Optimizing to Identify Flood Mitigation Solutions in the City of Alexandria

StormCon – September 27, 2022

Cheri Salas

Jacobs Challenging today. Reinventing tomorrow.

Agenda

I. Flood Action Alexandria & Drivers

II. Review of the Project Approach & Existing Conditions

III. Iterative Optimization Approach & Lessons Learned

IV. Conceptual Design of Preferred Alternative

V. Next Steps: Risk Assessment & Expanding this approach to more sites

Ashby Street, July 25, 2020
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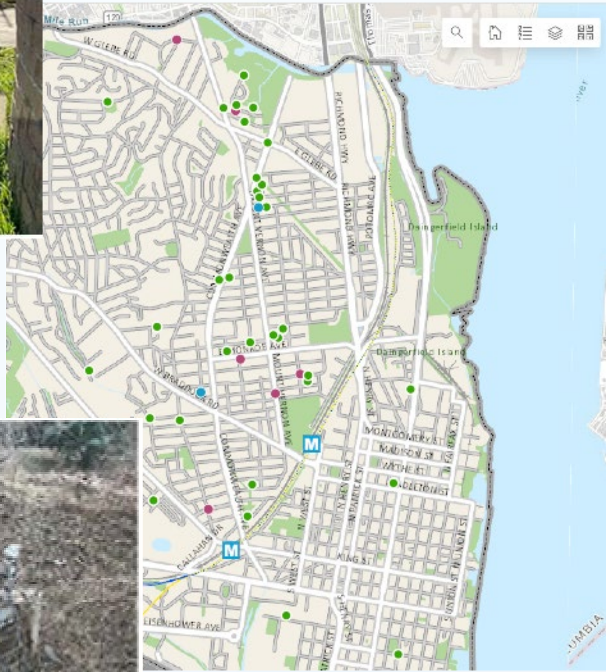
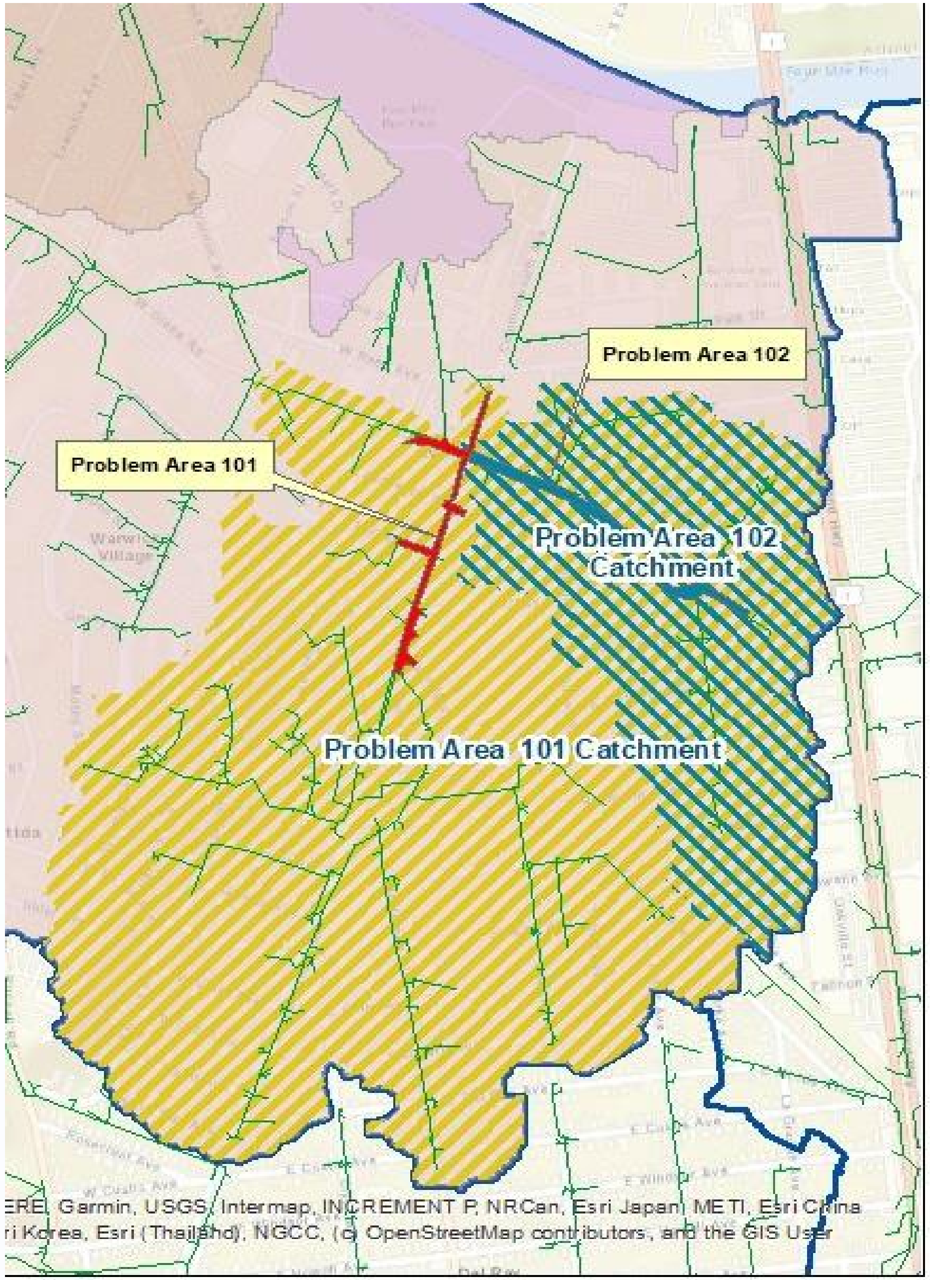
Flood Action Alexandria

Flood Action Alexandria is the City's comprehensive initiative to address flooding issues. The City is committed to working with its residents and businesses to mitigate the impacts of flooding and build community resiliency.

- 2021 - Flood Action Alexandria Launched
- Response to more frequent, intense climate-change-induced storm events
- Multi-pronged Program
  - Maintenance Projects
  - Sanitary Sewer Asset Renewal Program
  - Spot Improvements
  - Large Capacity Improvement Projects
  - Flood Mitigation Pilot Grant Program
  - Increased Public Outreach





Commonwealth Avenue & Glebe Road and Glebe Road and Ashby Street

Project Objectives

- Quantify flood inundation risk
- Identify the optimal set of feasible and cost-effective solutions to reduce flooding
- Provide conceptual location and sizing and budget level cost estimates for solutions.
- Quantify relative reduction of risk resulting from the proposed solutions

Review of the Project Approach and Existing Conditions

Commonwealth Avenue & E. Glebe Road
E. Glebe Road and Ashby Street

Project Approach

Model Development → **System Characterization** → **Alternative Analysis** → **Recommended Solution**

Model Development

- Convert CASSCA Model (1D)
- Update 1D Model with survey and best available information
- Focus on Problem Area
- Build 2D Model

System Characterization

- Run Model for range of conditions (Design/Historical events, Climate Change & Tailwater
- Summarize Results in Flood Inundation Tool

Alternative Analysis

- Formulate inputs (Alternatives, Cost, Model)
- Perform Preliminary Optimization
- Build 1D Dual Drainage Model
- Perform Final Optimization
- Select High Performing Alternatives

Recommended Solution

- 2D analysis of High Performing Alternatives (Key events)
- Select Recommended Solution
- Run Selected solution for range of conditions
- Develop Concepts
- Evaluate Benefit of Mitigation

Rainfall analysis and Future Projected Precipitation Methods and Climate Scenarios: 12 rainfall/SLR scenarios in PC-SWMM

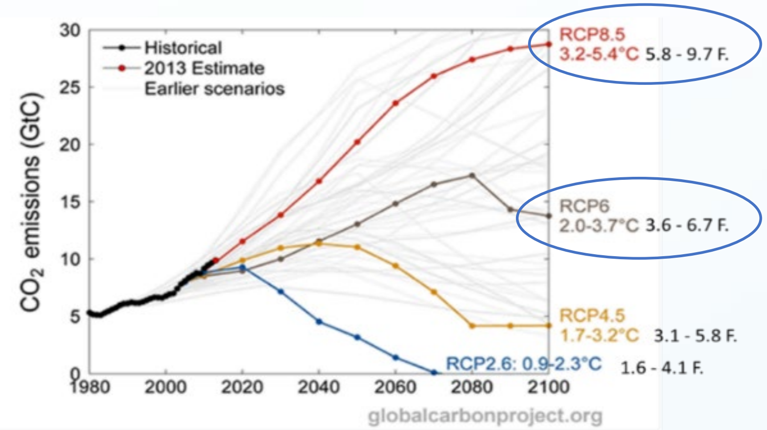
Methods:

› Update NOAA Atlas 14 baseline precipitation with most recent rainfall, applying L-Moments statistical methods

› SimCLIM tool – based on IPCC* models

› "Scaling factors"
  – Adjustment to 24-hour precipitation
  – Apply same factor to other durations

› Result: future climate IDF curves



*Intergovernmental Panel on Climate Change

Climate Scenarios:

- Planning time horizons
  - 2040
  - 2070
- Greenhouse Gas (GHG) scenarios
  - RCP 6.0
  - RCP 8.5
- Global Climate Model (GCM) ensemble summary
  - 50% non-exceedance
  - 90% non-exceedance

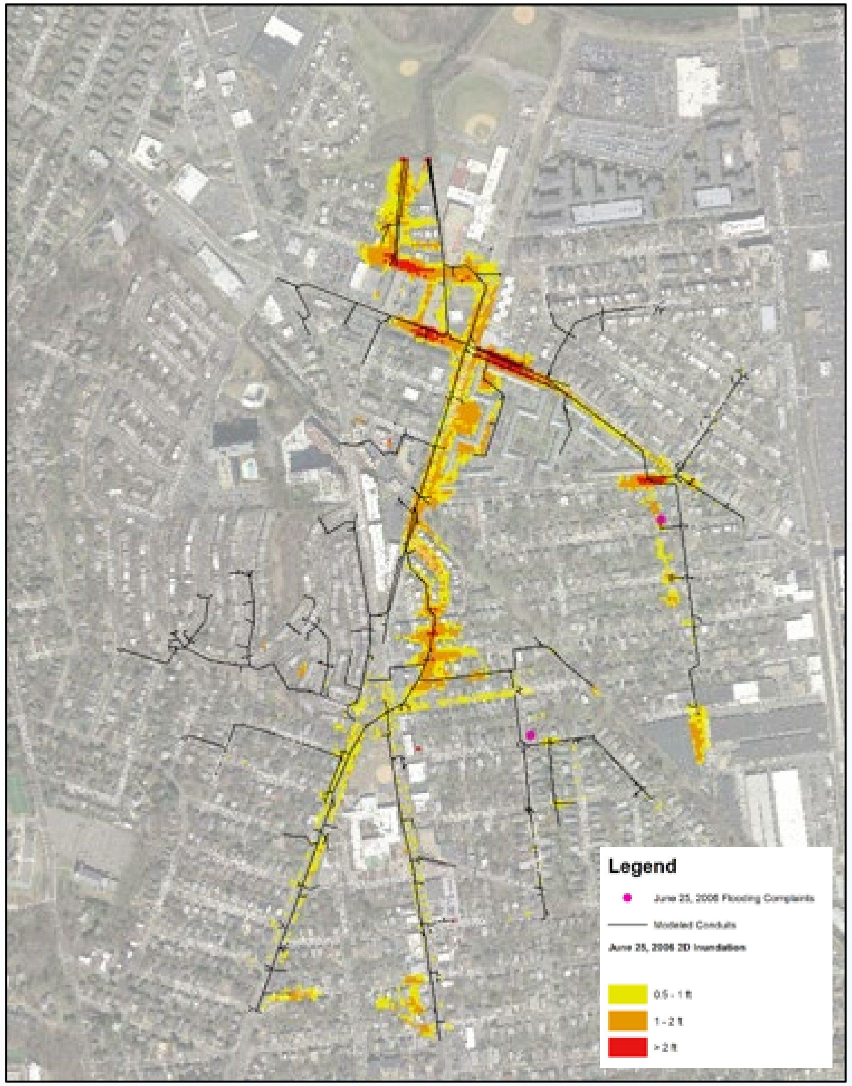
Existing Conditions Model Scenarios

REFERENCE POINTS
Outlet Invert – 2.86 – 3.05 ft
Outlet Crown – 6.11 – 6.3 ft

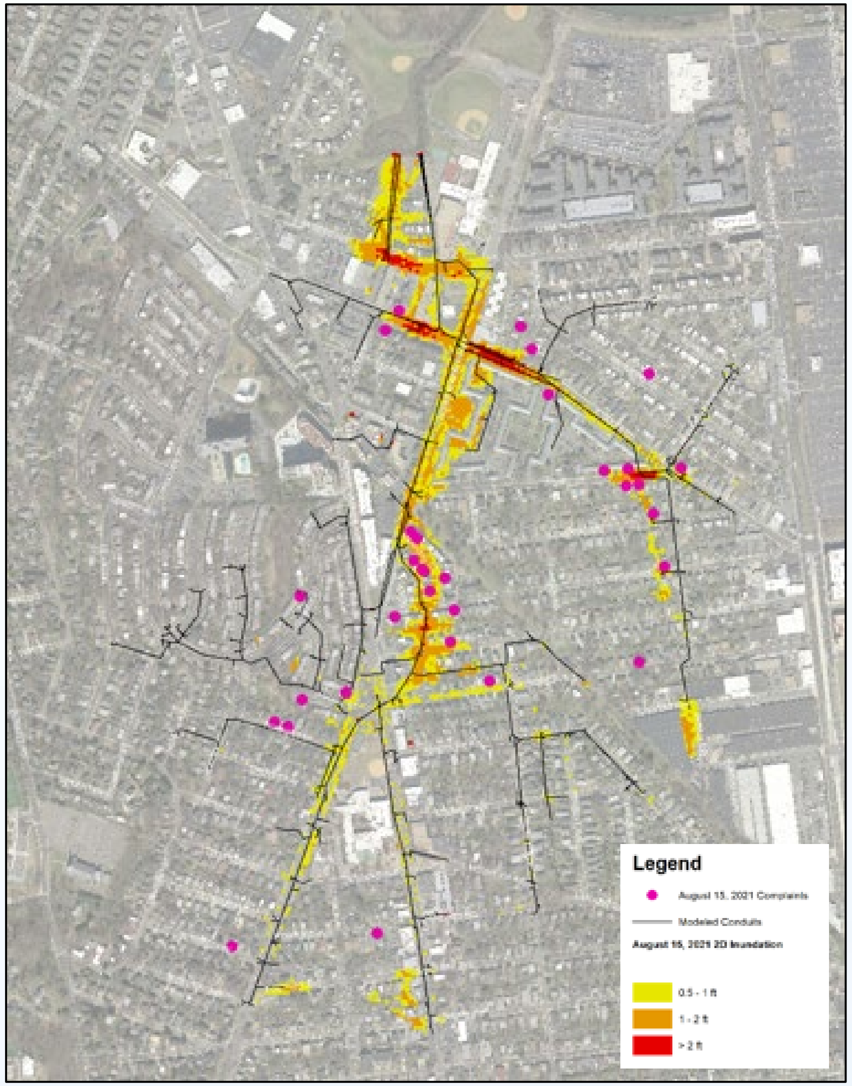
Scenario	Planning Horizon	Precipitation Scenario[a]	24-hr / observed Precipitation (inches)	Peak intensity 15 min. time step (in/hr)	Tailwater Scenario	Tailwater Level (feet, NAVD88))
1. Observed Event:Aug. 15, 2021	Current Conditions	Mount Vernon Elementary	3.84 in 5 hours	1.4 in / 15 min (5.6 in/hr)	Observed	1.96
2. Observed Event:June 25, 2006	Current Conditions	RG H2022 - Rte 7 and Walter Reed	7.96 in 32 hours 10.92 in 95 hours	1.15 in / 15 min (4.6 in/hr)	Observed	3.0/3.2/3.4 (peaks at high tide on 6/26 and 6/27)
3. Baseline:2-year	Current Conditions	Updated Baseline IDF	3.3	1.43	Current King Tide	3.5
4. Baseline:10-year	Current Conditions	Updated Baseline IDF	5.16	2.11	Current King Tide	3.5
5. Baseline:25-year	Current Conditions	Updated Baseline IDF	6.36	3.7	Crown of Outfall Pipe (13-yr probability)	6.3
6. Baseline: 100-year	Current Conditions	Updated Baseline IDF	8.48	3.47	Crown of Outfall Pipe (13-yr probability)	6.3
7. Baseline:500-year	Current Conditions	Updated Baseline IDF	11.47	4.69	Crown of Outfall Pipe (13-yr probability)	6.3
8. Projected Future:2-year	2070	RCP 8.5, 50%, 2-year	3.69	1.51	2070 King Tide	7.2
9. Projected Future:10-year	2070	RCP 8.5, 50%, 10-year	5.81	2.38	2070 King Tide	7.2
10. Projected Future:25-year	2070	RCP 8.5, 50%, 25-year	7.17	2.93	2070 King Tide	7.2
11. Projected Future:100-year	2070	RCP 8.5, 50%, 100-year	9.57	3.91	2070 King Tide	7.2
12. Projected Future:500-year	2070	RCP 8.5, 50%, 500-year	12.94	5.29	2070 King Tide	7.2

Model Validation

- June 25, 2006 Validation Event



- August 15, 2021 Validation Event

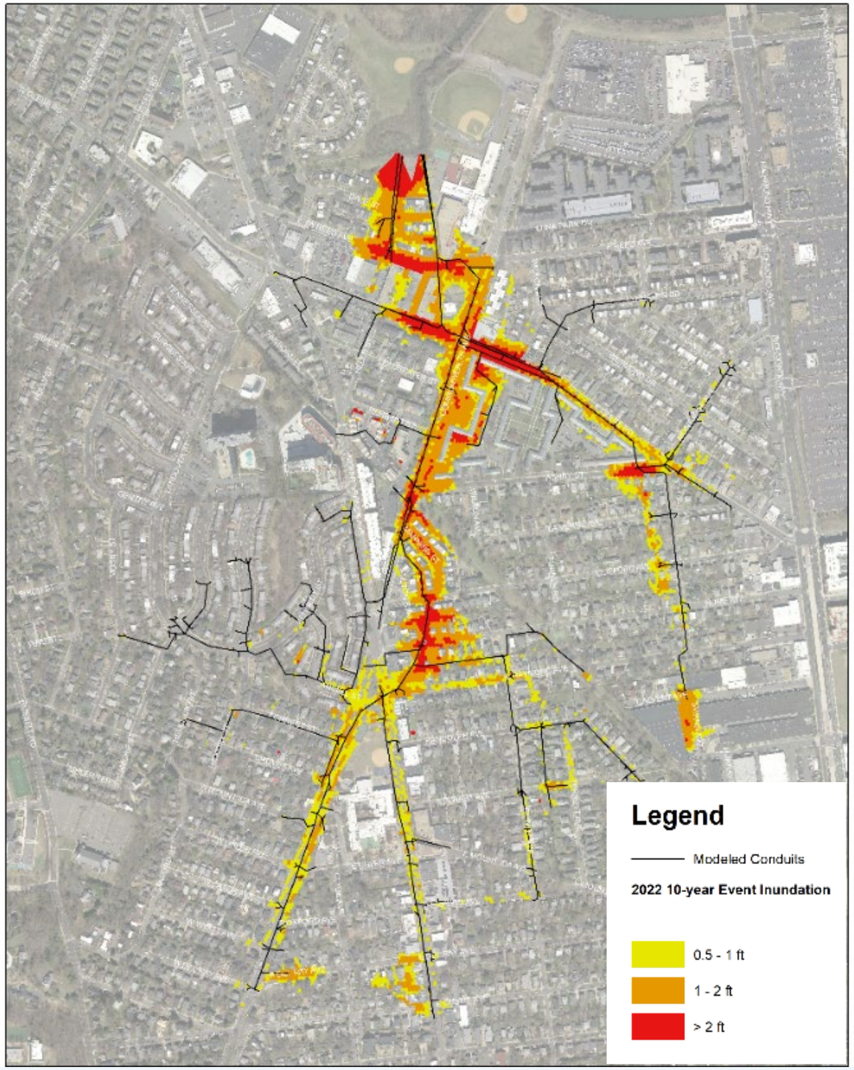


* Inundation displayed for flooding over 6-inches

Existing Conditions Modeled Scenario and Results

- 10-Year Current Condition

- 500-year Future Condition



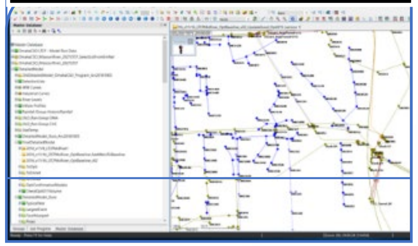
* Inundation displayed for flooding over 6-inches

Iterative Optimization Approach & Lessons Learned

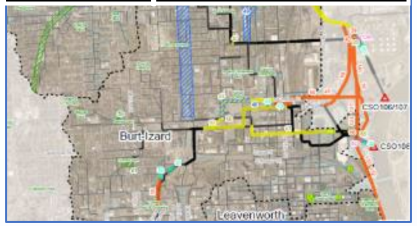
Optimization Approach

Leveraging the hydraulic model with cloud computing and advanced algorithms to systematically search for better and better solutions

H&H Model



Project Options



Performance Criteria

- Cost
- Flood Depths

Optimizer Software

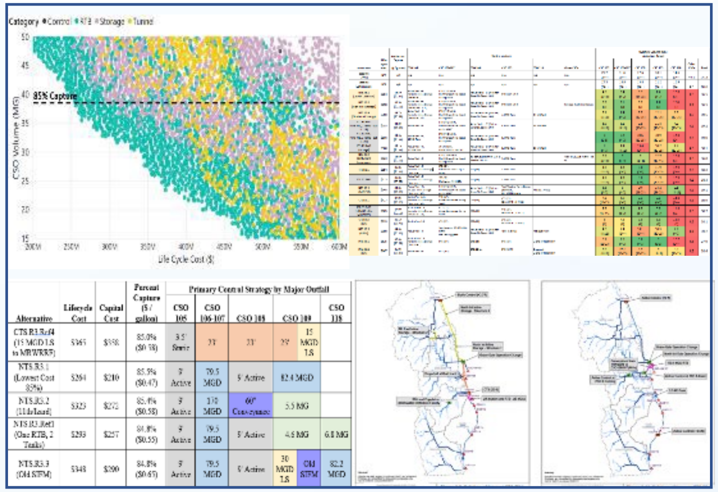
Automation

Computational Power

Algorithms

- Drives Process
- Evaluates 10s or 100s of thousands of solutions

Review and Interrogate Results



Validate High Performing Scenarios with 2D

***<u>Iterate</u>** based on increased system understanding*

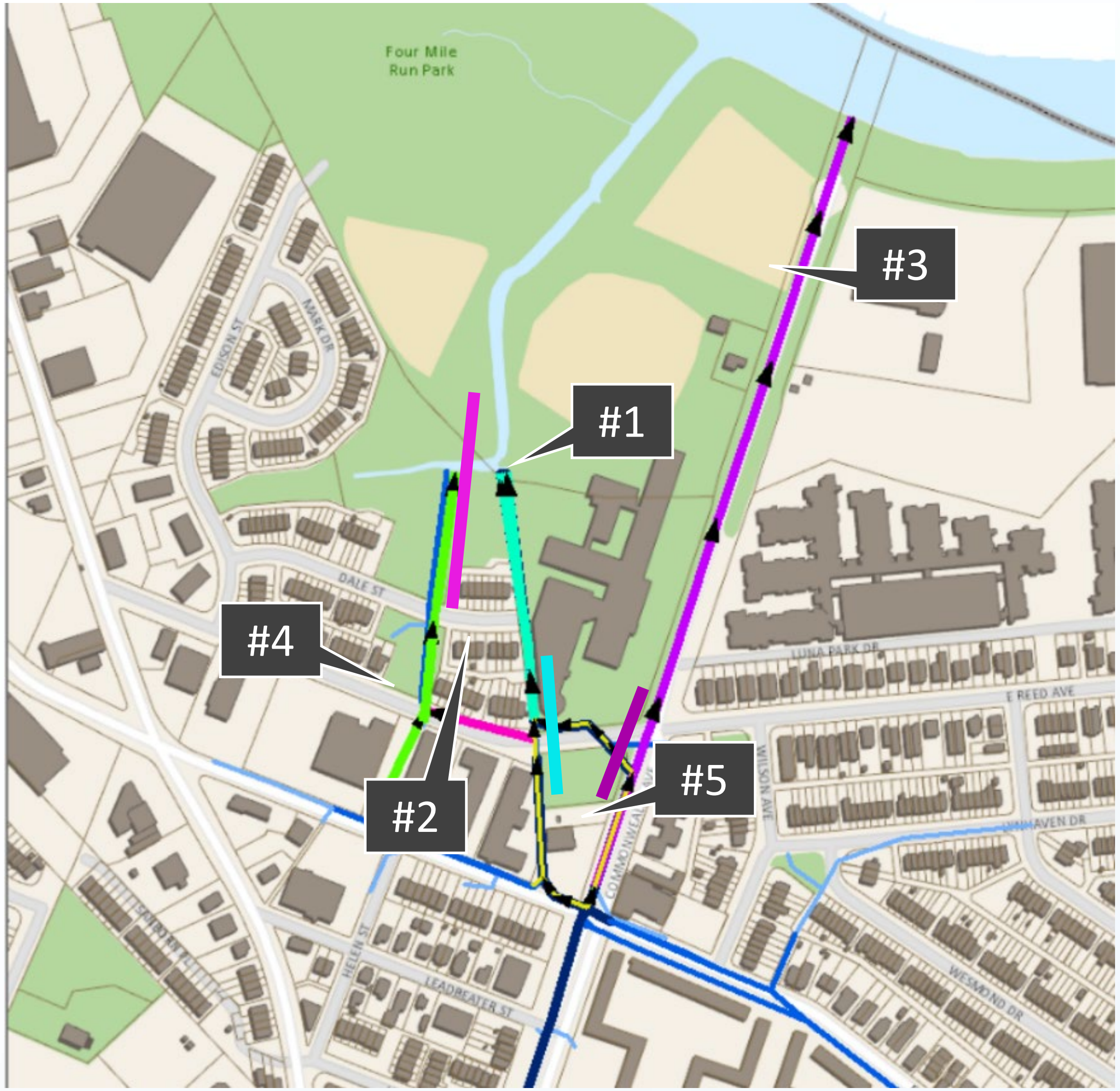
Early Identification of Solutions - Storage and GI Sites

- Relief Storage
- Hybrid (Relief storage and GI)
- GI

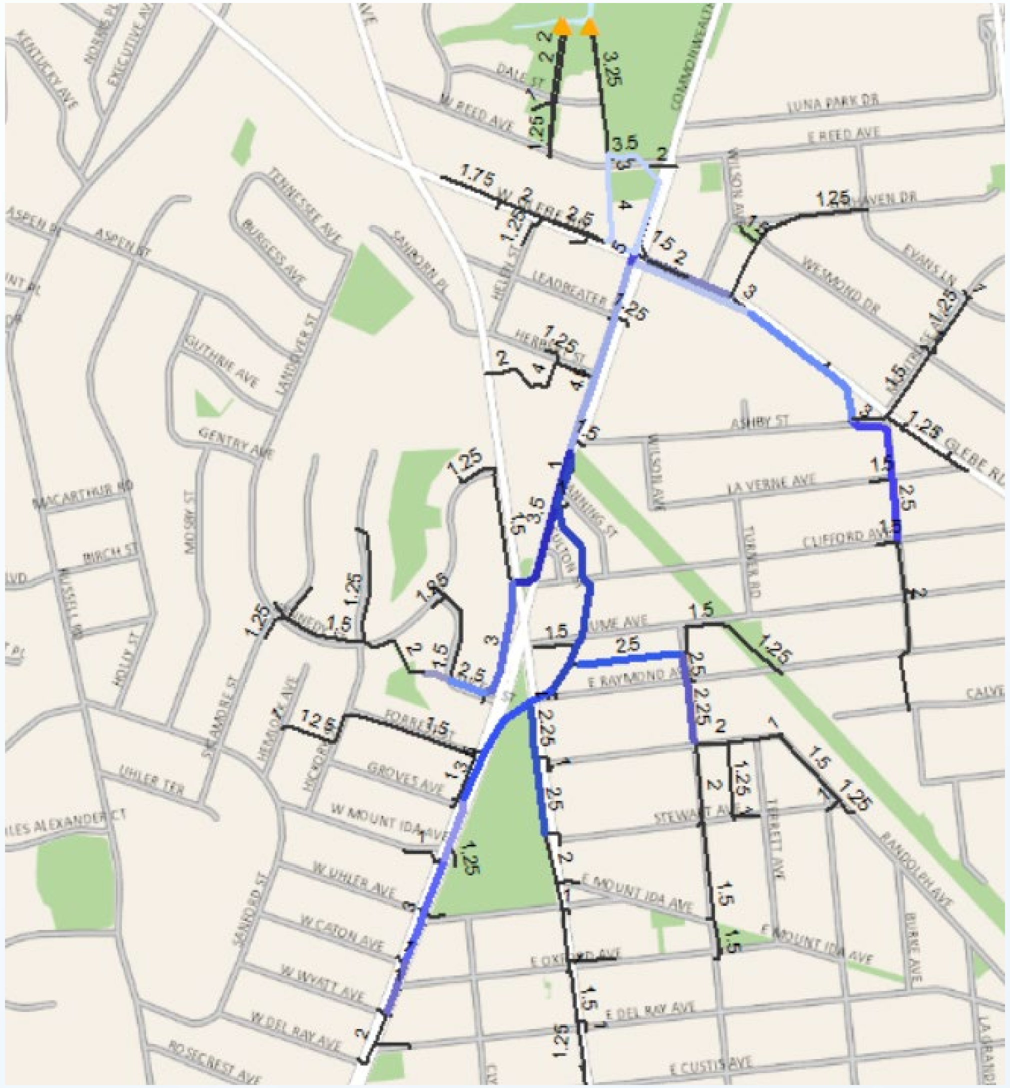
Problem Area	Relief Storage	Hybrid Storage/Green Infrastructure	Green Infrastructure
101 - Commonwealth Ave & E. Glebe Rd			
Private	2	4	0
Public	3	14	1
Total	**5**	**18**	**1**
102 - Ashby St & E. Glebe Rd			
Private	2	1	0
Public	1	2	4
Total	**3**	**3**	**4**

Early Identification of Solutions – Big Conveyance Improvements

Large-scale Downstream Conveyance Alts



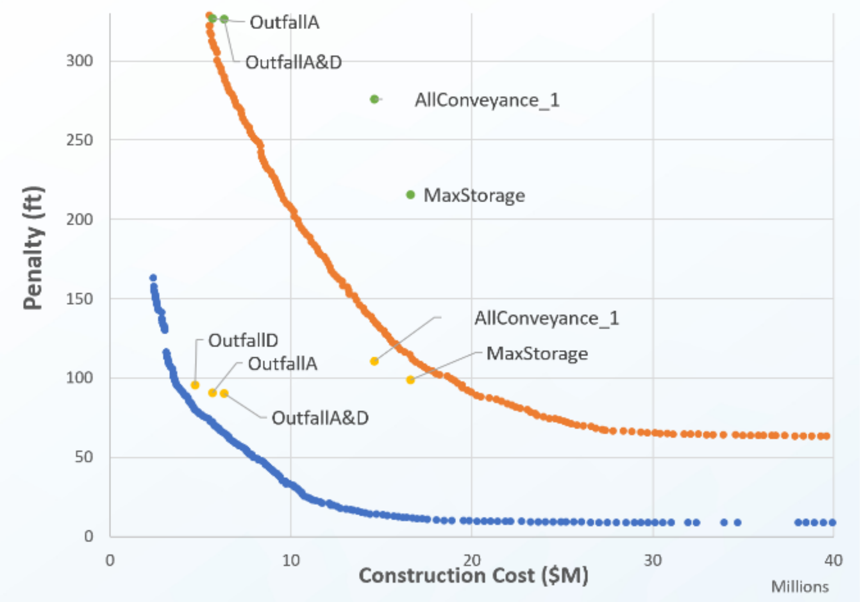
Small-scale Upstream Conveyance Alts



Multi-phased Optimization Approach to find the best solution

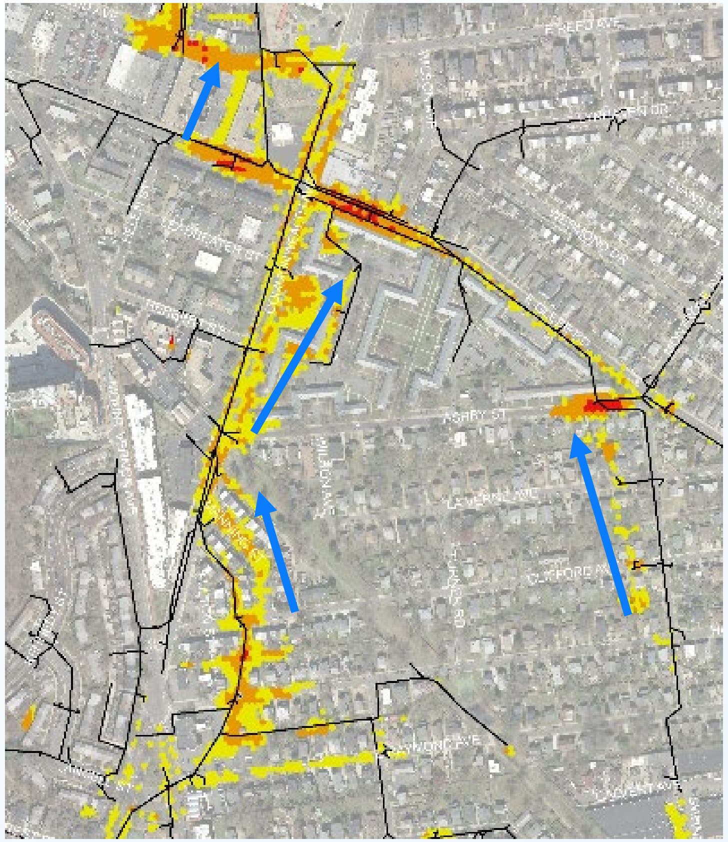
Preliminary Optimization

Lack of pipe capacity system wide for even the 2-year event



- Limited benefits of Gravity In/Out Tanks
- Best solutions included relief to new outfall and extensive pipe upsizing, but still did not fully remove problem areas

2D Modeling



Impact of Street flow and Overland Flow Paths on Problem Area

Updated Optimization Formulation

Optimization Inputs

Input	Preliminary	Current
Model	1D	1D Dual Drainage
Performance Metrics	System Wide	-Problem Area Focused -Weighted
Alternative Components Included	-Gravity In/Out -Storage -Pipe Upsizing -New FMR Outfall	-New FMR Outfall -Deeper Conveyance Large Storage

Two Phased Approach

Simplified Diversion Optimization

- *Test relieving a range of locations across system the system to mimic impact of conveyance or storage alternatives*
- *Determine which locations are most effective and the level of relief needed*

Identify specific conveyance & storage alternatives that have potential to reduce flooding

Full Optimization

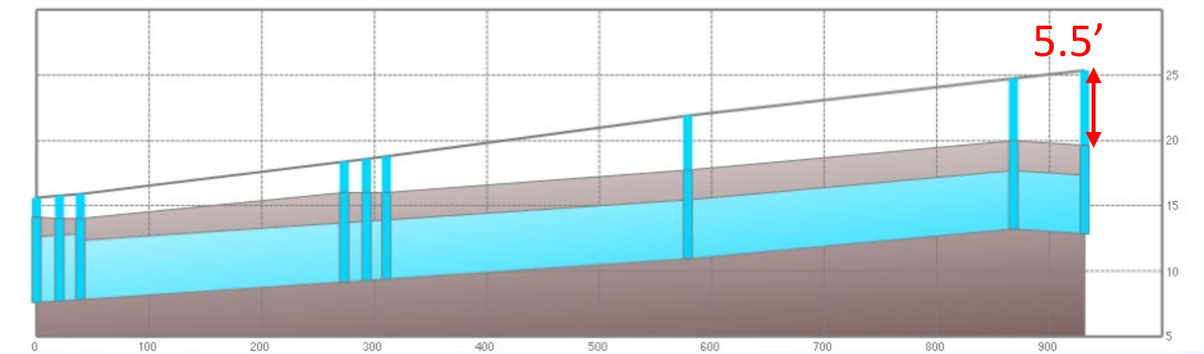
Evaluate specific project alternatives

Hydraulic Model used for Optimization

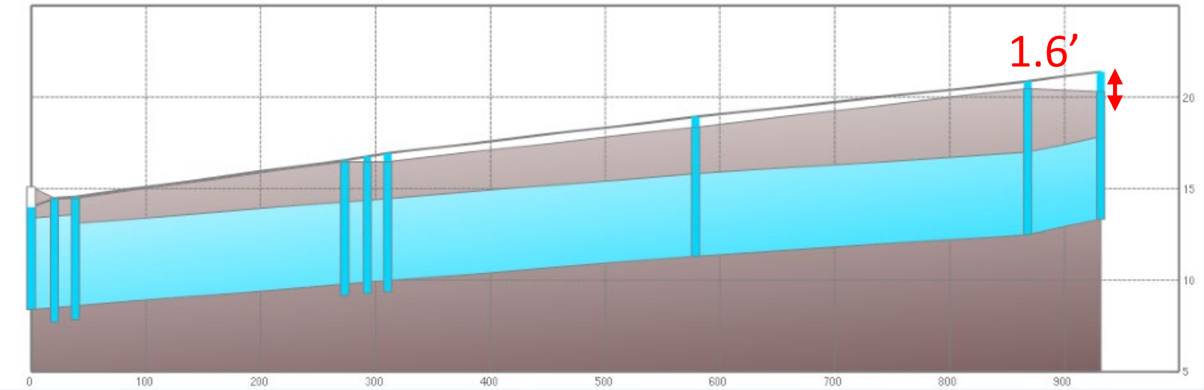
- 1D Model with ponding above nodes
  - Required solving systemwide issues since ponded flow stays
  - Insufficient storage identified to solve flooding. Best solutions relied heavily on upsizing majority of sewers
- Dual Drainage Model
  - 1D representation of 2D overland flow paths
  - Allows focus on solutions for the problem area only
  - Consider larger infrastructure to capture street flow upstream of problem area

On Commonwealth From Ashby to Glebe 10-year Max HGL

1D Model

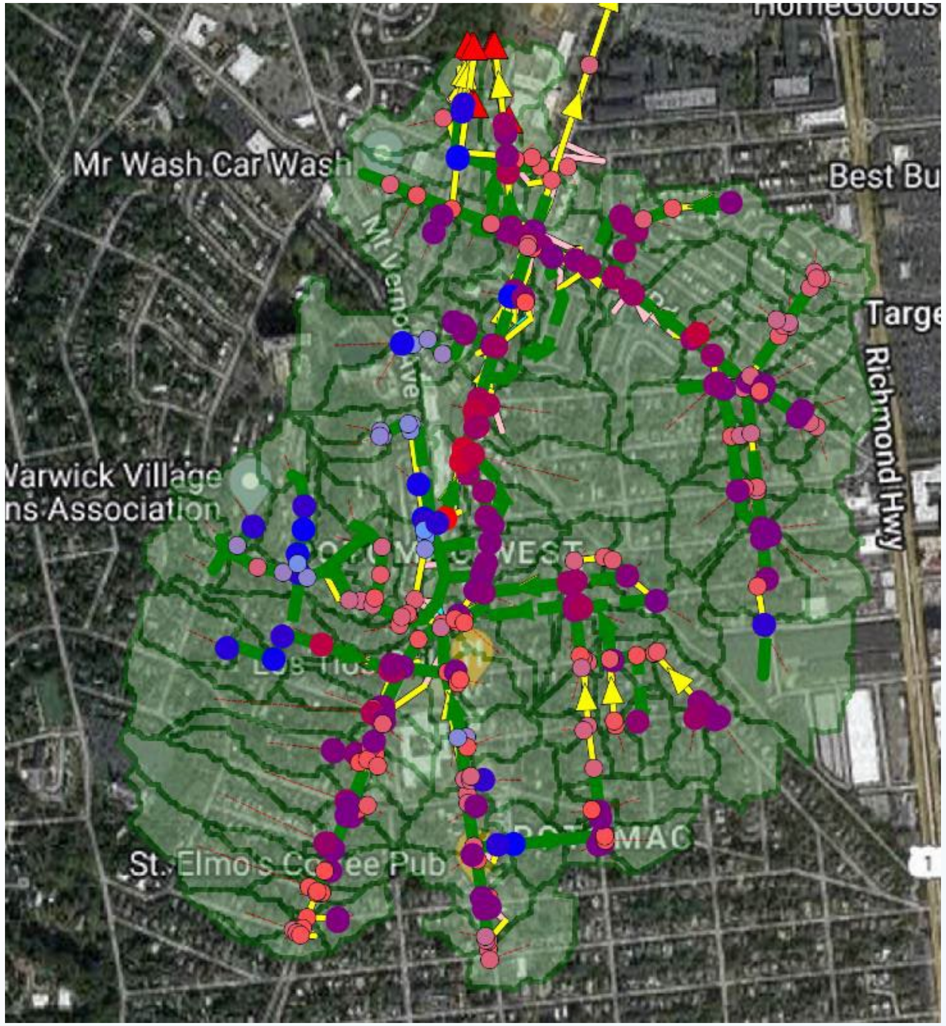


1D with Dual Drainage Network Model

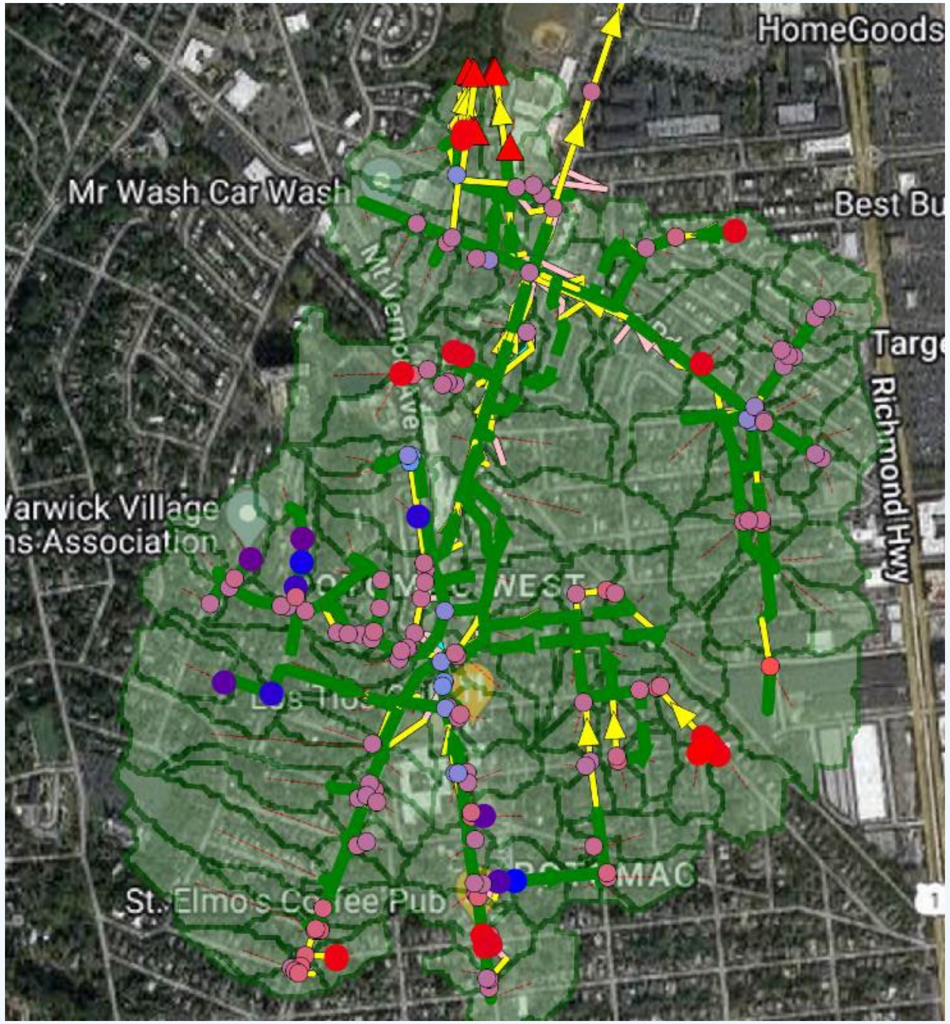


Dual Drainage model significantly improved 1D model results

1D vs 2D



1D Dual Drainage vs 2D



abs dif dual from 2D > 2ft

abs dif dual from 2D > 6 in

10-year Baseline Performance

Overflow Volumes

Outfall	Volume (MG)	Peak Flow (cfs)
West	1.4	40.6
East	22.7	274.4
Street	4.5	394.5

Storm Sewer
Overland Flow Route

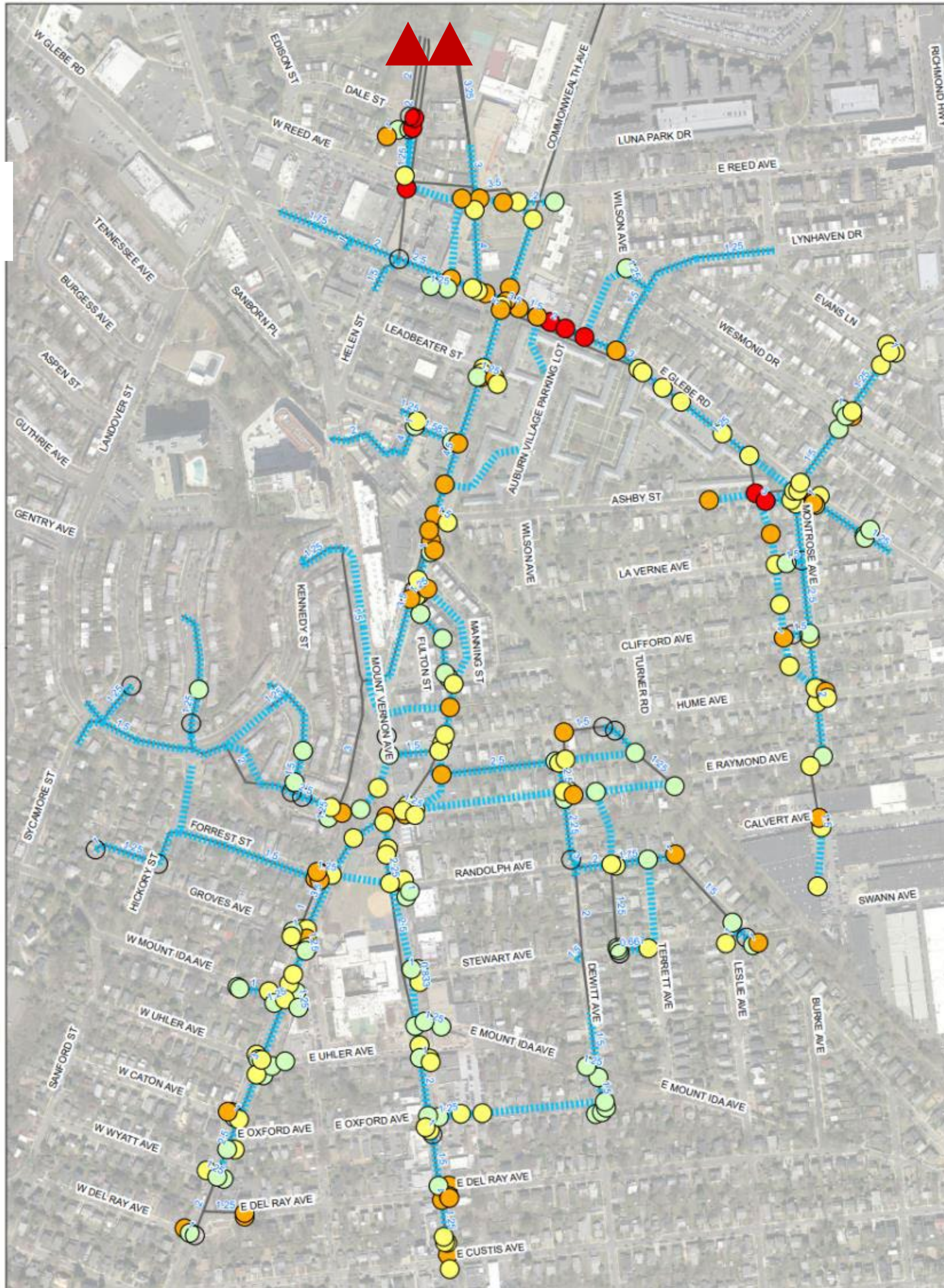
Max Overland Depth
- =<0.1'
- 0.11 to 0.5'
- 0.51 to 1.0'
- 1.1' to 2.0'
- >2.0'

Hydraulic Penalties

<u>Weighting</u>
- 0.01 to 0.5' ➔ x1
- 0.5' to 2' ➔ X2
- >2' ➔x3

Location	Total Flood Depths	Weighted Flood Depths
Problem Area Intersection	18.6'	41.8'
Problem Area Polygon	136.2'	193.4'
System Wide	183.3'	362.7'

*Use Problem Area Intersection for Optimization



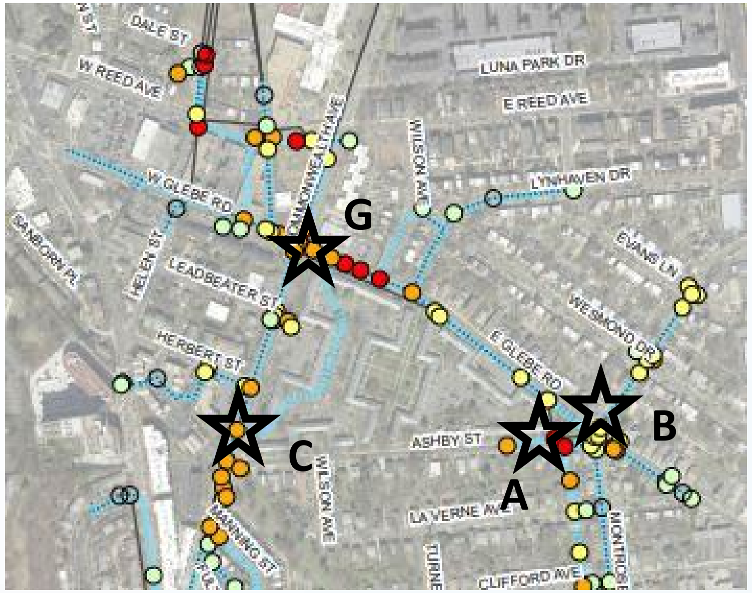
Simplified Diversion Optimization Formulation

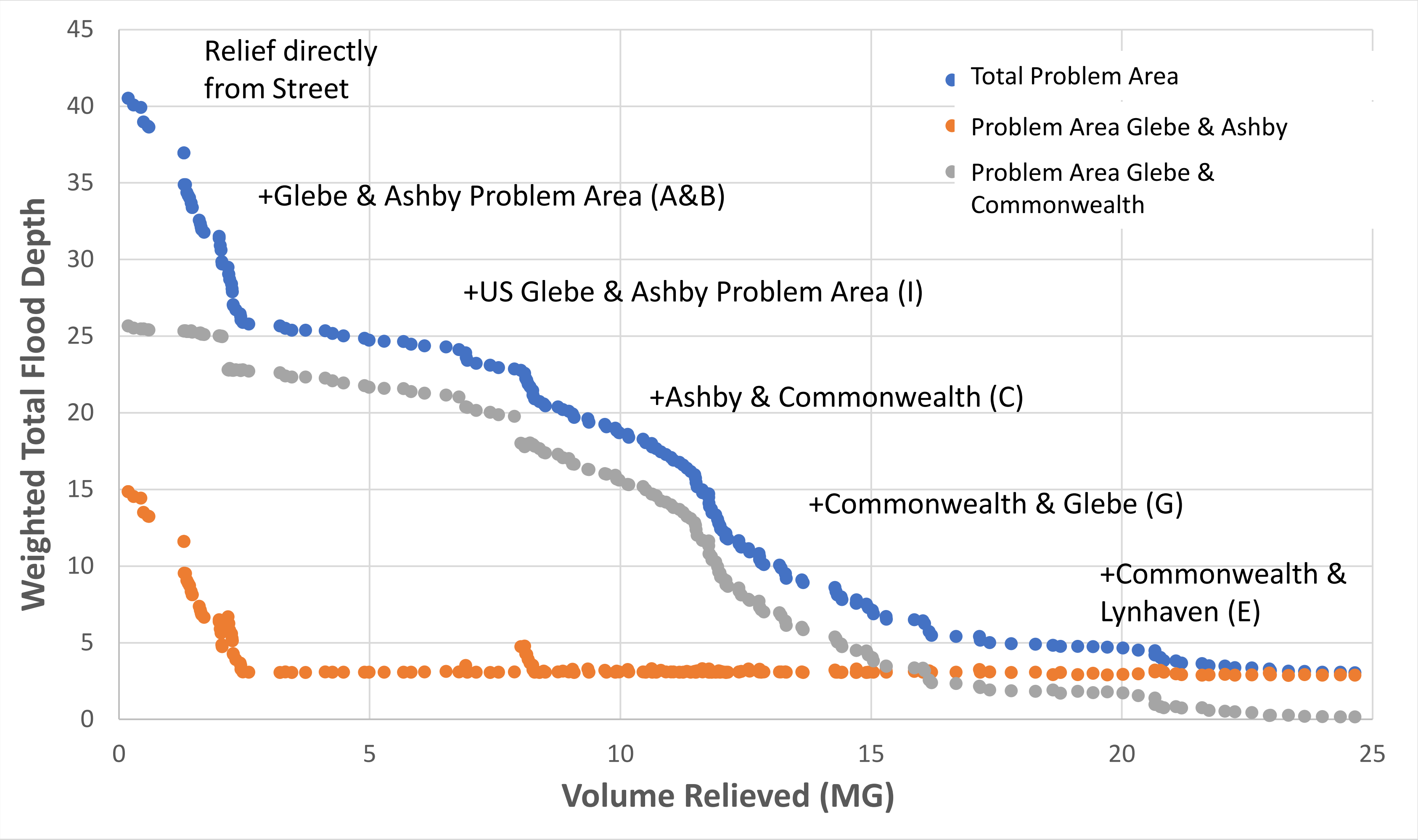
- Goal – Inform location and scale of alternative components required to solve flooding

- Added 11 Potential Diversion Locations that can relieve system at different levels:
  - Street
  - 2’ Pipe Crown
  - Pipe Crown
  - Invert
  - 5’ below Invert

Diversion Optimization identifies areas for most effective solutions

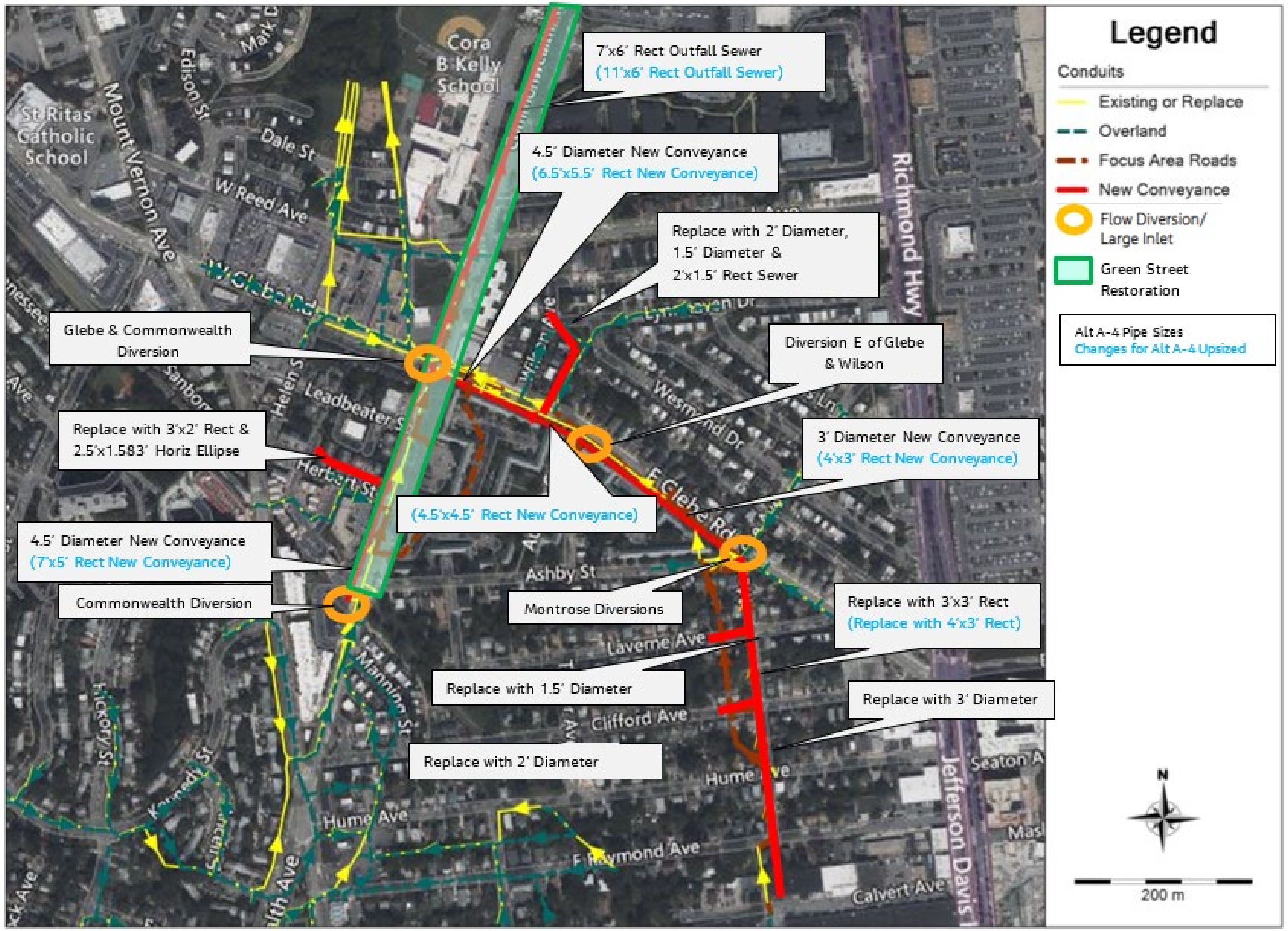
- Distributed Solutions necessary
- Problem Area 102 requires much less relief to solve than 101
- Key relief points





Alternative A-4 and A-4 Upsized

- New Bypass Sewer on Commonwealth from Ashby to Four Mile Run
- New Bypass Sewer on Glebe from Commonwealth to Ashby
- Replacement/Parallel Pipe on Montrose from Calvert to Glebe



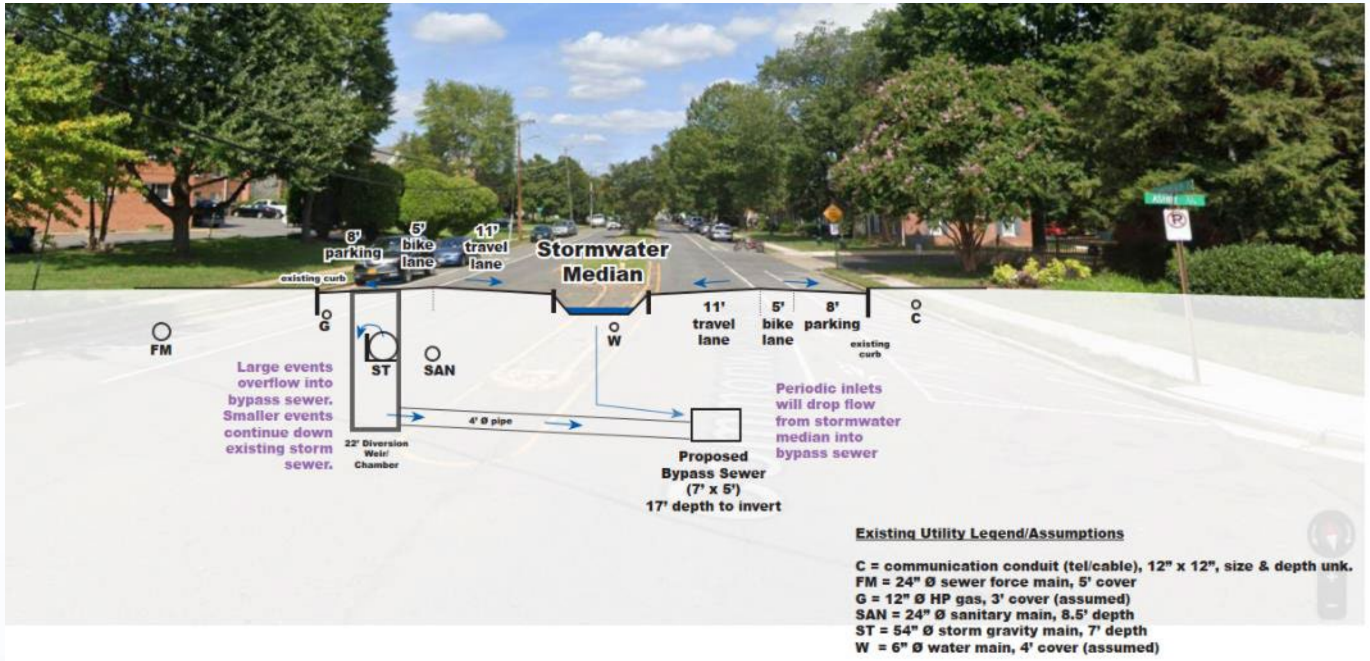
Lessons Learned

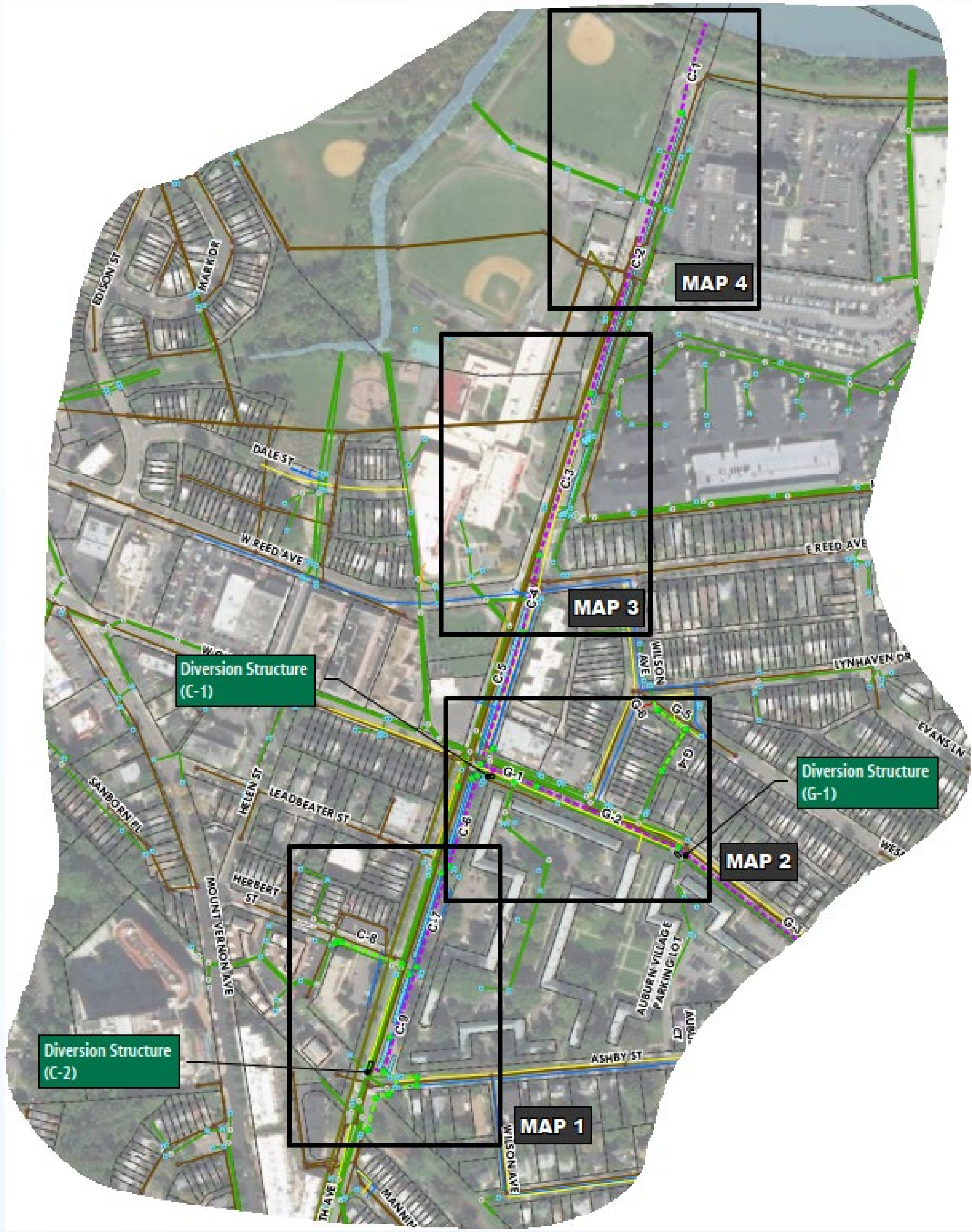
- Surface runoff contributions can be critical if you aren’t able to address all flooding in the watershed. (2D model or 1D dual drainage)
- Fast-tracking optimization step prior to fully understanding the system and the problems may not be effective
- Initial optimization can be effective at better understanding your best locations and types of solutions prior to defining the feasible solutions.
- Large-scale analyses and approaches to project planning and prioritization only take us so far in understanding the solution. Alternative evaluations need to look more closely at the site-specific conditions. Especially for our most complex problem areas.

Conceptual Design of Preferred Alternative

Commonwealth Avenue Corridor Concept

- Deep Relief Sewer
- Drainage Structure & Local Conveyance Upgrades
- ***Green Infrastructure Stormwater Median***





Flood Mitigation for 10-year event

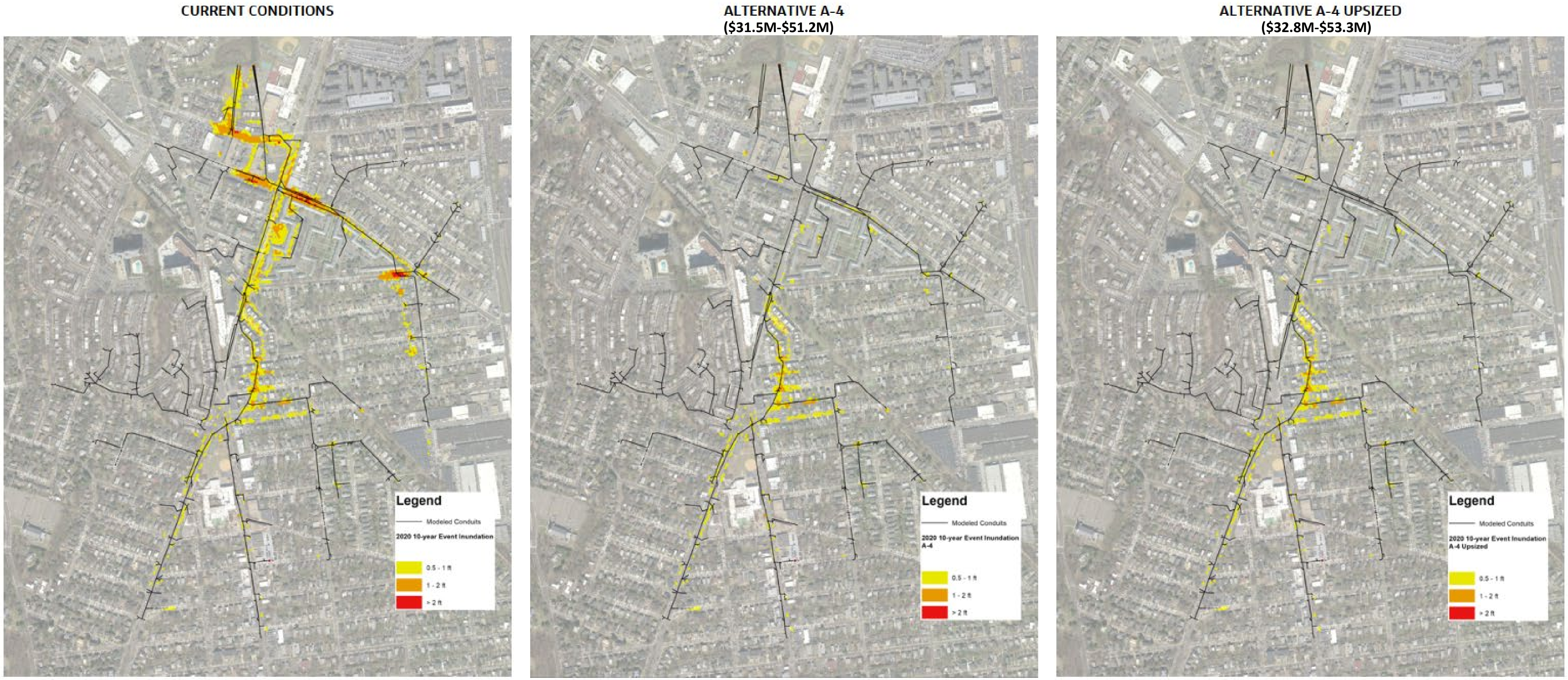


Figure 16. Current (Year 2020) 10-Year Storm Predicted Flood Inundation under Current Conditions and Preferred Alternatives

Flood Mitigation for 25-year event

CURRENT CONDITIONS | **ALTERNATIVE A-4 ($31.5M-$51.2M)** | **ALTERNATIVE A-4 UPSIZED ($32.8M-$53.3M)**

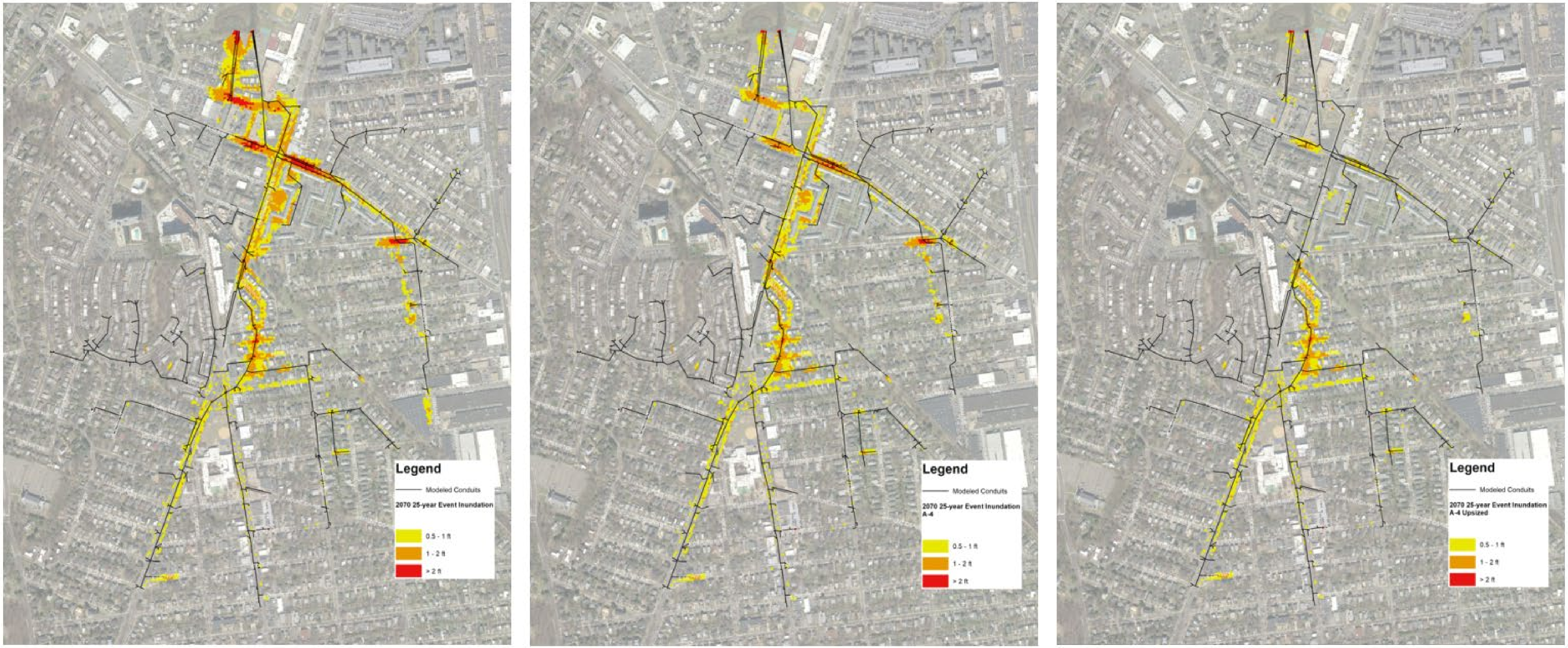
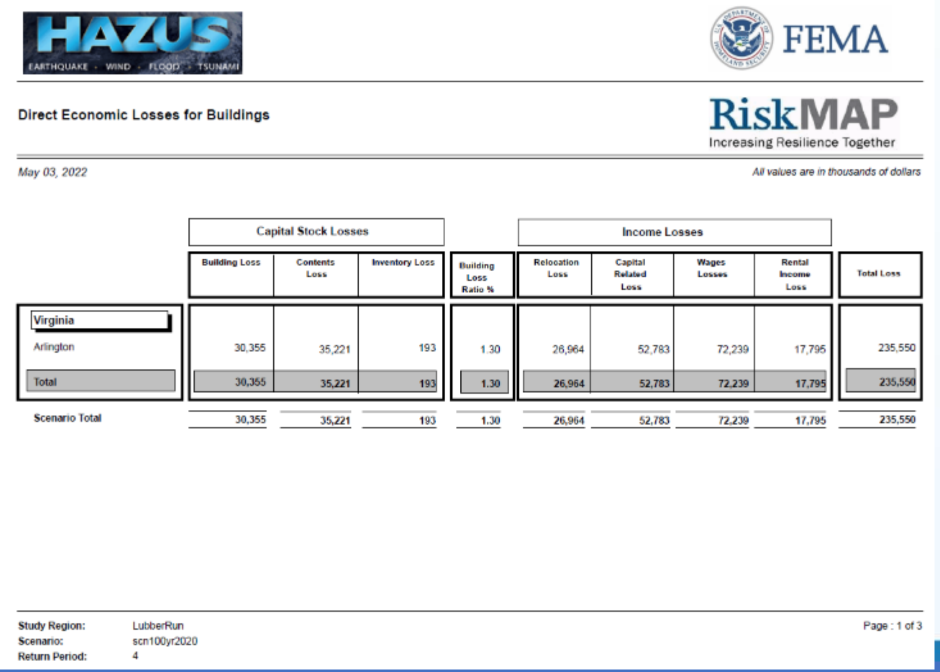


Figure 17. Future (Year 2070) 25-Year Storm Predicted Flood Inundation under Current Conditions and Preferred Alternatives

Next Steps

Next Steps
- Level 3 Risk Assessment with HAZUS

- Use PCSWMM Model output (Flood Depth Grids)
- Tax Assessor Property Values
- HAZUS Depth Damage Curves, Vehicle Stock, Indirect Damages
- Generate Annualized Monetized Risk
  - 5 design storms for existing conditions and 2 alternatives


HAZUS
EARTHQUAKE • WIND • FLOOD • TSUNAMI
FEMA

RiskMAP
Increasing Resilience Together

Direct Economic Losses for Buildings

May 03, 2022

All values are in thousands of dollars

	Capital Stock Losses				Income Losses				
	Building Loss	Contents Loss	Inventory Loss	Building Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Virginia									
Arlington	30,355	35,221	193	1.30	26,964	52,783	72,239	17,795	235,550
Total	30,355	35,221	193	1.30	26,964	52,783	72,239	17,795	235,550
Scenario Total	30,355	35,221	193	1.30	26,964	52,783	72,239	17,795	235,550

Study Region: LubberRun
Scenario: scn100yr2020
Return Period: 4

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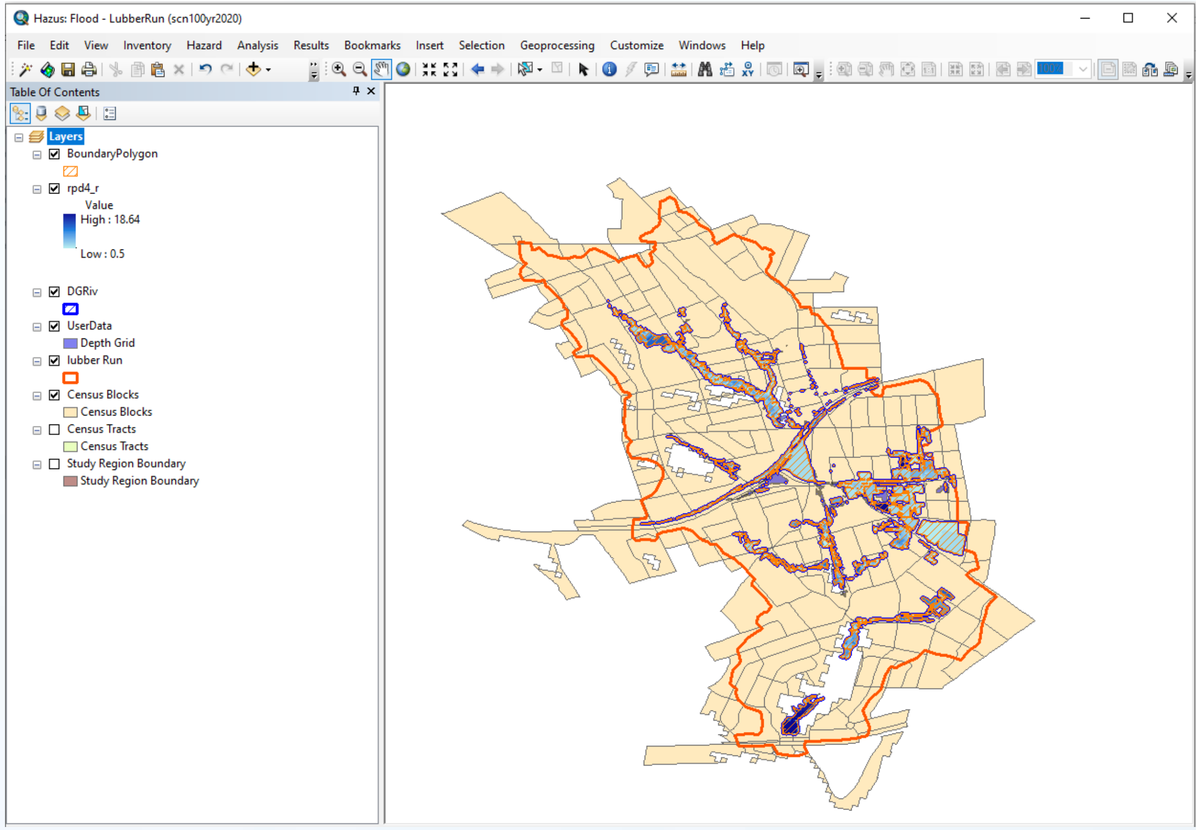

Next Steps

- Expanded Flood Modeling and Optimization

- 2D modeling of Four Mile Run East Watershed
- Identify solutions to resolve upstream flooding
- Identify solutions for remainder of Four Mile Run East
- Evaluate need for pumping

- Design and Construction of Preferred Alternative

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Thanks

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