WSDOT
Scour Workshop

Module 7
Contraction Scour

May 31st, 2023

Scott Hogan

Senior Hydraulic Engineer

FHWA Resource Center

Current Duties

- Training
- Technical Support
- Technology Development and Deployment

Background and Experience

- 10 years at FHWA Resource Center
- 7 years at Central Federal Lands Hydraulics Team Lead
- 14 years consulting engineering

Education

- B.S. Civil Engineering (Colorado State University)
- M.S. Hydraulics (Colorado State University)

Personal Interests

- Hiking
- Camping
- Fishing and Hunting
- Cycling
- DIY Home Improvement

Casey Kramer

Principal River Engineer

Natural Waters, LLC

Current Duties

- Owner of Natural Waters, LLC
- WSDOT HQ staff augmentation team assisting State Hydraulics Engineer

Background and Experience

- Previous WSDOT State Hydraulic Engineer
- Private sector hydraulics and river engineering consultant
- Research River Engineer

Education

- B.S. Civil Engineering (Washington State University)
- M.S. River Engineering (University of Iowa – Iowa Institute of Hydraulic Research)

Personal Interests

- Spending time with family
- Rivers
- Dirt biking, Fishing, Camping, and Coaching/Watching Sports

Contraction Scour Overview

- Types of contraction scour
- Summary for how to compute contraction scour
- Steps to compute contraction scour

Image Source: Casey Kramer

Types of Contraction Scour

- **Clear-water** – No transport of bed material sediment from upstream. The area of the contracted section increases until the velocity of the flow is equal to the critical velocity of the bed material

- **Live-bed** – Bed material from the riverbed upstream is transported into the crossing

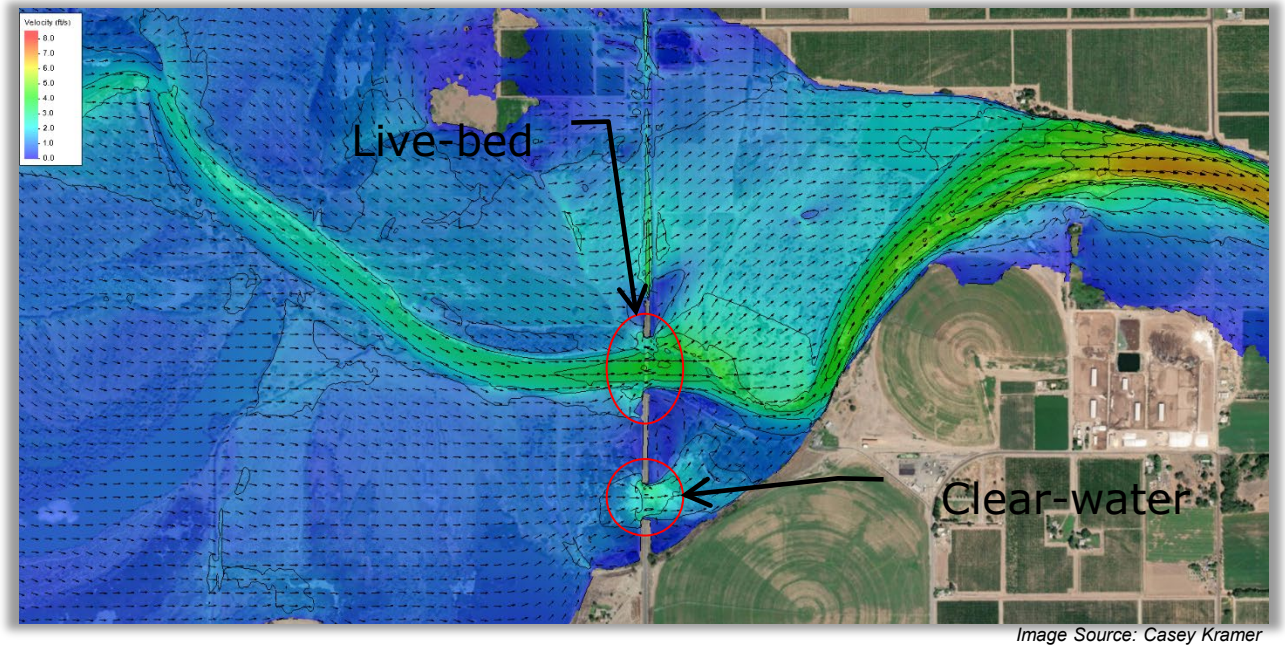


Image Source: Casey Kramer

Contraction Scour – Clear-water or Live-Bed

- Compare the average velocity (V_1) and the critical velocity (V_c) for bed material transport at the approach section
  - If $V_1 > V_c$ → live-bed is most likely
  - If $V_1 < V_c$ → clear-water is most likely
- Compute clear-water scour using the bed material gradation (D_{50}) at the water crossing
- Always compute contraction scour for live-bed and clear-water scour conditions

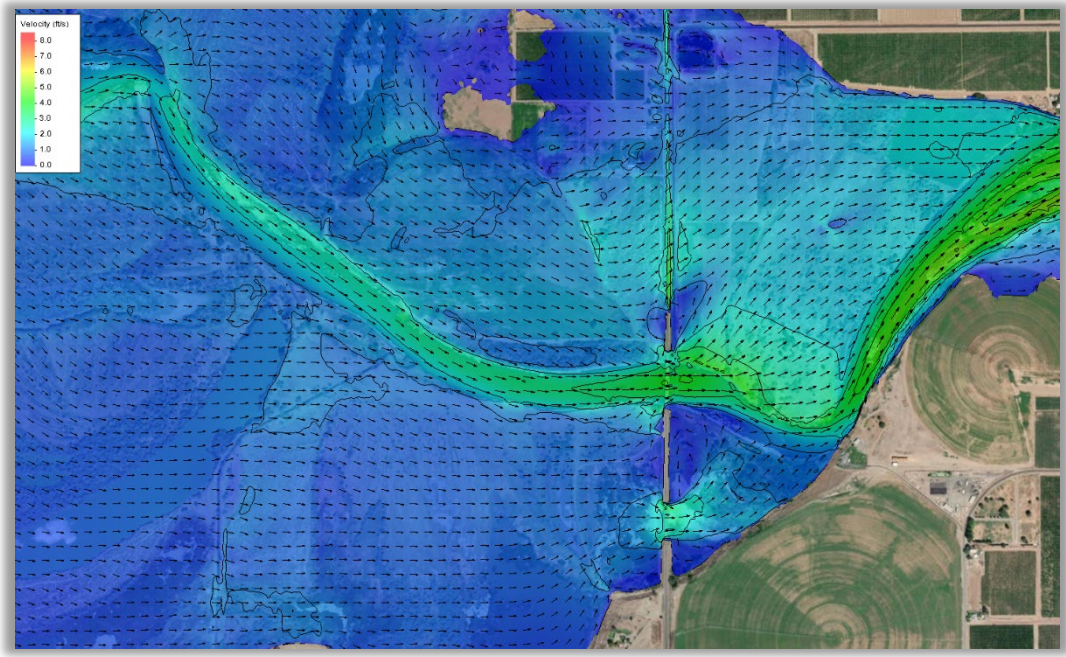


Image Source: Casey Kramer

How to Compute Contraction Scour

- **Approach Section location:**
  - Upstream of where overbank flow is diverted into the main channel
  - Width represents the flow that would likely transport sediment:
    - Toe to toe (of slopes) or between tops of banks
    - Field observations (e.g., sediment being mobilized, vegetation, etc.)
    - Critical velocity or shear for incipient motion
  - Avoid locally higher velocity locations, as they result in underestimating contraction scour

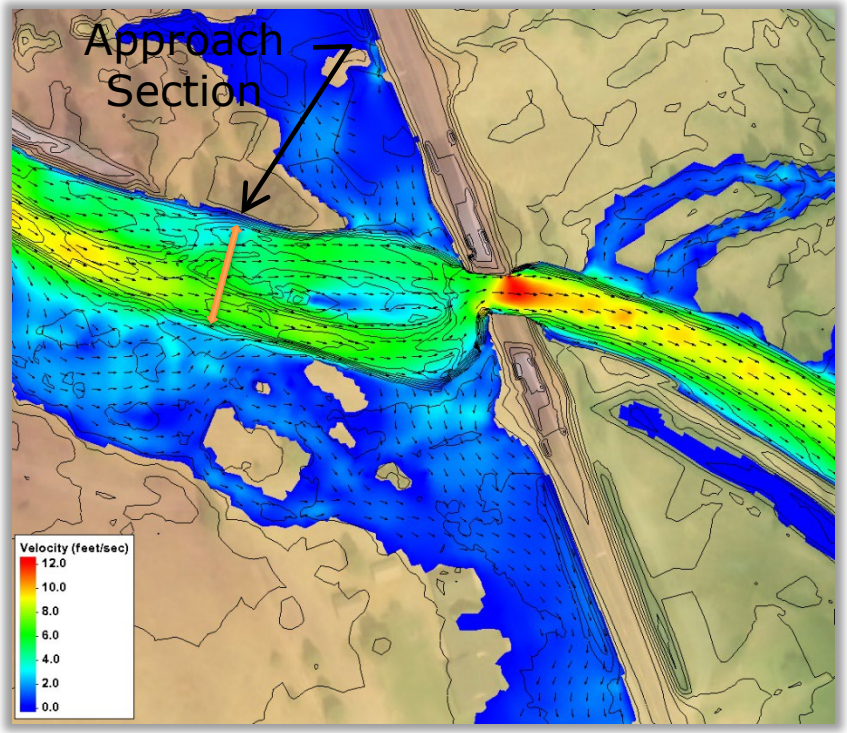


Image Source: Casey Kramer

How to Compute Contraction Scour

- **Contracted Section location:**
  - Where flow is most contracted through the bridge
  - Width should be consistent with the approach section reference (i.e., toe to toe (of slopes) or between tops of banks)
  - Width should exclude effective width of piers
  - Width needs to be adjusted for skew

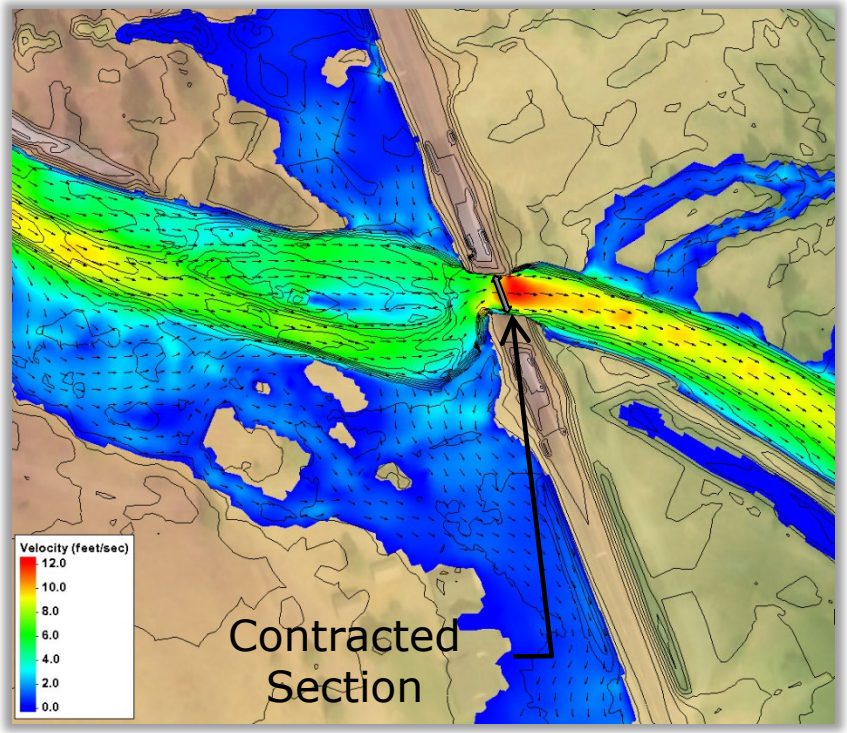


Image Source: Casey Kramer

Main Channel vs Overbank Contraction Scour

- If the main channel can migrate to either abutment, the main channel computed contraction scour is applied to the entire opening width
- Main channel contraction scour is likely live-bed scour, but clear-water scour may occur
- Overbank contraction scour is not common for most WSDOT fish passage projects. When it does occur, it is predominantly clear-water scour when channel is assessed to be stable and the overbanks are vegetated (i.e., secondary and relief structures)

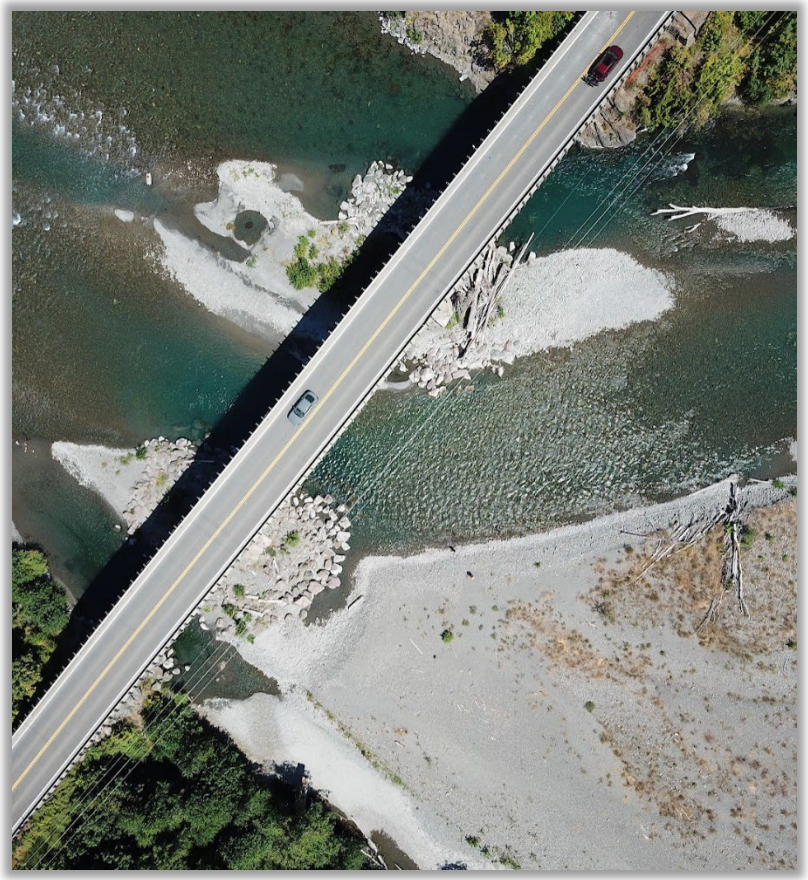


Image Source: Casey Kramer

Contraction Scour

- The following provides an example for computing contraction scour for a PHD

- Key assumptions:
  - The structure type, size and location has not been determined

  - Contraction scour is determined at the selected contracted section location.
    - Per the WSDOT H_HD template other total scour tables may be necessary to perform scour analysis at appropriate locations

  - Channel profile and geometry is typical through the crossing, therefore flow depths are assumed to be uniform.
    - Applying depths of scour at locations other than the location of the selected contraction scour arc needs to be assessed carefully

Contraction Scour

- The hydraulic engineer of record determines appropriate total scour elevations that are commensurate with the site and acceptable level of risk in coordination with WSDOT

- Ultimate goal is to determine scour elevations at each infrastructure component being designed. Coordination MUST happen with the project, geotechnical, and bridge and structures offices to determine appropriate scour elevations to be used for design as the design progresses

- The intent of the next series of slides is to show an example for how contraction scour should be calculated but does not go into detail of all scenarios and analyses required to develop total scour. Completion of NHI Course 135046 and the FHWA scour workshop is required for more details on computing total scour

Contraction Scour

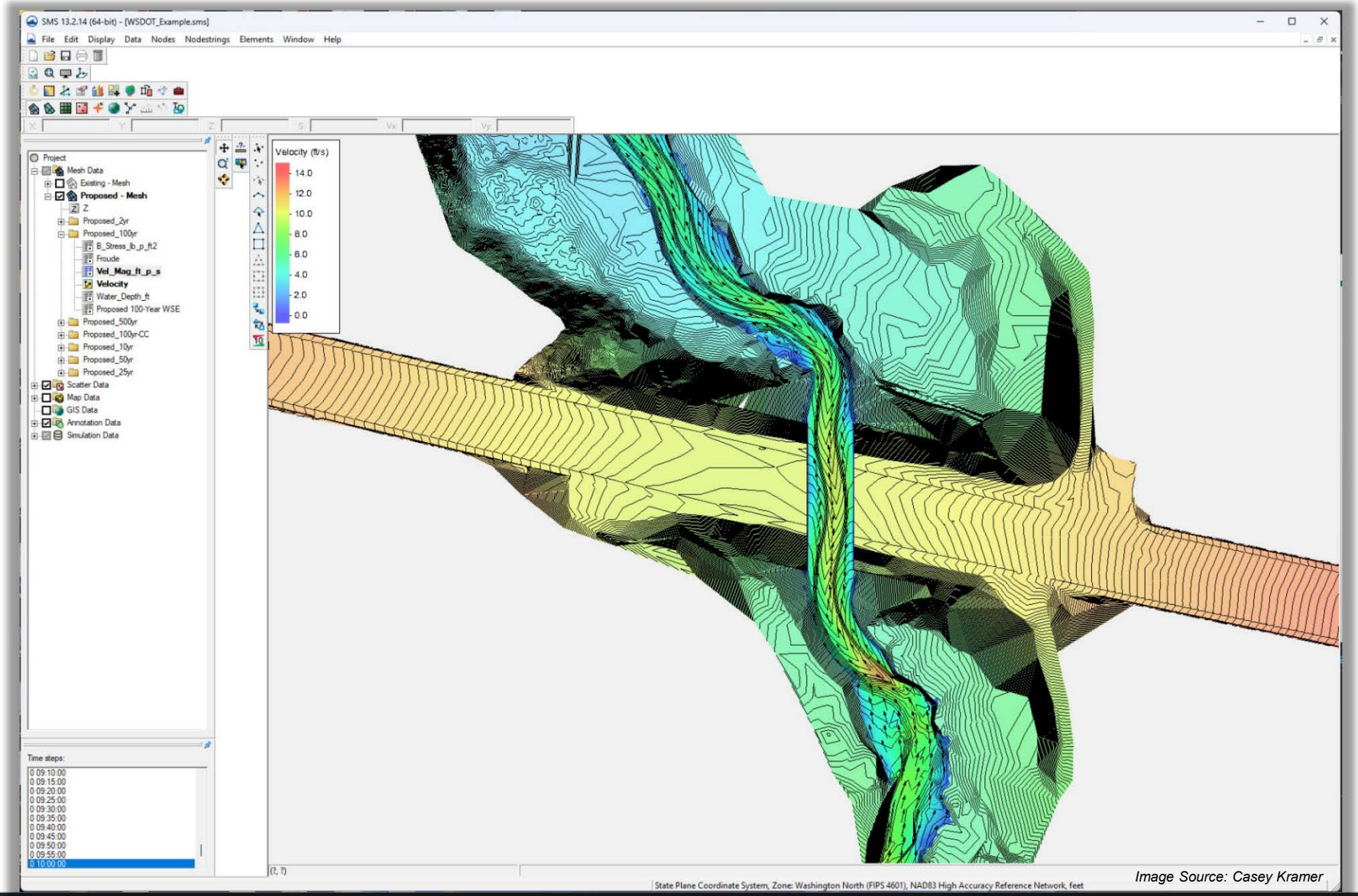
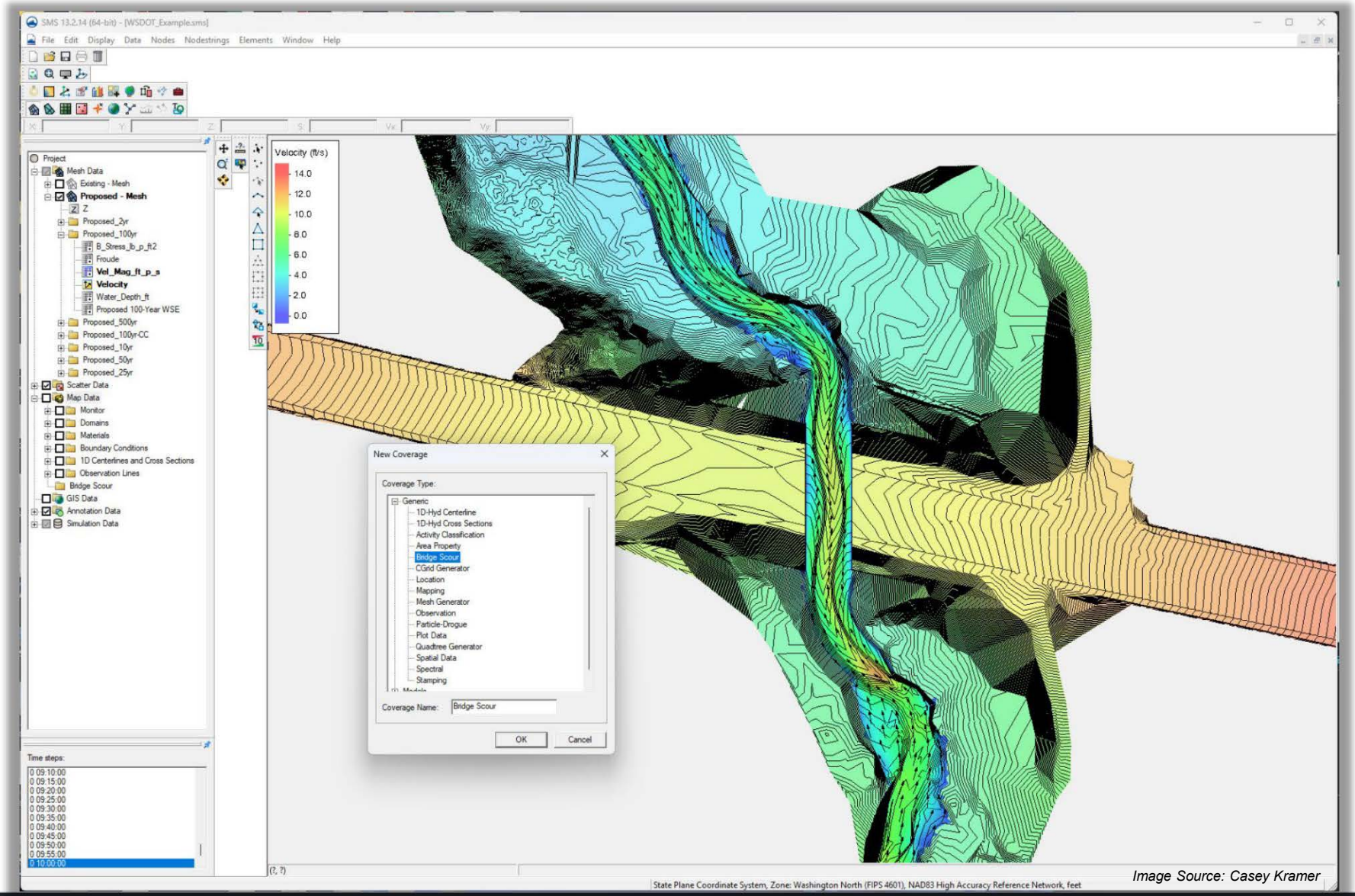


Image Source: Casey Kramer

Contraction Scour



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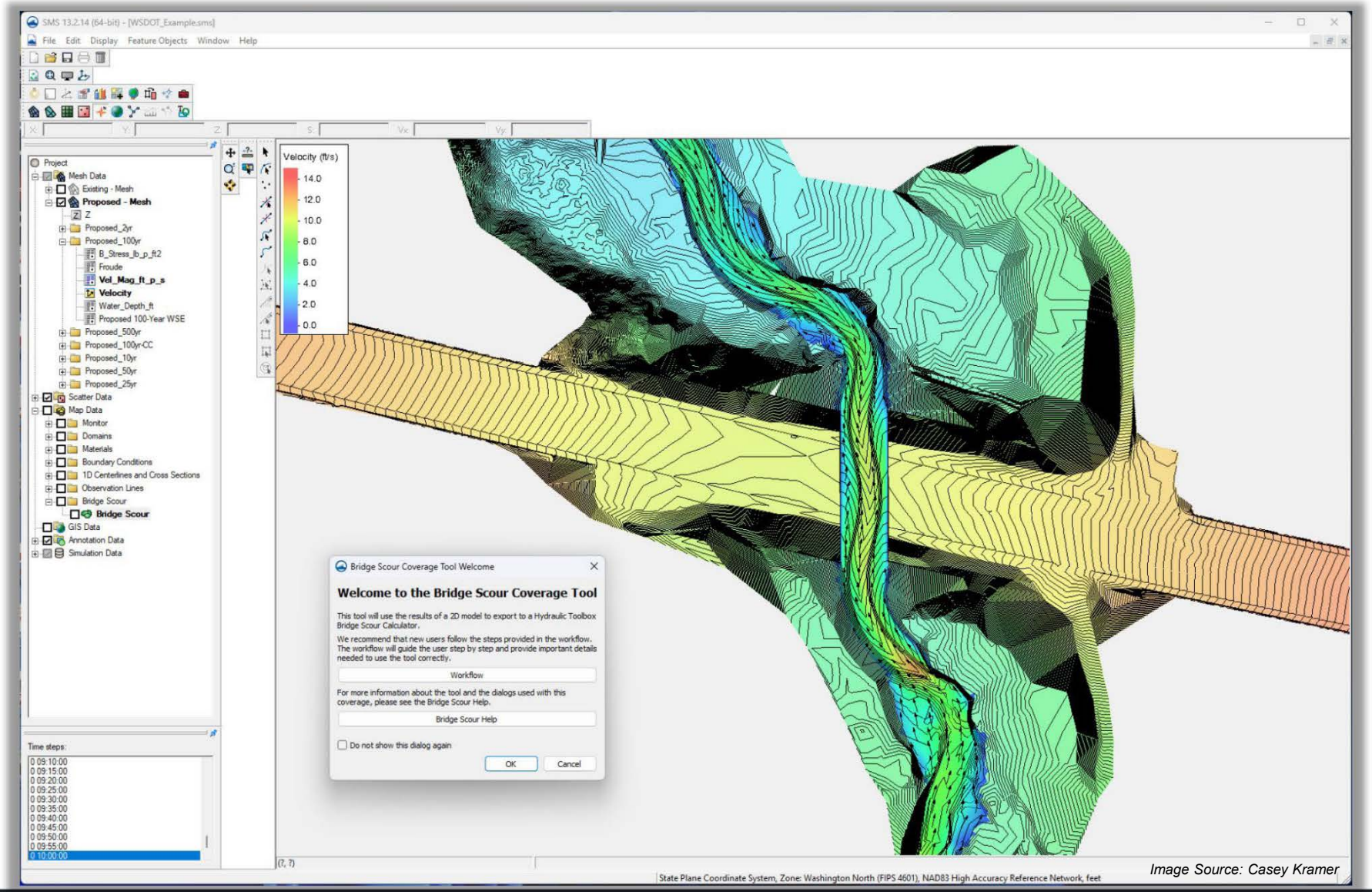

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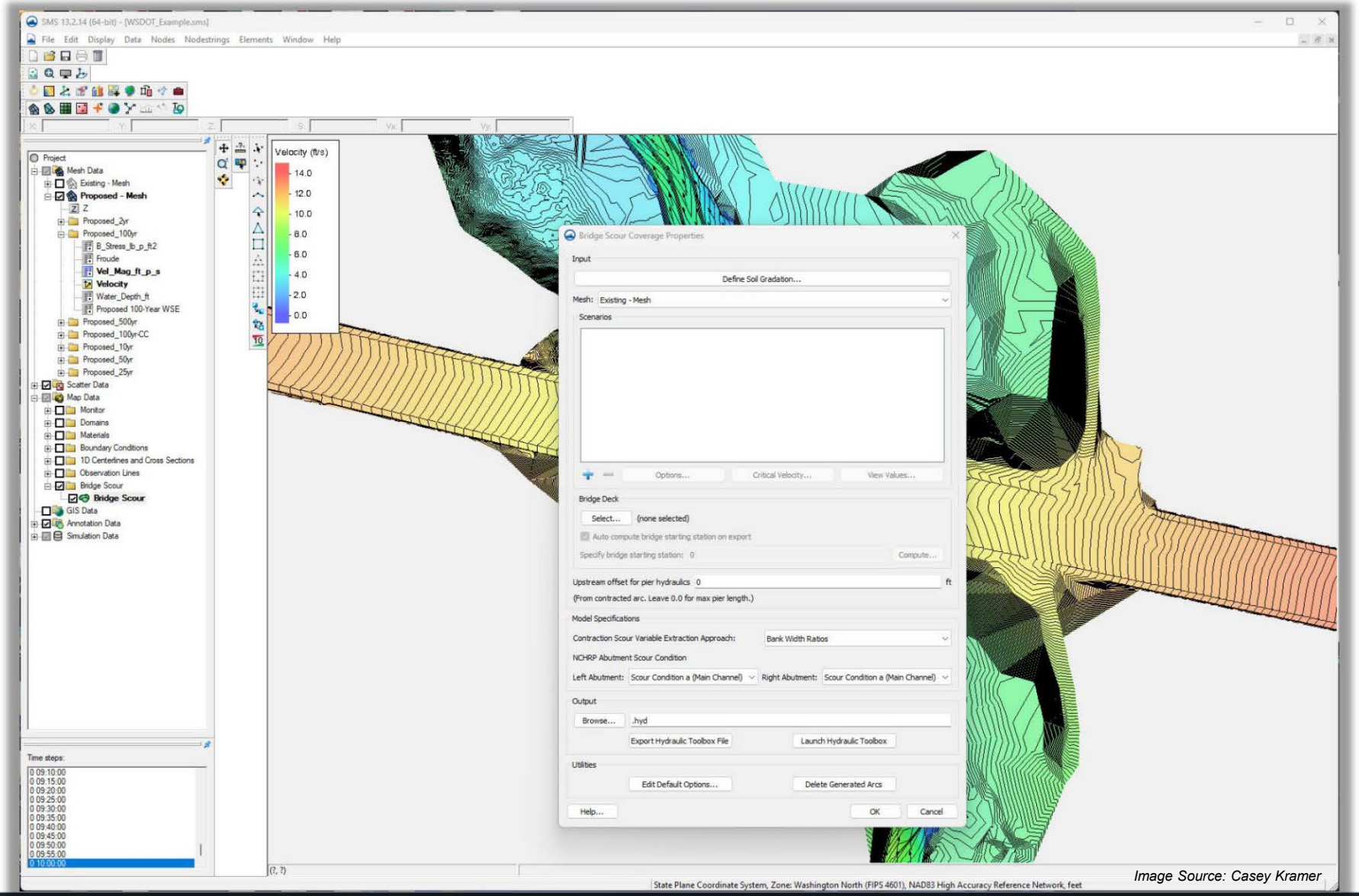
Contraction Scour



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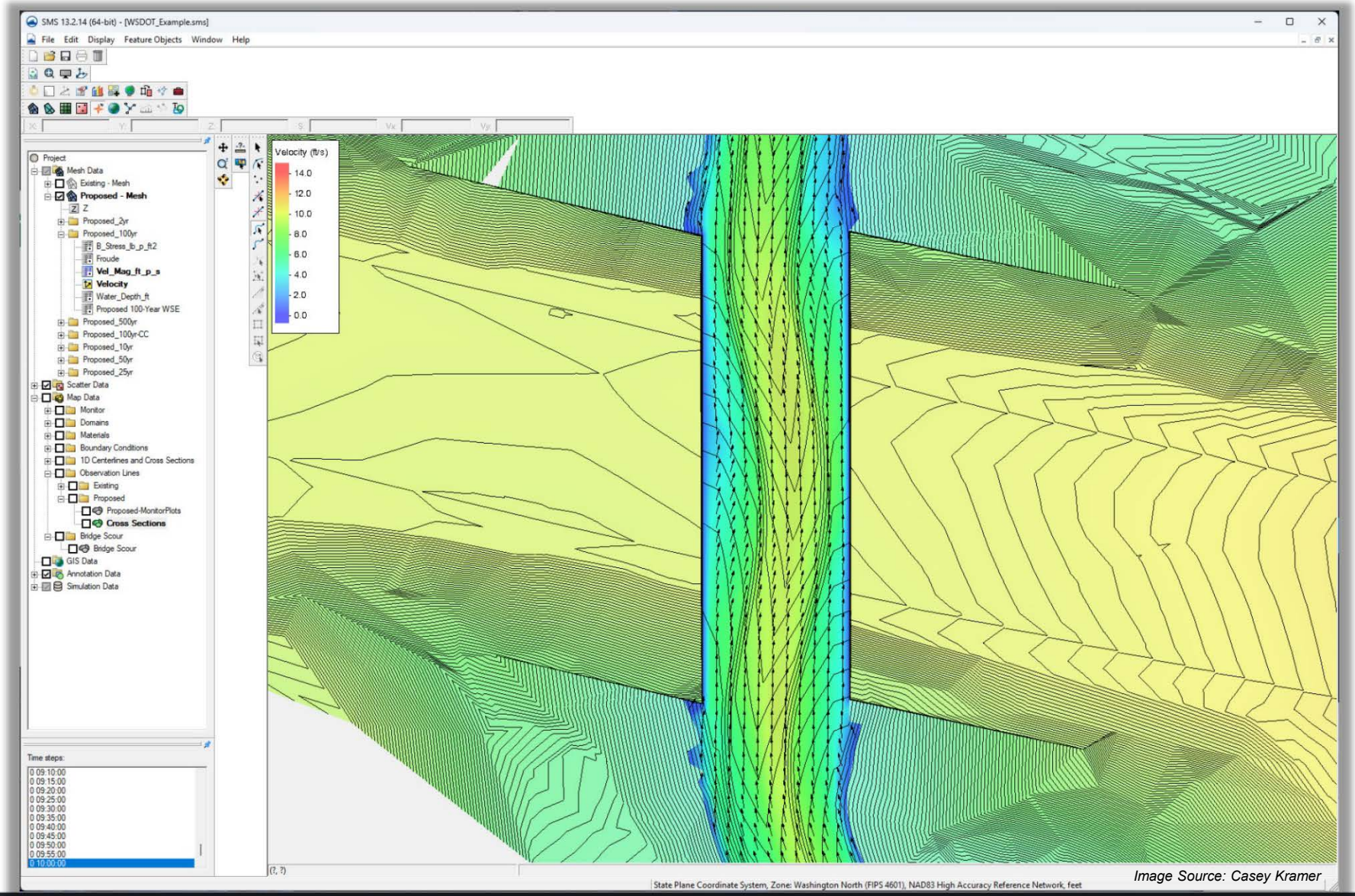

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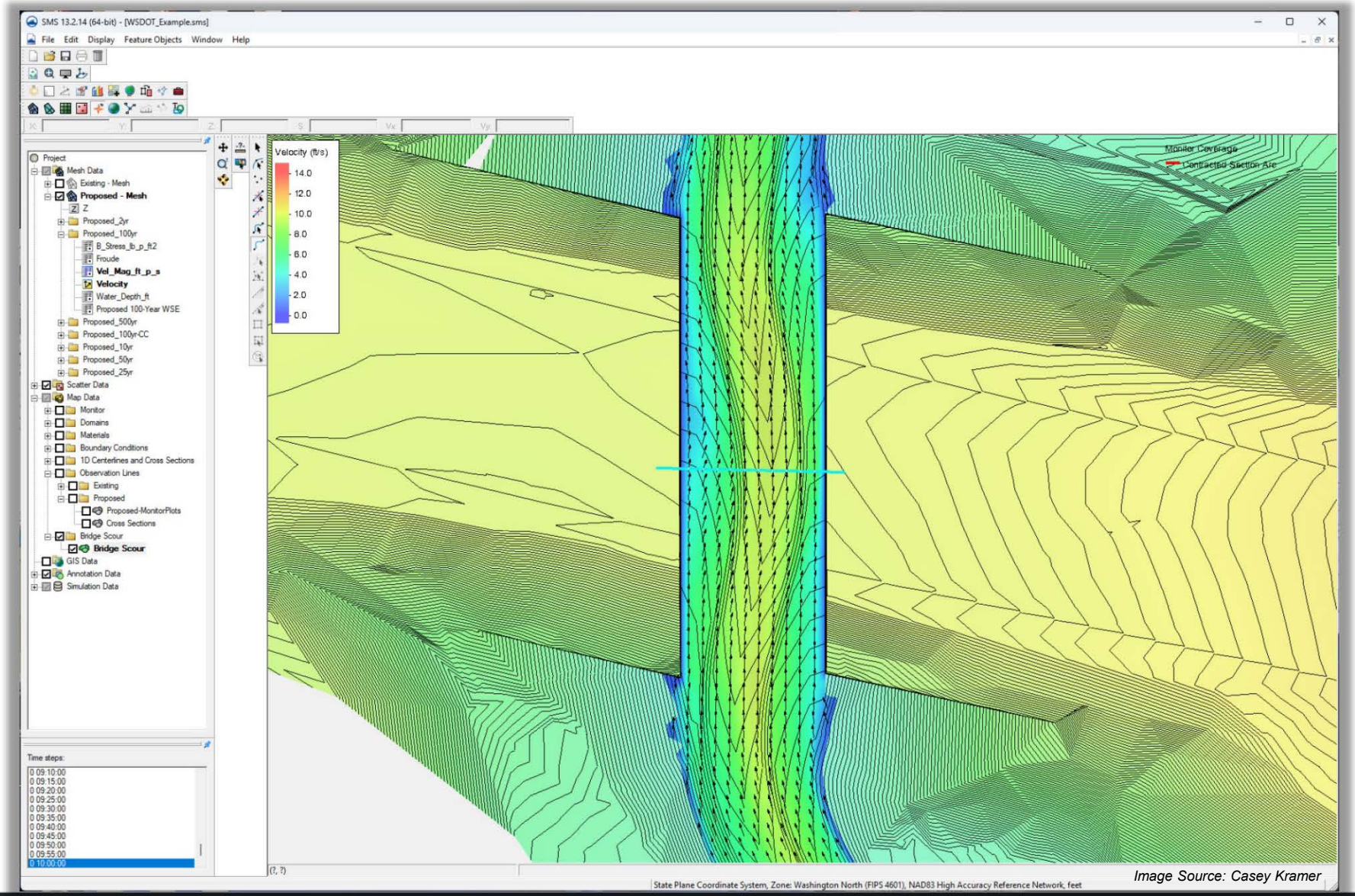

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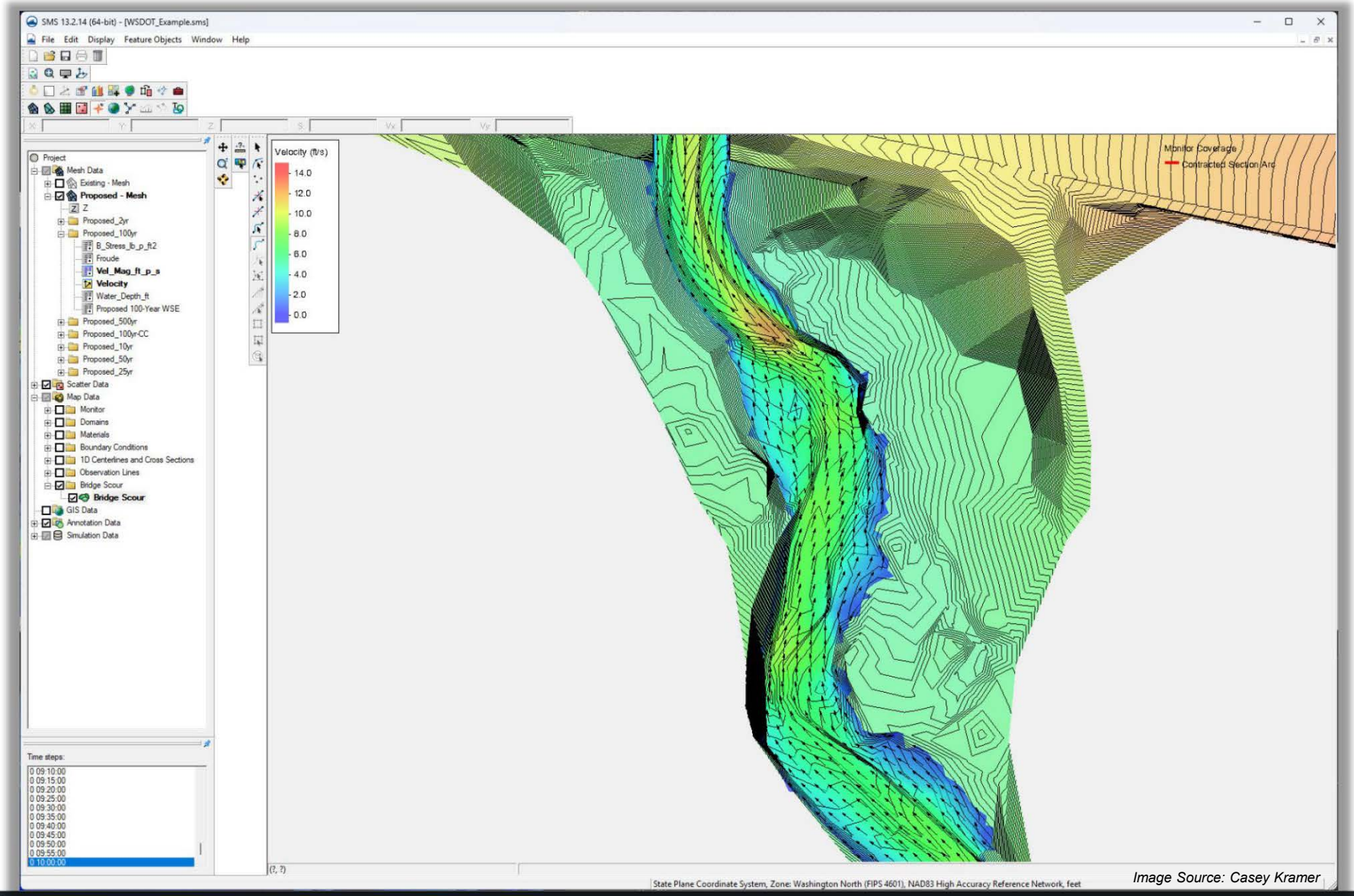

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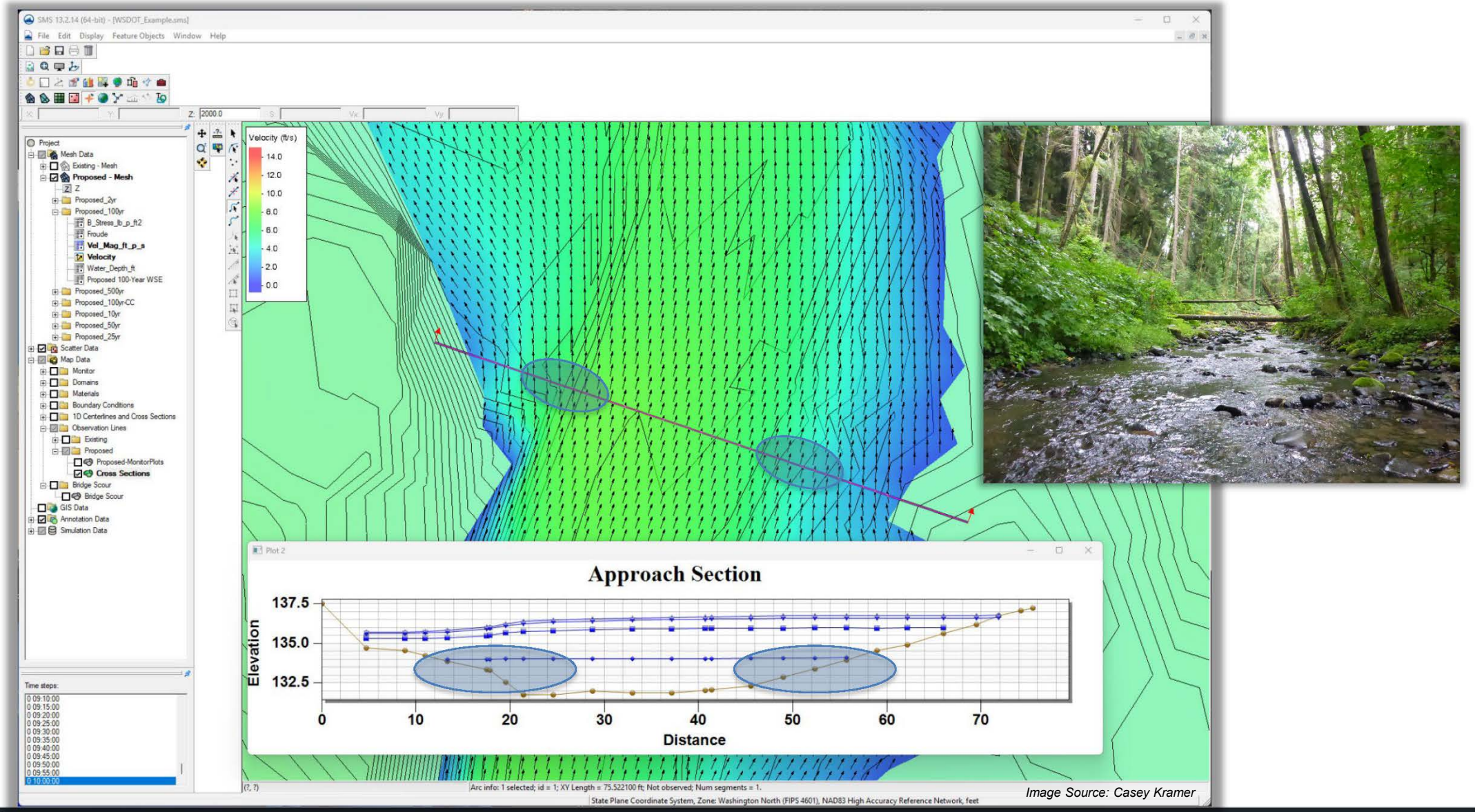

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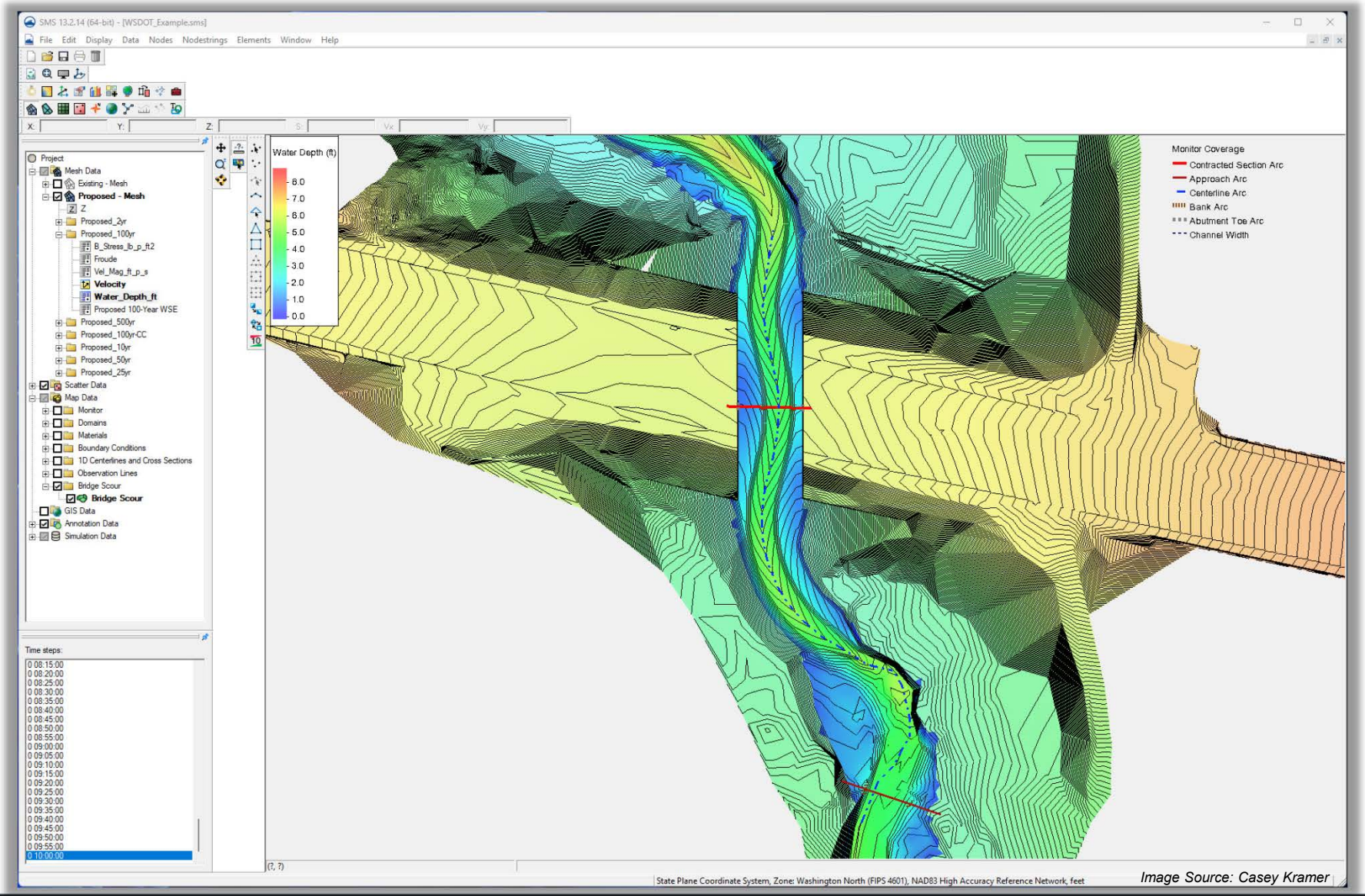

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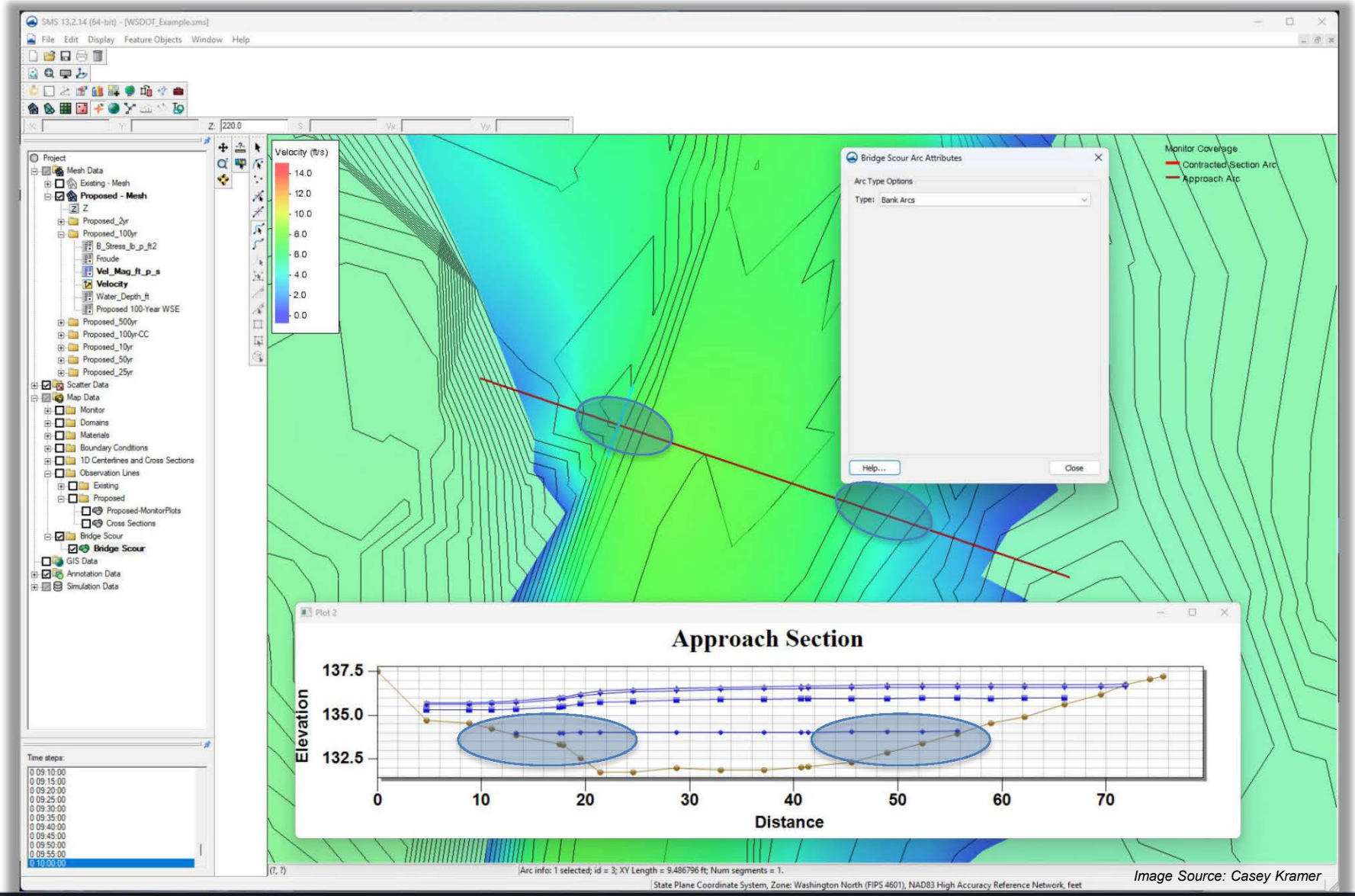

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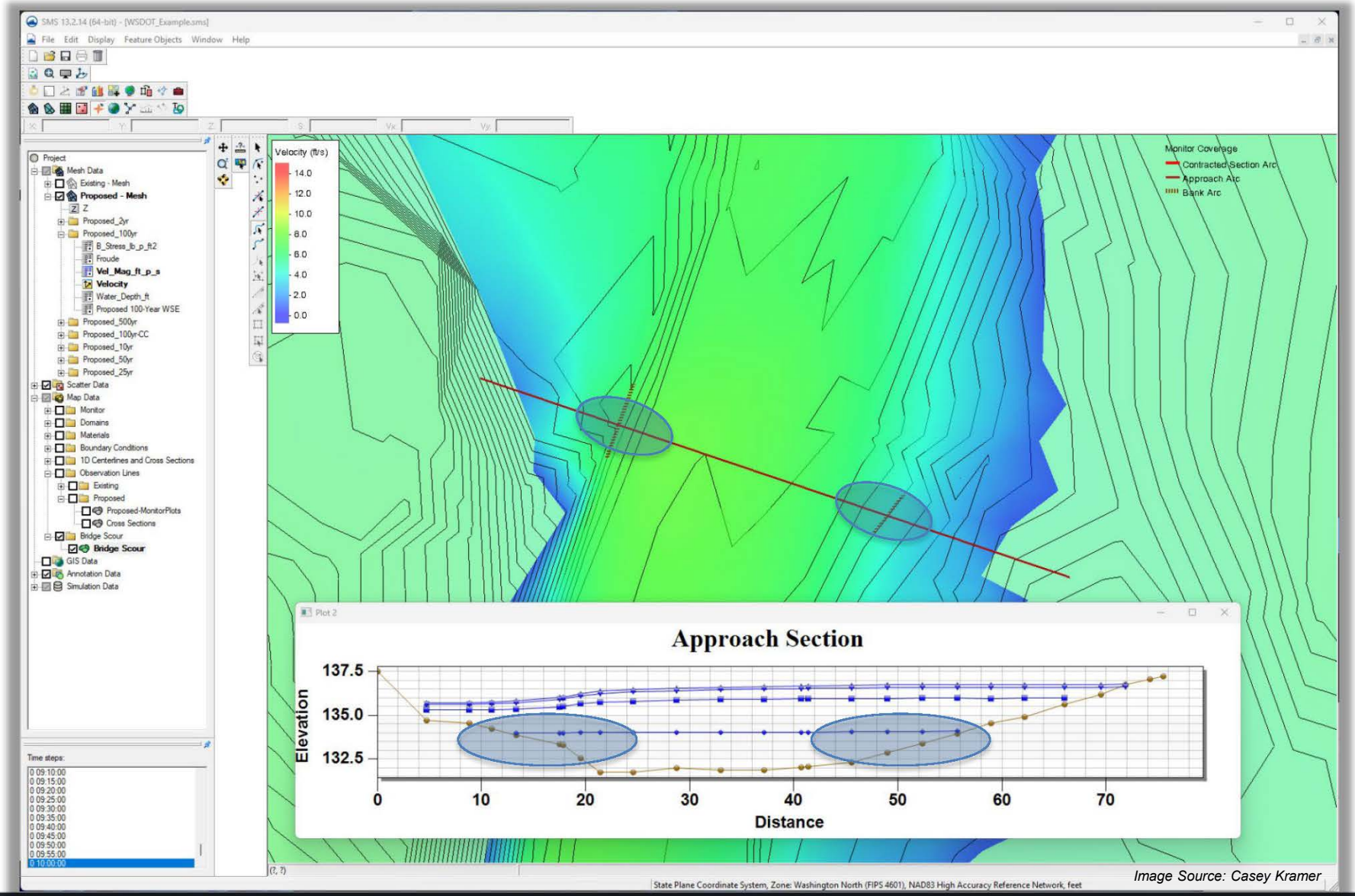

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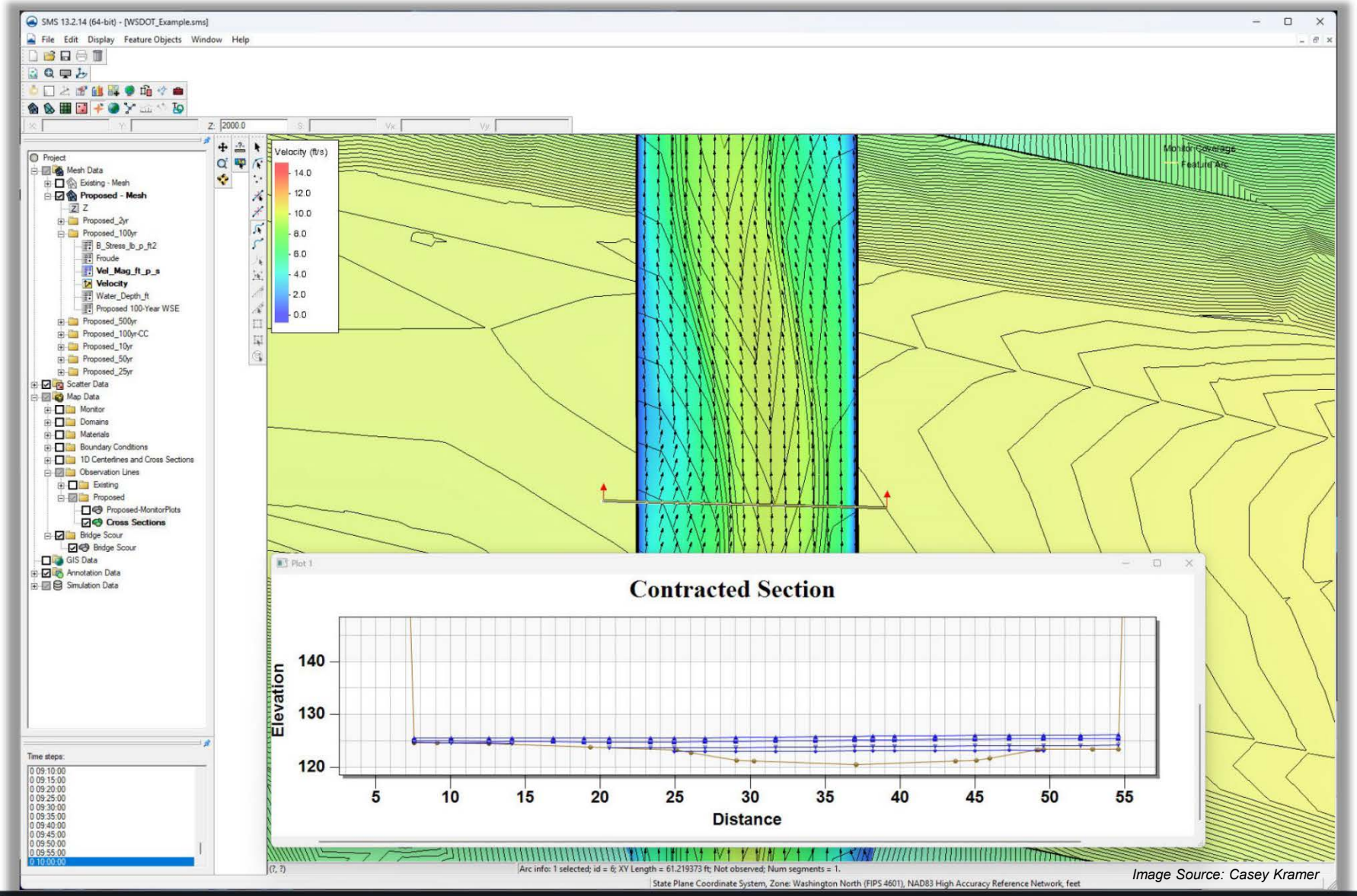

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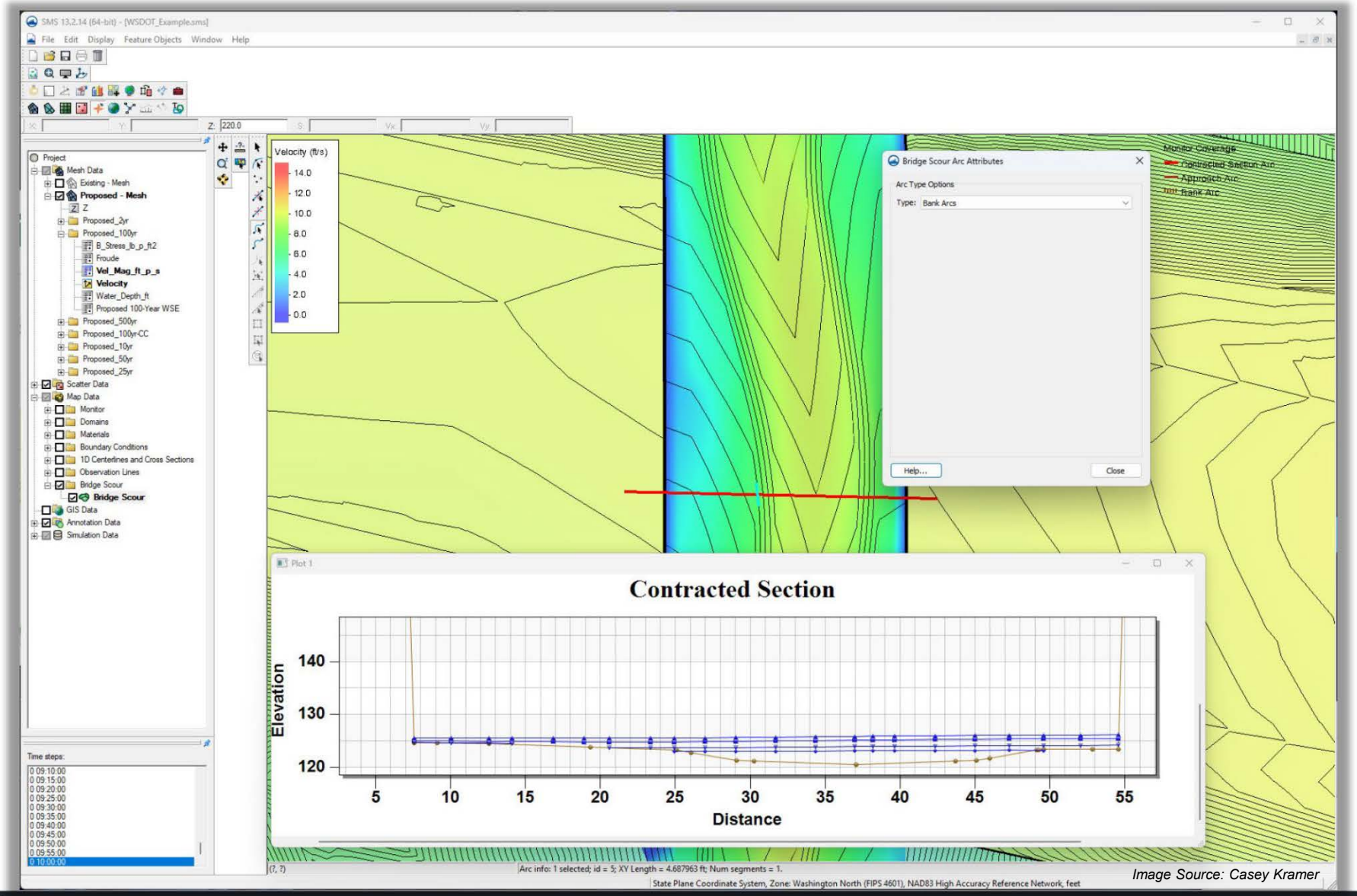

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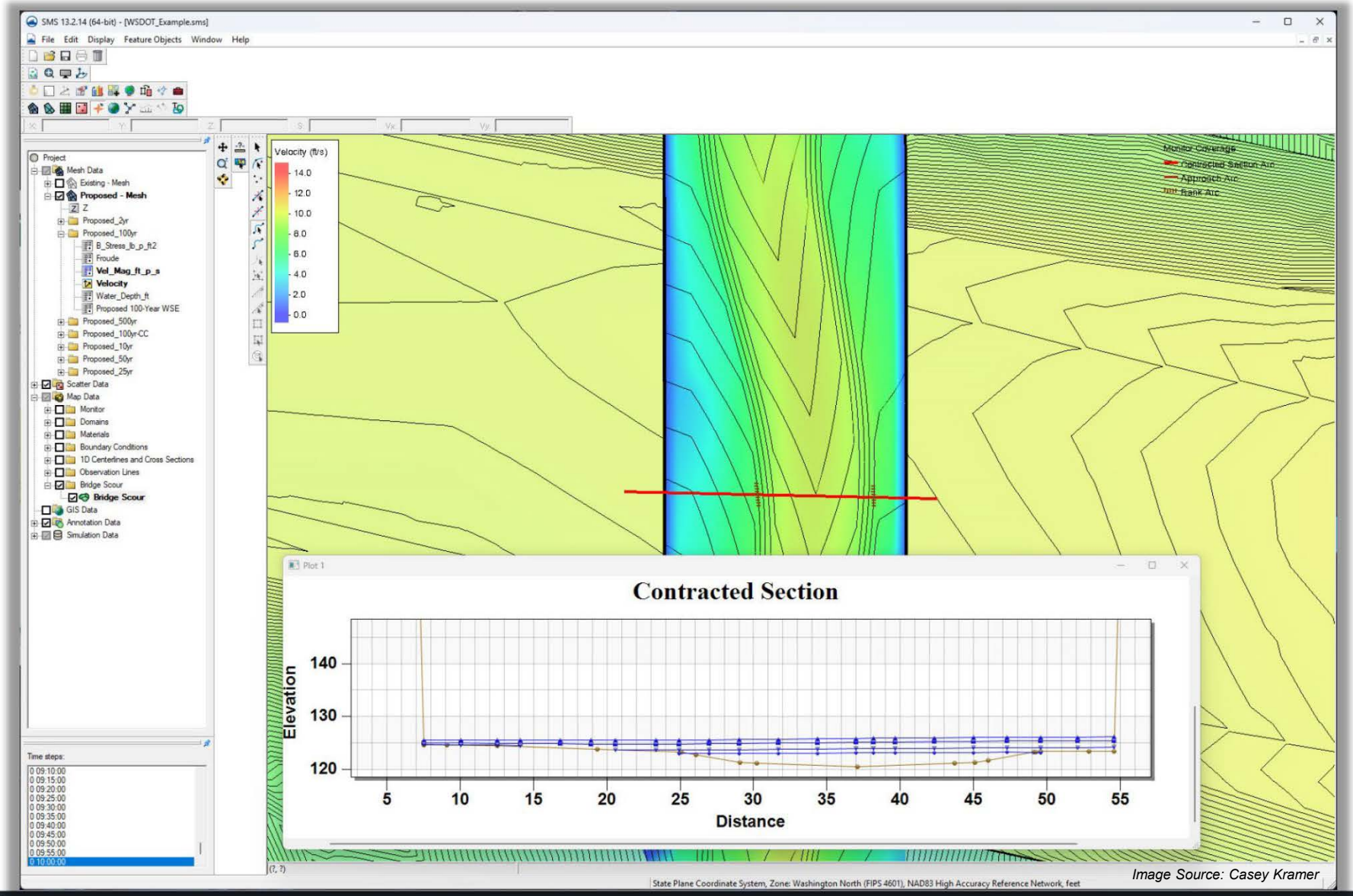

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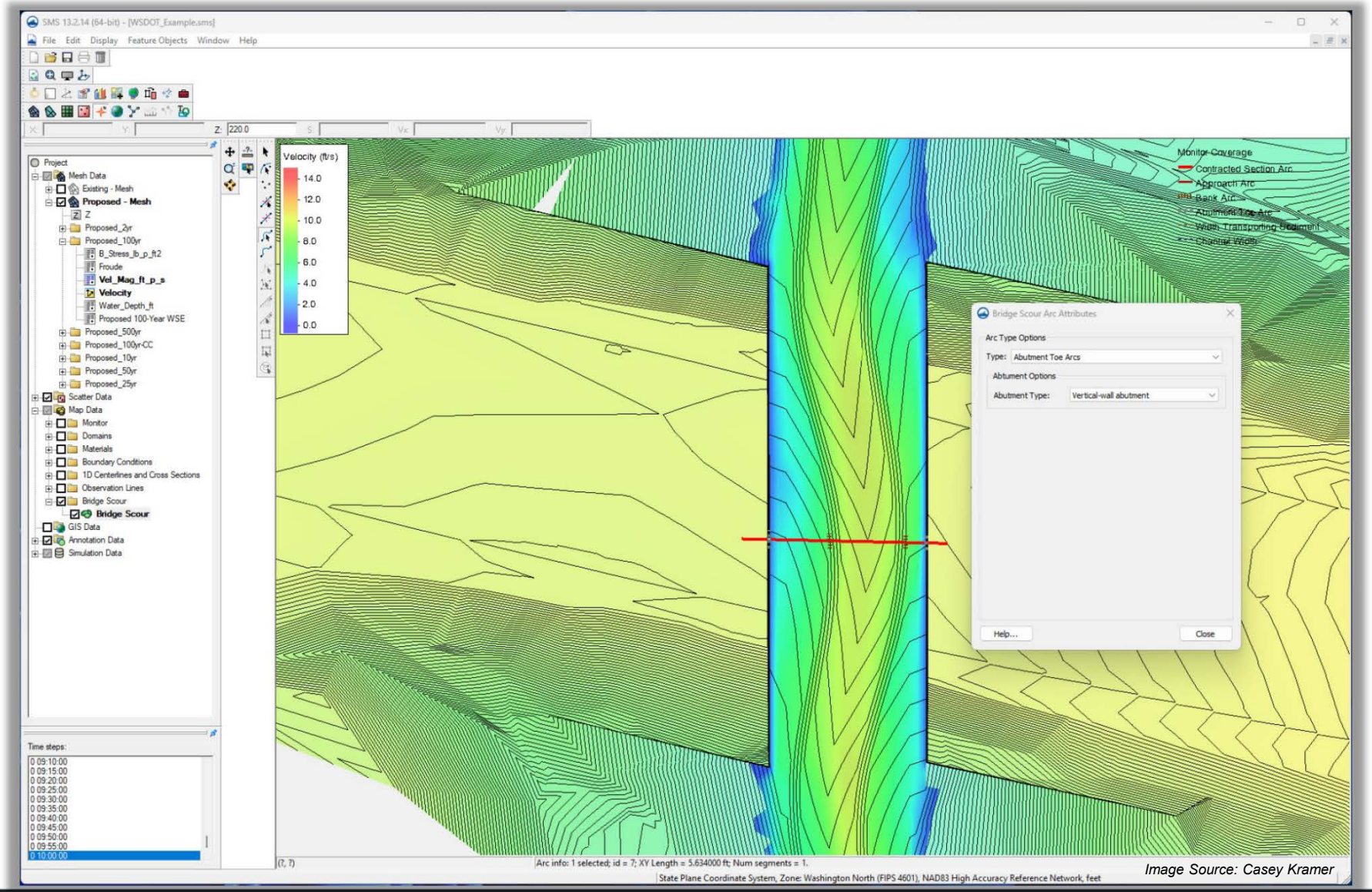

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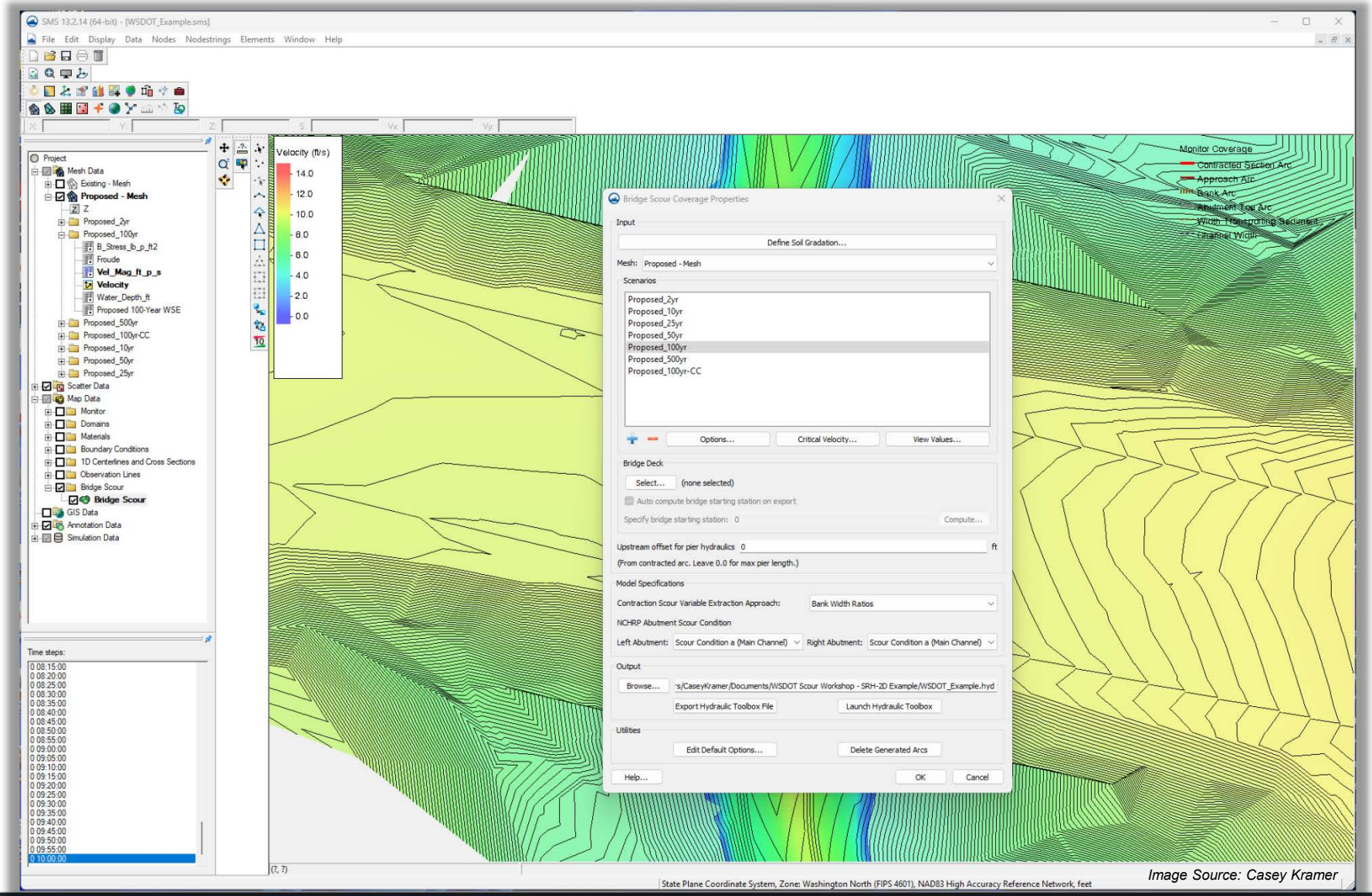

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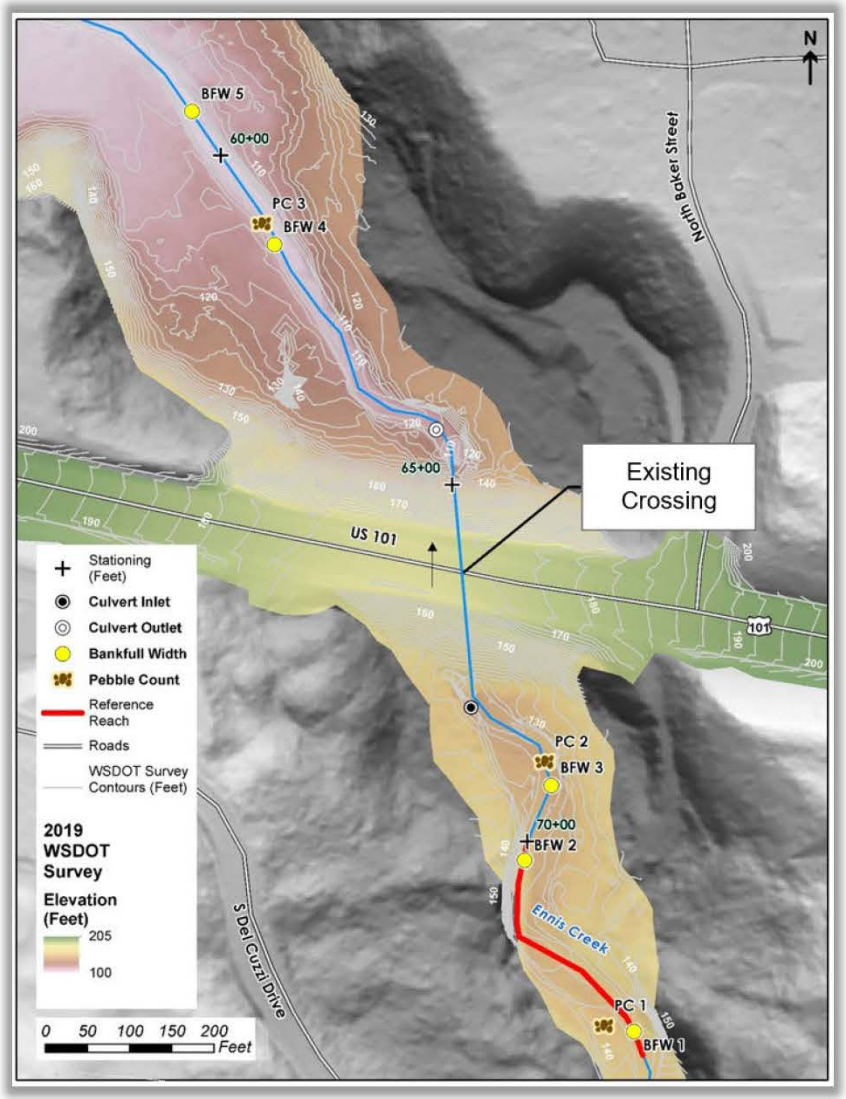


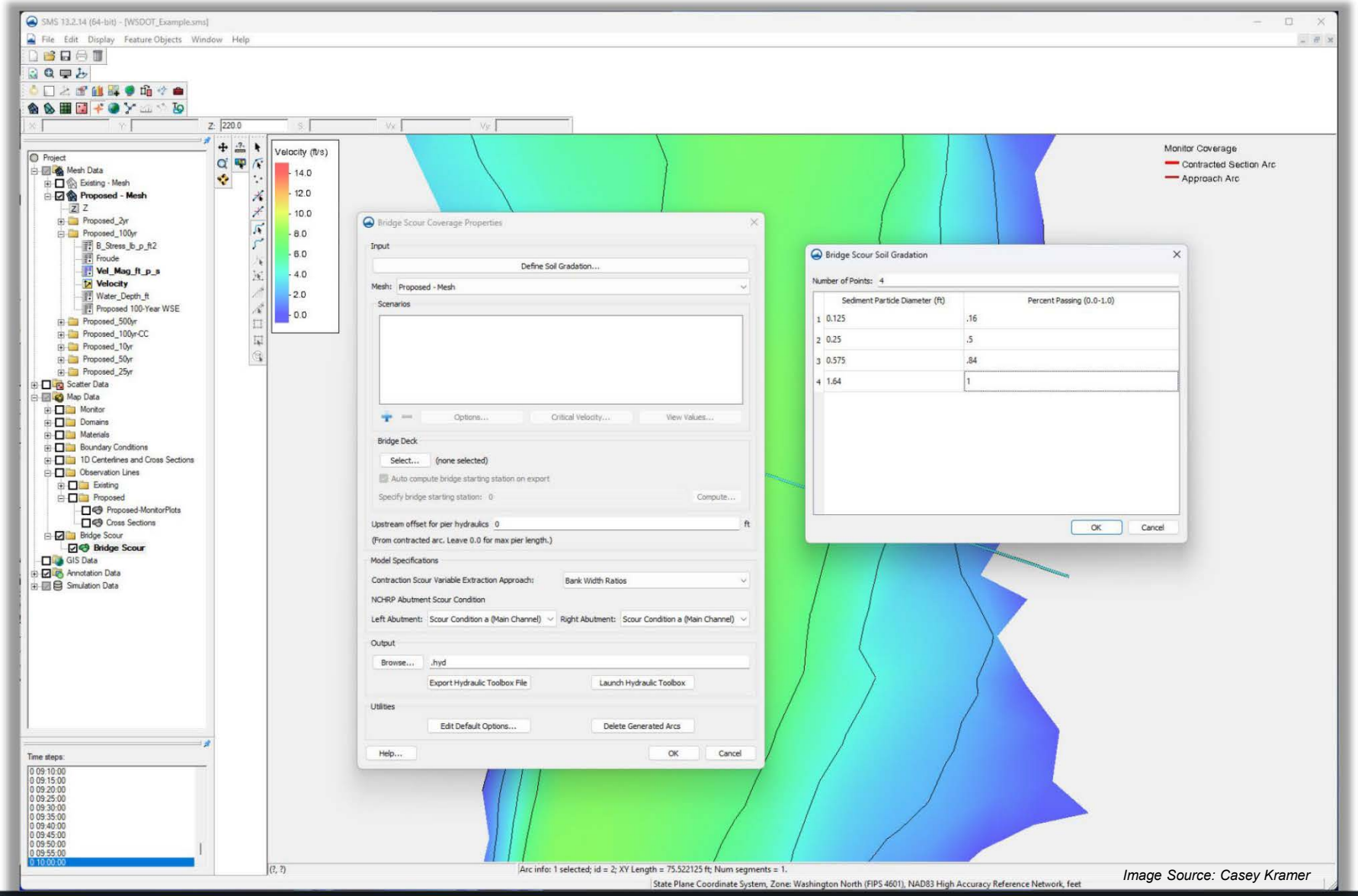
Image Source: WSDOT

Wolman Pebble Counts

Particle Percent Smaller Than	Pebble Count 1, Particle Diameter (Inches)[a]	Pebble Count 2, Particle Diameter (Inches)[b]	Pebble Count 3, Particle Diameter (Inches)[c]
D_{16}	1.5	1.3	1.6
D_{50}	3.0	3.1	4.3
D_{84}	6.9	5.9	12.8
D_{100}	19.7	17.7	39.4

a. Pebble Count 1 taken about 500 feet upstream of culvert in riffle of active channel.
b. Pebble Count 2 taken about 115 feet upstream of culvert at cobble bar.
c. Pebble Count 3 taken about 300 feet downstream of culvert in active channel where alluvial cover was present.

Contraction Scour



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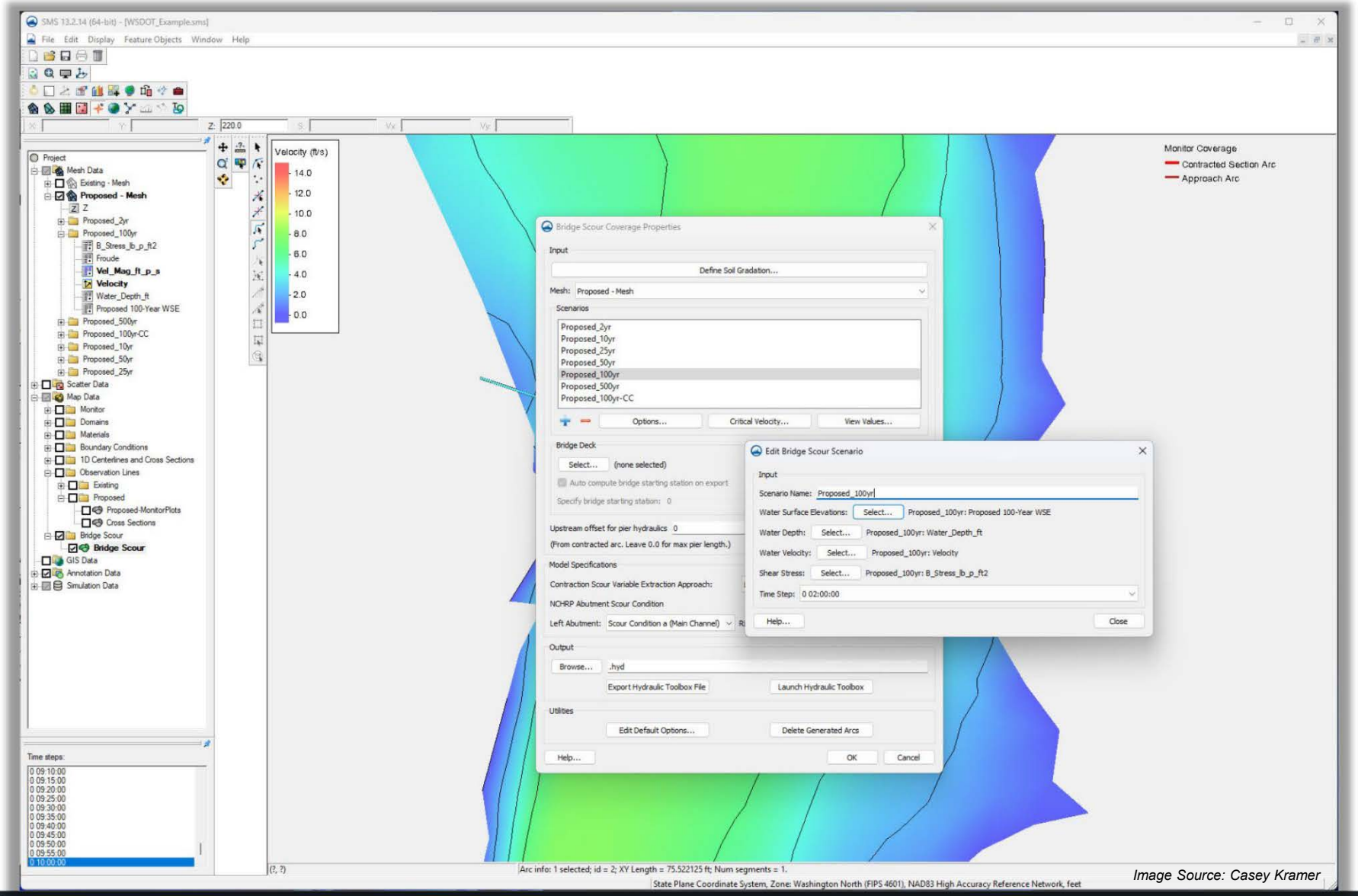

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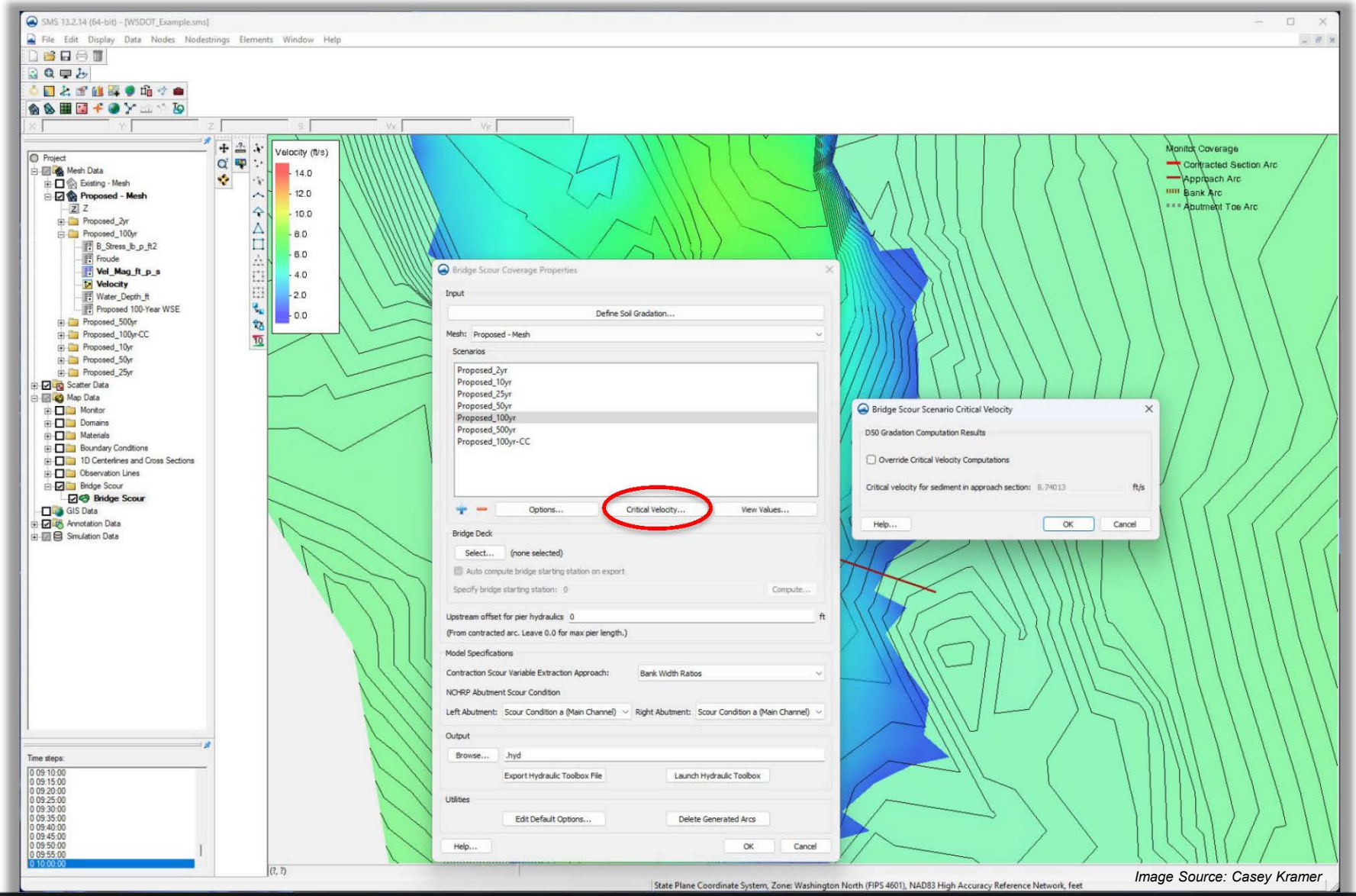

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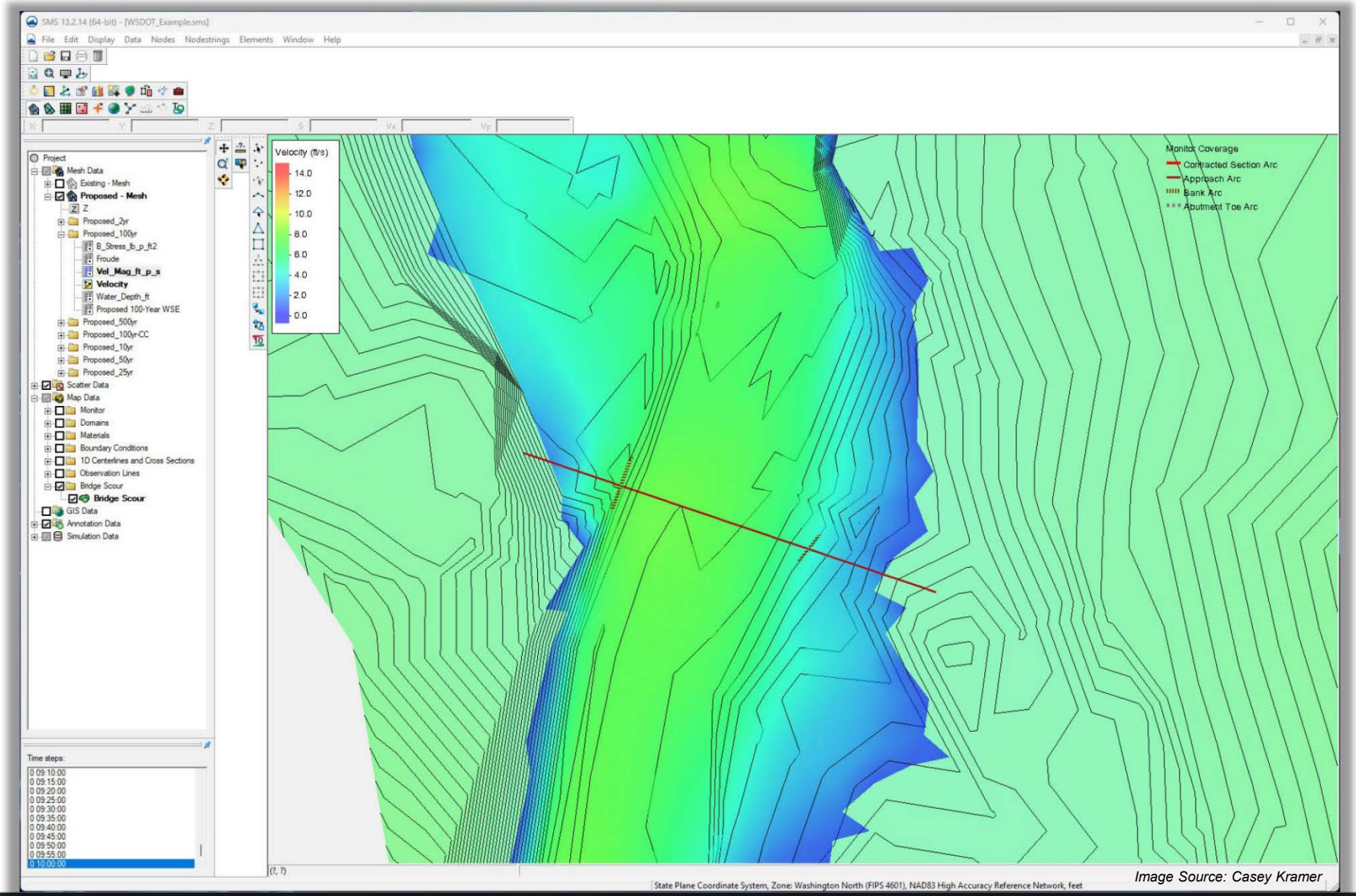

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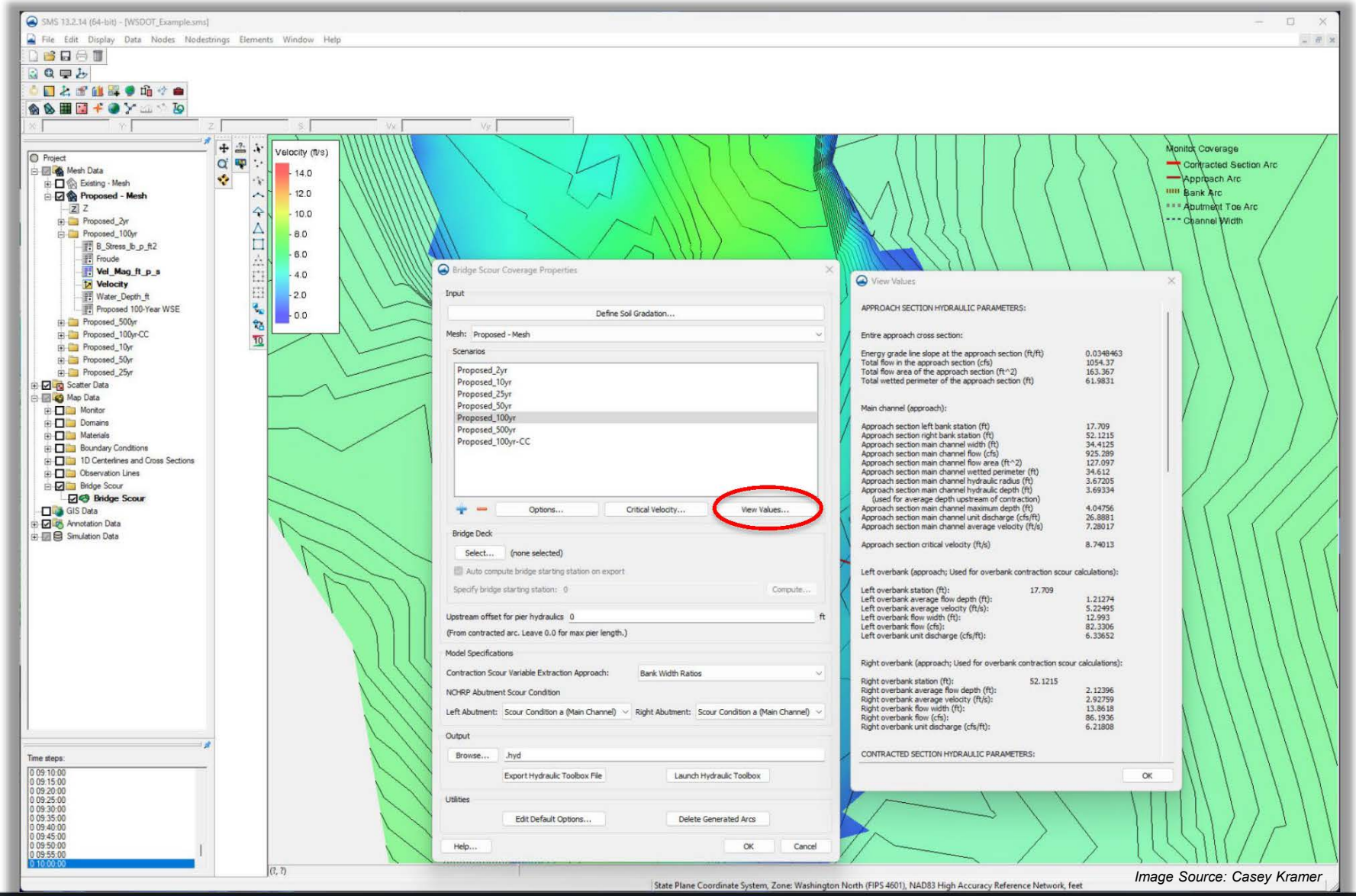

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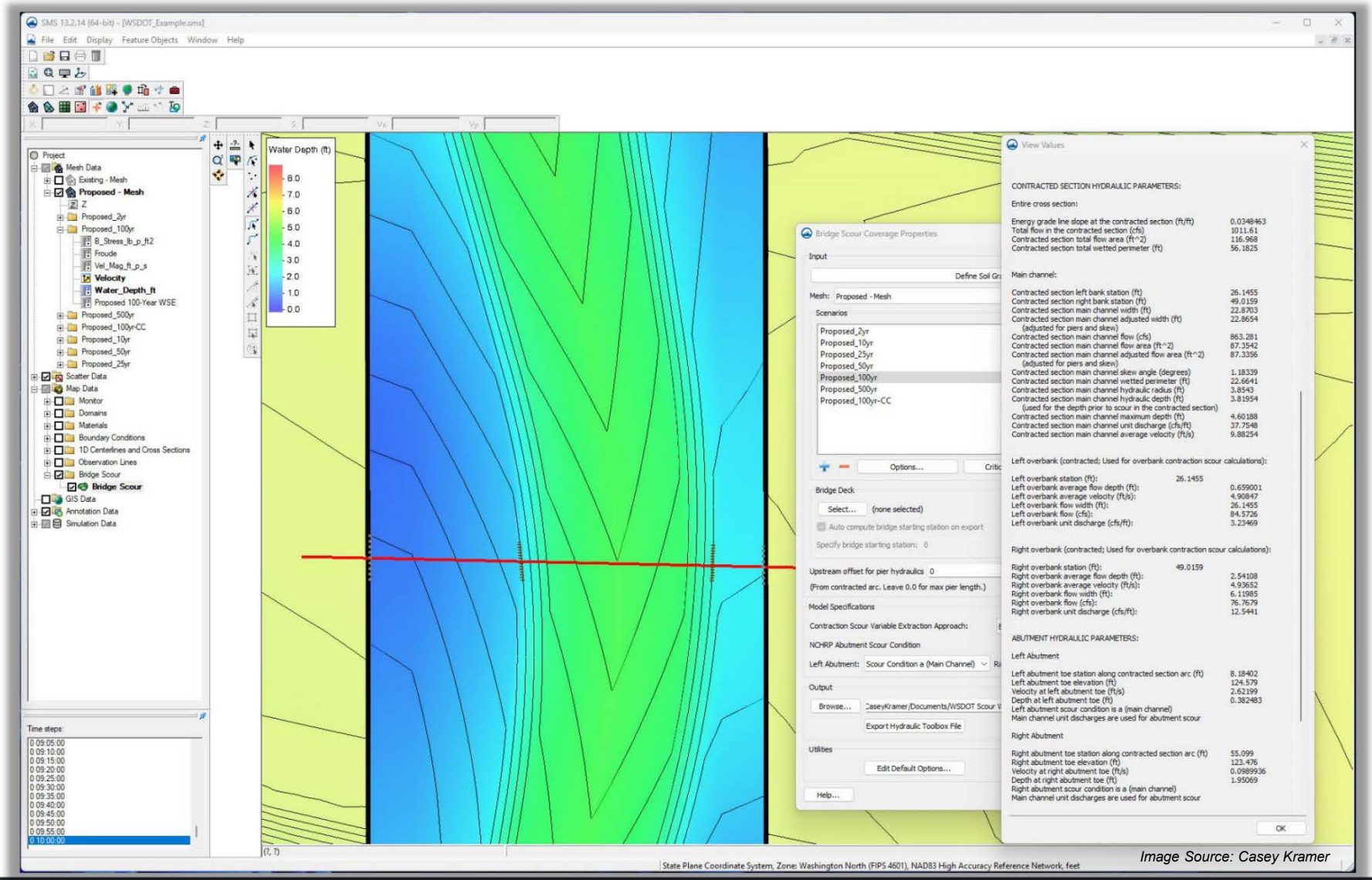

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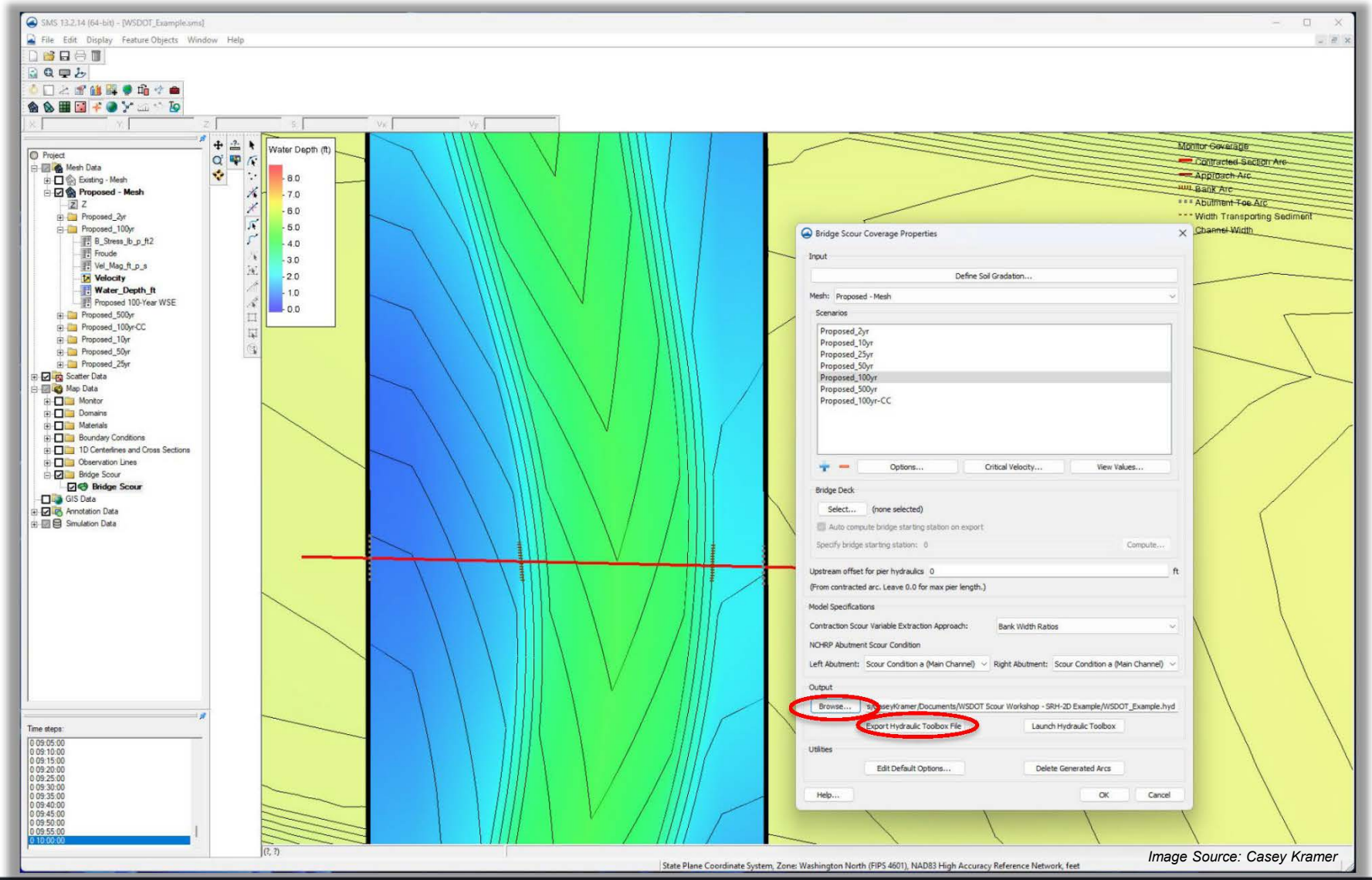

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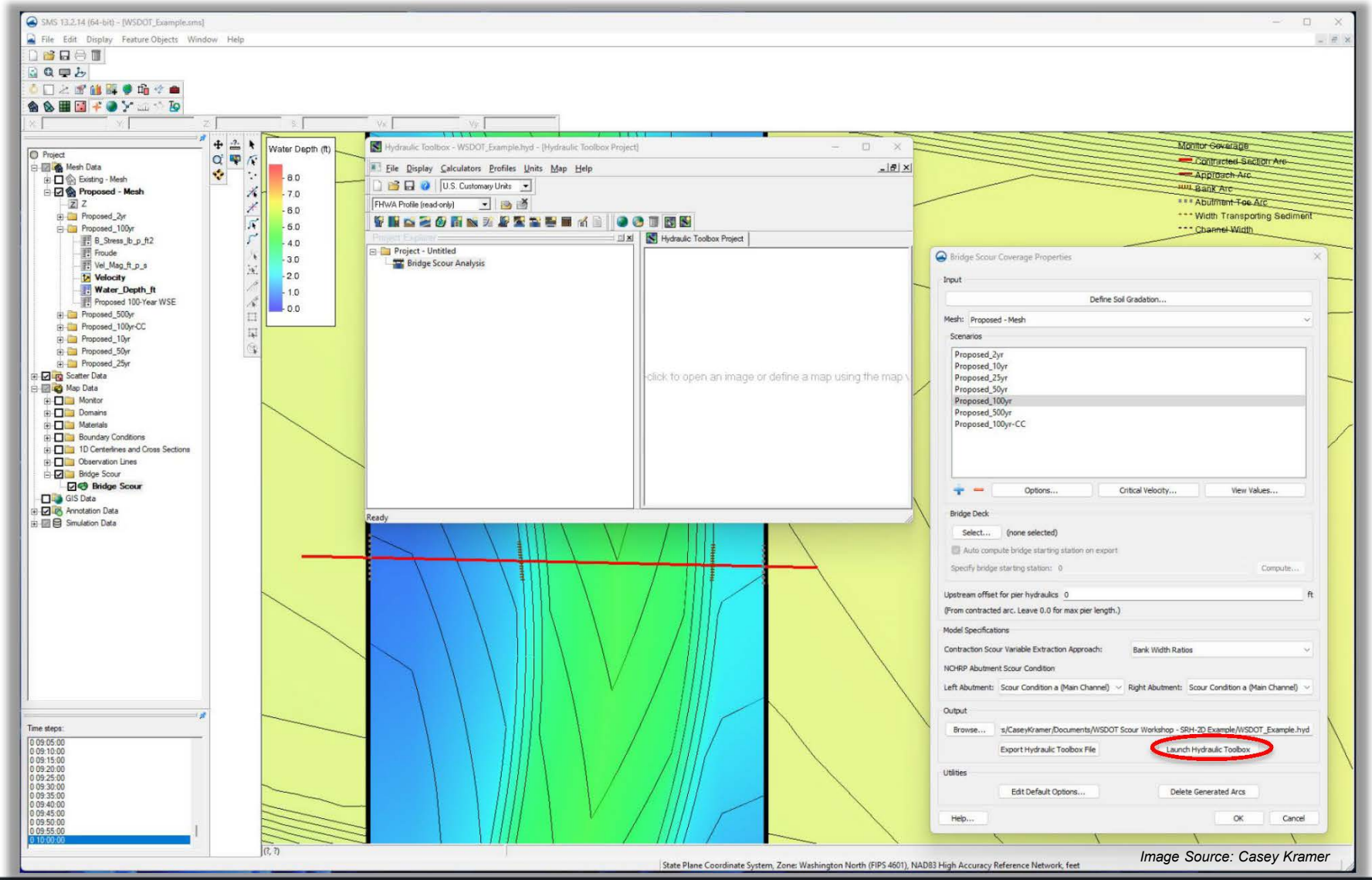

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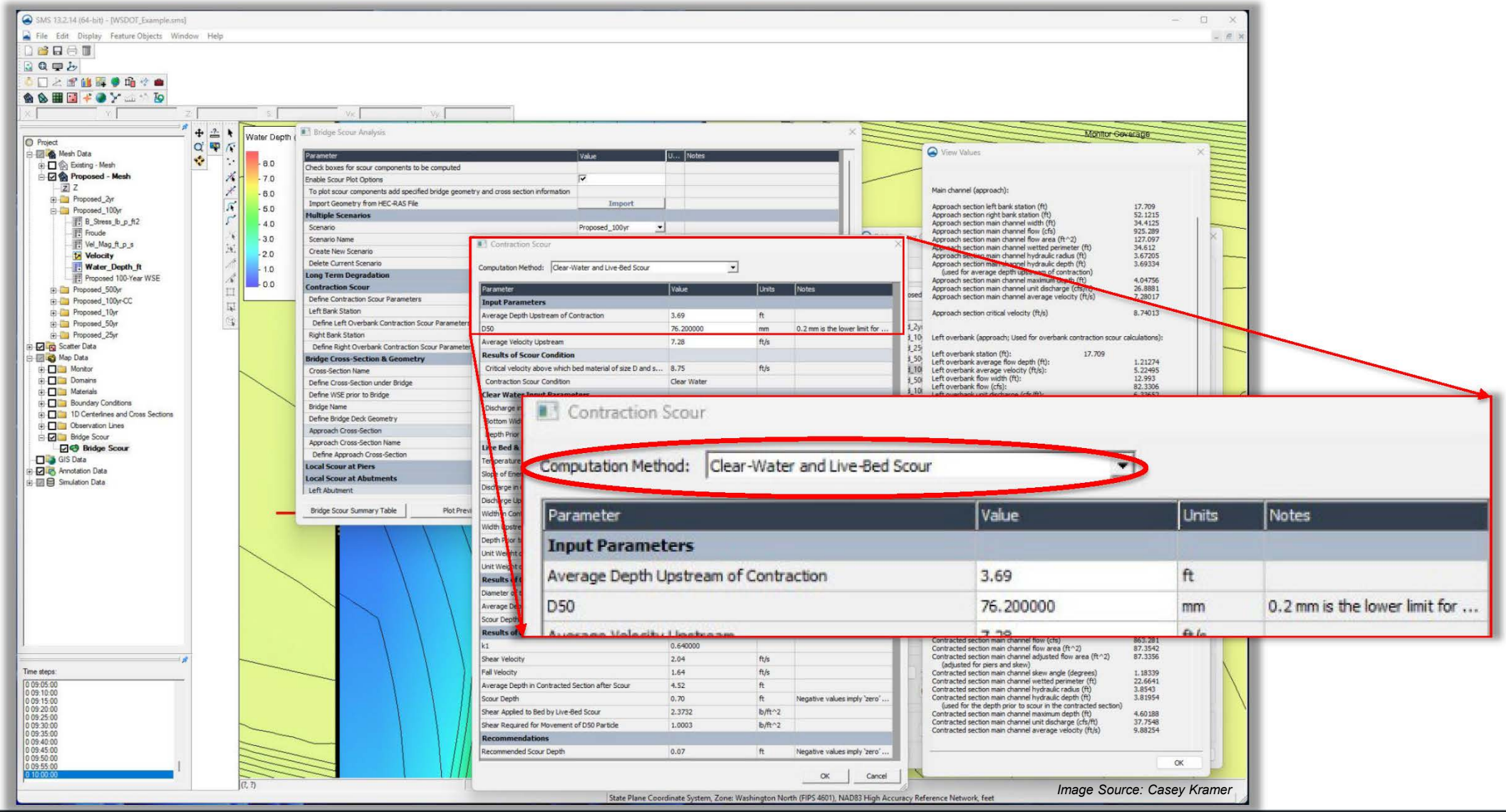

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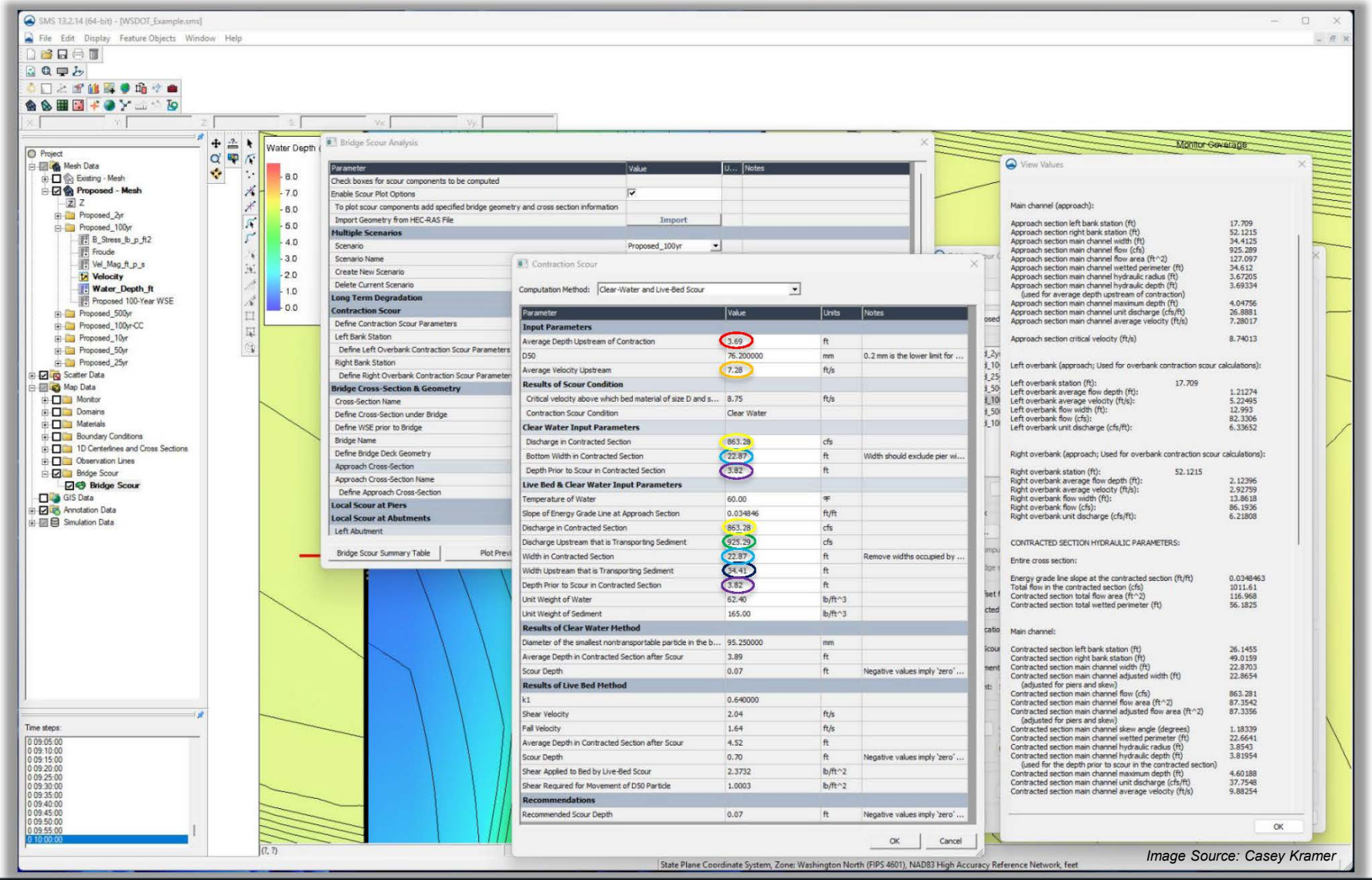

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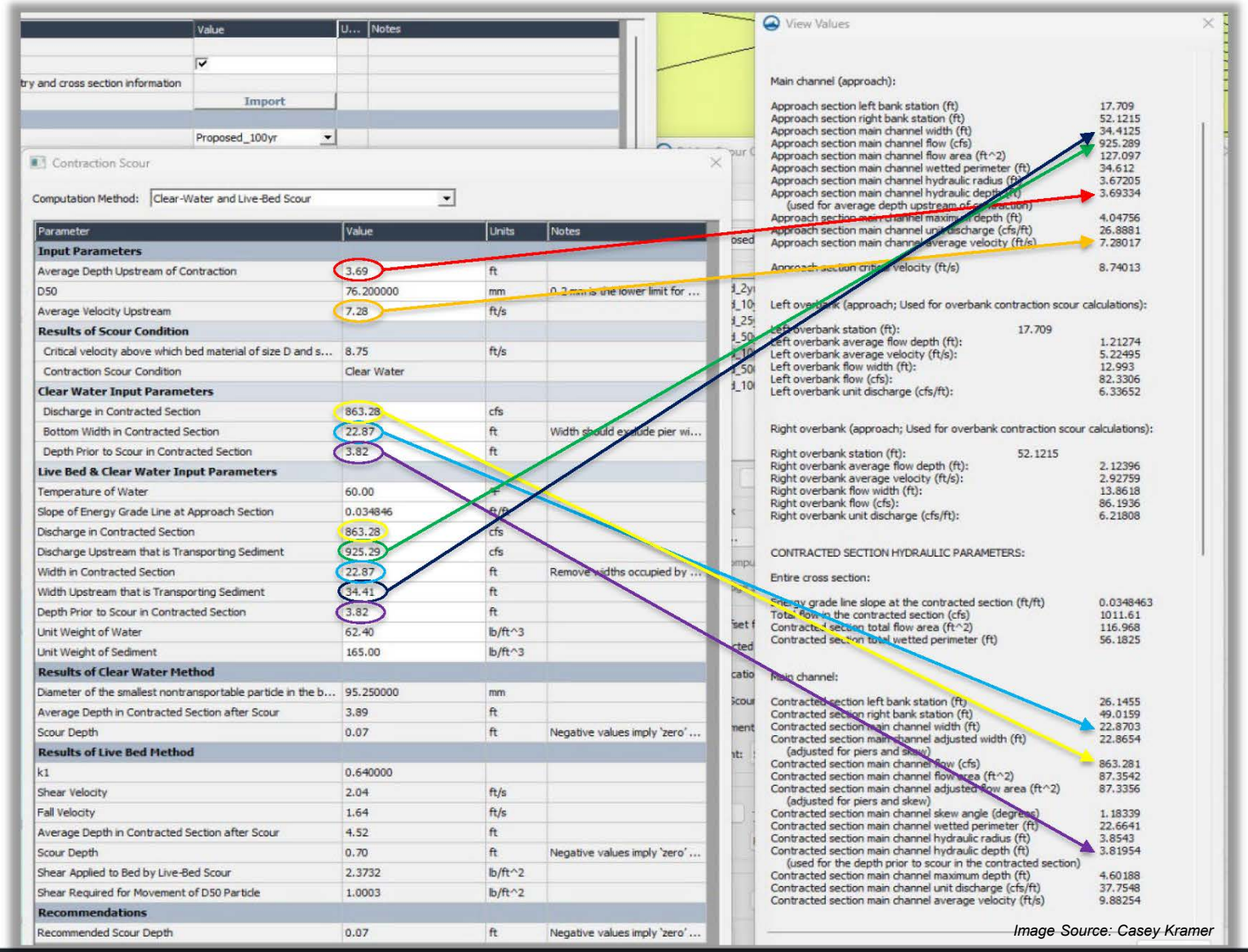

Image Source: Casey Kramer

Contraction Scour

Particle Percent Smaller Than	Bathurst Calculated 100-Year Particle Diameter (Inches)	Proposed Streambed Gradation (Inches)
D_{16}	1.1	0.5
D_{50}	3.6	3.5
D_{84}	9.1	11.8
D_{100}	22.7	18.0

Approach Section Pebble Count D_{50}

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	3.69	ft	
D50	76.200000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	7.28	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	8.75	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	863.28	cfs	
Bottom Width in Contracted Section	22.87	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	3.82	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	°F	
Slope of Energy Grade Line at Approach Section	0.034846	ft/ft	
Discharge in Contracted Section	863.28	cfs	
Discharge Upstream that is Transporting Sediment	925.29	cfs	
Width in Contracted Section	22.87	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	34.41	ft	
Depth Prior to Scour in Contracted Section	3.82	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	95.250000	mm	
Average Depth in Contracted Section after Scour	3.89	ft	
Scour Depth	0.07	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	2.04	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	4.52	ft	
Scour Depth	0.70	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	2.3732	lb/ft^2	
Shear Required for Movement of D50 Particle	1.0003	lb/ft^2	
Recommendations			
Recommended Scour Depth	0.07	ft	Negative values imply 'zero' ...

OK Cancel

Design Mix D_{50}

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	3.69	ft	
D50	88.900000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	7.28	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	9.21	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	863.28	cfs	
Bottom Width in Contracted Section	22.87	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	3.82	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	°F	
Slope of Energy Grade Line at Approach Section	0.034846	ft/ft	
Discharge in Contracted Section	863.28	cfs	
Discharge Upstream that is Transporting Sediment	925.29	cfs	
Width in Contracted Section	22.87	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	34.41	ft	
Depth Prior to Scour in Contracted Section	3.82	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	111.125000	mm	
Average Depth in Contracted Section after Scour	3.72	ft	
Scour Depth	-0.09	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	2.04	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	4.52	ft	
Scour Depth	0.70	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	2.4983	lb/ft^2	
Shear Required for Movement of D50 Particle	1.1671	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.09	ft	Negative values imply 'zero' ...

OK Cancel

Contraction Scour

*To Demonstrate Requirement of All Flows Up To Scour Design Flood and Scour Check Flood **ONLY***

Bridge Scour Summary Table

Parameter	Proposed_2yr	Proposed_10yr	Proposed_25yr	Proposed_50yr	Proposed_100yr	Proposed_500yr	Proposed_100yr-CC	Units	Notes
Scenario									
Contraction Scour									
Selected Contraction Computation Method	Clear-Water...	Clear-Water ...	Clear-Water ...	Clear-Water ...	Clear-Water a...	Clear-Water an...	Clear-Water and Li...		Clear-Water and Live-Bed Scour
Applied Contraction Scour Depth	0.00	0.00	0.00	0.00	0.00	**0.16**	0.10	ft	
Clear Water Contraction Scour Depth	**-0.37**	**-0.30**	**-0.24**	**-0.17**	**-0.09**	**0.16**	**0.10**	ft	Item bolded is the governing contraction scour for scenario
Live Bed Contraction Scour Depth	0.61	0.77	0.73	0.71	0.70	0.71	0.71	ft	Item bolded is the governing contraction scour for scenario

Depths of Scour are Determined at PHD as Structure Type, Size and Location has not Been Determined

Total Scour Elevation at Each Infrastructure Component is Determined by Interdisciplinary Team as Design Progresses