Comparing Three 2D Software Packages for Modeling Highway Drainage Structures

2018 ASFPM Conference
Phoenix, Arizona, June 20, 2018

woodplc.com

Agenda

- Project Background
- Pilot Study Area – Gunsight Canyon
- When is 2D Modeling Appropriate?
- Modeling Software Overview
- Results and Comparisons
- Recommendations and Guidance

Project Background

EDC-4 CHANGE Program Adoption

- Steven Olmsted, ADOT, Group Manager, Environmental Planning
- ADOT's Rotation Towards Asset Management, Risk Based, $1B 5-yr Construction Program:
    - Better Adaptation of Technology, Science, & Engineering
    - Aligns with advancements in point cloud and 3D use
    - Adaptation of extreme weather / climate resilience engineering

Pilot Study Area – Gunsight Canyon

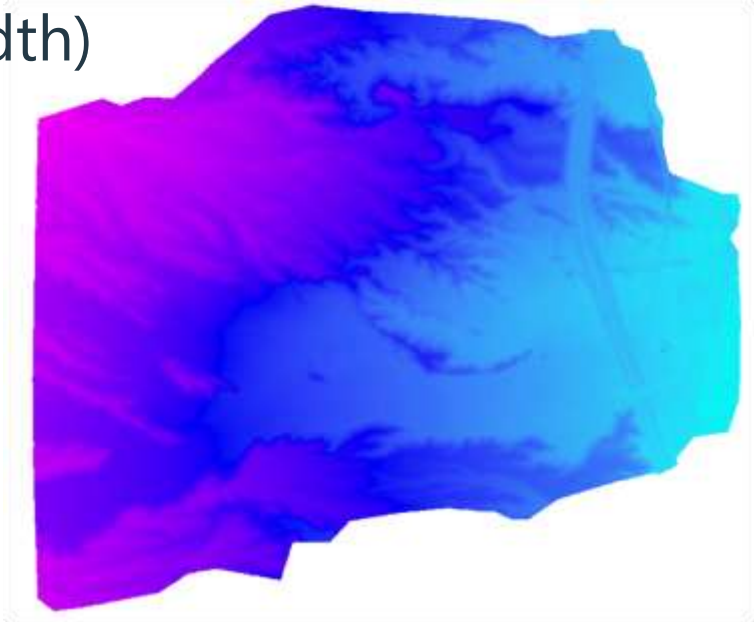
- Rural
- Braided Flow Condition
- Design Cross-Culvert

Pilot Study Area – Gunsight Canyon

Pilot Study Area – Gunsight Canyon

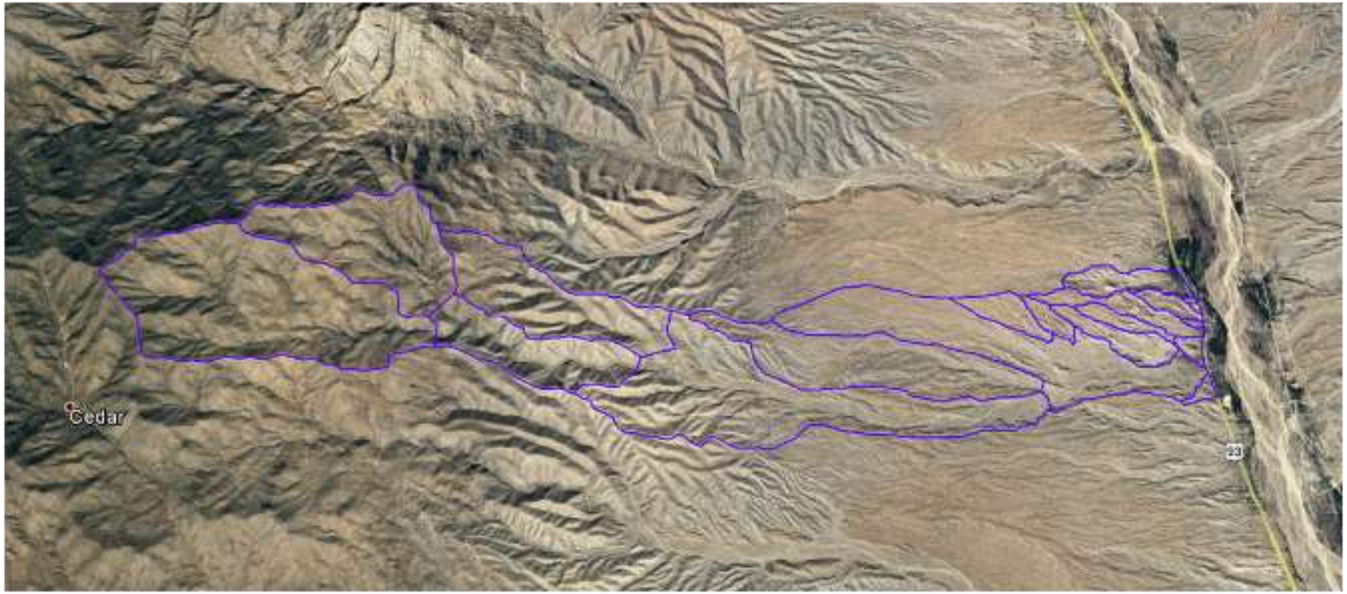
- Define Survey Requirements
- ADOT typically provides strip topographic mapping (limited width)

- Mapping
  - USGS Existing Surface Raster
  - Combined Raster with Proposed Roadway



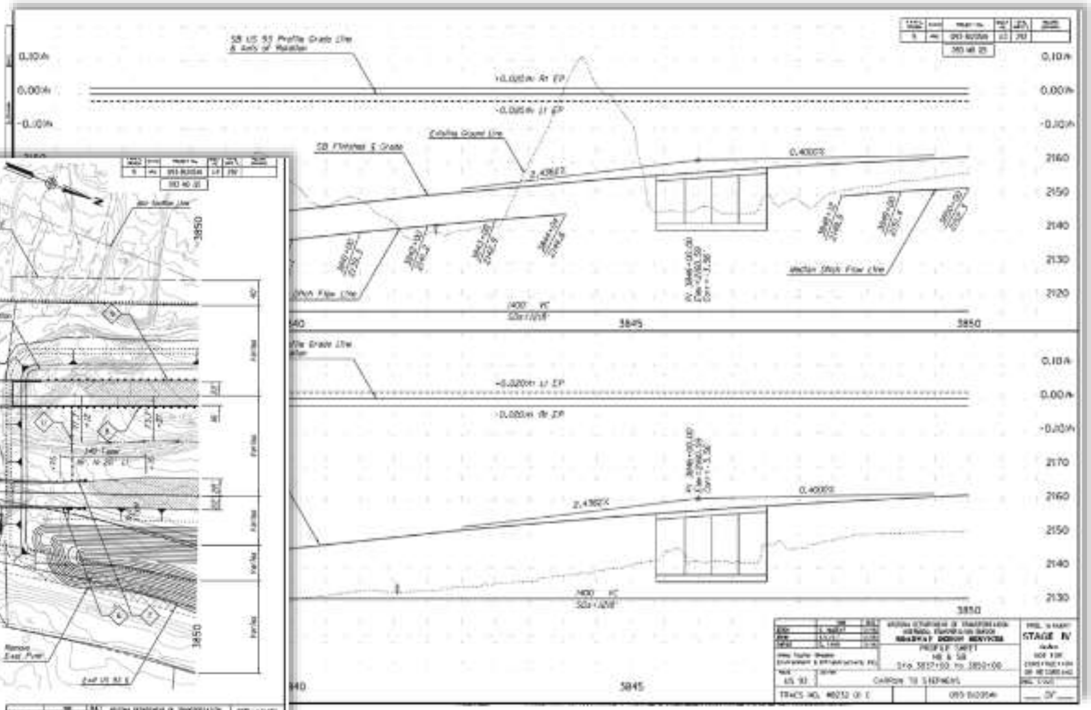
Pilot Study Area – Gunsight Canyon

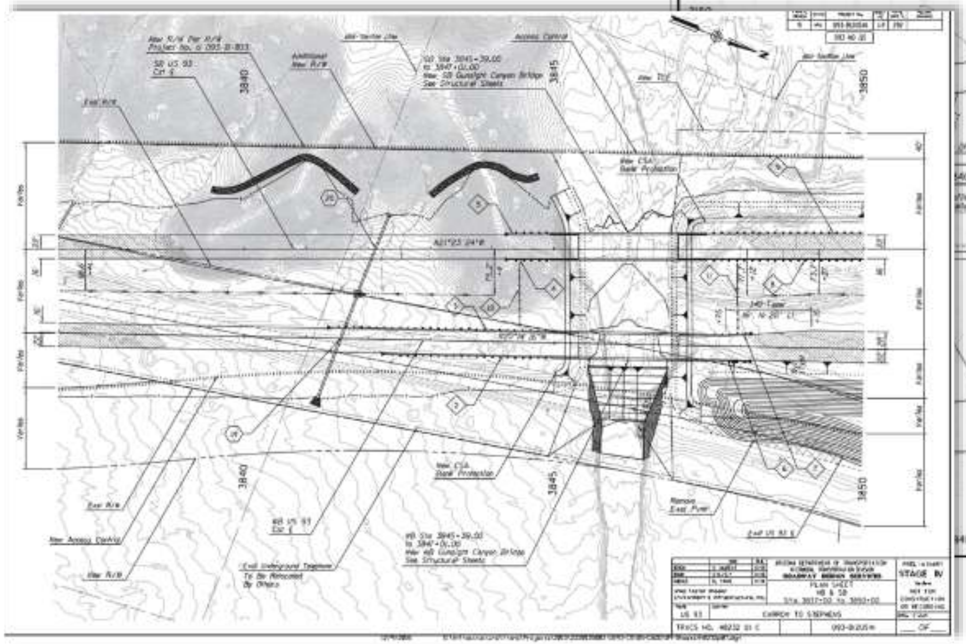
- Hydrology – HEC-1
  - Q_{100} = 6,719 cfs   Drainage Area = ~11 mi^2



Input Data

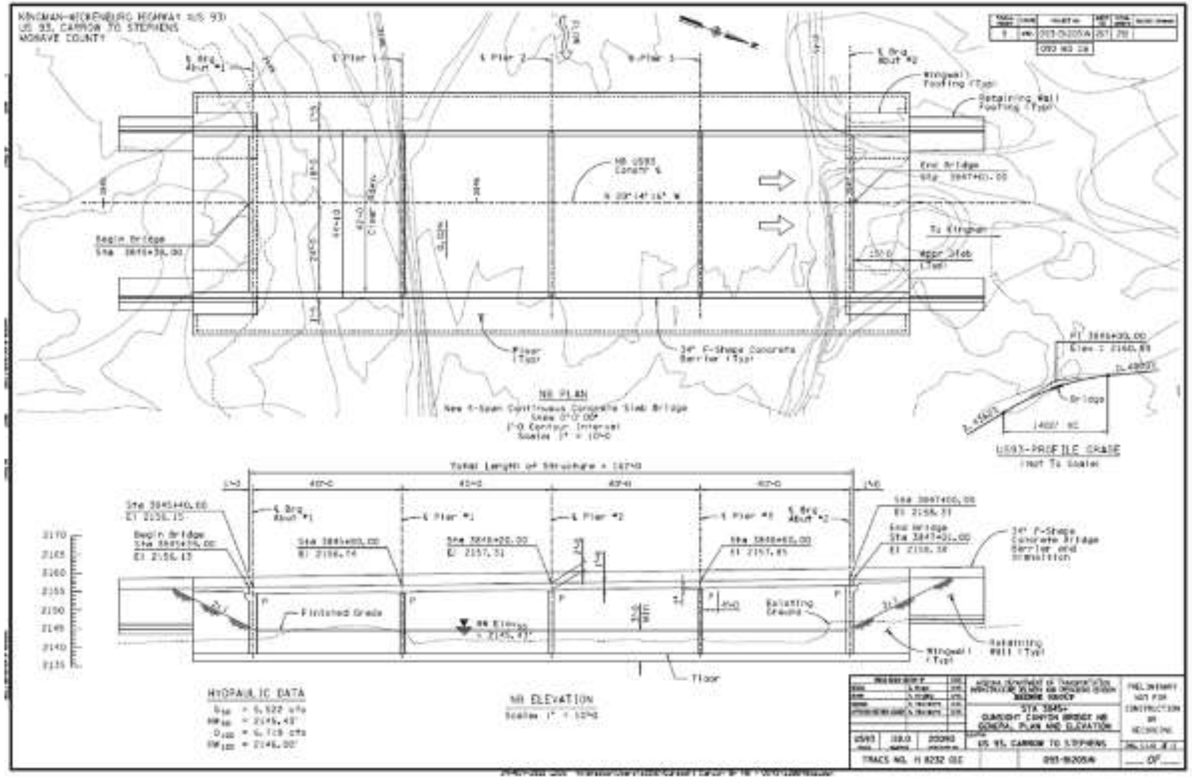
- Bridge Design Plans





Pilot Study Area – Gunsight Canyon

- Bridge Design Plans

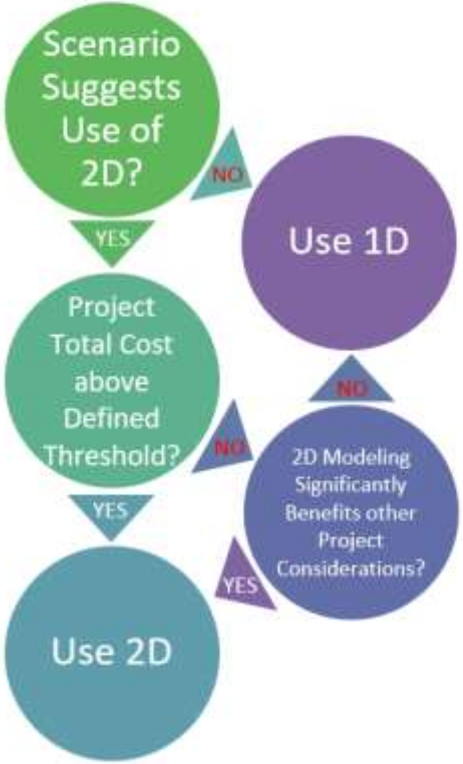


When is 2D Modeling Appropriate?

- 1D Vs. 2D Hydraulic Modeling
  - 1D Cross Sections Vs. 2D Domain
  - 1D modeling generally provides one flow depth and one flow velocity in an assumed direction.
  - 2D modeling allows for prediction of flow depth, direction, and velocity at any given modeling node.

When is 2D Modeling Appropriate?

- Better Data Improves Project Design
- Better Tools for Communicating Results
- Streamlined Delivery – Improved collaboration can reduce environmental and regulatory delays



Modeling Software Overview

Software		Developed/ Supported By	Numerical Method	Cost	Primary GUI
HEC-RAS		USACE	Finite Volume	Free	RASMapper
SRH-2D		Aquaveo FHWA USBR	Finite Volume	$3,100 (Riverine Pro) Free (Community)	SMS
FLO-2D		FLO-2D Riada	Finite Difference	$995/year (Pro) Free (Basic)	QGIS GDS

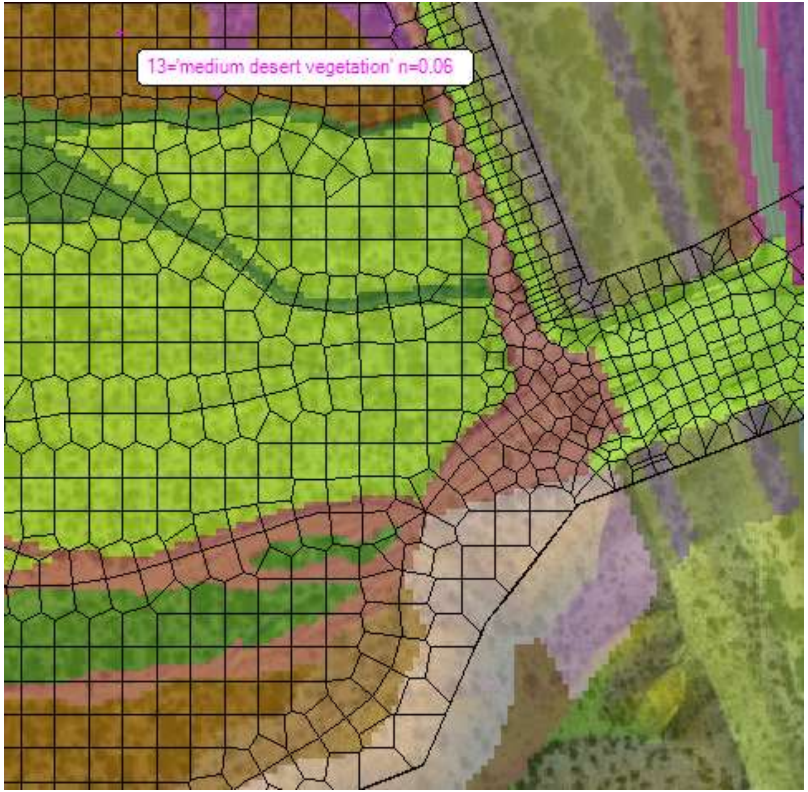
Modeling Software Overview - HEC-RAS

Input

- Boundary Conditions
- Topographic Mapping
- N values
- Mesh Network

Bridge Modeling Options

- Approximated as Culvert
- Modeled in Terrain



Modeling Software Overview - HEC-RAS

Culvert Method

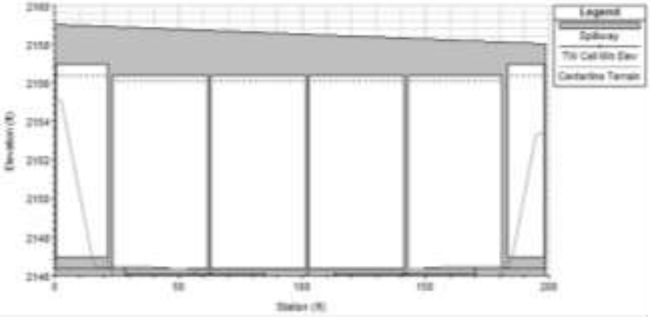
Considerations

-Simplified Input

-Approximation of Opening

-Pressure Flow ✓

-Flow Direction ✗



Modeling Software Overview - HEC-RAS

DTM Piers

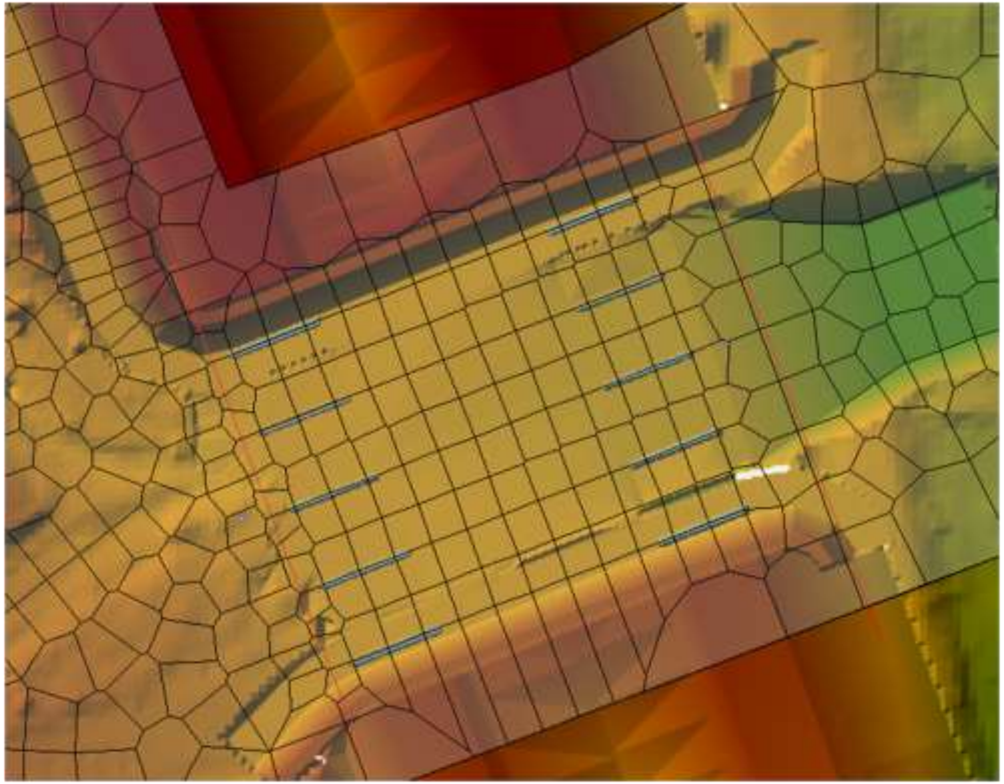
Considerations:

-DTM Modeling

-Cell Boundary Alignment

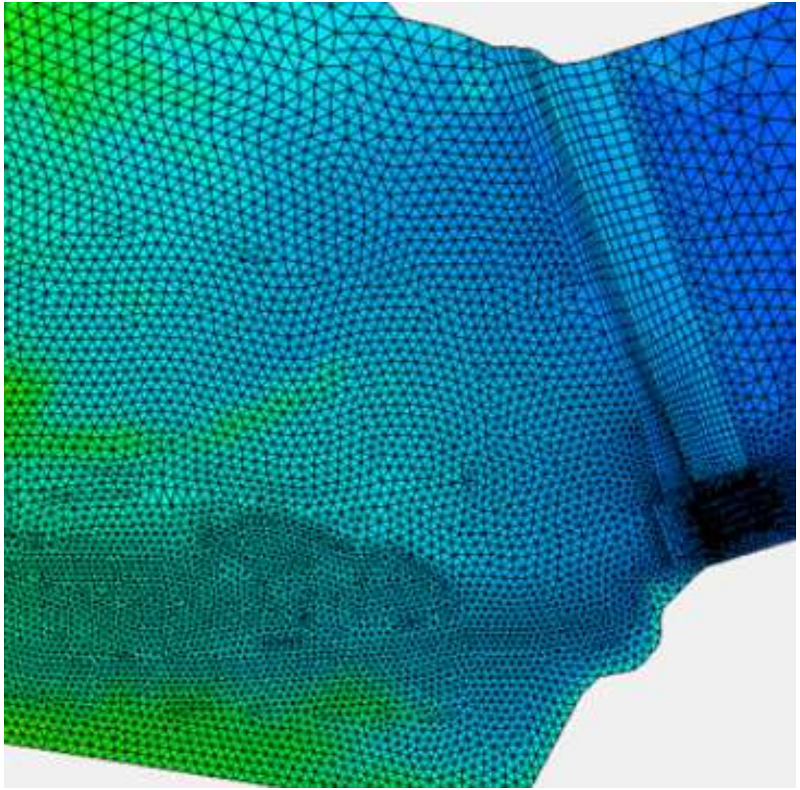
-Pressure Flow ✗

-Flow Direction ✓



Modeling Software Overview – SRH-2D

- Input
  - Boundary Conditions
  - Topographic Mapping
  - N values
  - Mesh Network
- Bridge Modeling Options
  - Culvert Equations
  - HY-8
  - Piers Modeled as Holes in Mesh
  - Obstructions



Modeling Software Overview – SRH-2D

Culvert Equations

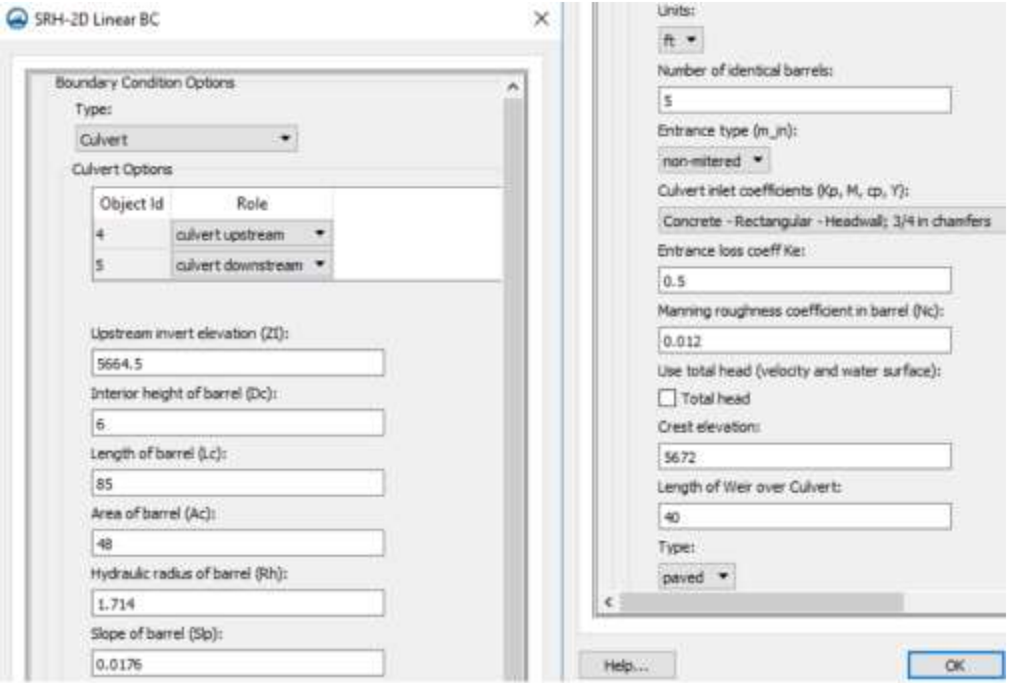
Considerations

-Simplified Input

-Approximation of Opening

-Pressure Flow ✓

-Flow Direction ✗



Modeling Software Overview – SRH-2D

Culvert Method using HY-8

Considerations

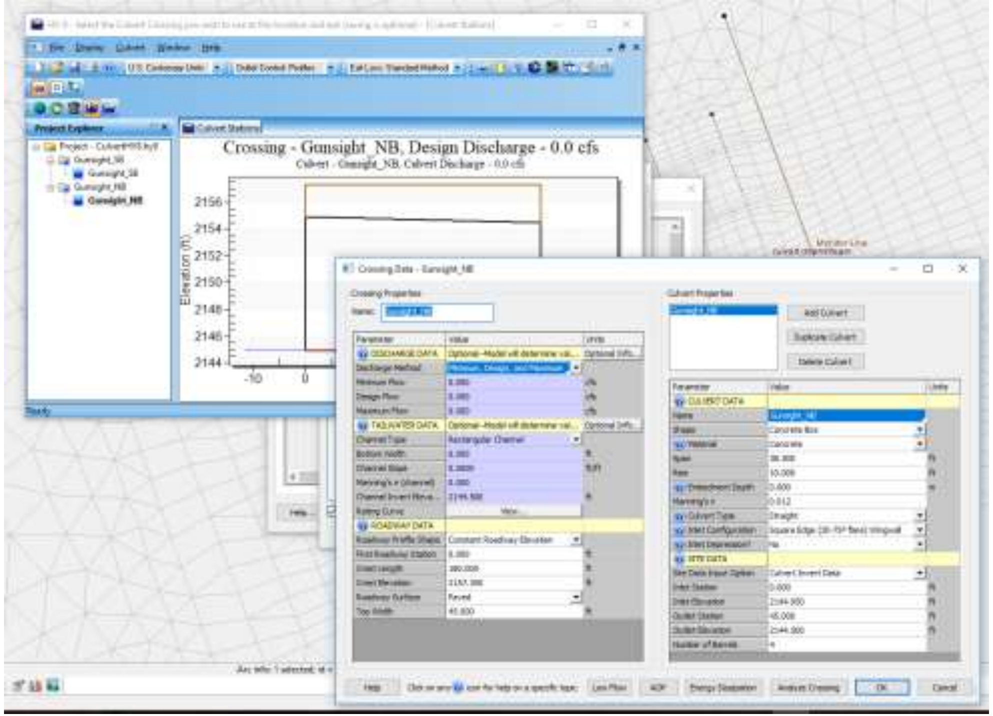
-Simplified Input

-Approximation of Opening

-Zero Velocity at Inlet

-Pressure Flow ✓

-Flow Direction ✗



Modeling Software Overview – SRH-2D

Holes in Mesh

Considerations

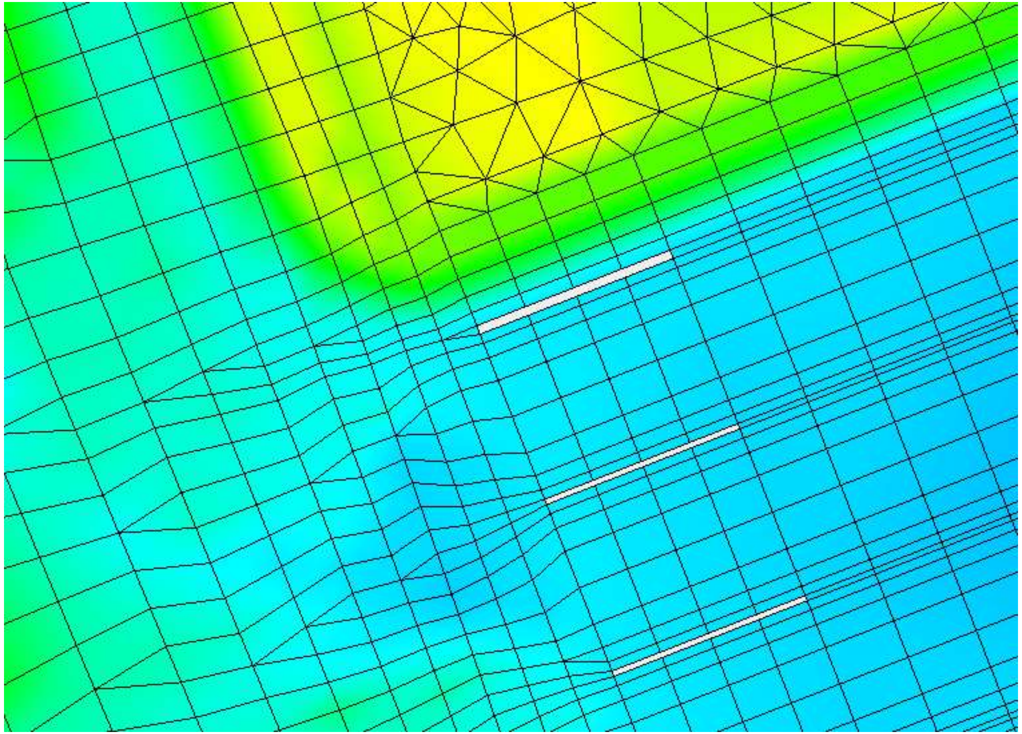
-Mesh Modification

-Vertical Walls at Boundary

-Most Accurate

-Pressure Flow ✓

-Flow Direction ✓



Modeling Software Overview – SRH-2D

Obstructions

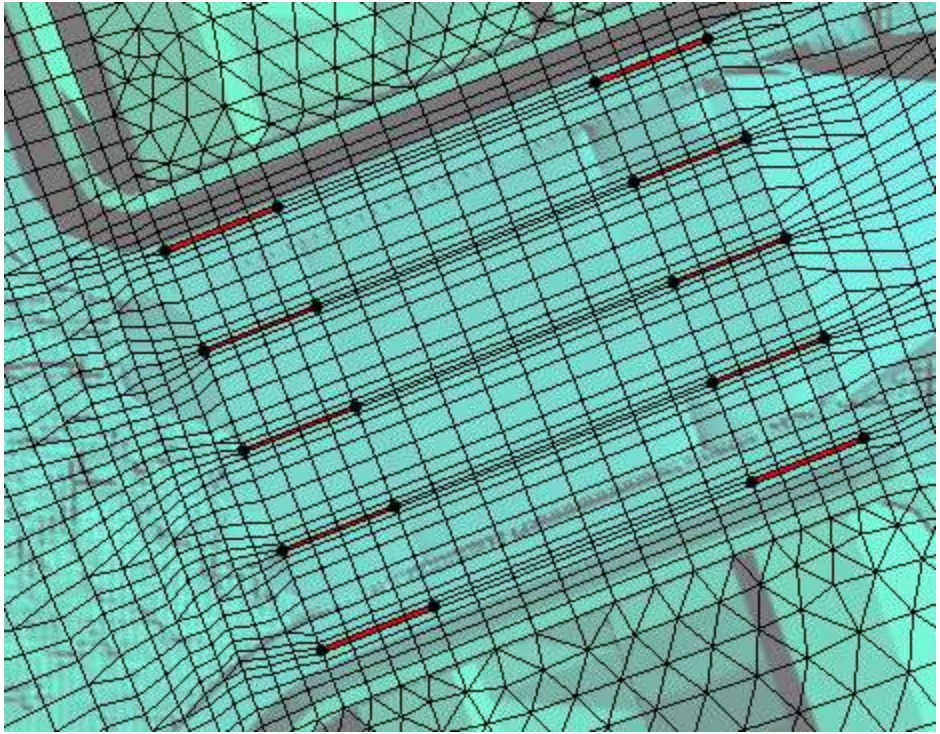
Considerations

-No Mesh Modification

-Simplified Head Loss

-Pressure Flow ✓

-Flow Direction ✓



Modeling Software Overview – FLO-2D

Input

- Boundary Conditions
- Topographic Mapping
- N values
- Grid Element Size

Bridge Modeling Options

- Culvert Equations
- Structure Rating Table
- Open Channel / Grid Only

Modeling Software Overview – FLO-2D

Culvert Equations

Considerations

-Simplified Input

-Approximation of Opening

-Pressure Flow ✓

-Flow Direction ✗

HYSTRUC.DAT

```
S  GC_BR_CELL_1    0  2  45437  46199  0  0.0  212.0  10.0
F  1  1  0.025  0.50  27.0
S  GC_BR_CELL_1A   0  2  45537  46200  0  0.0  212.0  10.0
F  1  1  0.025  0.50  27.0
S  GC_BR_CELL_2    0  2  45538  46294  0  0.0  212.0  10.0
F  1  1  0.025  0.50  27.0
S  GC_BR_CELL_2A   0  2  45637  46295  0  0.0  212.0  10.0
F  1  1  0.025  0.50  27.0
S  GC_BR_CELL_3    0  2  45638  46389  0  0.0  212.0  10.0
F  1  1  0.025  0.50  27.0
S  GC_BR_CELL_4    0  2  45639  46390  0  0.0  212.0  10.0
F  1  1  0.025  0.50  27.0
```

1 1 Read Ovr Block Sync Rec Caps

Modeling Software Overview – FLO-2D

Structure Rating Table

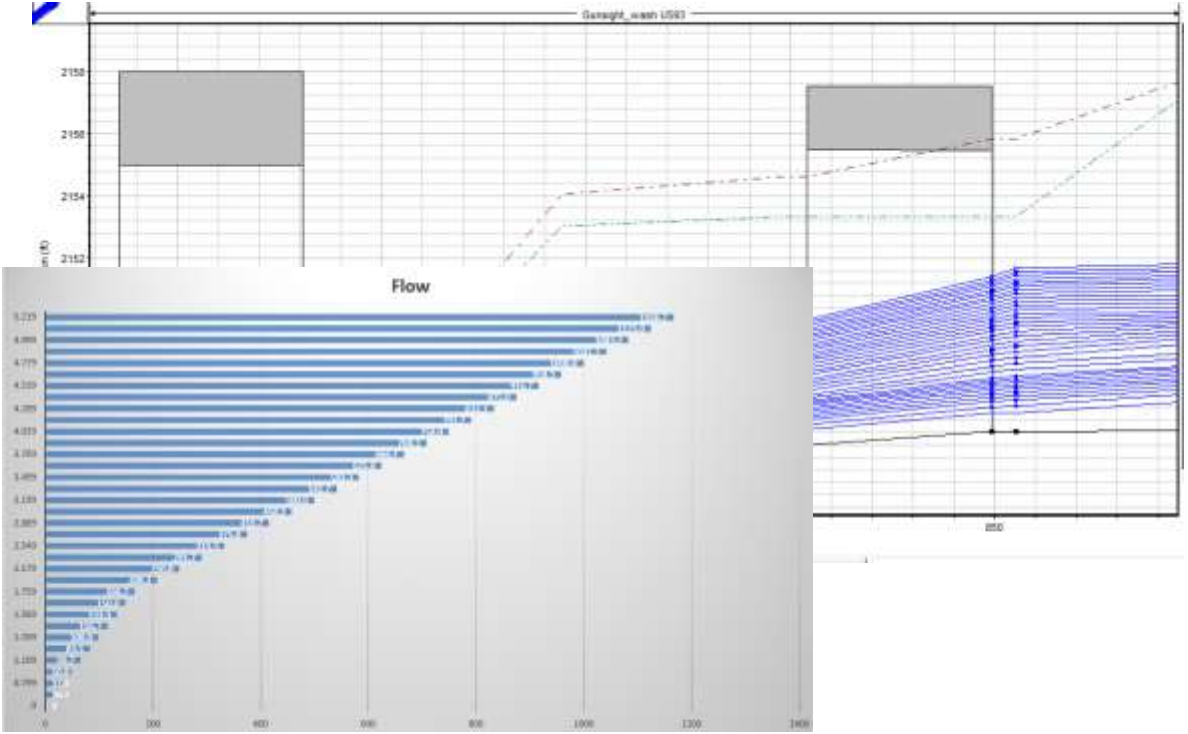
Considerations

-Simplified Input

-Rating Development

-Pressure Flow ✓

-Flow Direction ✗



Modeling Software Overview – FLO-2D

Open Channel / Grid Only

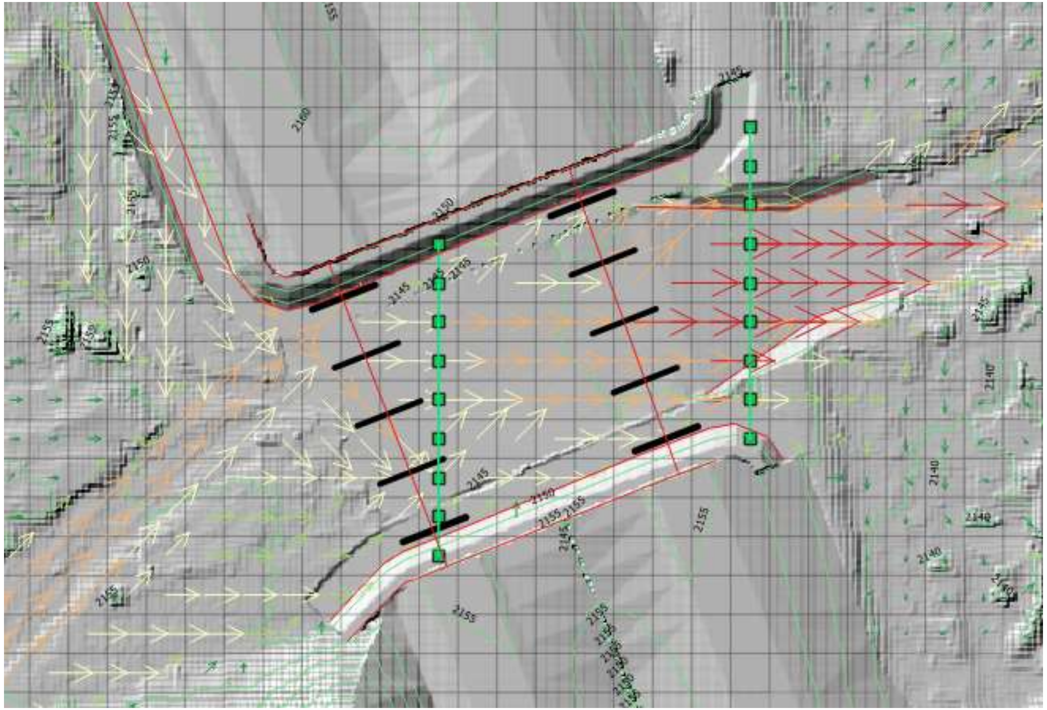
Considerations

-Simplified Input

-Area Reduction Factor

-Pressure Flow ✗

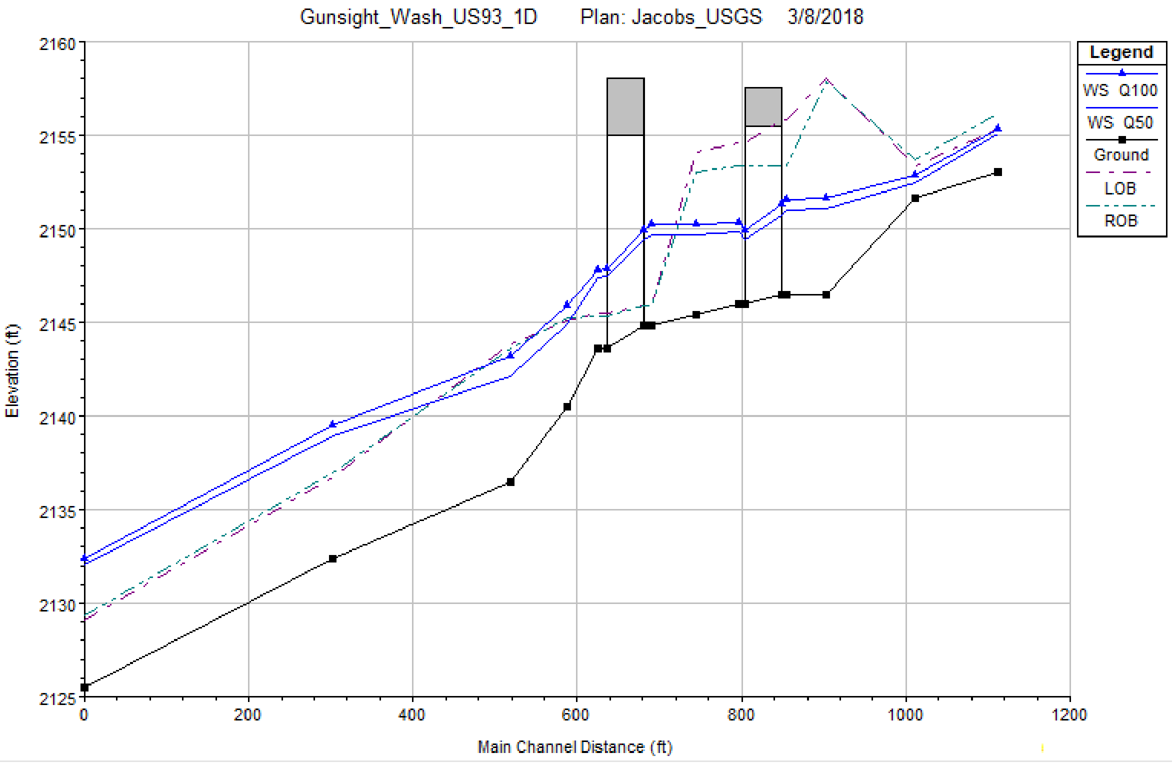
-Flow Direction ✓



Results - HEC-RAS 1D

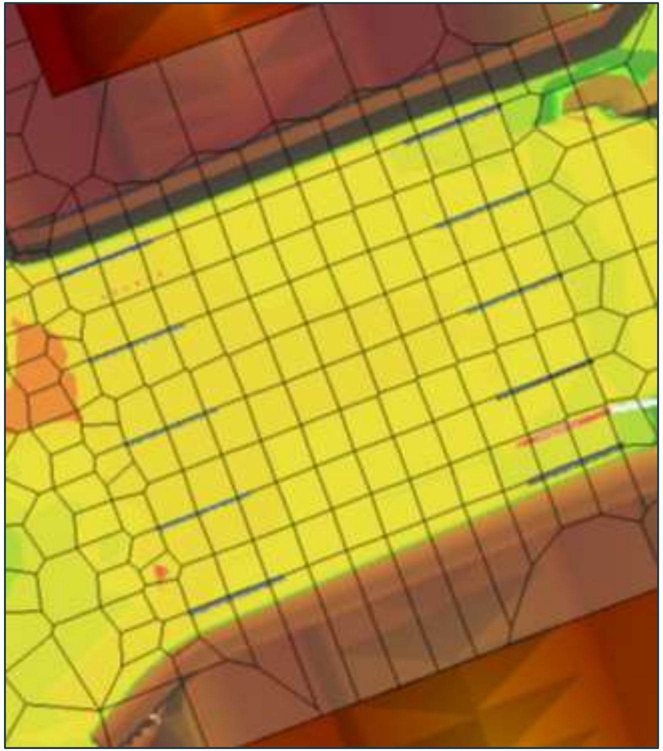
-Upstream WSEL

-Max Velocity

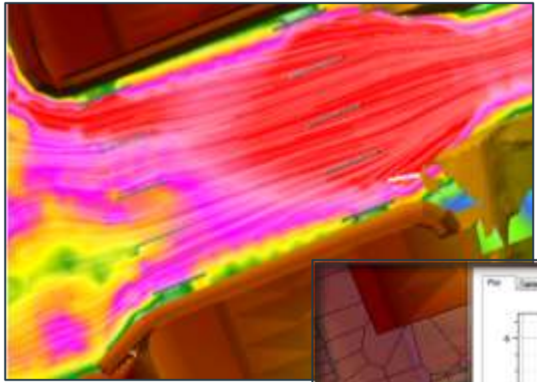


Results - HEC-RAS 2D

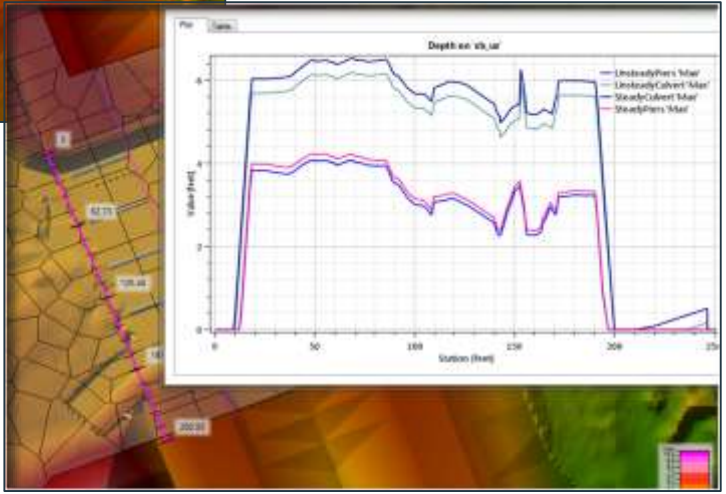
Max Flow Depth



Velocity with Flow-Tracing

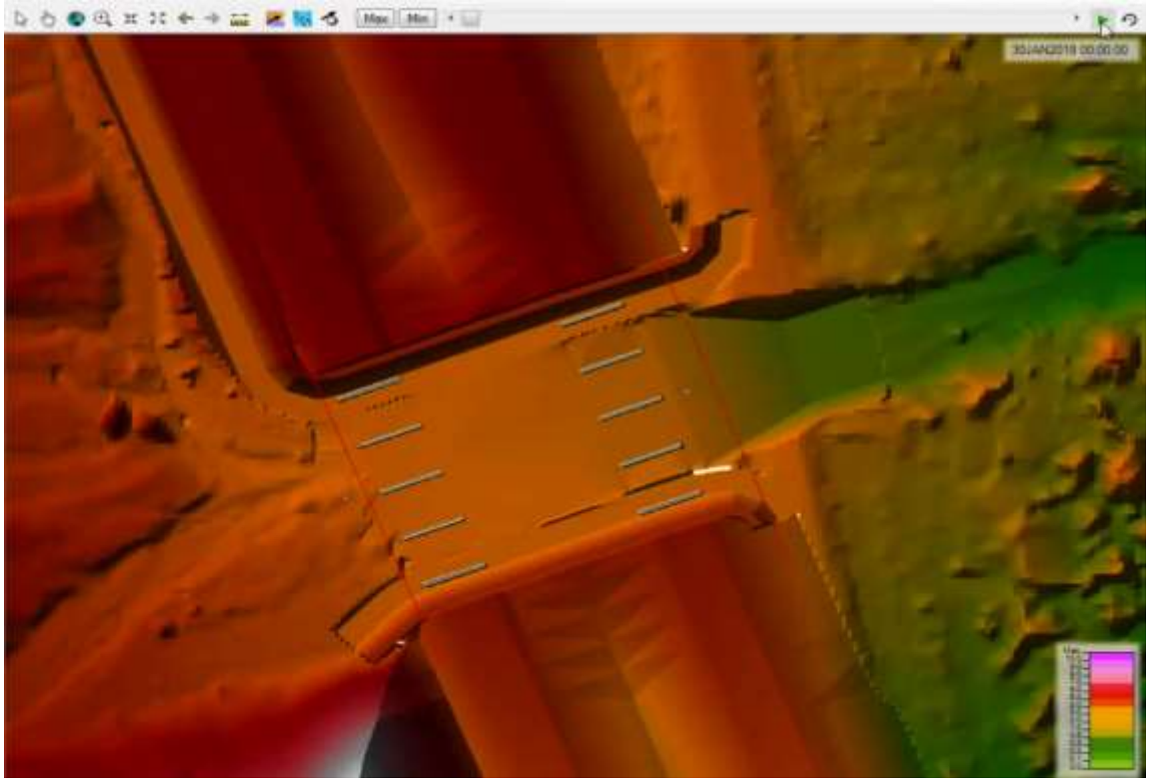


Profile Lines



Results - HEC-RAS 2D

- Animation

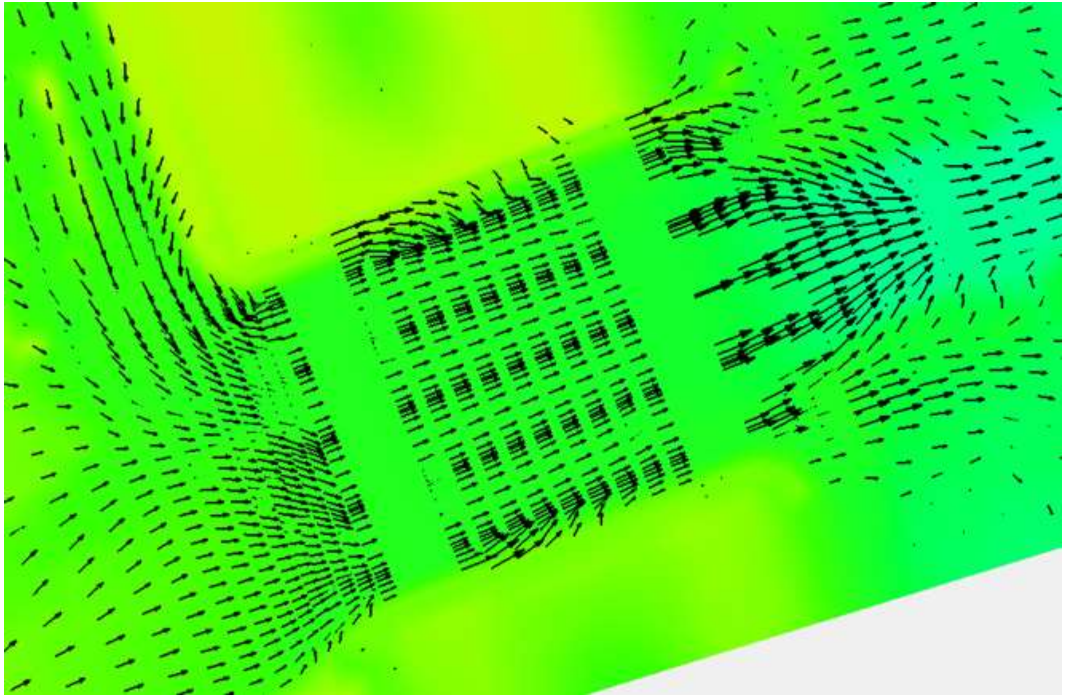


Results - HEC-RAS

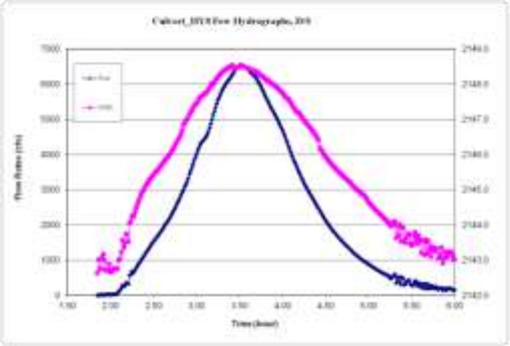
HEC-RAS Results - (100 Year)				
Bridge Modeling Method			Culvert	DTM Piers
1D	Steady	WSEL (ft)	2151.7	N/A
		Vel (ft/s)	9.1	N/A
2D	Steady	WSEL (ft)	2152.8	2150.4
		Vel (ft/s)	9.7	12.7
	Unsteady	WSEL (ft)	2152.4	2150.2
		Vel (ft/s)	8.1	11.3

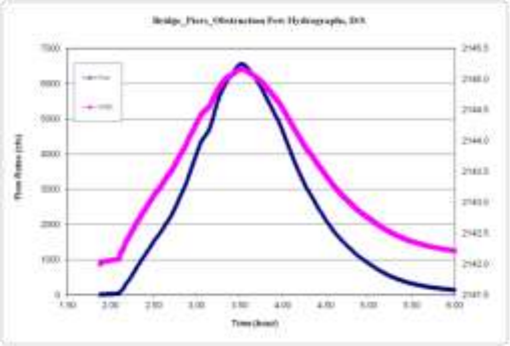
Results – SRH-2D

Velocity



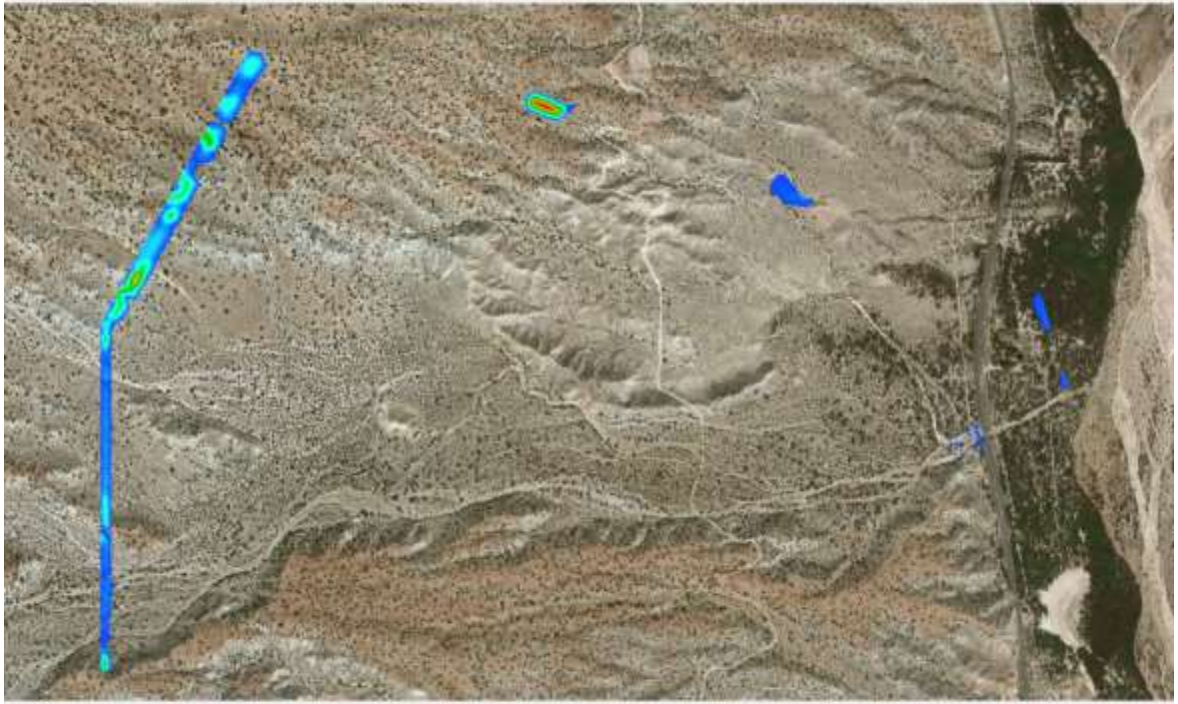
Observation Lines





Results – SRH-2D

Animation

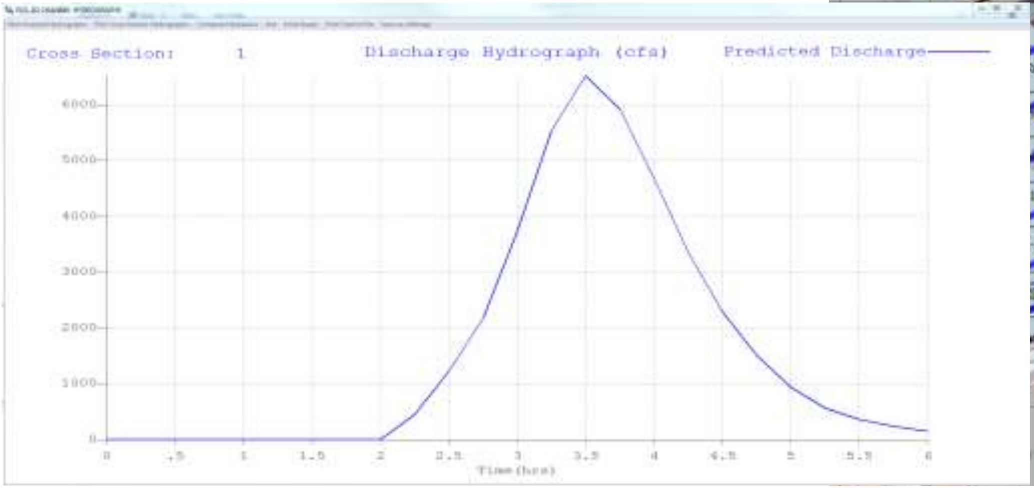


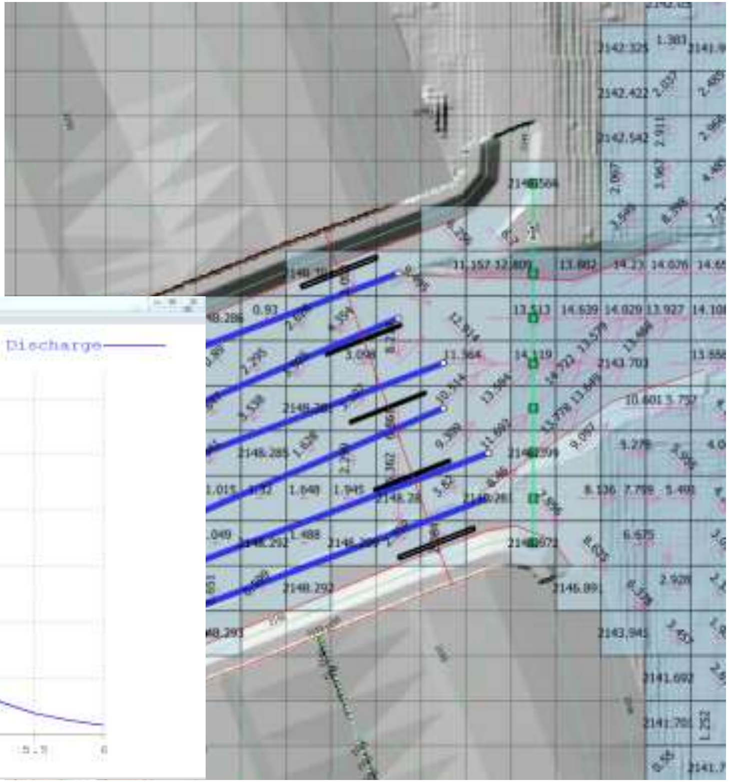
Results - SRH 2D

SRH-2D Results - (100 Year)				
Bridge Modeling Method		HY-8	Holes	Obstruction
Steady	WSEL (ft)	2153.3	2151.1	2151.0
	Vel (ft/s)	8.0	13.1	13.3
Unsteady	WSEL (ft)	2152.9	2150.8	2150.7
	Vel (ft/s)	7.9	12.9	13.1

Results – FLO-2D

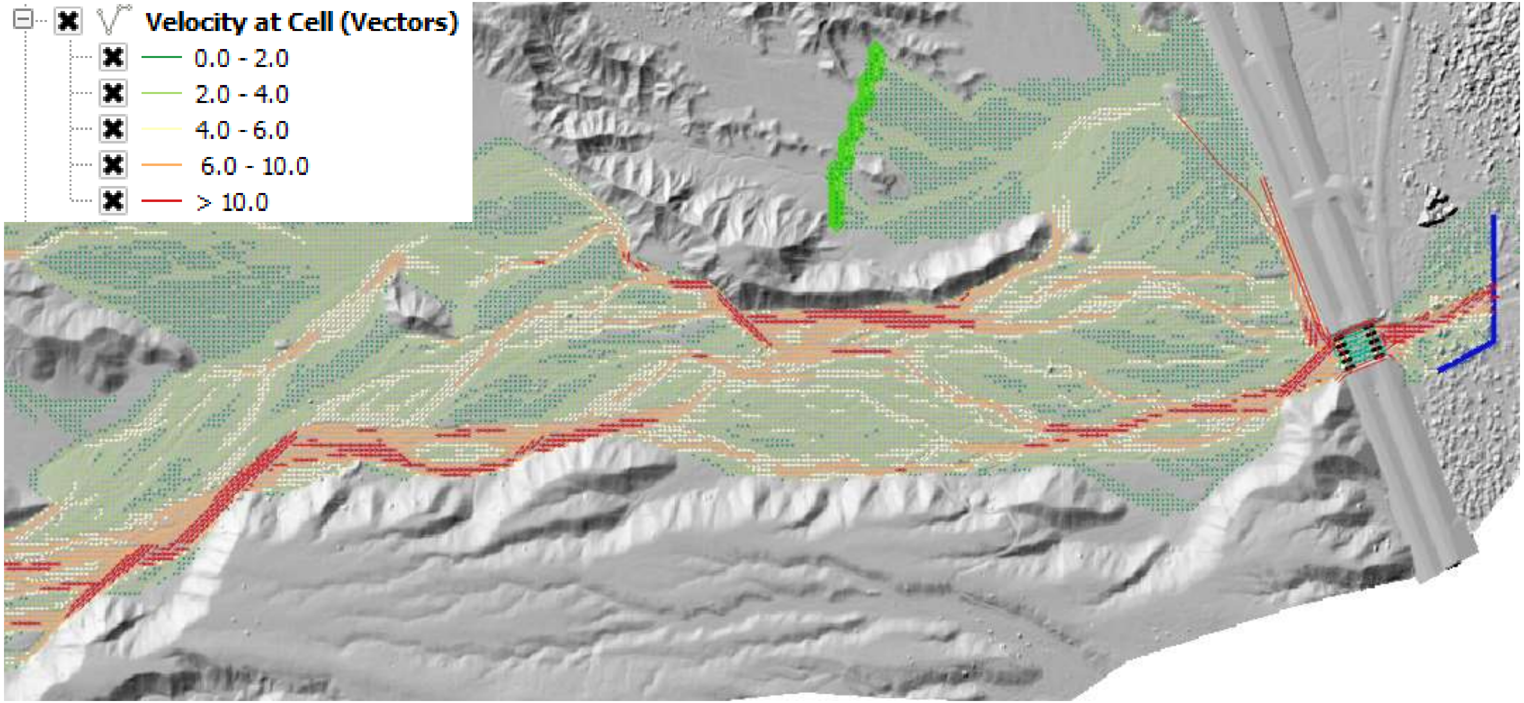
- Summary of Modeling Results





Results – FLO-2D

- Summary of Modeling Results



Results – FLO-2D

FLO-2D Modeling Summary Table for Gunsight Wash Bridge					
FLO-2D	Bridge Modeling Method		Culvert Equations	Rating Table	Open Channel / Grid Only
2D	Steady	WSEL (ft)	2153.4	2151.8	2151.0
		Vel (ft/s)	9.4	12.5	13.5
	Unsteady	WSEL (ft)	2153.3	2151.5	2150.8
		Vel (ft/s)	8.9	12.1	13.0

Comparison

Overall Comparison (100 Year)				
	HEC-RAS 1D	HEC-RAS 2D	SRH-2D	FLO-2D
Recommended Option	Culvert	DTM Piers	Holes	Rating Table
WSEL (ft)	2151.6	2151.3	2150.8	2151.5
Vel (ft/s)	9.1	11.1	12.9	12.1
Input Data	Simple	Complex	Medium	Medium

Recommendations & Guidance

Modeling Recommendations					
Applications		**HEC-RAS 1D**	**HEC-RAS 2D**	**SRH-2D**	**FLO-2D**
Existing Bridge/Culvert Hydraulics	1	Applicable	Applicable	Recommended	Applicable
New Bridge/Culvert Design	2	Applicable	Applicable	Recommended	Not Recommended
Simple Wash/Channel Hydraulics	3	Recommended	Not Recommended	Not Recommended	Not Recommended
Multiple Openings	4	Not Recommended	Applicable	Recommended	Applicable
Complex Flow Patterns/Braided Flow	5	Not Recommended	Recommended	Applicable	Applicable
Basin System Hydraulics	6	Applicable	Recommended	Not Recommended	Applicable
FEMA FIS/CLOMR/LOMR	7	Recommended	Applicable	Applicable	Applicable
Bridge Scour Evaluation	8	Applicable	Applicable	Recommended	Applicable
Urbanized/Stormdrain	9	Not Recommended	Applicable	Applicable	Recommended

Q&A

wood.

J2

engineering and environmental design

woodplc.com