WSDOT
Scour Workshop

Module 4
Scour Overview

May 30th, 2023

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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 Hydraulic Research)

Personal Interests

- Spending time with family
- Rivers
- Dirt biking, fishing, camping, and coaching/watching sports

Scour Overview

- Stream stability and scour process
- Worst case scour
- Total scour
- Components of total scour
- Importance of:
  - understanding applicability and limitations
  - surface and subsurface material data
  - good hydrologic and hydraulic information
- SMS and extraction of hydraulic information to support scour calculations in hydraulic toolbox

Image Source: Casey Kramer

Stream Stability and Scour Analyses

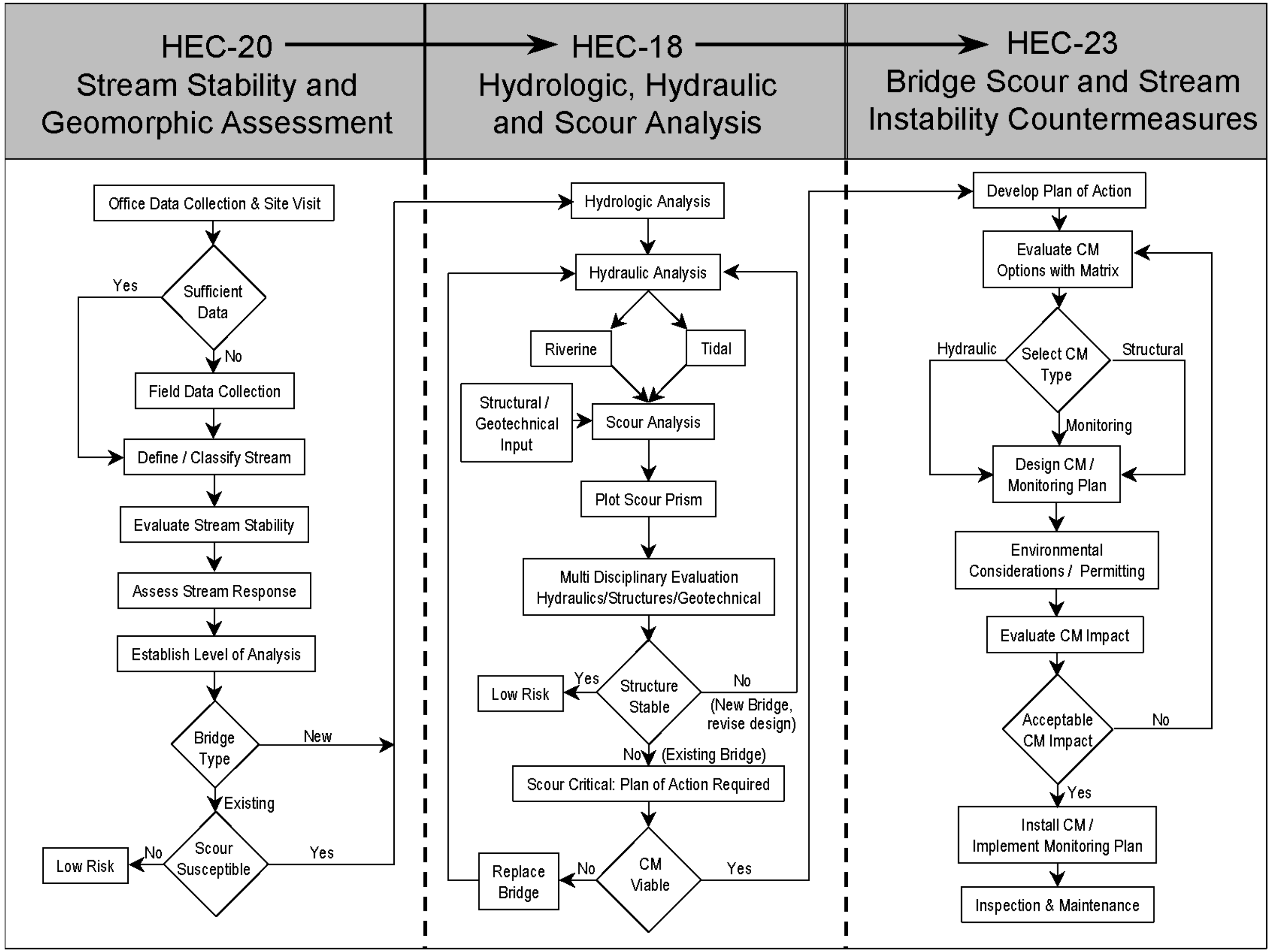


Image Source: FHWA

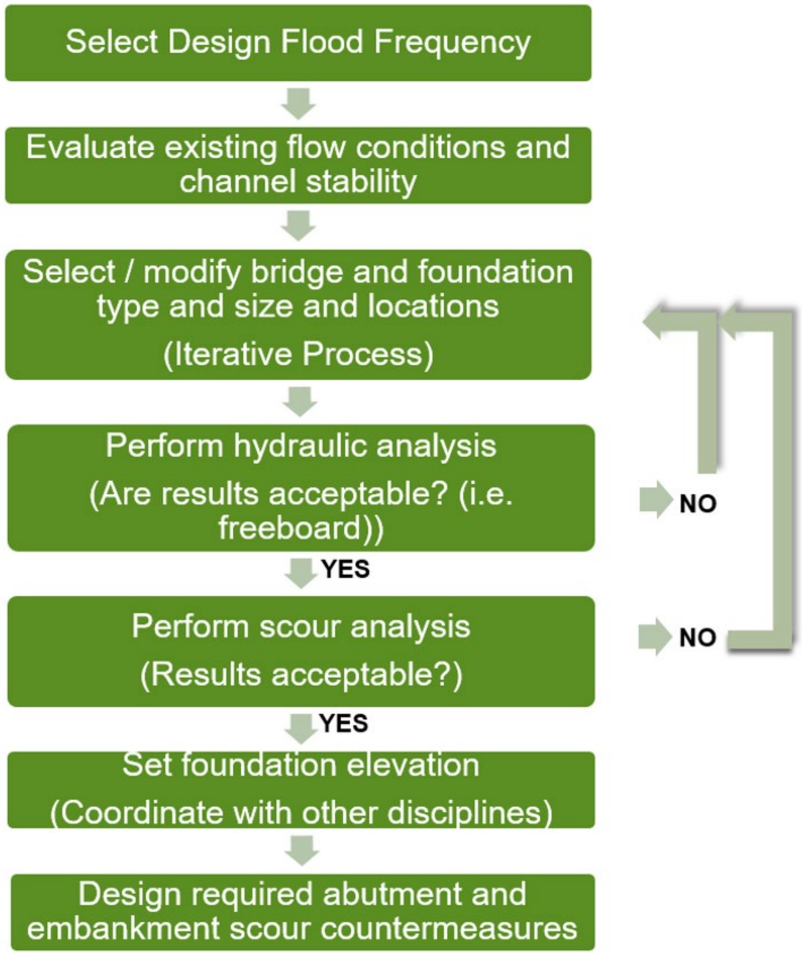
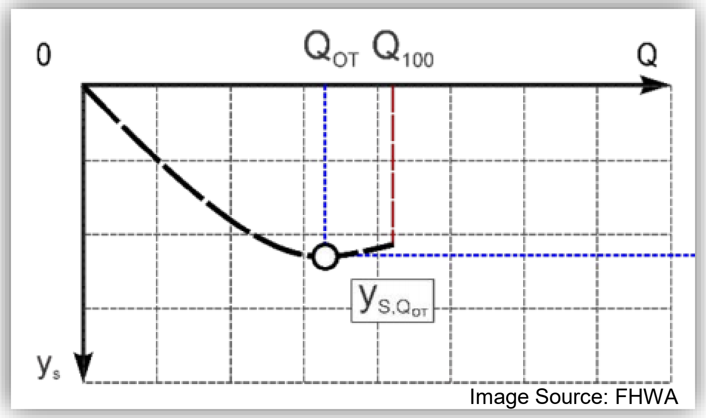
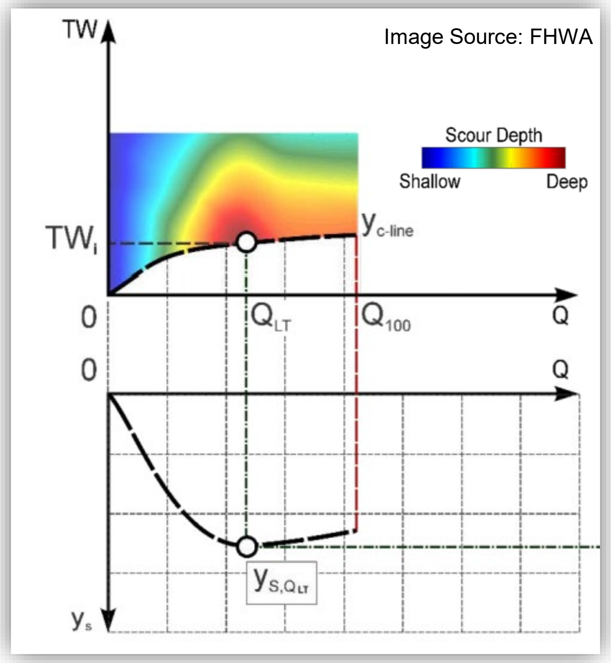


Image Source: FHWA

Worst Case Scour

- **FHWA -** Worst Case Scour Depth – "The conditions (e.g., discharge, velocity, depth, tailwater, geometry, orientation, type of foundation, etc.) that would produce the maximum scour depth at a particular foundation element."





Worst Case Scour

- Floods smaller than the scour design flood or scour check flood can cause deeper scour
- Evaluate several key scenarios to assess worst case scour condition
  - Low tailwater conditions
  - Tidal conditions
  - Variety of angles of attack
  - Debris and ice, where applicable
  - Live-bed and clear-water conditions

Total Scour

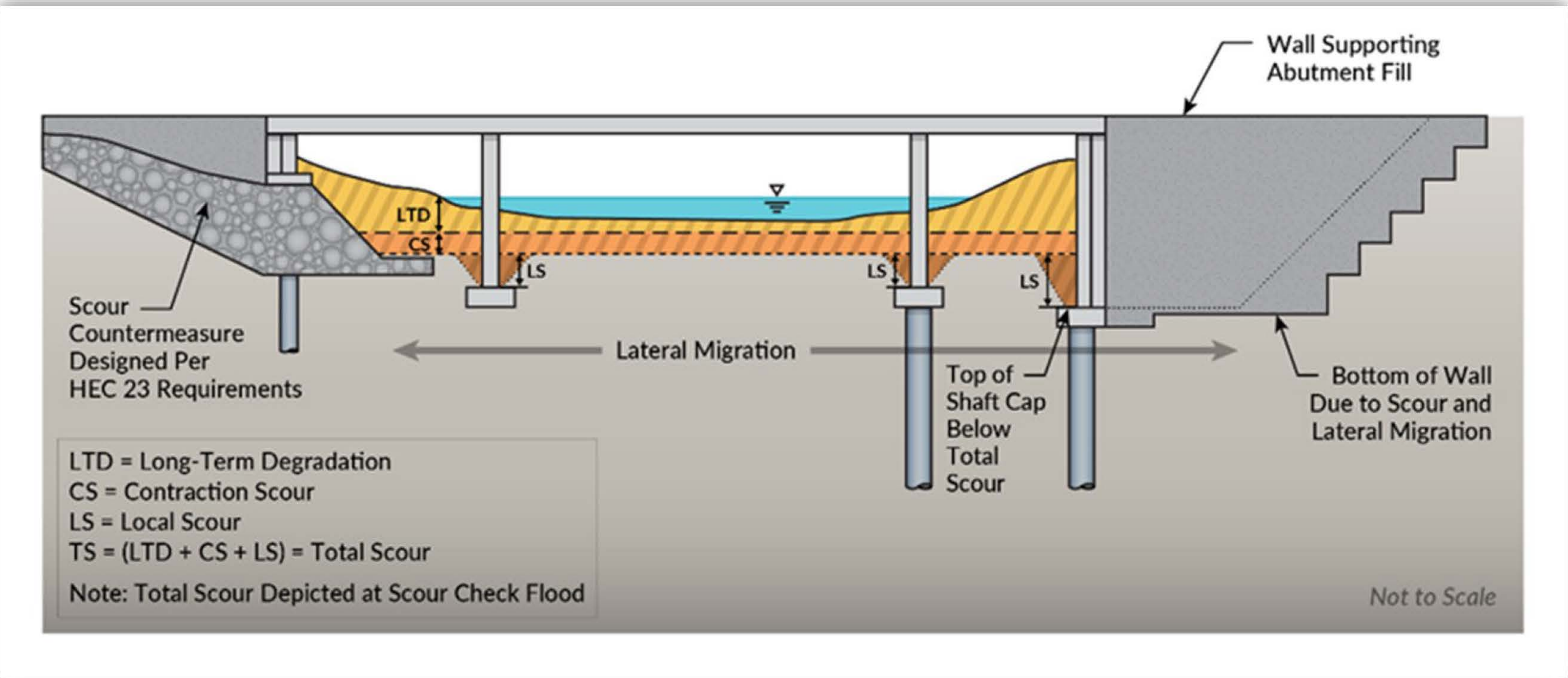


Image Source: WSDOT

Total Scour

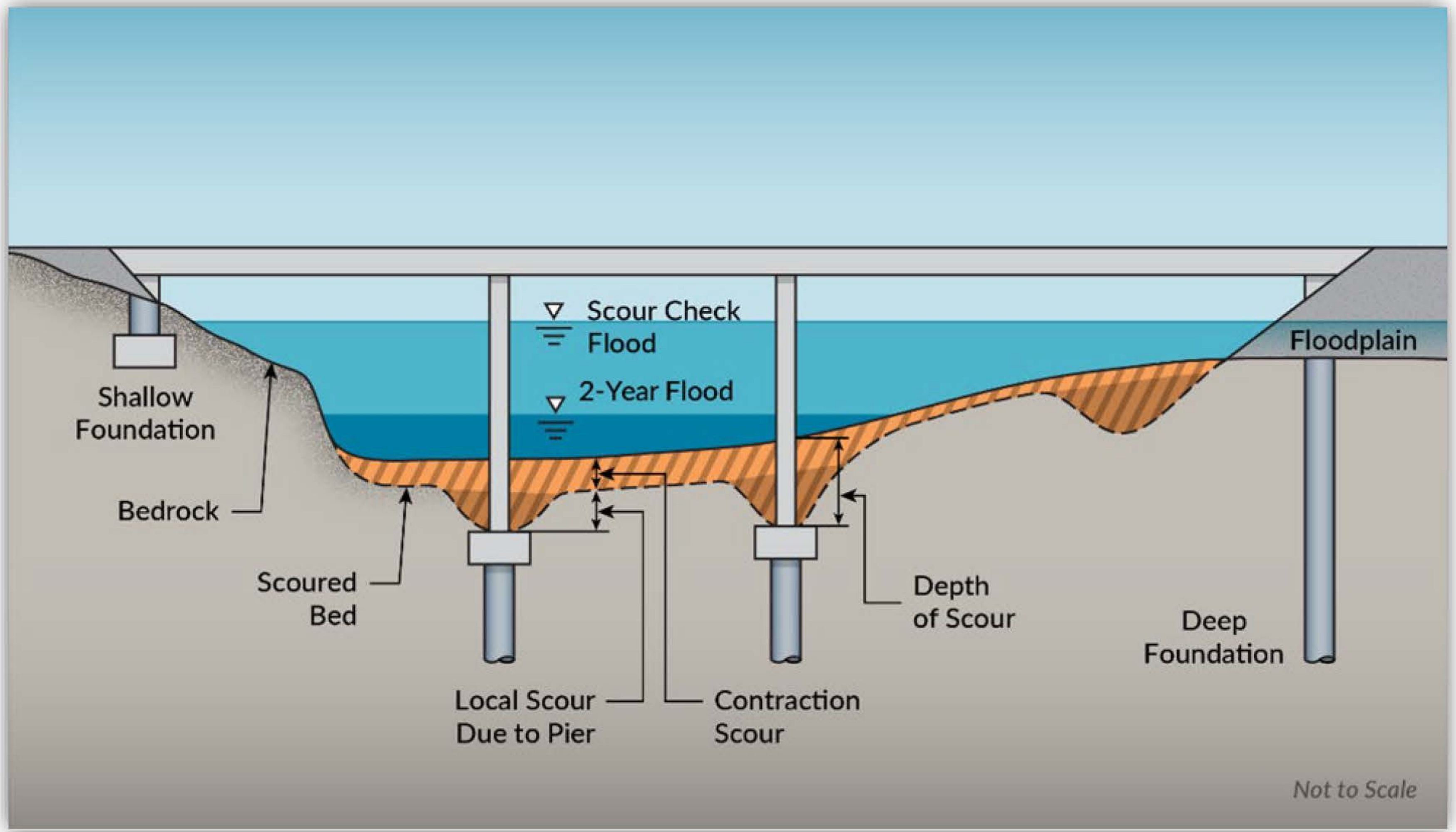


Image Source: WSDOT

Lateral Migration

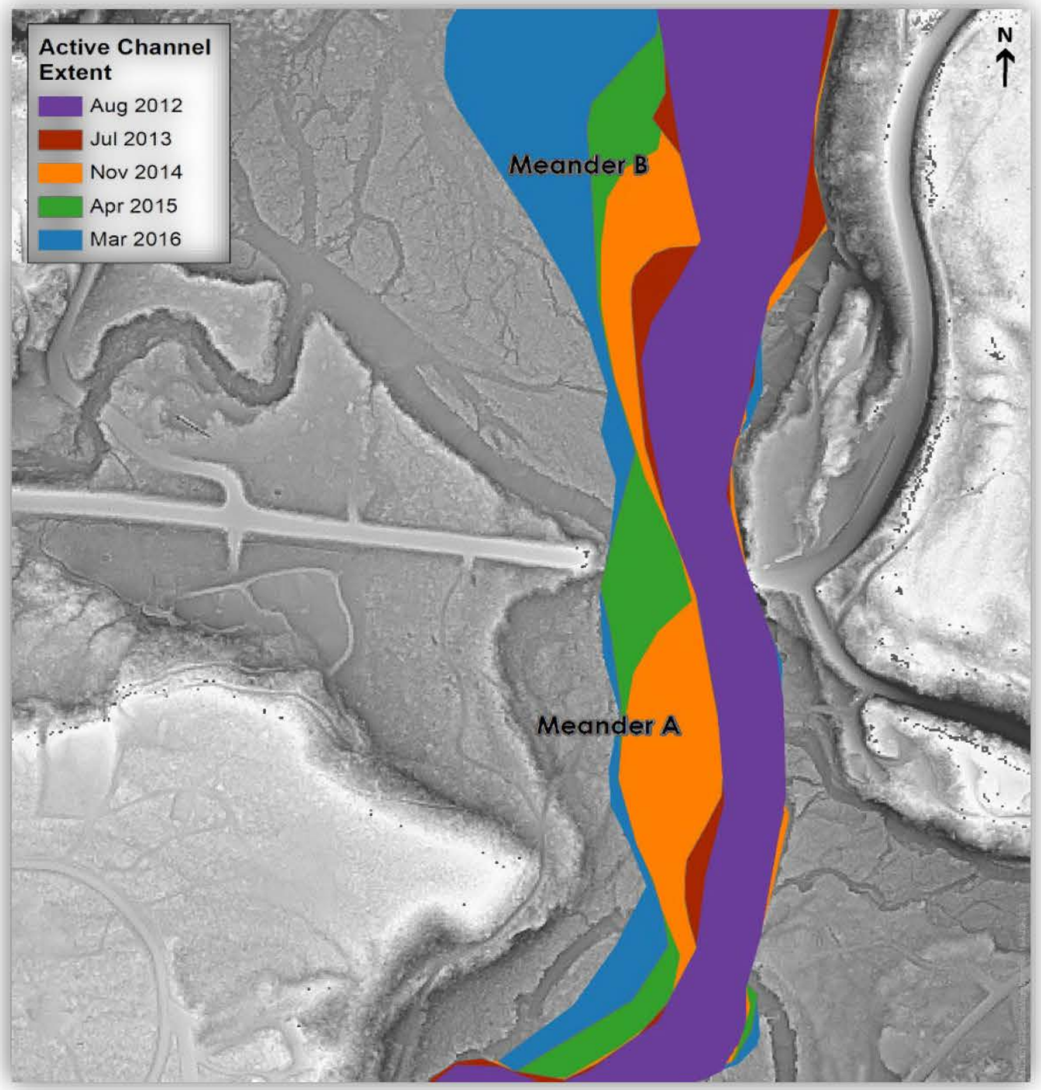


Image Sources: USBR and Casey Kramer

Lateral Migration

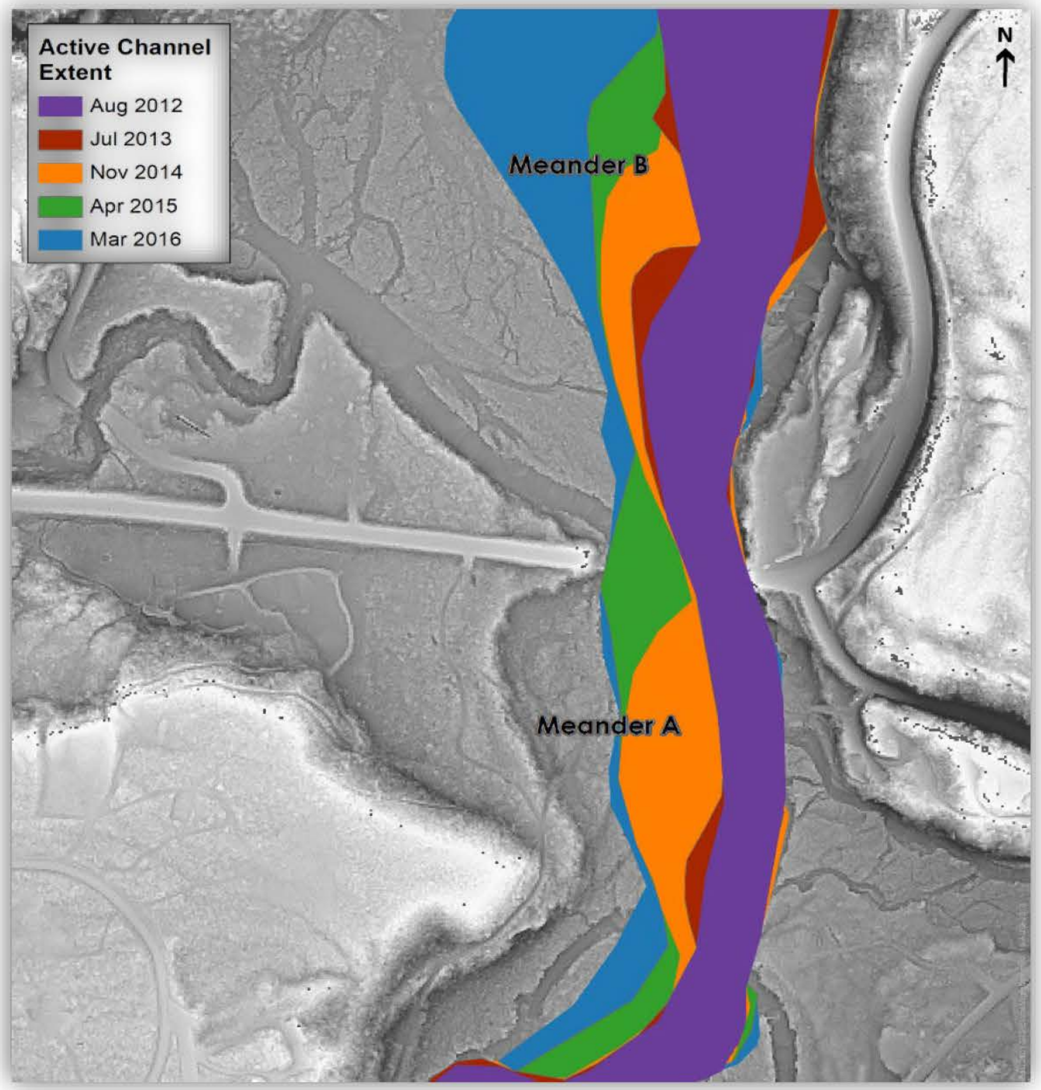


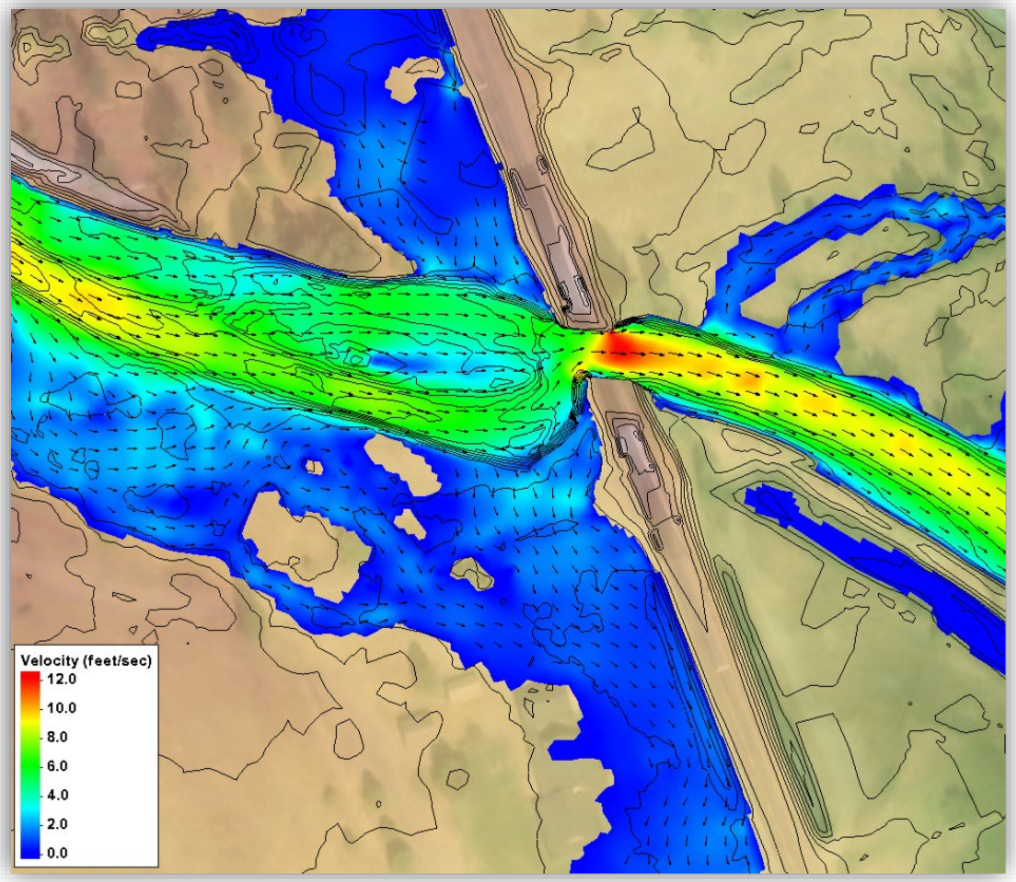
Image Sources: USBR and Casey Kramer

Long-Term Degradation

- Downstream base level changes
- Dams and reservoirs
- Change in watershed land use
- Cutoffs of meander bends

Image Sources: Casey Kramer

Contraction Scour



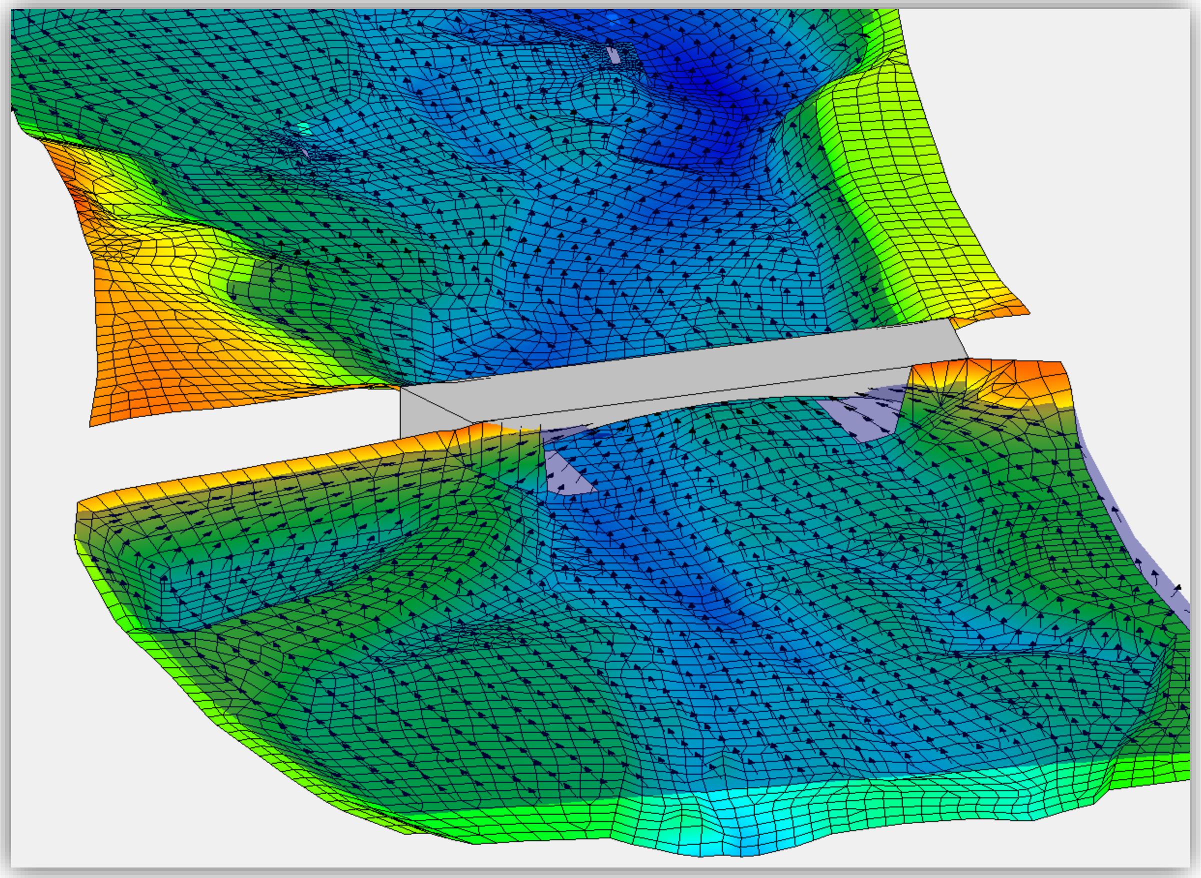


Image Sources: Casey Kramer

Local (Abutment) Scour

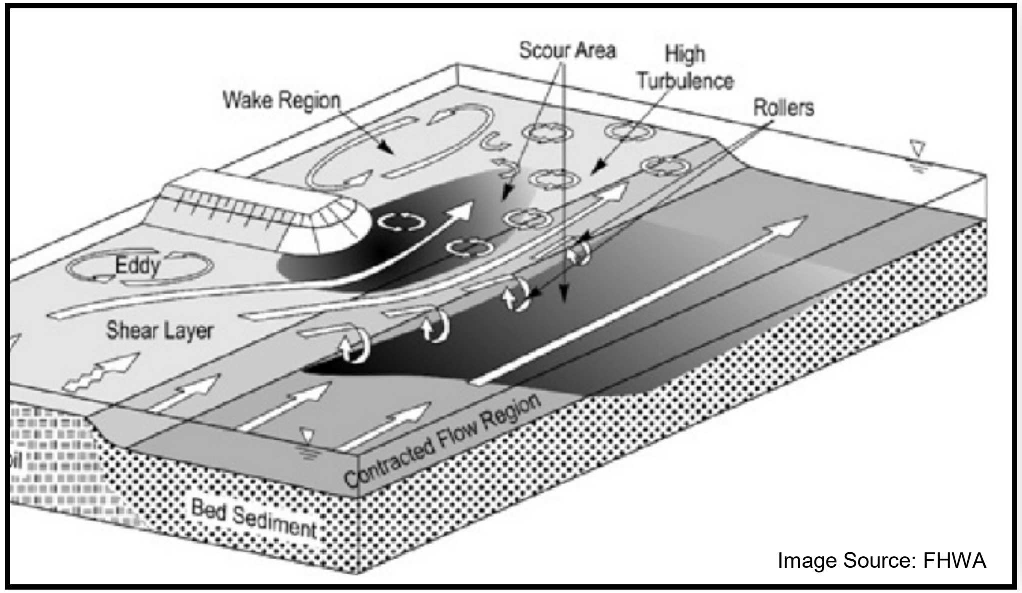


Image Source: FHWA

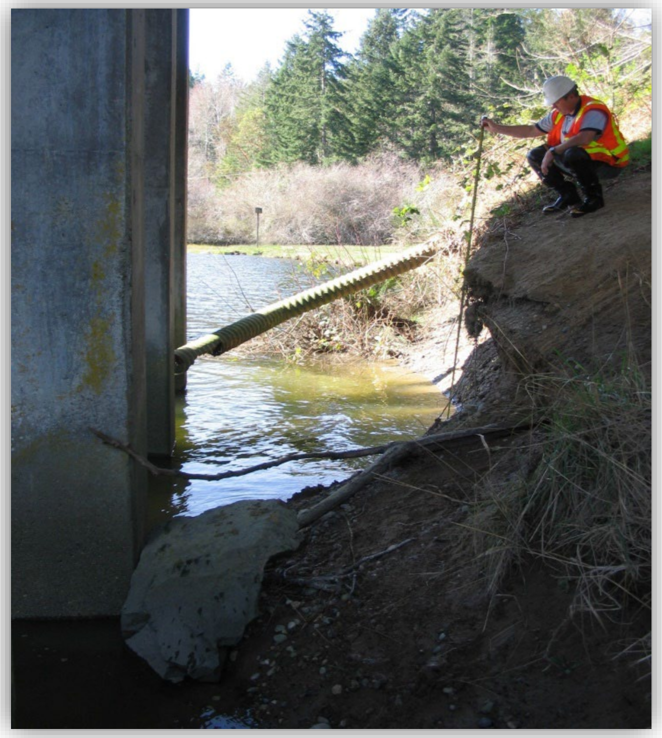


Image Sources: Casey Kramer

Local (Pier) Scour

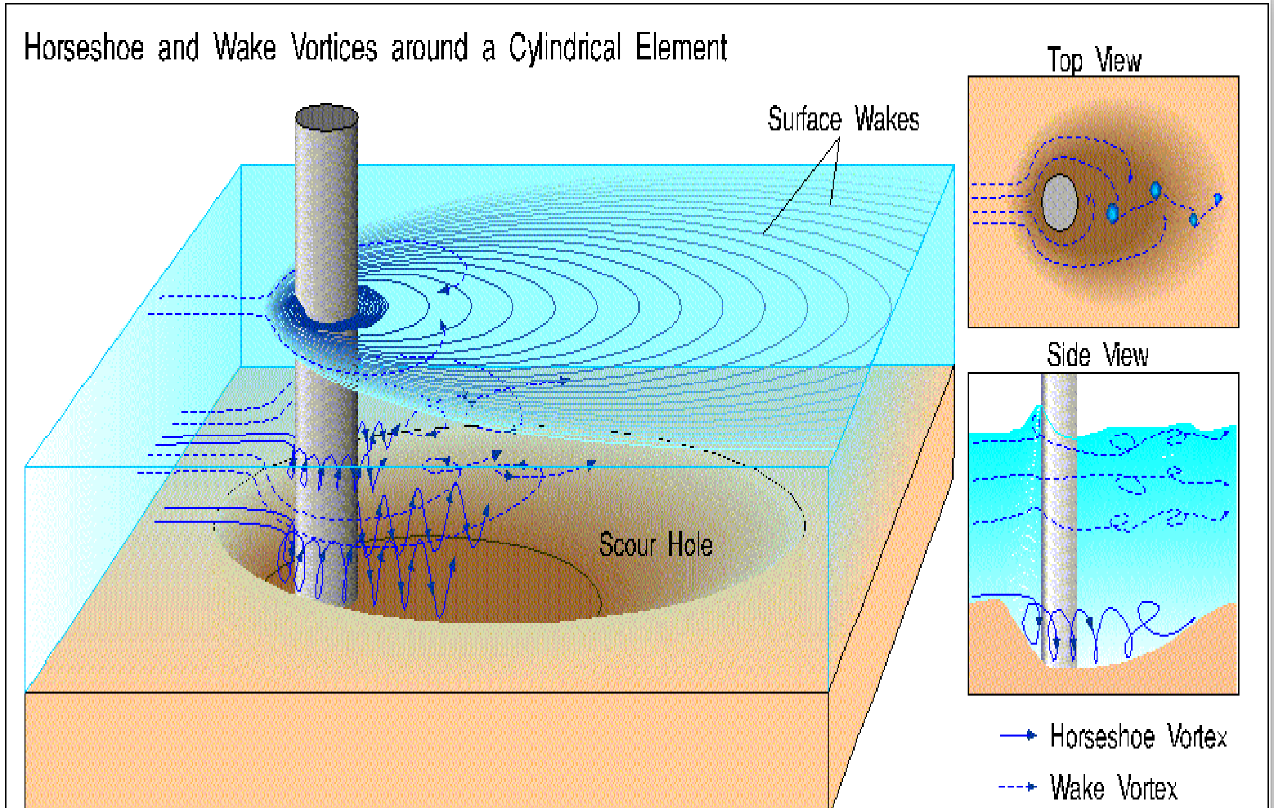


Image Source: FHWA

Image Sources: Casey Kramer

Freeboard and Long-Term Aggradation

Image Sources: Casey Kramer

Debris

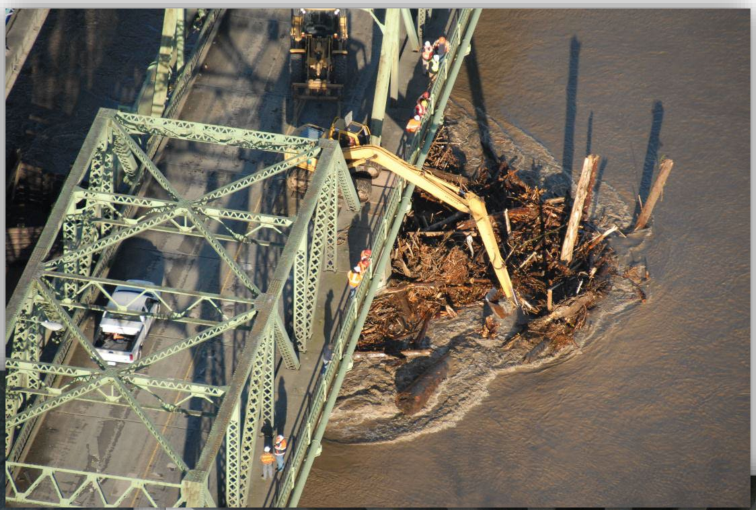


Image Sources: WSDOT

Image Sources: Casey Kramer

Importance of Understanding Applicability and Limitations

- Designers need to understand key assumptions of various scour equations
- Applicability and limitations for each method may include:
  - Sediment type/size
  - Foundation type/size
  - Averaged or local hydraulic inputs
  - Clear-water or live-bed
  - **Rivers are Dynamic!**
  - Etc.

Image Sources: Casey Kramer

Sediment Sampling for Scour Analyses

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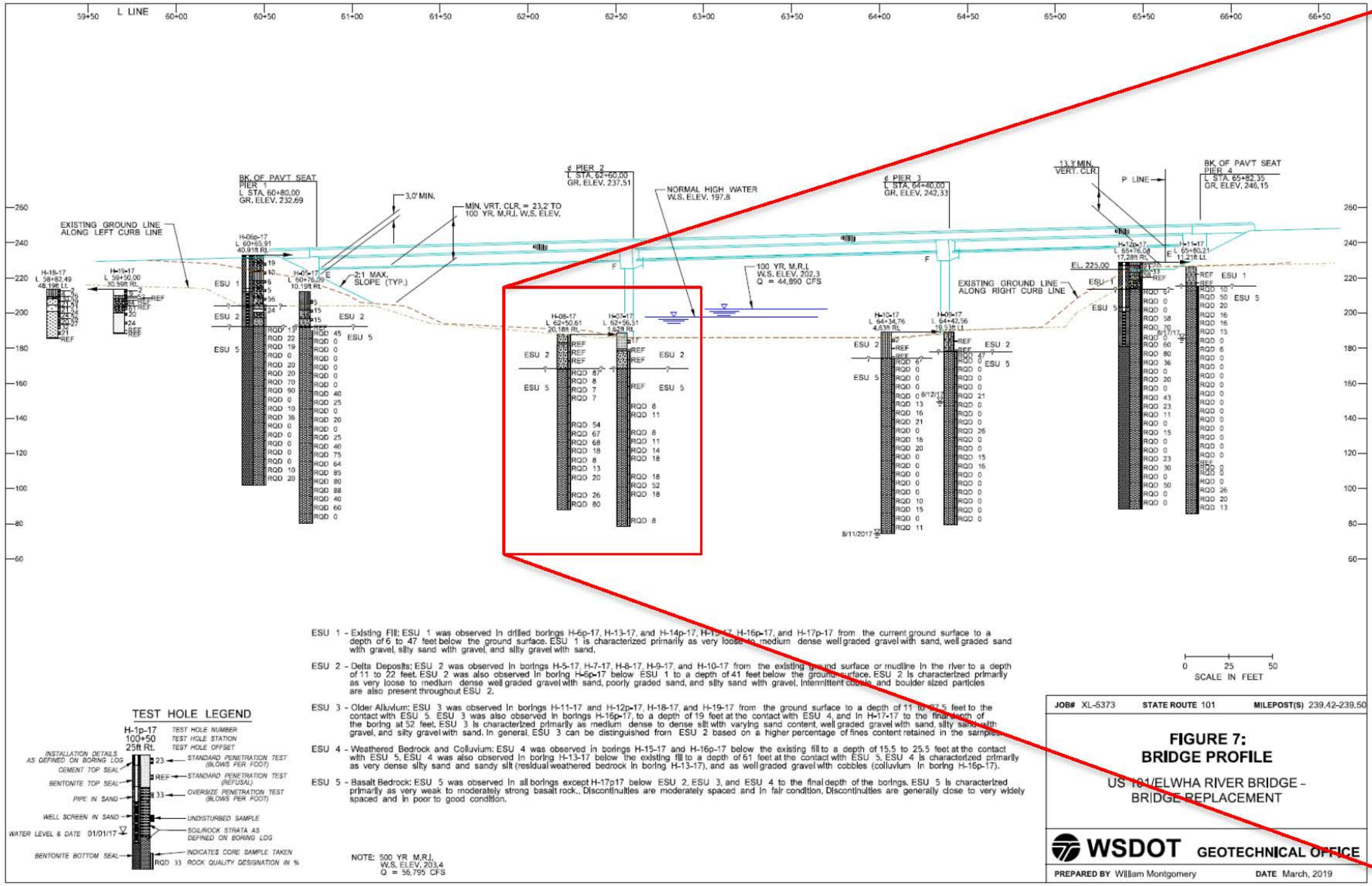
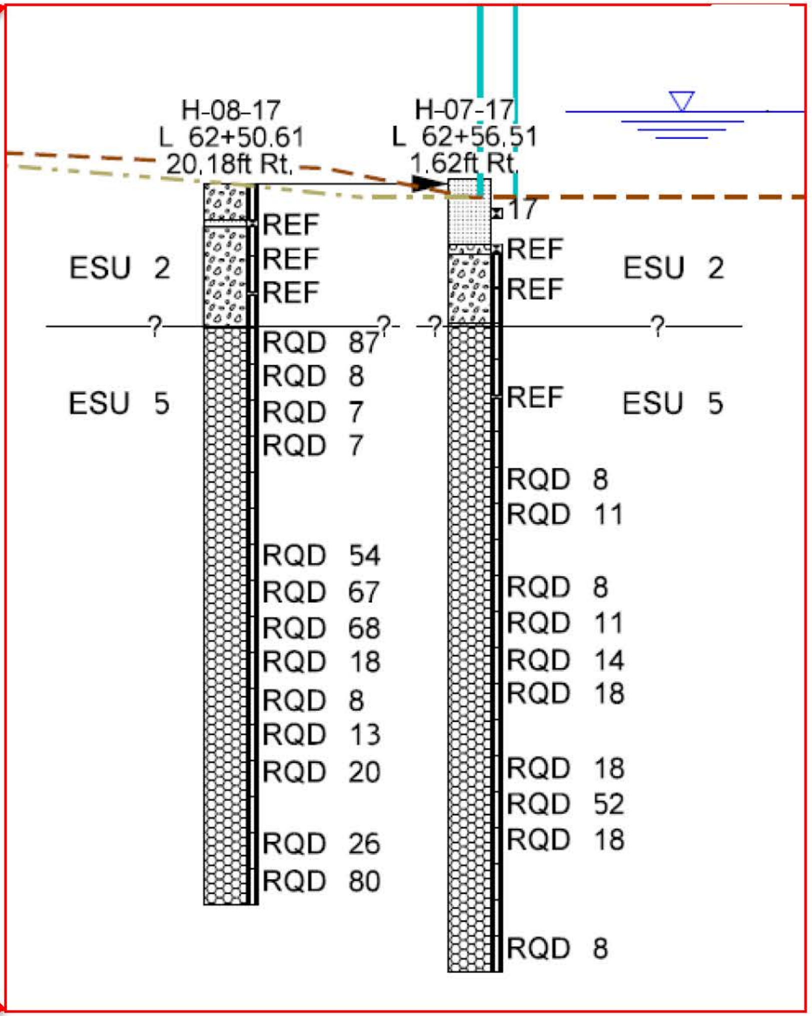




Importance of Good Hydrology and Hydraulic Modeling

- Hydrology is the fundamental parameter to understanding site hydraulics
- WSDOT HM (Chapter 2) shall be followed to develop hydrology based on best available data
- Understanding uncertainty in hydrologic estimates must be properly documented

MAP ID	Station Number	State	Flood Region	Number of Systematic Peaks used in Analysis	Kendall's Tau for Systematic Record	P-value	Flood discharge information Each Station has four lines of flood-discharge information for the indicated annual exceedance probabilities: Line 1: Flood discharge, in cubic feet per second, from frequency analysis of station data using a weighted skew coefficient. Line 2: Flood discharge , in cubic feet per second, from regional regression equation. Line 3: Weighted flood discharge, in cubic feet per second. Line 4: (95-percent confidence interval of weighte flood discharge)								Maximum peak used in analysis, cubic feet per second
							0.5	0.2	0.1	0.04	0.02	0.01	0.005	0.002	
69	12045500	WA	3	100	0.118	0.084	14,100	21,200	26,100	32,400	37,200	42,100	47,000	53,700	41,600
							10,400	15,600	19,200	23,800	27,300	31,000	34,600	39,700	
							14,100	21,100	25,900	32,100	36,800	41,400	46,200	52,500	
							(12700 - 15600)	(19000 - 23500)	(22900 - 29400)	(27500 - 37500)	(30600 - 44200)	(33500 - 51300)	(36100 - 59000)	(39300 - 70200)	

Regression region	Number of stations used in analysis	Form of the regression equation	Annual exceedance probability	Constant	Coefficents			S_p (percent)	R^2_{pseudo}	SEM (percent)	Range of values		
				a	*b*	*c*	*d*				*A*	*P*	CAN
1	93	$Q = aA^{b}10^{cP}/10^{dCAN}$	0.5	3.846	0.745	0.032	0.0078	95.04	85.1	90.72	0.25–3,304	9.82–52.45	0.0–77.4
			0.2	12.106	0.713	0.028	0.0098	71.93	87.66	68.33			
			0.1	22.080	0.695	0.026	0.0107	70.67	86.72	66.91			
			0.04	42.170	0.674	0.024	0.0117	77.42	83.38	73.12			
			0.02	63.826	0.661	0.023	0.0124	84.76	80.32	79.92			
			0.01	92.470	0.649	0.022	0.0130	93.55	77.01	88.08			
			0.005	129.42	0.637	0.021	0.0136	103.98	73.32	97.75			
			0.002	193.20	0.624	0.020	0.0143	118.69	68.66	111.33			

Identify Project Type and Goals

- Prior to a water crossing design or hydraulic modeling, the designer should clearly identify the type and goals of the project, for example:
  - Flood risk
  - Water crossing design
  - Water crossing hydraulics
  - Scour
  - Scour countermeasure design
  - Etc.

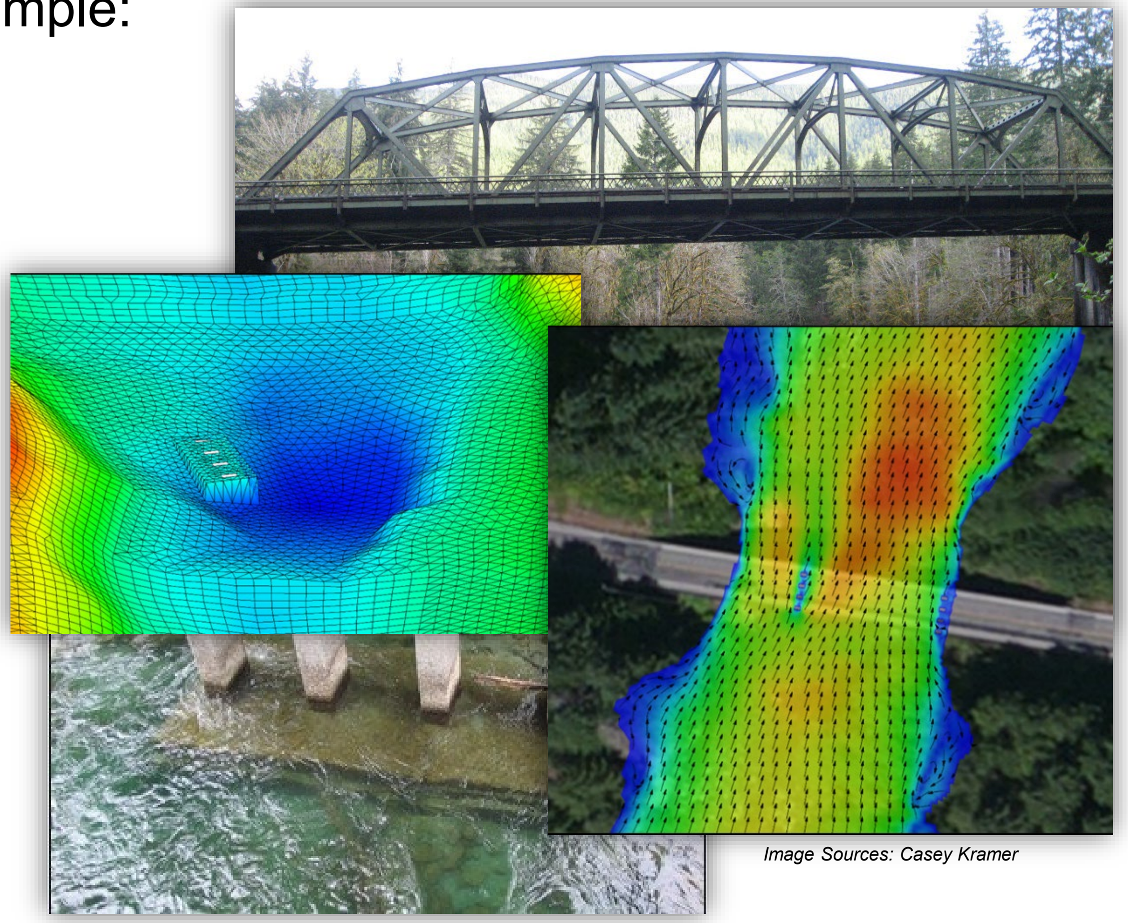


Image Sources: Casey Kramer

Extracting Hydraulic Variables from a Hydraulic Model for Computing Scour

- Aligning water crossing hydraulic modeling with intended application
  - Appropriate losses as part of flood inundation modeling
  - Detailed water crossing hydraulics for scour assessment

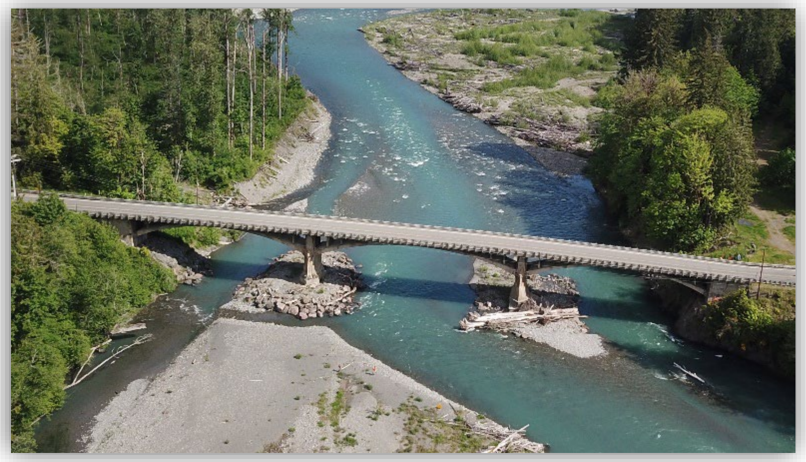


Image Sources: Casey Kramer

- Aligning water crossing hydraulic modeling results to a given scour equation
  - Averaged hydraulic parameters
  - Localized hydraulic parameters

Why SMS?

- Efficient, effective, and consistent means of extracting hydraulic variables for scour analysis
- Uses arcs to define the approach and contracted sections, bank stations, piers, and abutments
- Extracts main channel averaged hydraulic parameters
- Extracts overbank averaged hydraulic parameters
- Adjusts for structure and pier skew

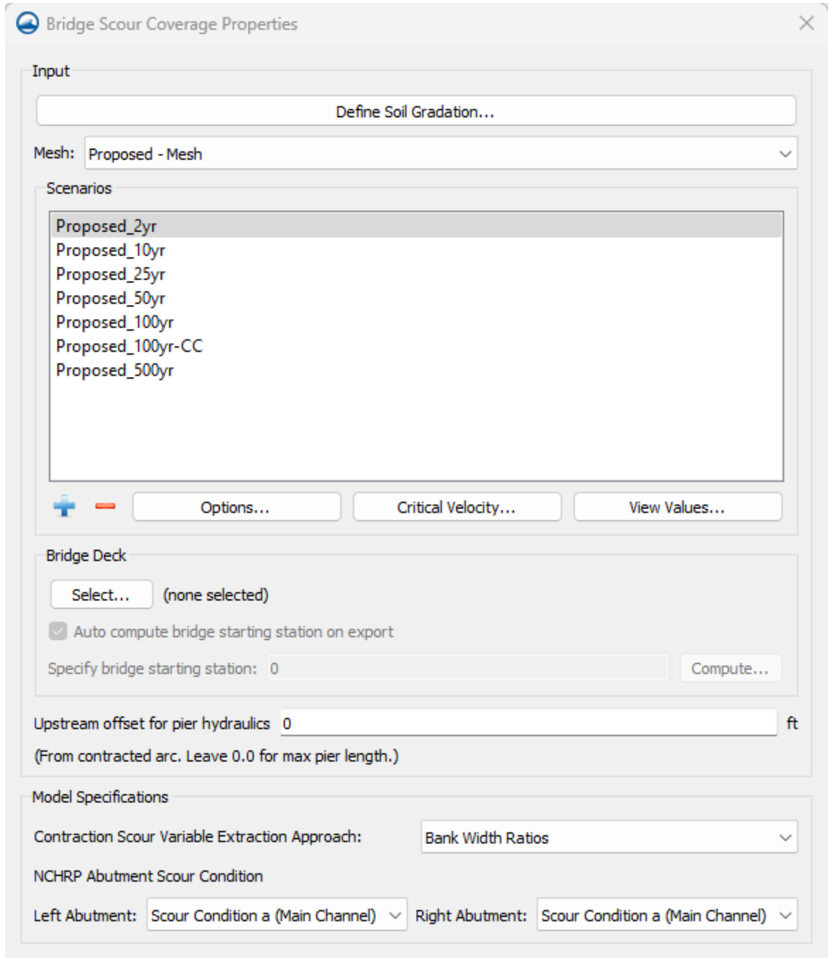
Image Source: Casey Kramer

Why SMS?

- SMS/SRH-2D (v13.2/v3.5)
  - Community version free to all
  - ‘Pro’ version licenses provided to all FHWA/DOT staff
  - ‘Pro’ version licenses free to anyone in an official review role
- SMS/SRH-2D Bridge Scour Tutorials
  - Introduction to Bridge Scour Tool (Aquaveo Learning Center)
  - FHWA Bridge Scour Overview and Tutorials
  - SMS Bridge Scour Workflow Instructions (Aquaveo website)

Why SMS?

- Prompts for supporting data
  - Channel bed (and subsurface) material gradation
  - Pier shape and type
  - Abutment type and scour condition
- Extracts values for multiple flows
- Extracts channel geometry
- Extracts bridge geometry (when present)
- Generates a Hydraulic Toolbox input file
- View values allows preview of variables or use in other applications
- <u>**Always confirm values from SMS are properly used in Hydraulic Toolbox**</u>



Why FHWA Hydraulic Toolbox?

- Efficient, effective, and consistent means of computing scour following HEC-18 (2012)
- Includes calculators for each scour component
- Summary Table provides scour estimates for multiple flow events
- FHWA Hydraulic Toolbox (v5.2.0) (March 20, 2023)