A New Competitor in 2D Modeling: Complex Comparison of AdH and HEC-RAS 5.0

Engineering | Planning | Allied Services

IAFSM 2016 Annual Conference
10 March 2016

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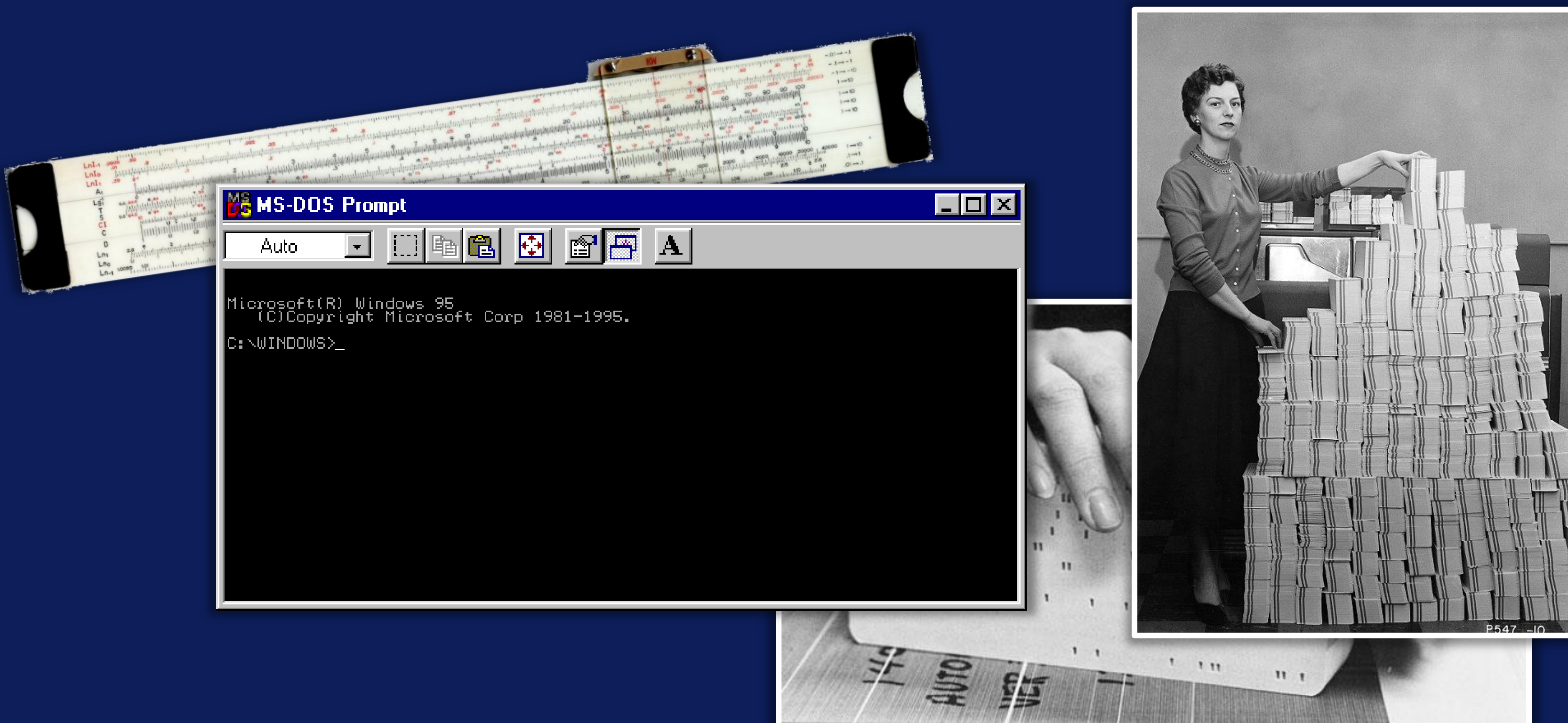
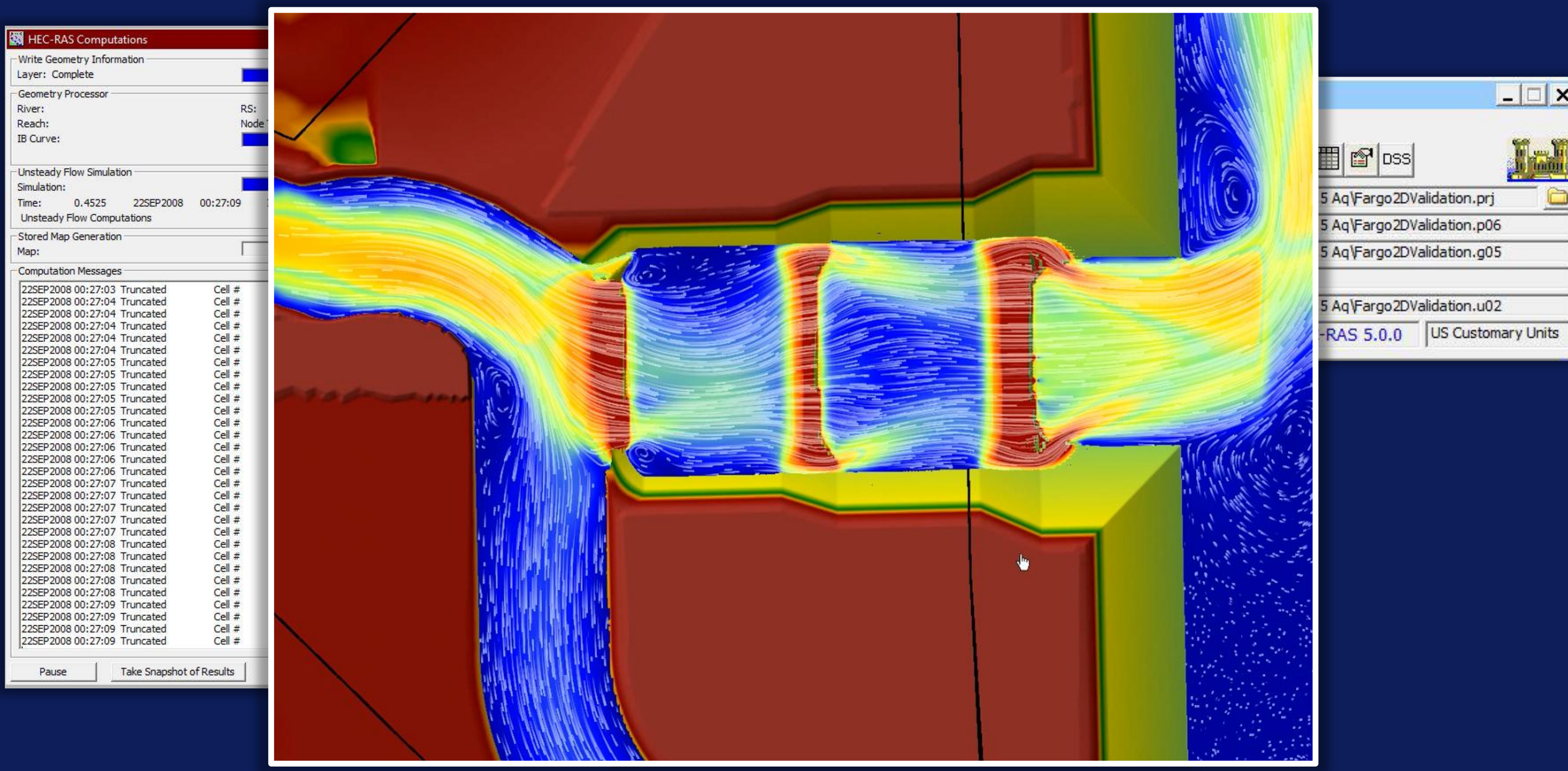
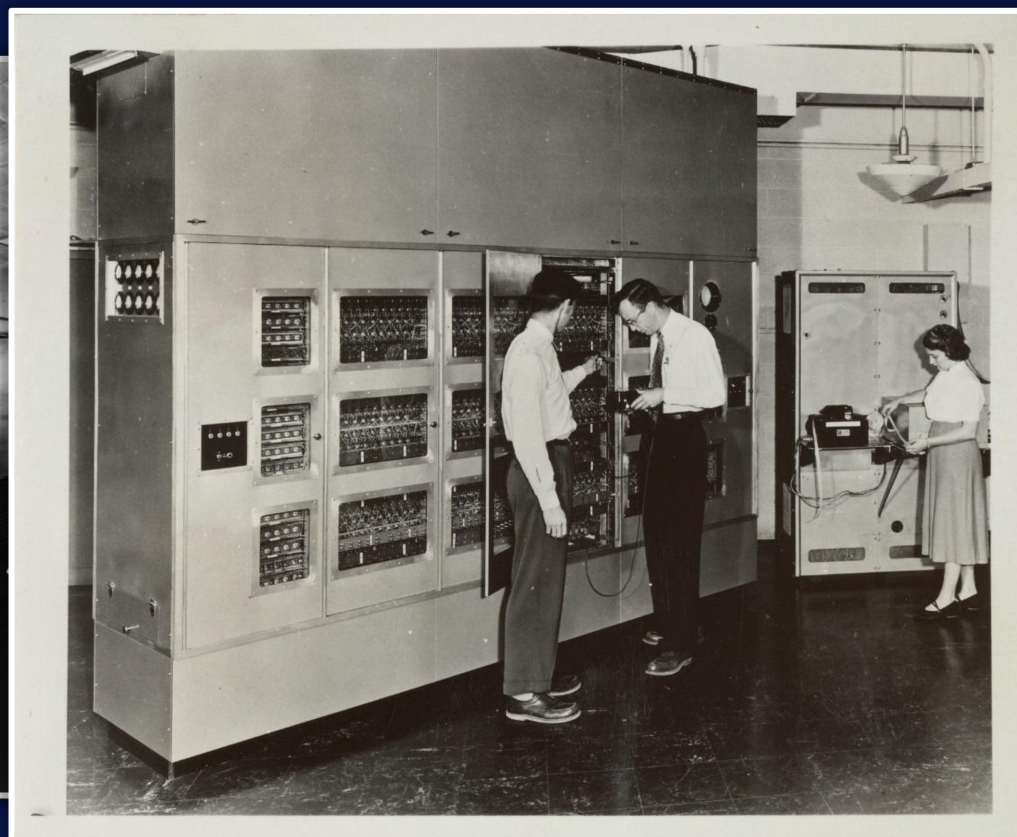
EVOLUTION OF HYDRAULIC MODELING



EVOLUTION OF HYDRAULIC MODELING

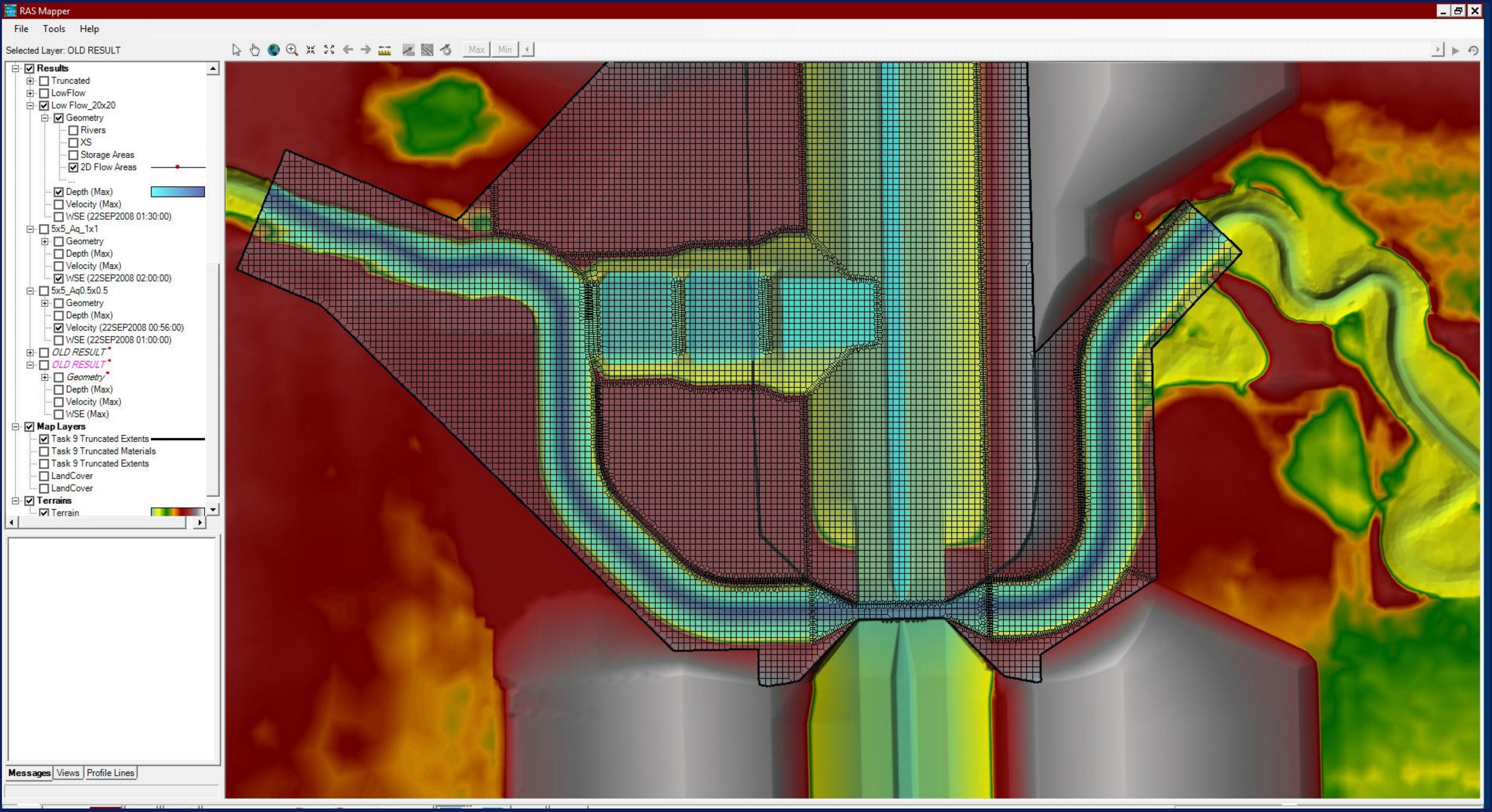


WHAT DRIVES CHANGE?



TECHNOLOGY

HEC-RAS 5.0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File Tools Help
Selected Layer: OLD RESULT
Max Min
Results
Truncated
LowFlow
Low Flow_20x20
Geometry
Rivers
XS
Storage Areas
2D Flow Areas
Depth (Max)
Velocity (Max)
WSE (22SEP2008 01:30:00)
5x5_Aq_1x1
Geometry
Depth (Max)
Velocity (Max)
WSE (22SEP2008 02:00:00)
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Geometry
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OLD RESULT
OLD RESULT
Geometry
Depth (Max)
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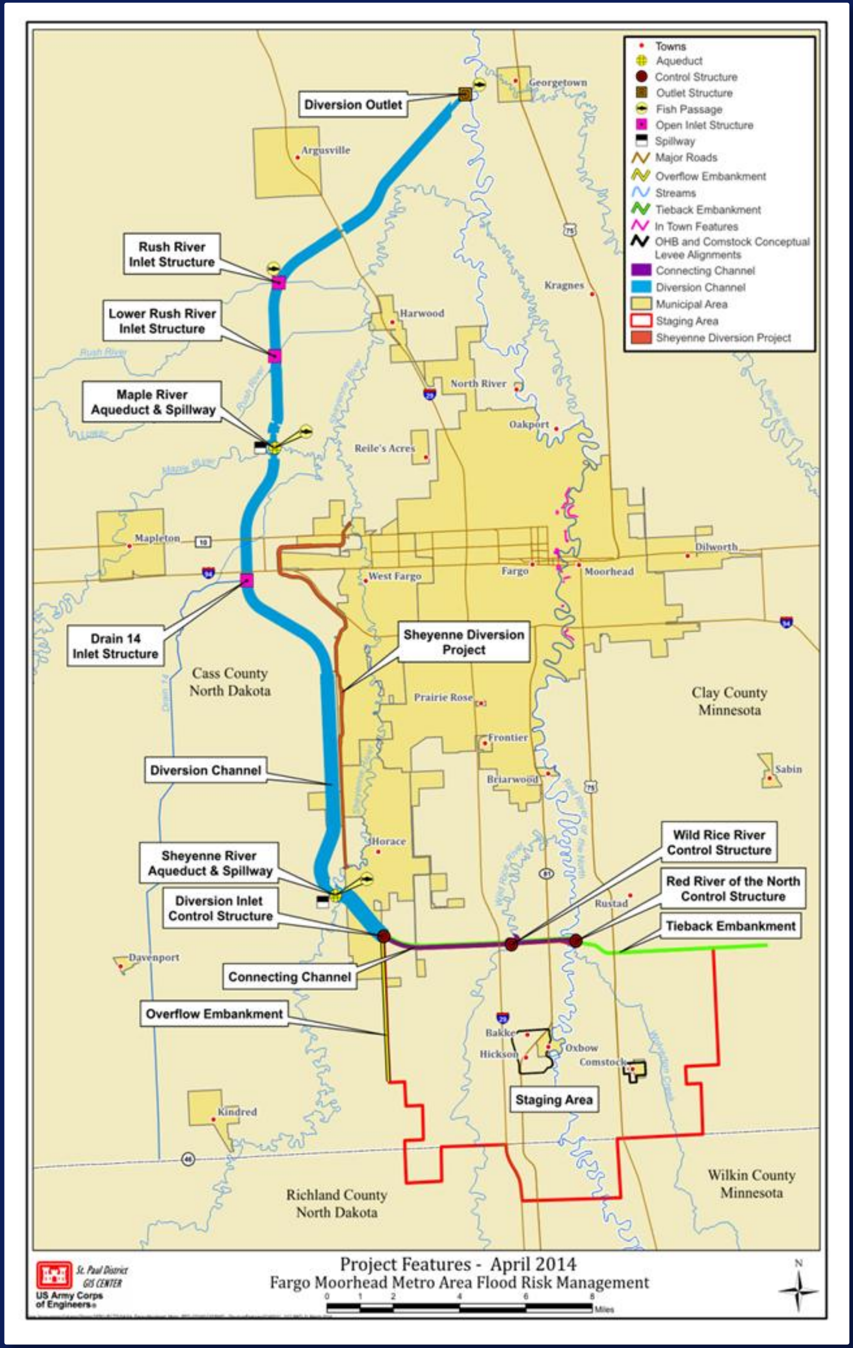
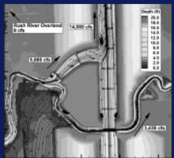
WSE (Max)
Map Layers
Task 9 Truncated Extents
Task 9 Truncated Materials
Task 9 Truncated Extents
LandCover
LandCover
Terrains
Terrain
Messages Views Profile Lines

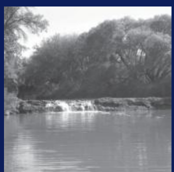
Why are we doing this presentation?

- Unprecedented Case Study Opportunity
- Extensive calibration to a physical model
- It is rare that we have the ability to compare two models side by side with the same level of scrutiny
- Is HEC-RAS 5.0 all that it claims to be?
  - Is the build and calibration process faster than other 2D models?
  - Is the runtime faster than other 2D models?
  - Do we have confidence in the model results?
  - Are the post processing tools robust enough?
- When do I need a 2D model?

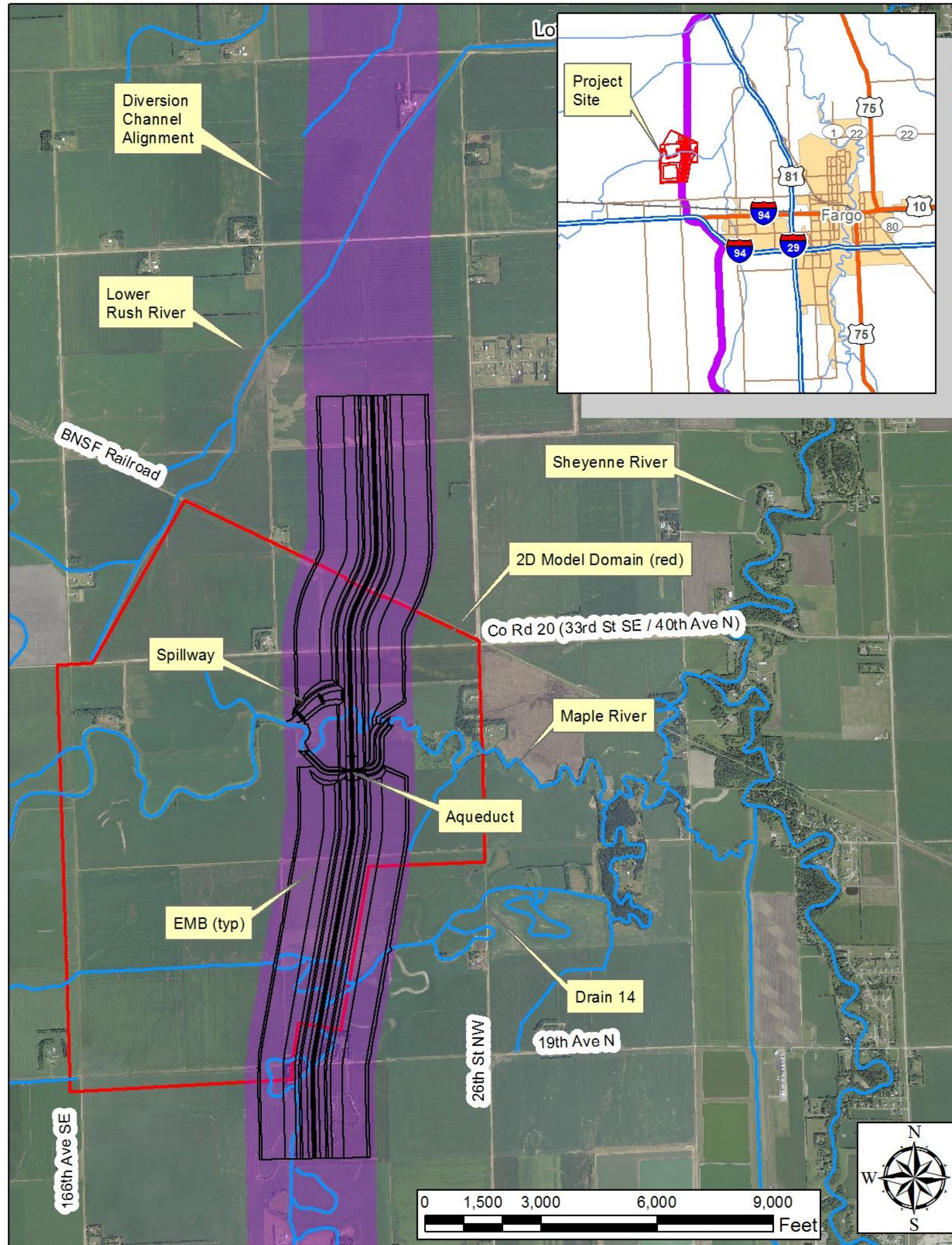
2D Case Study

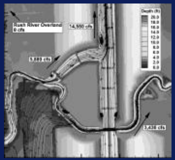






Site Location

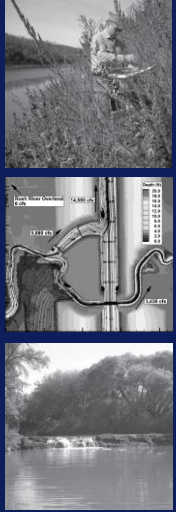




Purpose of Project

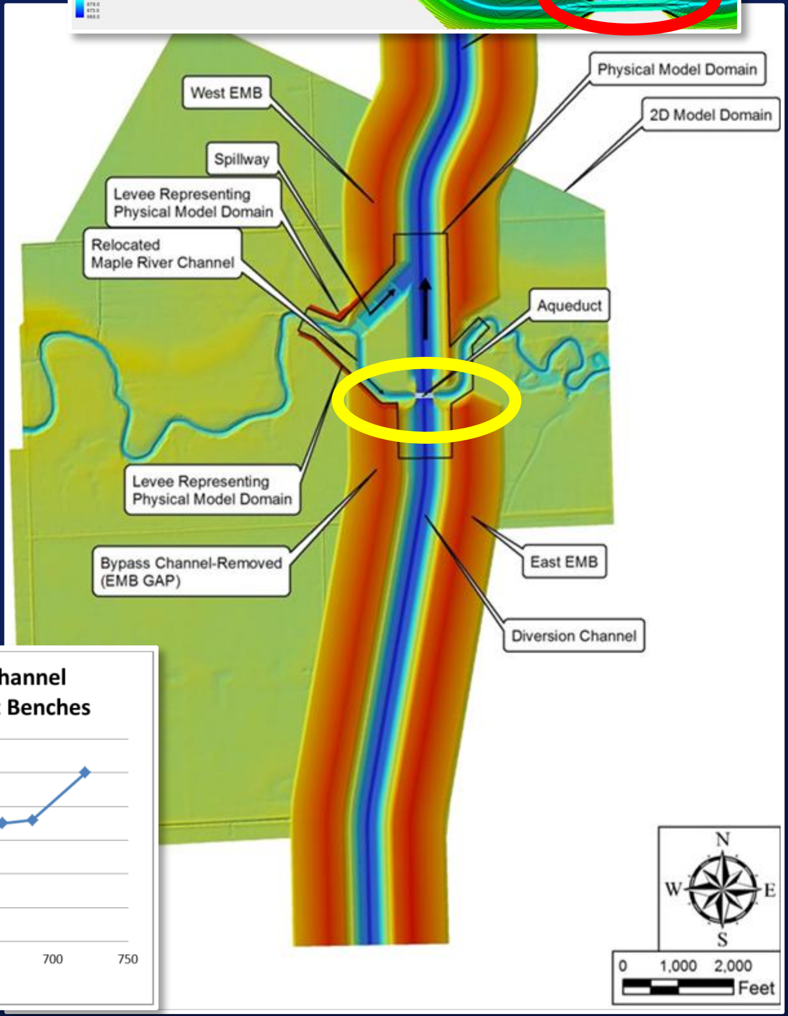
- Provide aquatic and hydraulic connectivity of Maple River across the Diversion channel while reducing flooding on the East side of the Diversion channel.

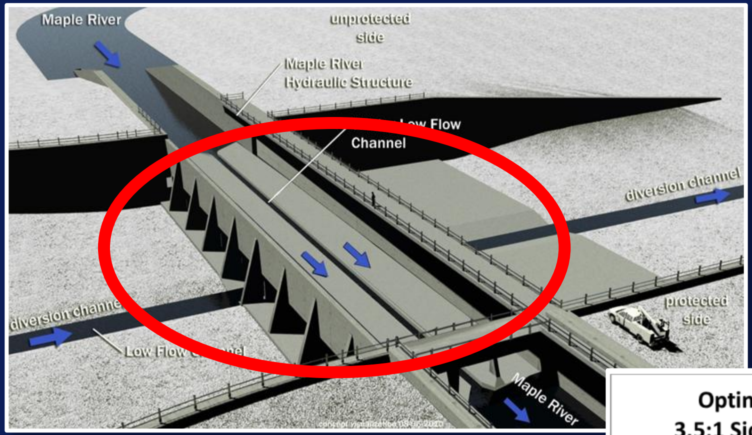
- Numeric and Physical modeling was conducted to verify assumptions made during feasibility design and refine the final design.

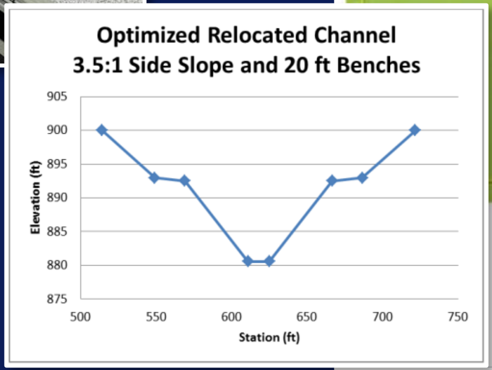


Project Components

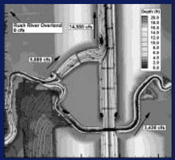
- Aqueduct
- Spillway
- Relocated Maple River Channel
- Bypass Channel

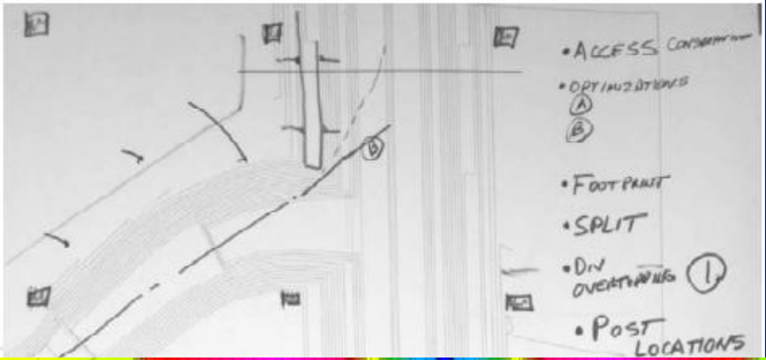


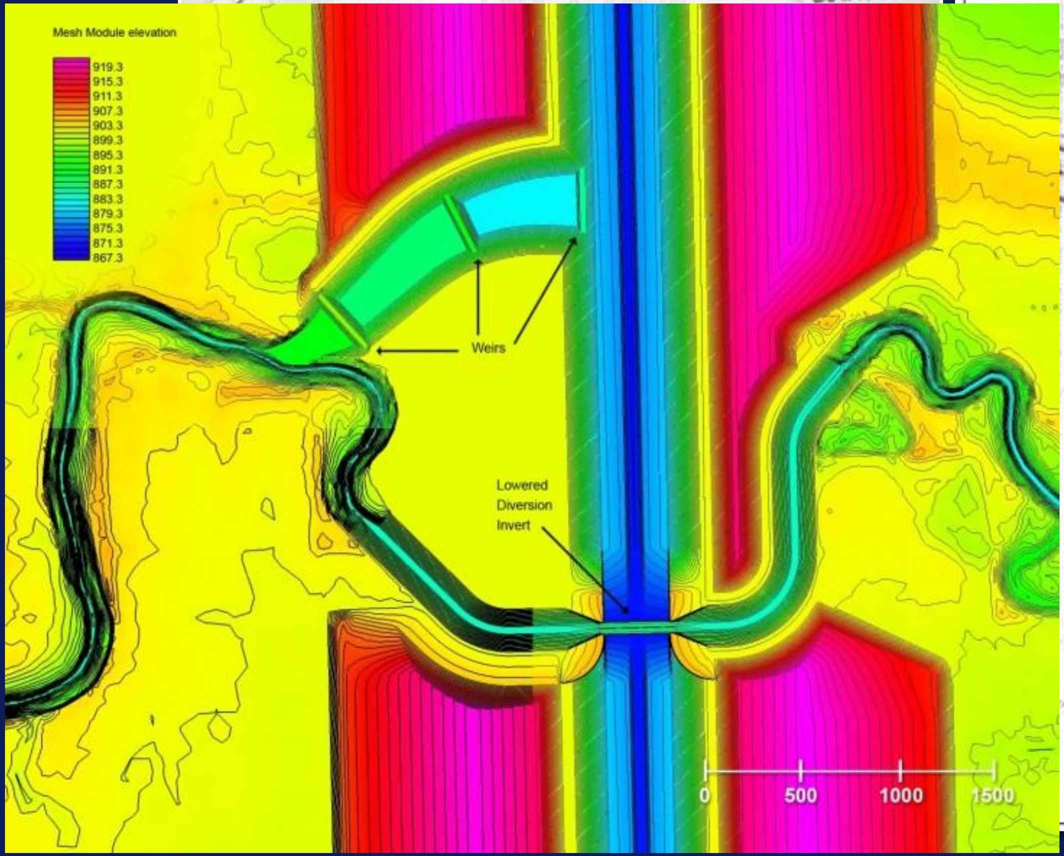


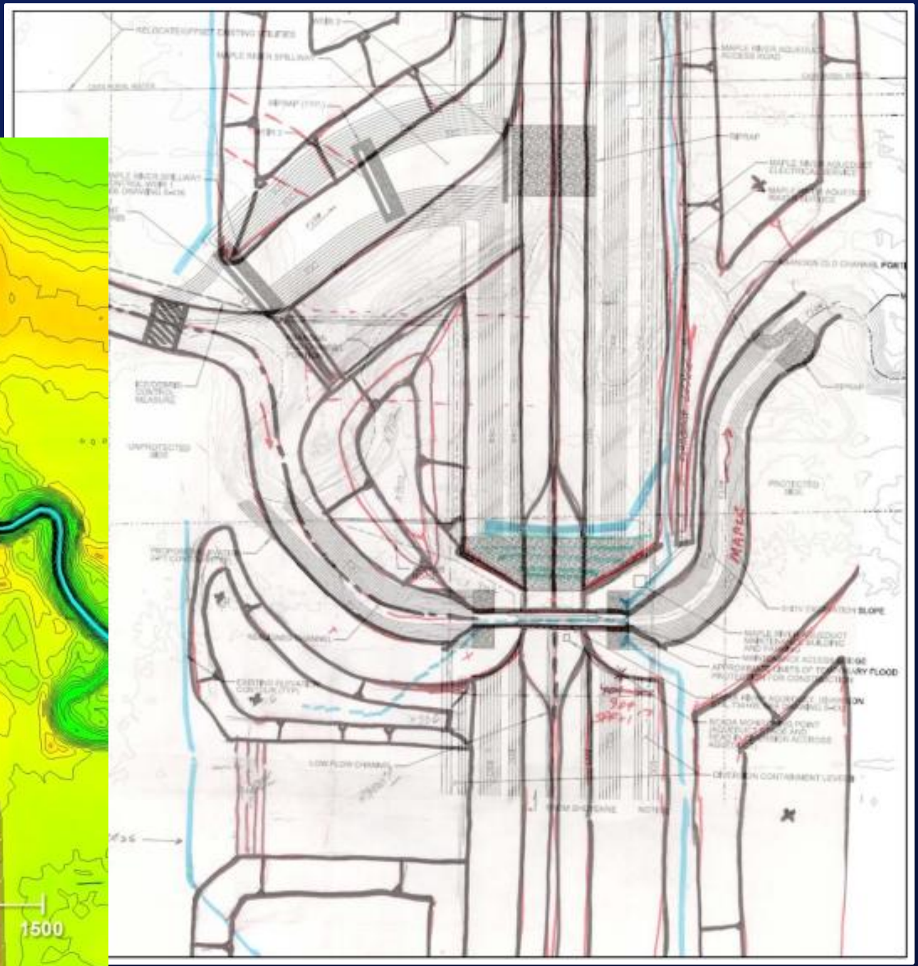


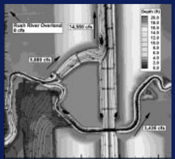
Alternatives Evaluation







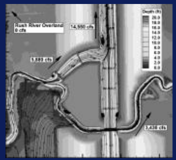



Analysis

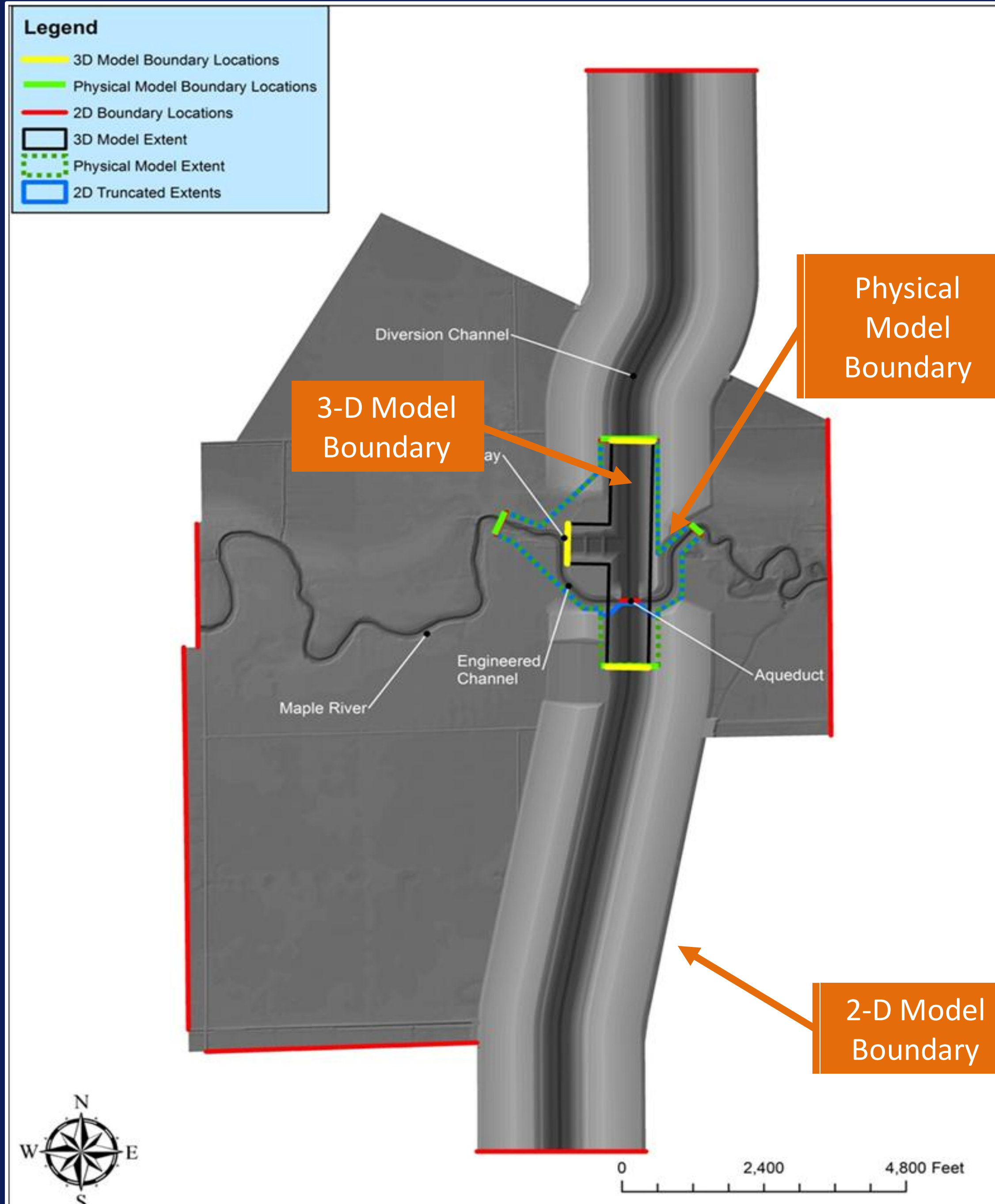
- Hydraulic modeling
  - Physical model
  - 1-D model
  - 2-D model
  - 3-D model

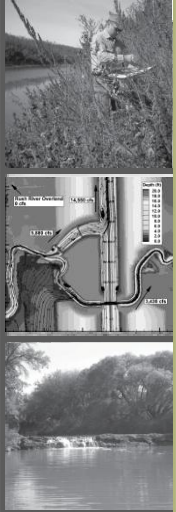
- 1-D unsteady provides flow and boundary conditions
- Physical model used to calibrate the numeric models
- 2-D model focused on the Maple River flow split
- 3-D model focused on the Diversion flow through the conduits


AdH Numeric Model Extents

- Full Domain
  - 5.2 sq. mi.
- Truncated Domain
  - 0.2 sq. mi.

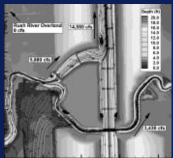
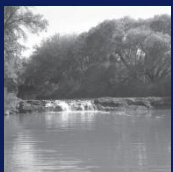




Test: M4

Tributary Inflow: 8000cfs
Diversion Inflow: 5000cfs

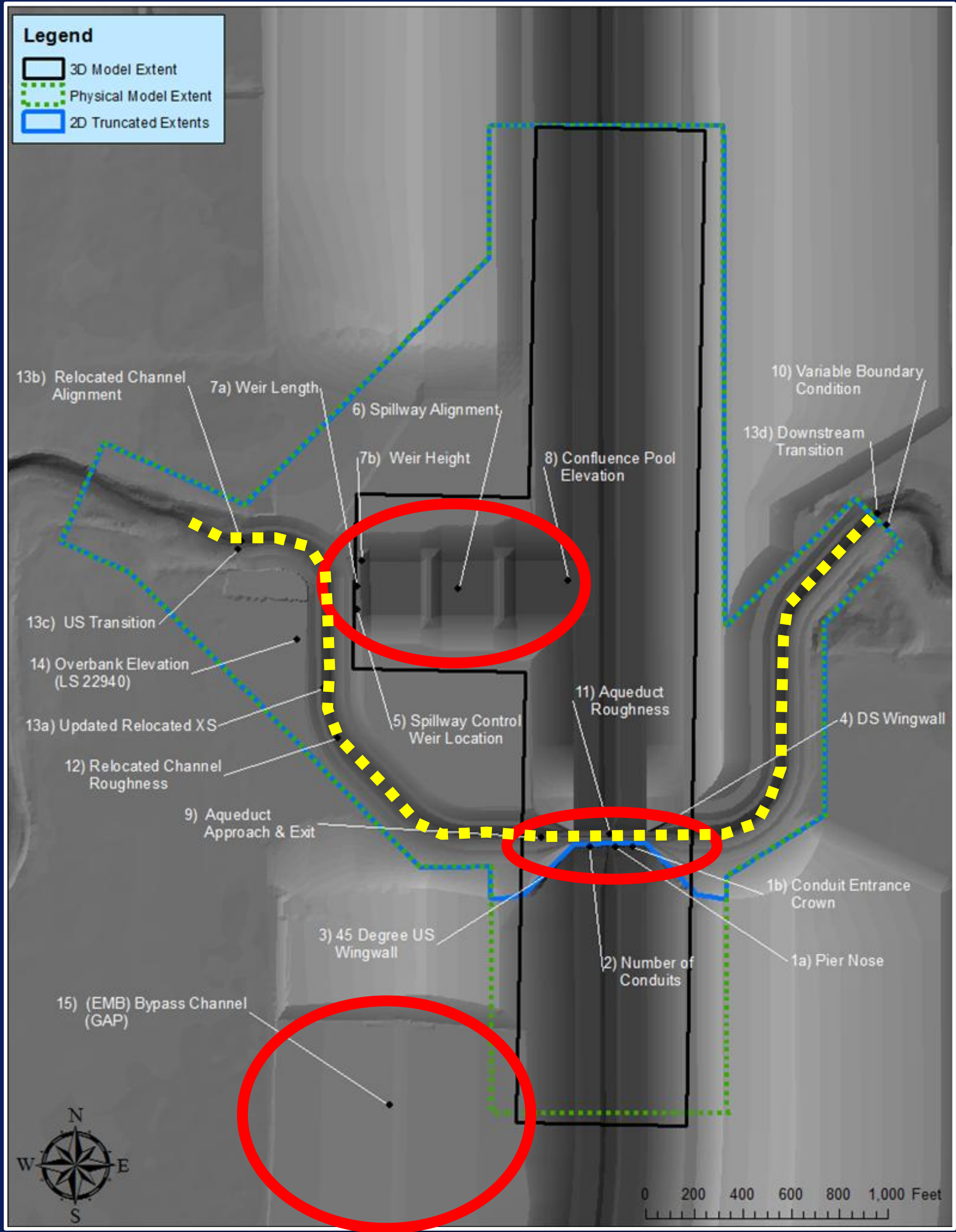
Date: January 11, 2015

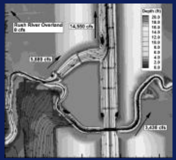




Why 2D?

Optimization for Complex Flow Patterns

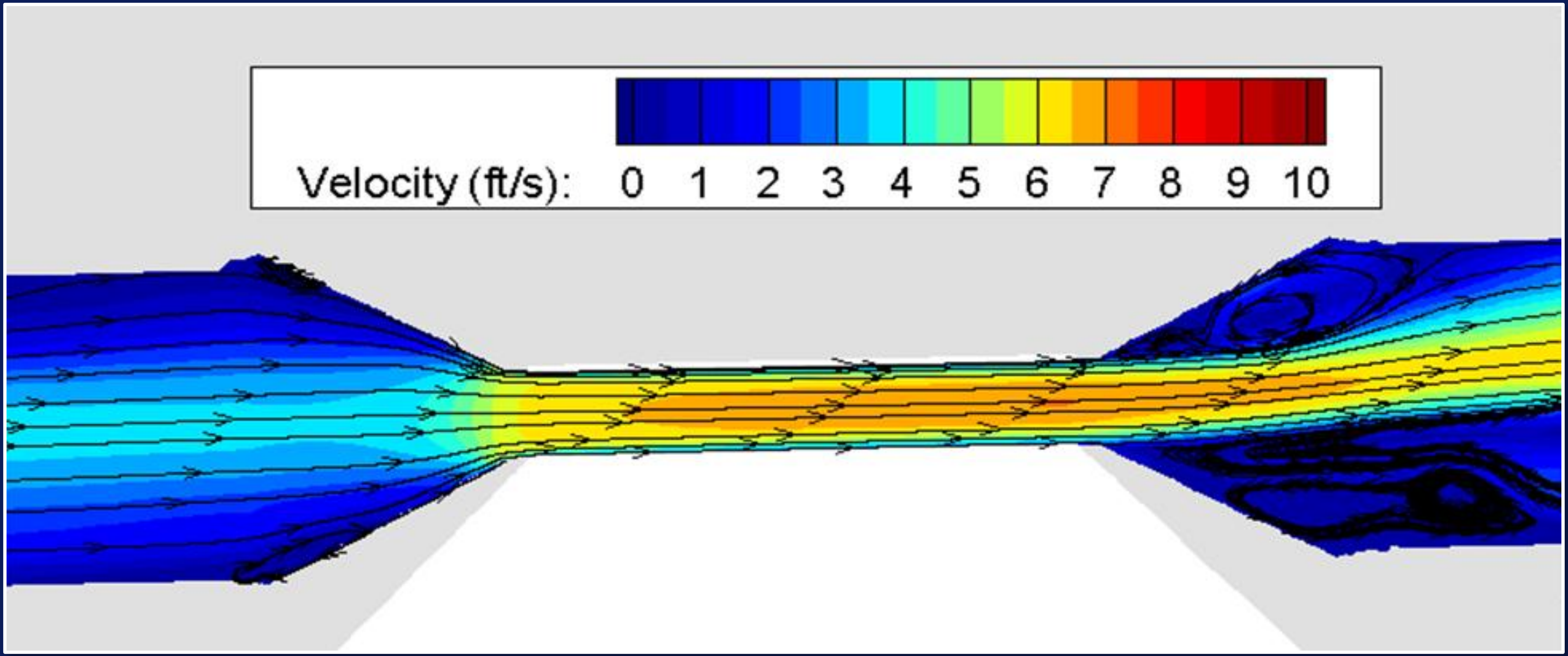
- Aqueduct
- Spillway
- Relocated Maple River Channel
- Bypass Channel

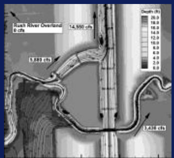


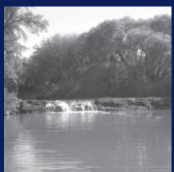


Aqueduct

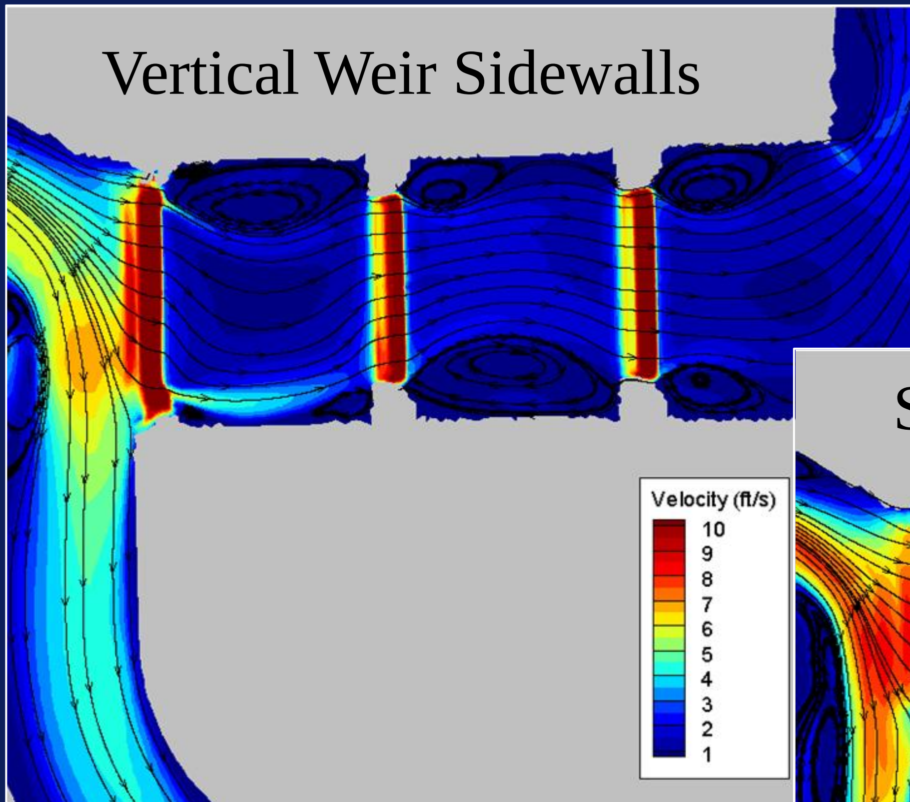
- Contractions / Expansions
- Recirculation
- Velocity Direction & Magnitude



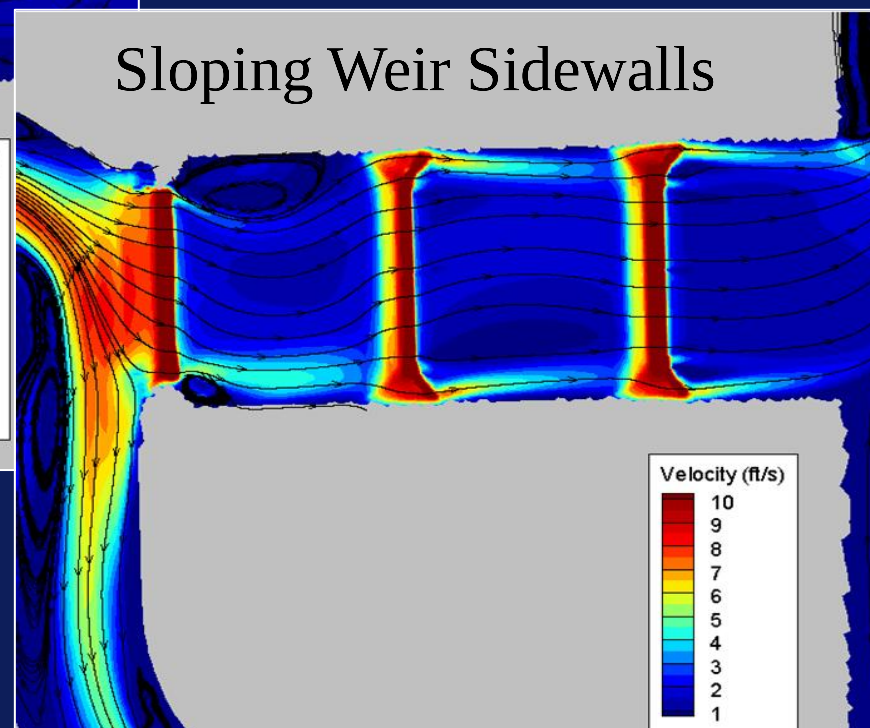




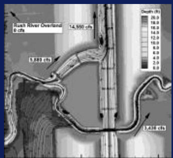
Spillway



- Complex flow patterns
- Recirculation

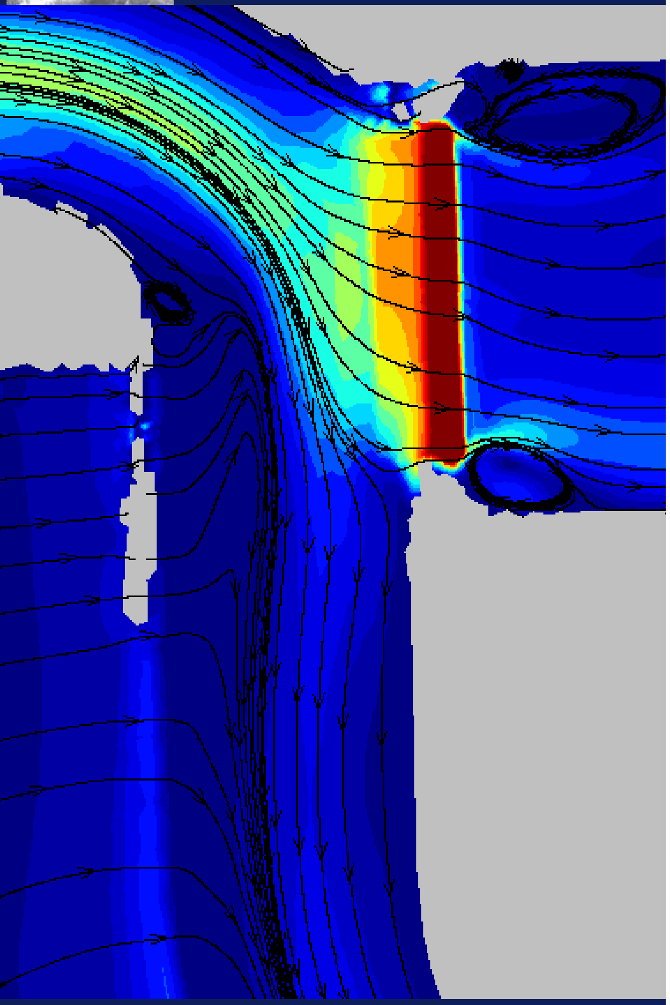


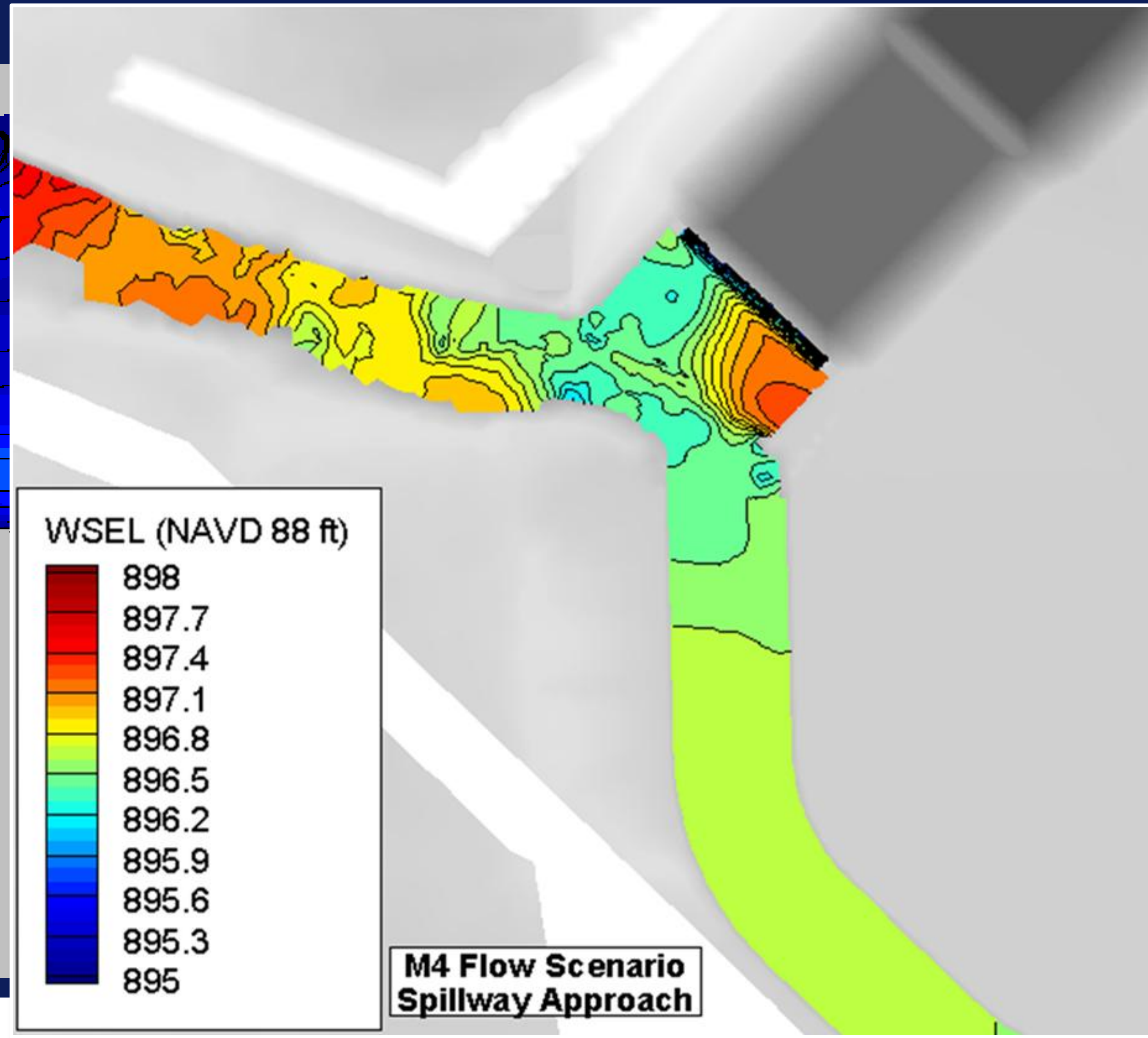
- Velocity direction & magnitude
- Scour potential

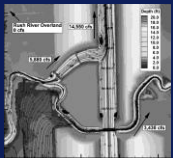
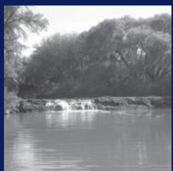


Relocated Channel

- Complex flow patterns
- Recirculation
- Velocity direction & magnitude
- Variable WSEL





Lessons Learned – 2D Case Study

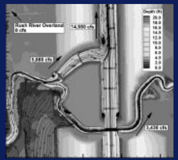
- Challenging to get 1-D, 2-D, 3-D, and Physical models to have good correlation between models
- Your model is only as good as your data
- 2D modeling is very useful for design optimization when complex flow patterns are expected
- Before selecting a 2D model, verify the model capabilities and limitations

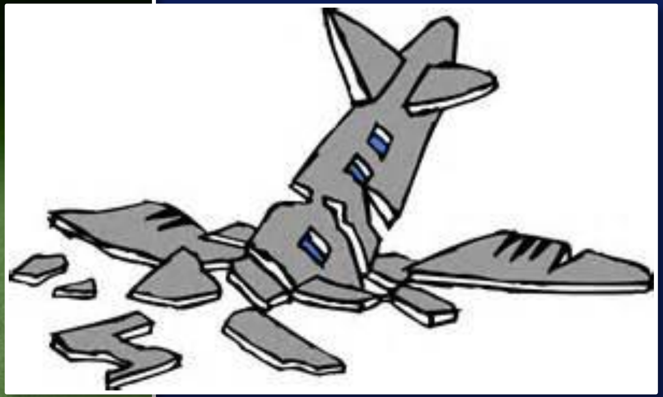
- CALIBRATION IS CRITICAL !!!

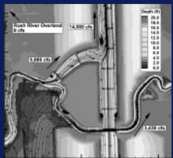
- Start Simple...Start Simple…Start Simple

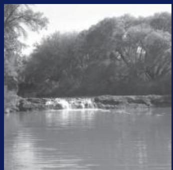
How Does HEC-RAS 5.0 Compare

BETA





What's New in HEC-RAS

- 2D St. Venants Shallow Water Equation
  – Momentum additions for turbulence and Coriolis Effect
- Diffusion Wave
  – Faster (More Forgiving Numerically)
  – Greater Stability
  – Inappropriate for Rapid Velocity Change
- Volume Conservation
  – Implicit Finite Volume Solution
    • Implicit = Larger Computation Timestep

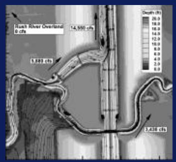
<u>Full Saint Venant Equations:</u>

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

Where: C = Courant Number
V = Velocity of the Flood Wave (ft/s)
ΔT = Computational Time Step (seconds)
ΔX = The average Cell size (ft)

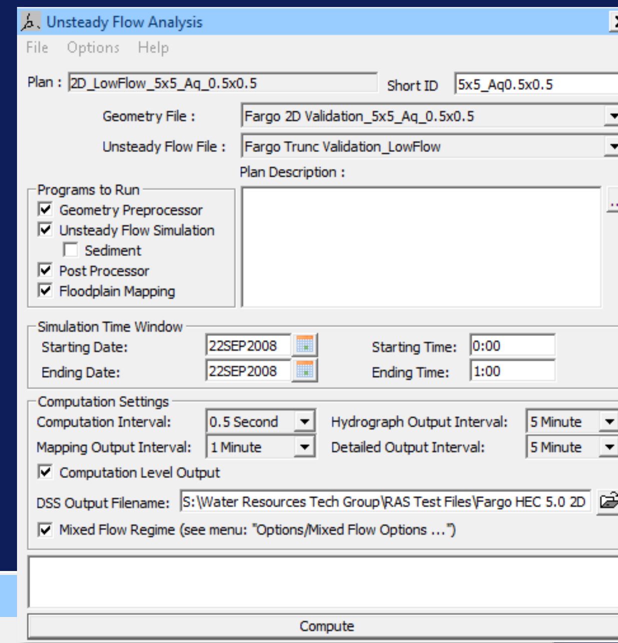
<u>Diffusion Wave Equations:</u>

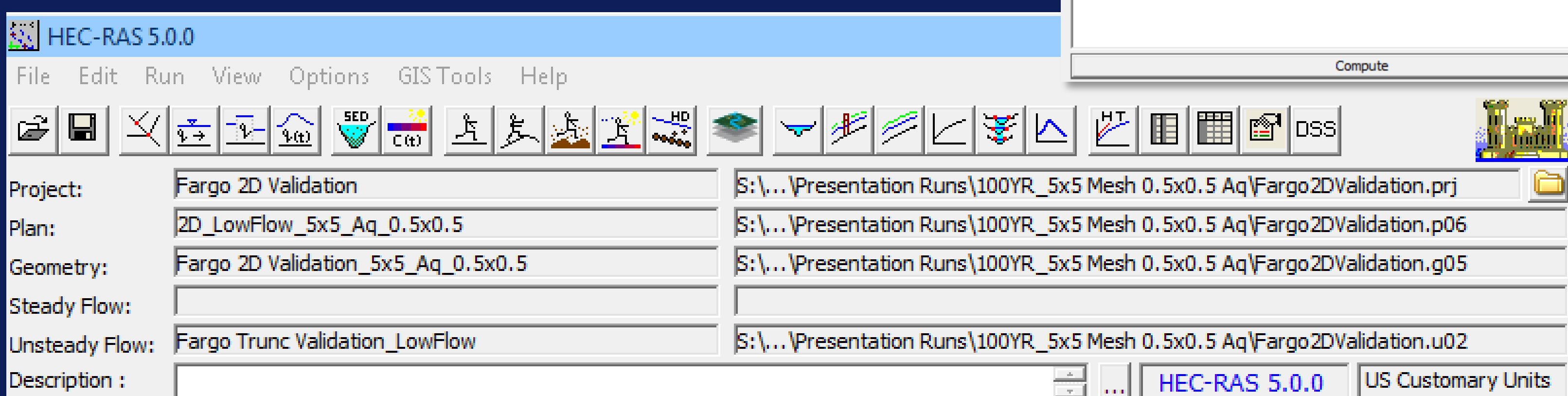
$$C = \frac{V * \Delta T}{\Delta X} \leq 2.0 \quad (with\ a \max\ C = 5.0)$$

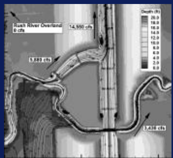

Familiar Platform

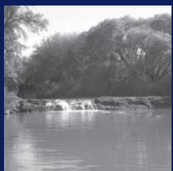
- Still Looks and Feels Like RAS
  - Additional Menus, but familiar setting
- RAS Mapper
- AdH
  - Learning curve
  - BC files, Flux files, .dat files
  - SMS makes it easier





AdH Interface





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10 0

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0 0
10 0

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0 0
10 0

XY1 21 2 3 0 "Comparison_Physical_Extents_DS_Maple"
0 0
10 0

XY1 22 2 3 0 "Comparison_Physical_Extents_US_Maple"
0 0
10 0

XY1 23 2 3 0 "Time Step Sizes"
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24.0 300.0

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0.0 24.0 1 2

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FR MNG 3 0.043 "Channel_Vegetation"
FR MNG 4 0.03 "EMB"
FR MNG 5 0.015 "DS_Wingwall"
FR MNG 6 0.03 "Diversion Channel"
FR MNG 7 0.03 "LowFlowChannel"
FR MNG 8 0.03 "Spillway"
FR MNG 9 0.03 "Grass"
FR MNG 10 0.015 "US_Wingwall"
FR MNG 11 0.04 "Aqueduct"
FR MNG 12 0.04 "Ditch"
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NB DIS 38 9 "Aqueduct Weir US"
NB DIS 39 10 "Aqueduct Weir DS"
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NB OTW 44 14 "Diversion_US_Aqueduct"
DB LID 46 21 "Comparison_Physical_Extents_DS_Maple"
DB LID 48 22 "Comparison_Physical_Extents_US_Maple"
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NB DIS 54 3 "Rush SC-34 & Rush SC-106 (Rush SA-15)"
NB DIS 55 4 "Maple_US_XS-35955"
NB DIS 56 5 "MpSSC-541 + MpSSC-529"
NB DIS 57 6 "MpSSC-530"
NB DIS 58 8 "Diversion_US_domain"
NB OTW 59 12 "Maple_DS_BR-14481"
NB OTW 60 13 "Diversion_DS_domain"

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FLX 34 "Flux_GAP"
FLX 37 "Diversion_DS_Aqueduct"
FLX 39 "Aqueduct Weir DS"
FLX 40 "Flux_Aqueduct_DS"
FLX 42 "Flux_Aqueduct_US"
FLX 44 "Diversion_US_Aqueduct"
FLX 45 "Comparison_Physical_Extents_DS_Maple"
FLX 47 "Comparison_Physical_Extents_US_Maple"
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FLX 52 "Rush_SC-120 (Rush SA50 to SA45)"
FLX 53 "Rush_LS-27712"
FLX 54 "Rush SC-34 & Rush SC-106 (Rush SA-15)"
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FLX 56 "MpSSC-541 + MpSSC-529"
FLX 57 "MpSSC-530"
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FLX 60 "Diversion_DS_domain"

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String  52  Flux 0.0000e+000  WSE 0.0000e+000  WSEMin 8
String  53  Flux 0.0000e+000  WSE 0.0000e+000  WSEMin 8
String  54  Flux 0.0000e+000  WSE 0.0000e+000  WSEMin 8
String  55  Flux 6.4000e+003  WSE 9.0256e+002  WSEMin 9
String  56  Flux 1.4995e+003  WSE 9.0104e+002  WSEMin 9
String  57  Flux 9.9992e+001  WSE 9.0110e+002  WSEMin 9
String  58  Flux 5.0000e+003  WSE 8.8405e+002  WSEMin 8
String  59  Flux -3.3689e+003  WSE 8.9410e+002  WSEMin
String  60  Flux -9.6320e+003  WSE 8.8212e+002  WSEMin
```

```
----------
  ADH VERSION #4.3
----------
Physics Time     dt        Progress         Nonlinear Iteration     Linear Iterations         Max Resid Norm  Worst Node        X          Y          Z          Inc Max Norm
The Flux to the downstream (+ve going out) is 5000.000000           The Upstream WSE is 883.502195 Submergence Modifier is 1.000000

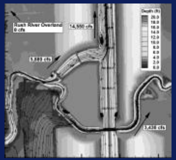
HYD      0.00000000e+000   3.000000e+002 %0.00          1    0      1.2905e+007      37113    2.85083677e+006 4.80644215e+005 8.9986e+002       3.1262e+001      37113
HYD      0.00000000e+000   3.000000e+002 %0.00          2    0      9.9553e+004      48675    2.85227790e+006 4.80622553e+005 8.8159e+002       1.1218e+001      47728
The Flux to the downstream (+ve going out) is 5000.000000           The Upstream WSE is 883.502195 Submergence Modifier is 1.000000

HYD      3.00000000e+002   3.000000e+002 %0.35          1    0      2.0708e+005      35539    2.85085265e+006 4.80669885e+005 8.9843e+002       1.0825e+001      47728
The Flux to the downstream (+ve going out) is 5000.000000           The Upstream WSE is 883.502195 Submergence Modifier is 1.000000

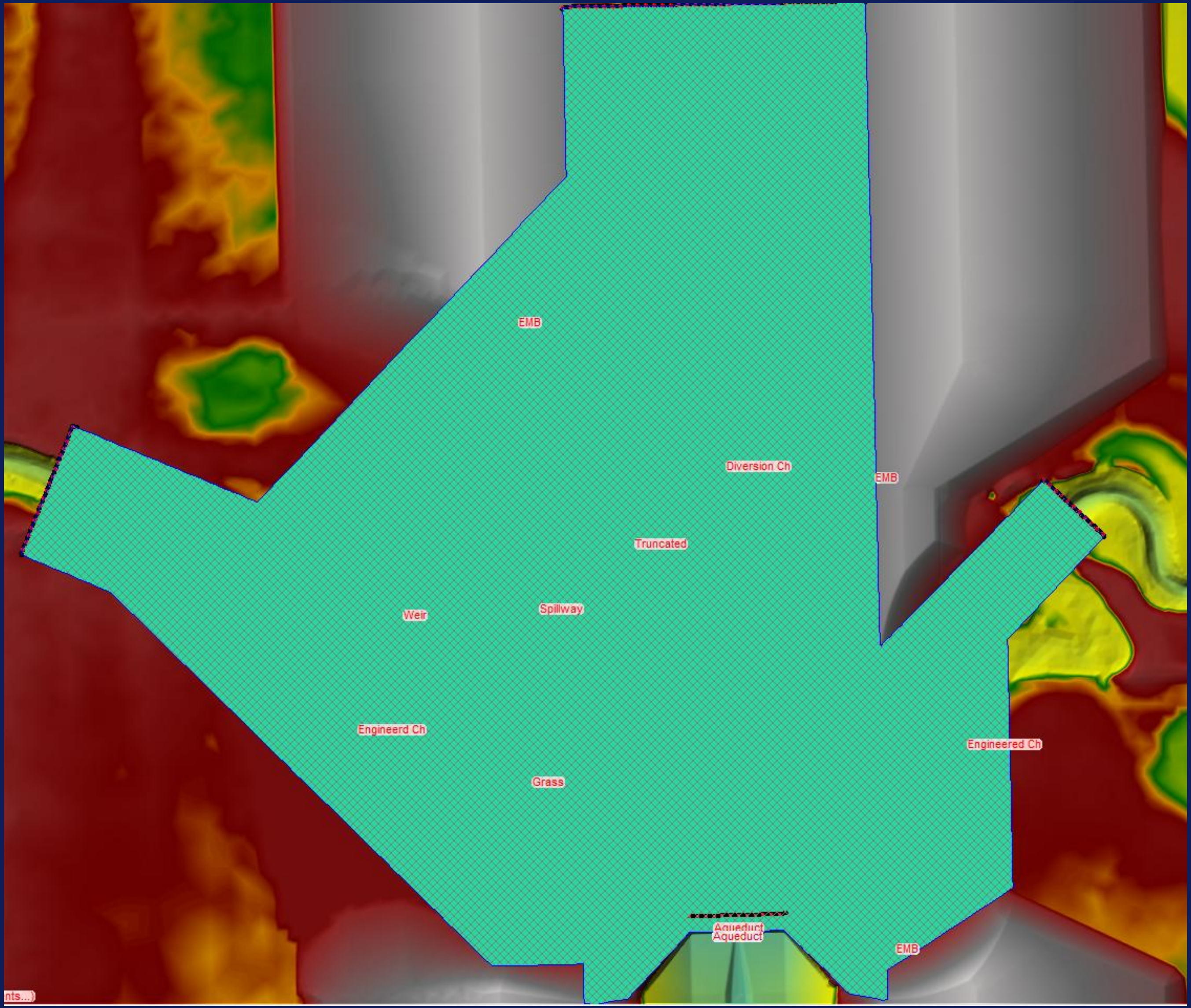
HYD      6.00000000e+002   3.000000e+002 %0.69          1    0      1.0901e+006      35579    2.85032011e+006 4.80700878e+005 9.0000e+002       1.7494e+001      47729
HYD      6.00000000e+002   3.000000e+002 %0.69          2    0      1.8692e+005      48674    2.85228347e+006 4.80621537e+005 8.8025e+002       1.7662e+001      47727
HYD      6.00000000e+002   3.000000e+002 %0.69          3    0      9.6921e+004      47728    2.85227622e+006 4.80627872e+005 8.8269e+002       9.3486e+000      47727
The Flux to the downstream (+ve going out) is 5000.000000           The Upstream WSE is 883.502195 Submergence Modifier is 1.000000

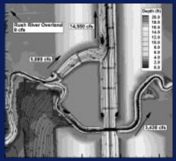
HYD      9.00000000e+002   3.000000e+002 %1.04          1    0      2.6940e+008      34679    2.85167558e+006 4.80642695e+005 8.9401e+002       5.8019e+001      34679
HYD      9.00000000e+002   3.000000e+002 %1.04          2    0      1.1891e+008      65858    2.85144860e+006 4.80286151e+005 8.9900e+002       1.7492e+002      65858
HYD      9.00000000e+002   3.000000e+002 %1.04          3    0      2.9180e+006      34681    2.85166323e+006 4.80642367e+005 8.9456e+002       1.7412e+001      34679
HYD      9.00000000e+002   3.000000e+002 %1.04          4    0      1.0617e+005      49616    2.85228203e+006 4.80617466e+005 8.8000e+002       8.3797e+000      36992
The Flux to the downstream (+ve going out) is 5000.000000           The Upstream WSE is 883.502195 Submergence Modifier is 1.000000

HYD      1.20000000e+003   3.000000e+002 %1.39          1    0      2.2780e+006      38655    2.85167004e+006 4.80615665e+005 8.9428e+002       2.5553e+001      38655
HYD      1.20000000e+003   3.000000e+002 %1.39          2    0      3.3785e+005      36996    2.85164239e+006 4.80627534e+005 8.9596e+002       1.9340e+001      36996
HYD      1.20000000e+003   3.000000e+002 %1.39          3    0      2.0689e+005      36198    2.85164459e+006 4.80632788e+005 8.9567e+002       1.2123e+001      37812
```



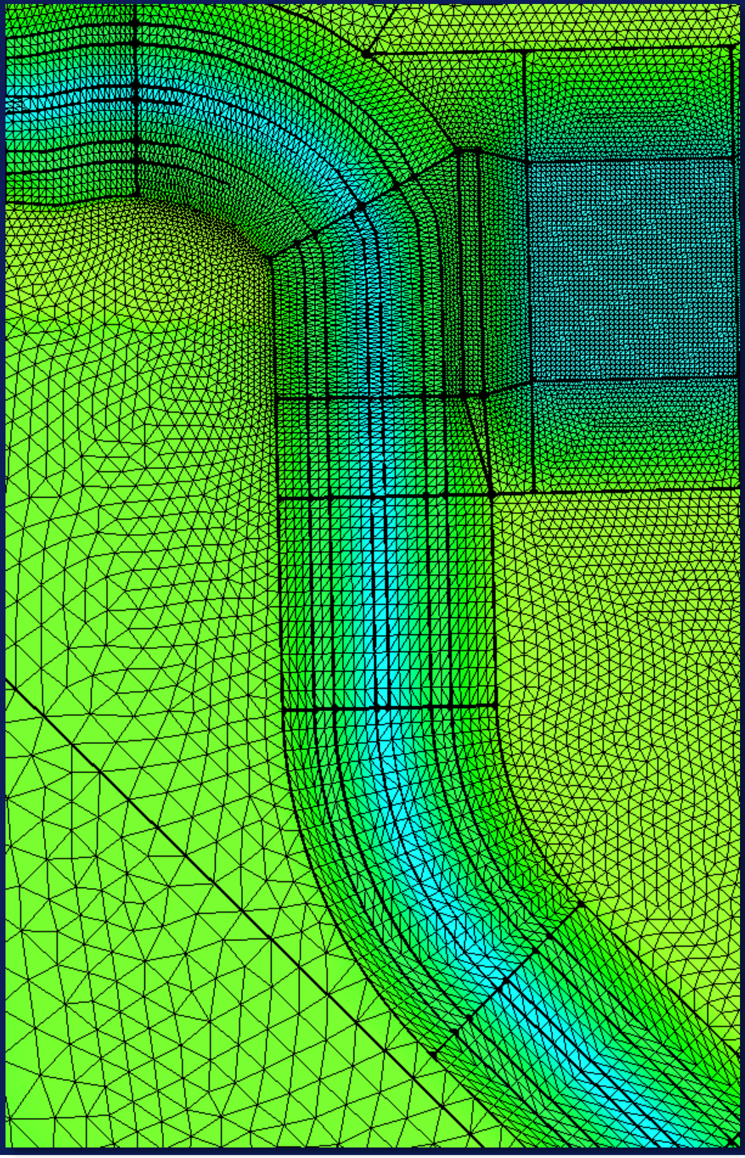
Mesh Generation



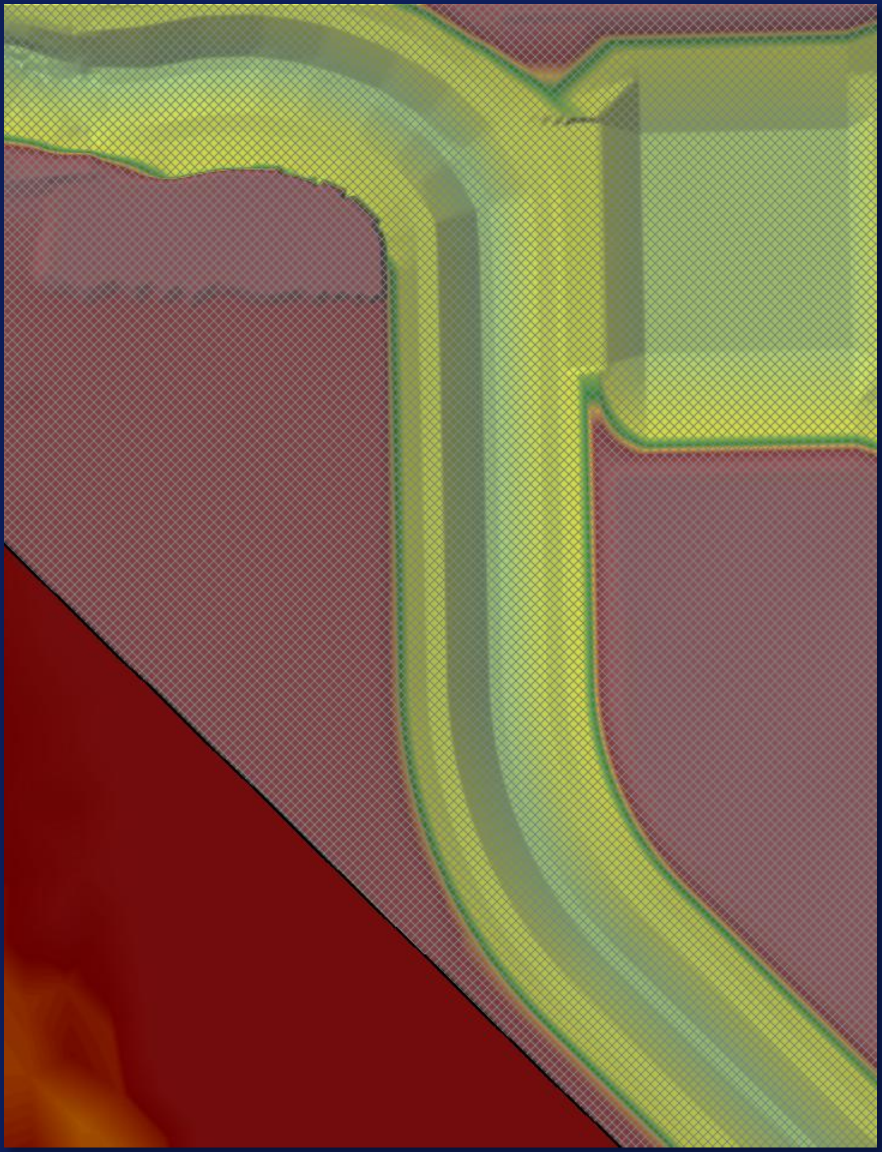


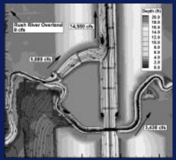
Unstructured vs Structured Mesh

AdH

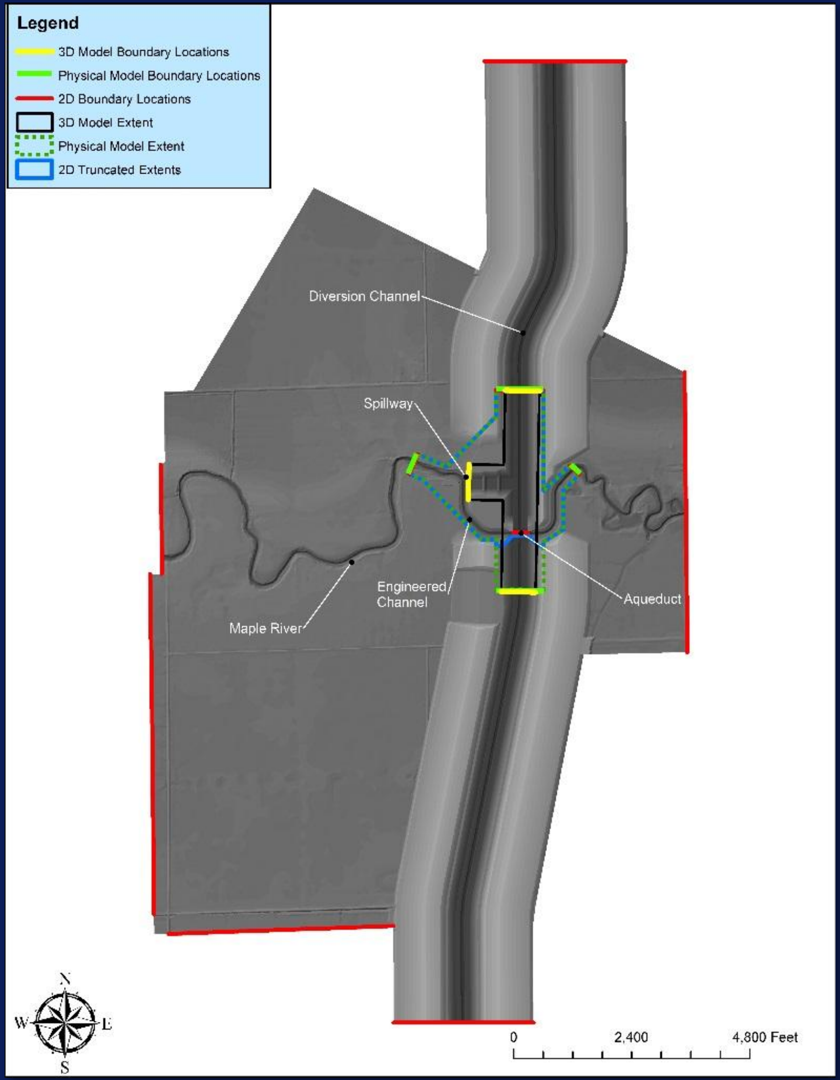


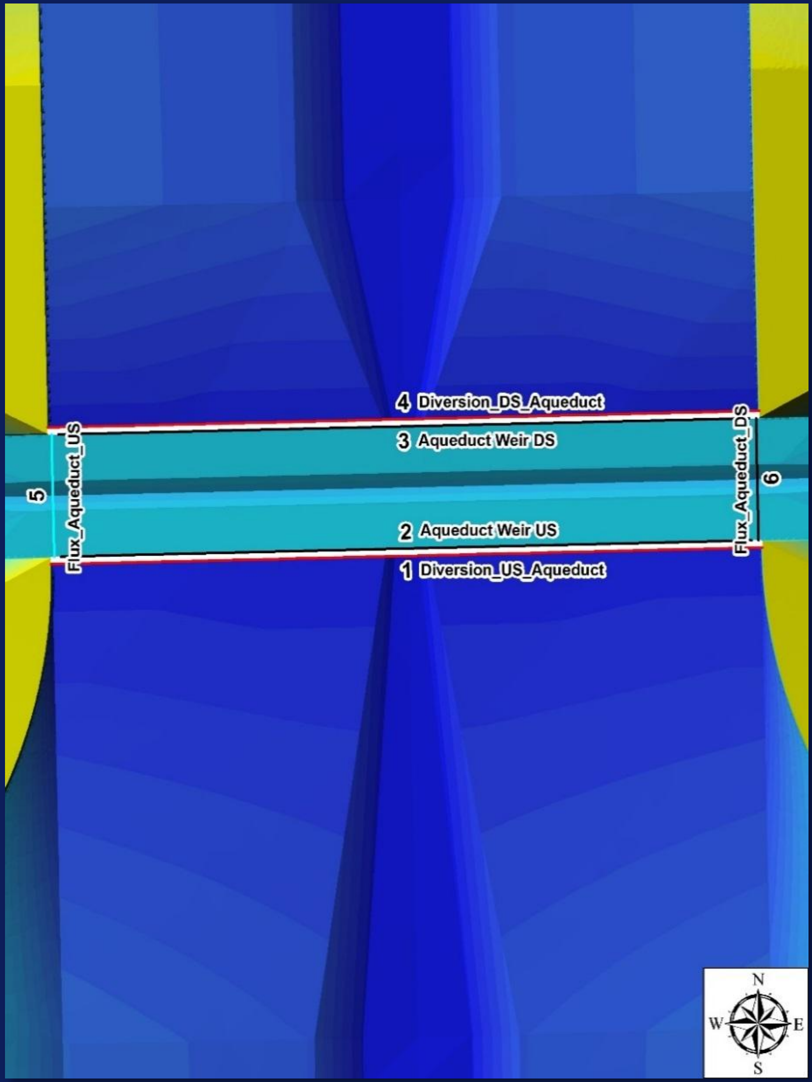
HEC-RAS 5.0

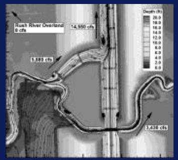




Boundary Conditions

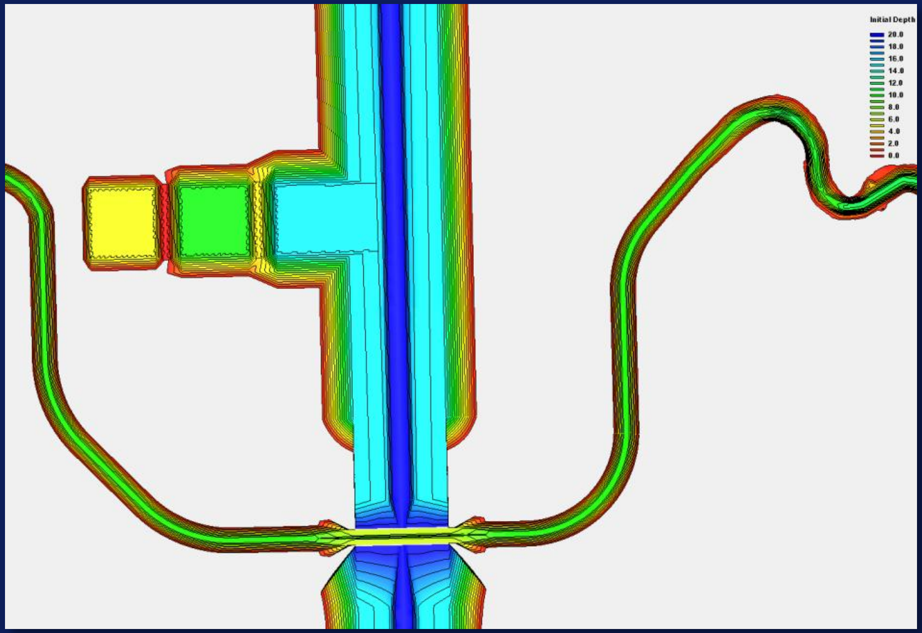


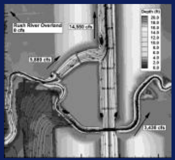




Starting Conditions

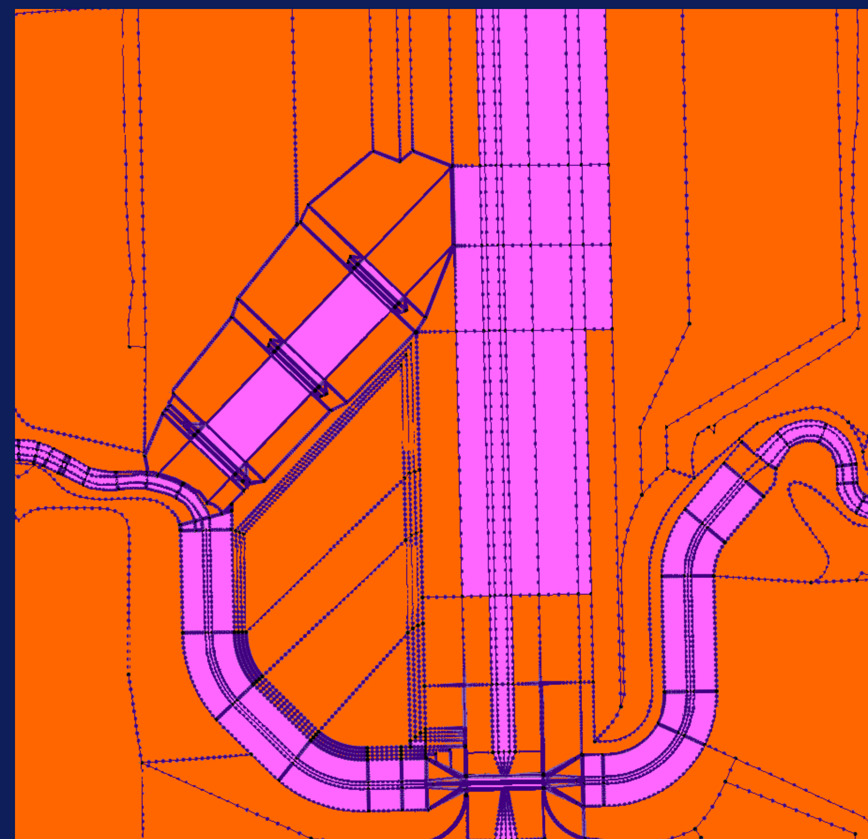
- Initial WSEL (Hot Start)
  - AdH
    - Critical to model stability
    - Must start WET
  - HEC-RAS
    - Optional (Additional Tool to Increase Stability)
    - Can start DRY
    - May need warm up period

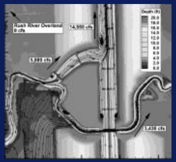


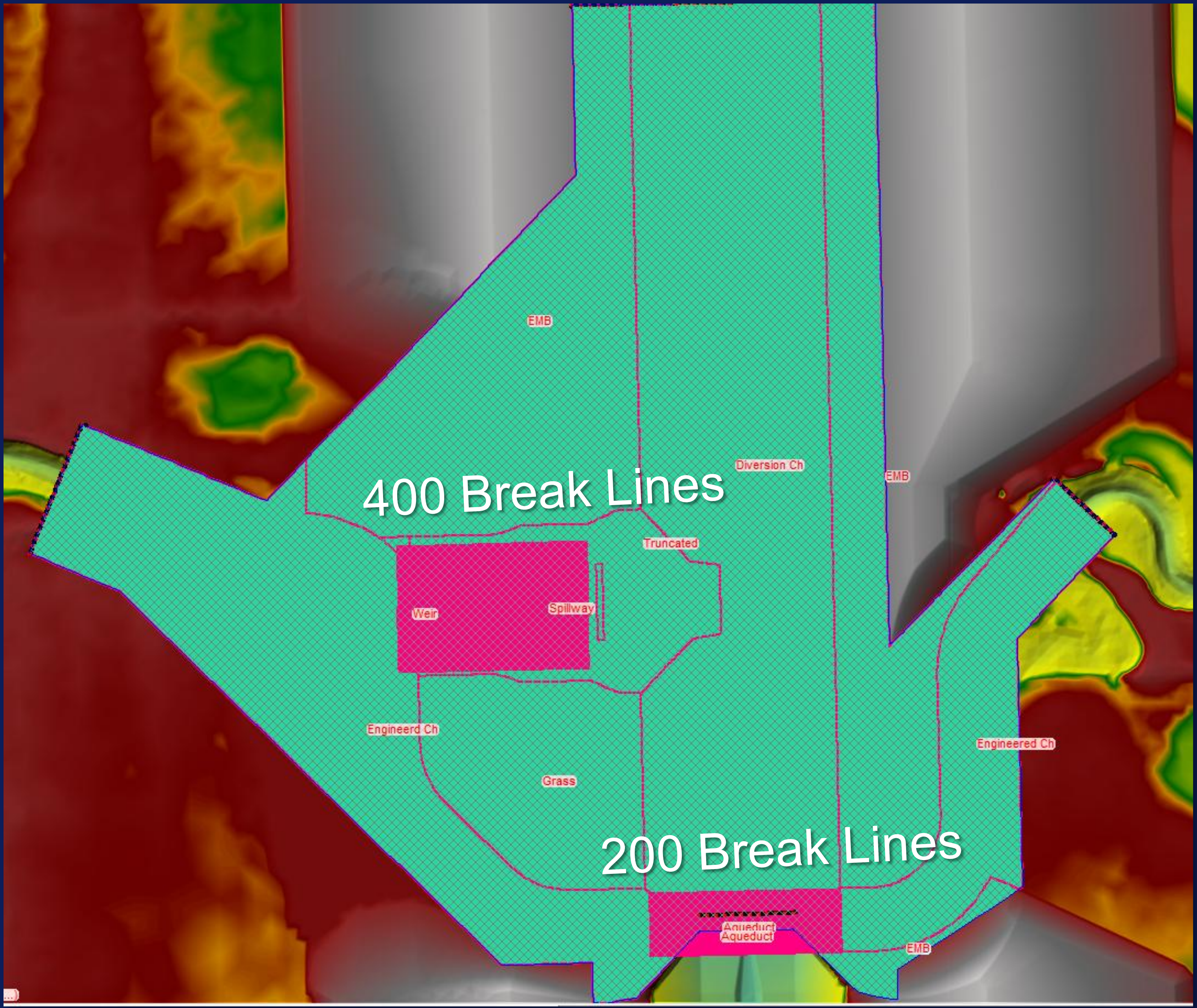



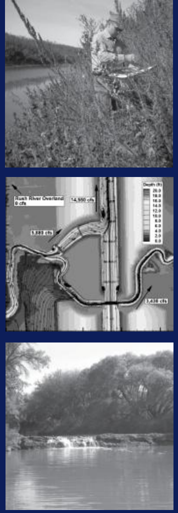

Which Build is Faster?

- **Dependent on Familiarity With Model**
- **AdH**
  - Mesh Generation Requires More Detail at Startup
  - – Regional Mesh Density
- HEC-RAS
  - – Draw a Polygon and Run
    - Refine Through Break Lines
- Both use GIS to expedite process



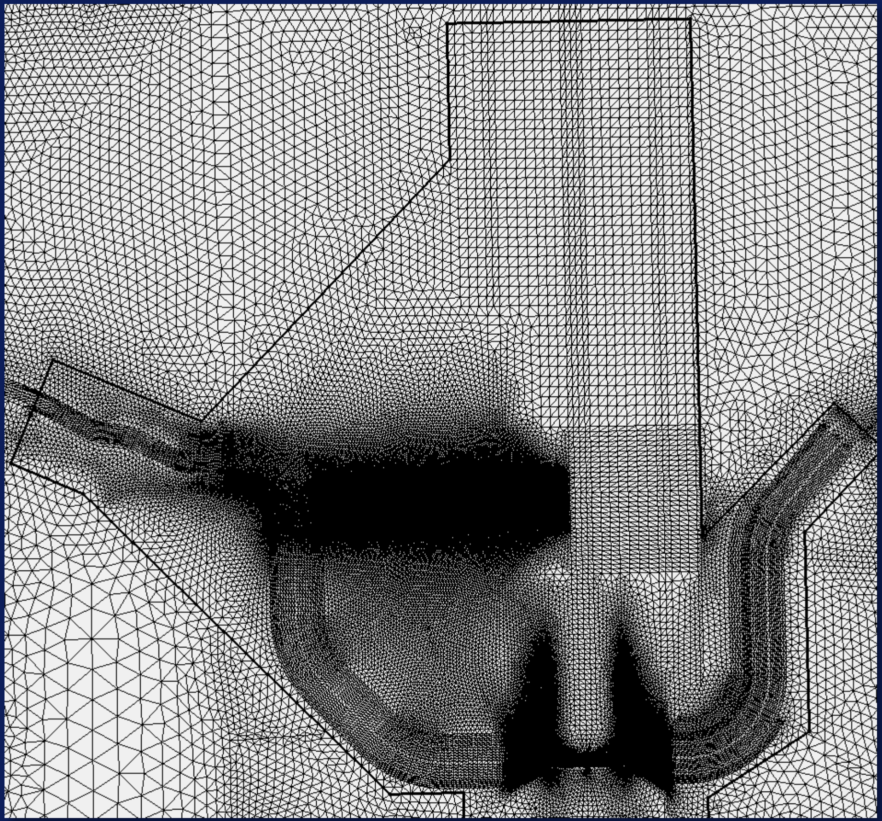


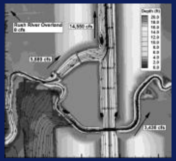

EMB
400 Break Lines
Diversion Ch
EMB
Truncated
Weir
Spillway
Engineerd Ch
Grass
Engineered Ch
200 Break Lines
Aqueduct
Aqueduct
EMB



Computational Time

- AdH
  - Preliminary Runs – 6 hours
  - Final Refined Product – 1-2 hours
  - Timestep = 300 sec (average timestep = 1sec)
  - 16 Core processor
  - Mesh Density = 1ft to 40 ft
- HEC-RAS
  - Final Product – 24 hours
  - Timestep = 0.2 sec
  - 16 Core processor
  - Mesh Density = 1ft to 5 ft




Mesh Density - Number of Elements

Affects Computation Time!!

AdH Truncated Model

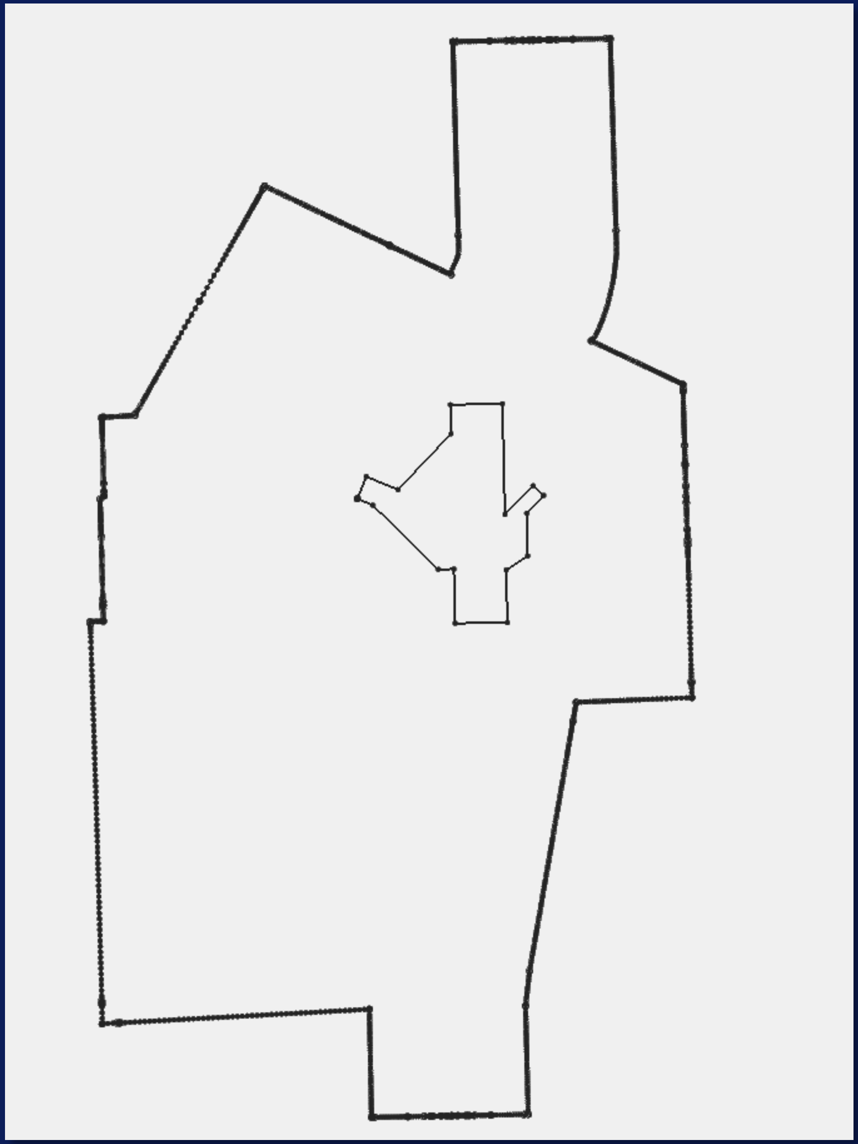
239,338

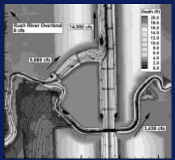
HEC-RAS Truncated Model

399,616

AdH Full Domain Model

437,338

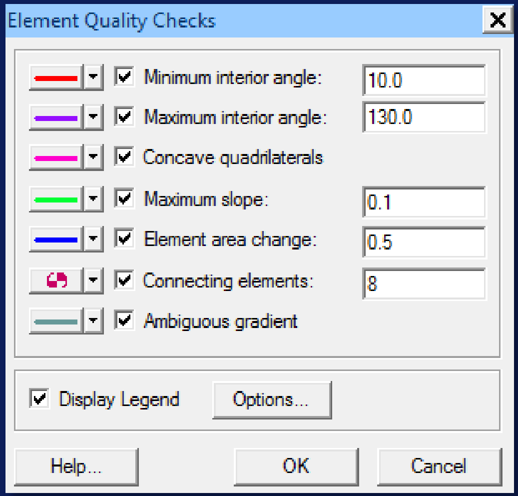


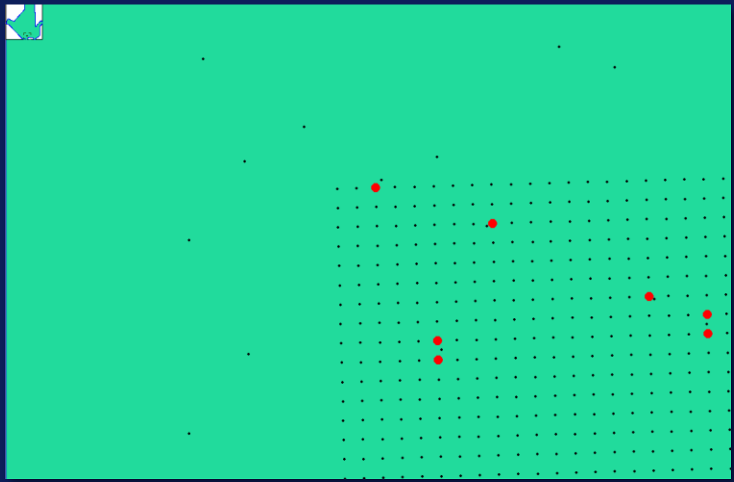



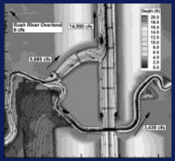

Mesh Quality

Affects Stability and Results !

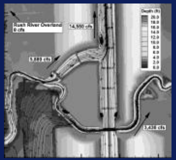
- What are we looking for?
  - Mesh error (i.e. area change, angle, connecting elements)
  - Density
  - Boundary Sensitivity
  - Land Use
- Iterative Process!
- Both Make Identifying Mesh Errors Simple
- AdH
  - Terrain Errors Slip Through
  - Often aren't caught until a model is completed
  - Export data while running
- HEC-RAS
  - Wait until it's done





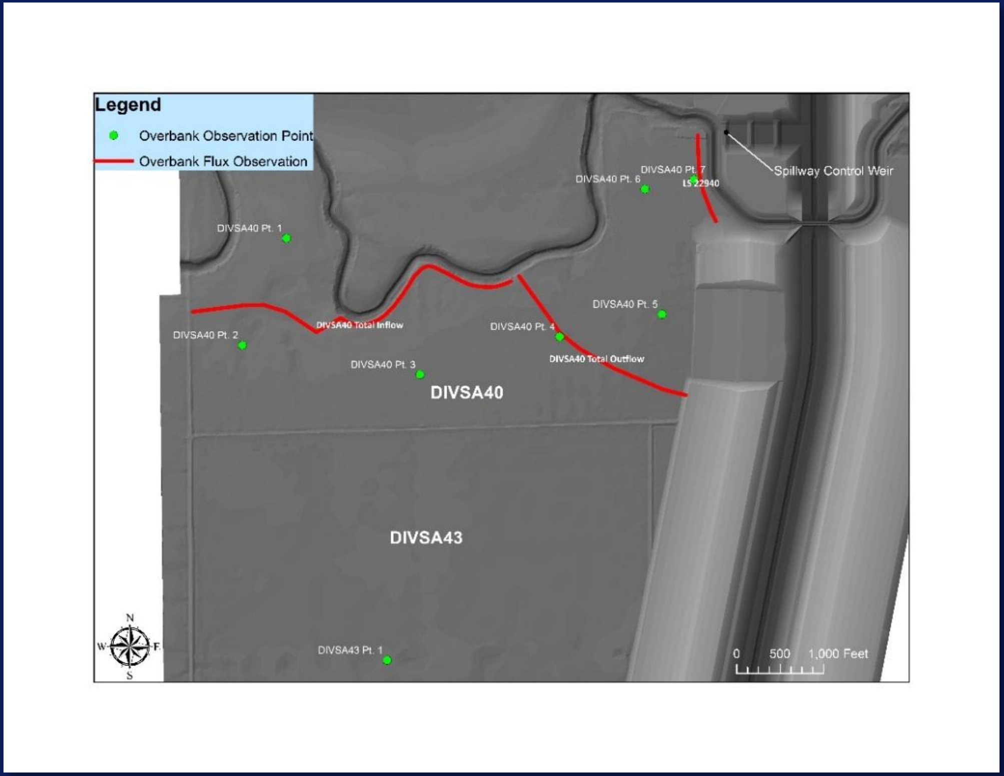


Results Comparison

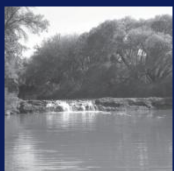


Viewing Results-AdH

- **Observation Lines & Nodes**
- **Data Calculator**
  - WSEL is calculated
  - Data Filter
- **Output Flux**

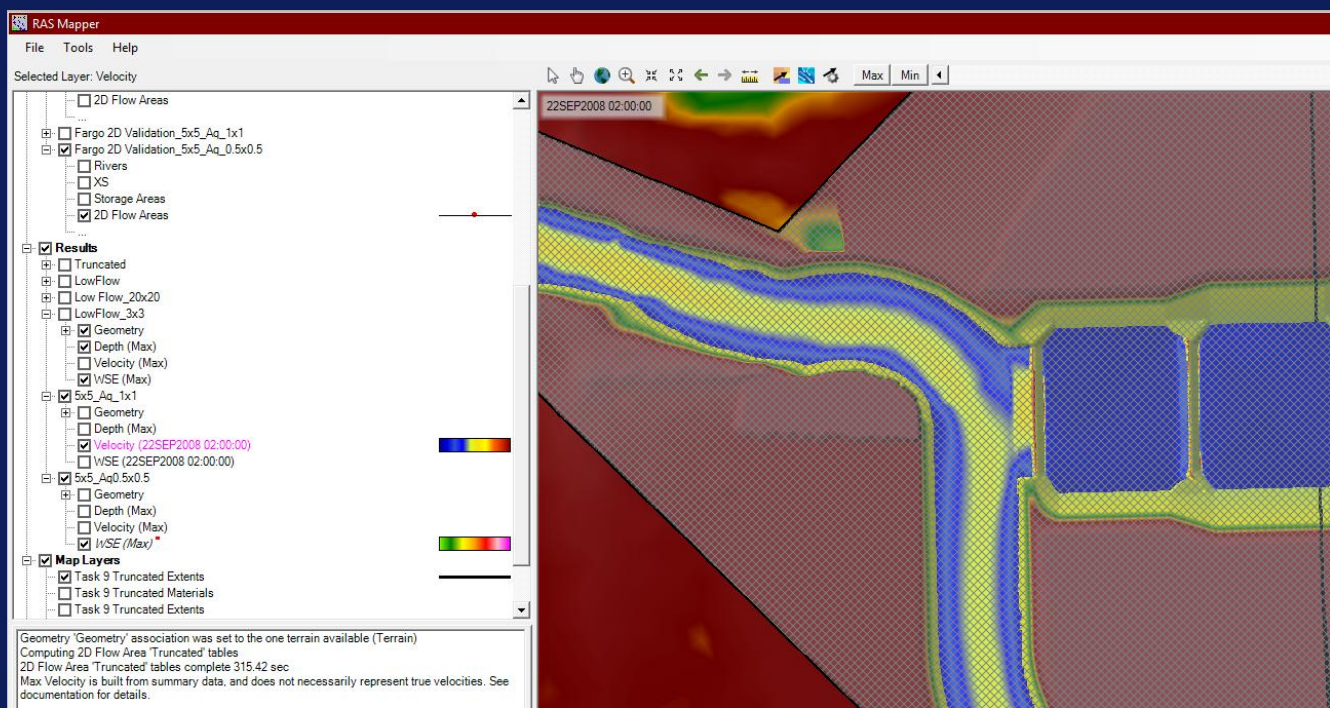


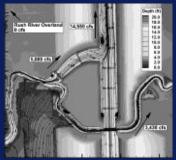




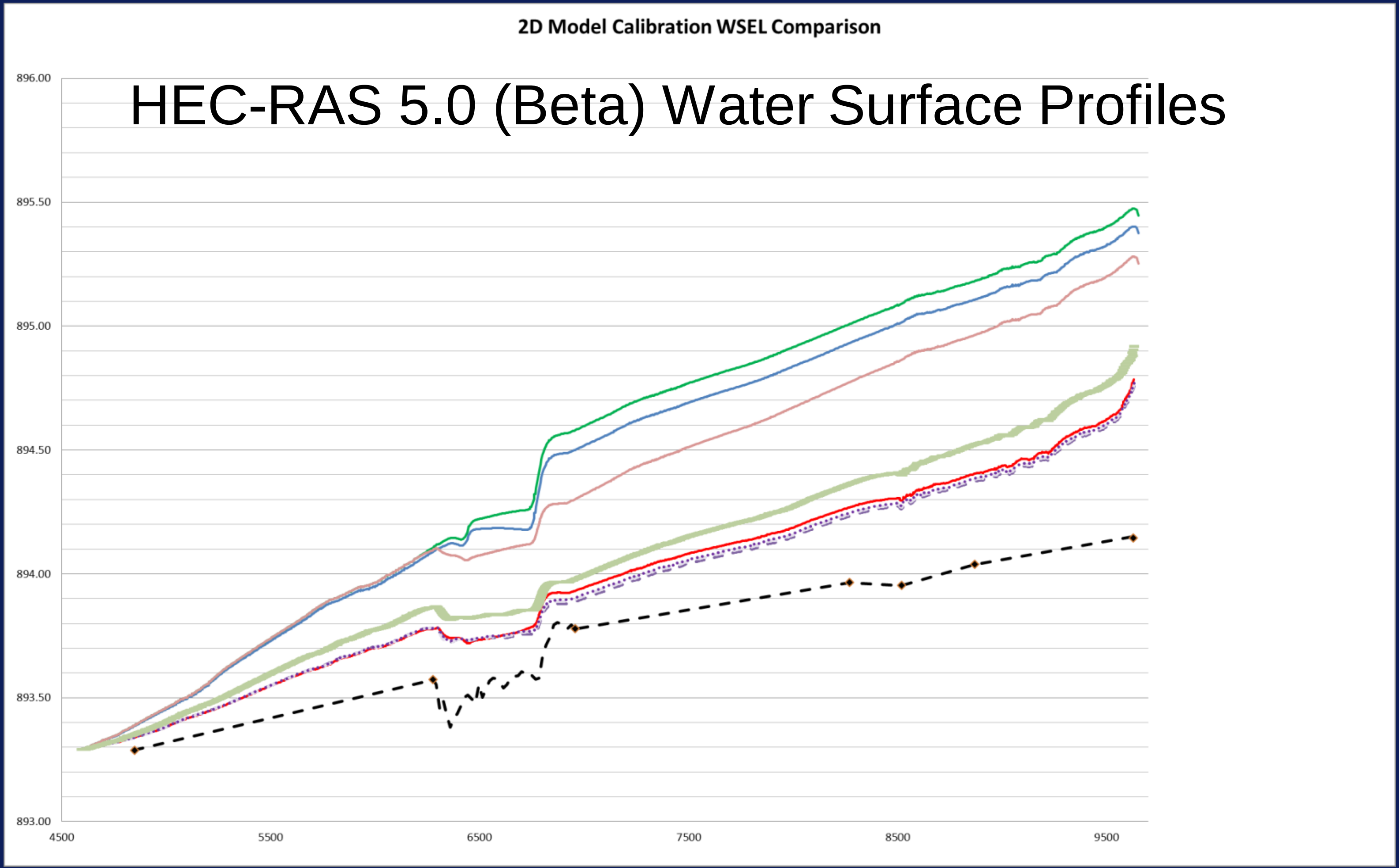
Viewing Results – RAS Mapper

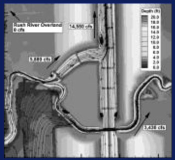
- Observation Line Hiccups
- Discharge Internal Flux Observation
- Output is currently limited

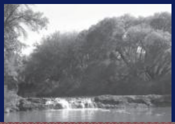



WSEL Results Comparison
Which one is correct?

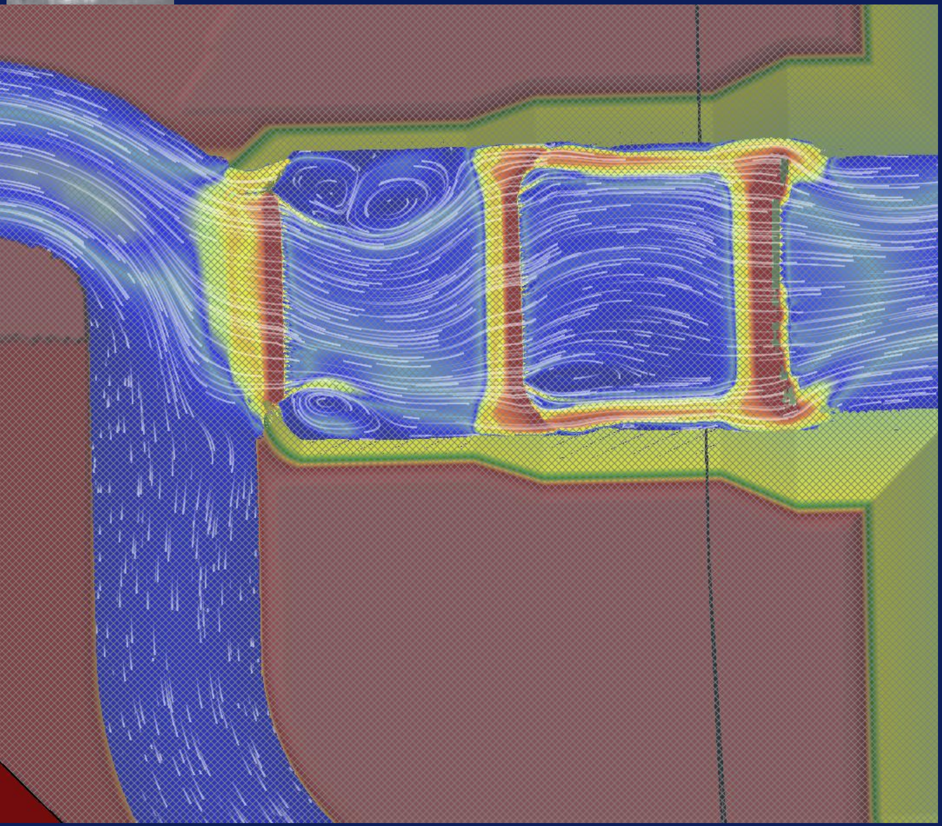


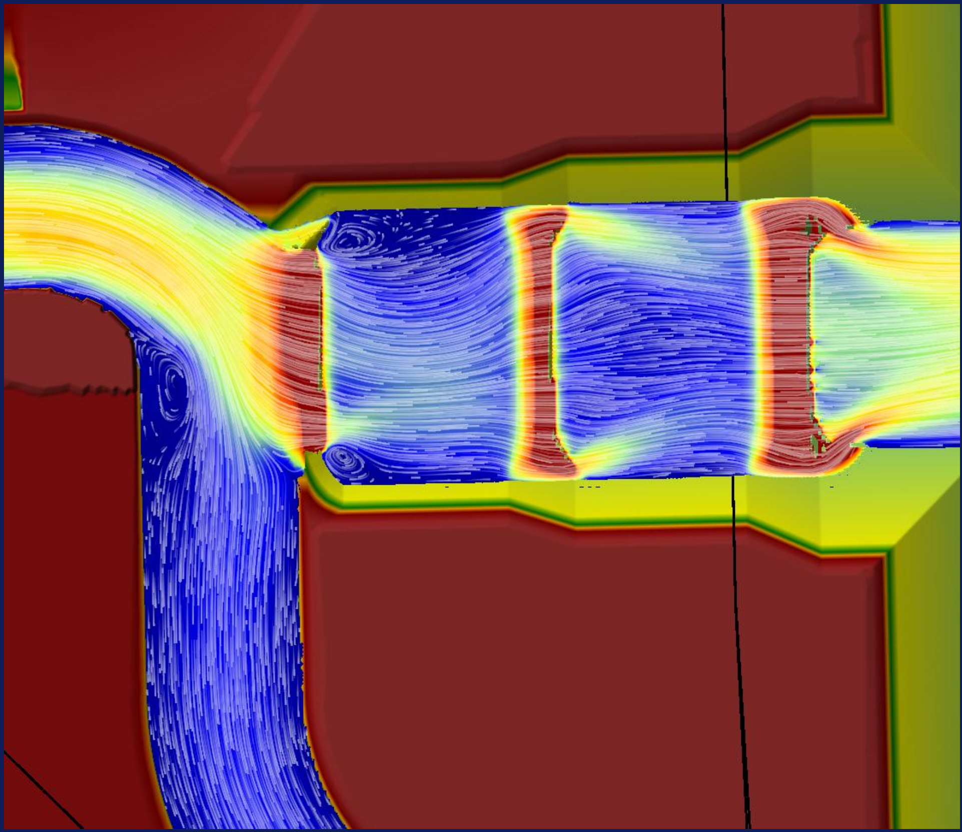


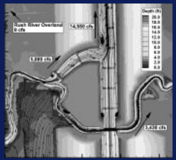


Results Comparison
Which one is correct?

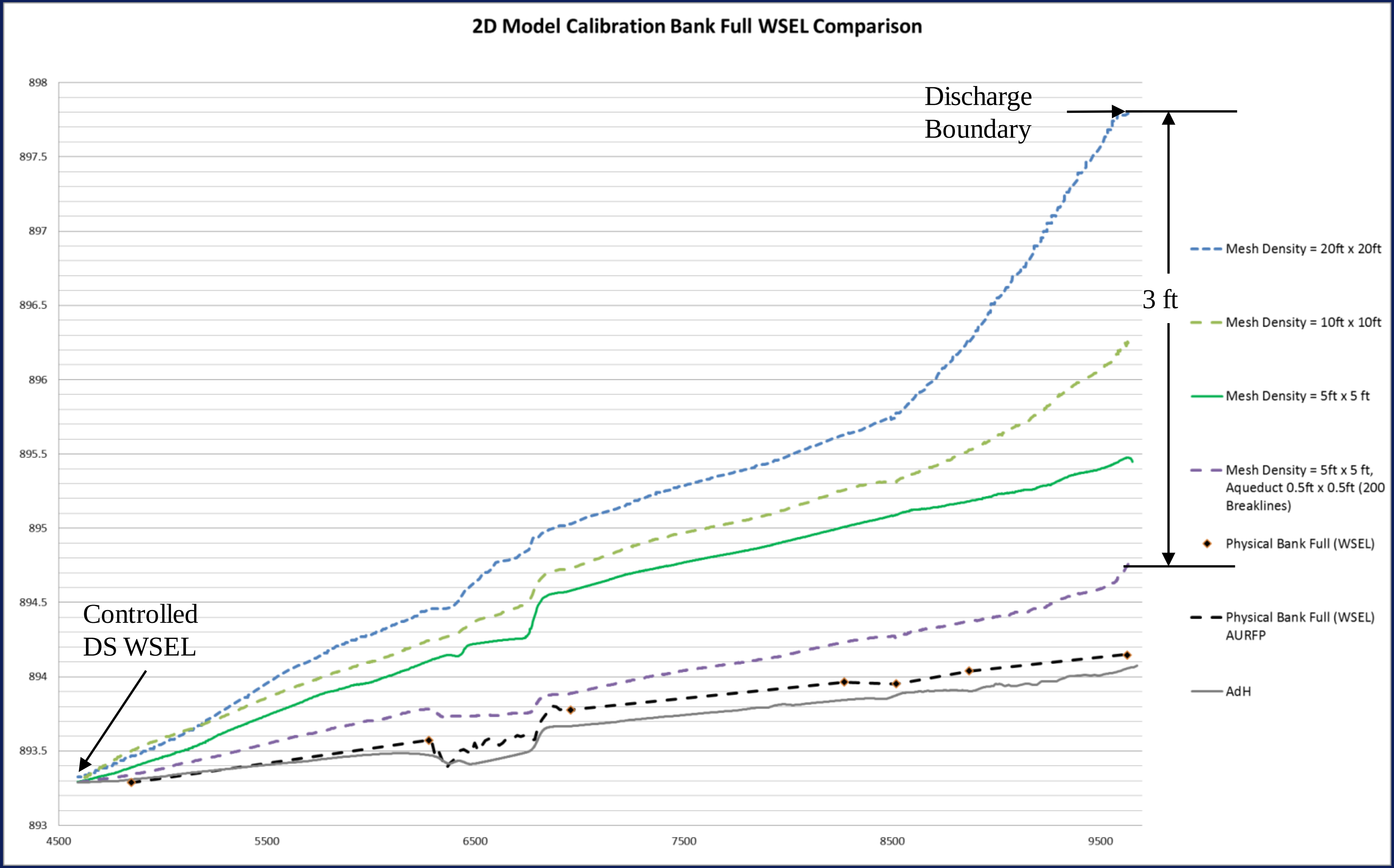
HEC-RAS 5.0 (Beta)Velocity Magnitude & Distribution

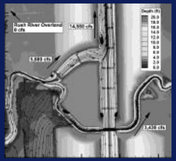





Size Matters!
WSEL

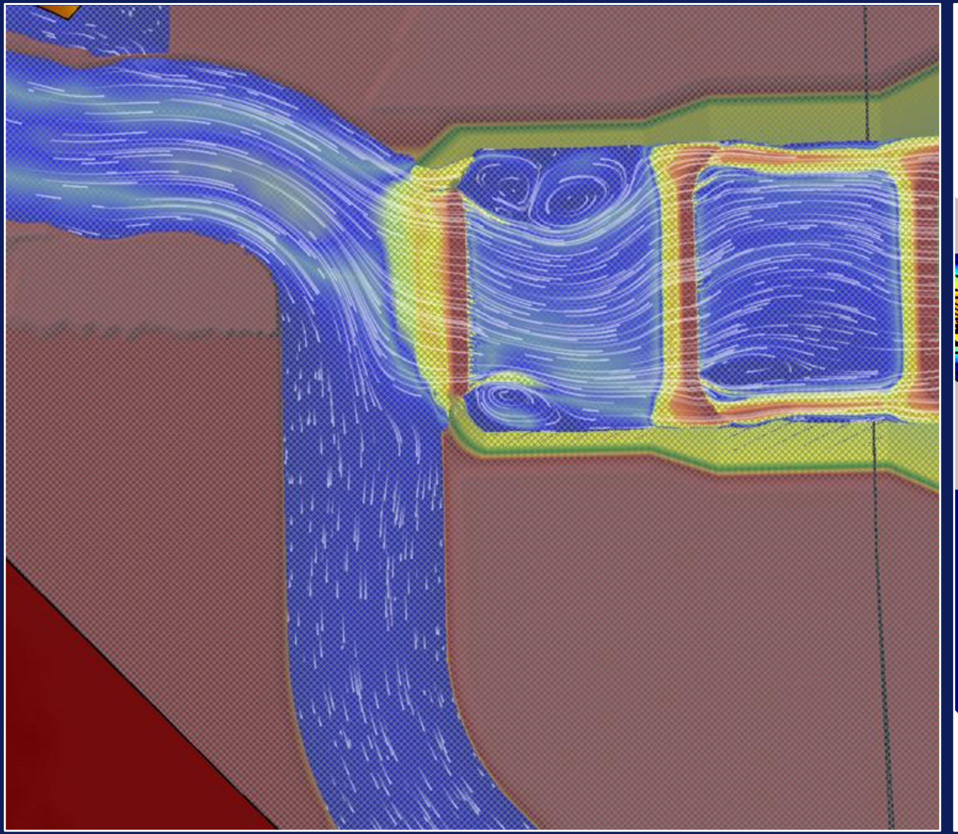


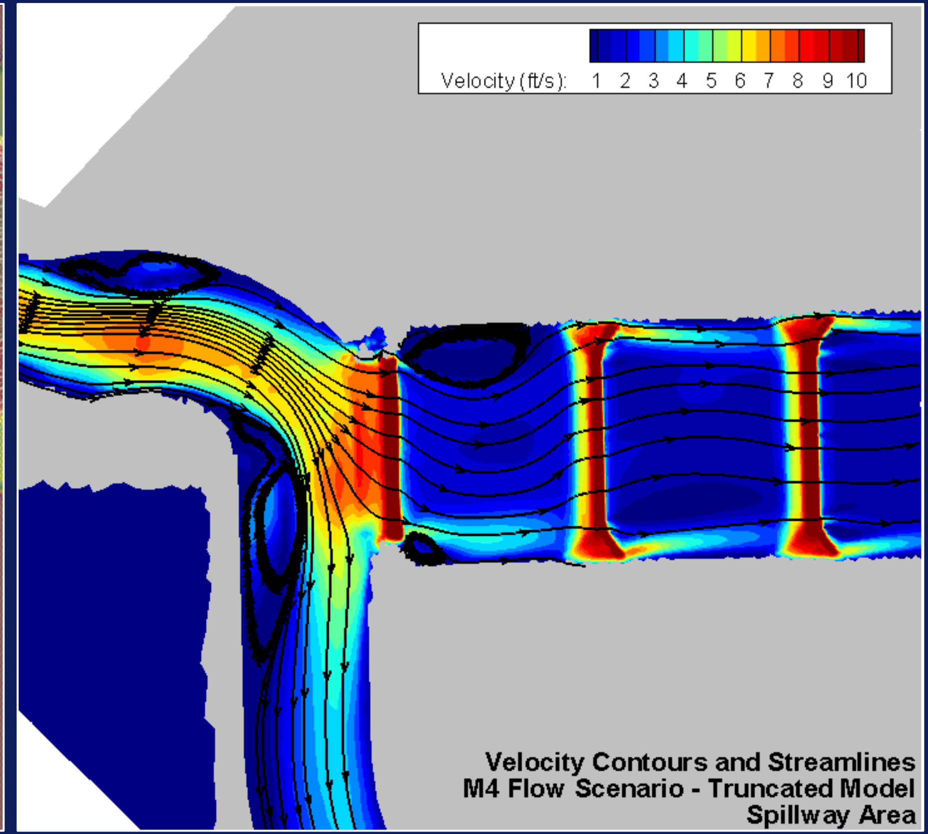


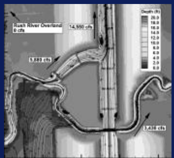
Size Matters!
Velocity

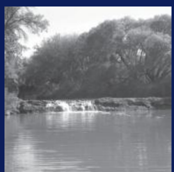
HEC-RAS 5.0

AdH

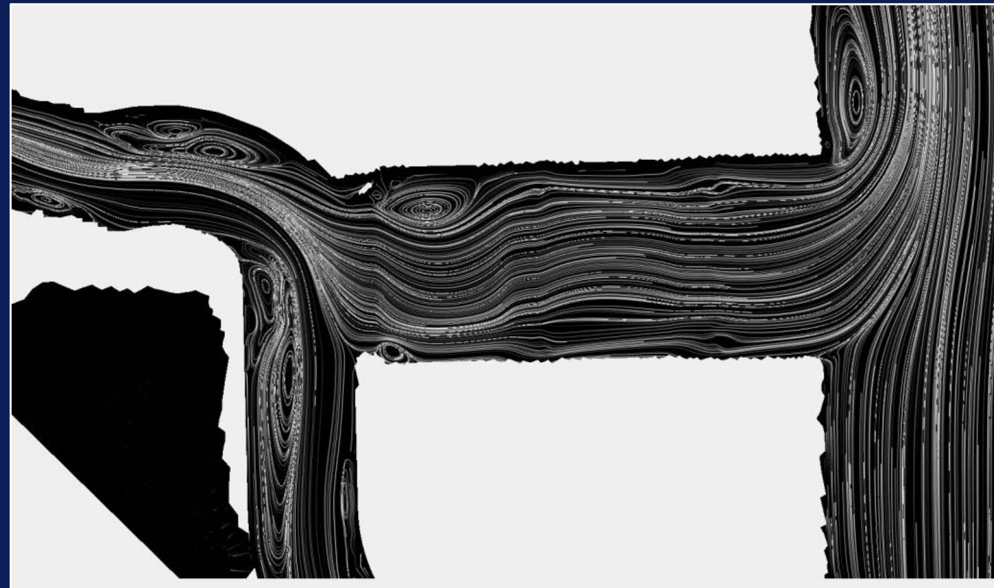




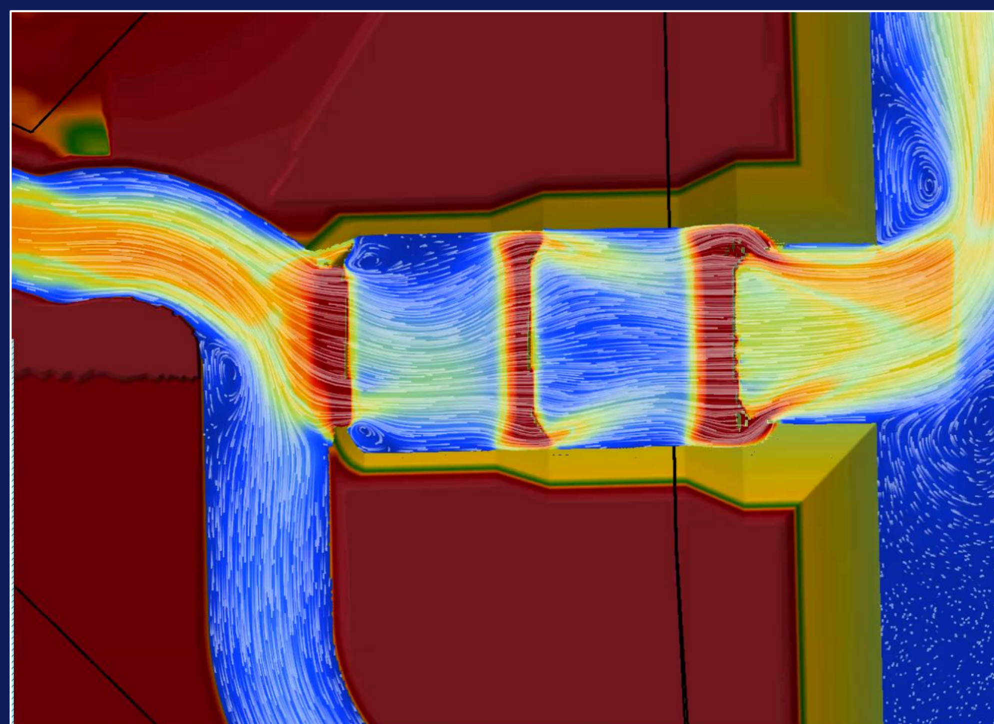




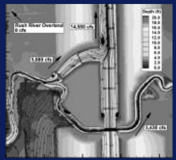
AdH



HEC-RAS 5.0



2-D Results – Aqueduct Velocity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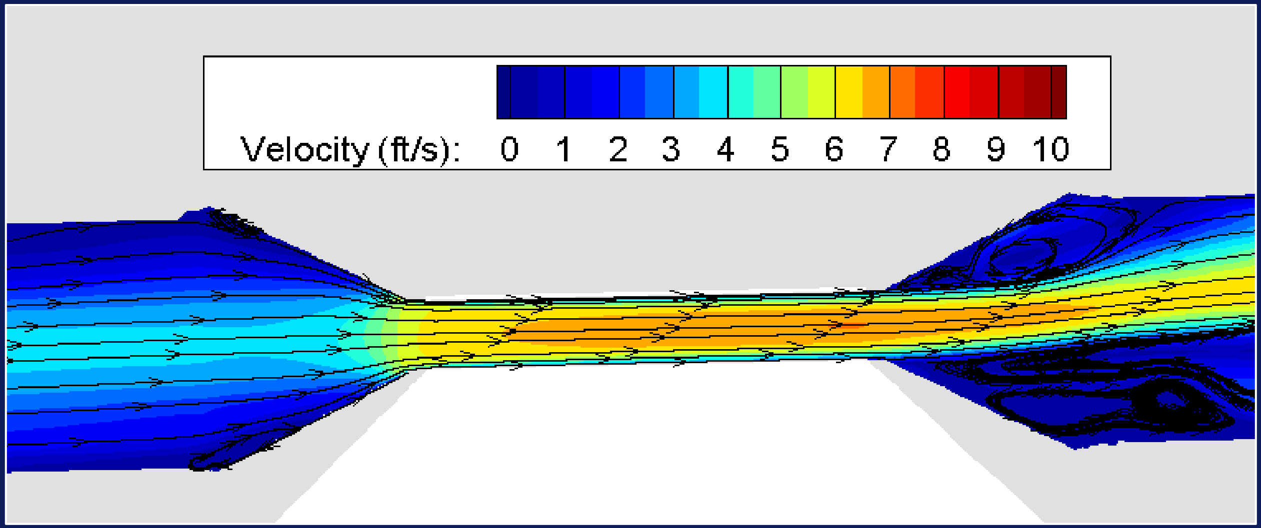
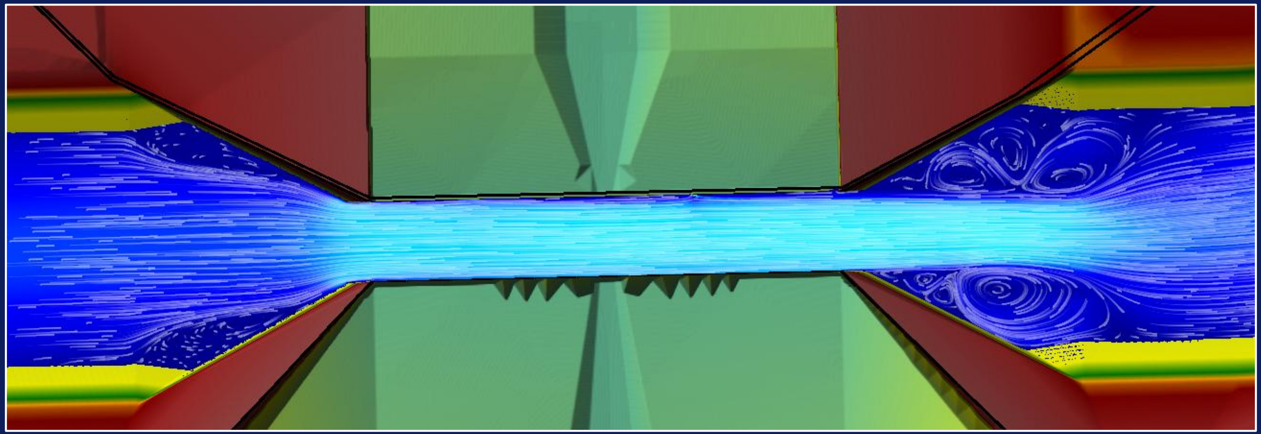
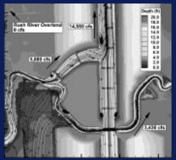


HEC-RAS 5.0





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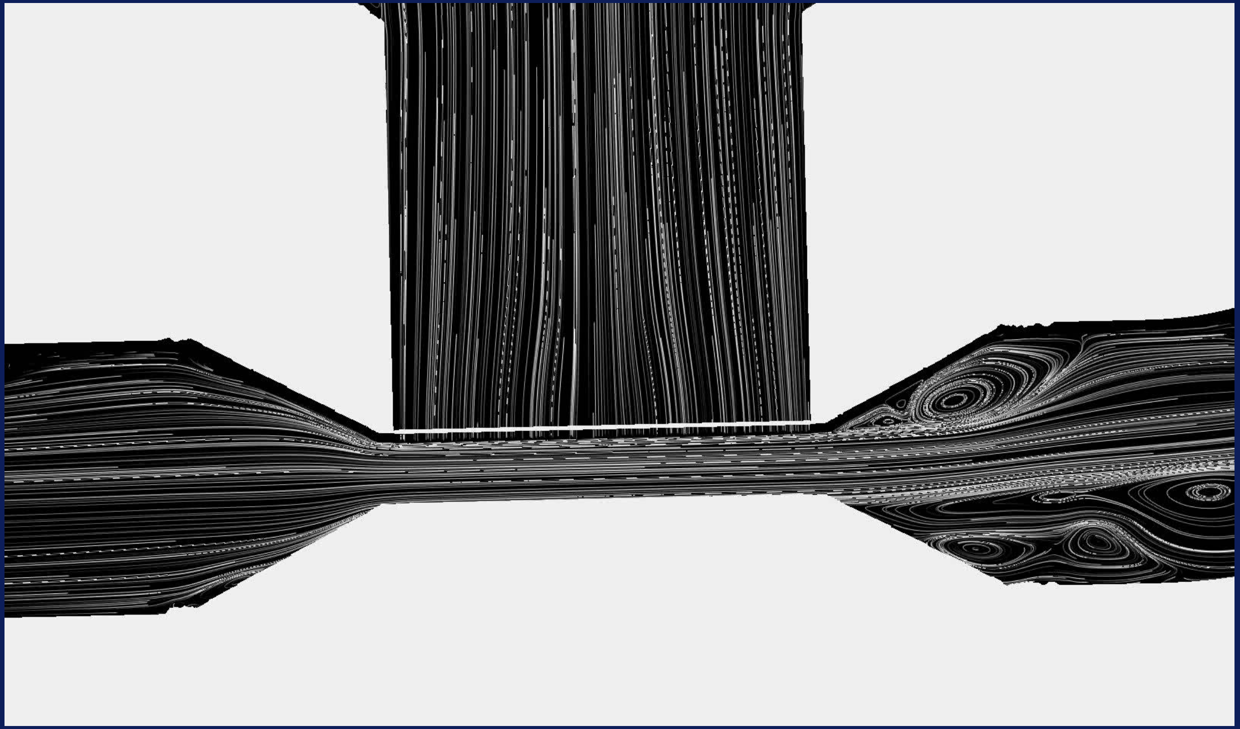

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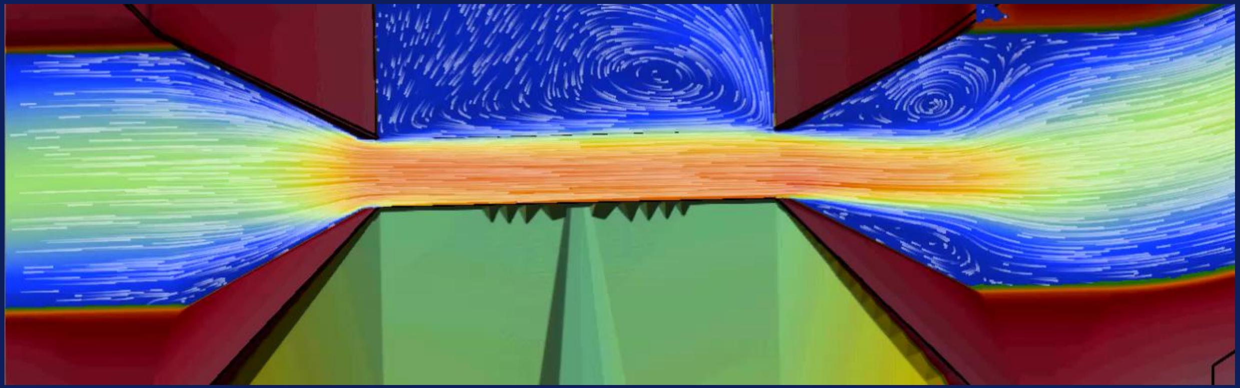
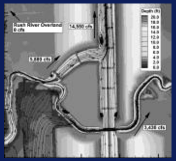
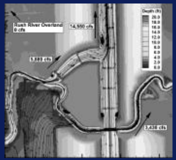
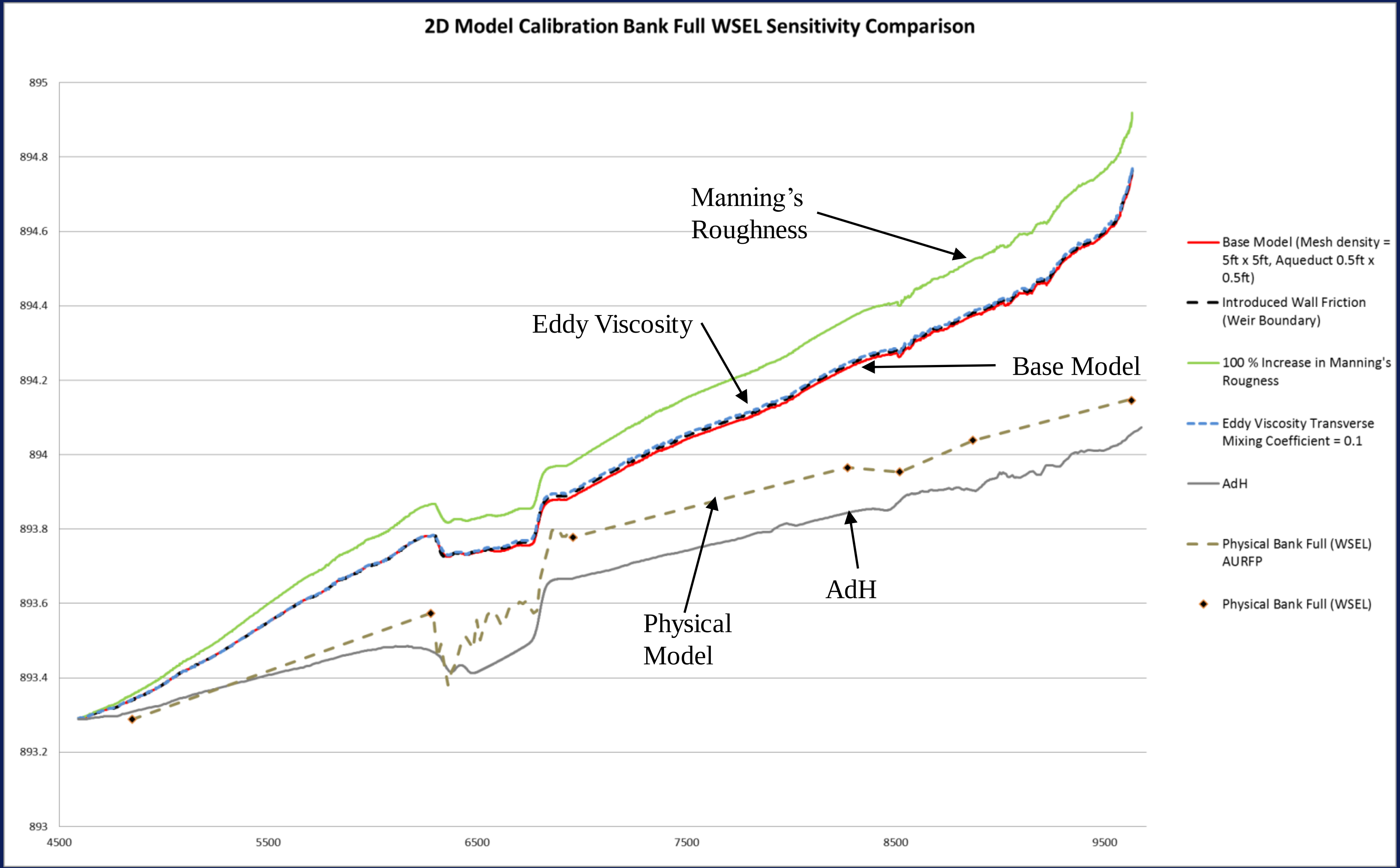




Sensitivity Analysis

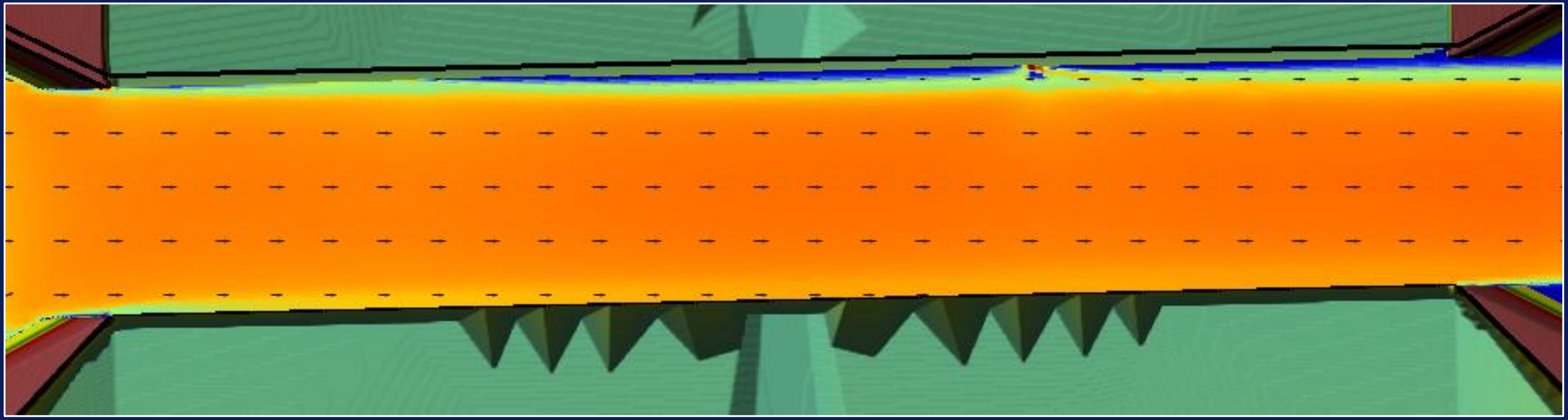


HEC-RAS Variable Sensitivity - WSEL

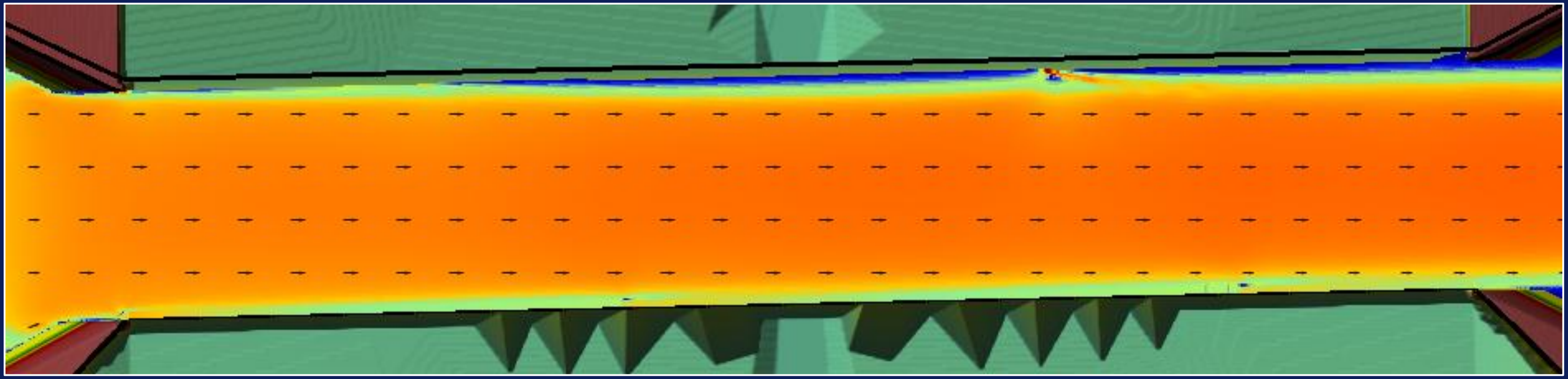


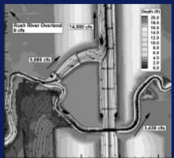
Variable Sensitivity - Velocity

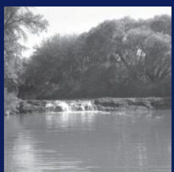
- Base Model



- Wall Roughness (Weir Boundary)



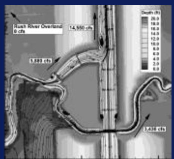


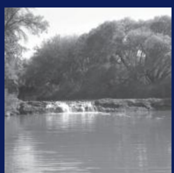


AdH Flow Split Sensitivity Analysis

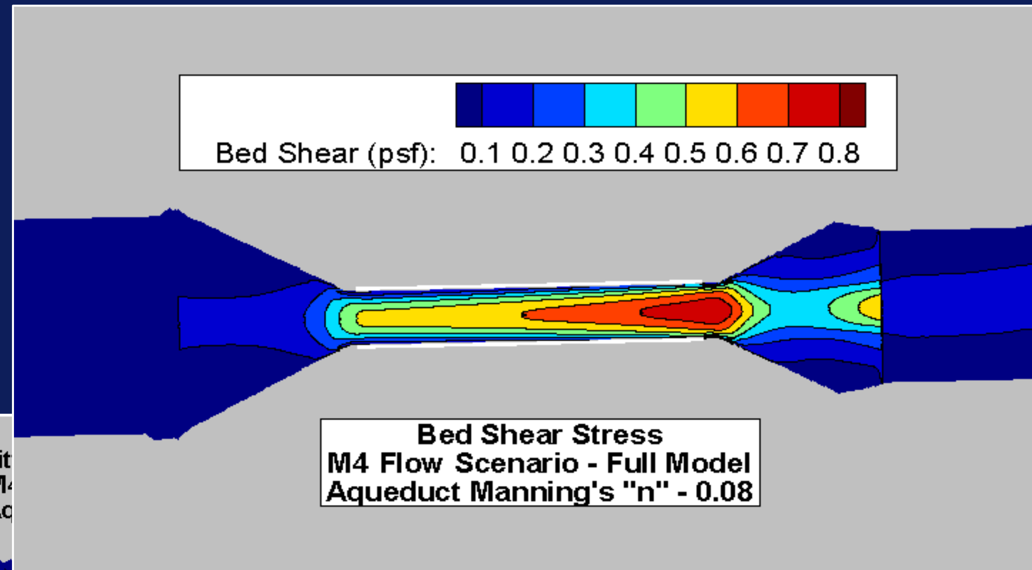
2D M4 Tailwater and Manning's "n" Sensitivity Analysis

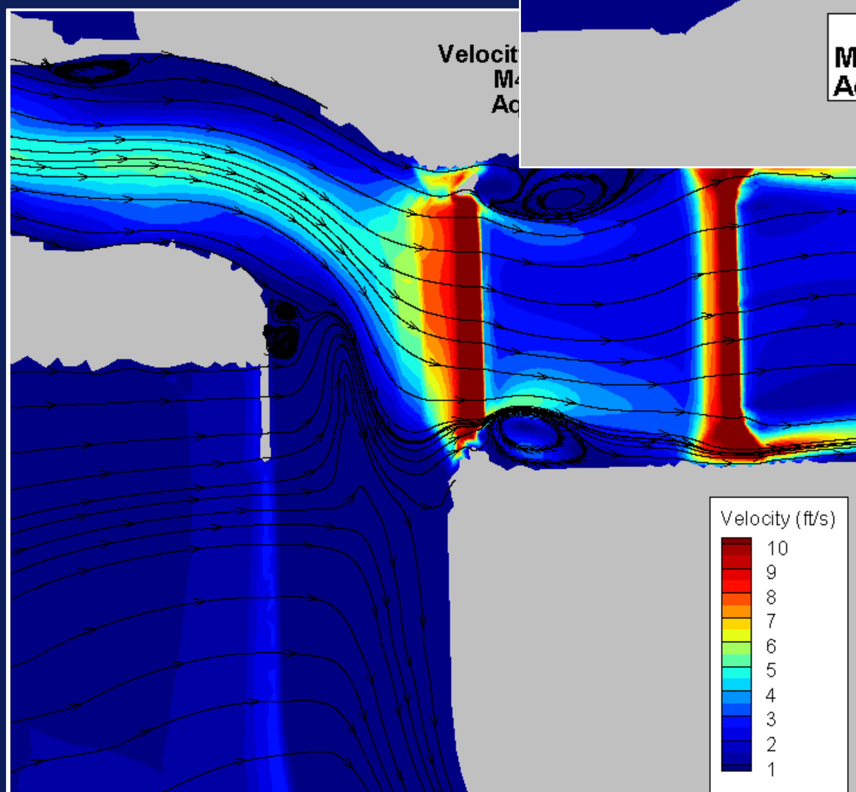
Sensitivity Variables	Plot Title	M4 HTW H"n" (WSEL)	M4 HTW L"n" (WSEL)	M4 LTW H"n" (WSEL)	M4 LTW L"n"(WSEL)	M4 LTW Physical "n"(WSEL)
	TW Curve	Unsteady HEC-RAS	Unsteady HEC-RAS	Steady HEC-RAS	Steady HEC-RAS	Steady HEC-RAS
	DS Maple WSEL (ft)	891.56	895.04	891.19	894.10	894.57
	Spillway Control Elevation	894.00	894.00	894.00	894.00	894.00
	LS 22940 Overbank Elevation	899.00	899.00	899.00	899.00	899.00
	Aqueduct "n"	0.08	0.040	0.08	0.040	0.015
	US Aqueduct Approach "n"	0.08	0.040	0.08	0.040	0.015
	DS Aqueduct Exit "n"	0.08	0.040	0.08	0.040	0.015
	Engineered Channel "n"	0.045	0.045	0.045	0.045	0.029
Boundary Flux Output	US Maple Flow (cfs)	8000.00	8000.00	8000.00	8000.00	8000.00
	Spillway Flow (cfs)	6369.00	4850.00	6368.00	4651.00	4194.00
	Total DIVSA40 Outflow	3167.24	3033.16	3165.97	3013.35	2703.63
	Total DIVSA40 Inflow From Maple	1479.72	1377.35	1480.11	1364.38	1103.00
	LS Discharge to Relocated Channel(cfs)	1806.59	1649.72	1803.37	1634.95	1597.73
	Discharge to Risk Reduction Area (cfs)	**1633.00**	**3160.00**	**1643.00**	**3369.00**	**3830.00**



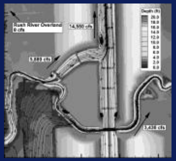


Roughness Sensitivity



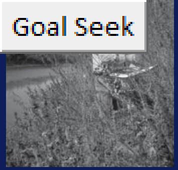


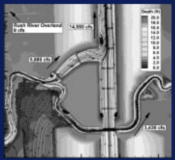
Significant Impact on Overbank and Spillway flows

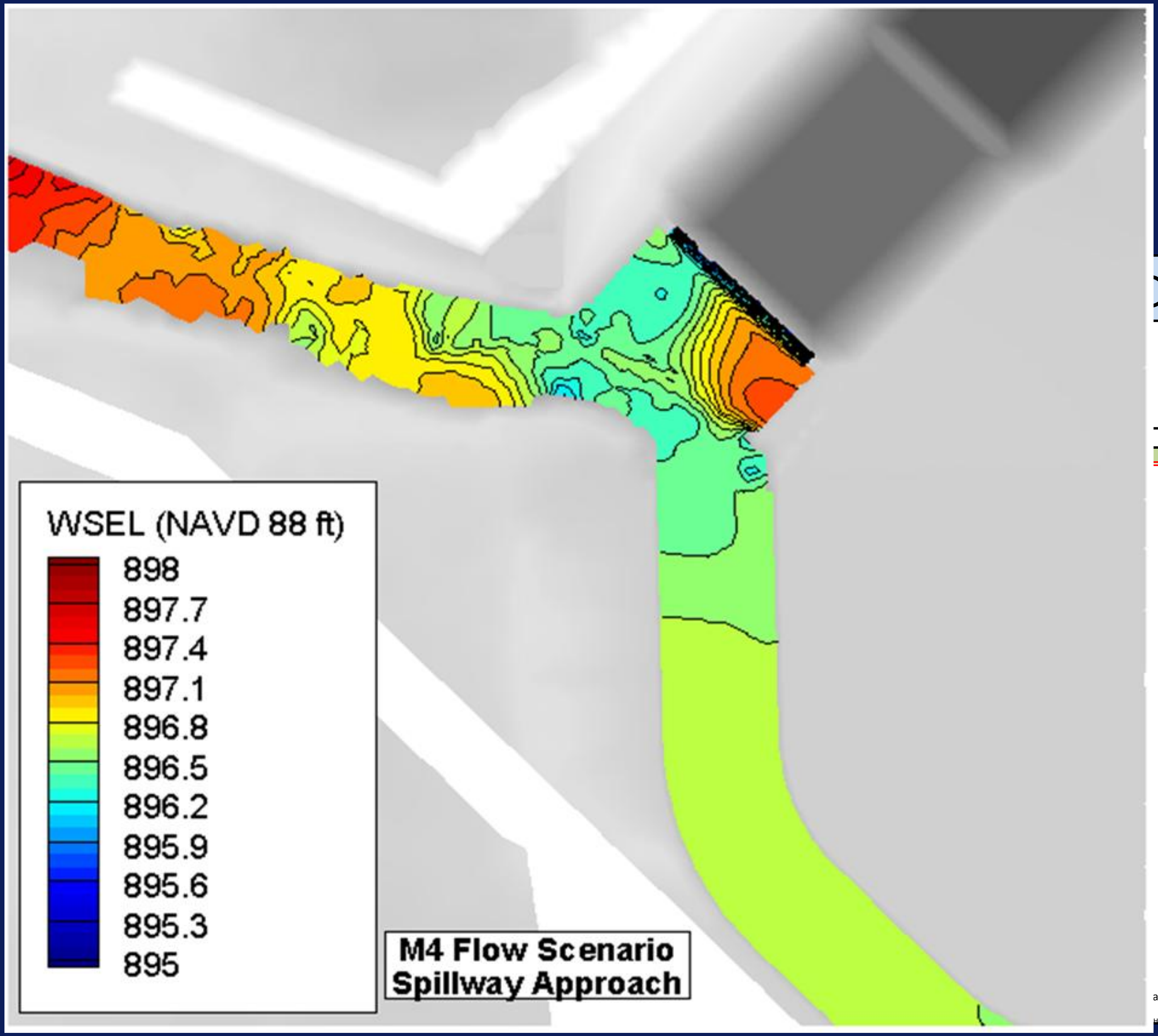


Lessons Learned / Modeling Limitations

AdH - Hydraulic Structures



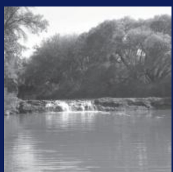


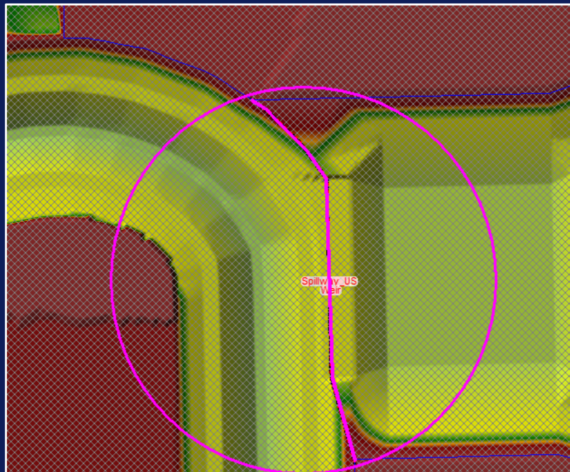


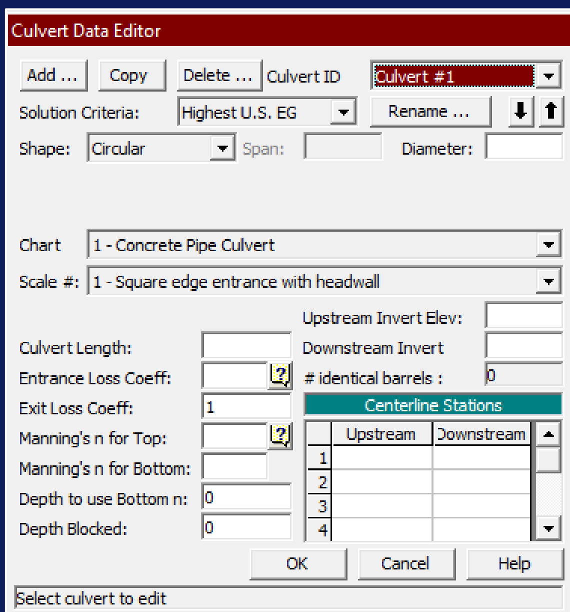
Coefficient, C

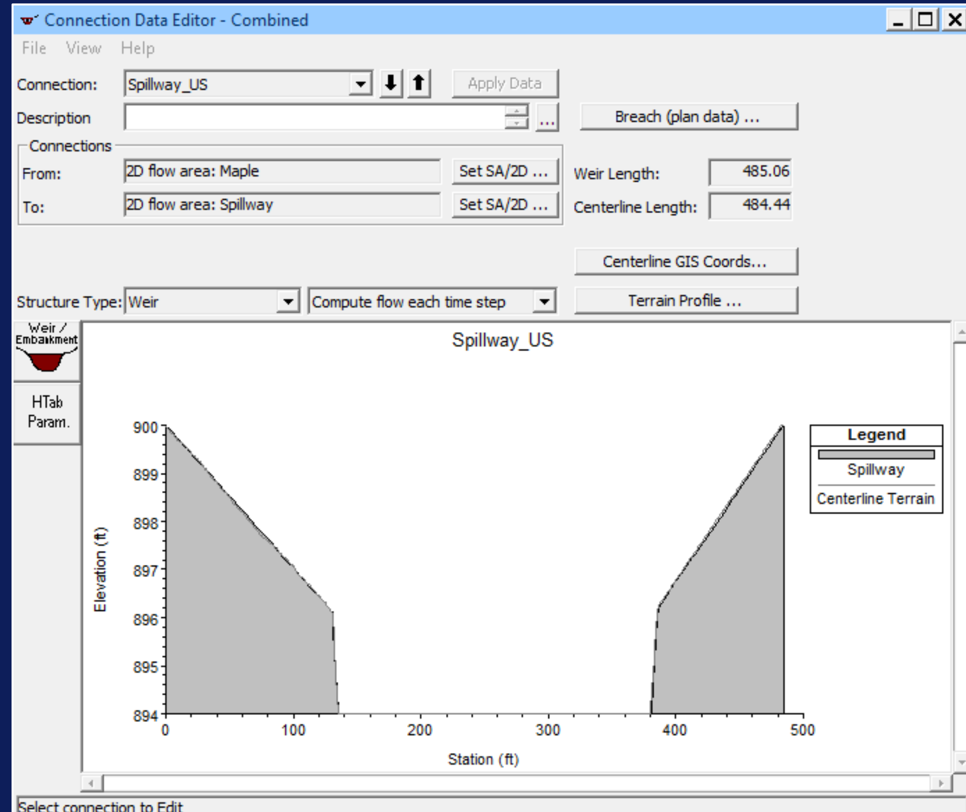
	C	Q_F (cfs)	SMS Point Distance From L Bank
	2.89	61.45	3.5
		77.58	10.5
		84.98	17.5
		89.06	24.5
		91.27	31.5
		93.03	38.5
		94.38	45.5
		95.40	52.5
		96.09	59.5
		96.42	66.5
		96.59	73.5
		96.64	80.5
		96.44	87.5
		96.14	94.5
		95.73	101.5
		95.16	108.5
		94.54	115.5
		93.74	122.5
		93.04	129.5
		92.12	136.5
		91.19	143.5
		90.27	150.5
		89.44	157.5
		88.66	164.5
		88.02	171.5
		87.49	178.5
		87.29	185.5
		87.44	192.5
		88.08	199.5
		89.34	206.5
		91.41	213.5
		94.12	220.5
		97.56	227.5
		101.07	234.5
		105.20	241.5
al Q (cfs)		3206.40941	
$_H$ - Q_{calc}		0	

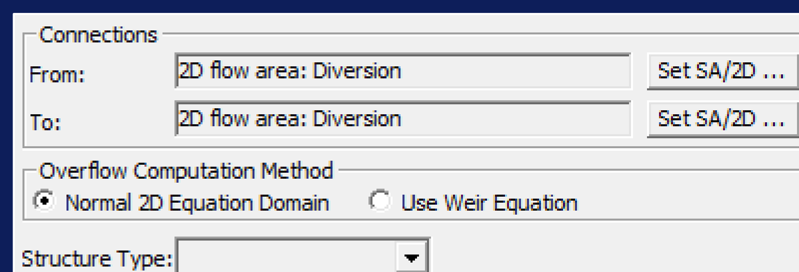
HEC-RAS – Hydraulic Structures



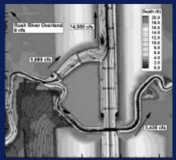




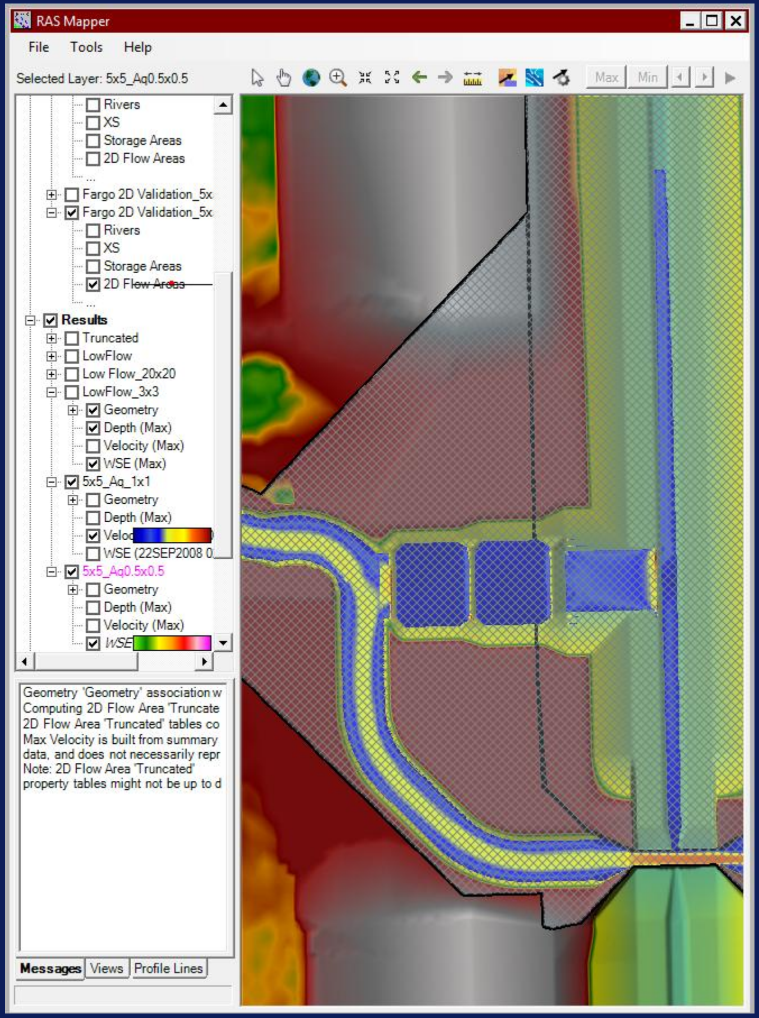




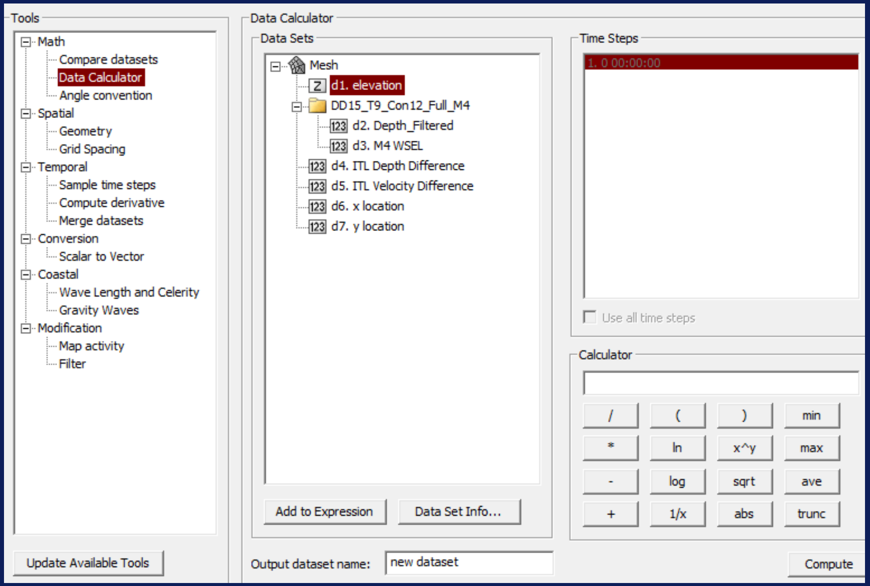
Output Options



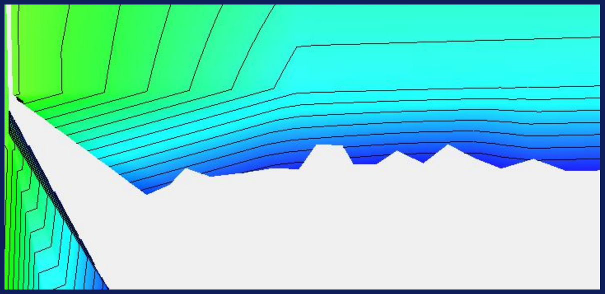
HEC-RAS 5.0

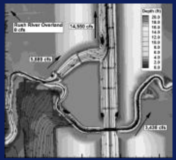


AdH



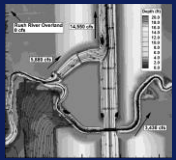
$$\tau = \rho g n^2 \frac{V^2}{R^{1/3}}$$



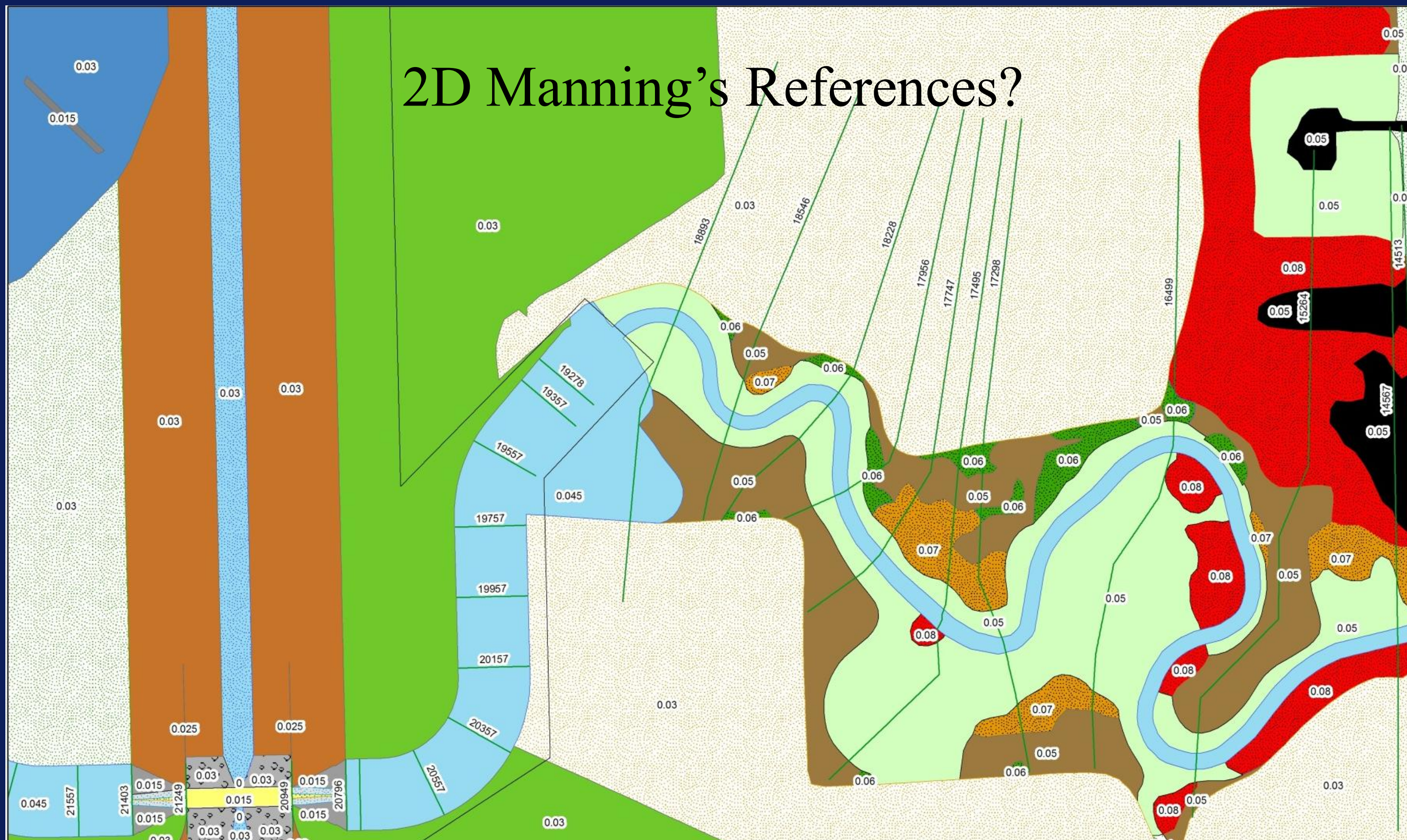



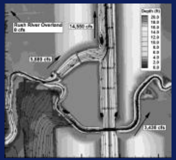

Summary

- Time!
- HEC-RAS 5.0 is ~~still BETA~~ HERE!
- Verification of model capabilities and limitations
- What could we have done differently
- What are we looking for in the future
- Still wondering how to choose Manning’s ‘n’ and Eddy Viscosity parameters?
- Calibration is critical – model parameters vary

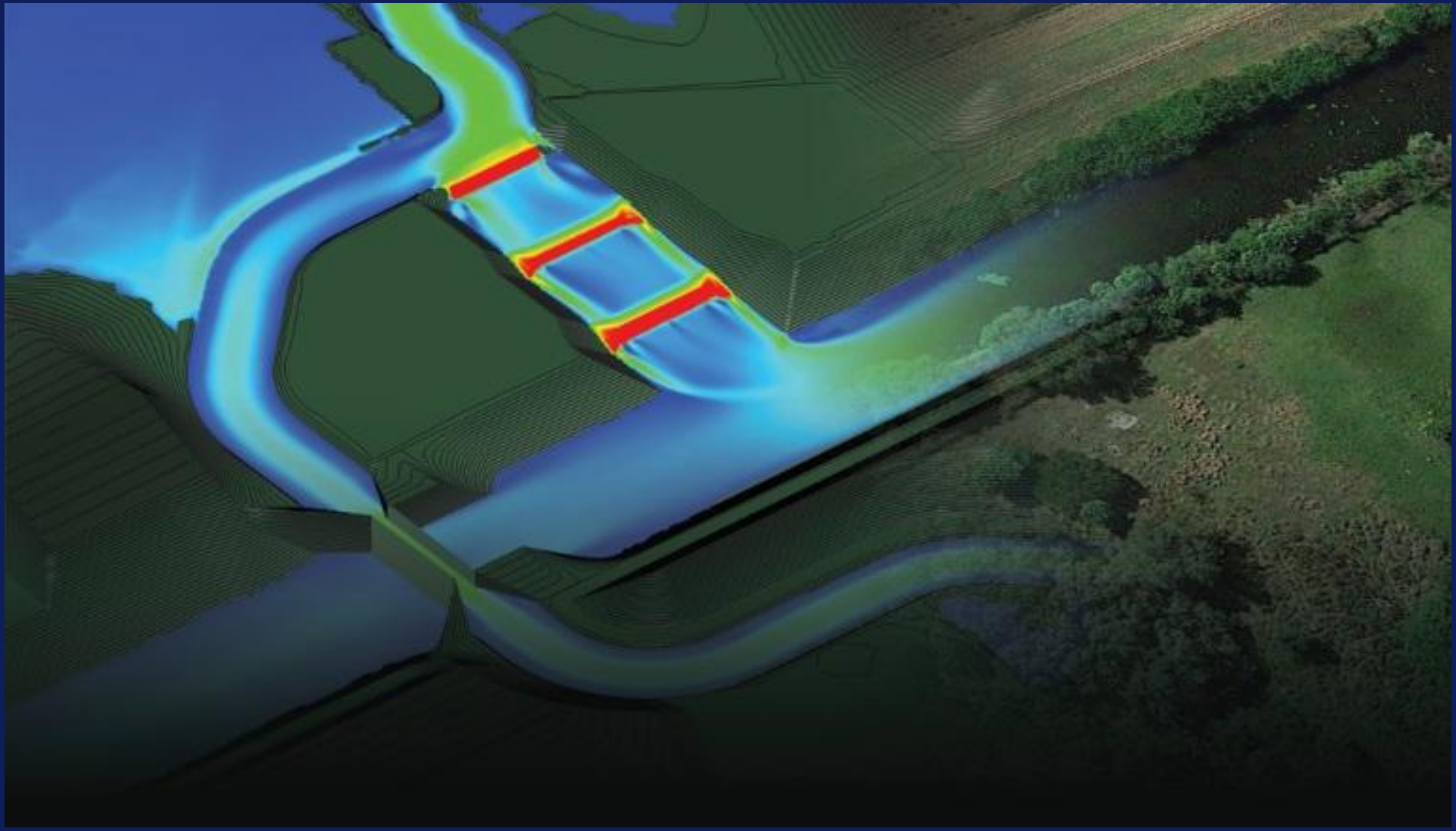


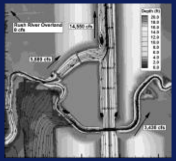
Eddy Viscosity and Manning's "n"



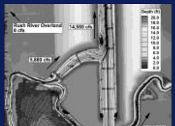




Would I recommend HEC-RAS 5.0 (in its current form) for a project of this complexity?




Press Release…
HEC-RAS 5.0 Released

Questions

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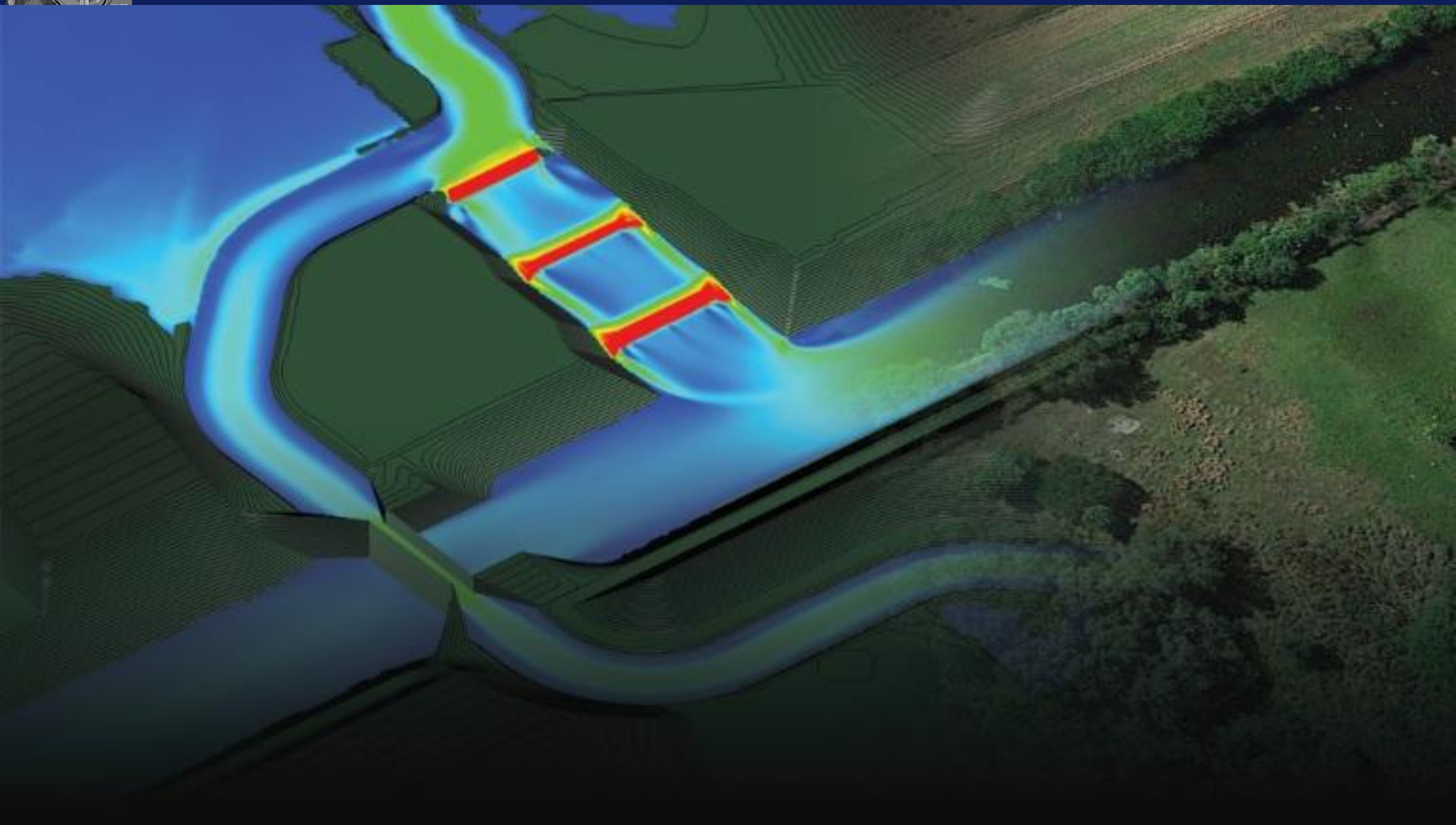
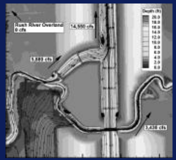
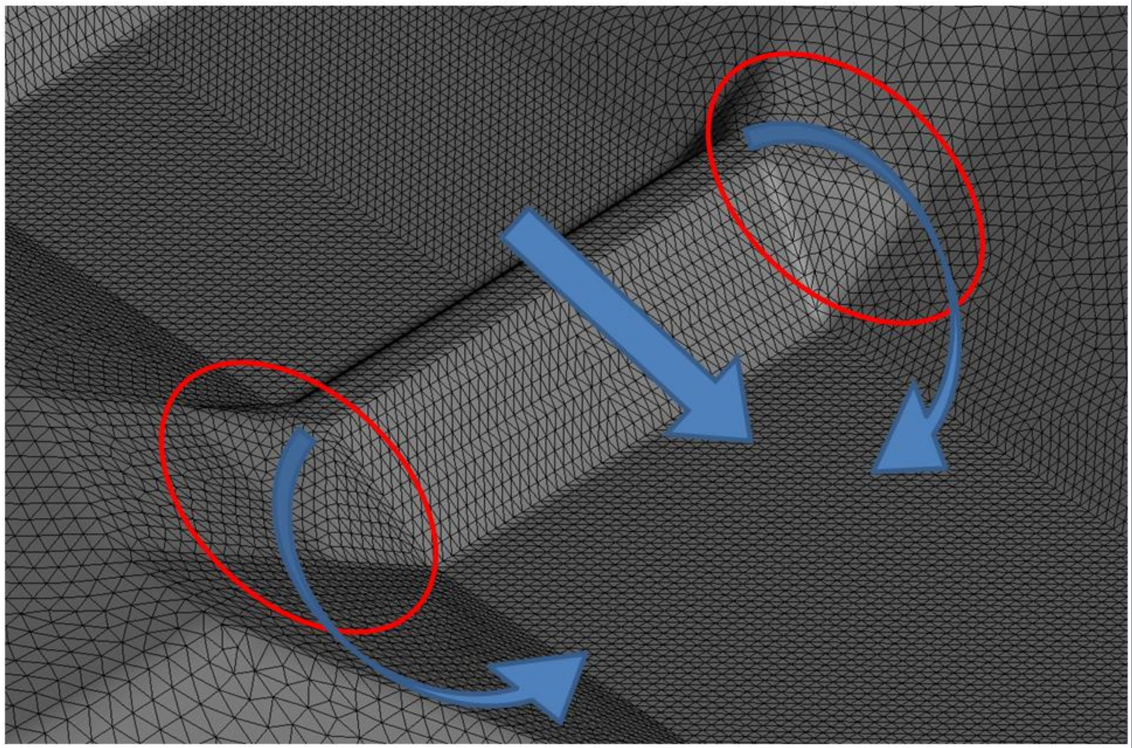




Flow Arrows Showing Flow Over Weir



	Required Weir Crest Length to Eliminate Edge Jets (M4)		Spillway Invert Width (At Weir Base)		Required Weir to Spillway Base Ratio to Eliminate Edge Jets (M4)
Weirs	Model Scale (ft)	Prototype Scale (ft)	Model Scale (ft)	Prototype Scale (ft)	
Control	5.68	284	4.4	220	1.29
Middle	5.41	270.5			1.23
Lower	4.98	249			1.13