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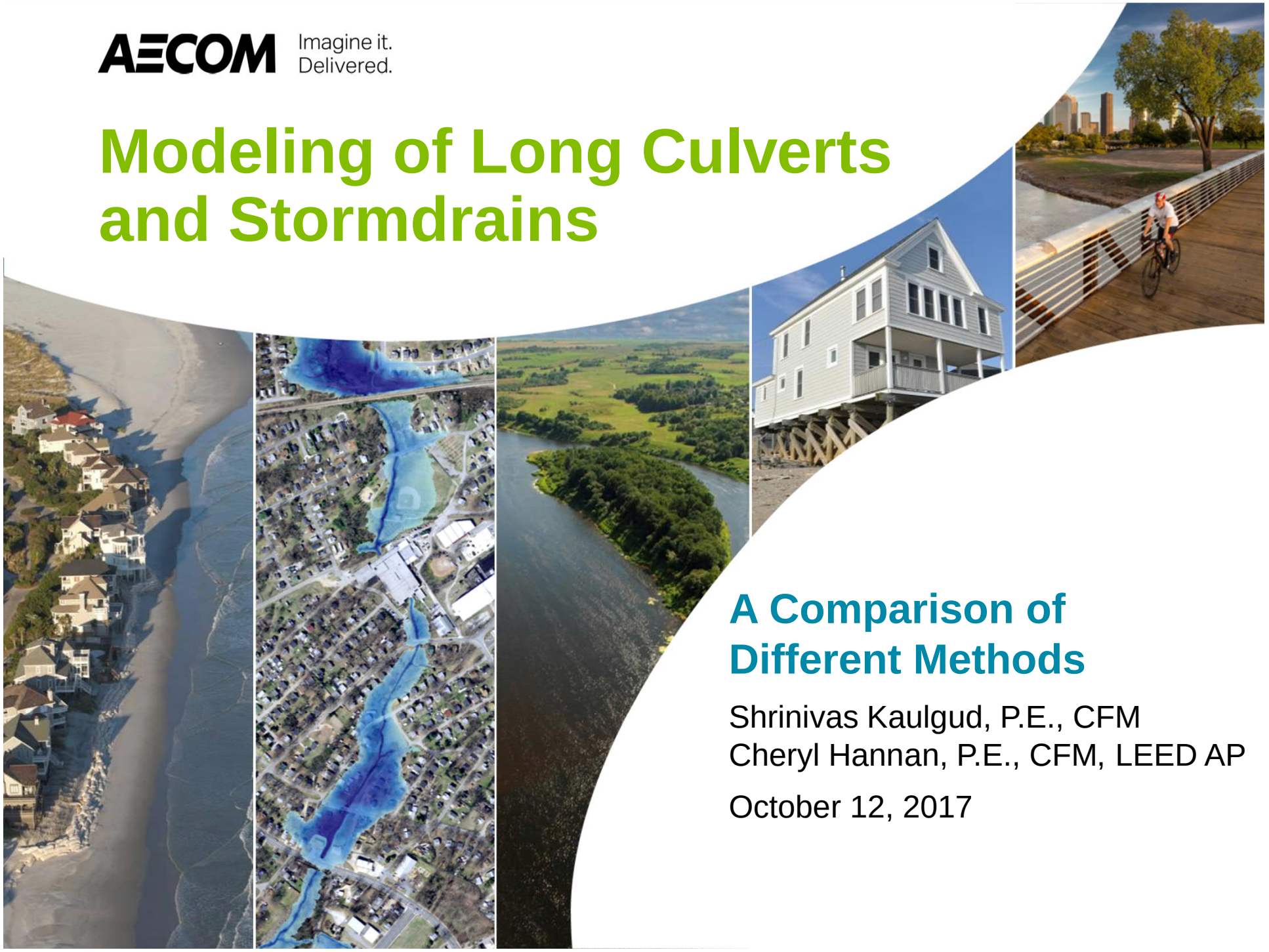
Modeling of Long Culverts and Stormdrains



A Comparison of Different Methods

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October 12, 2017

Presentation Outline

- Introduction
- Case Studies
- Scenario Comparisons
- Conclusions

Introduction

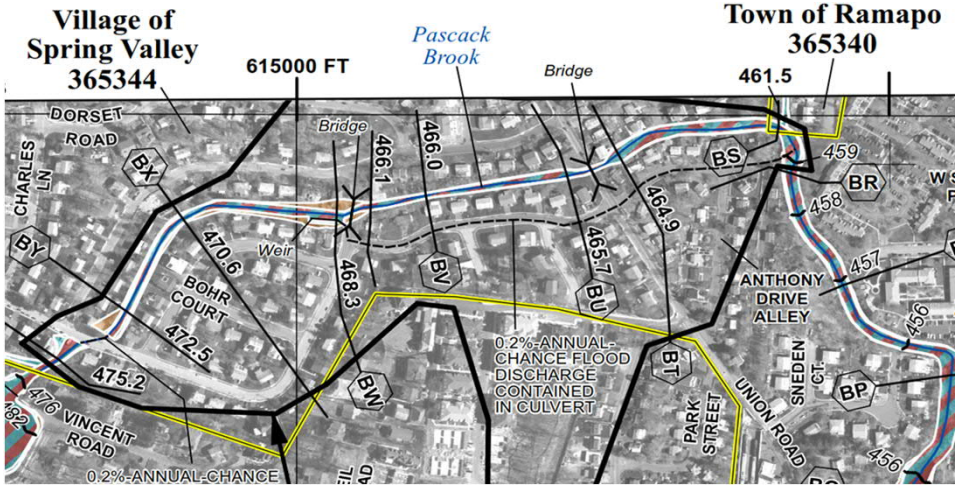
Selected models that can be used with long culverts

- HEC-RAS with Culvert Routine
- HEC-RAS with Lid Option (steady-state)
- CulvertMaster
- StormCAD
- XP-SWMM

Case Studies

Lateral weir with long culvert

Pascack Brook, Rockland County, NY



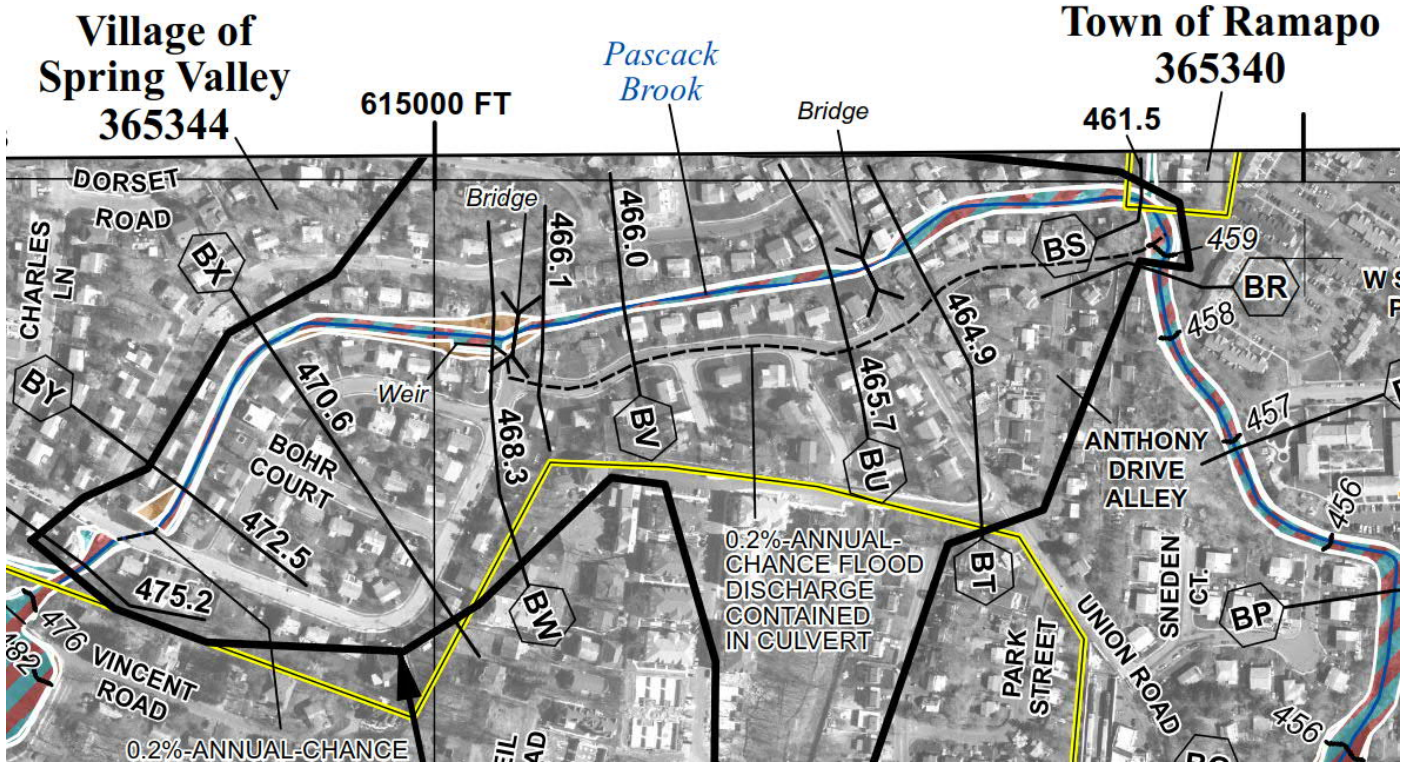
Long culvert with inlets

North Branch Pine Grove Brook, Onondaga County, NY

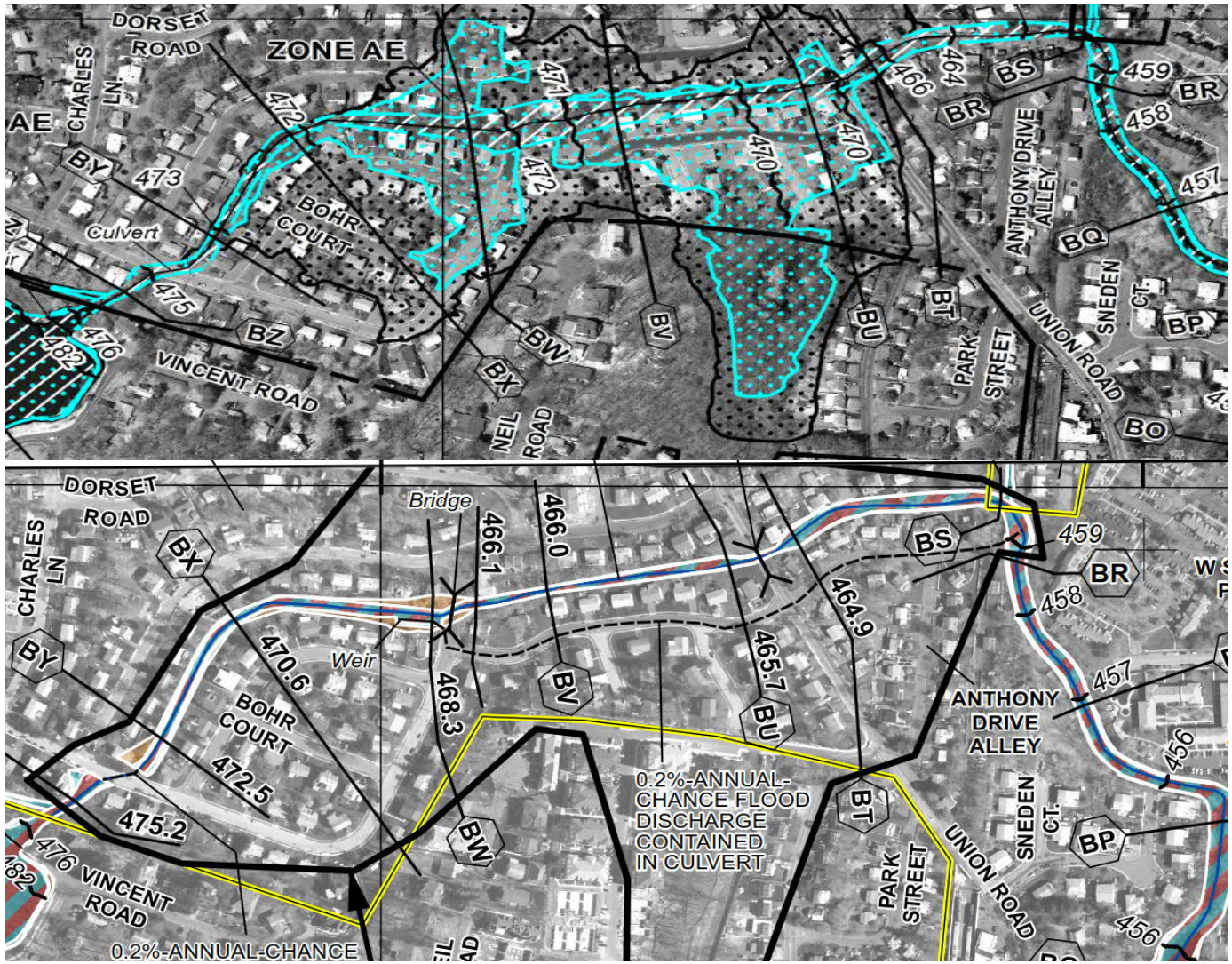
Case Study No. 1
Lateral Weir with Long Culvert
Pascack Brook, Rockland County, NY

Overview

Current FEMA floodwater elevations were modeled using HEC-RAS with a split flow. The flow going over the lateral weir enters a long culvert that was modeled using the lid option.

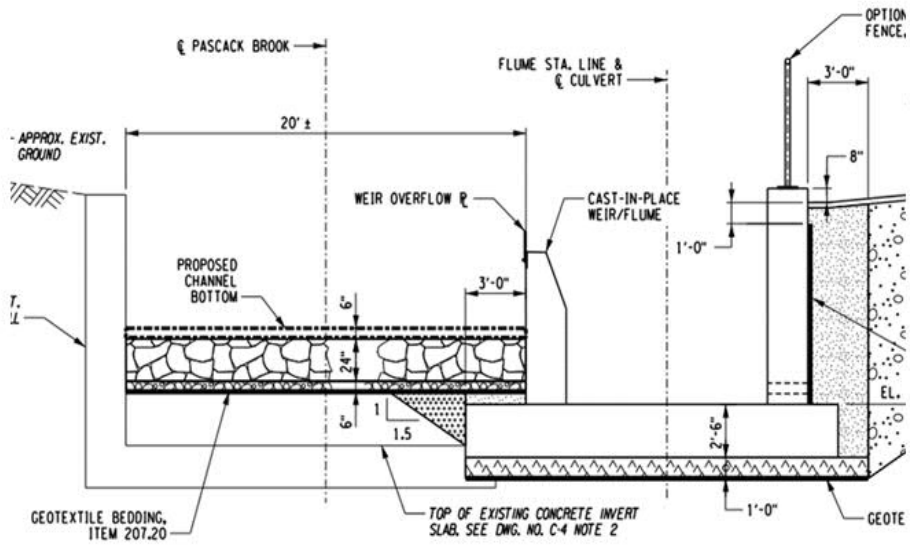


Overview


DORSET ROAD
ZONE AE
CHARLES LN.
AE
BY
473
Culvert
BOHR COURT
475
476
482
BZ
VINCENT ROAD
472
471
470
BX
BW
BV
NEIL ROAD
466
464
BS
459
BR
458
457
ANTHONY DRIVE ALLEY
BQ
SNEDEN CT.
BP
BU
BT
PARK STREET
UNION ROAD
BO
DORSET ROAD
Bridge
466.1
466.0
464.9
465.7
CHARLES LN
BX
BY
470.6
Weir
468.3
BV
BU
BS
459
BR
458
ANTHONY DRIVE ALLEY
457
456
BOHR COURT
472.5
475.2
476
482
VINCENT ROAD
BW
0.2%-ANNUAL-CHANCE FLOOD DISCHARGE CONTAINED IN CULVERT
BT
PARK STREET
UNION ROAD
SNEDEN CT.
BP
456
0.2%-ANNUAL-CHANCE

Overview

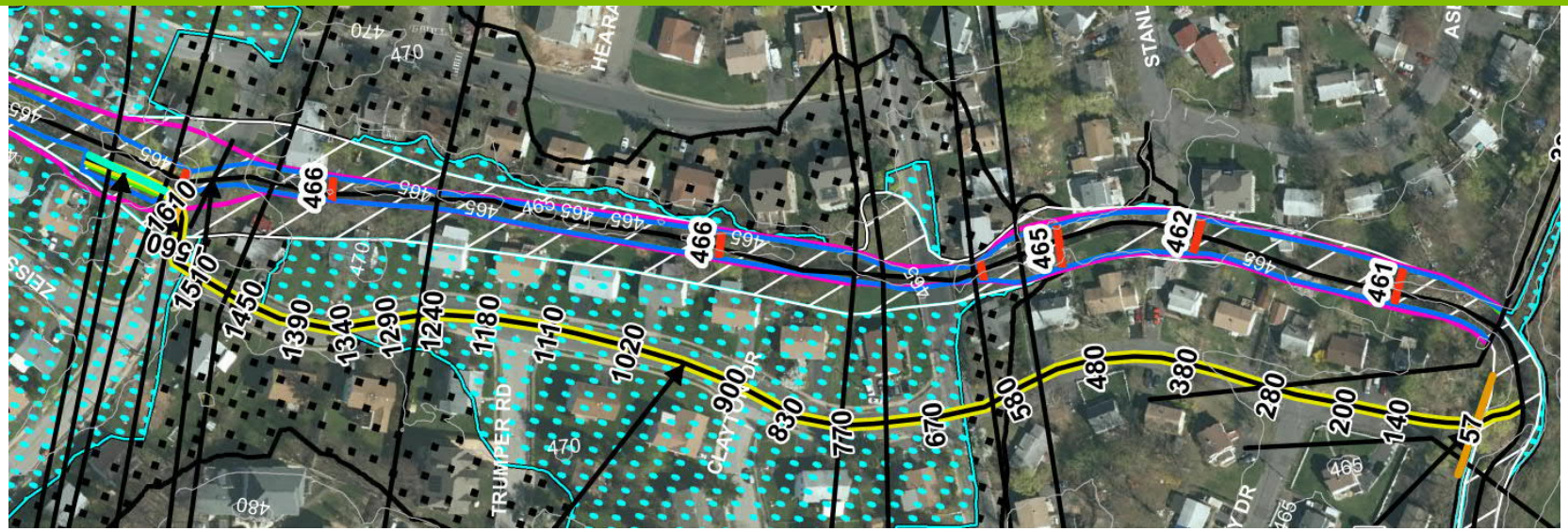
1. The project features a sharp-crested overflow weir at the upstream (inlet) end of the bypass culvert:

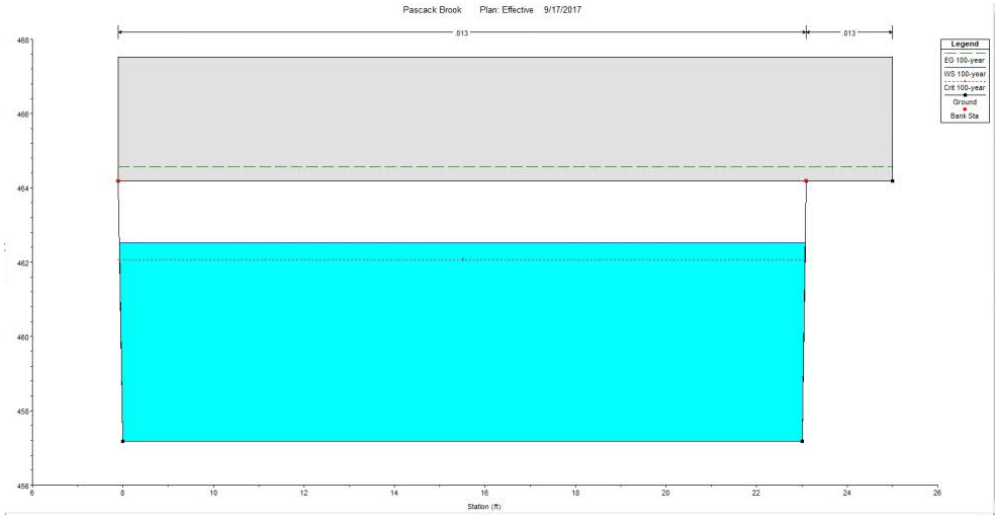


Scenarios

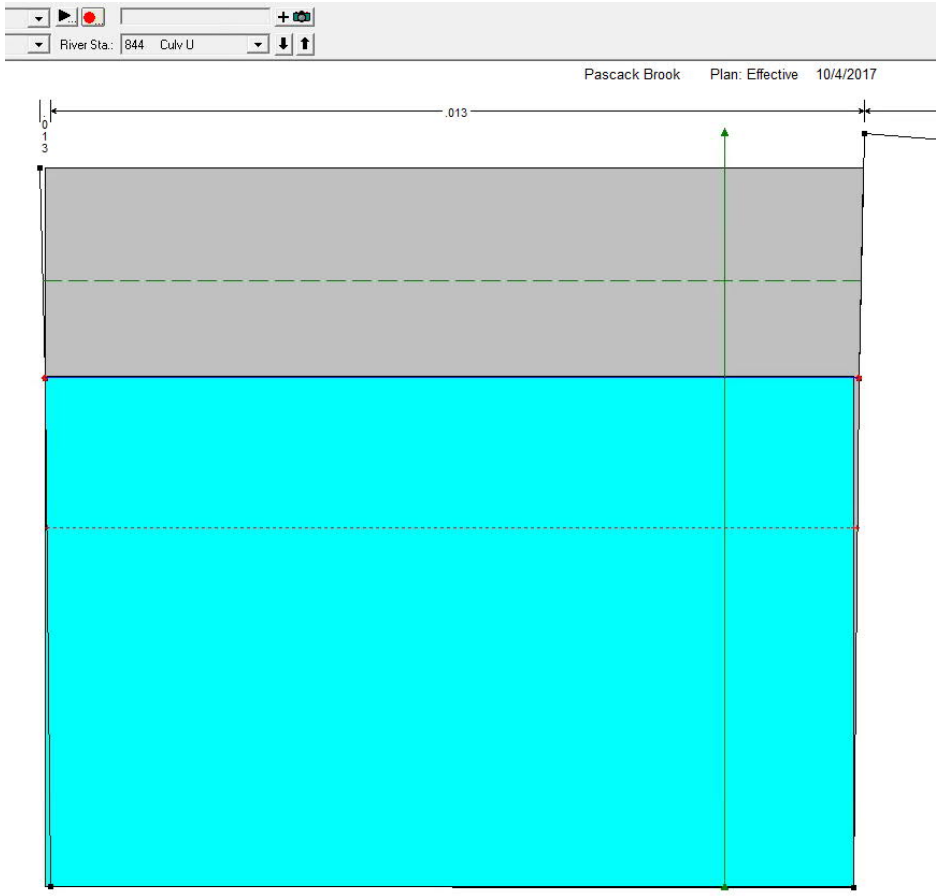
1. Current FEMA Model: HEC-RAS with Lid Option
2. HEC-RAS with Culvert Routine
3. CulvertMaster

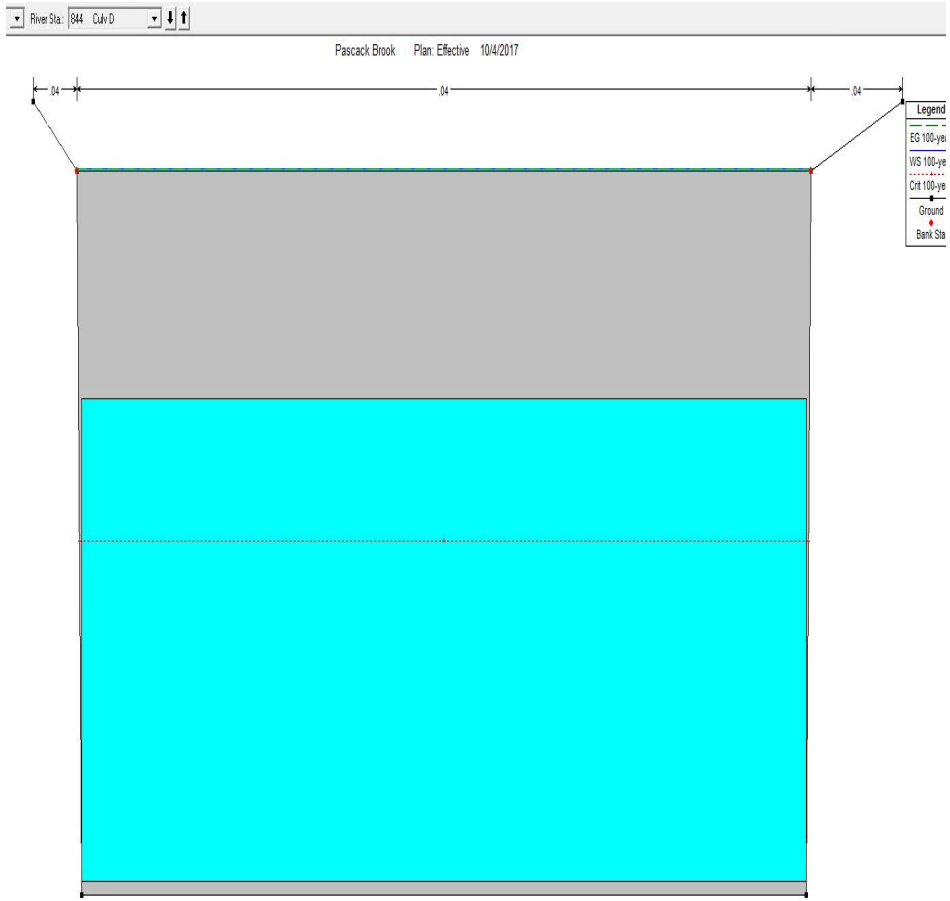
Scenario 1: Current FEMA Model





Scenario 2: HEC-RAS with Culvert Routine





Scenario 3: CulvertMaster

Culvert Designer/Analyzer Report
Long Culvert for Pascack Brook

Analysis Component			
Storm Event	Design	Discharge	928.00 cfs

Peak Discharge Method: User-Specified			
Design Discharge	928.00 cfs	Check Discharge	0.00 cfs

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	460.00 ft

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-7 x 7 ft Box	928.00 cfs	467.15 ft	9.47 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Long Culvert for Pascack Brook

Analysis Component			
Storm Event	Design	Discharge	928.00 cfs

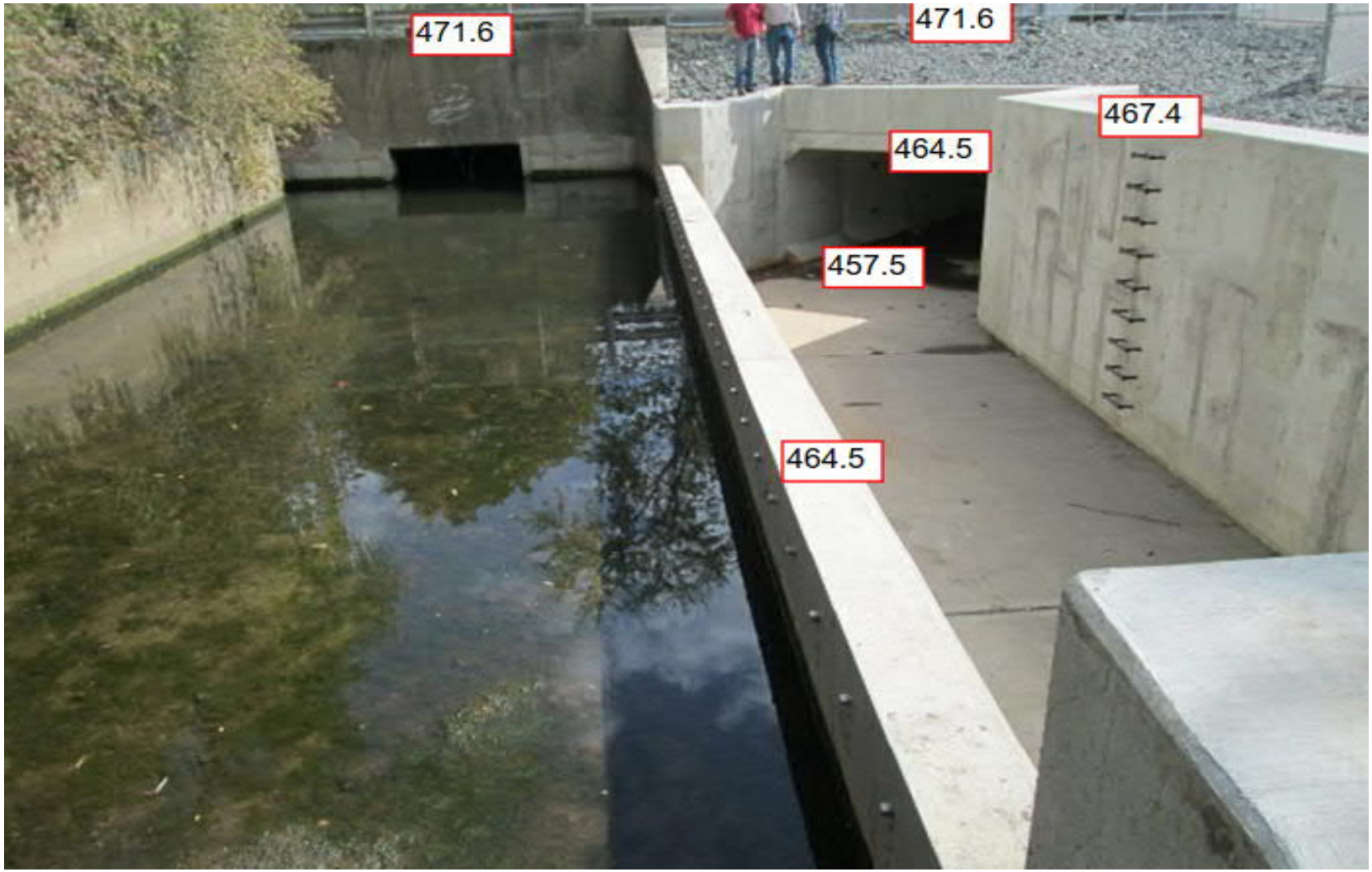
Peak Discharge Method: User-Specified			
Design Discharge	928.00 cfs	Check Discharge	0.00 cfs

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	460.00 ft

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-8 x 7 ft Box	928.00 cfs	465.62 ft	8.29 ft/s
Weir	Not Considered	N/A	N/A	N/A

Average HW = 466.4 feet

Culvert routine HWdepth = 464.5 feet
CulvertMaster HW depth = 466.4 feet Lid option headwater depth = 462.6 feet



Case Study No. 1: Final Thoughts

- Most accurate model could be an unsteady model
- All three ways of modeling showed the flow contained in the culvert
- Lid option gave the least conservative values and there are concerns that the culvert is actually under pressure

Case Study No. 2

Long Culvert with Inlets

North Branch Pine Grove Brook, Onondaga County, NY

Overview

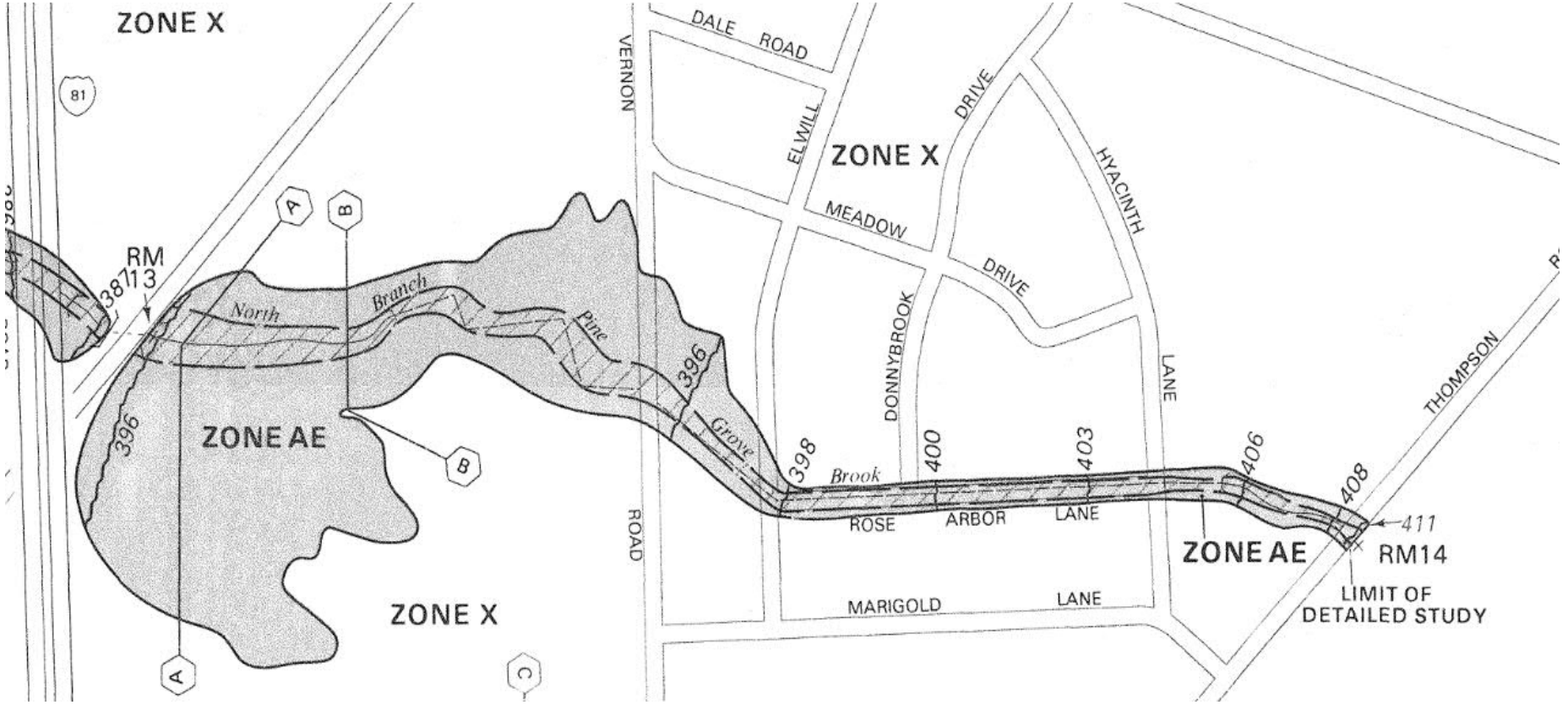
- 2,600’ stormdrain
- Watershed area: 170 AC. at S. Bay Road
- Effective 1% flow: 80 CFS at S. Bay Road

Scenarios

1. Historic FEMA Study: HEC-2 (no stormdrain)
2. Current FEMA Study: HEC-RAS Lid Option
3. HEC-RAS with Culvert Routine
4. Culvert Master (stormdrain) + HEC-RAS Overland
5. StormCAD (stormdrain) + HEC-RAS Overland
6. XP-SWMM
7. XP-SWMM with Hydrology Updates

Scenario 1: Historic Study

- Floodwater elevations were modeled using HEC-2
- The stormdrain was ignored



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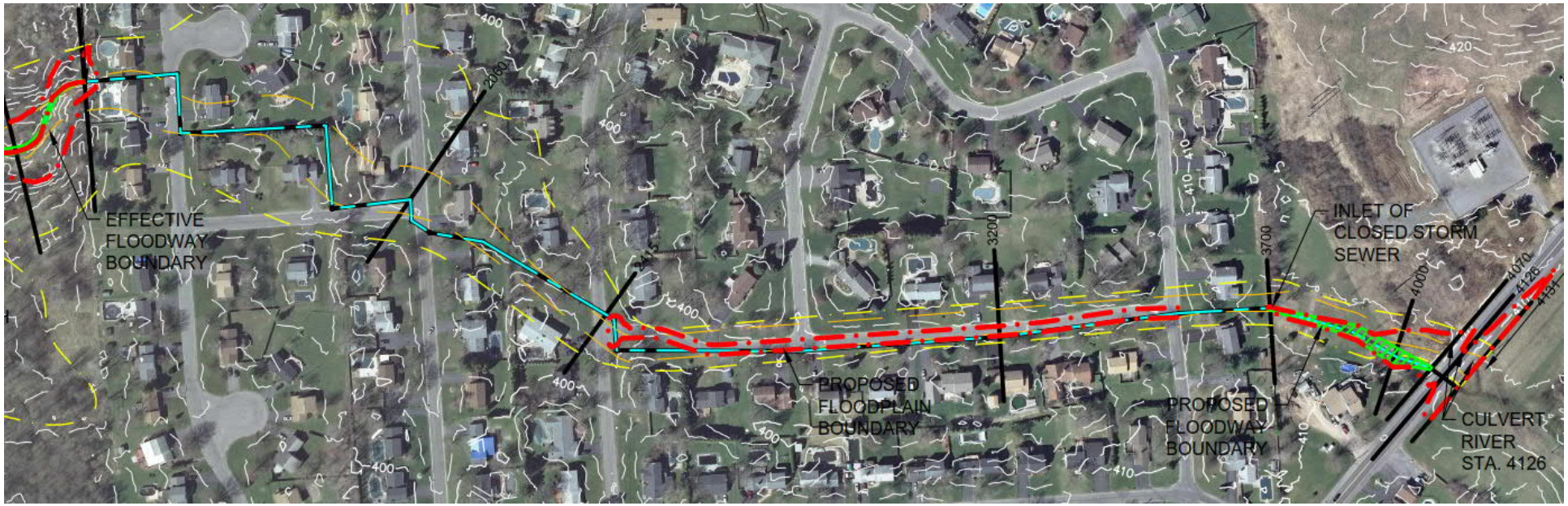
Scenario 2: Current FEMA Study

- Floodwater elevations were modeled using the lid option in HEC-RAS
- Model shows flow is contained in the culvert

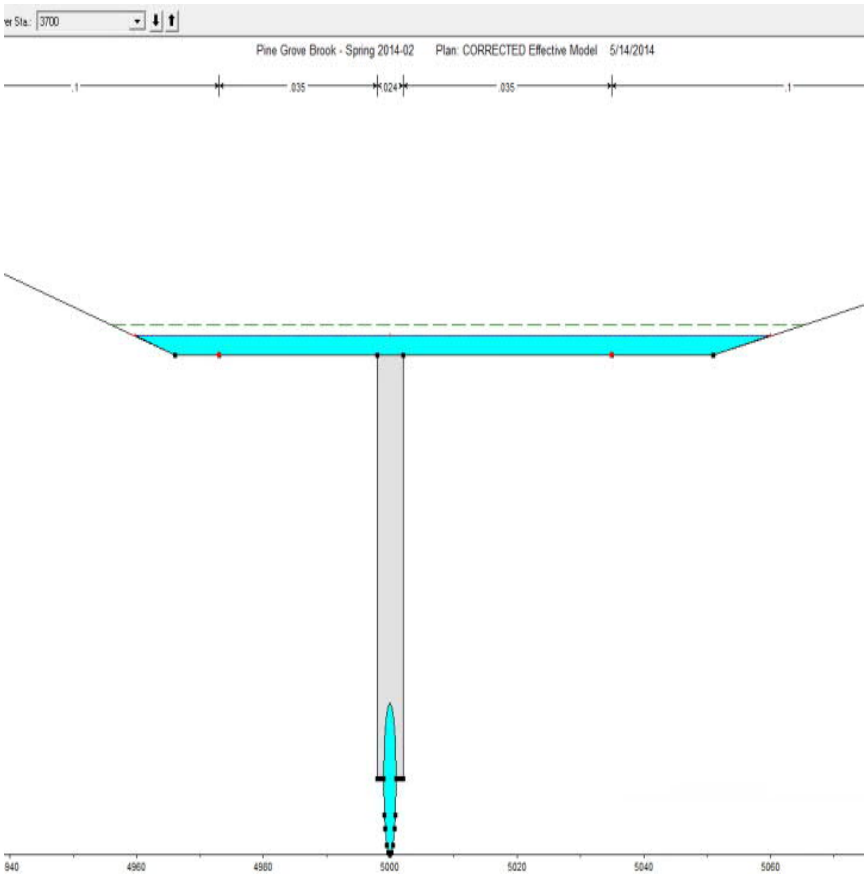
Scenario 2: Lid Option

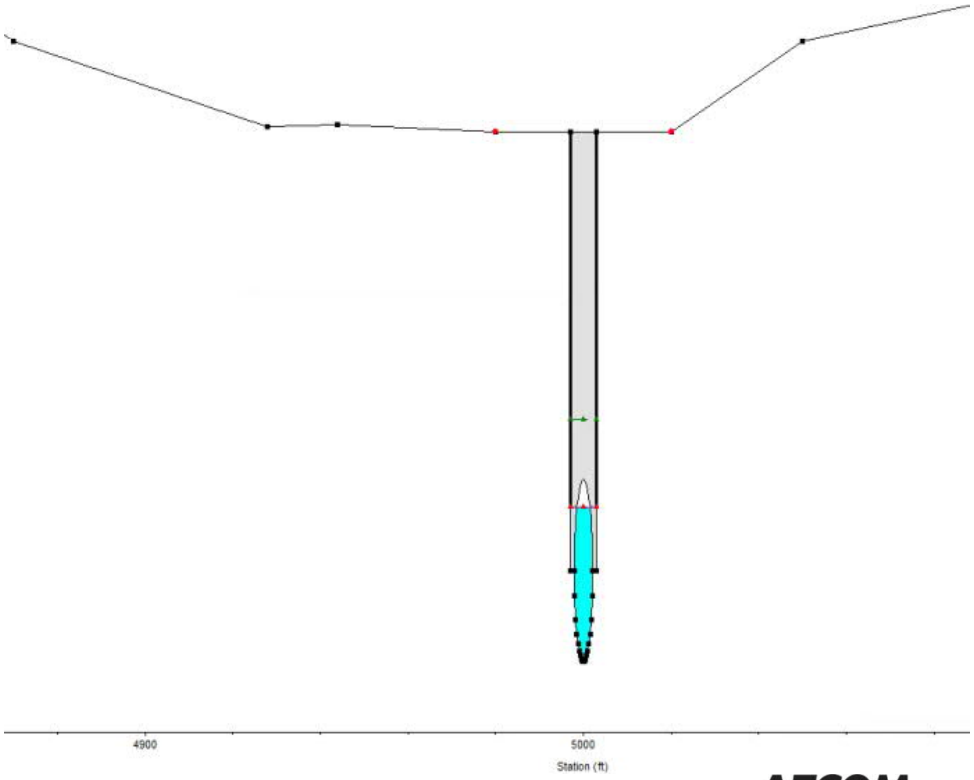
- Model uses historic cross section locations and discharges
- Takes into account both storage in the pipe and overland flow
- Overland flow is generally located directly over the pipe
- Model produces a narrow floodplain with an average depth of less than 0.5 foot



Scenario 2: Lid Option

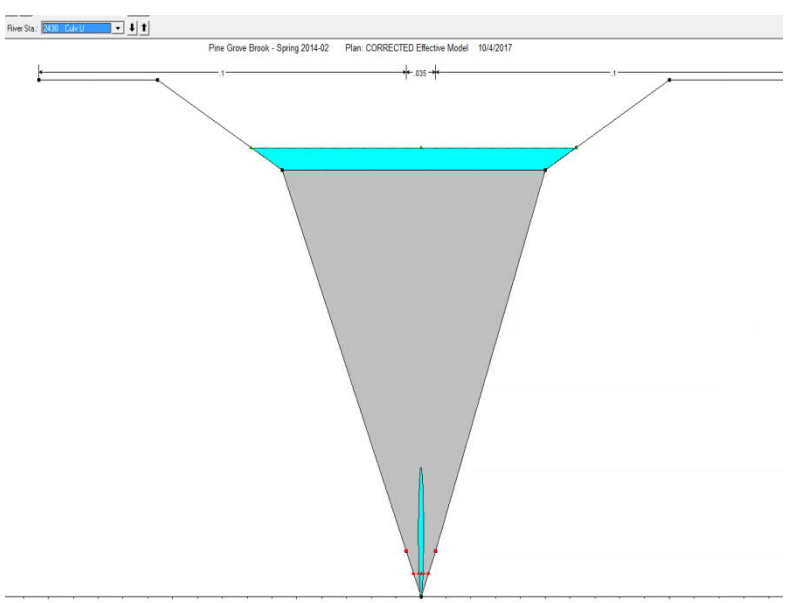
Maximum depth of flow above ground was 0.3 foot at upstream end and contained in the stormdrain at the downstream end

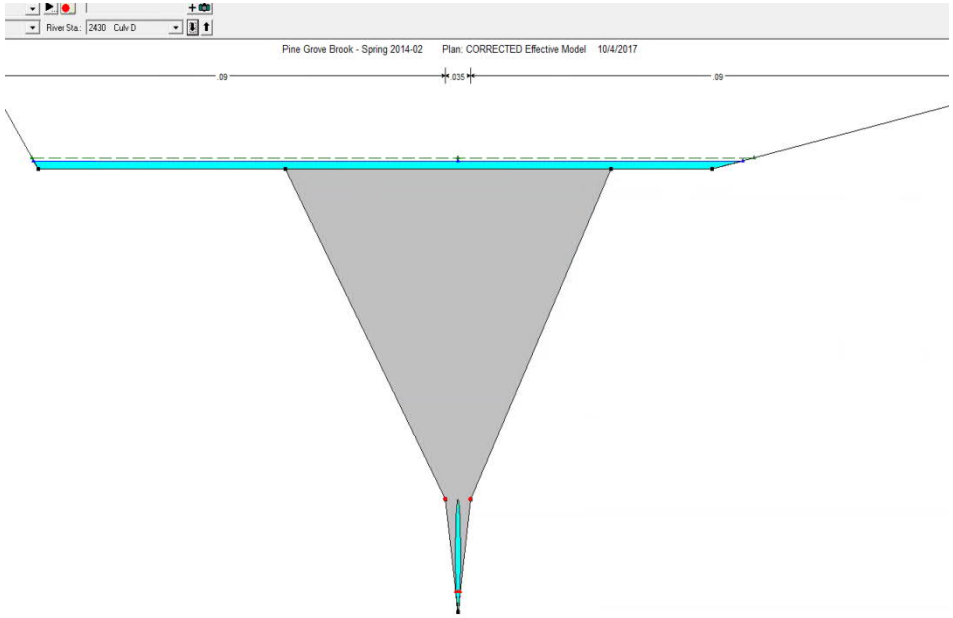




Scenario 3: HEC-RAS with Culvert Routine

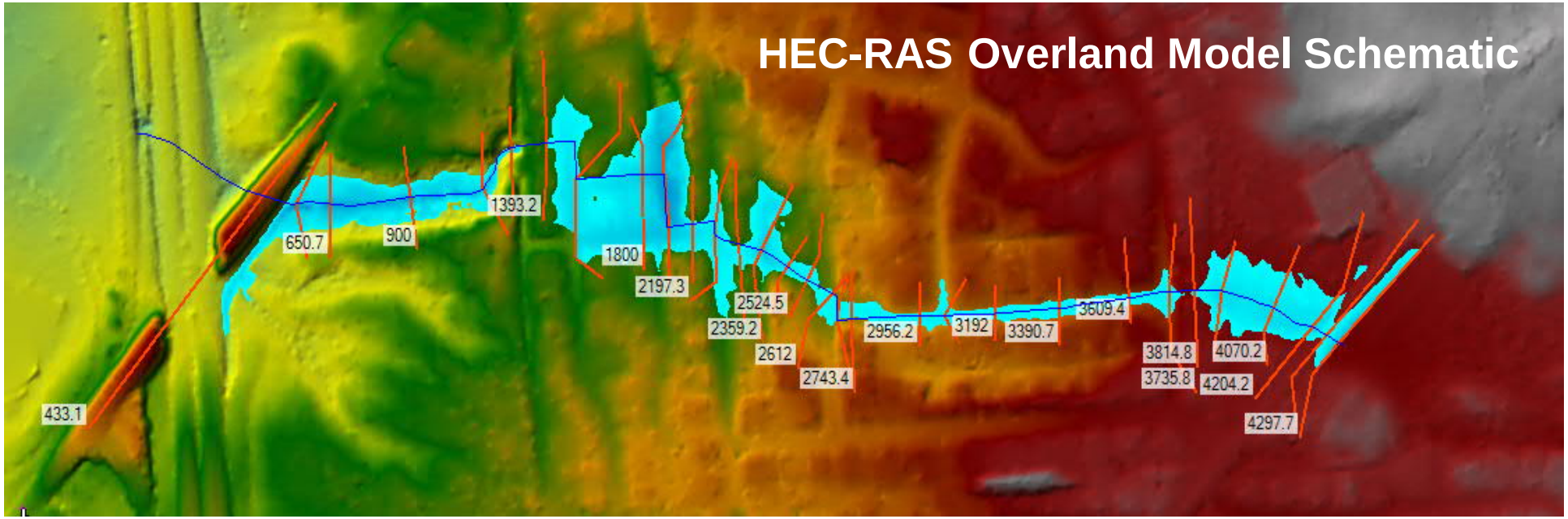
- Stormdrain modeled as a regular culvert
- Used the smallest diameter pipe and an average slope
- Maximum depth of overland flow equal to 0.35 foot at upstream end and 0.14 foot at downstream end





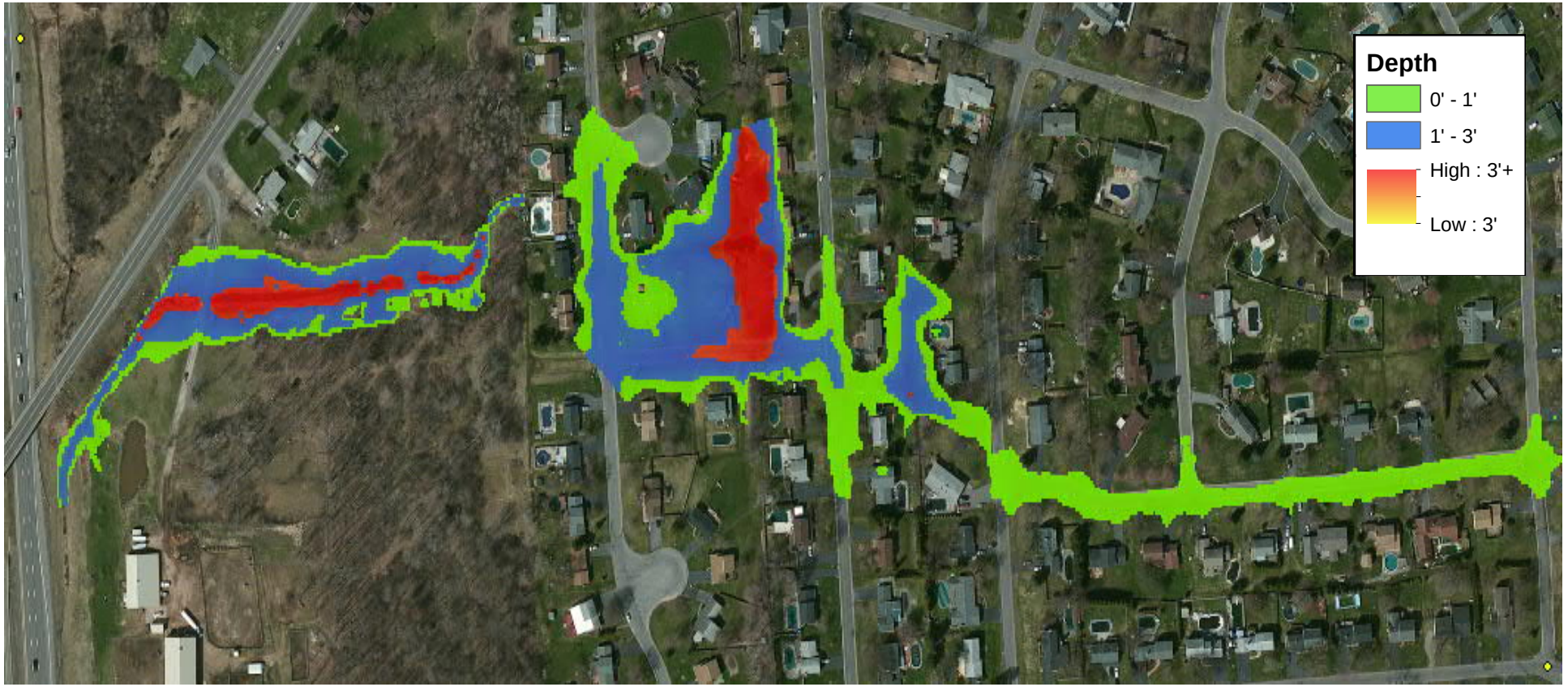
Scenario 4: CulvertMaster + HEC-RAS

- Pipe capacity using CulvertMaster
- 3 pipe sizes, 3 runs
- Overland flow using HEC-RAS
- Overland flow = total flow – pipe capacity



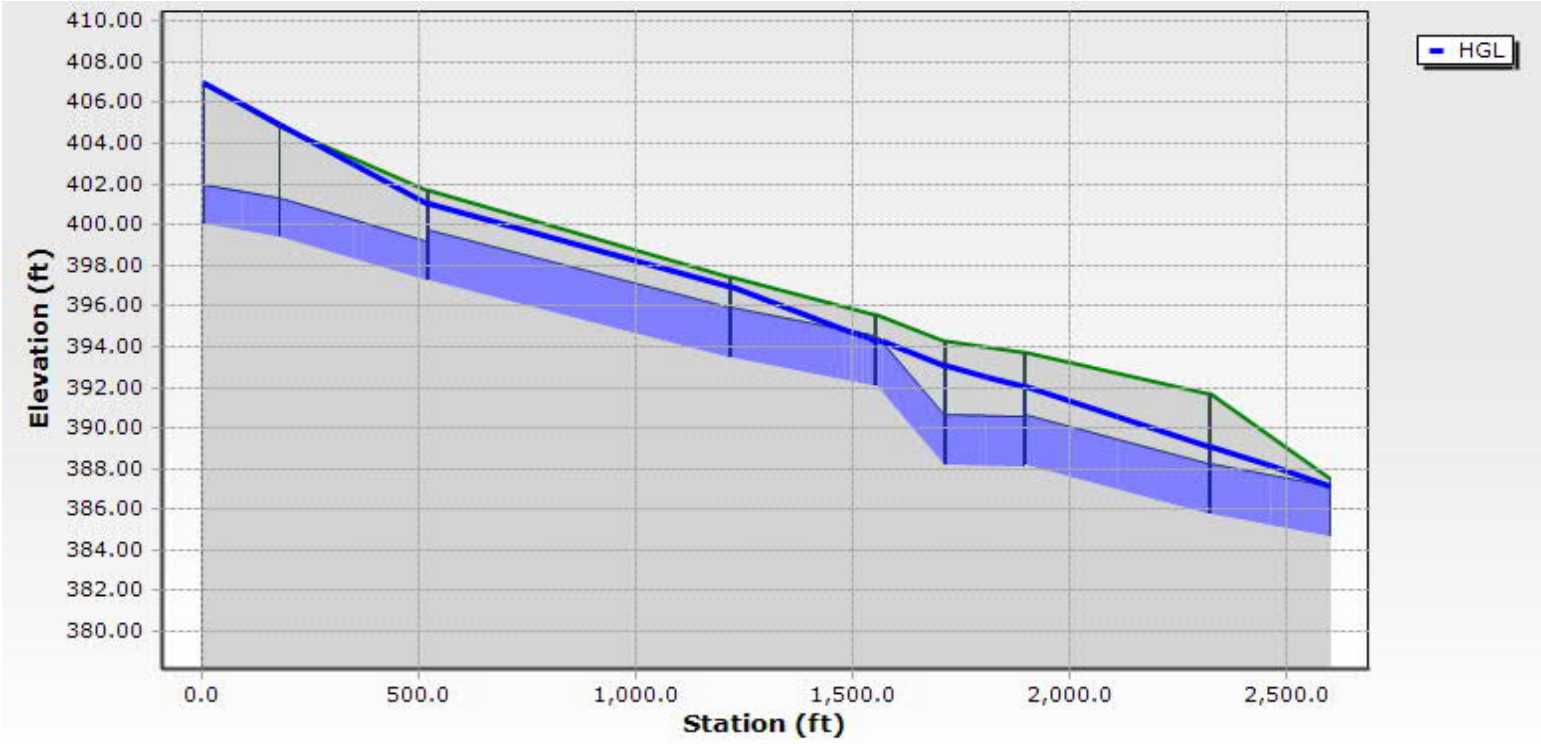
Scenario 4: CulvertMaster + HEC-RAS (continued)

CulvertMaster + HEC-RAS results



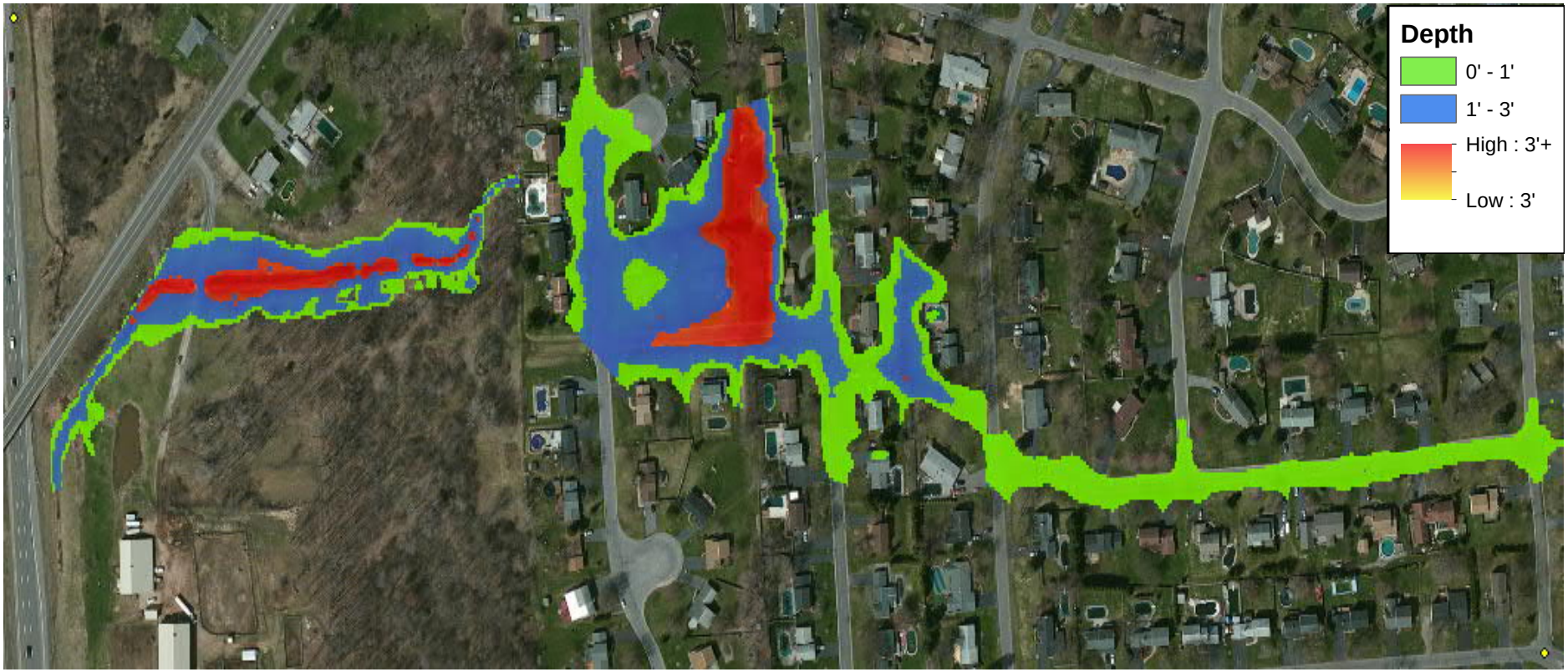
Scenario 5: StormCAD + HEC-RAS

- Pipe capacity using StormCAD
- 8 pipes, 9 manholes/inlets
- Overland flow using HEC-RAS
- Overland flow = total flow – pipe capacity



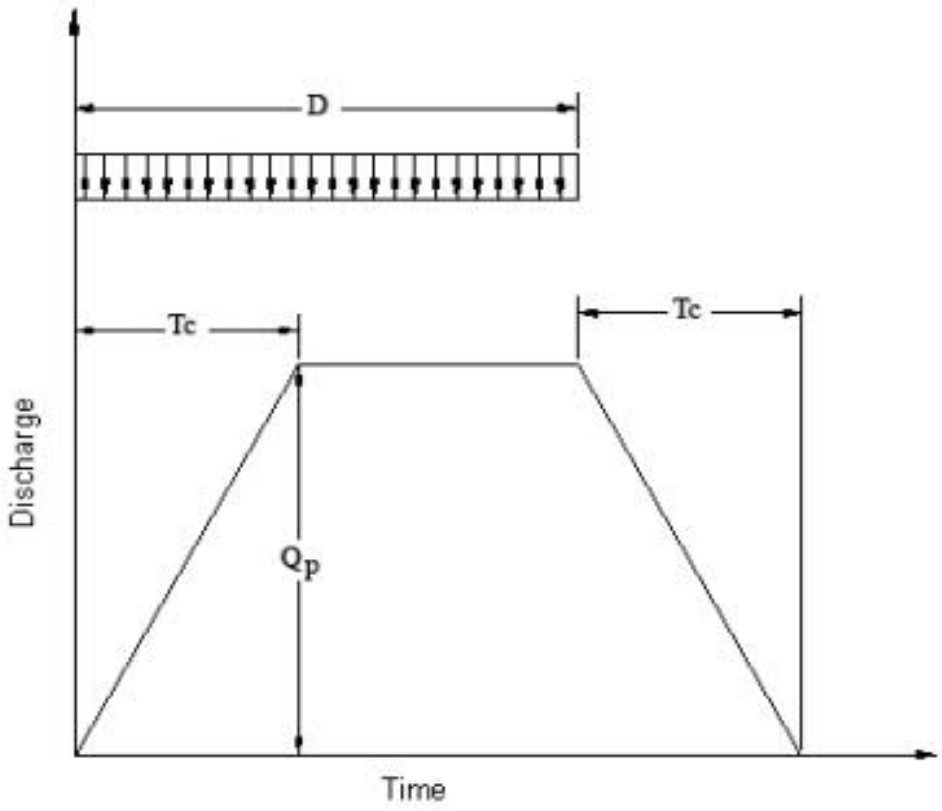
Scenario 5: StormCAD + HEC-RAS (continued)

StormCAD + HEC-RAS results



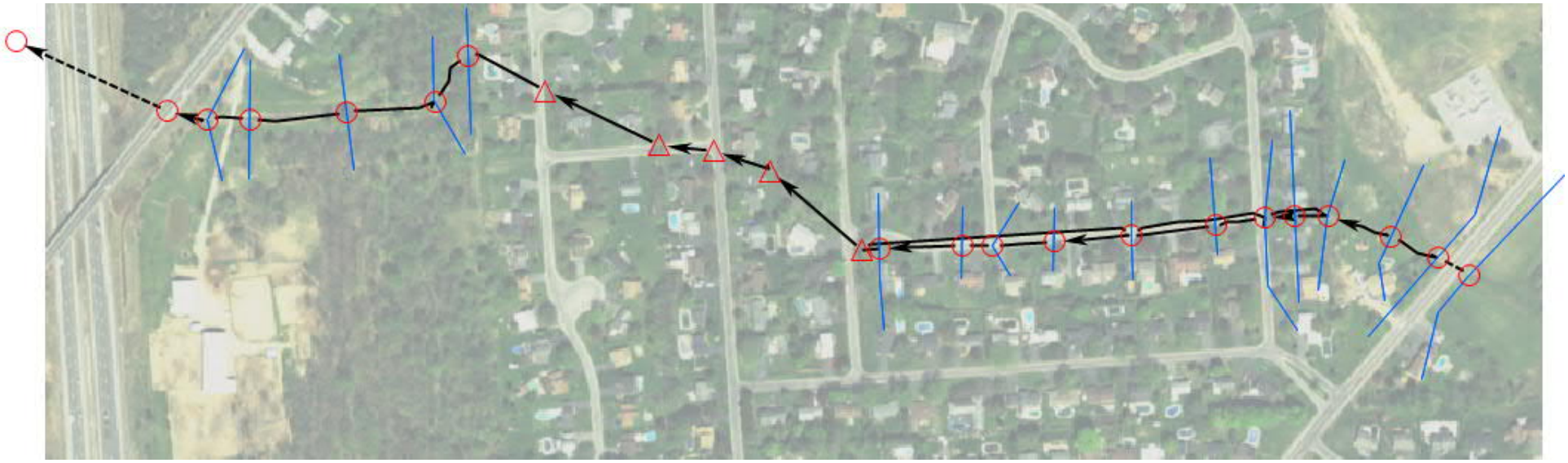
Scenario 6: XP-SWMM

- Stormdrain and overland flow modeled in XP-SWMM
- Unsteady state
- Tc calculations using TR-55
- Modified rational flat top hydrograph (figure below)
- 8 stormdrains, 2 culverts, 16 overland XSs , 5 storage nodes
- At each manhole. pipes are connected to overland cross-sections



Scenario 6: XP-SWMM

XP-SWMM model schematic



Scenario 6: XP-SWMM (continued)

XP SWMM results

Scenario 7: XP-SWMM with hydrology updates

SWMM Updates: What and Why

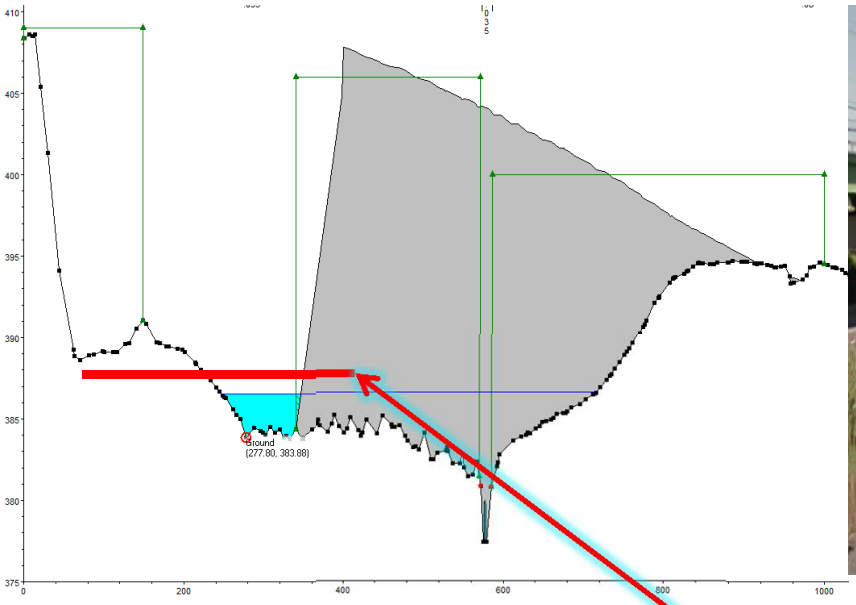
– Current FEMA flows lower than typically expected

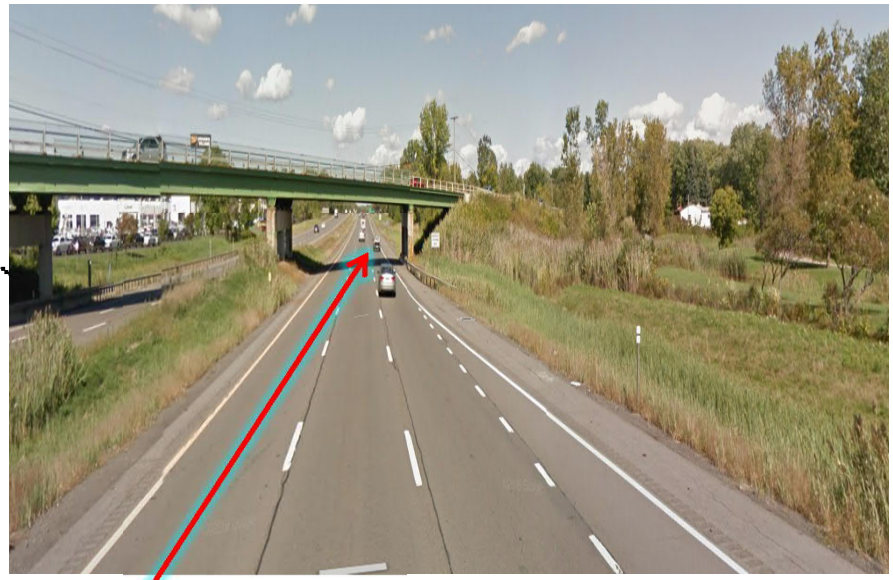
Location	Area (ac)	1% Peak Flow (cfs)	cfs /ac
At Stormdrain Inlet	50	28	0.6
At Stormdrain Outlet	145	62	0.4
At South Bay Road	170	80	0.5

Scenario 7: XP-SWMM with hydrology updates

SWMM Updates: What and Why

– S Bay Road underpass geometry setup incorrect





Underpass Elev. 388’

Scenario 7: XP-SWMM with hydrology updates
(continued)

XP-SWMM with Hydrology Updates

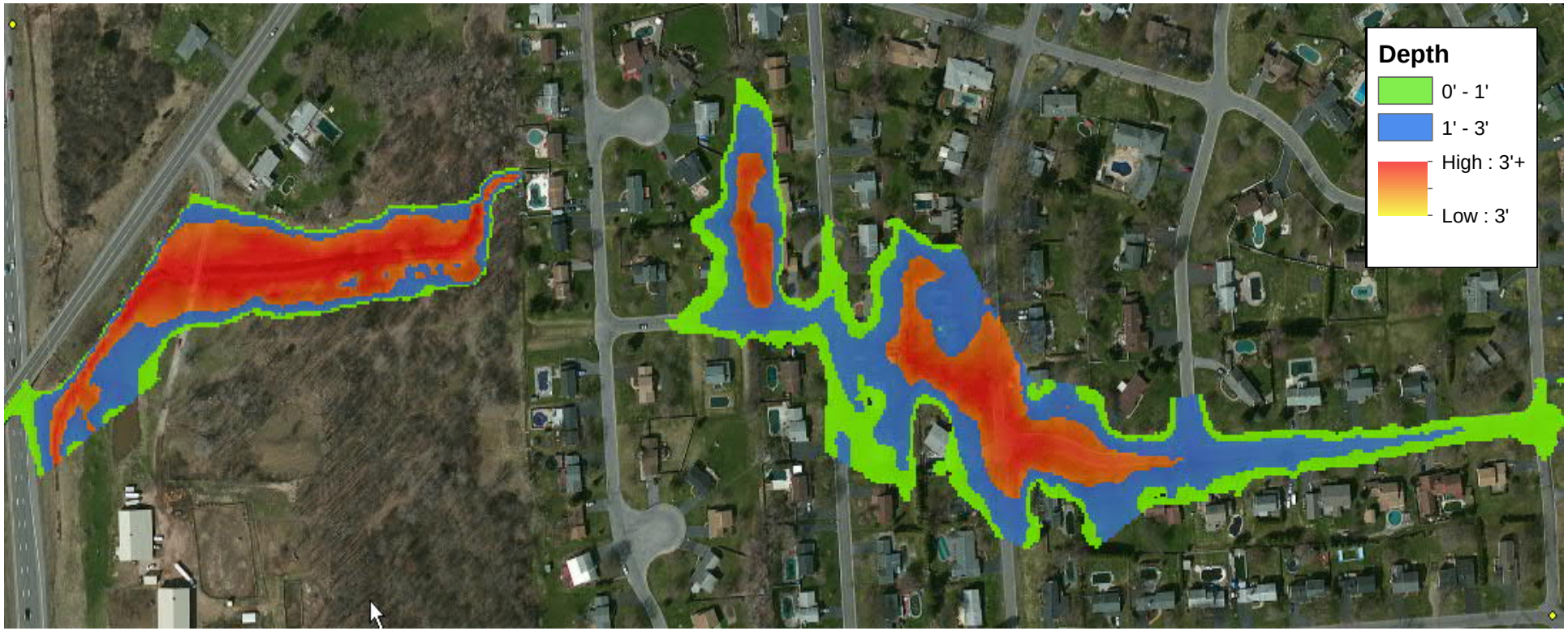
- Rational method
- Watershed delineation using 5 ft LiDAR DEM
- Tc calculations using TR-55
- Runoff coefficient values from 0.4-0.6 (soil types C and D)
- NOAA 14 IDF information
- Modified rational flat top hydrograph with 15 min constant time
- Typical 1% peak flow per acre values ranged from1-2 cfs/ac

S Bay Road Underpass Weir Update

- S Bay Road underpass weir elevation corrected to 388’

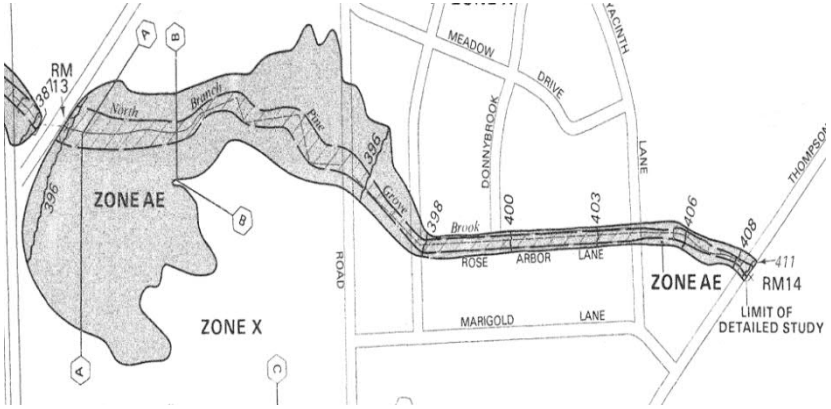
Scenario 7: XP-SWMM (continued)

XP-SWMM with Hydrology Updates Results



Scenario Comparisons

1. HEC-2: No Stormdrain



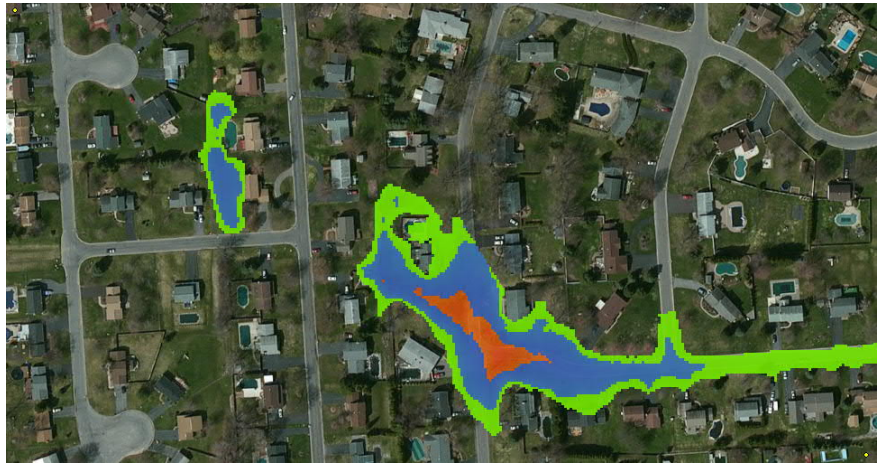
2. HEC-RAS Lid Option

3. HEC-RAS Culvert Routine

4. CulvertMaster + HEC-RAS

5. StormCAD + HEC-RAS

6. XP-SWMM



Scenario / Model Comparisons

Scenario / Model	Pro	Con
1: HEC-2 (No Stormdrain)		• Too Conservative
2: HEC-RAS Lid option (Steady State)	• Applicable for non-pressurized pipes • HEC-RAS is widely used • Floodway analysis is easy	• Underestimated WSELs for pressurized pipes • Coding Lid geometry is tedious
3: HEC-RAS with Culvert	• Setup is simple and quick	• Pipe/culvert size changes cannot be captured
4: Culvert Master+ HEC-RAS	• Simplified analysis	• All pipe network details cannot be captured • Rough pipe capacity estimates
5: StormCAD + HEC-RAS	• Detailed pipe network • Better accuracy	• Overland flow overestimate flooding
6: XP-SWMM	• Detailed overland and pipe networks • Unsteady State • Seamlessly captures overland flow and underground pipe flow interactions	• Model Stability / Continuity Errors • Model setup is tedious • Bridge links tend to overestimate backwater compared to HEC-RAS • Floodway analysis is tedious

Conclusions

- Steady State HEC-RAS with Lid option for pressurized pipes underestimated the floodplain and water surface elevations for long culverts/ stormdrain pipes
- If an engineer prefers using the HEC-RAS lid option for long culvert/ stormdrains then alternative pipe capacity analysis should be considered for comparison
- CulvertMaster+HEC-RAS or StormCAD + HEC-RAS combination could be used for moderate level accuracy.
- If high accuracy is desired EPA SWMM/ XP-SWMM or similar program should be considered

Which Model Works Best?

Model	Pressurized		Desired Accuracy		Shape / Size Changes	Ground profile Changes	Culvert / Stormdrain Length	
	Yes	No	High	Low-Medium			Short < ~300'	Long > ~300'
HEC-RAS with Culvert	X	X		X			X	
HEC-RAS Lid Option		X		X			X	X
CulvertMAster/ HY 8 + HEC-RAS	X	X		X			X	X
StormCAD / SSA + HEC-RAS	X	X		X	X	X	X	X
XP-SWMM / EPA SWMM	X	X	X	X	X	X	X	X

Questions??

Thank You

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