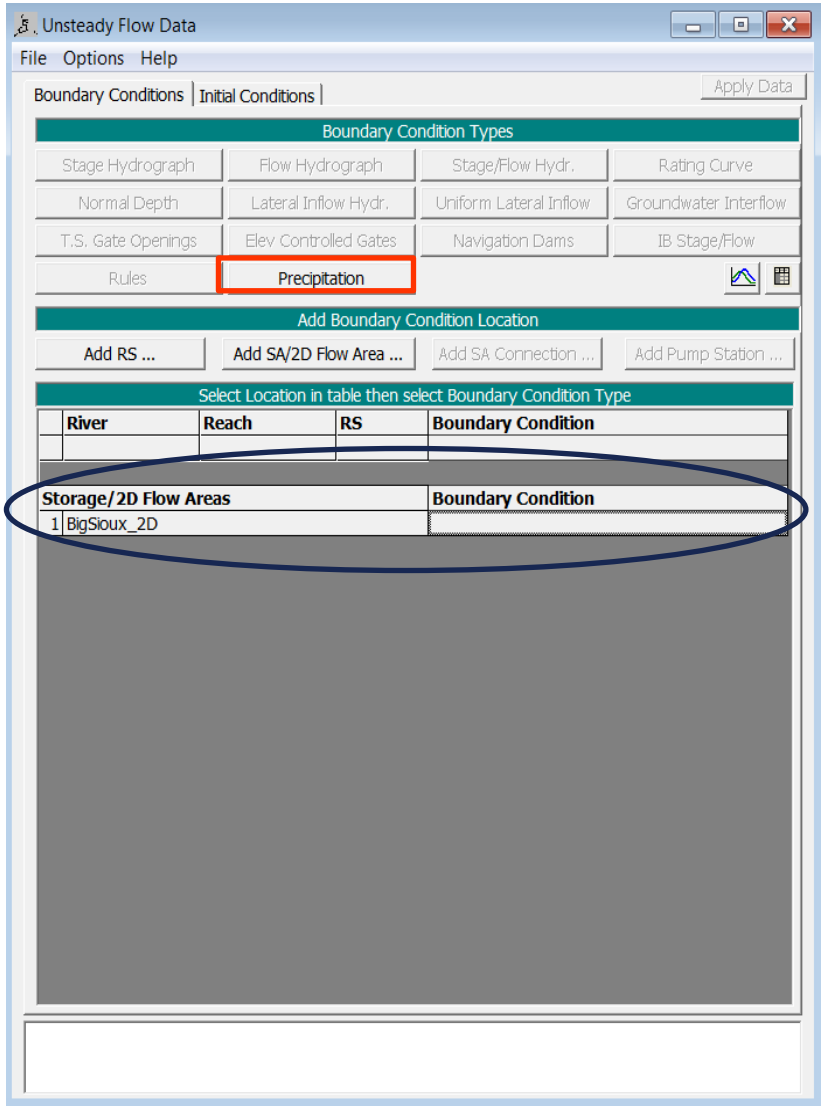
Add Precipitation Boundary



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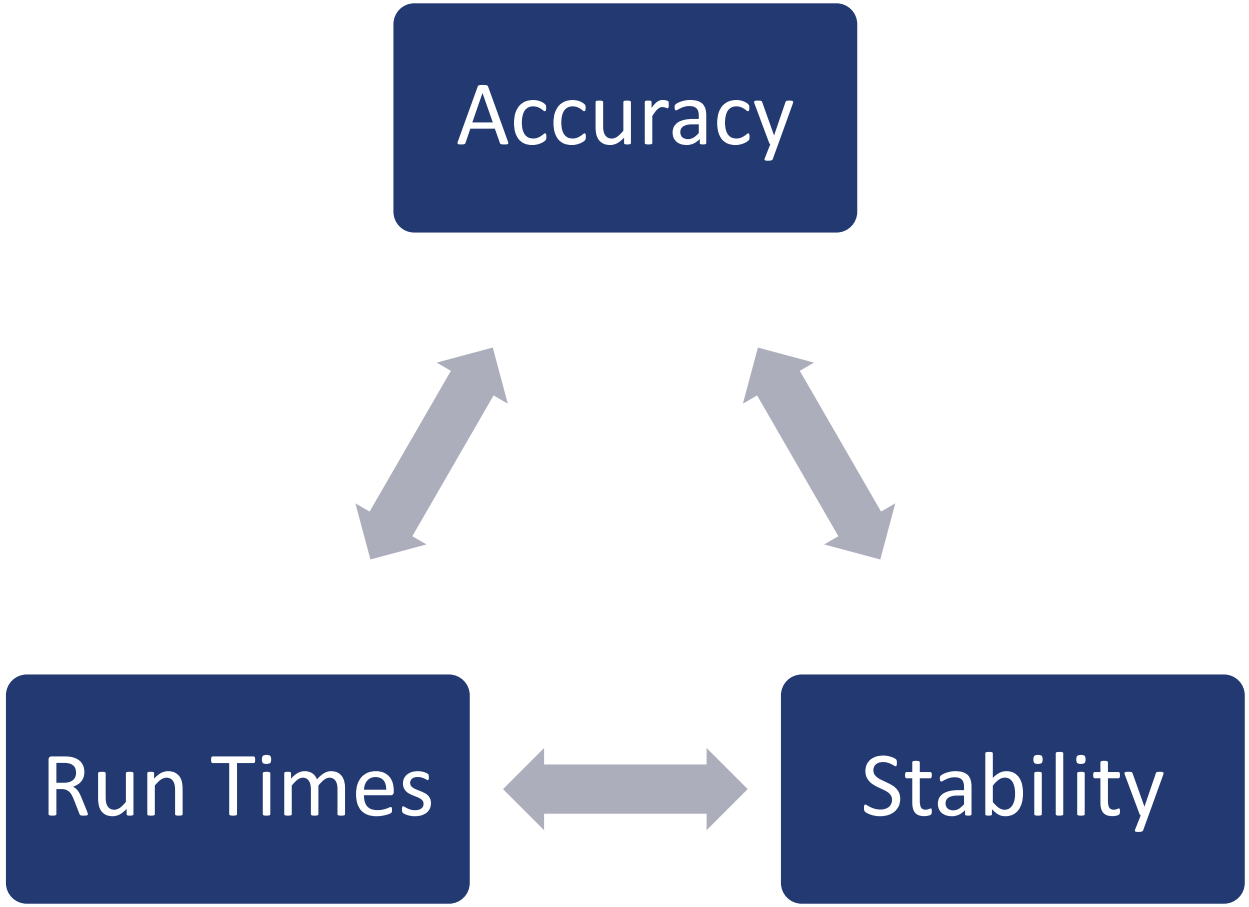
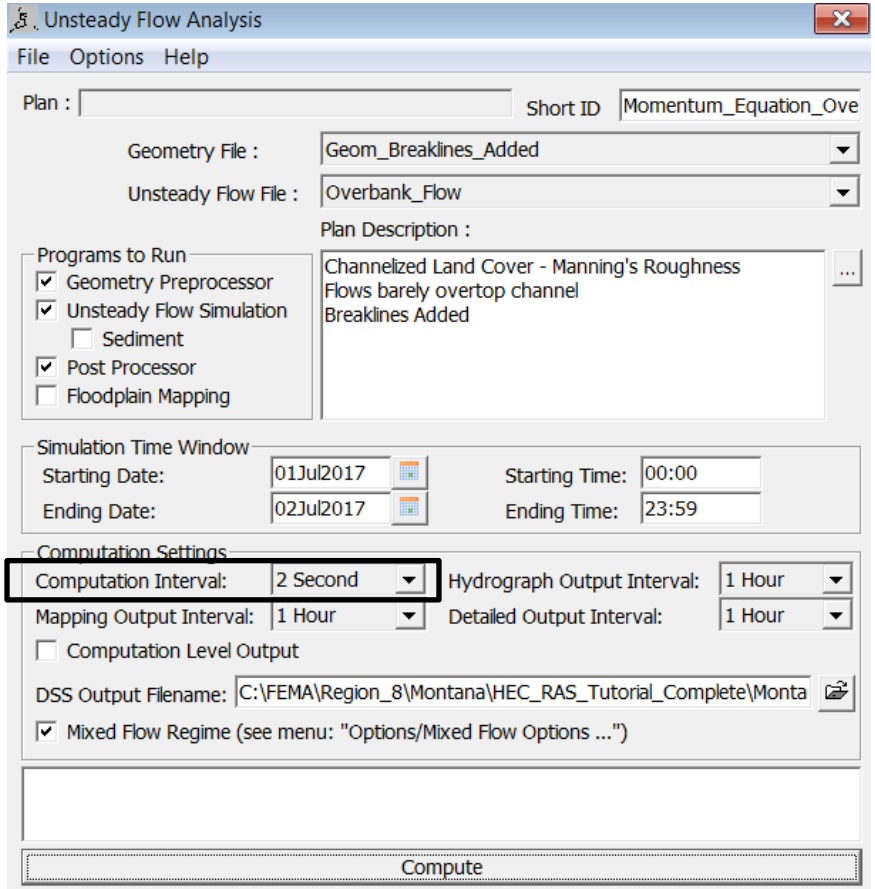
Computational Considerations



Computational Timestep

- Plan file editor window
- Computational Interval (timestep)
  - Frequency of model computations
  - Courant Number Criteria
  - Relates to grid cell size (depends on equations)
- Model results must be reviewed carefully for instabilities
- Adjust grid cell size and timestep



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Courant Number

- Should aim for C < 1 based on average velocities

Saint Venant Equations (full momentum):

$$C = \frac{V\Delta T}{\Delta X} \leq 1.0 \quad (with\ a\ \max\ C = 3.0)$$

Or

$$\Delta T \leq \frac{\Delta X}{V} \text{ (With C = 1.0)}$$

Where:	C	=	Courant Number
	V	=	Flood wave velocity (wave celerity) (ft/s)
	ΔT	=	Computational time step (s)
	ΔX	=	Average cell size (ft)

Diffusion Wave Equations:

$$C = \frac{V\Delta T}{\Delta X} \leq 2.0 \quad (with\ a\ \max\ C = 5.0)$$

Or

$$\Delta T \leq \frac{2\Delta X}{V} \text{ (With C = 1.0)}$$

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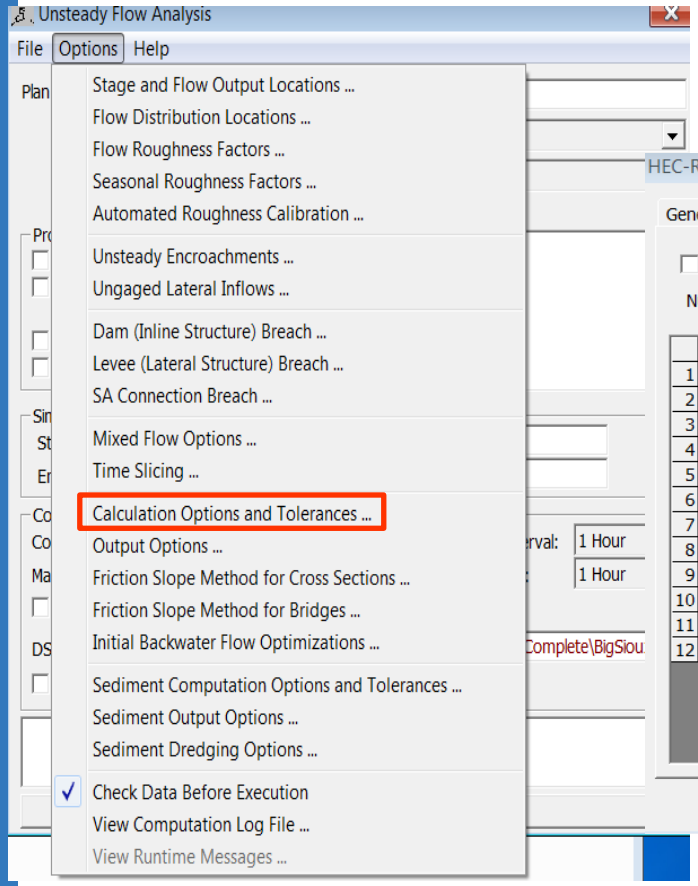
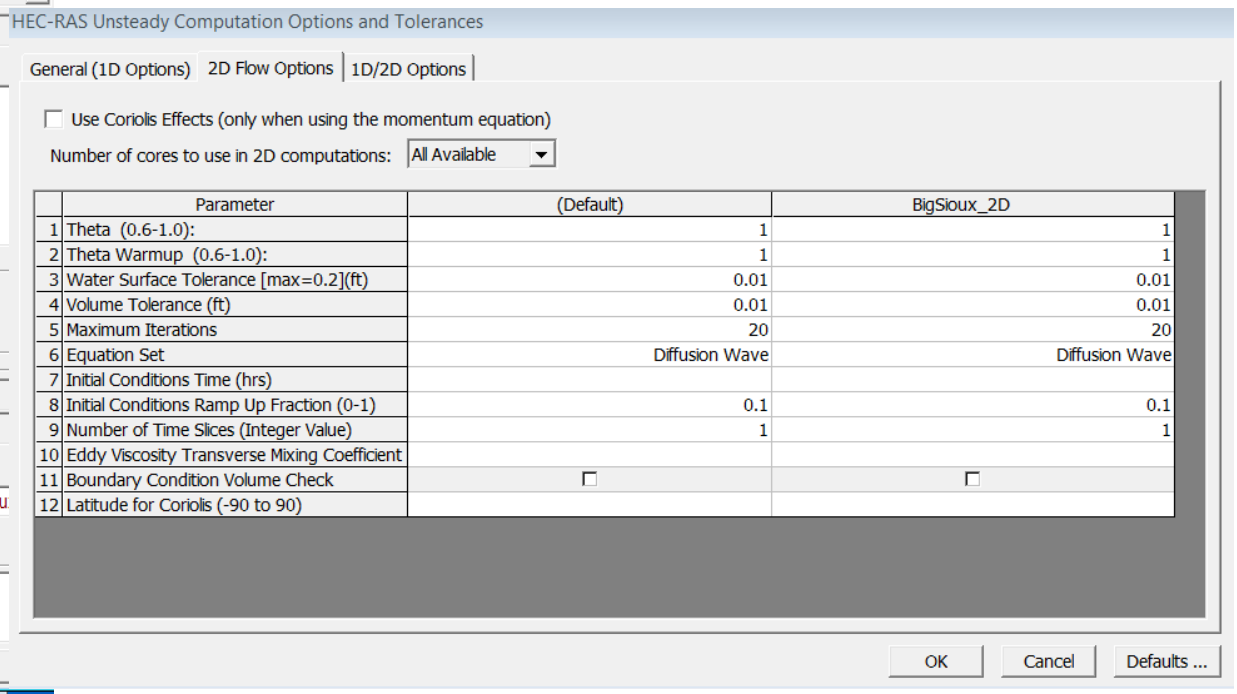
More Computational Options





	Parameter	(Default)	BigSioux_2D
1	Theta (0.6-1.0):	1	1
2	Theta Warmup (0.6-1.0):	1	1
3	Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4	Volume Tolerance (ft)	0.01	0.01
5	Maximum Iterations	20	20
6	Equation Set	Diffusion Wave	Diffusion Wave
7	Initial Conditions Time (hrs)		
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9	Number of Time Slices (Integer Value)	1	1
10	Eddy Viscosity Transverse Mixing Coefficient		
11	Boundary Condition Volume Check	☐	☐
12	Latitude for Coriolis (-90 to 90)		

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Equation Set

- Diffusion Wave
  - Simplified Momentum Equation
  - Greater numerical stability
  - Less accurate, faster run times
- Full Momentum (St. Venant)
  - Less stable, requires much smaller timestep → model is solving much more complex set of equations
  - More accurate, slower run times
- Recommended procedure
  - Use Diffusion Wave to build model, then run with Full Momentum
  - If large differences, **trust Full Momentum**

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More Equation Info

- Scenarios that always require full momentum:
  - Dynamic flood waves (e.g. dam breaches)
  - Sudden expansions and contractions
  - Wave propagation analysis
  - Super elevation around bends
  - Multiple hydraulic structures (bridges, bridge piers etc.)

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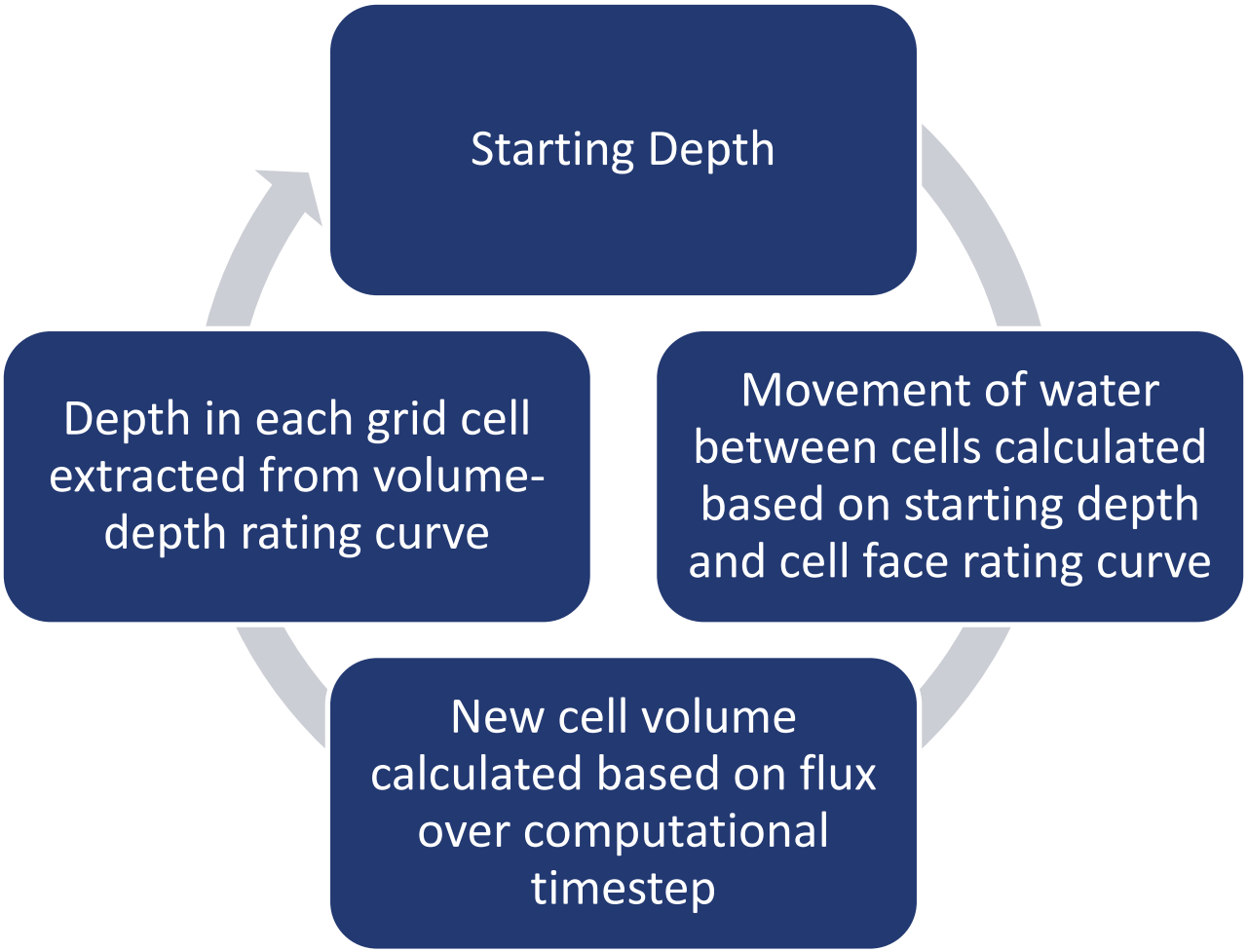
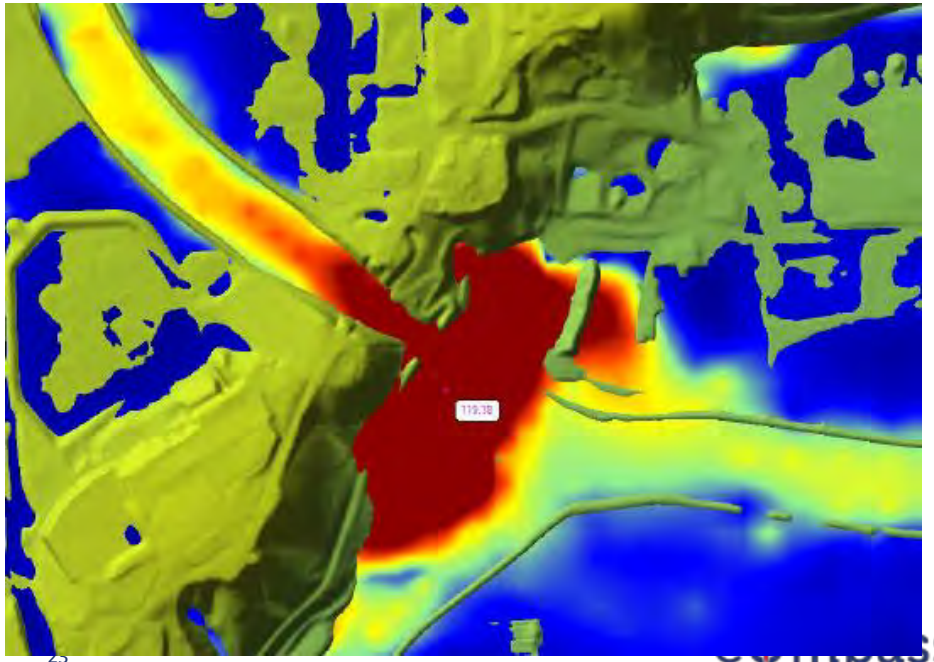
Simplified Computation Process



Model Instabilities

- Initial wetting of grid cell
  - Cell goes from dry to large depth, causes a spike in depth and velocity due to instability
  - Review initial wave via animations
- High velocity areas
  - Steep reaches, abrupt contractions
- Adjustments?
  - Timestep
  - Grid cell size
  - Grid cell alignment
  - Manning's n
  - Equation set
  - Warmup?



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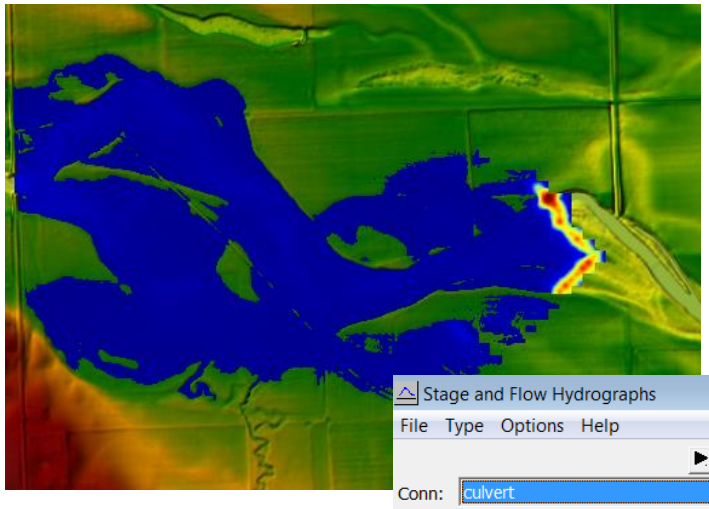
Identifying Instabilities



Computation Messages

Plan: 'Momentum_Equation_100yr_flood' (Montana_Tutorials.p10)
Simulation started at: 15Jul2017 01:08:52 PM
Using 64 Bit Computation Engines

Writing Geometry
2D_Flow_Area: Mesh property tables are current.
Completed Writing Geometry

Geometric Preprocessor HEC-RAS 5.0.3 September 2016

Finished Processing Geometry

Writing Event Conditions
Event Conditions Complete

Performing Unsteady Flow Simulation HEC-RAS 5.0.3 September 2016

Maximum iterations of 20		**Cell**	**WSEL**	**ERROR**	**CONVERGENCE**
01JUL2017 00:10:00 2D_Flow_Area	Cell #	19341	1565.20	4.8421	1

Stage and Flow Hydrographs

File Type Options Help

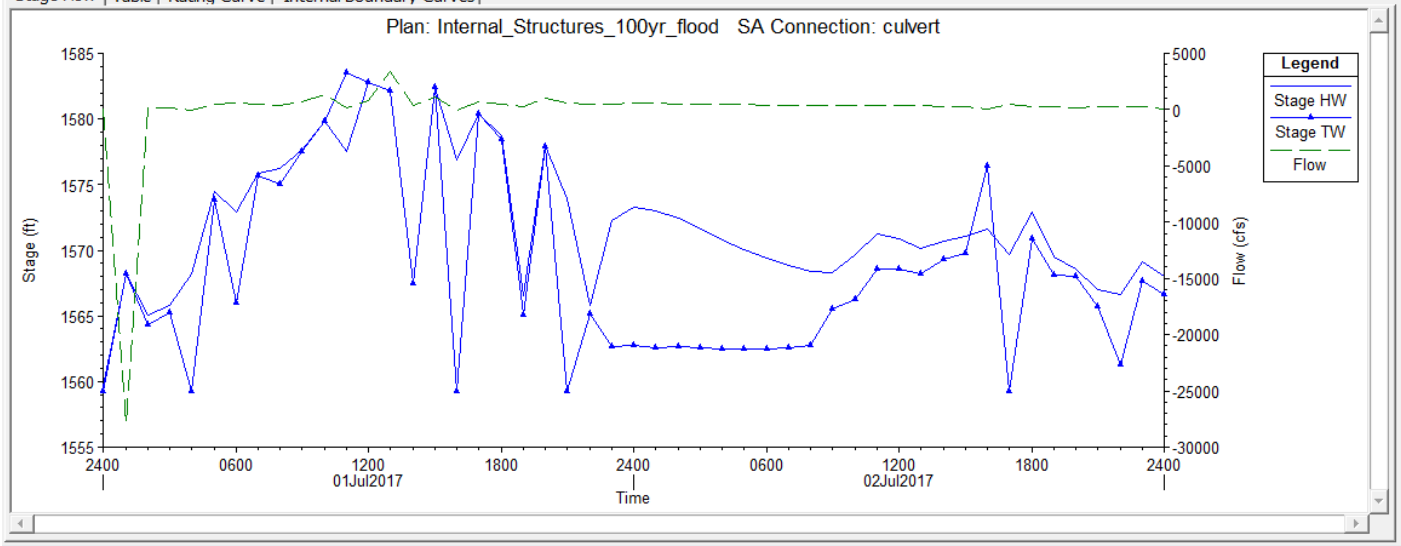
Data

Conn: culvert

☑ Plot Stage ☑ Plot Flow ☑ Obs Stage ☑ Obs Flow ☐ Use Ref Stage

1	HW Stage	1582.83	01Jul2017 1200	
2	TW Stage	1583.56	01Jul2017 1100	
3	Flow	3415.10	01Jul2017 1300	-453.52

Stage Flow | Table | Rating Curve | Internal Boundary Curves



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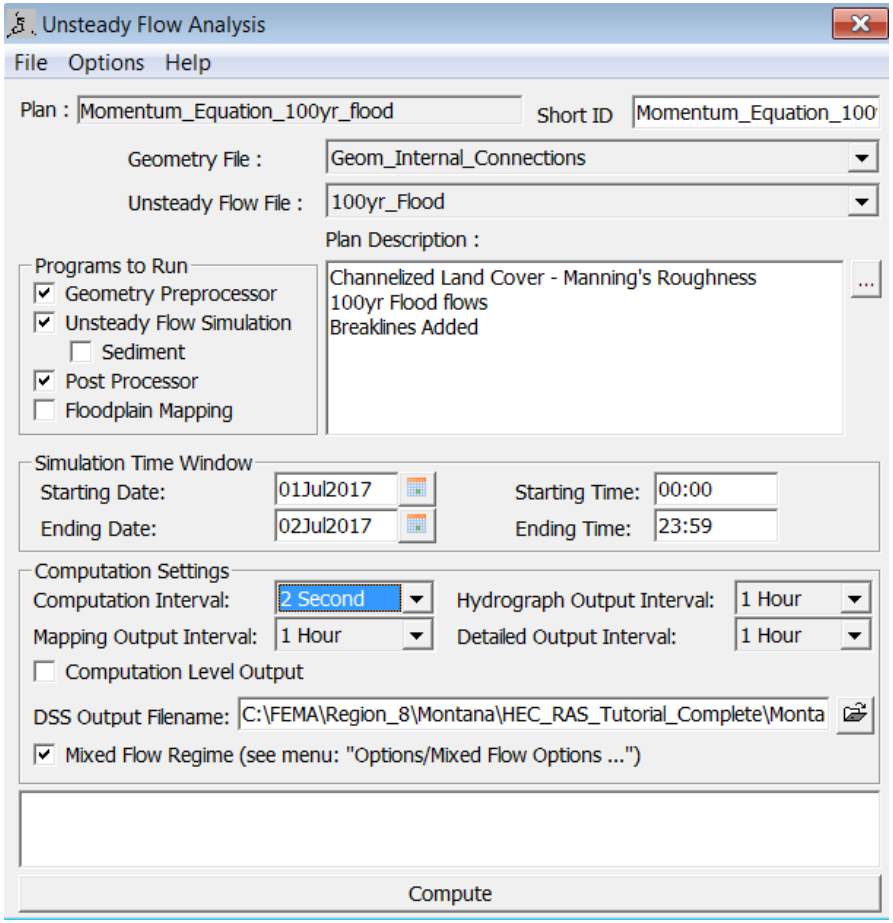
Model Run Time Considerations

- Should always prioritize accuracy, but run time often a constraint with large models
- Preliminary runs with larger timestep
- Refine model with smaller timesteps
- Use larger nominal grid cell size, refine in areas where more detail is necessary via breaklines

Model Run Setup

- Name plan
  - Logical name; can't change these later
  - Short ID will show up in RAS Mapper
- Select Geometry and Unsteady Flow files
- Plan description



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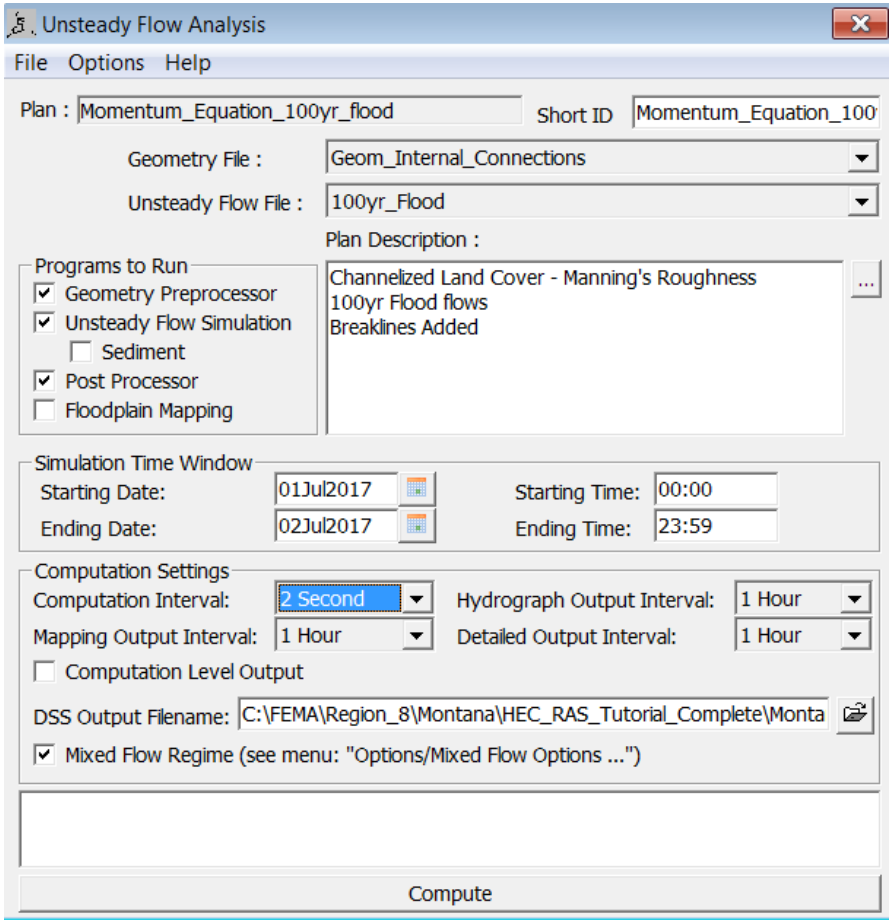
Executing a Model Run

- Programs to Run
  - Geo. Preprocessor
  - Unsteady Flow
  - Post Processor
- Simulation Time
  - Inundation study: Long enough to route peak through model domain
- Computational Settings
  - Output intervals
  - Timestep: Already discussed!
- **Compute!**



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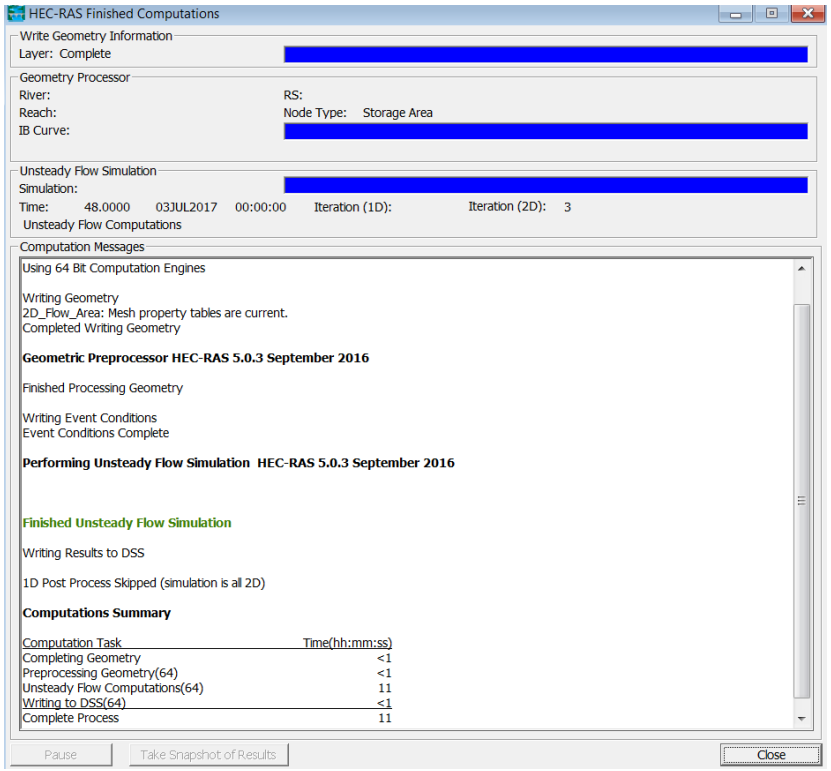
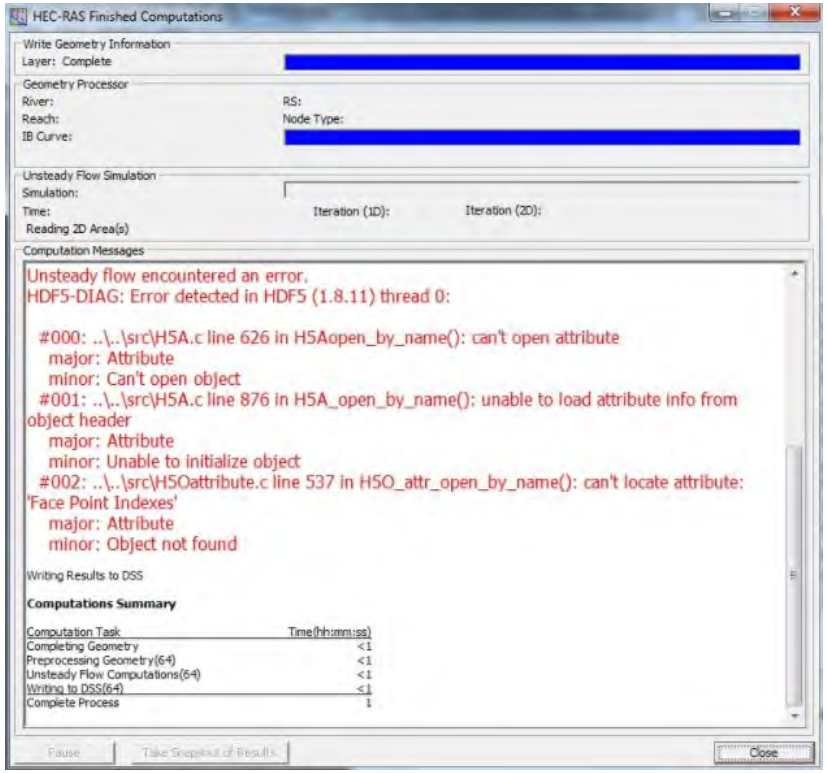
Did it work?

Good!



Not Good….



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Errors

- Many error possibilities, HEC-RAS may provide good information or cryptic messages
- Only gives one error at a time
  - Long process with large mesh
  - Runs preprocessor, then gives error
  - Best practice to spend more time avoiding problems

Questions

Photo from FEMA

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