# WSDOT
# Scour Workshop

## Module 9
## Pier Scour

June 1st, 2023

# 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

# Pier Scour Overview

- Pier scour processes and alignment of appropriate analysis
- Factors that influence pier scour
- Importance of surface and subsurface material data
- Bridge hydraulics and pier design
- Pier Scour calculations and evaluation

*Image Source: Casey Kramer*

# Pier Scour Processes

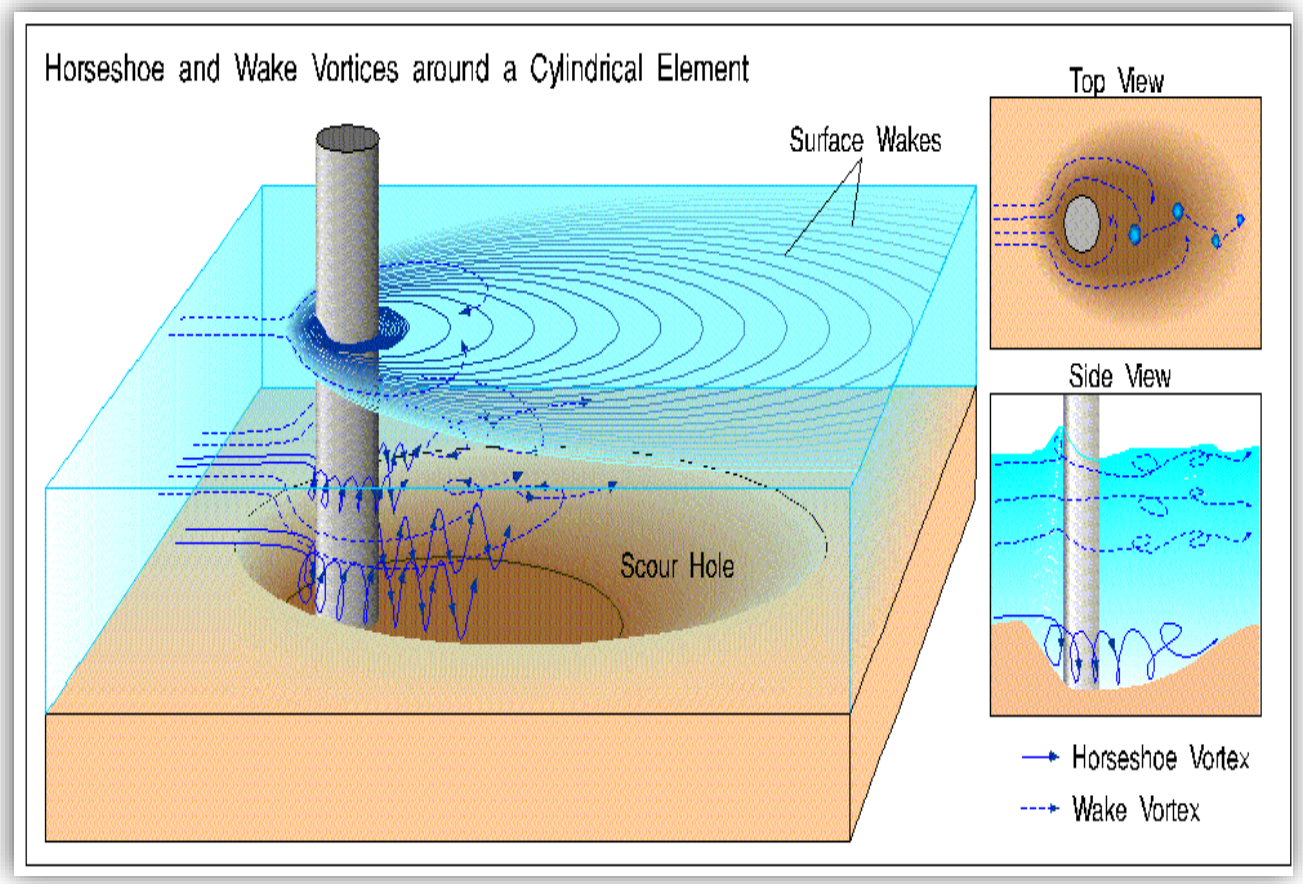



Image Source: FHWA

*Image Source: Casey Kramer*

# Pier Scour

- Detailed information on pier scour can be found in HEC-18

- HEC-18 includes pier scour equations for:
  - Sand bed channels
  - Coarse bed channels
  - Cohesive and erodible rock materials
  - Complex pier geometry
  - Debris accumulations

HEC-18 Available Pier Scour Methods

- HEC-18 Equation (Section 7.2)
- Florida DOT Methodology (Section 7.3)
- Wide Piers (Section 7.4)
- Complex Pier Geometry (Section 7.5)
- Multiple Columns (Section 7.6)
- Debris on Piers (Section 7.7)
- Coarse Bed Materials (Section 7.11)
- Cohesive Materials (Section 7.12)
- Erodible Rock (Section 7.13)

# Pier Scour

*Image Sources: Casey Kramer*

Pier Scour – Rule of Thumb

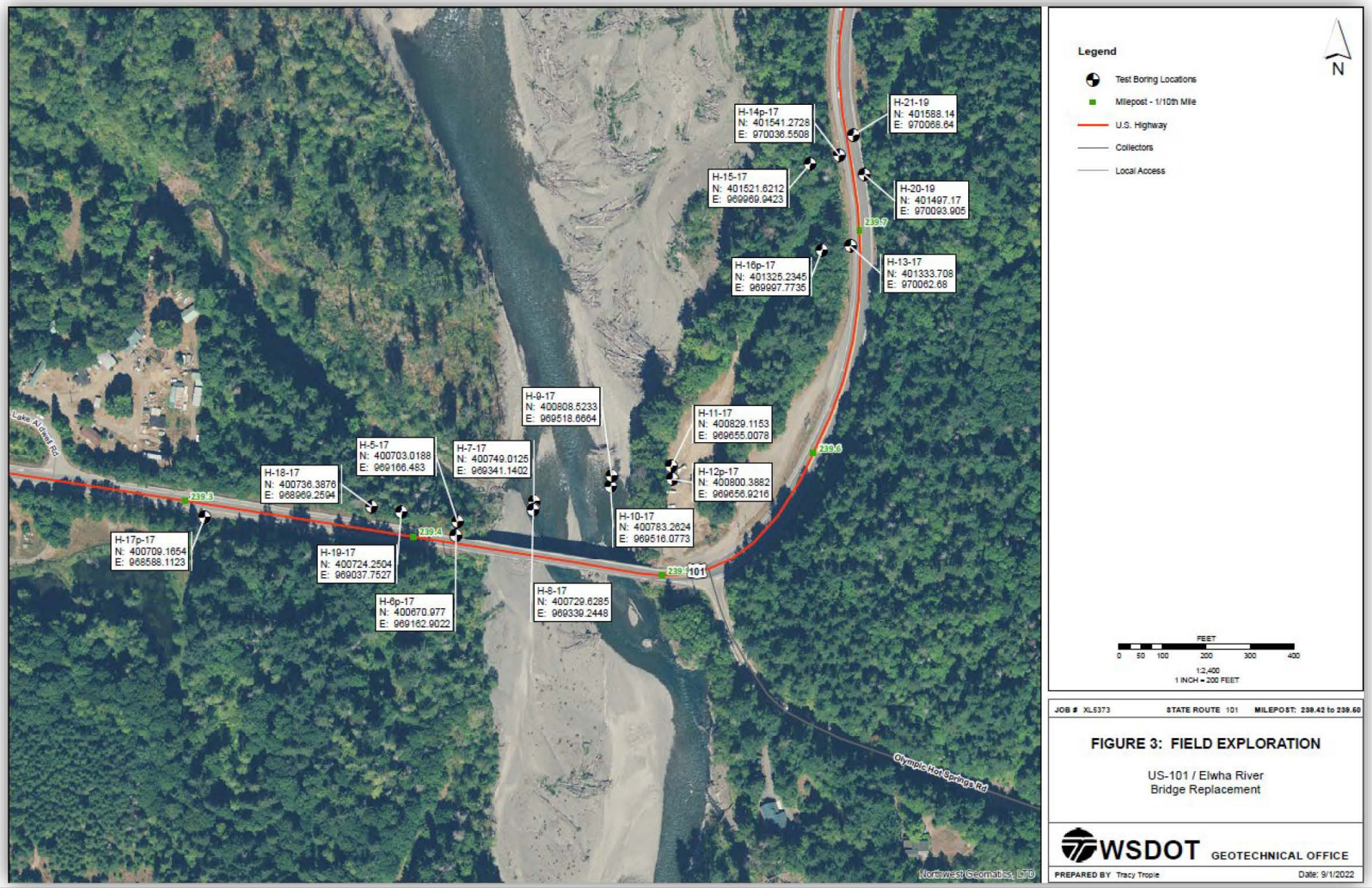
$y_s \leq$ 2.4 times pier diameter for $Fr \leq 0.8$

$y_s \leq$ 3.0 times pier diameter for $Fr > 0.8$

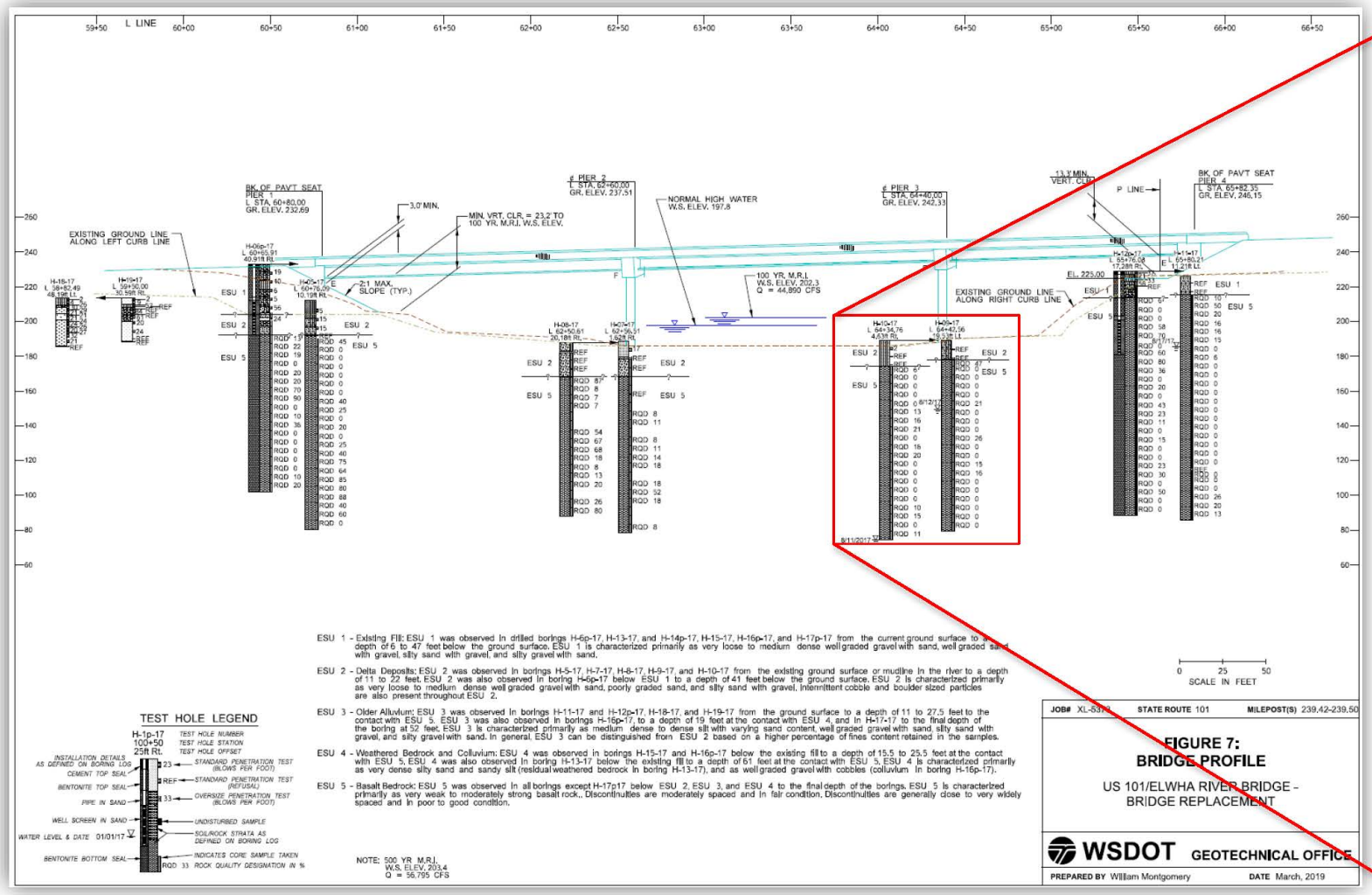
# Surface and Subsurface Material

*Image Sources: Casey Kramer*

# Surface and Subsurface Material



# Subsurface and Subsurface Material



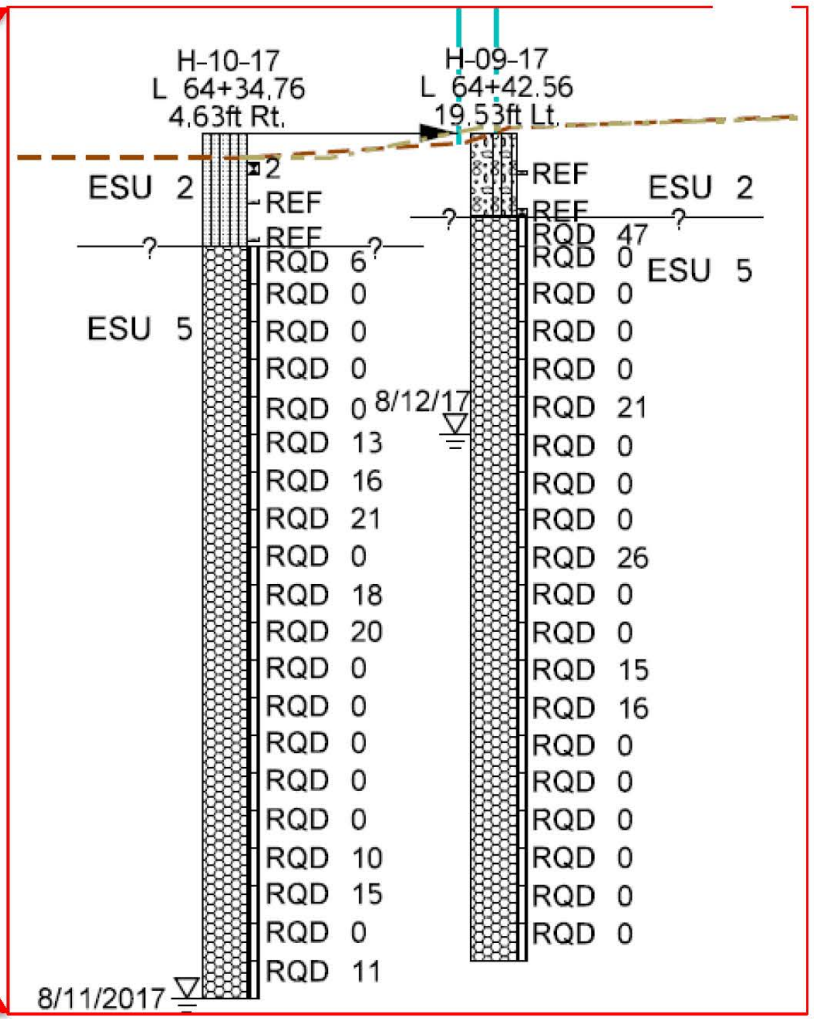




*Image Source: WSDOT*

# Subsurface and Subsurface Material

Surface Gradation
(Pebble Count)

| Particle Percent Smaller Than | Downstream Diameter (in) |
|---|---|
| $D_{16}$ | 1.7 |
| $D_{50}$ | 3.4 |
| $D_{84}$ | 6.8 |
| $D_{100}$ | 14.3 |

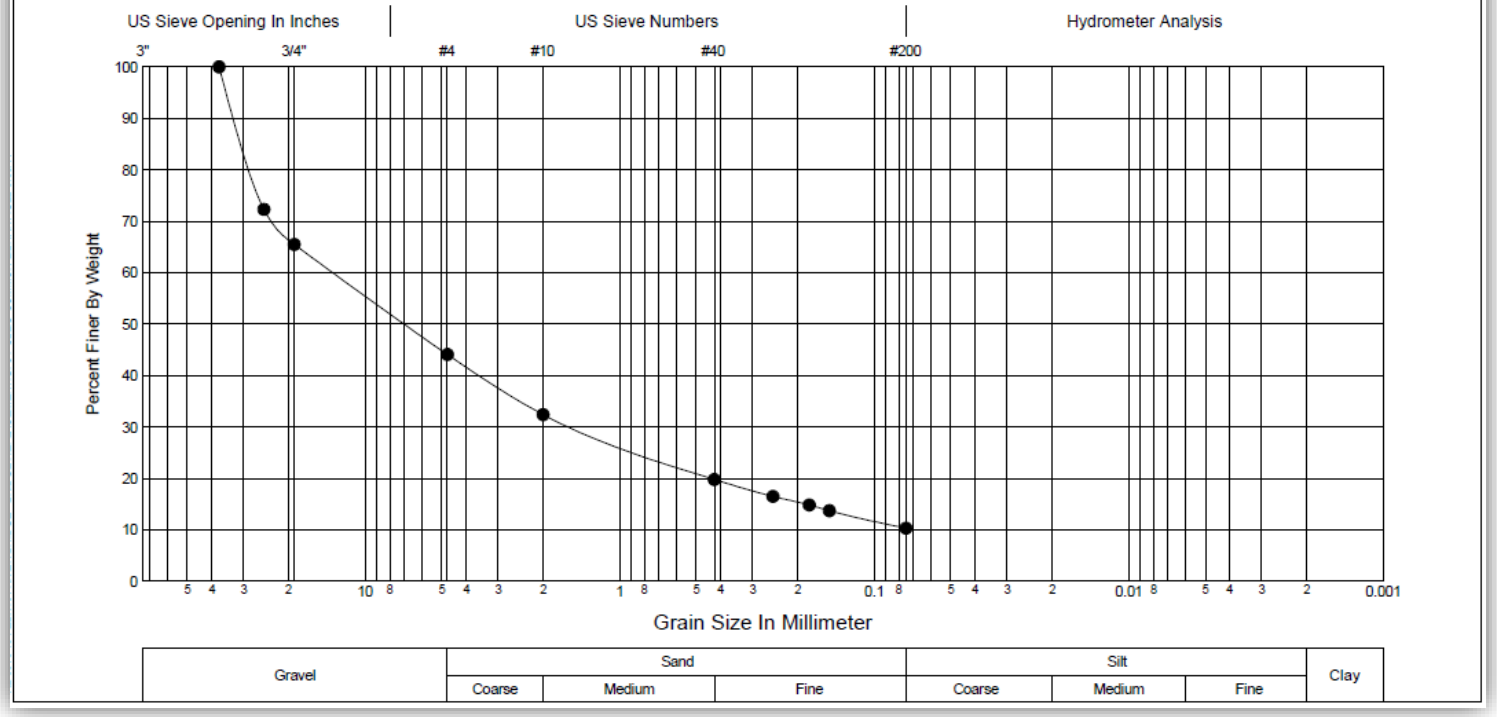
*Image Sources: WSDOT*

Job No. XL-5373 Date August 30, 2017
Hole No. H-9-17 Pier 3 Downstream Sheet 1
Project US101 Elwha River Bridge - Bridge Replacement

Laboratory Summary

WSDOT

| | Depth (ft) | Sample No. | USCS | Description | MC% | LL | PL | PI | Moist Density (lbs/ft³) | Specific Gravity | Gravel (%) | Sand (%) | Fines (%) | Cc | Cu | D60 | D50 | D30 | D20 | D10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | 10.0 | D-2 | GW-GM | WELL-GRADED GRAVEL with SILT and SAND | 7 | | | | | | 55.9 | 33.8 | 10.3 | 2.4 | 189.2 | 13.322 | 6.97 | 1.49 | 0.44 | |




Subsurface Gradation – Geotechnical Boring

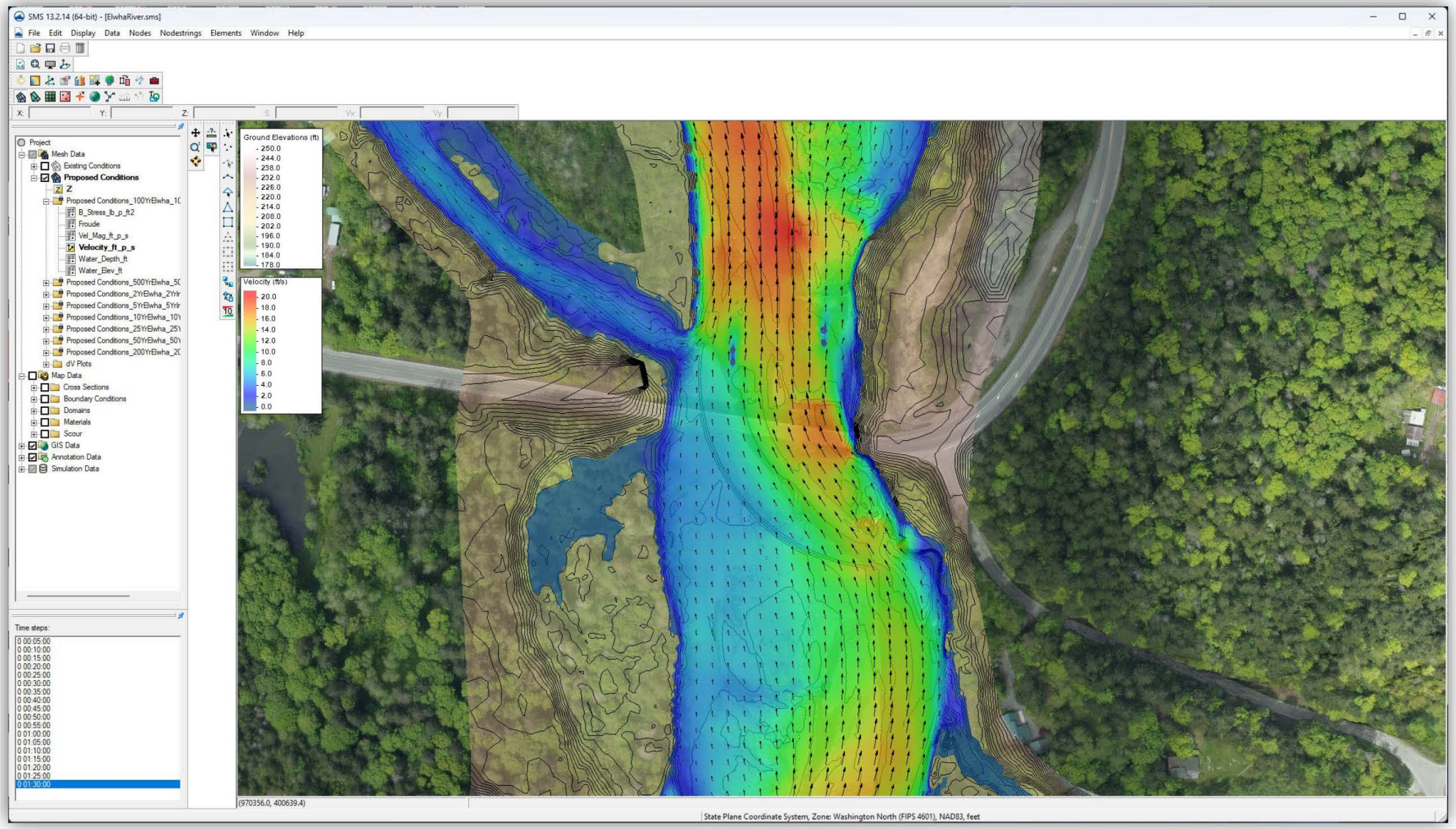
# Debris Potential

*Image Source: Casey Kramer*

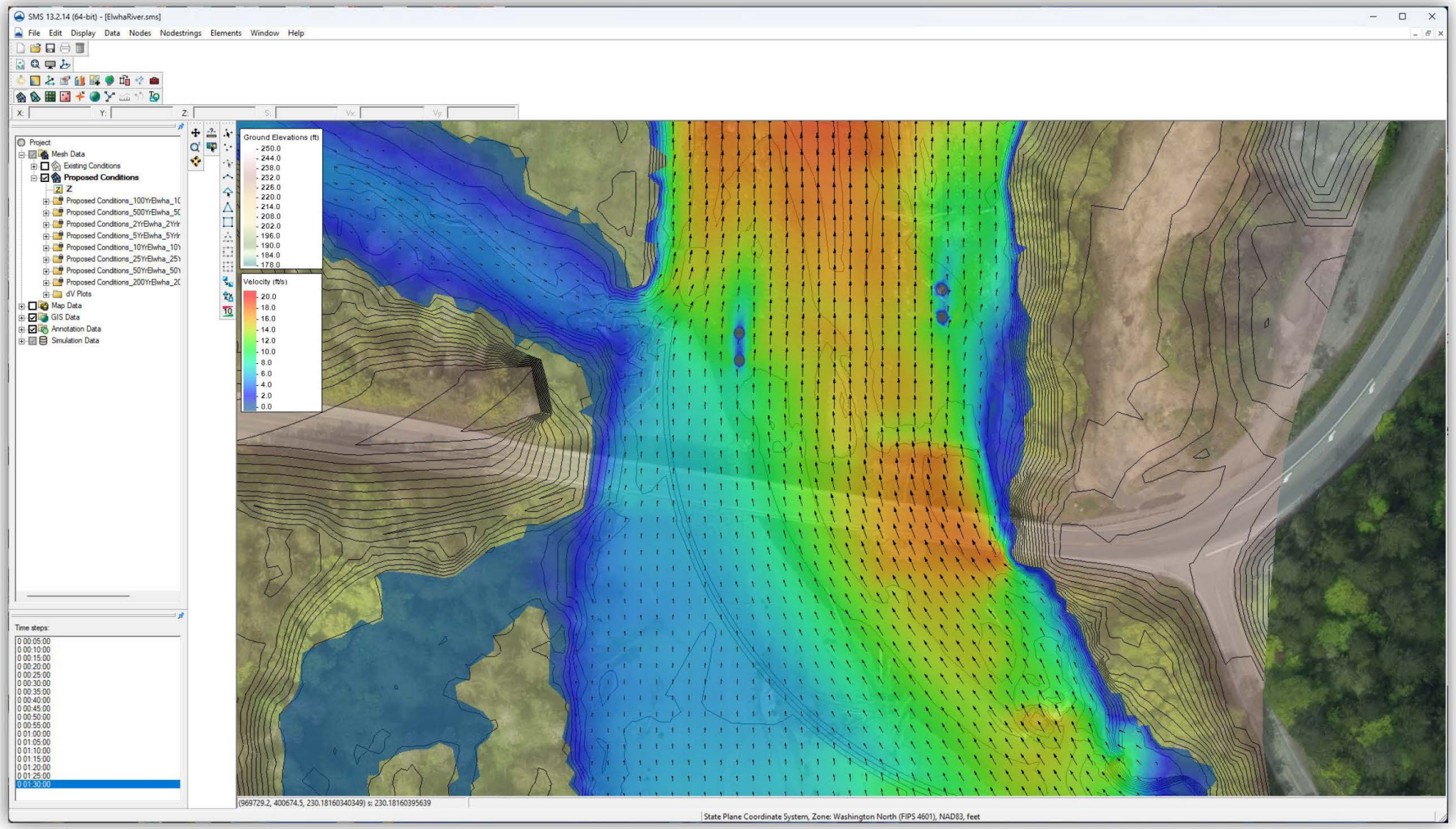
# Debris Potential

*Image Sources: Casey Kramer*

# Bridge Hydraulics



# Bridge Hydraulics



# Bridge Layout

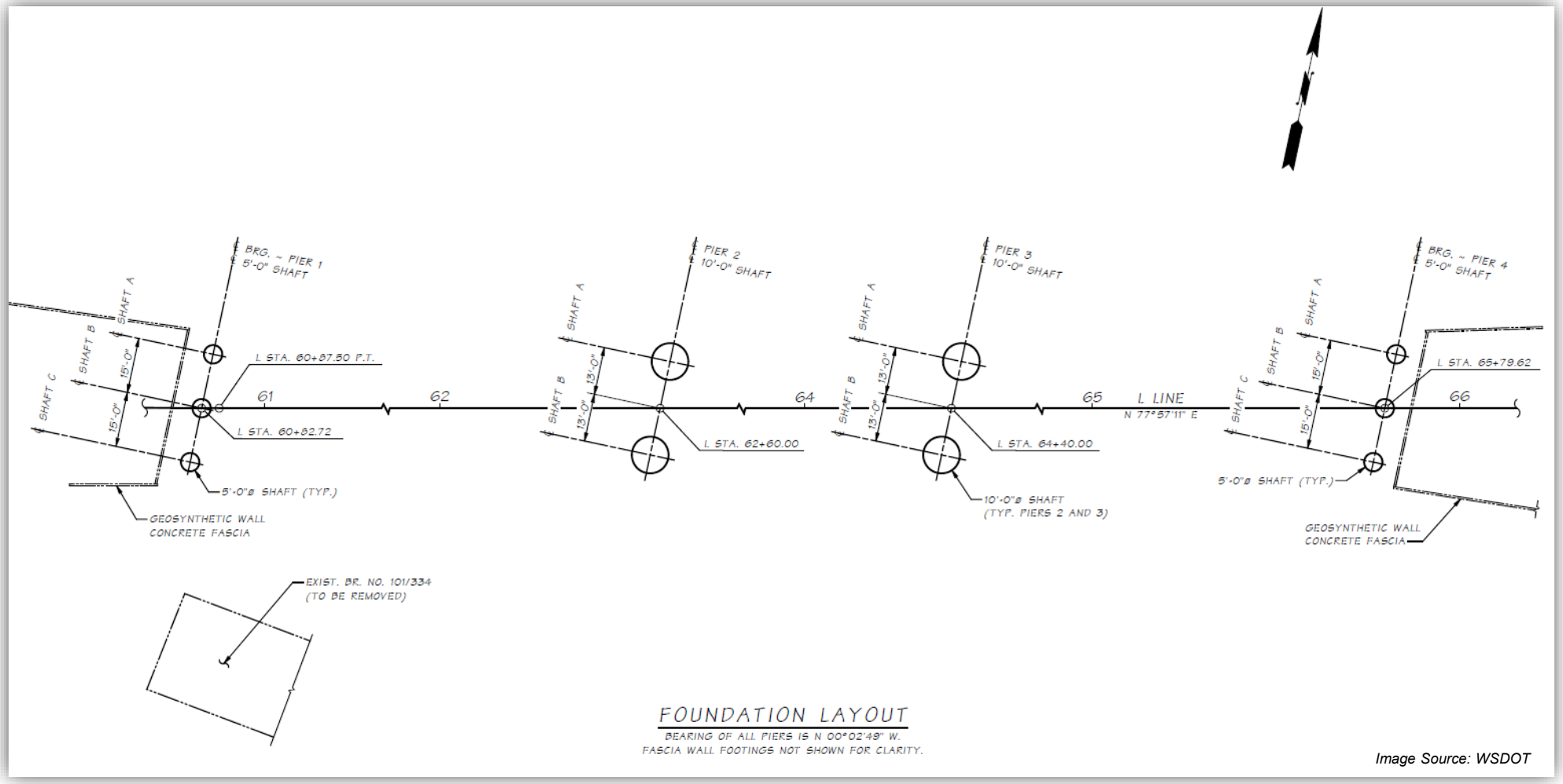



*Image Source: WSDOT*

# Pier 2 and Pier 3 Layout

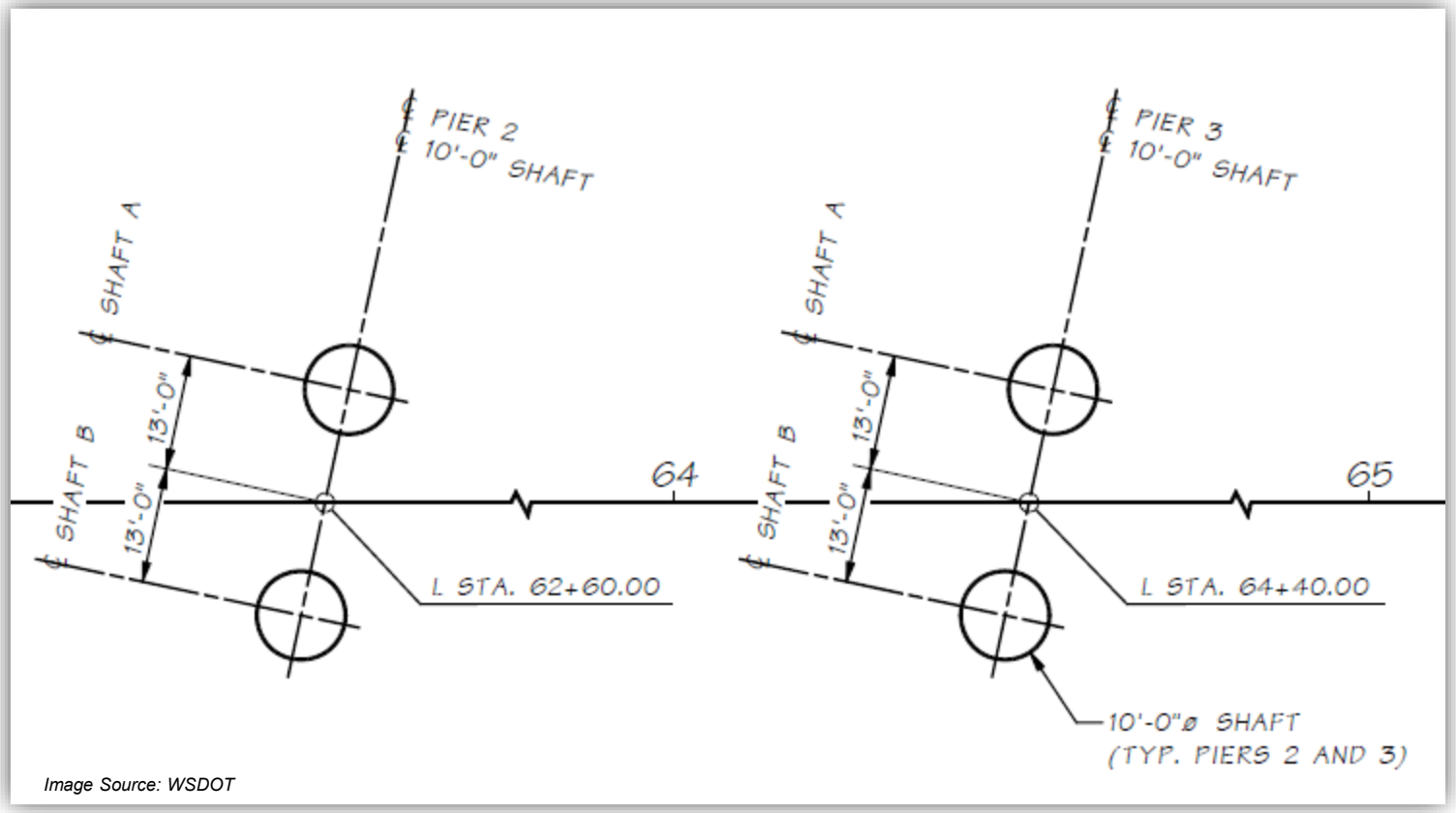



*Image Source: WSDOT*

# Pier 2 Details

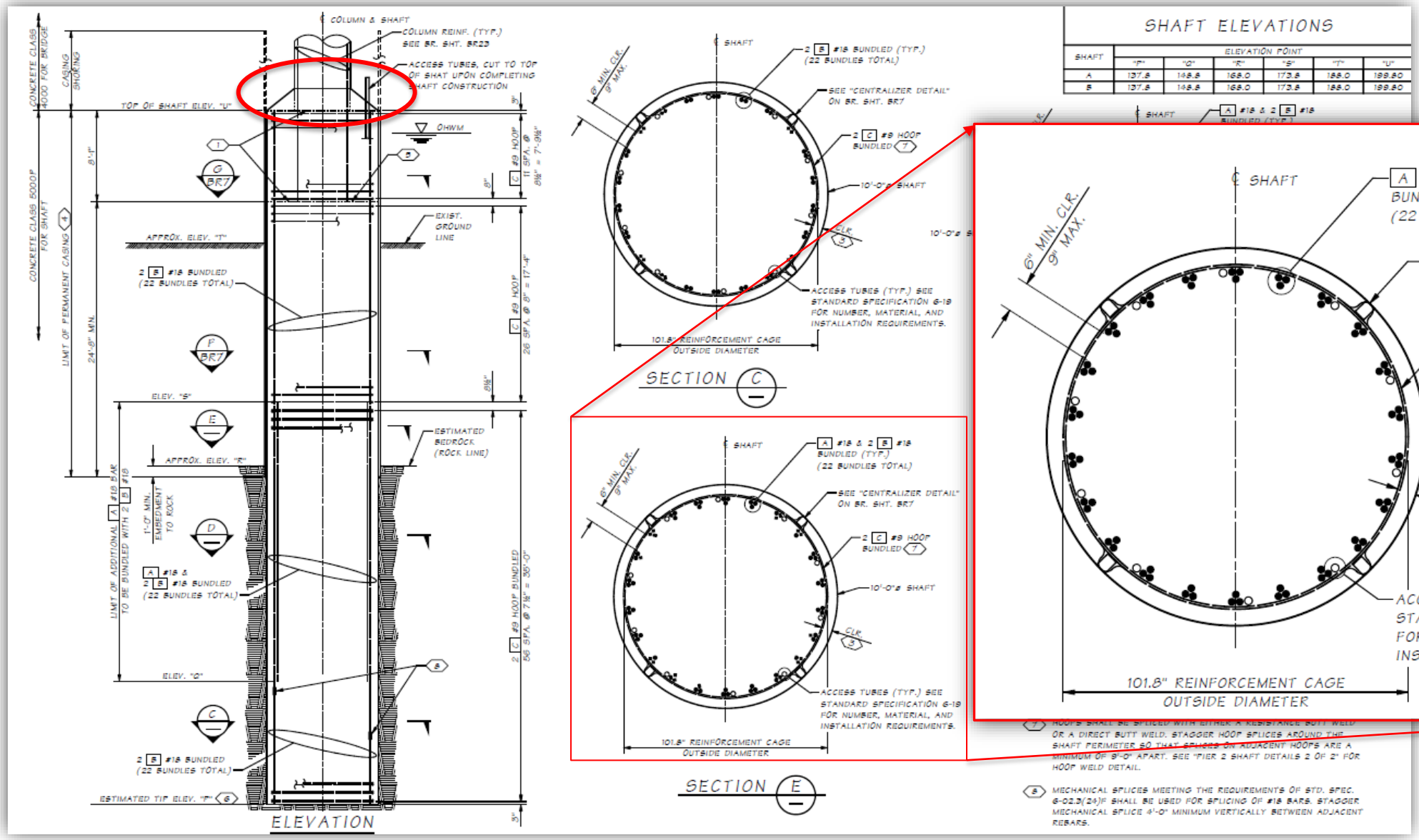
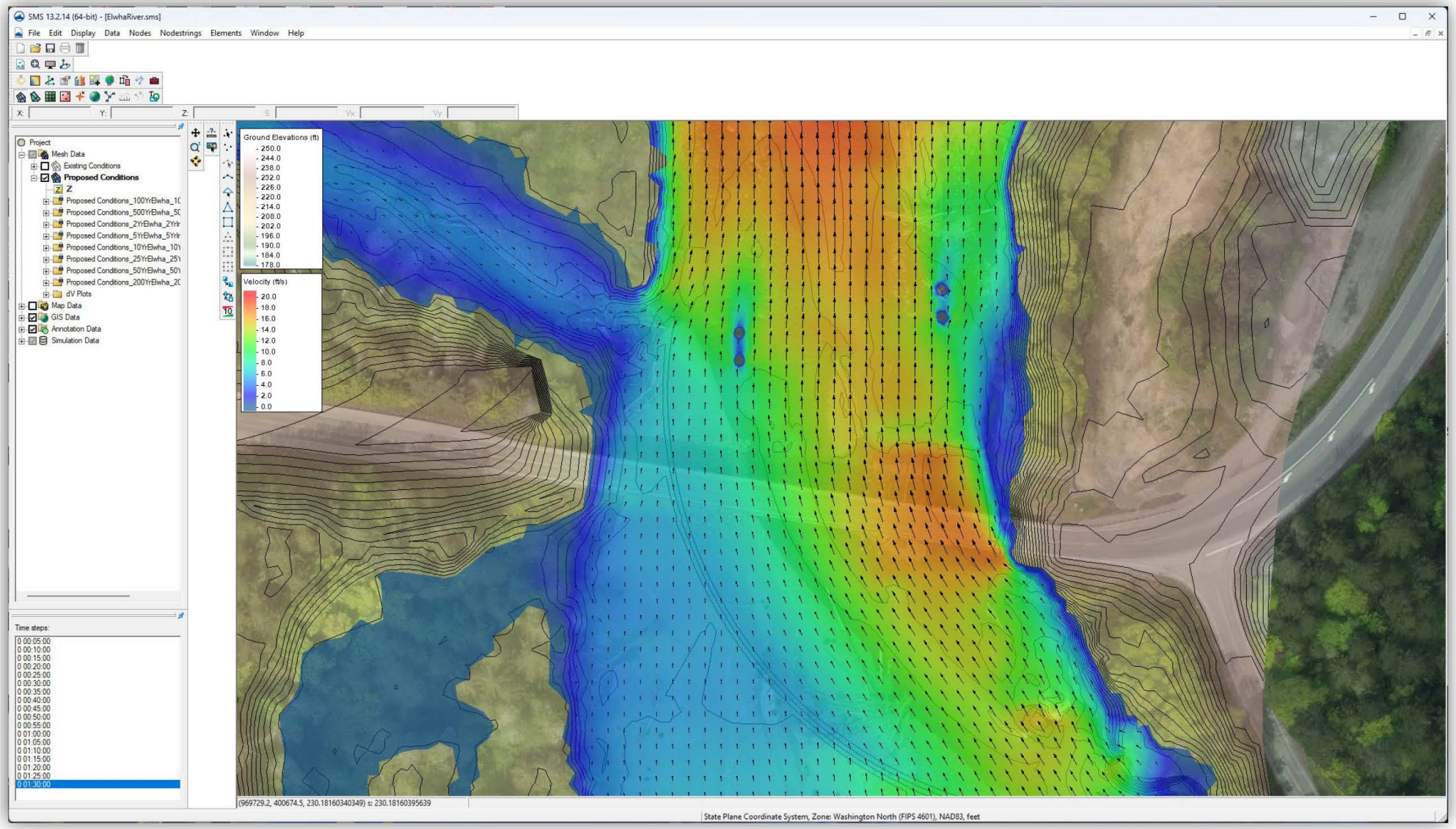



Image Sources: WSDOT

# Bridge Hydraulics



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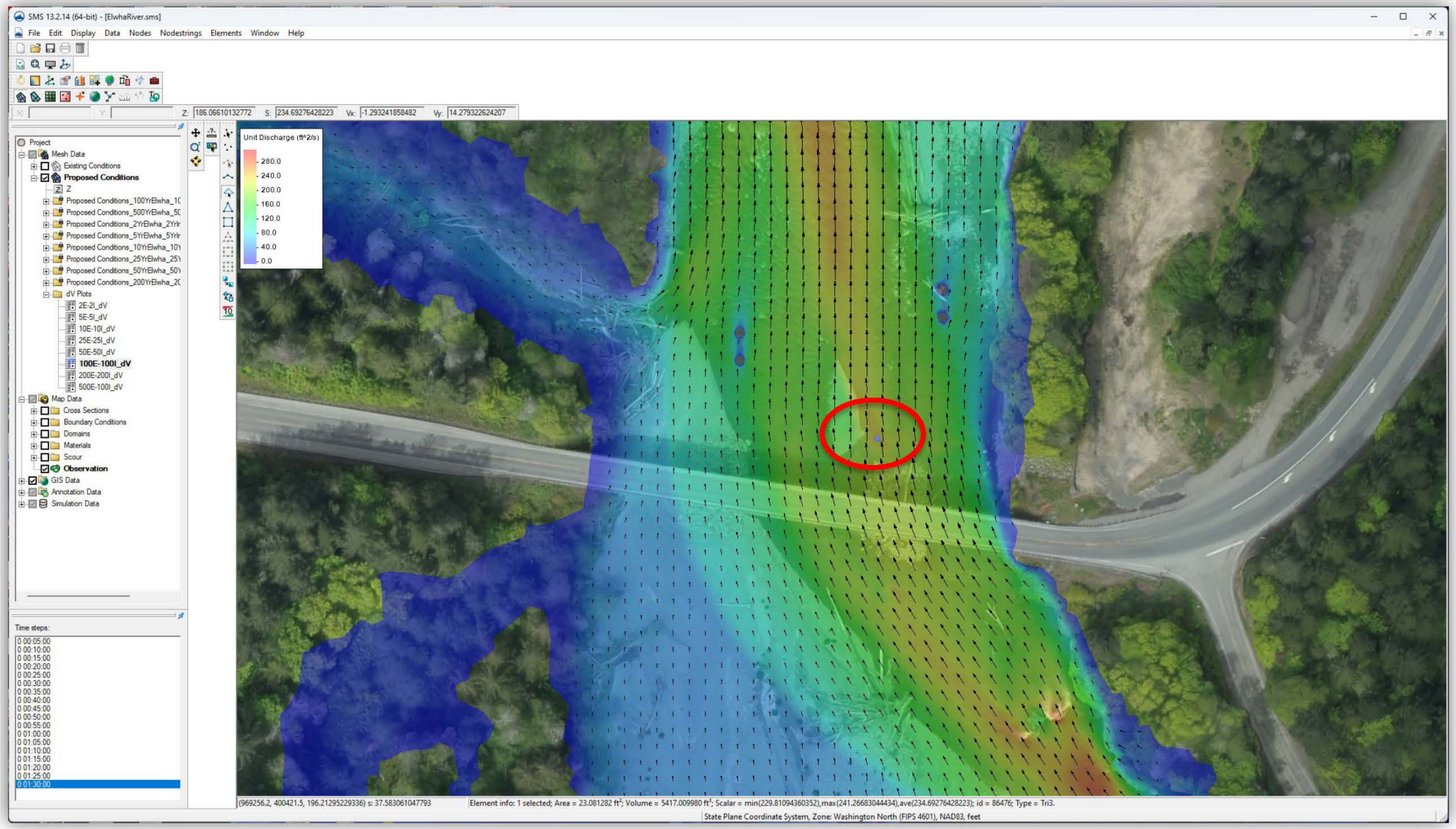
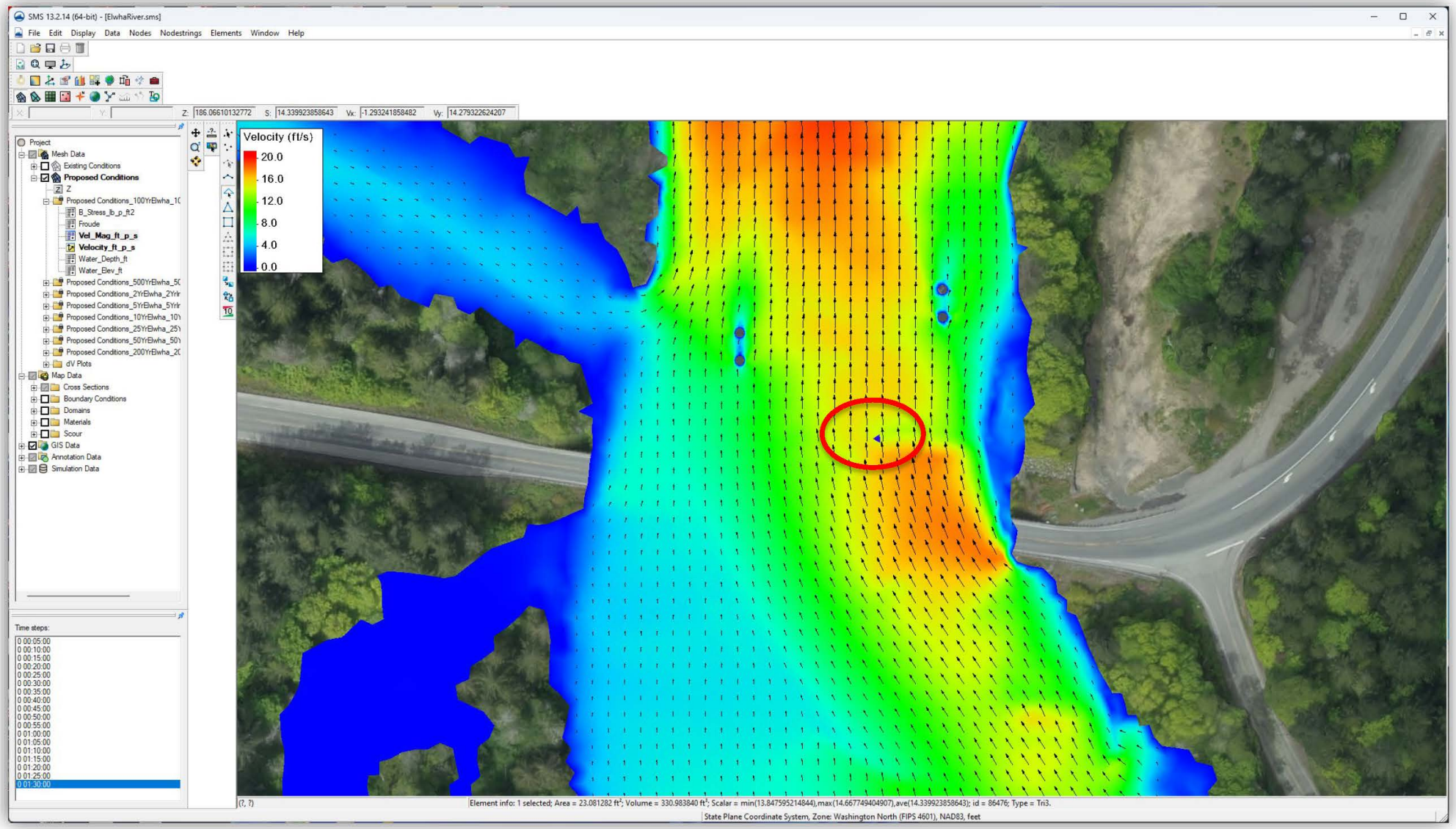


# Bridge Hydraulics



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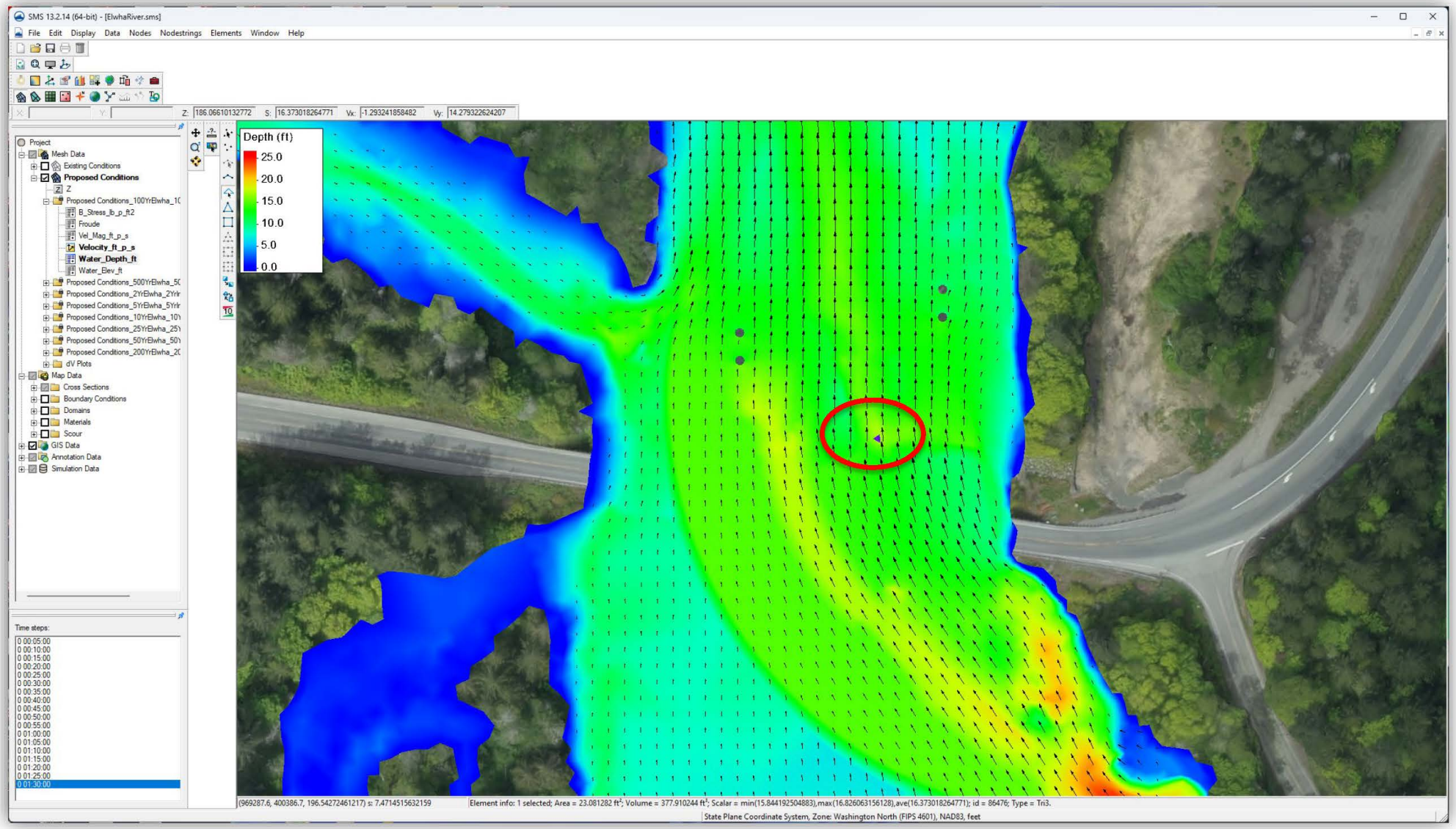

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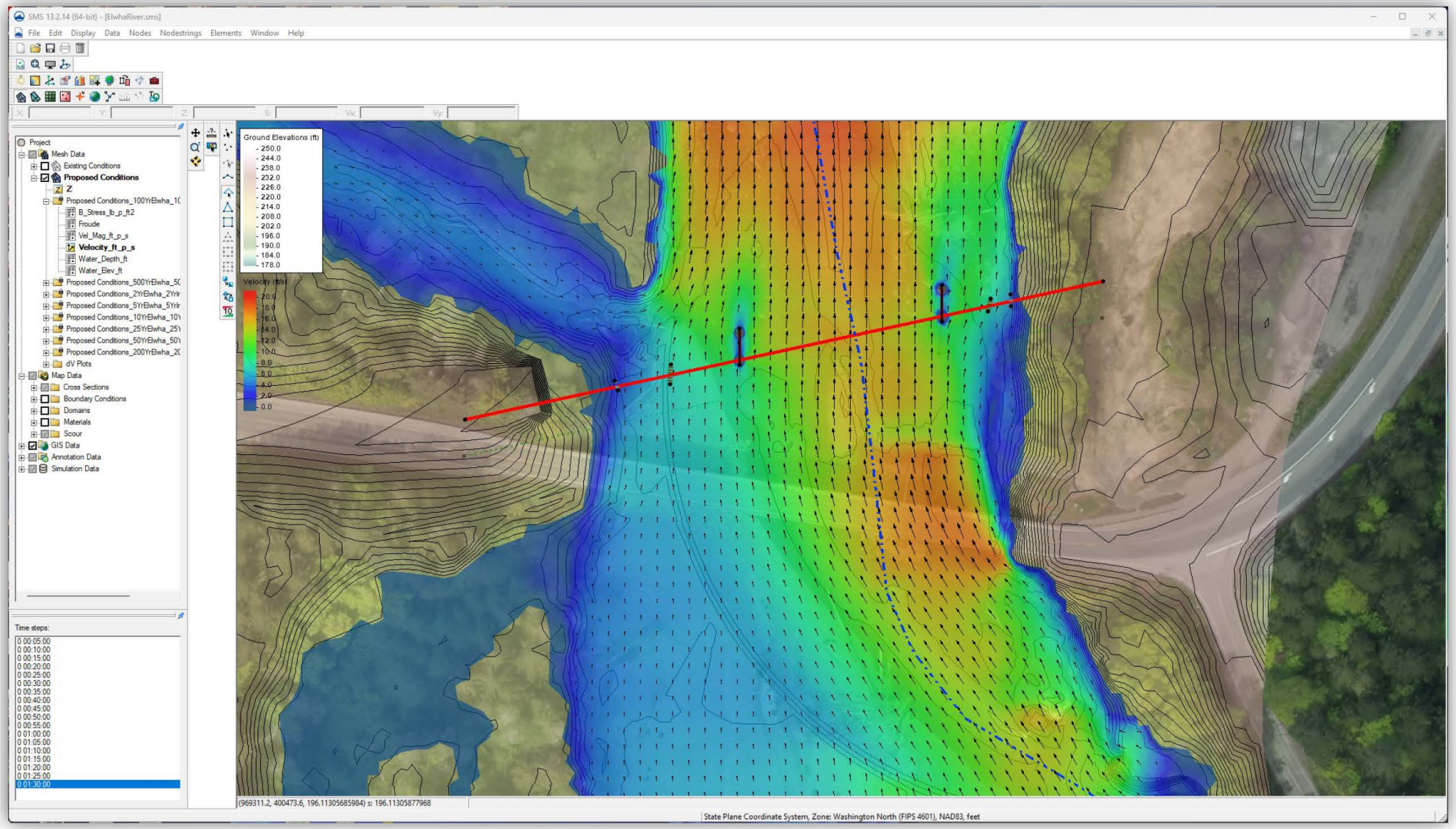

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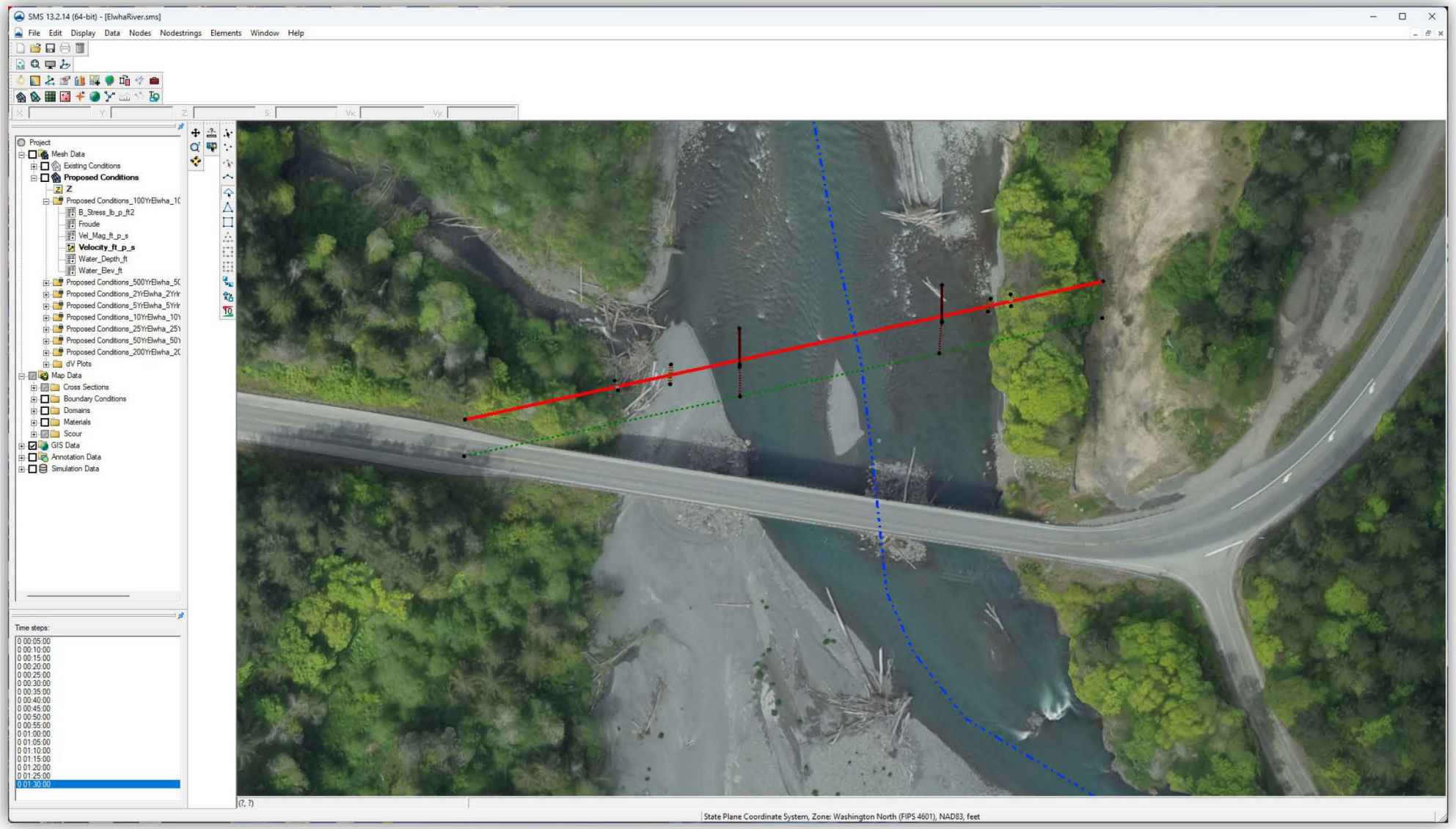

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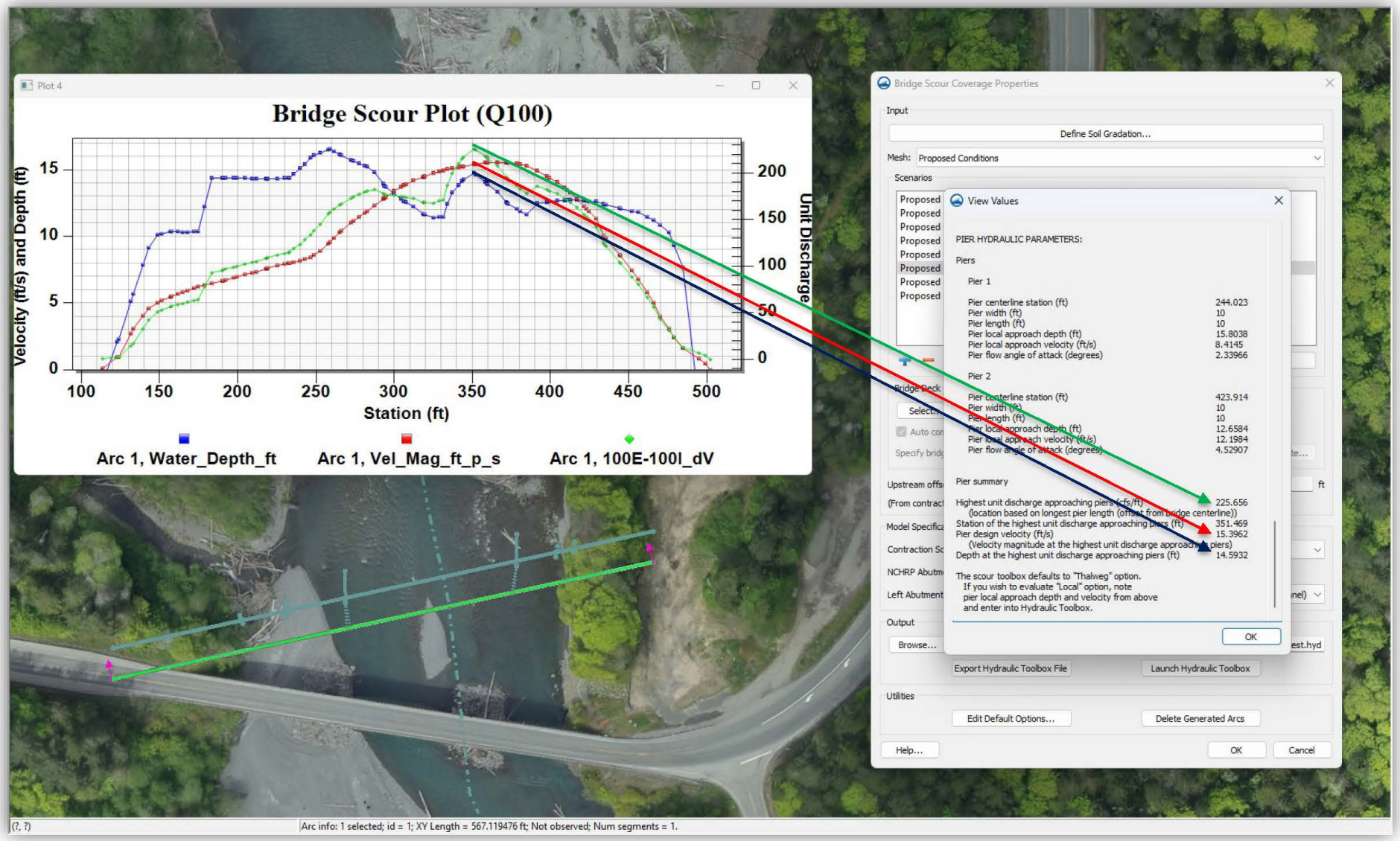

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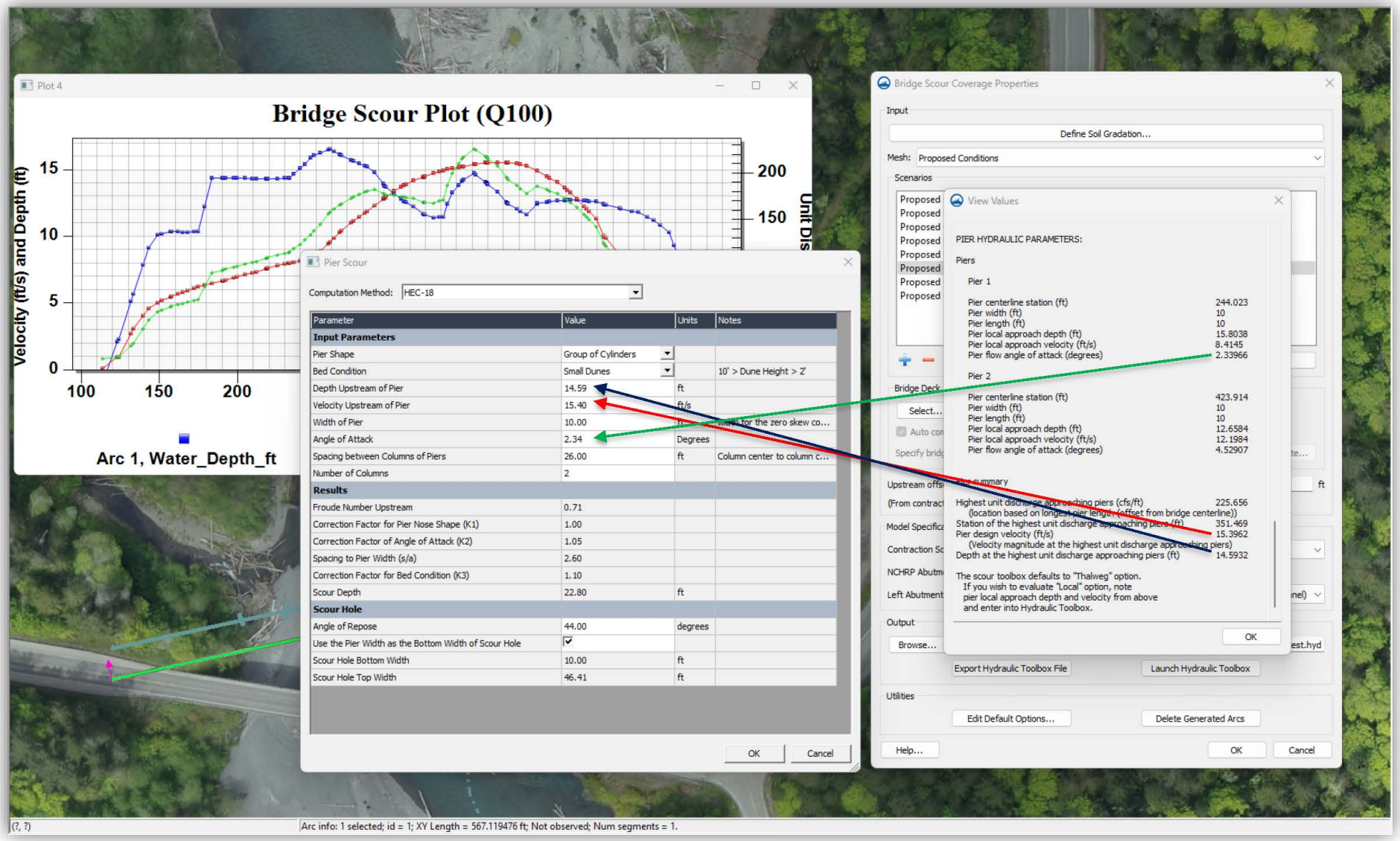


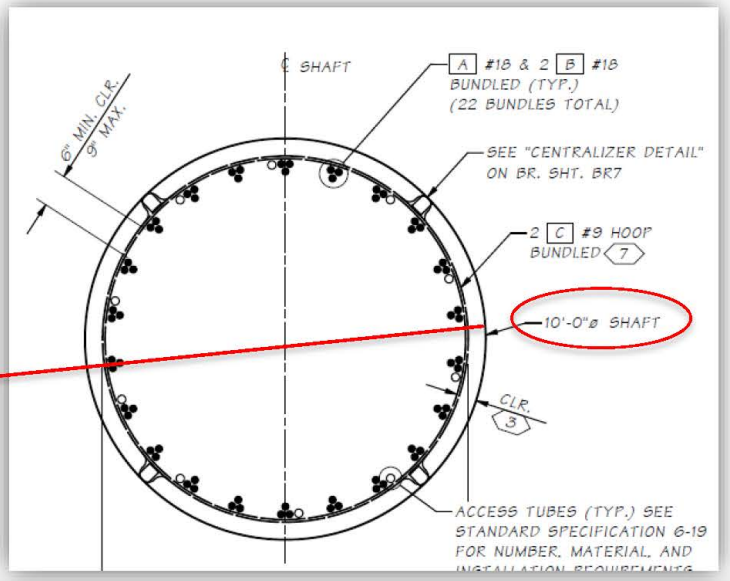
# Pier Scour Inputs

Pier Scour

Computation Method: HEC-18

| Parameter | Value | Units | Notes |
|---|---|---|---|
| **Input Parameters** | | | |
| Pier Shape | Group of Cylinders | | |
| Bed Condition | Small Dunes | | 10' > Dune Height > 2' |
| Depth Upstream of Pier | 14.59 | ft | |
| Velocity Upstream of Pier | 15.40 | ft/s | |
| Width of Pier | 10.00 | ft | width for the zero skew co... |
| Angle of Attack | 2.34 | Degrees | |
| Spacing between Columns of Piers | 26.00 | ft | Column center to column c... |
| Number of Columns | 2 | | |
| **Results** | | | |
| Froude Number Upstream | 0.71 | | |
| Correction Factor for Pier Nose Shape (K1) | 1.00 | | |
| Correction Factor of Angle of Attack (K2) | 1.05 | | |
| Spacing to Pier Width (s/a) | 2.60 | | |
| Correction Factor for Bed Condition (K3) | 1.10 | | |
| Scour Depth | 22.80 | ft | |
| **Scour Hole** | | | |
| Angle of Repose | 44.00 | degrees | |
| Use the Pier Width as the Bottom Width of Scour Hole | ☑ | | |
| Scour Hole Bottom Width | 10.00 | ft | |
| Scour Hole Top Width | 46.41 | ft | |

OK Cancel



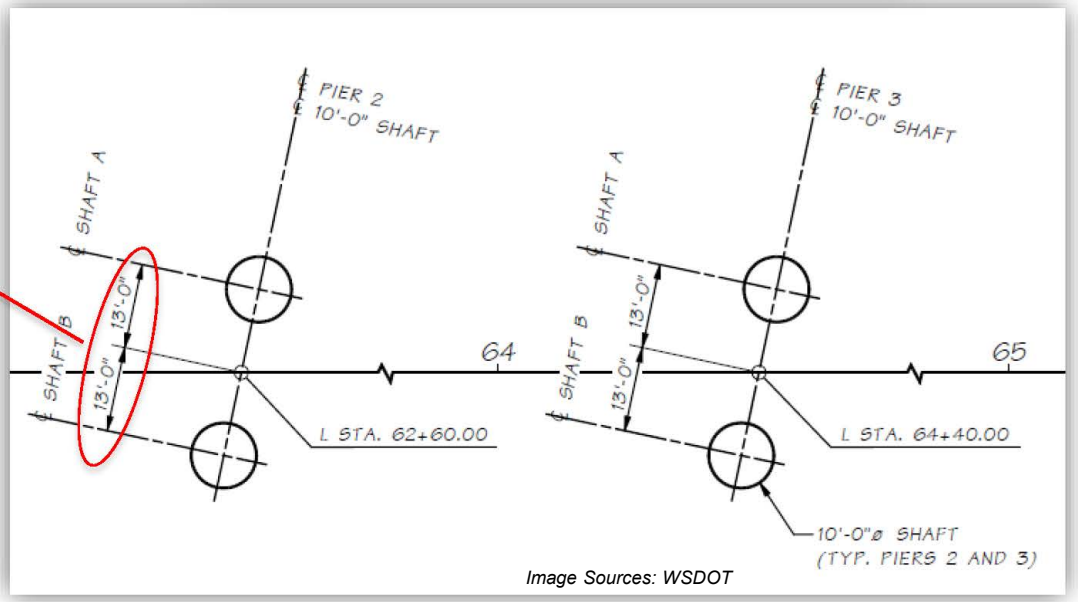
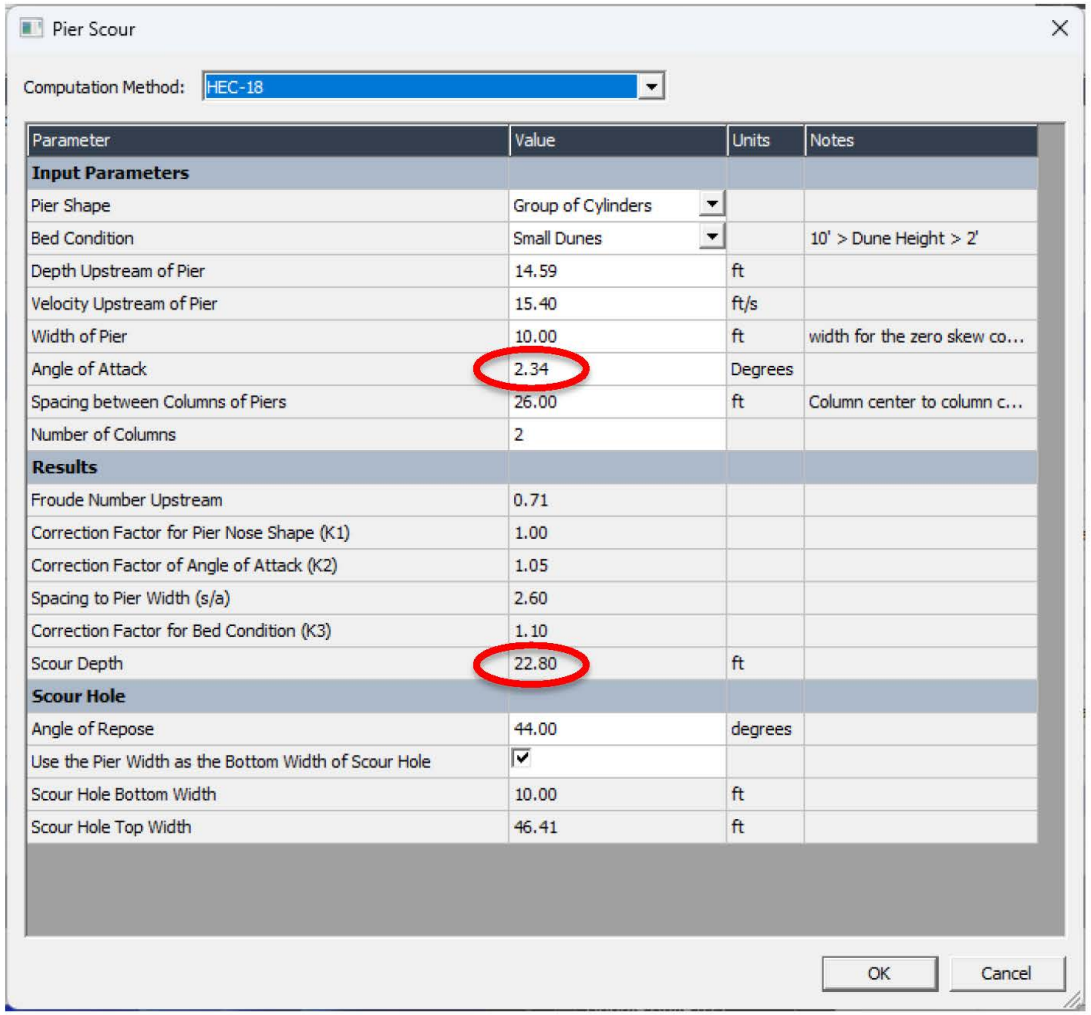




Image Sources: WSDOT

# Bridge Hydraulics




| Parameter | Value | Units | Notes |
|---|---|---|---|
| **Input Parameters** | | | |
| Pier Shape | Group of Cylinders | | |
| Bed Condition | Small Dunes | | 10' > Dune Height > 2' |
| Depth Upstream of Pier | 14.59 | ft | |
| Velocity Upstream of Pier | 15.40 | ft/s | |
| Width of Pier | 10.00 | ft | width for the zero skew co... |
| Angle of Attack | 2.34 | Degrees | |
| Spacing between Columns of Piers | 26.00 | ft | Column center to column c... |
| Number of Columns | 2 | | |
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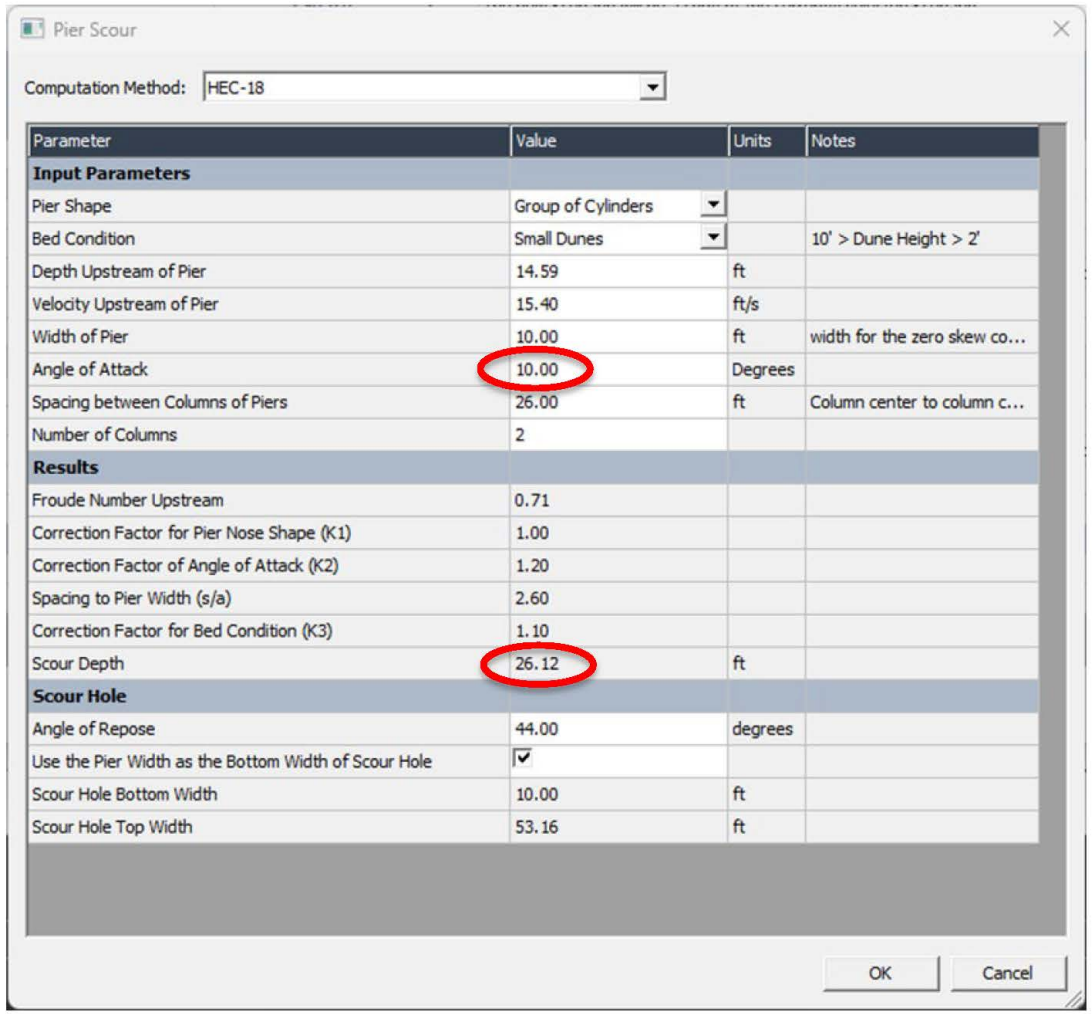
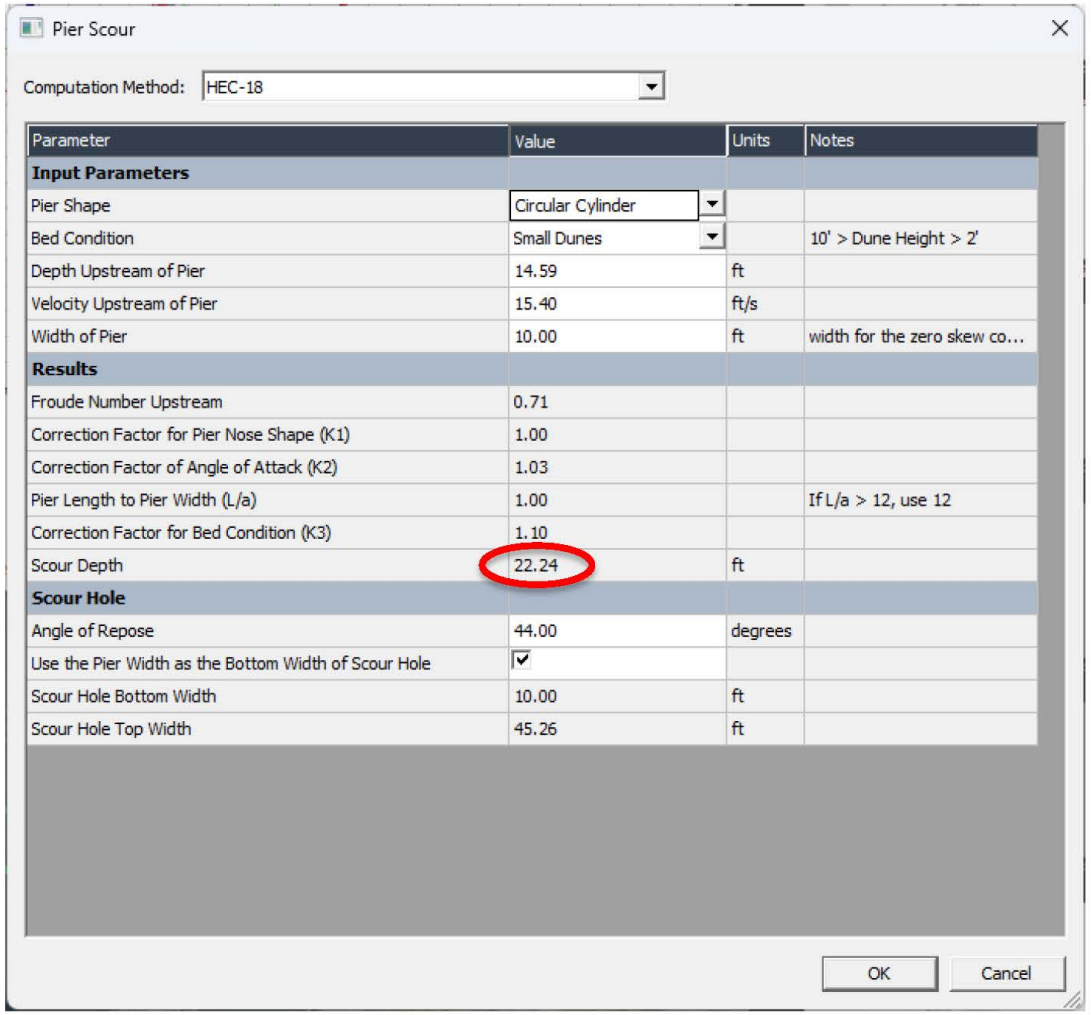
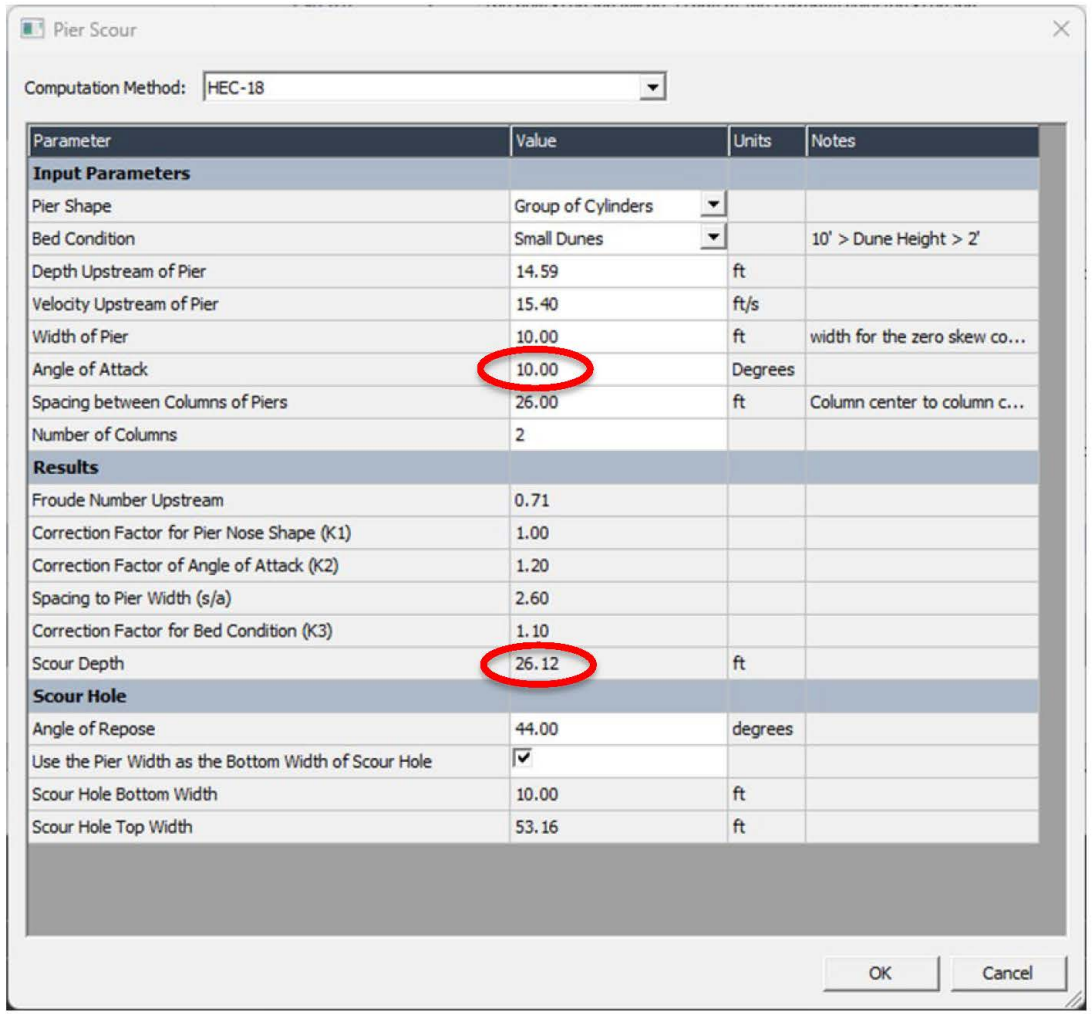
| Scour Depth | 22.80 | ft | |
| **Scour Hole** | | | |
| Angle of Repose | 44.00 | degrees | |
| Use the Pier Width as the Bottom Width of Scour Hole | ☑ | | |
| Scour Hole Bottom Width | 10.00 | ft | |
| Scour Hole Top Width | 46.41 | ft | |



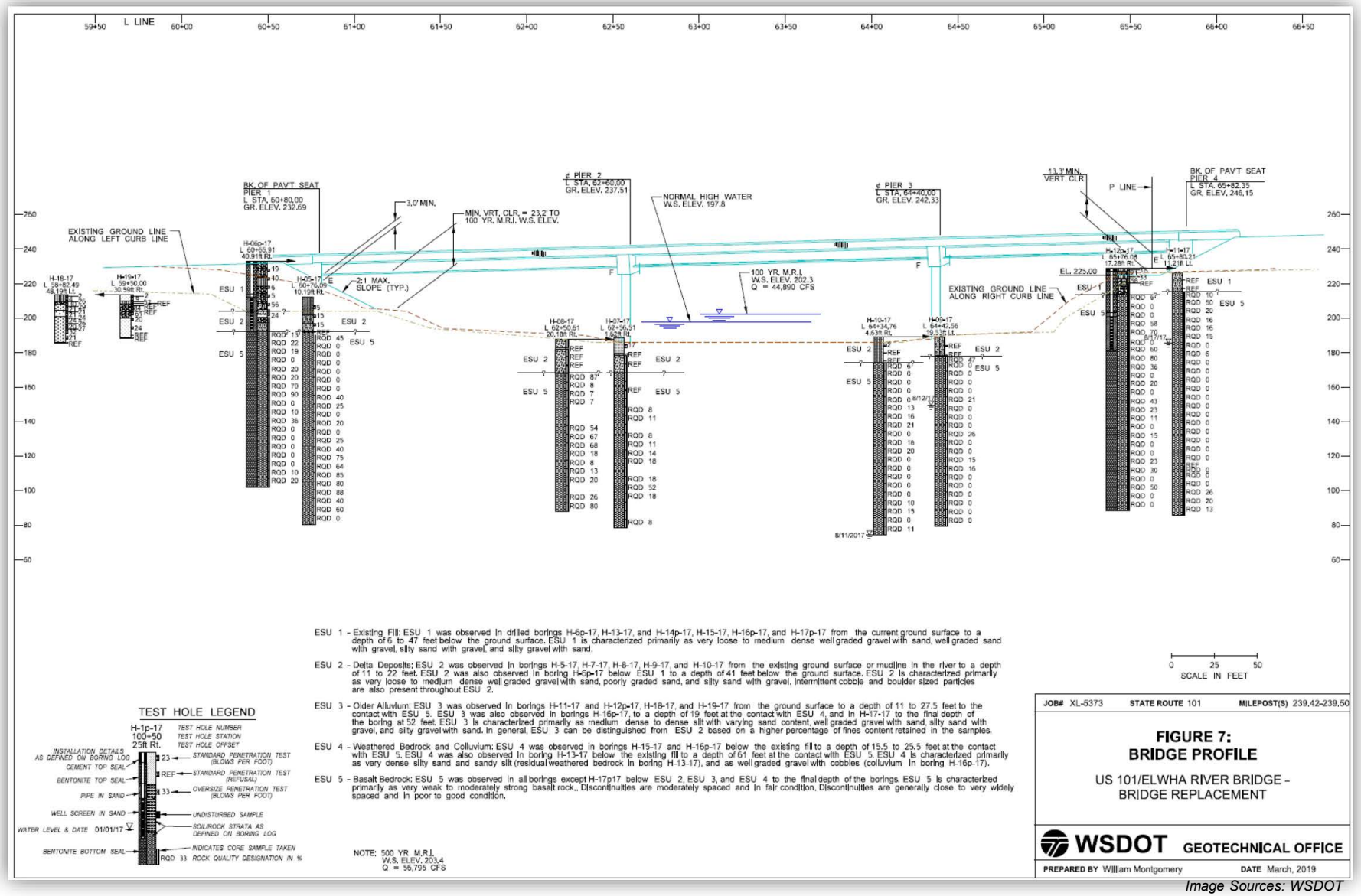

| Parameter | Value | Units | Notes |
|---|---|---|---|
| **Input Parameters** | | | |
| Pier Shape | Group of Cylinders | | |
| Bed Condition | Small Dunes | | 10' > Dune Height > 2' |
| Depth Upstream of Pier | 14.59 | ft | |
| Velocity Upstream of Pier | 15.40 | ft/s | |
| Width of Pier | 10.00 | ft | width for the zero skew co... |
| Angle of Attack | 10.00 | Degrees | |
| Spacing between Columns of Piers | 26.00 | ft | Column center to column c... |
| Number of Columns | 2 | | |
| **Results** | | | |
| Froude Number Upstream | 0.71 | | |
| Correction Factor for Pier Nose Shape (K1) | 1.00 | | |
| Correction Factor of Angle of Attack (K2) | 1.20 | | |
| Spacing to Pier Width (s/a) | 2.60 | | |
| Correction Factor for Bed Condition (K3) | 1.10 | | |
| Scour Depth | 26.12 | ft | |
| **Scour Hole** | | | |
| Angle of Repose | 44.00 | degrees | |
| Use the Pier Width as the Bottom Width of Scour Hole | ☑ | | |
| Scour Hole Bottom Width | 10.00 | ft | |
| Scour Hole Top Width | 53.16 | ft | |

# Bridge Hydraulics



# Subsurface and Subsurface Material




ESU 1 - Existing Fill: ESU 1 was observed in drilled borings H-6p-17, H-13-17, and H-14p-17, H-15-17, H-16p-17, and H-17p-17 from the current ground surface to a depth of 6 to 47 feet below the ground surface. ESU 1 is characterized primarily as very loose to medium dense well graded gravel with sand, well graded sand with gravel, silty sand with gravel, and silty gravel with sand.

ESU 2 - Delta Deposits: ESU 2 was observed in borings H-5-17, H-7-17, H-8-17, H-9-17, and H-10-17 from the existing ground surface or mudline in the river to a depth of 11 to 22 feet. ESU 2 was also observed in boring H-6p-17 below ESU 1 to a depth of 41 feet below the ground surface. ESU 2 is characterized primarily as very loose to medium dense well graded gravel with sand, poorly graded sand, and silty sand with gravel. Intermittent cobble and boulder sized particles are also present throughout ESU 2.

ESU 3 - Older Alluvium: ESU 3 was observed in borings H-11-17 and H-12p-17, H-18-17, and H-19-17 from the ground surface to a depth of 11 to 27.5 feet to the contact with ESU 5. ESU 3 was also observed in borings H-16p-17, to a depth of 19 feet at the contact with ESU 4, and in H-17-17 to the final depth of the boring at 52 feet. ESU 3 is characterized primarily as medium dense to dense silt with varying sand content, well graded gravel with sand, silty sand with gravel, and silty gravel with sand. In general, ESU 3 can be distinguished from ESU 2 based on a higher percentage of fines content retained in the samples.

ESU 4 - Weathered Bedrock and Colluvium: ESU 4 was observed in borings H-15-17 and H-16p-17 below the existing fill to a depth of 15.5 to 25.5 feet at the contact with ESU 5. ESU 4 was also observed in boring H-13-17 below the existing fill to a depth of 61 feet at the contact with ESU 5. ESU 4 is characterized primarily as very dense silty sand and sandy silt (residual weathered bedrock in boring H-13-17), and as well graded gravel with cobbles (colluvium in boring H-16p-17).

ESU 5 - Basalt Bedrock: ESU 5 was observed in all borings except H-17p17 below ESU 2, ESU 3, and ESU 4 to the final depth of the borings. ESU 5 is characterized primarily as very weak to moderately strong basalt rock,. Discontinuities are moderately spaced and in fair condition. Discontinuities are generally close to very widely spaced and in poor to good condition.

NOTE: 500 YR. M.R.I. W.S. ELEV. 203.4 Q = 56,795 CFS

TEST HOLE LEGEND

H-1p-17 TEST HOLE NUMBER
100+50 TEST HOLE STATION
25ft Rt. TEST HOLE OFFSET

INSTALLATION DETAILS AS DEFINED ON BORING LOG
CEMENT TOP SEAL
BENTONITE TOP SEAL
PIPE IN SAND
WELL SCREEN IN SAND
WATER LEVEL & DATE 01/01/17
BENTONITE BOTTOM SEAL

23 STANDARD PENETRATION TEST (BLOWS PER FOOT)
REF STANDARD PENETRATION TEST (REFUSAL)
33 OVERSIZE PENETRATION TEST (BLOWS PER FOOT)
UNDISTURBED SAMPLE
SOIL/ROCK STRATA AS DEFINED ON BORING LOG
INDICATES CORE SAMPLE TAKEN
RQD 33 ROCK QUALITY DESIGNATION IN %

JOB# XL-5373 STATE ROUTE 101 MILEPOST(S) 239.42-239.50

**FIGURE 7: BRIDGE PROFILE**

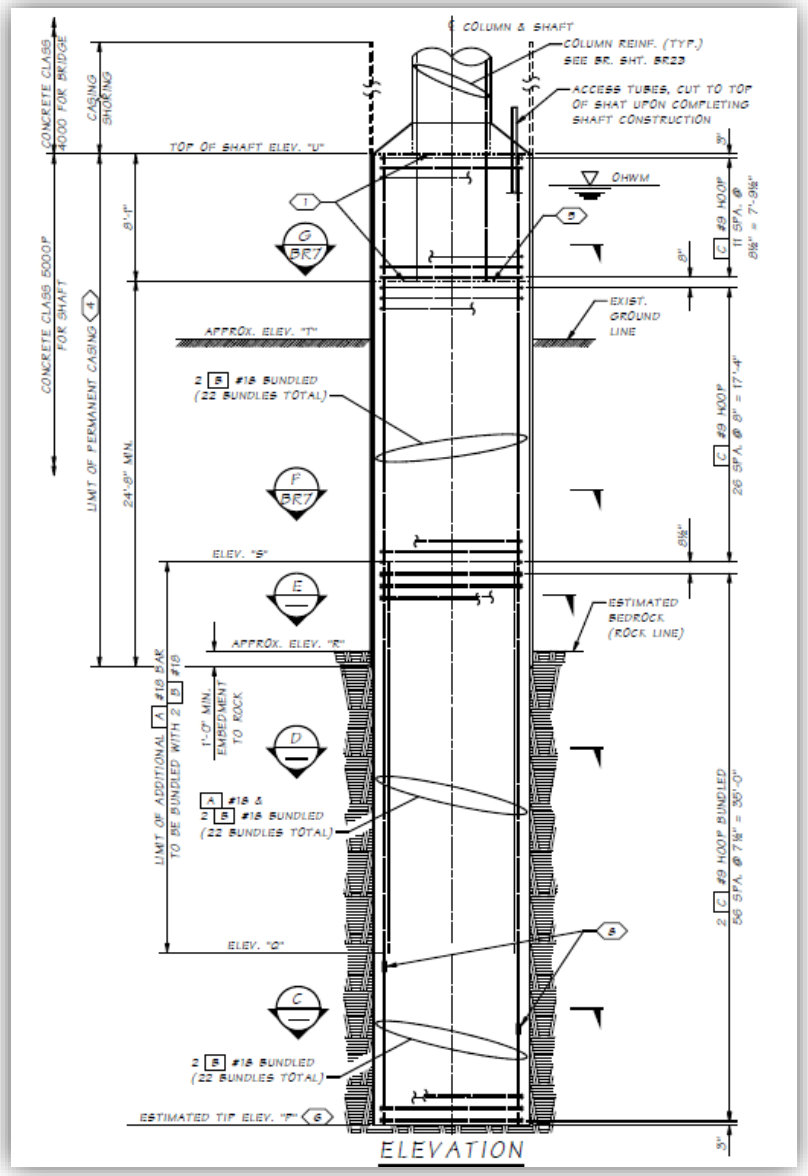
US 101/ELWHA RIVER BRIDGE - BRIDGE REPLACEMENT

WSDOT GEOTECHNICAL OFFICE

PREPARED BY William Montgomery DATE March, 2019

*Image Sources: WSDOT*

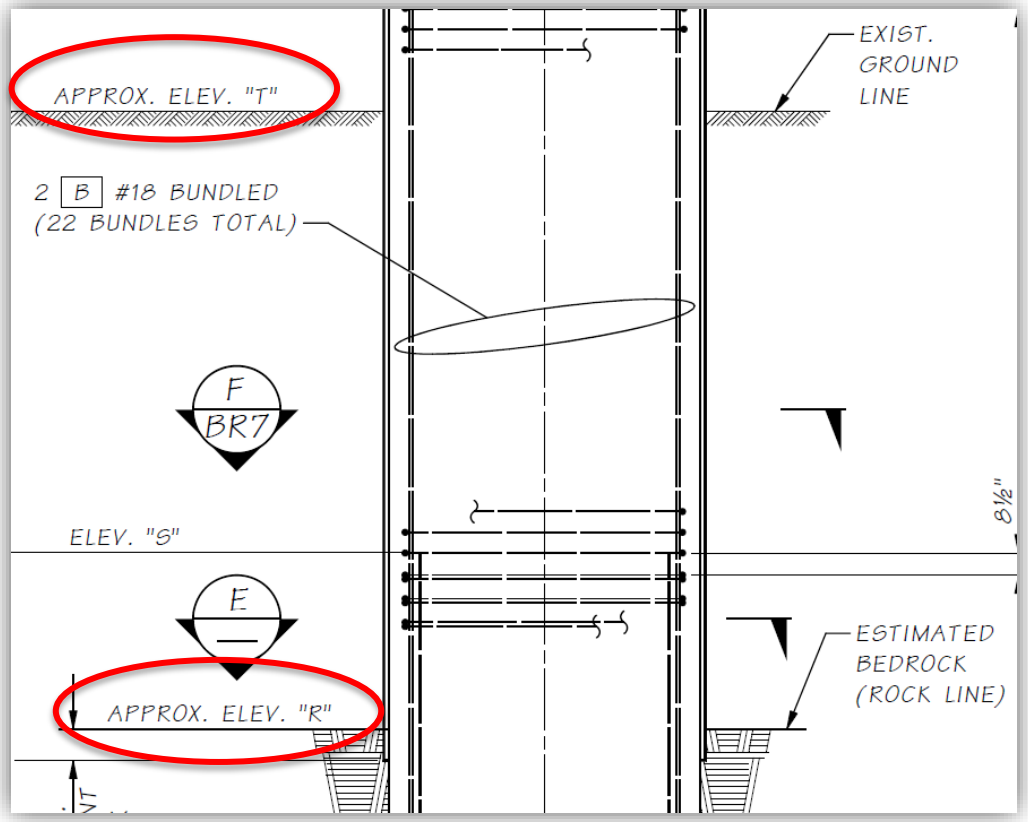
# Pier 2 Details



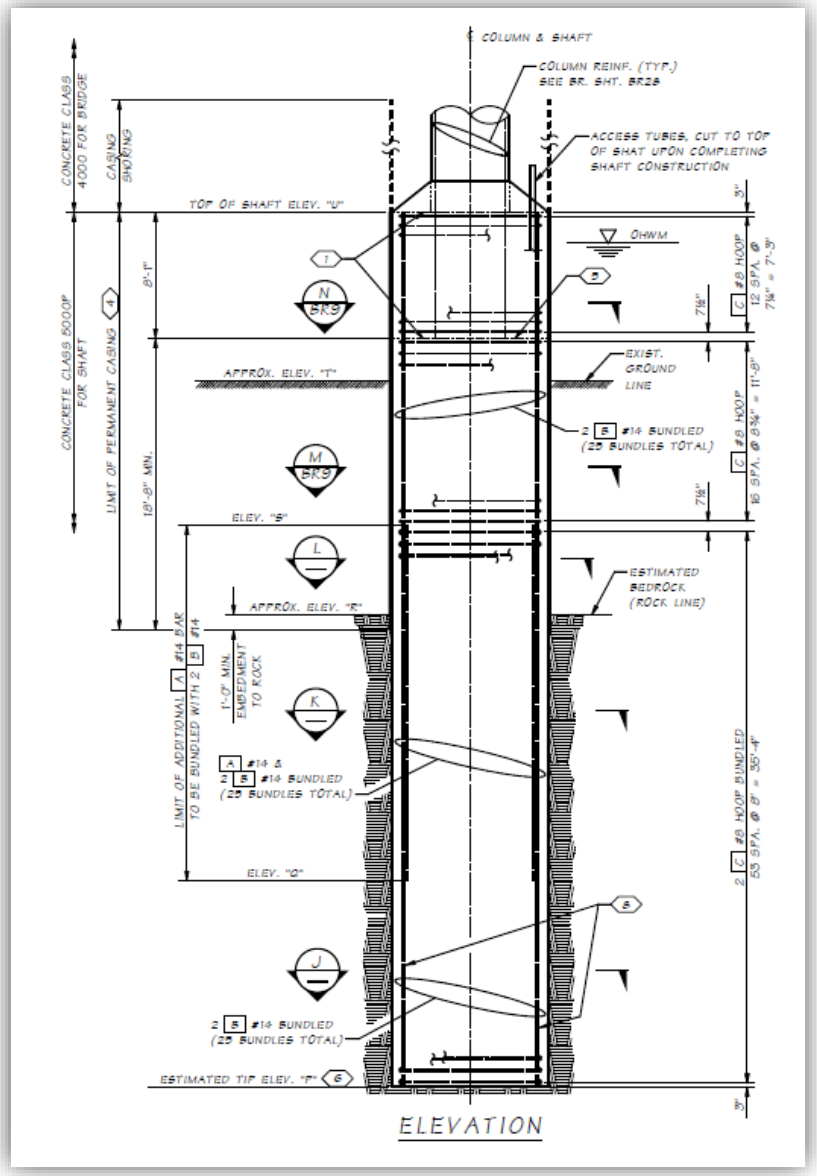

## SHAFT ELEVATIONS

| SHAFT | ELEVATION POINT | | | | | |
|---|---|---|---|---|---|---|
| | "P" | "Q" | "R" | "S" | "T" | "U" |
| A | 137.8 | 148.8 | 168.0 | 173.8 | 188.0 | 199.80 |
| B | 137.8 | 148.8 | 168.0 | 173.8 | 188.0 | 199.80 |

Image Sources: WSDOT



# Pier 3 Details




## SHAFT ELEVATIONS

| SHAFT | ELEVATION POINT | | | | | |
|---|---|---|---|---|---|---|
| | "P" | "Q" | "R" | "S" | "T" | "U" |
| A | 143.8 | 157.0 | 174.0 | 177.0 | 189.0 | 199.80 |
| B | 143.8 | 157.0 | 174.0 | 177.0 | 189.0 | 199.80 |

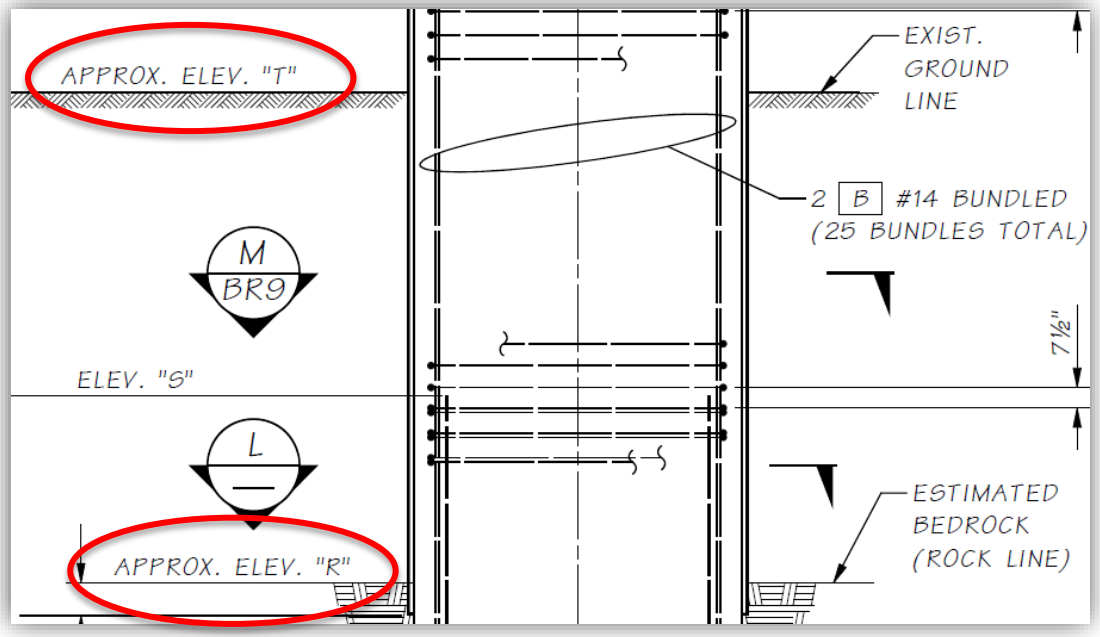



*Image Sources: WSDOT*

# Tsunami Scour

- BDM 3.16.8

***Bridges Subjected to Tsunami Effects***

The AASHTO *Guide Specifications for Bridges Subject to Tsunami Effects* are intended for the design and construction of conventional bridges to resist the effects of tsunami waves.

- Tsunami Guide Specs 8.1

**8.1.1—Expected Scour**

The tsunami-induced scour, $y_{s_t}$ (ft), shall be taken as:

$$y_{s_t} = R_t y_{s_{corr}} \qquad (8.1.1\text{-}1)$$

- Wave direction, velocity and depth from DNR

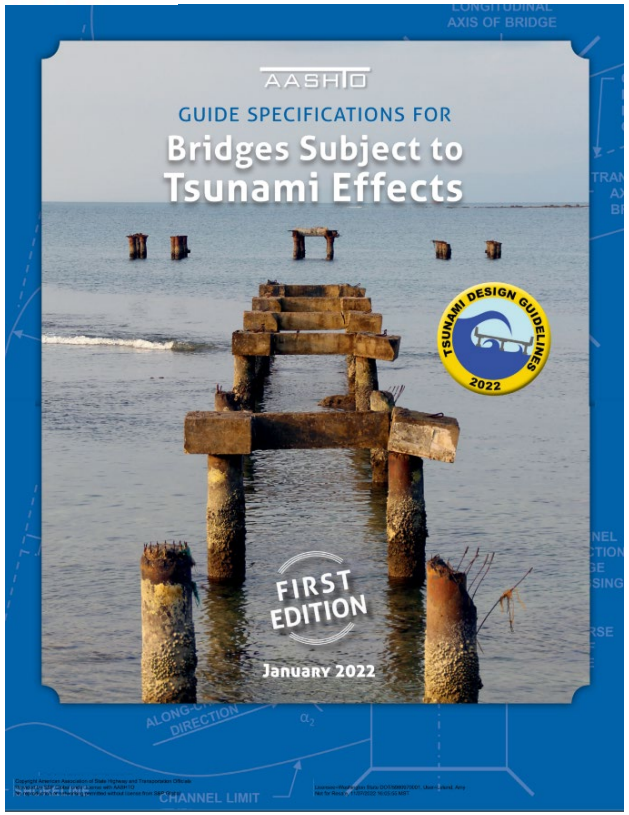



*Image Source: AASHTO*