Innovative Grade Controls for Restoring an Incised Urban Channel at Millbrook Exchange Park, Raleigh, NC

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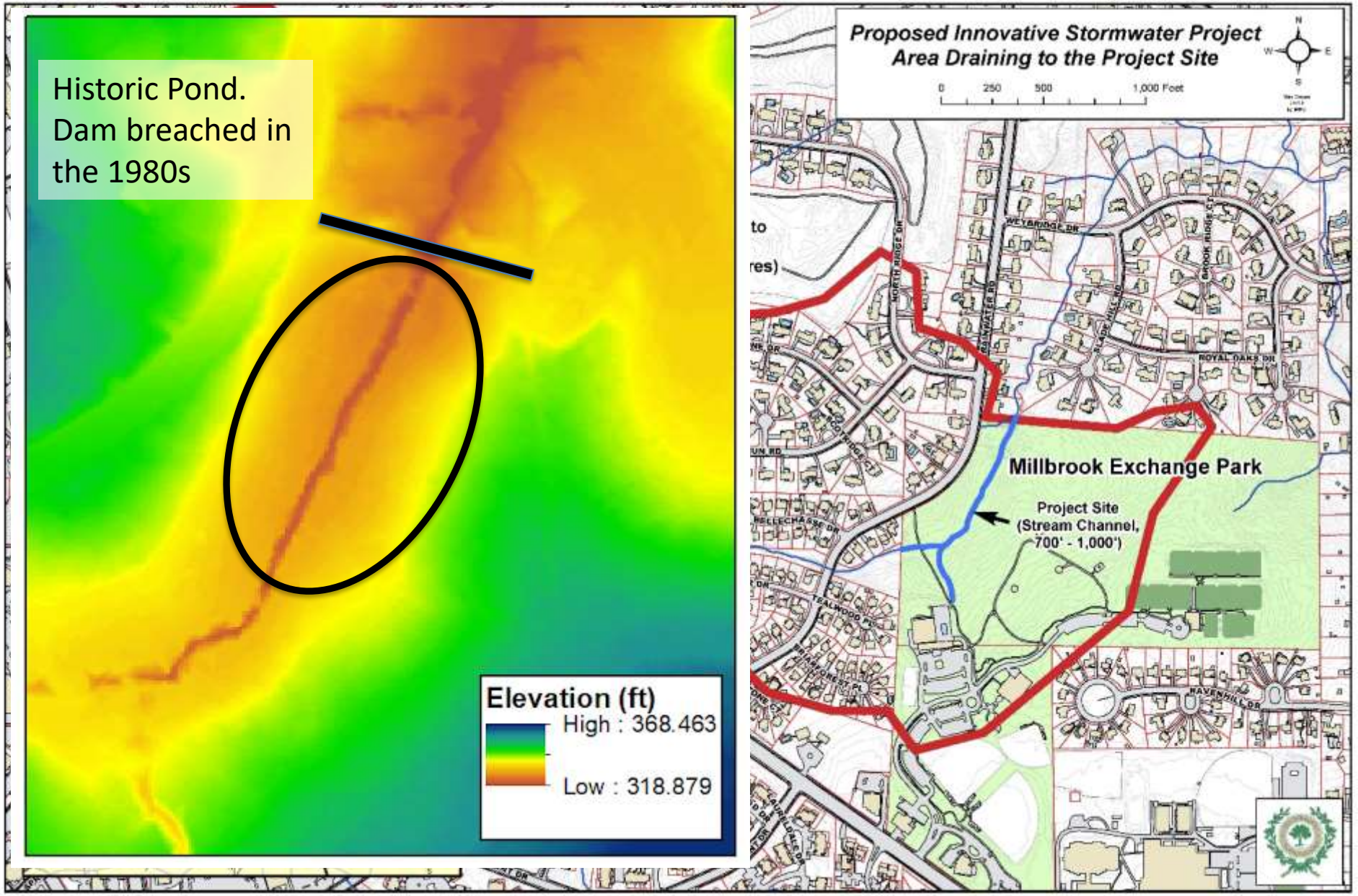
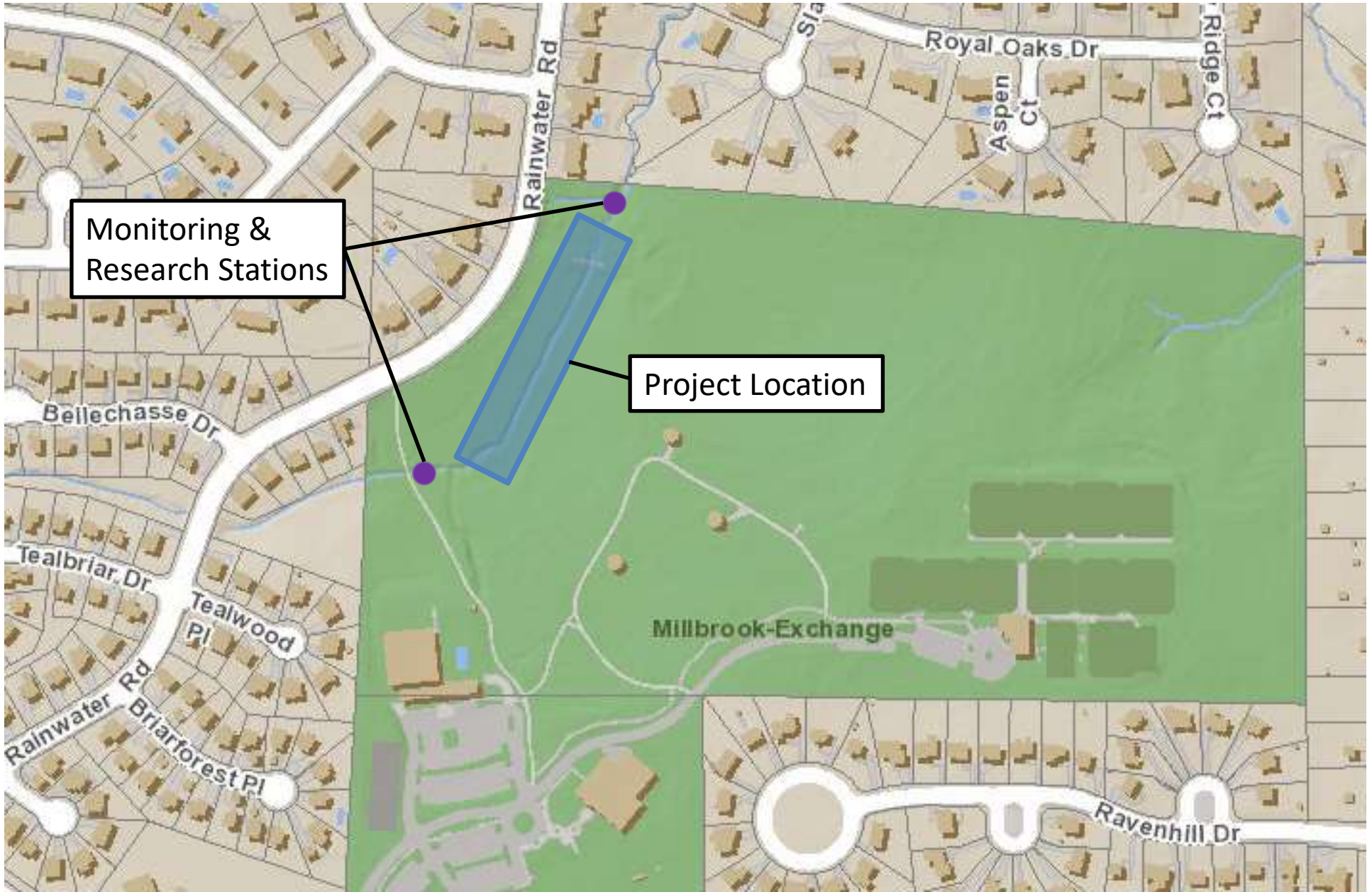

Historic Pond.
Dam breached in the 1980s
Elevation (ft)
High : 368.463
Low : 318.879
Proposed Innovative Stormwater Project
Area Draining to the Project Site
0 250 500 1,000 Feet
N
W
E
S
Millbrook Exchange Park
Project Site
(Stream Channel,
700' - 1,000')
NORTH RIDGE DR
RAINWATER RD
ROYAL OAKS DR
TEALWOOD PL
HAVERHILL DR

Pre-Restoration Condition

Project Goals & Objectives

- Arrest channel incision and erosion
- Improve floodplain connection
- Improve water quality
- Minimize cost
- Minimize urban forest disturbance

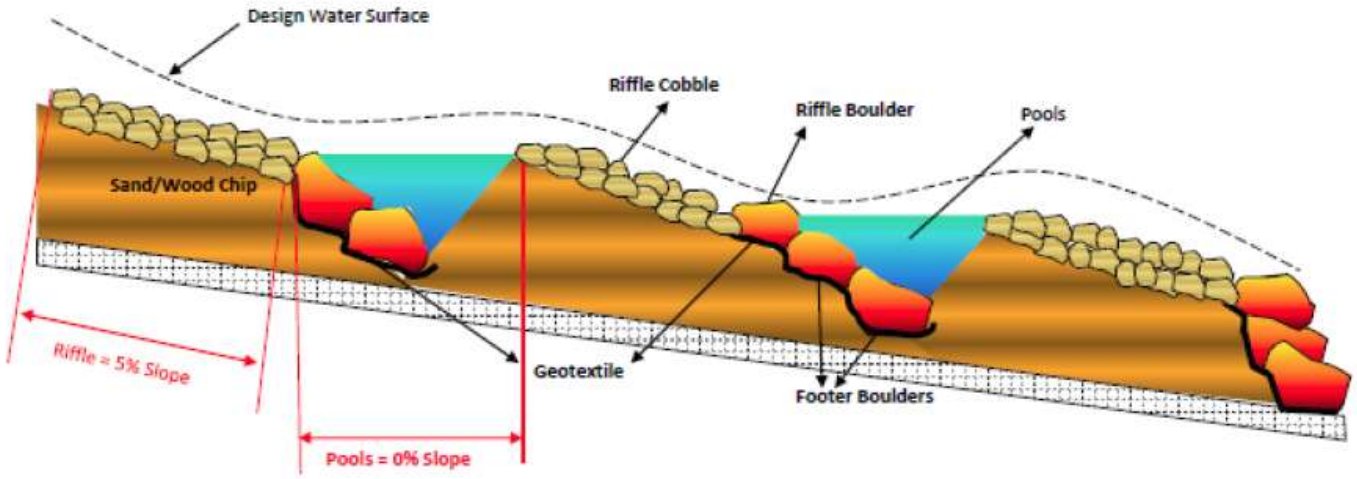
Tributary to Perry Creek, Neuse River Basin
Reach Length = 870 ft
Impairments: 303(d) and TMDL (2010)
Drainage Area = 122 acres
Developed = 91%
Impervious = 11%


Monitoring &
Research Stations
Project Location
Rainwater Rd
Royal Oaks Dr
Aspen Ct
Ridge Ct
Bellechasse Dr
Tealbriar Dr
Tealwood Pl
Rainwater Rd
Briarforest Pl
Millbrook-Exchange
Ravenhill Dr

Pre-Restoration Monitoring (Upstream & Downstream)

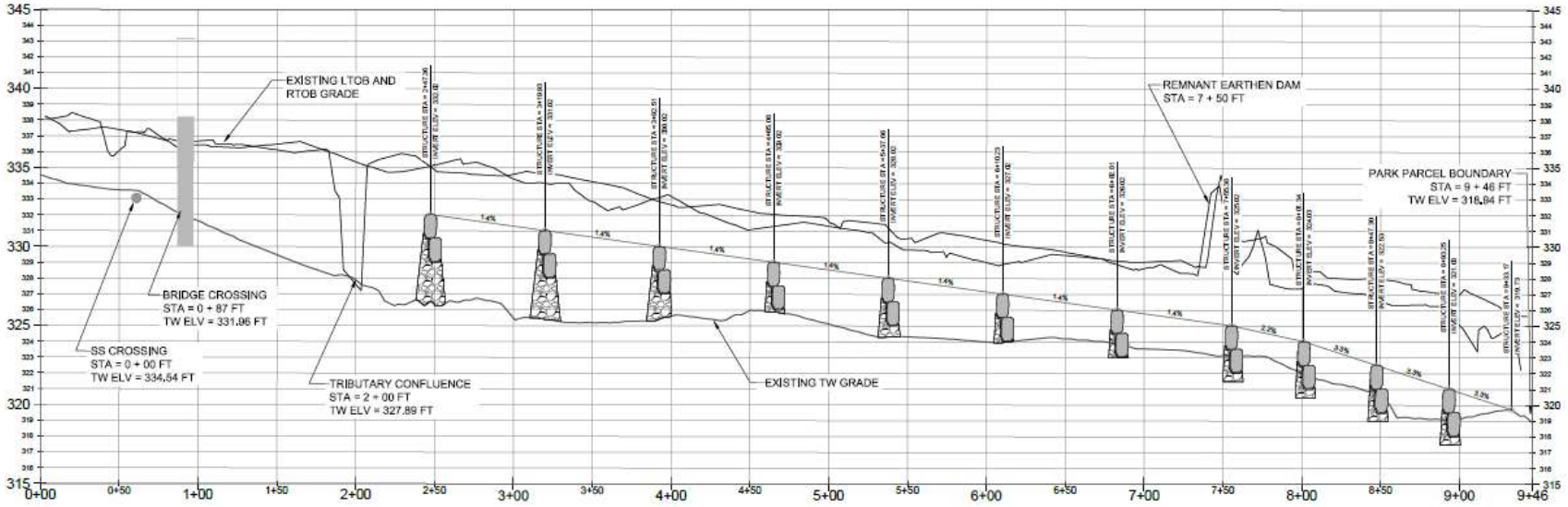
- Discharge
- Total Solids (TS) & Total Suspended Solids (TSS)
- Bedload Trap (Upstream)
- Rainfall

Regenerative Stormwater Conveyance (RSC)

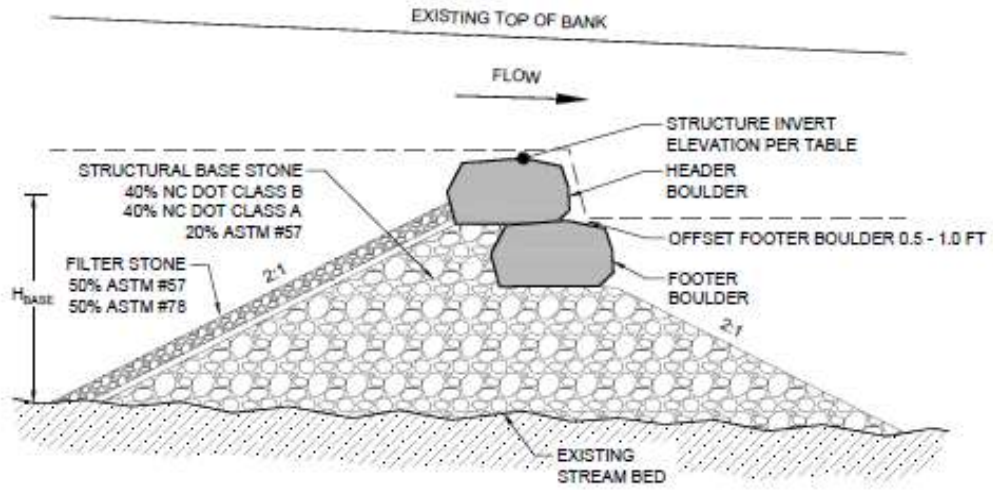


Millbrook Exchange Park Alternative Designs - Cost Summary

Item Category	Grade Control	Priority 1	Priority 2	RSC
Mobilization, Site Preparation & Demo	$66,306	$157,011	$205,786	$112,221
E&SC	$8,475	$27,990	$32,475	$10,875
Earthwork	$8,400	$364,000	$917,000	$189,700
Structures	$43,455	$69,100	$52,500	$98,620
Stabilization	$14,800	$32,425	$33,950	$19,150
Site Cleanup	$4,400	$4,400	$4,400	$4,400
Total =	$145,836	$654,926	$1,246,111	$434,966
Cost Per Linear Foot =	$217	$701	$1,291	$680
Cost Per Structure =	$13,258	-	-	$28,998



11 Grade Control Structures 2-6 feet in height and spaced 40-60 feet apart

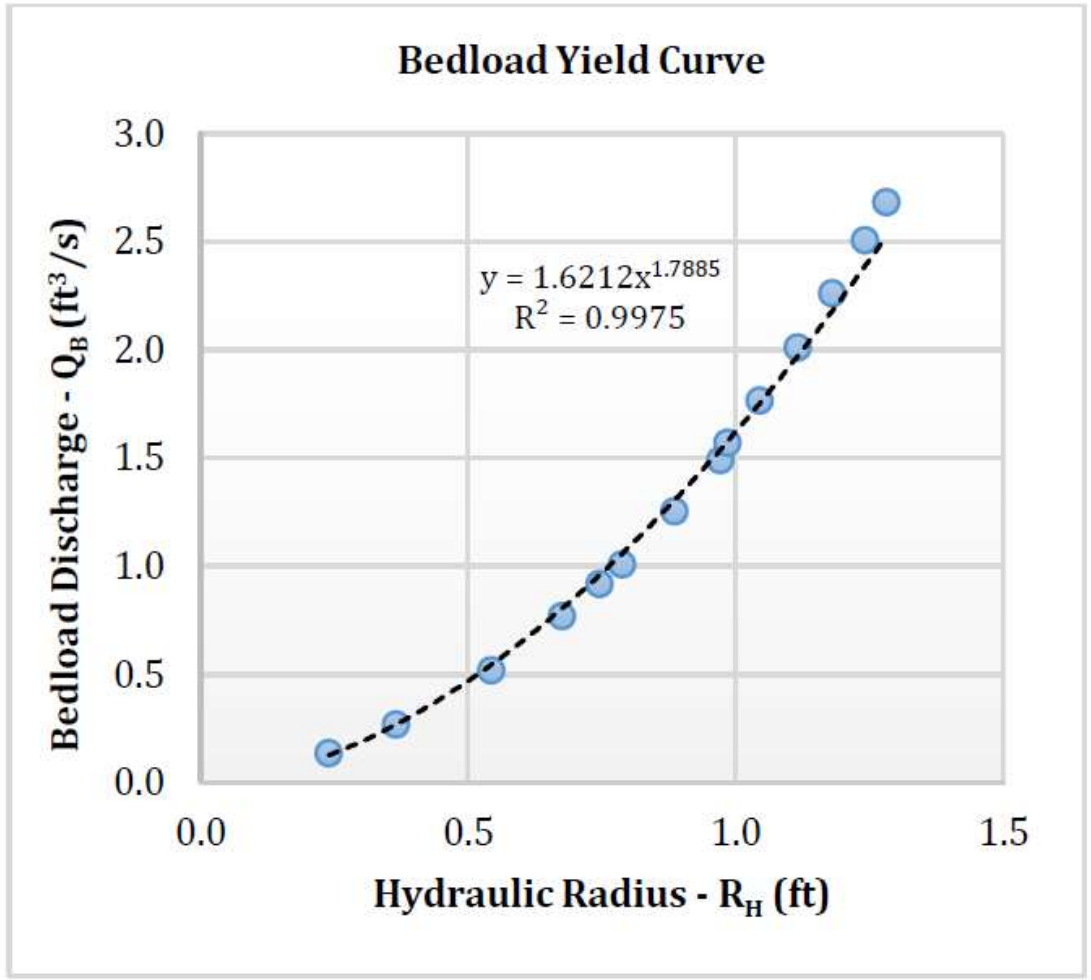


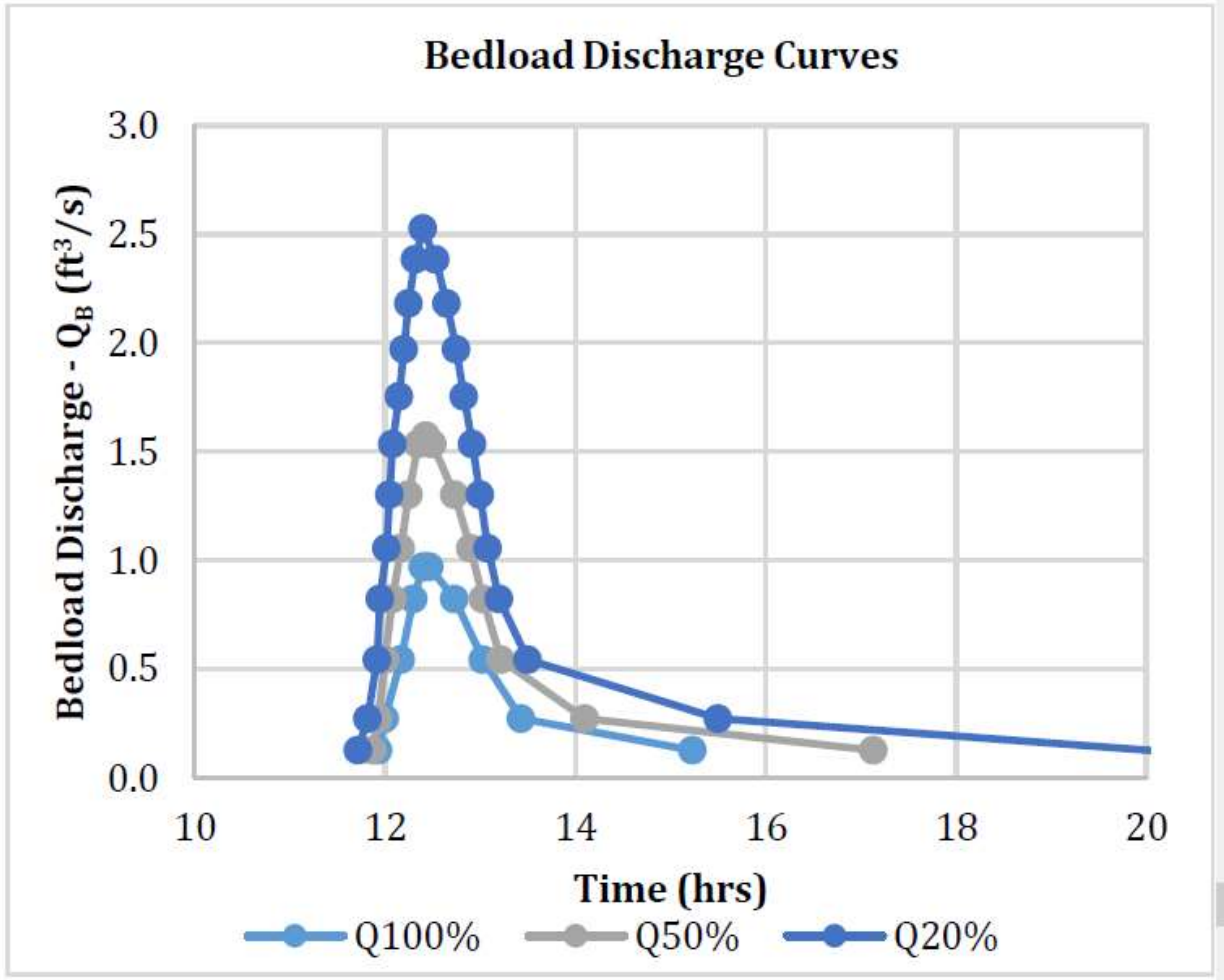
GRADE CONTROL STRUCTURE

NOT TO SCALE

Construction Completed January, 2019

Sediment Discharge Relationships





Estimate Channel Filling

Event	Bedload (CY)	Bedload (tons)
$Q_{100\%}$	151	211
$Q_{50\%}$	273	382
$Q_{20\%}$	485	679

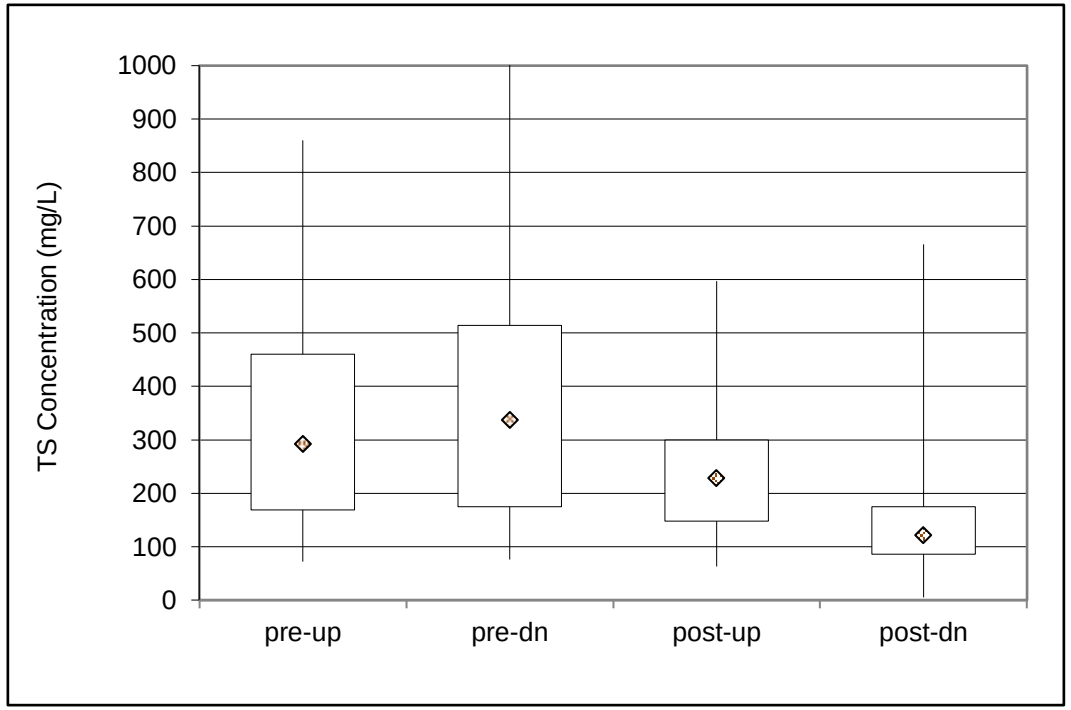
- Structures created 935 CY or 1,309 tons of storage capacity for sediment (AutoCAD)
- Channel will fill in 3-5 years

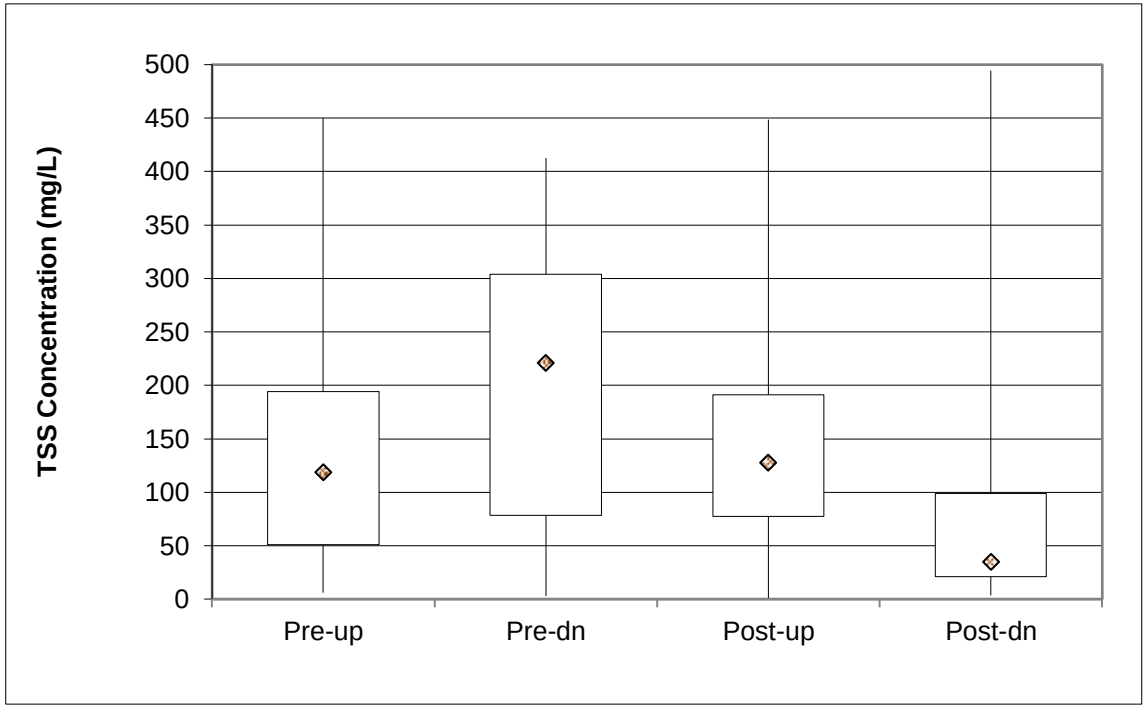
	$Q_{100\%}$	$Q_{50\%}$	$Q_{20\%}$	Incr. Vol. (CY)	Cum. Vol. (CY)
Year 1	X			151	151
Year 2	X	X		424	575
Year 3	X			151	726
Year 4	X	X		424	1150
Year 5	X		X	636	1786

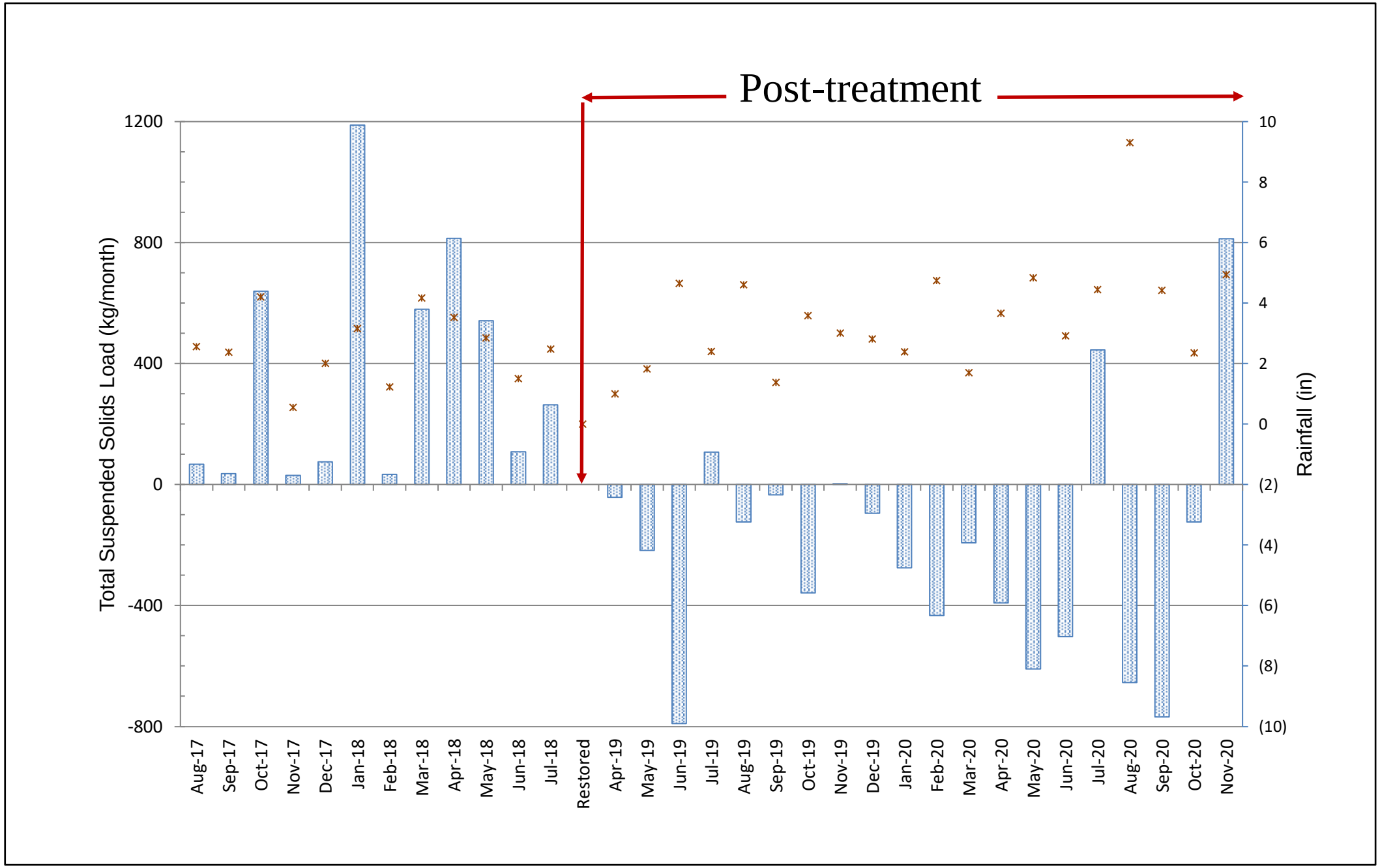
Post Construction Monitoring - March 2019 to December 2020

- Rainfall
- Upstream/Downstream Flow & Water Quality
  - Discharge
  - Total solids (TS)
  - Total suspended solids (TSS)
- Morphology (13 Surveys)
  - 11 permanent cross section
  - Longitudinal profile

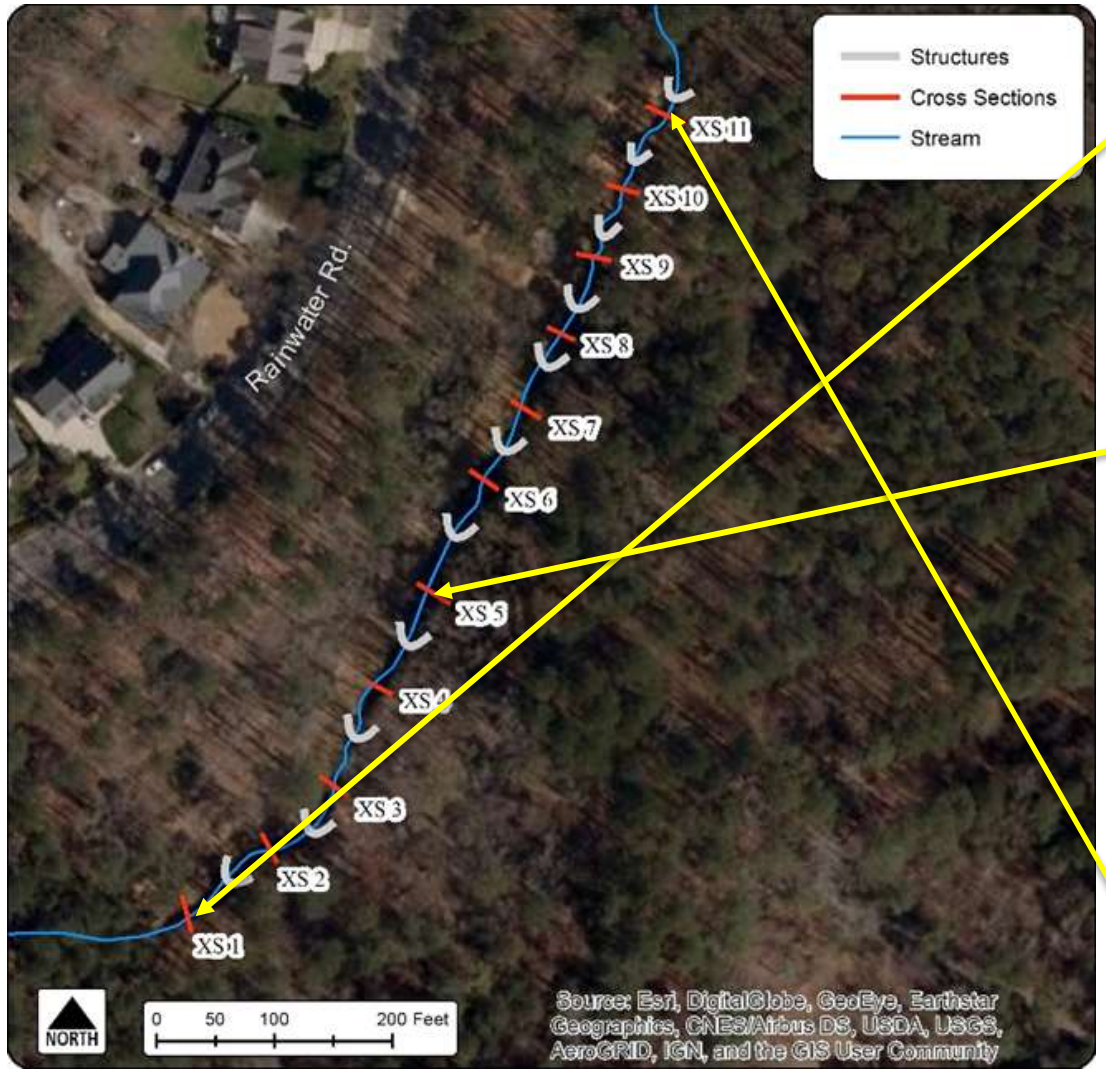
Post Construction Monitoring – Water Quality

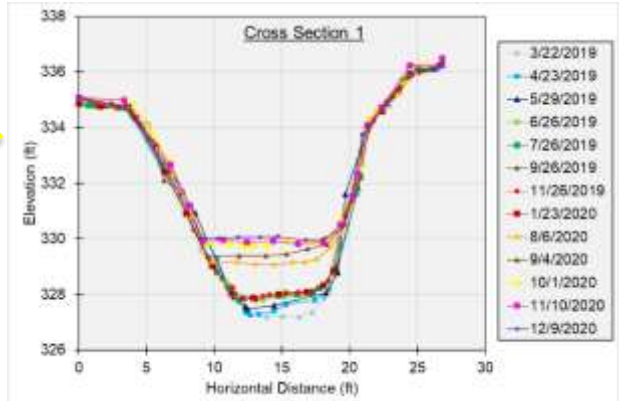


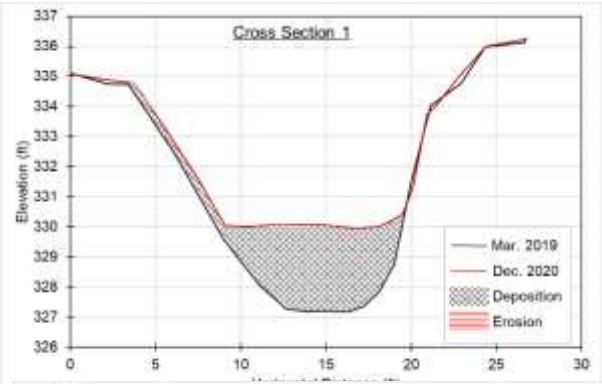


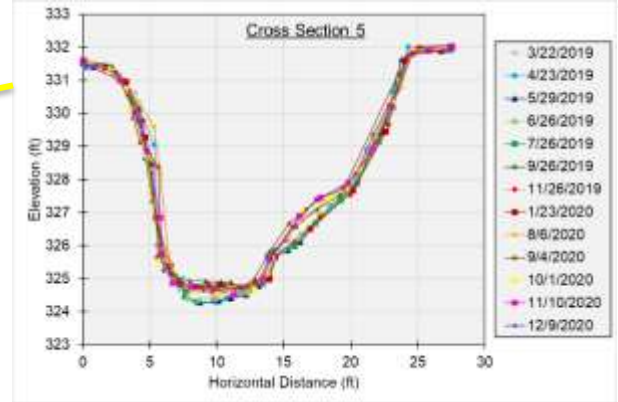

Post-treatment
Total Suspended Solids Load (kg/month)
Rainfall (in)
1200
800
400
0
-400
-800
10
8
6
4
2
0
(2)
(4)
(6)
(8)
(10)
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Restored
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20

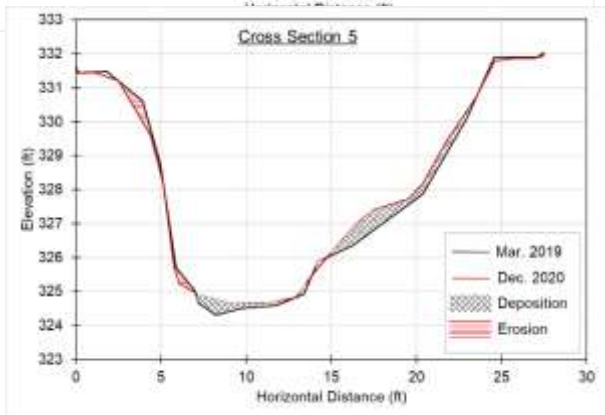
Post Construction Monitoring

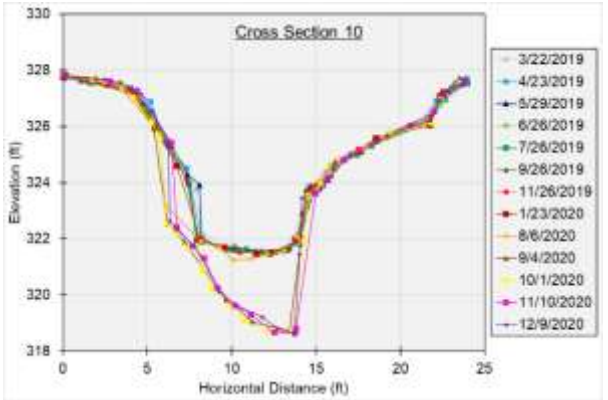


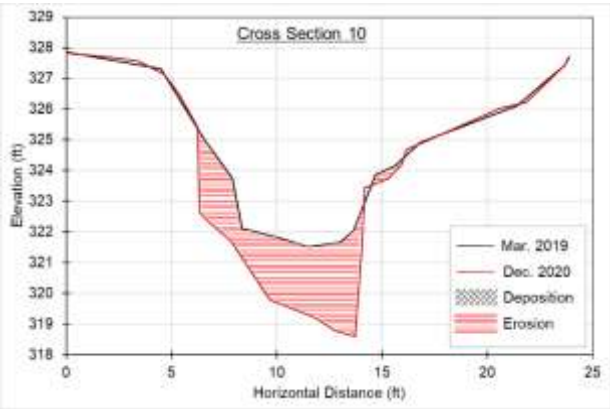




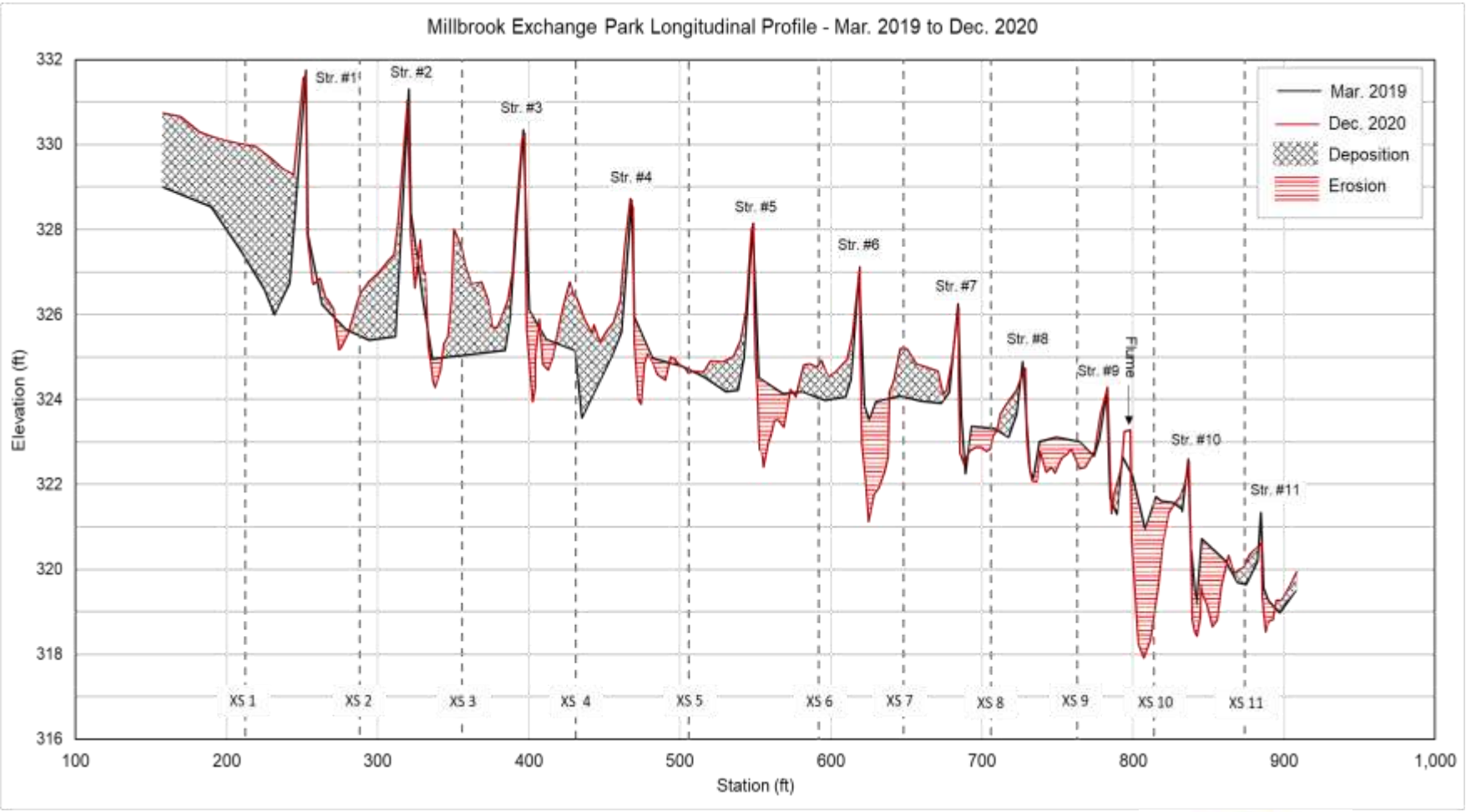








Post Construction Monitoring

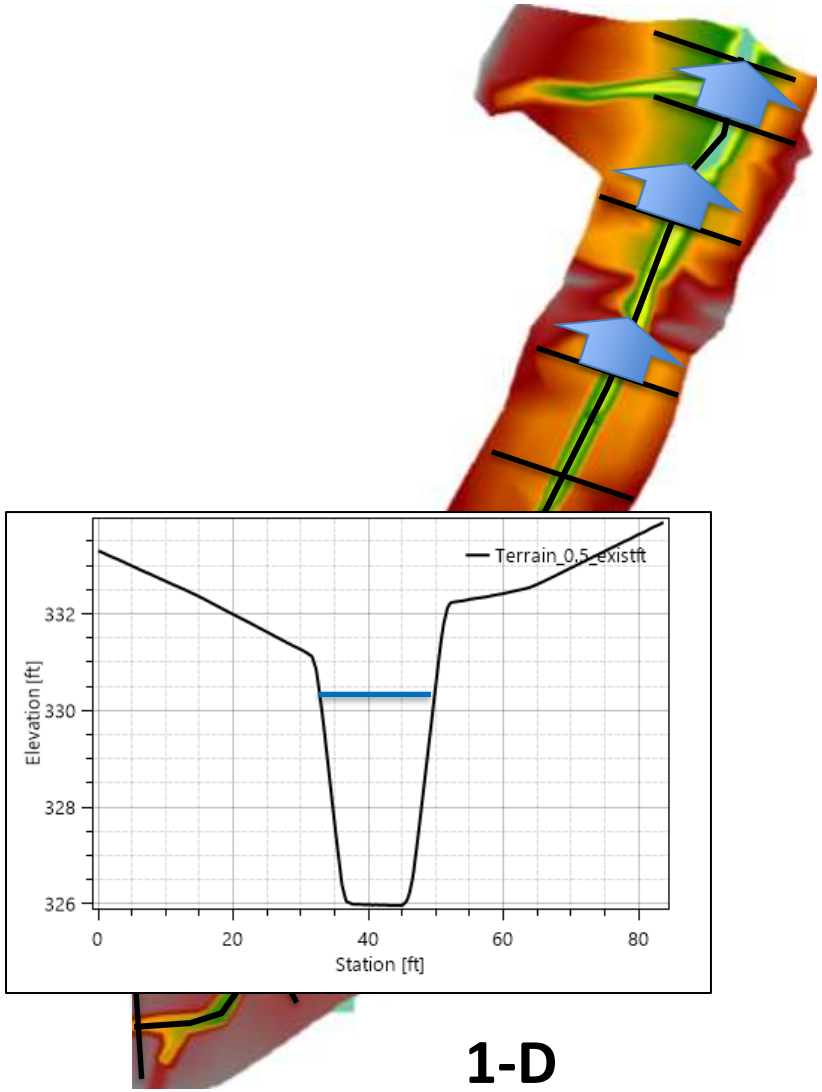


- 42 tons sediment aggraded per year
- Estimated 21 years to fill the channel

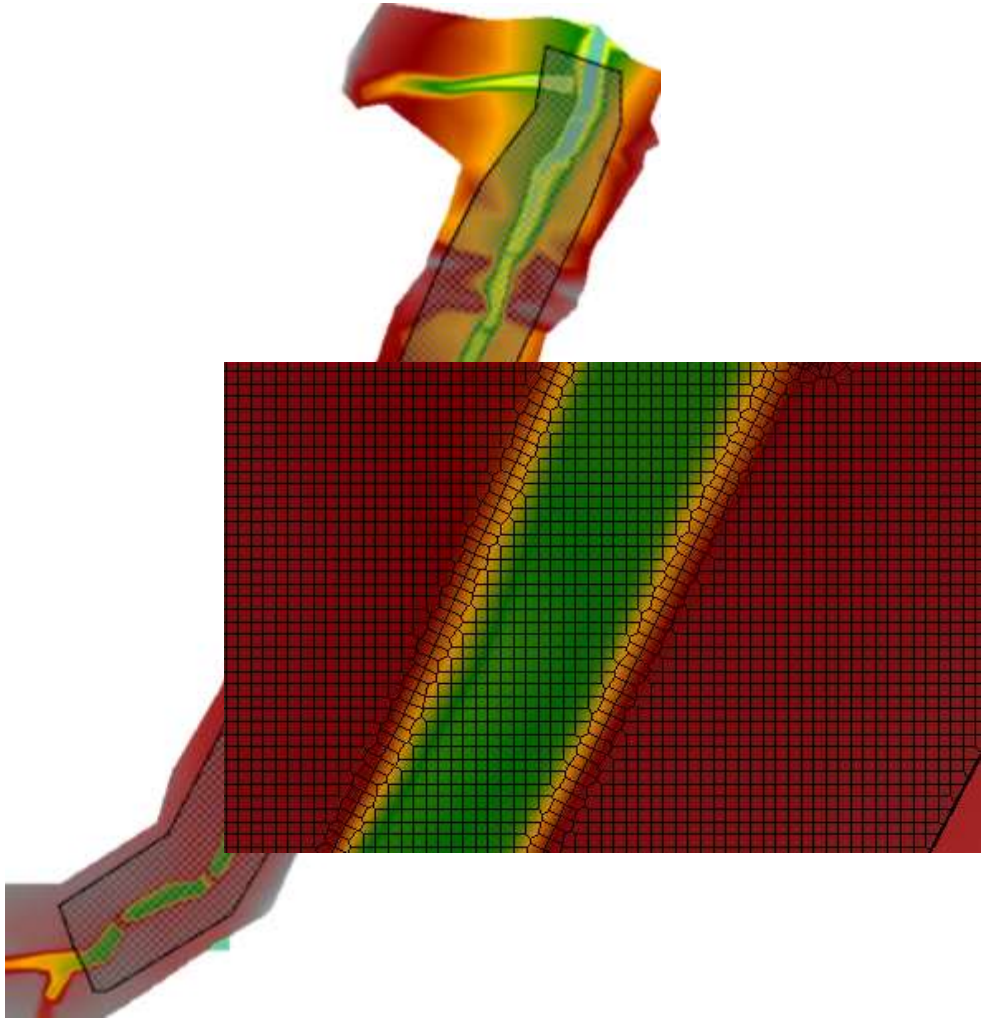
Problems/Concerns

- Channel Not aggrading as Fast as Anticipated
- Structure Arms Undermined

Hydraulic modeling – HEC-RAS2D



1-D



2-D

HEC-RAS2D Model simulations

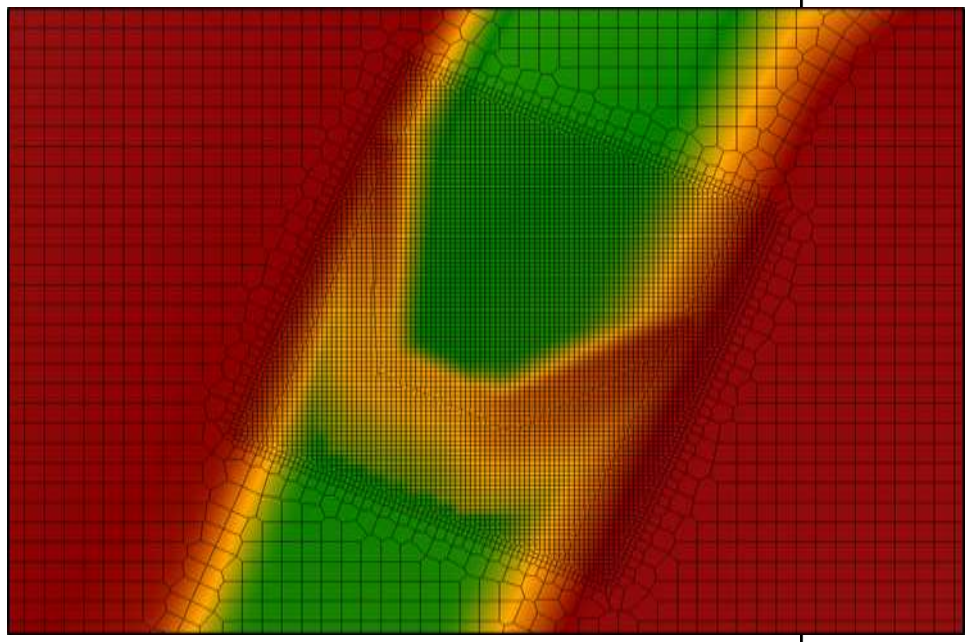
Simulated discharges (Design from Hydraflow – TR55)

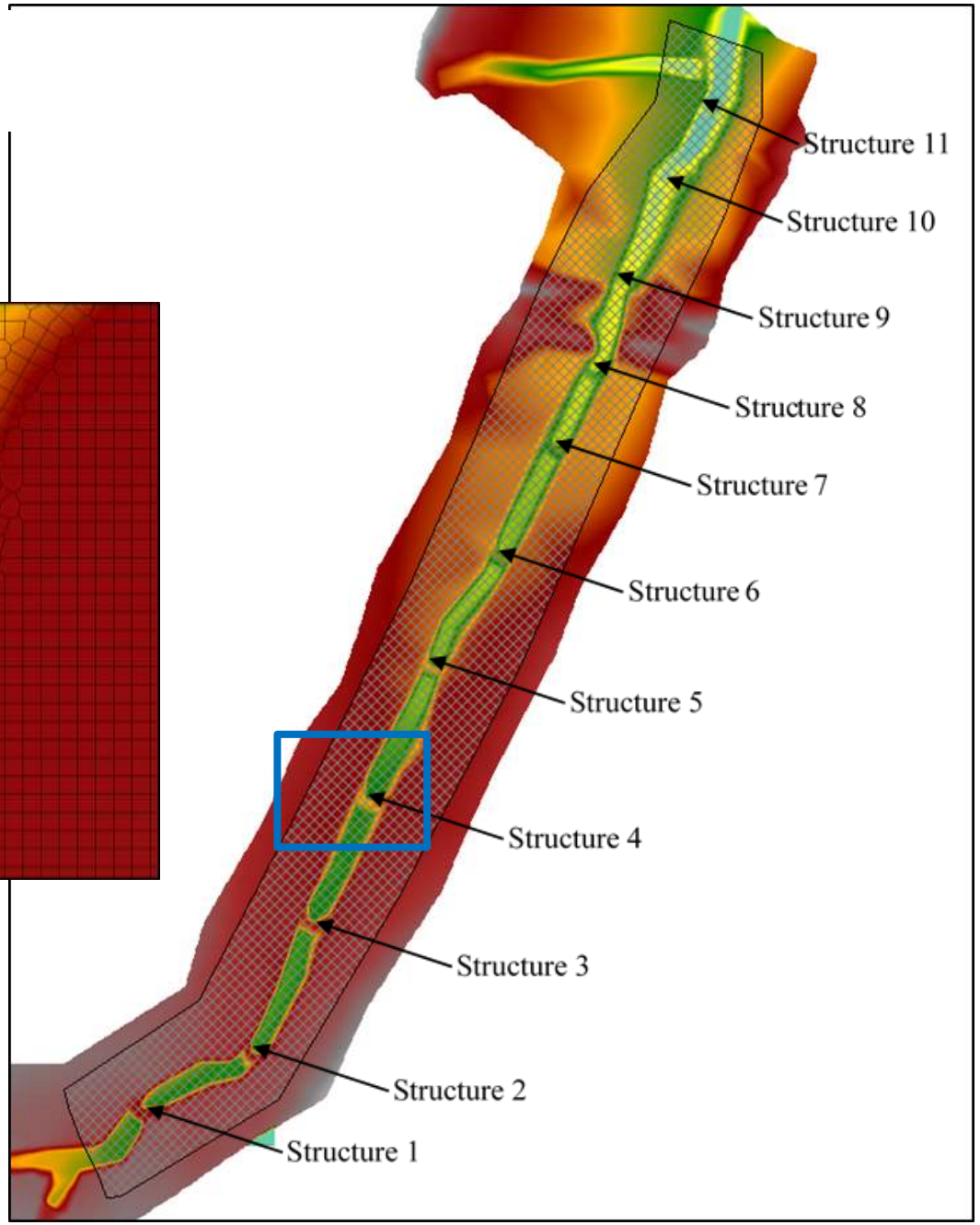
Storm Event	Discharge
1-year	30 cfs
2 year	60 cfs
5 year	107 cfs
25 year	200 cfs
100 year	300 cfs

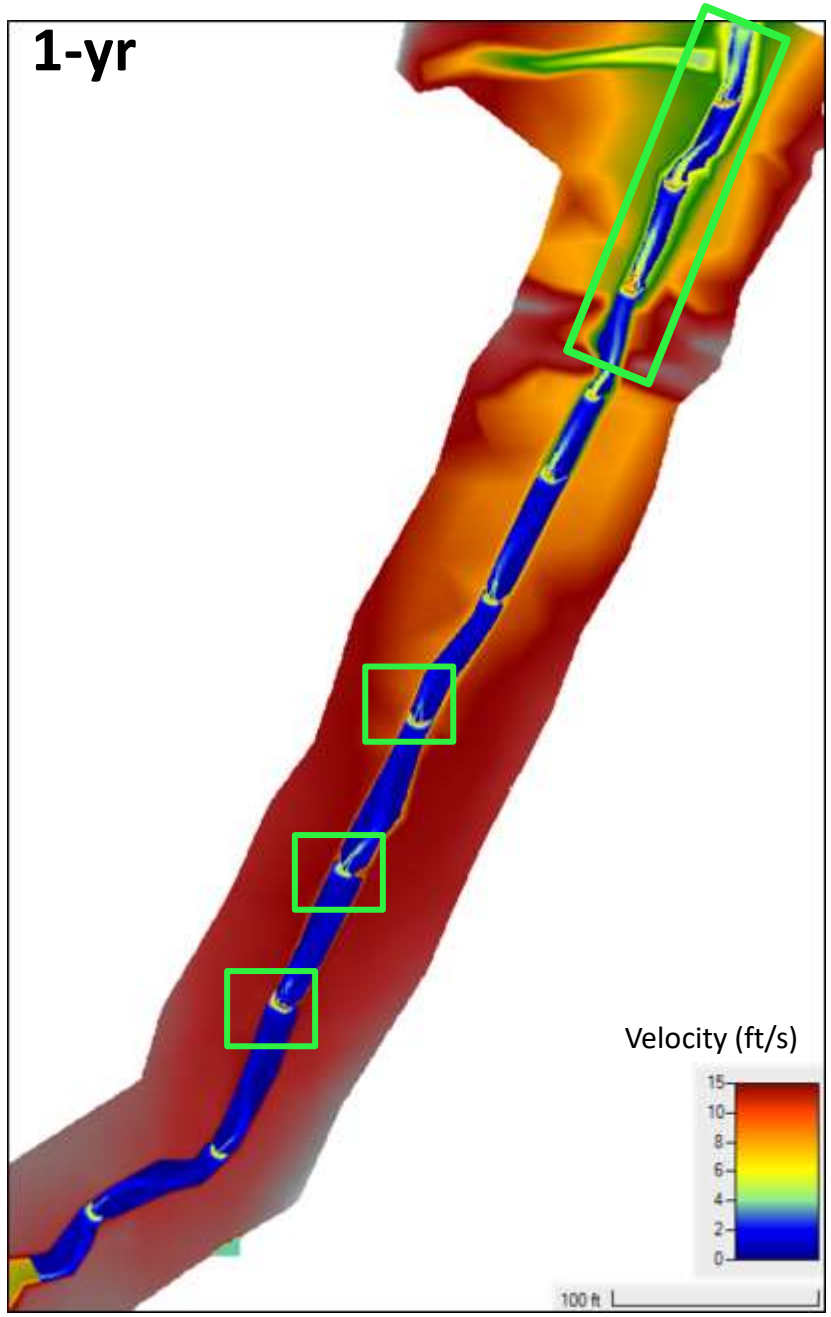
Observed flow events

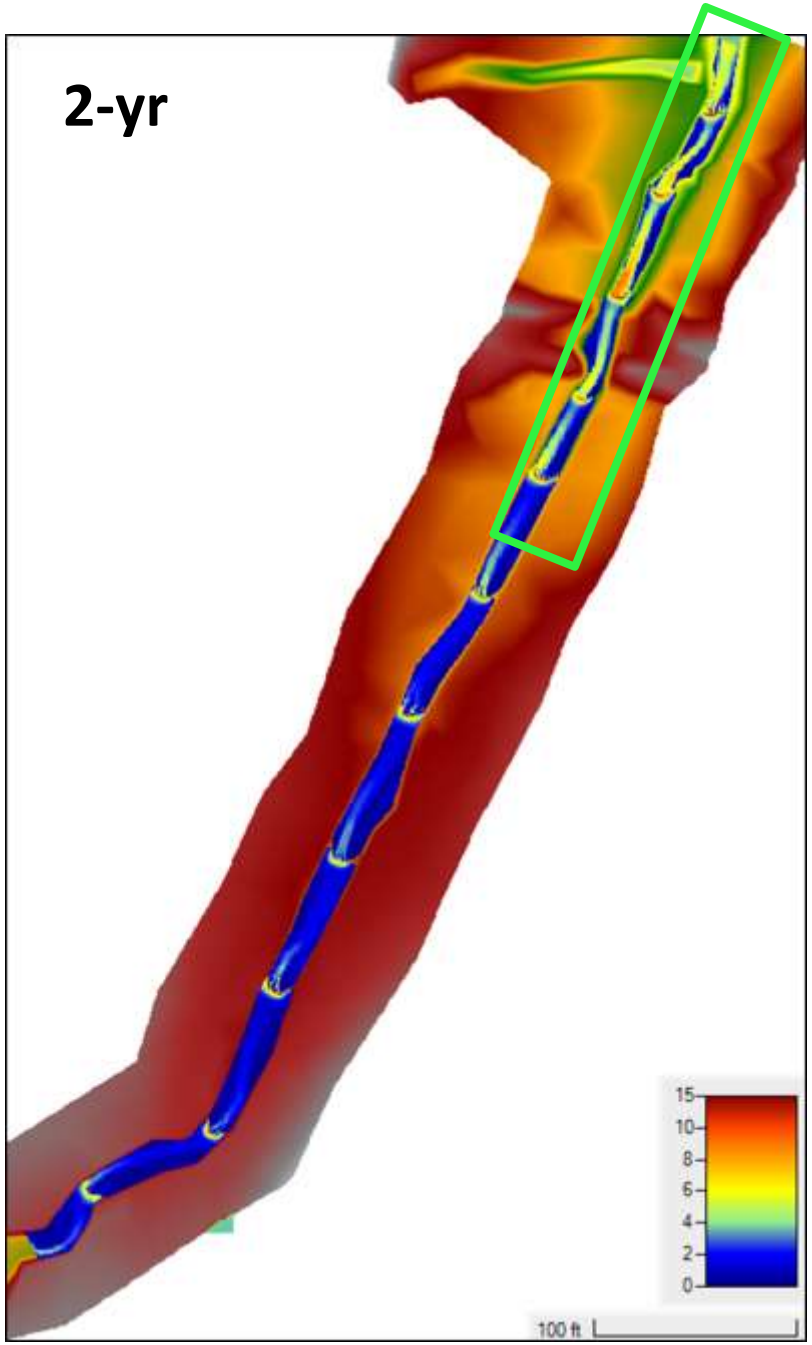
Peak Flow Magnitude	Flow (cfs)	Number of Events
1-yr	27-35	5
1-2 year	38-45	3
2-yr	55	1
2-5 yr	85	1
>5 yr	>100	0

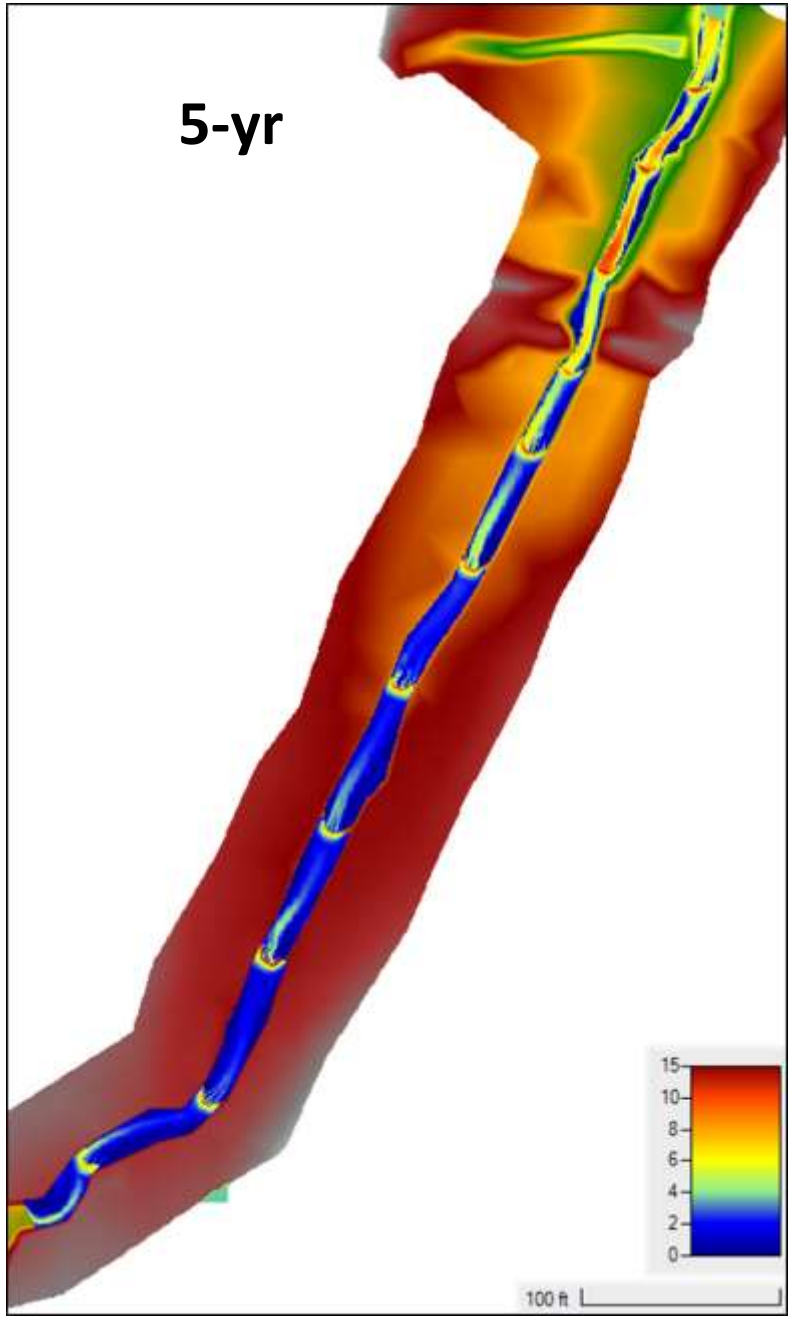
HEC-RAS 2D Model

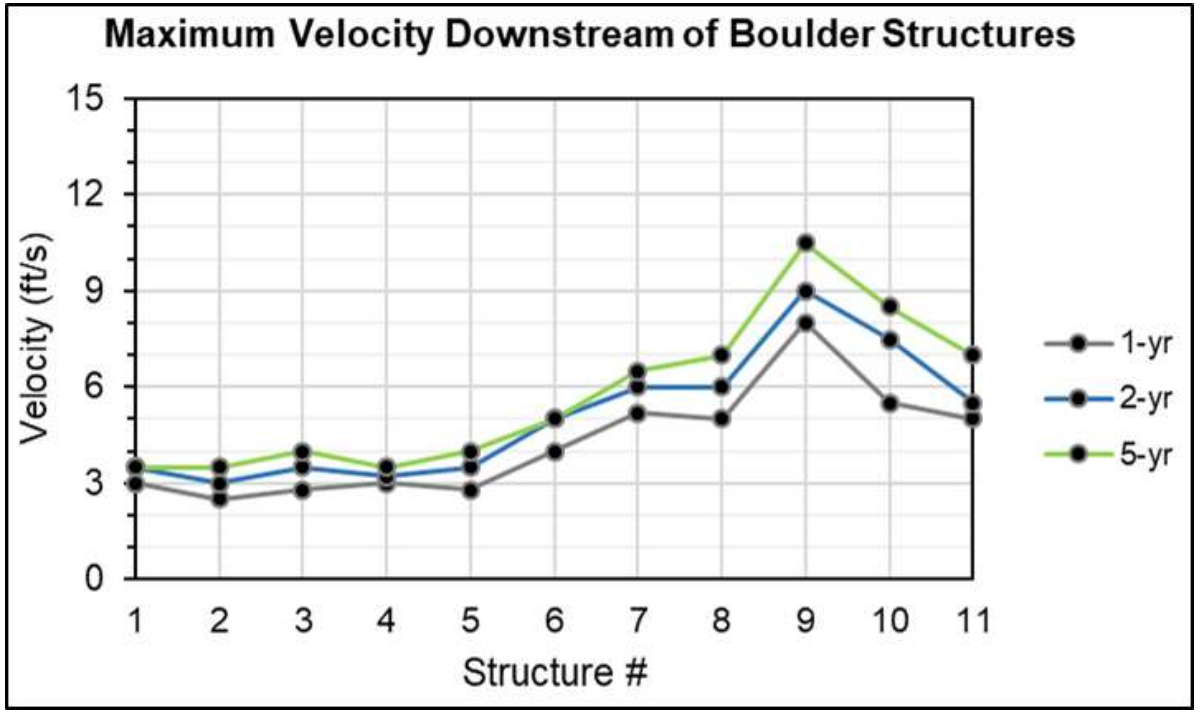





1-yr
Velocity (ft/s)
15
10
8
6
4
2
0
100 ft

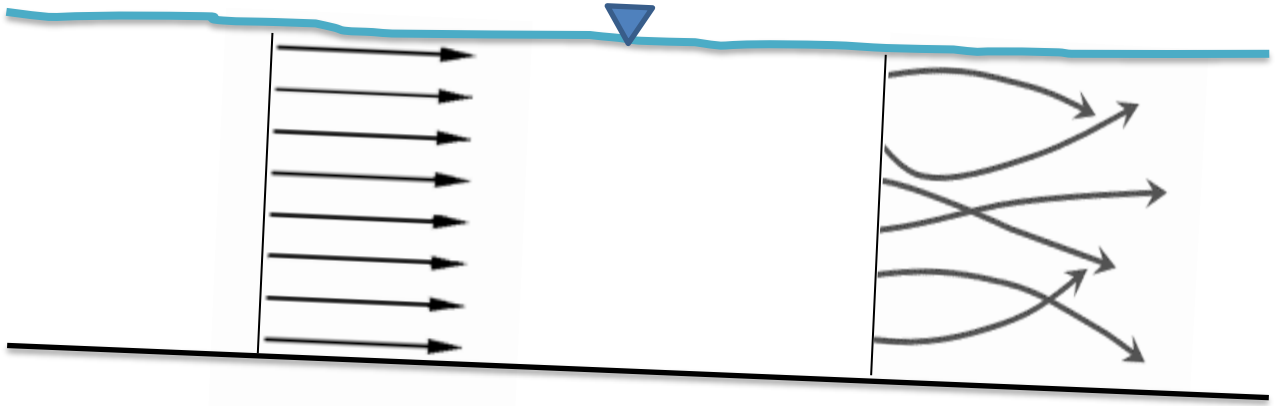

2-yr
15
10
8
6
4
2
0
100 ft


5-yr
15
10
8
6
4
2
0
100 ft


Maximum Velocity Downstream of Boulder Structures
Velocity (ft/s)
15
12
9
6
3
0
1
2
3
4
5
6
7
8
9
10
11
Structure #
1-yr
2-yr
5-yr

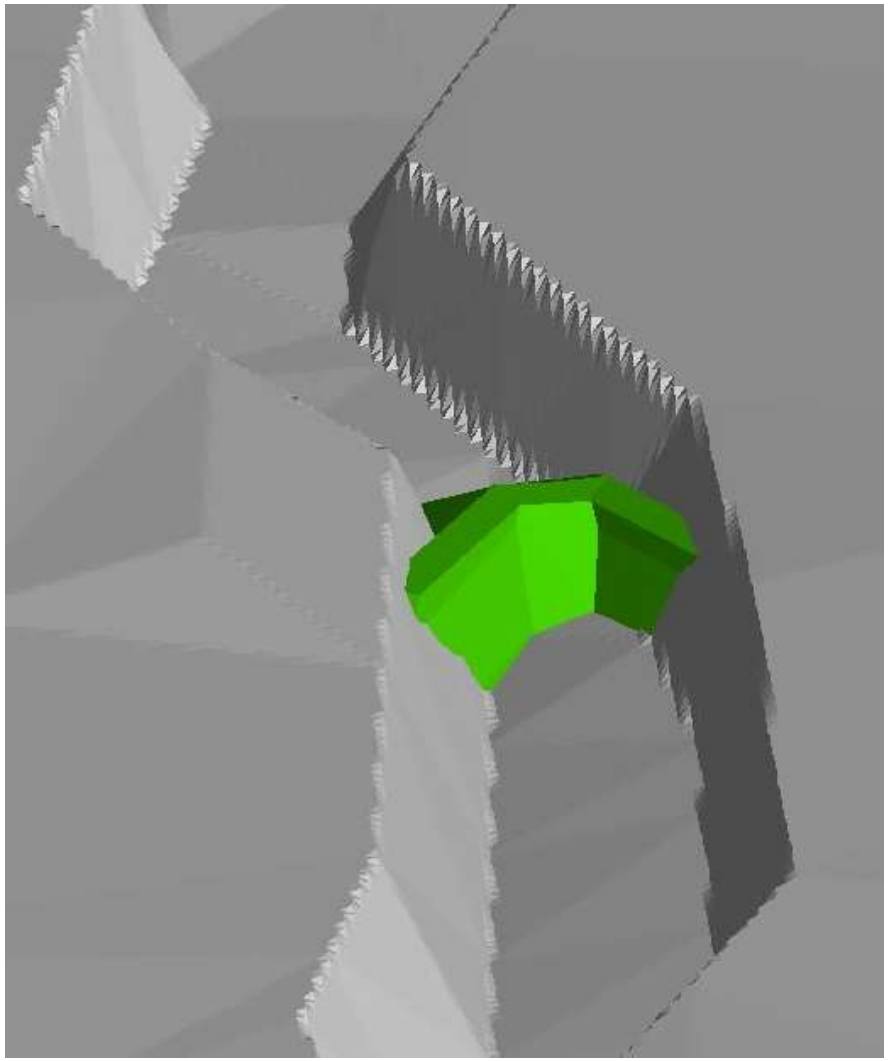
2D hydraulic models

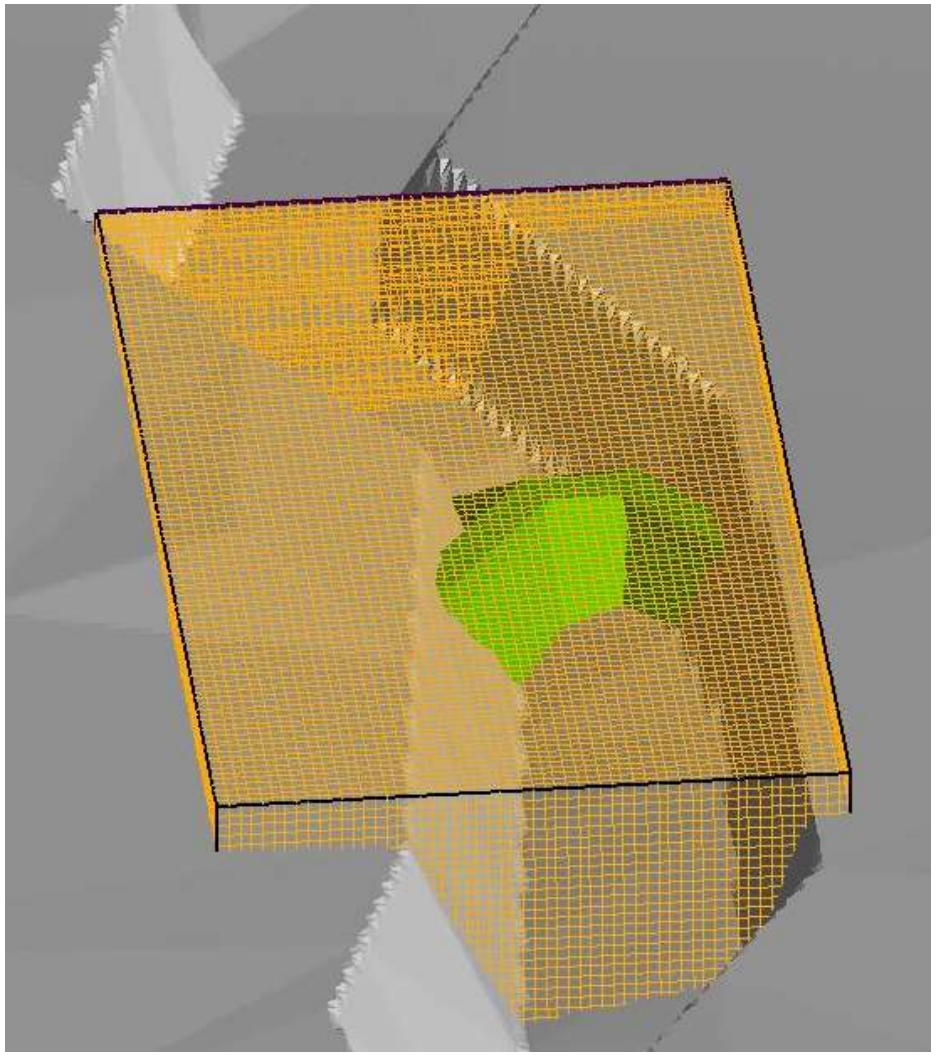
- Gives good idea of velocity in channel and water depth
  - BUT-



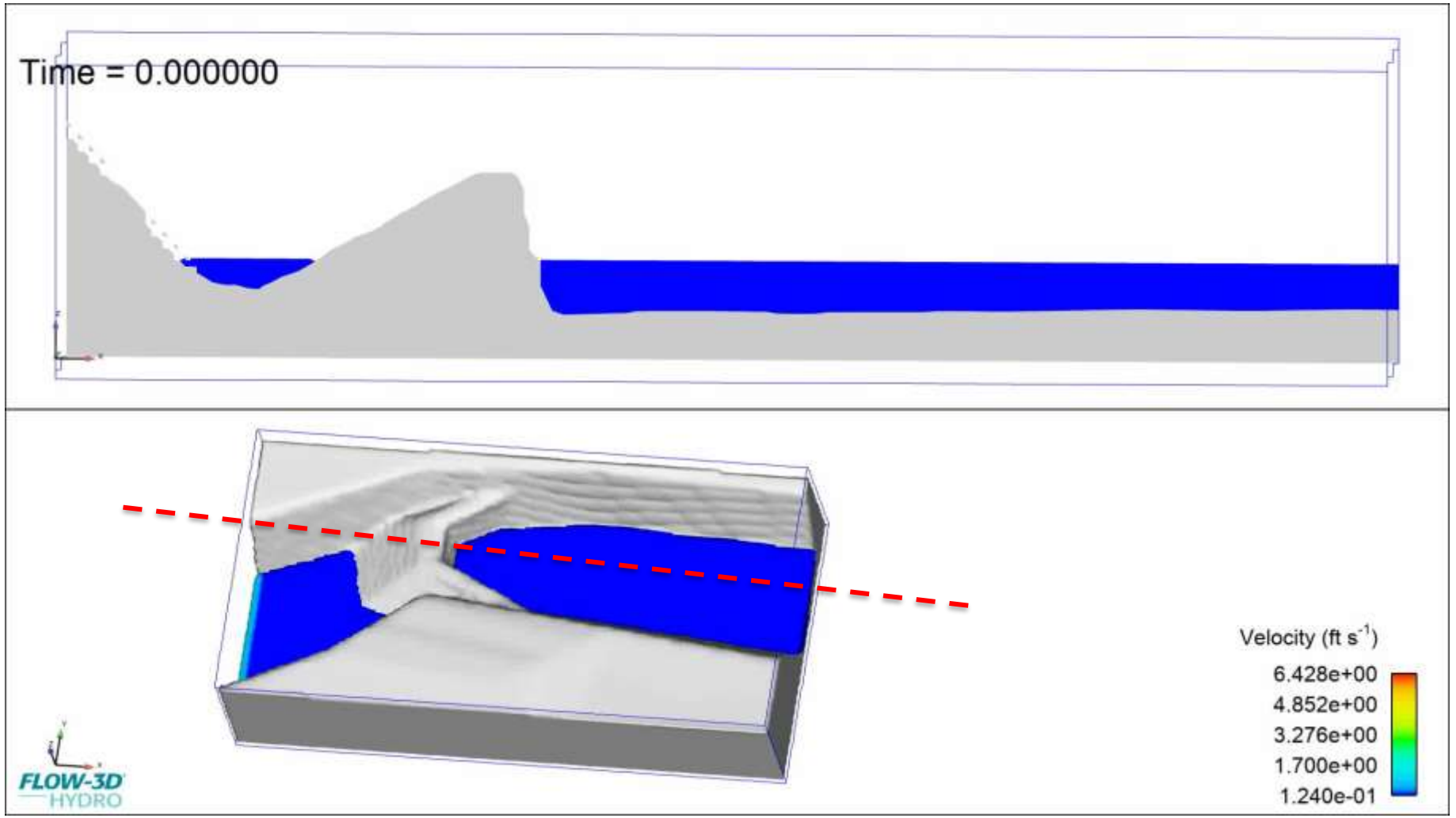
- Assumed constant velocity with depth
- Not well suited for large elevations changes – energy loss and turbulence

FLOW-3D HYDRO





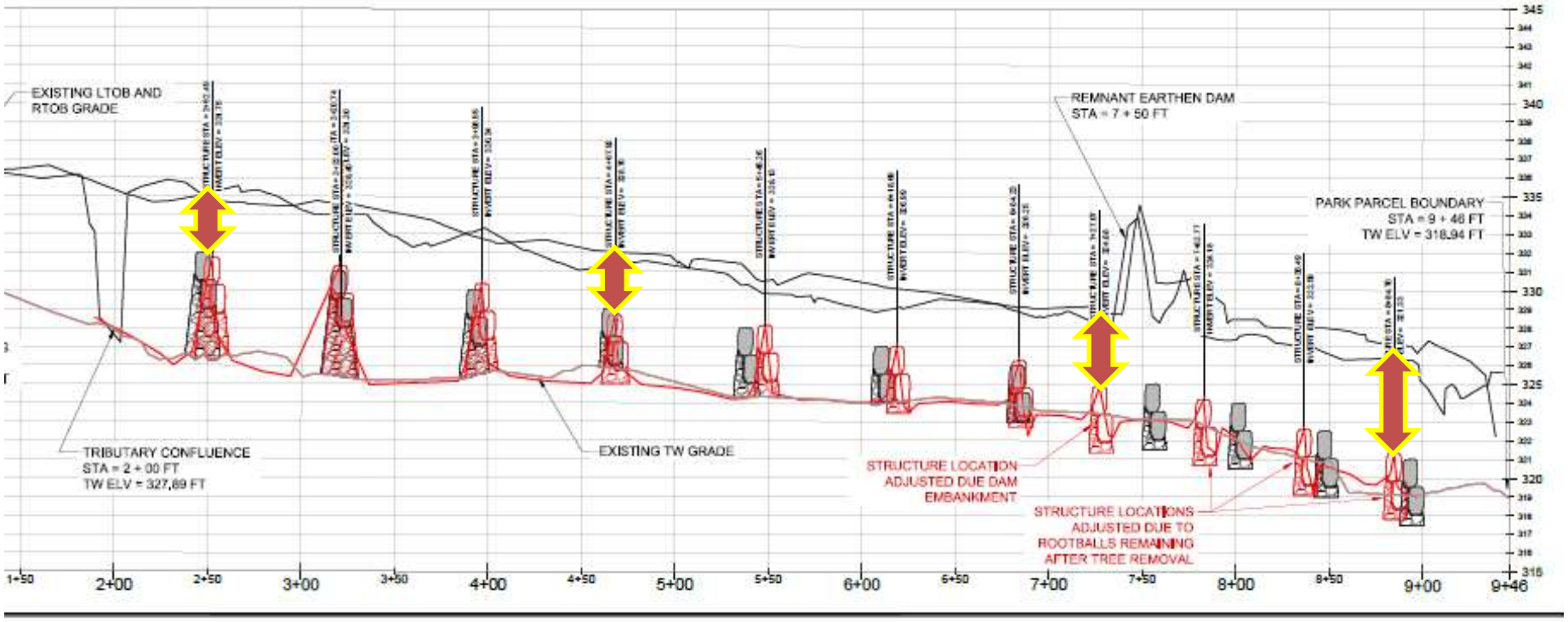
Flow Recirculation (2-yr)

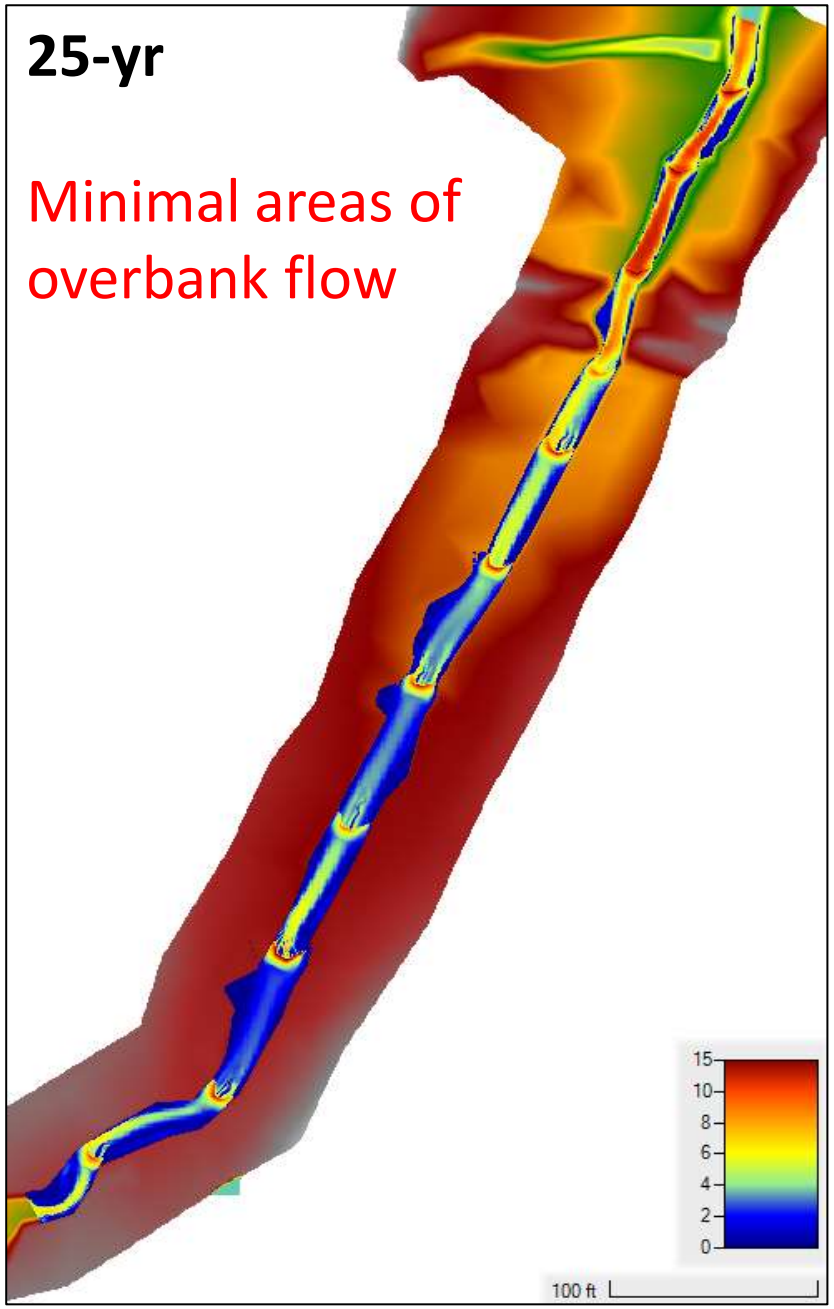


Not an actual event hydrograph but provides illustration of recirculating hydraulics

Other Concerns

- Grade control structures did not adequately connect the channel to the floodplain
- Q > 25-yr flow still confined to channel
- Very high velocity and shear




25-yr
Minimal areas of overbank flow
15
10
8
6
4
2
0
100 ft


100-yr
No overbank flow!
15
10
8
6
4
2
0
100 ft

Lessons Learned / Recommendations

- Use 2D and 3D models to evaluate shear and velocity of grade control designs
  - Model results seem to explain observed erosion/deposition
- Improve floodplain connection
  - Minimize velocity and recirculation
- Consider an alternate design approach
  - Priority 2/3 stream restoration with step-pool channel
  - RSC
  - Stage 0 Channel
- Use Experienced Contractor!!!!