NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Adaptive Flood Relief Techniques to Enhance Resiliency

September 21, 2022

2:00 – 3:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Beth Ewoldsen at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

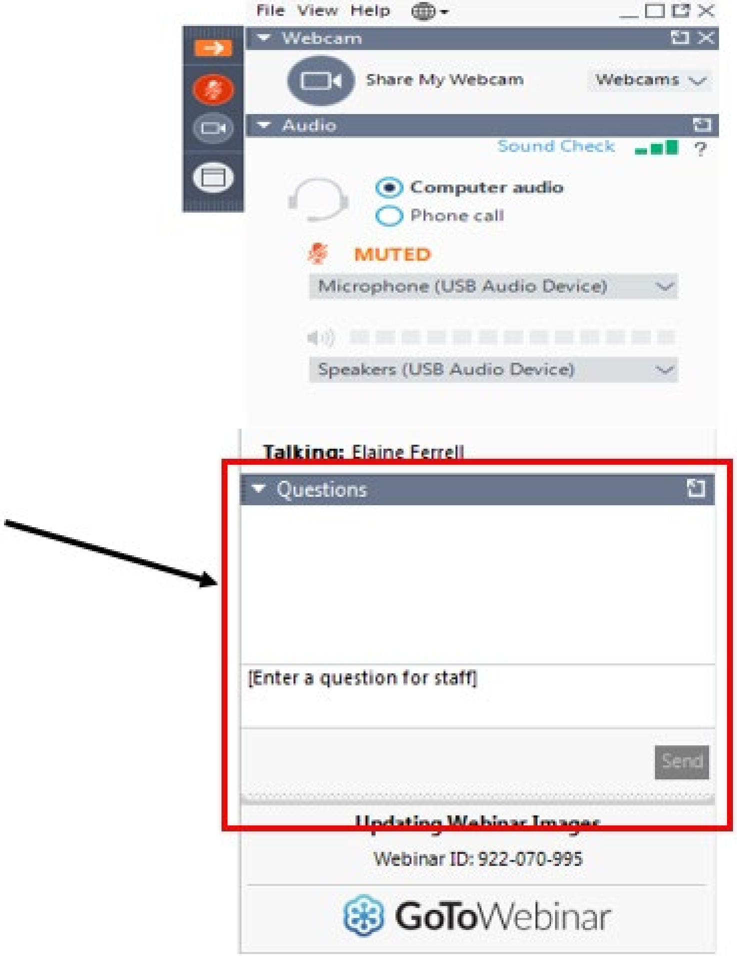
RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

Learning Objectives

- Estimate precipitation for resilient infrastructure design
- Define floodplain mitigation strategies for coastal installation resiliency
- Improve response to extreme rainfall events

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Roger Kilgore
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Kilgore Consulting and Management

John Siekmeier
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Minnesota Department of Transportation

Murari Paudel
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Hassan Water Resources

Gamal Hassan
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Adaptive Flood Relief Techniques to Enhance Resiliency

Transportation Research Board Webinar
September 21, 2022

Moderator: John Siekmeier P.E. M.ASCE
TRB AKG40 “Mechanics and Drainage of Saturated and Unsaturated Geomaterials”
Minnesota DOT Advanced Materials and Technology, Maplewood, Minnesota

Sponsoring Committees

Mechanics and Drainage of Saturated and Unsaturated Geomaterials (AKG40)

Hydrology, Hydraulics, and Stormwater (AKD50)

Today's Agenda

Introduction and Opportunities (5 minutes)

Three Presentations (20 minutes each)

- Estimating Precipitation for Resilient Infrastructure Design
  Roger Kilgore
- Resilient Infrastructure Response to Extreme Rainfall Events
  Murari Paudel
- Floodplain Mitigation Strategies for Coast Installation Resiliency
  Gamal Hassan

Discussion (25 minutes)

Opportunity to Address Code of Federal Regulations

A state asset management plan includes:

1. Summary of assets on NHS including condition;
2. Asset management objectives and measures;
3. Performance gap identification;
4. Lifecycle cost and risk management analysis;
5. Financial plan; and
6. Investment strategies.

23 U.S.C. 119(e)(4), MAP-21 § 1106

Opportunity to Address State Priorities

2021 Minnesota Statutes, 174.03, Subdivision 12

Trunk highway performance, resiliency, and sustainability.

(a) The commissioner must implement performance measures and annual targets for the trunk highway system in order to construct resilient infrastructure, enhance the project selection for all transportation modes, improve economic security, and achieve the state transportation goals established in section 174.01.

(b) At a minimum, the transportation planning process must include an inventory of transportation assets, including but not limited to bridge, pavement, geotechnical, pedestrian, bicycle, and transit asset categories.

Life Cycle Assessment and Risk Assessment Required

Lag, and where practicable lead, performance measures, and annual targets that are statewide and district-specific in each asset category for a period of up to 60 years identified in collaboration with the public.

Gap identification and an explanation of the difference between performance targets and current status.

Life cycle assessment and corridor risk assessment as part of asset management programs in each district of the department.

This section is effective July 1, 2021. The initial performance implementation report under this section is due December 15, 2022.

New Opportunity and Resilience Resources

New Opportunity NCHRP 20-44(44) “Implementation of NCHRP 15-61 “Applying Climate Change Information to Hydrologic and Hydraulic Design of Transportation Infrastructure” Nomination Deadline: September 22
https://volunteer.mytrb.org/Panel/AvailableProjects

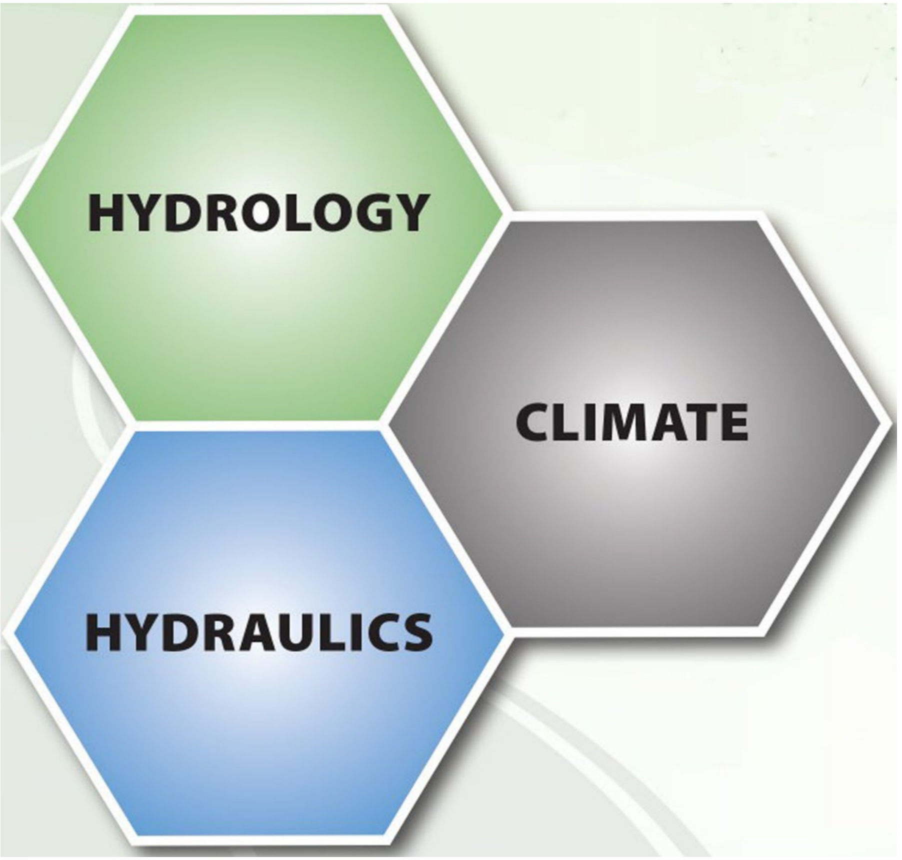
Resilience Research Becoming a Bigger Part of Transportation Planning
https://www.nationalacademies.org/trb/blog/resilience-research-becoming-a-bigger-part-of-transportation-planning

Improving Pavement Sustainability and Resiliency, FHWA, 2021
https://youtu.be/e-OOPUEdNnc

Today's Presentations

- Estimating Precipitation for Resilient Infrastructure Design
  Roger Kilgore
- Resilient Infrastructure Response to Extreme Rainfall Events
  Murari Paudel
- Floodplain Mitigation Strategies for Coast Installation Resiliency
  Gamal Hassan

Estimating Precipitation for Resilient Infrastructure Design



Roger Kilgore, P.E., D.WRE
Kilgore Consulting and Management
Denver, Colorado

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"Actionable" Words of Wisdom

"All models are wrong, but some are useful."

"Let not the perfect be the enemy of the good."

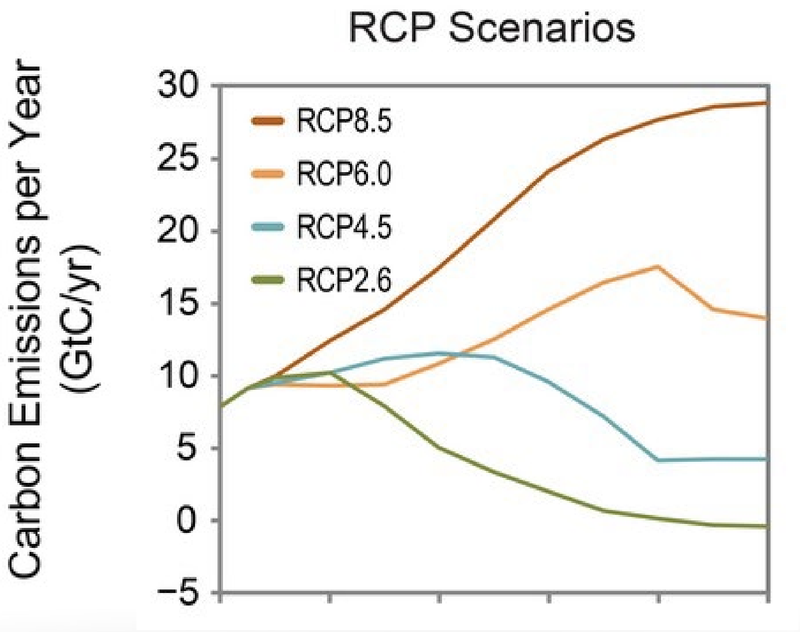
High Resolution Climate Information

Projecting Climate – An Uncertain Future

Scenarios of Human Activities + **Global Climate Models** + **Downscaling Methods** = **High-Resolution Climate Projections**

RCP = Representative Concentration Pathway

2.6 to 8.5 is the warming in Watts per square meter



HIGHER

MID-HIGH

LOWER

EVEN LOWER

Source: K. Hayhoe

Comparison of Five High-Resolution Datasets

GCM/CMIP		ARRM v1	LOCA	MACA	NARCCAP	NA-CORDEX
CMIP Generation		CMIP3	CMIP5	CMIP5	CMIP3	CMIP5
Future Scenarios		A1FI, A2, A1B, B1	RCP4.5, RCP8.5	RCP4.5, RCP8.5	A2	RCP4.5, RCP8.5
Time Period of Output		1960-2099	1950-2100	1950-2100	1968-2000, 2038-2070	1950-2100
Time Frequency	From Appendix 4A	Daily	Daily	Daily	3-hourly	Daily
Spatial Resolution		1/8th deg (~12 km)	1/16th deg (~6 km)	1/16th deg (~6 km)	50 km	25-50 km
Obs. Training Dataset		Maurer	Livneh	Livneh	not appl.	not appl.
Number of GCMs		16	30	20	4	6
Number of Group 1 GCMs		13	14	11	3	0
Number of RCMs		not appl.	not appl.	not appl.	8	6
Bias Evaluation	From Task 4 Table 7	Yes	Yes	Yes	Yes	Yes
Overfitting Evaluation		Yes	Yes	No	not appl.	not appl.
Stationarity Evaluation		Yes	Yes	No	No	Yes
Community of Users		Yes	Yes	Yes	Yes	Yes

High Resolution Dataset: LOCA (Localized Constructed Analogs)

CMIP Generation	CMIP5
Future Scenarios	RCP4.5, RCP8.5
Time Period of Output	1950-2100
Time Frequency	Daily
Spatial Resolution	1/16th deg (~6 km)
Type of Downscaling	ESDM
Number of GCMs (Group 1)	30 (14)

CMIP: Coupled Model Intercomparison Project

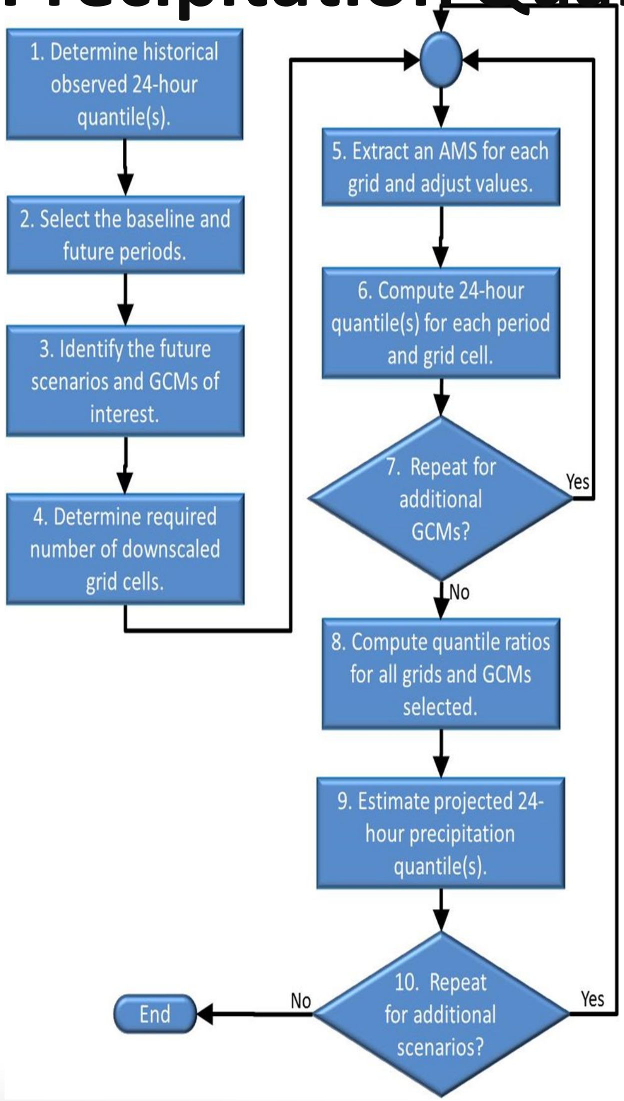
RCP: Representative Concentration Pathway

ESDM: Empirical-Statistical Downscaling Model

Projecting 24-hr Duration Precipitation – 10-Step Procedure

Procedure for Estimating Projected 24-Hour Precipitation Quantiles

- Uses a lower and higher scenario.
- Uses multiple GCMs (allows estimation of confidence limits).
- Adjusts historical rainfall frequency curve (RFC) with modeled ratios.



Historical Rainfall Frequency Curve from NOAA Atlas 14

Denver, CO

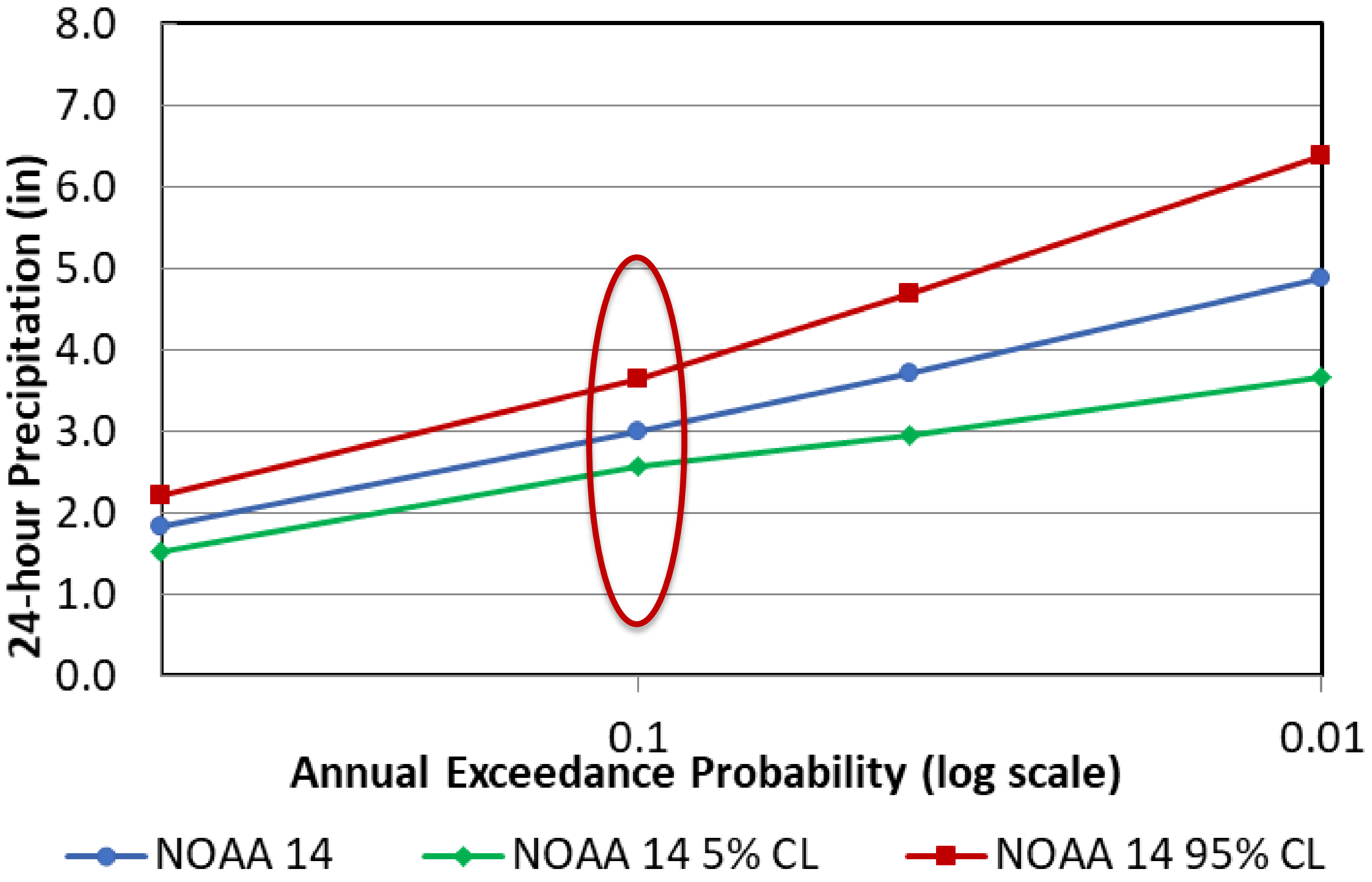
PF tabular

AMS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]									
Duration	Annual exceedance probability (1/years)								
	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/500	1/1000
5-min	**0.248** (0.200-0.311)	**0.355** (0.285-0.446)	**0.445** (0.354-0.560)	**0.573** (0.444-0.757)	**0.679** (0.513-0.906)	**0.792** (0.577-1.08)	**0.912** (0.637-1.28)	**1.08** (0.726-1.55)	**1.22** (0.793-1.76)
10-min	**0.364** (0.292-0.455)	**0.520** (0.417-0.653)	**0.651** (0.518-0.820)	**0.840** (0.650-1.11)	**0.994** (0.751-1.33)	**1.16** (0.844-1.58)	**1.34** (0.933-1.87)	**1.58** (1.06-2.28)	**1.78** (1.16-2.58)
15-min	**0.444** (0.356-0.555)	**0.635** (0.508-0.796)	**0.794** (0.632-1.00)	**1.02** (0.793-1.35)	**1.21** (0.915-1.62)	**1.41** (1.03-1.93)	**1.63** (1.14-2.28)	**1.93** (1.30-2.77)	**2.17** (1.42-3.15)
30-min	**0.623** (0.500-0.779)	**0.884** (0.707-1.11)	**1.10** (0.875-1.39)	**1.41** (1.09-1.86)	**1.67** (1.26-2.22)	**1.94** (1.41-2.64)	**2.23** (1.56-3.12)	**2.63** (1.77-3.79)	**2.96** (1.93-4.29)
60-min	**0.787** (0.632-0.984)	**1.10** (0.877-1.37)	**1.36** (1.08-1.71)	**1.74** (1.35-2.30)	**2.06** (1.56-2.75)	**2.40** (1.75-3.28)	**2.76** (1.93-3.88)	**3.28** (2.21-4.72)	**3.70** (2.41-5.36)
2-hr	**0.951** (0.768-1.18)	**1.31** (1.05-1.63)	**1.62** (1.29-2.02)	**2.07** (1.62-2.72)	**2.45** (1.87-3.25)	**2.86** (2.10-3.88)	**3.30** (2.33-4.59)	**3.93** (2.66-5.61)	**4.45** (2.92-6.38)
3-hr	**1.05** (0.849-1.29)	**1.43** (1.15-1.77)	**1.75** (1.41-2.18)	**2.24** (1.77-2.94)	**2.66** (2.03-3.51)	**3.10** (2.29-4.19)	**3.59** (2.54-4.97)	**4.28** (2.92-6.08)	**4.85** (3.20-6.92)
6-hr	**1.25** (1.02-1.53)	**1.70** (1.38-2.08)	**2.08** (1.68-2.56)	**2.64** (2.09-3.42)	**3.11** (2.39-4.07)	**3.62** (2.69-4.83)	**4.16** (2.97-5.71)	**4.94** (3.39-6.94)	**5.58** (3.71-7.88)
12-hr	**1.52** (1.25-1.85)	**2.08** (1.70-2.54)	**2.54** (2.07-3.11)	**3.19** (2.53-4.07)	**3.72** (2.87-4.79)	**4.28** (3.19-5.64)	**4.87** (3.49-6.58)	**5.69** (3.93-7.89)	**6.35** (4.26-8.89)
24-hr	**1.84** (1.52-2.22)	**2.49** (2.05-3.01)	**3.00** (2.46-3.65)	**3.72** (2.96-4.69)	**4.29** (3.34-5.47)	**4.89** (3.67-6.37)	**5.51** (3.98-7.37)	**6.37** (4.43-8.73)	**7.05** (4.76-9.76)
2-day	**2.17** (1.81-2.60)	**2.84** (2.36-3.41)	**3.38** (2.79-4.08)	**4.14** (3.31-5.16)	**4.74** (3.71-5.98)	**5.36** (4.06-6.92)	**6.01** (4.37-7.96)	**6.92** (4.84-9.38)	**7.63** (5.20-10.5)

$P_{0.1}$ = 3.00 inches

90% Confidence Interval: 2.46 to 3.65 inches

Rainfall Frequency Curve with Confidence Limits



$P_{0.1}$ = 3.00 inches

90% Confidence Interval: 2.46 to 3.65 inches (Consider a range for resilience)

Downscaled Climate and Hydrology Projections (DCHP)

RECLAMATION NCAR USGS

Santa Clara University CIRES CLIMATE CENTRAL

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

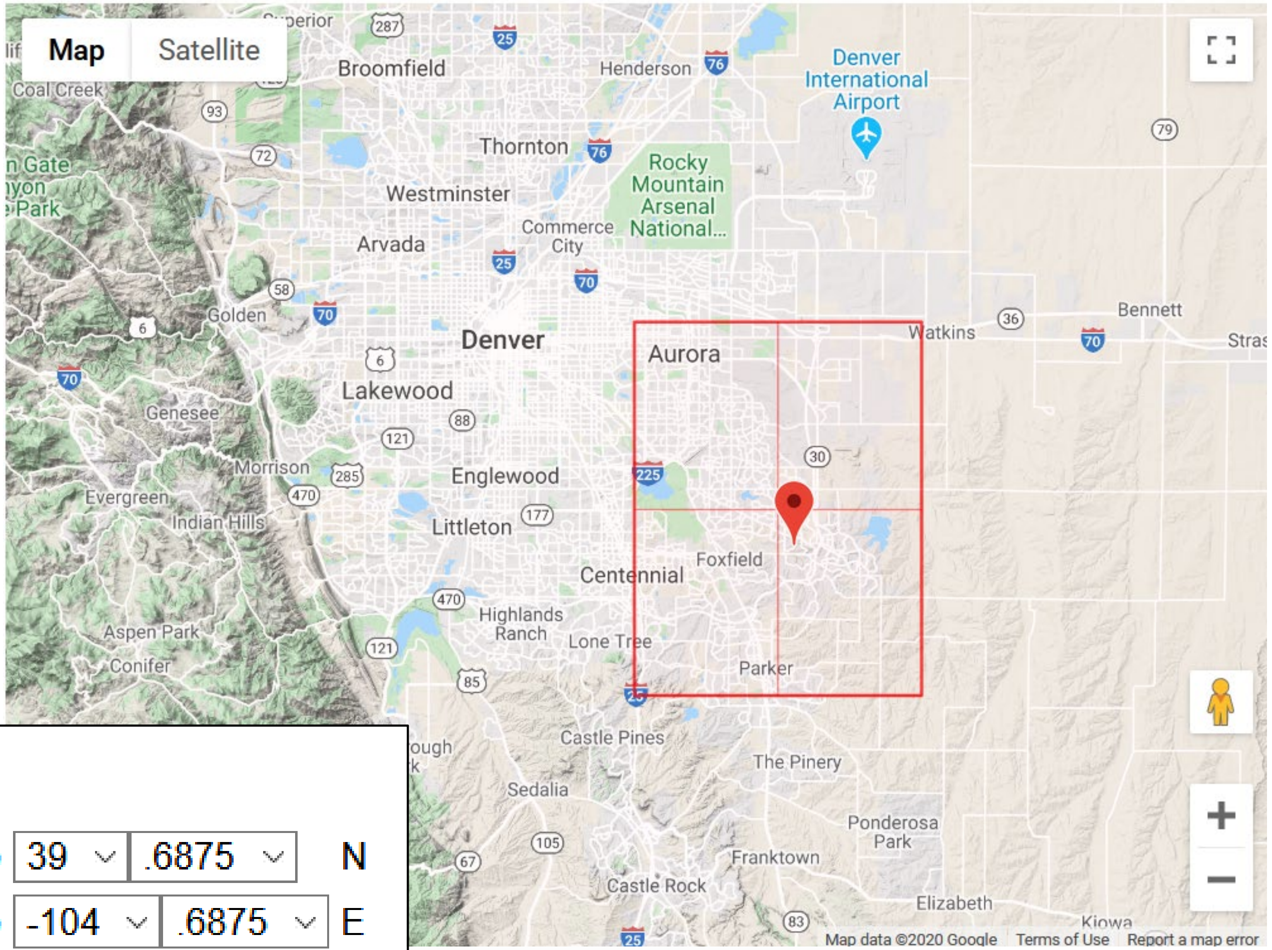
This site is best viewed with Chrome (recommended) or Firefox. Some features are unavailable when using Internet Explorer.

Welcome | About | Tutorials | Projections: Subset Request | Projections: Complete Archives | Feedback | Links

Downscaled CMIP5 climate and hydrology projections' documentation and release notes available here.

http://gdo-dcp.ucllnl.org/downscaled_cmip_projections

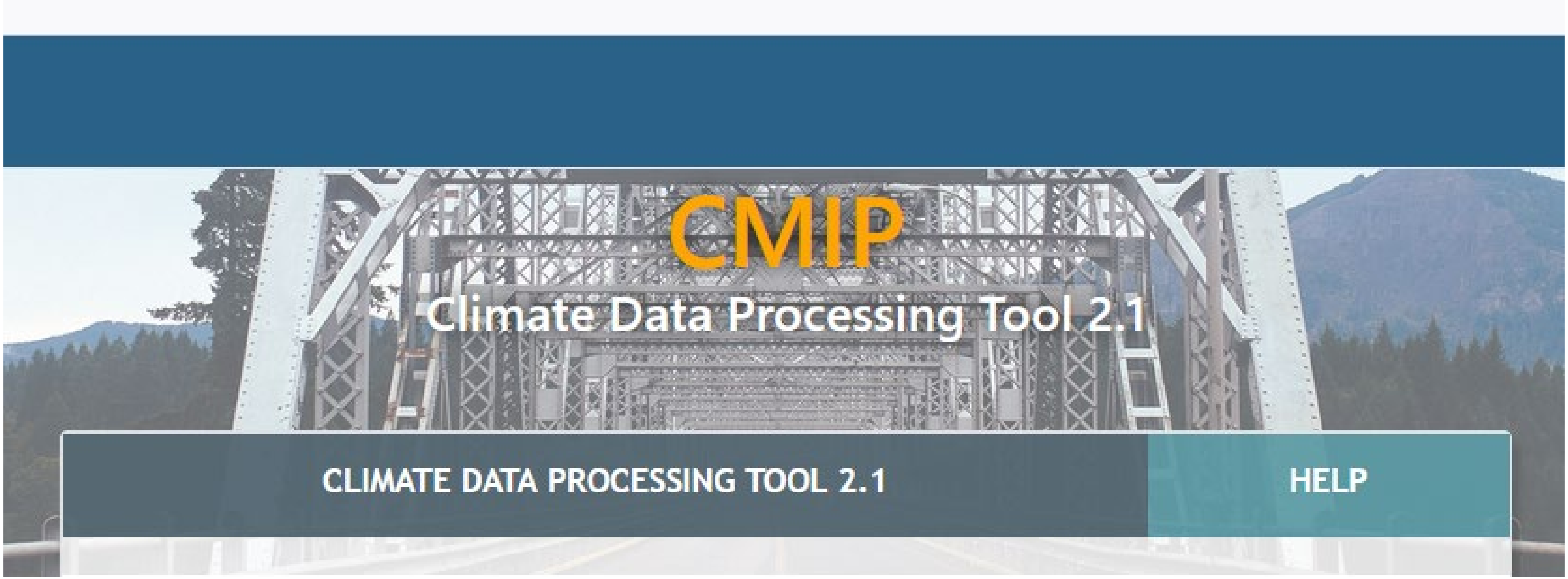
Data Retrieval: Example Rectangular Selection



Rectangular Area

Latitude	39	.5625	to	39	.6875	N
Longitude	-104	.8125	to	-104	.6875	E

The Federal Highway Administration CMIP Tool

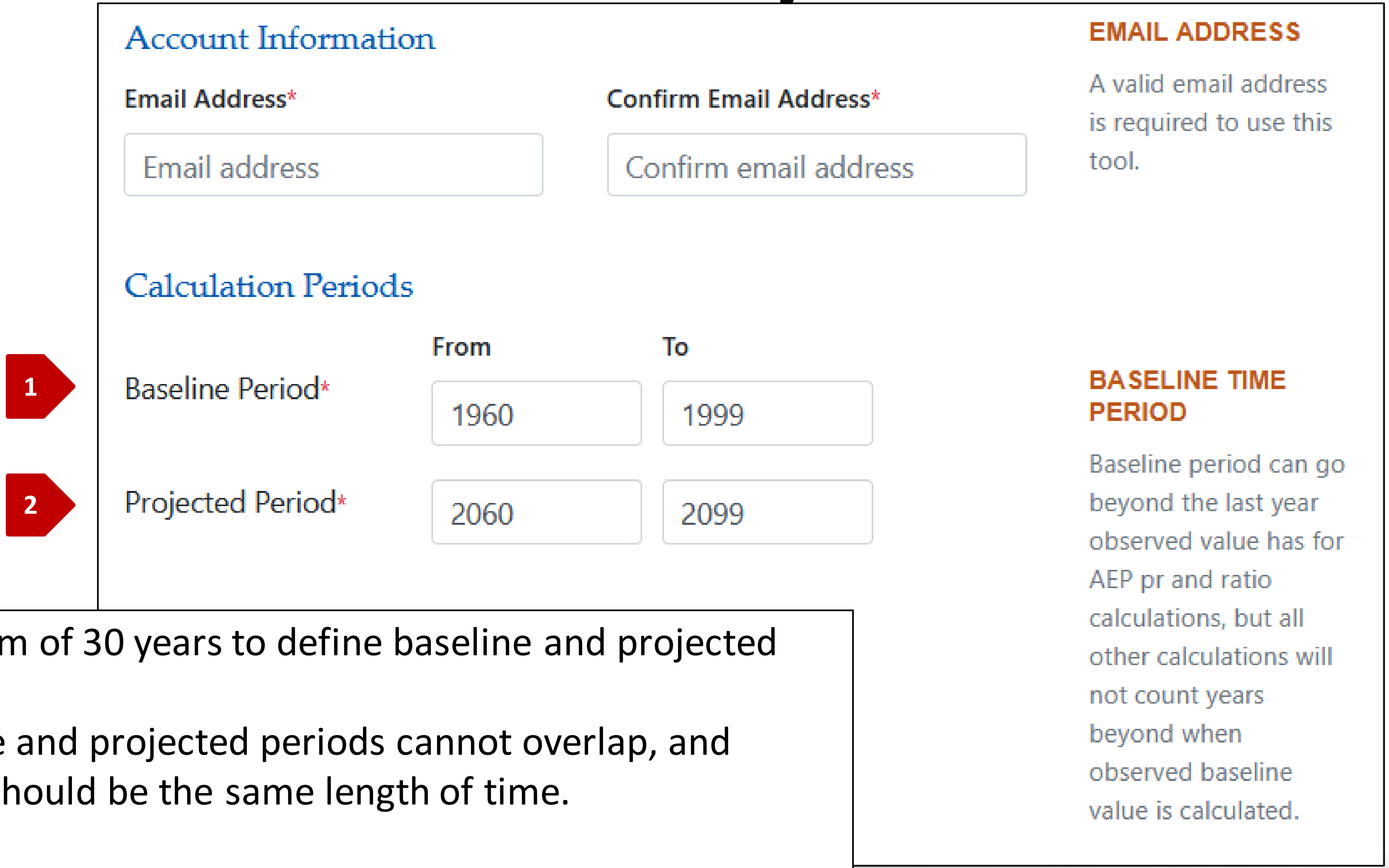


https://fhwaapps.fhwa.dot.gov/cmip

Climate Variables Available through the CMIP Tool

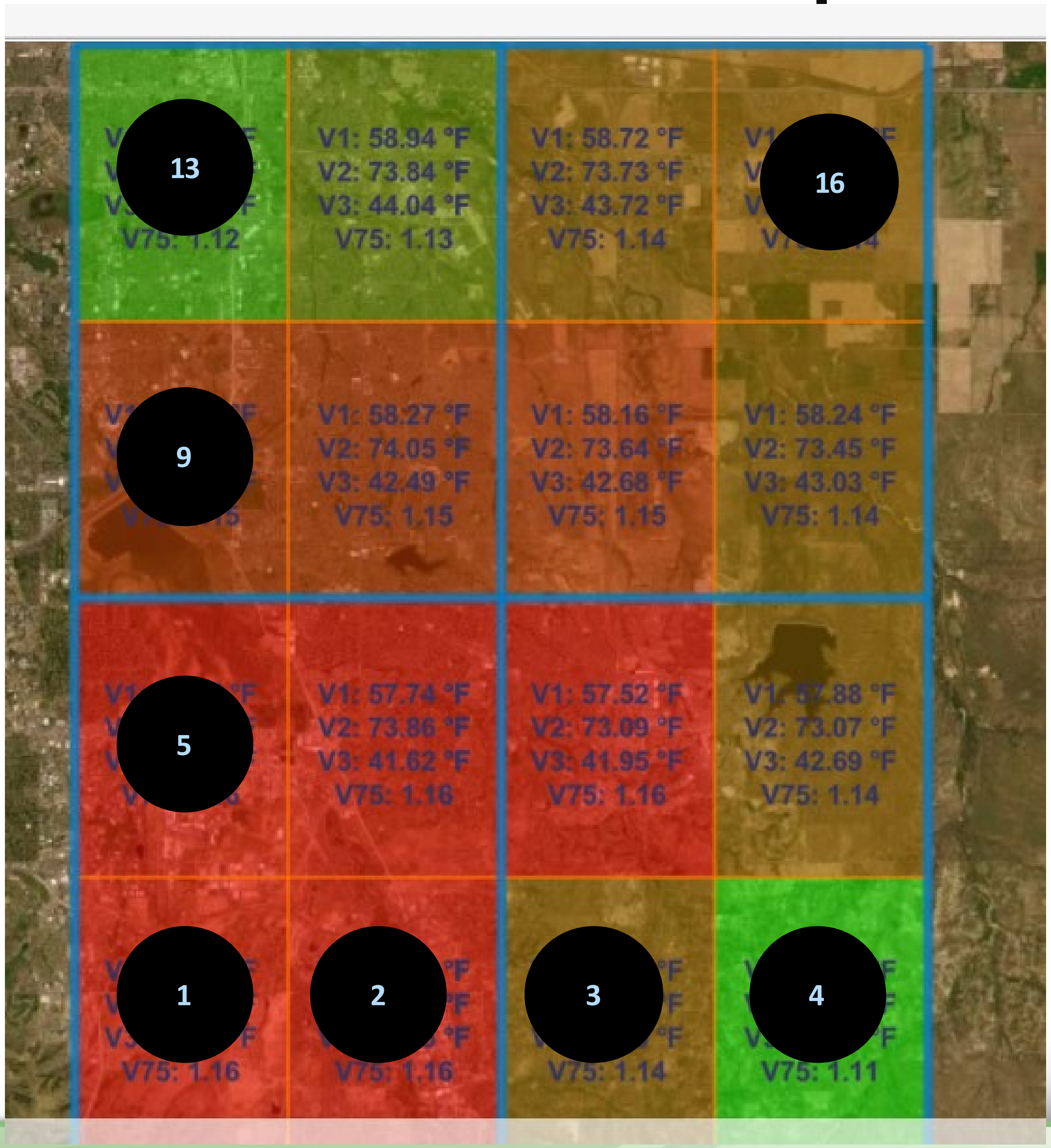
- Temperature
  - Annual averages and extremes
  - Seasonal averages and extremes
  - Days above high thresholds and below low thresholds
- Precipitation
  - Annual averages and extremes
  - Monthly and seasonal averages and extremes
  - 24-hr precipitation quantiles and ratios
  - Annual maxima series (24-hr)

Baseline and Projected Periods



- Minimum of 30 years to define baseline and projected periods.
- Baseline and projected periods cannot overlap, and ideally should be the same length of time.

CMIP Output: Grid by Grid Information



- 3 spreadsheets have information on separate tabs for each grid.
- Grid numbering begins at lower left corner of retrieved grids.
- Tabs identified by grid number and latitude and longitude.

Output From the "Simple" Spreadsheet

Temperature

		Unit	Observed Value - Baseline Period (1960 - 1999)	Projection Value - Projection Period (2060 - 2099)
	Annual Averages			
1	Average Annual Mean Temperature	°F	48.92	57.62
2	Average Annual Maximum Temperature	°F	63.37	72.43
3	Average Annual Minimum Temperature	°F	34.47	42.81

Precipitation

		Unit	Observed Value - Baseline Period (1960 - 1999)	Projection Value - Projection Period (2060 - 2099)
	Precipitation			
46	Average Total Annual Precipitation	Inches	16.40	16.79
47	"Very Heavy" 24-hr Precipitation Amount (defined as 95th percentile precipitation)	Inches	0.55	0.60
48	"Extremely Heavy" 24-hr Precipitation Amount (defined as 99th percentile precipitation)	Inches	1.21	1.30
49	Average Number of Baseline "Very Heavy" Precipitation Events per Year	times	5.83	6.37
50	Average Number of Baseline "Extremely Heavy" Precipitation Events per Year	times	1.18	1.40

Precipitation: Quantile Ratios

ID	Parameter	Unit	Observed Value - Baseline Period (1960 - 1999)	Projection Value - Projection Period (2060 - 2099)
75	Ratio of 24-hr Precipitation With an AEP of 10.0% (Table 4.12)	N/A	N/A	1.15
76	Ratio of 24-hr Precipitation With an AEP of 10.0% (Table 4.12) - Confidence Interval (90%)	N/A	N/A	0.63

$R_{0.1}$ = 1.15

90% Confidence Interval: 0.84 to 1.47 (Consider a range for resilience)

Compute Ratios of Future/Baseline GCM Quantiles

$$R_q = \frac{PF_q}{PB_q}$$

where:

$R_q =$ *Ratio of the future to baseline 24-hour precipitation quantile (q).*

$PF_q =$ *Future modeled 24-hour precipitation quantile (q).*

$PB_q =$ *Baseline modeled 24-hour precipitation quantile (q).*

$$P_{q,p} = P_{q,h}(R_q)$$

where:

$P_{q,p} =$ *Projected 24-hour precipitation quantile (q).*

$P_{q,h} =$ *Historical 24-hour precipitation quantile (q).*

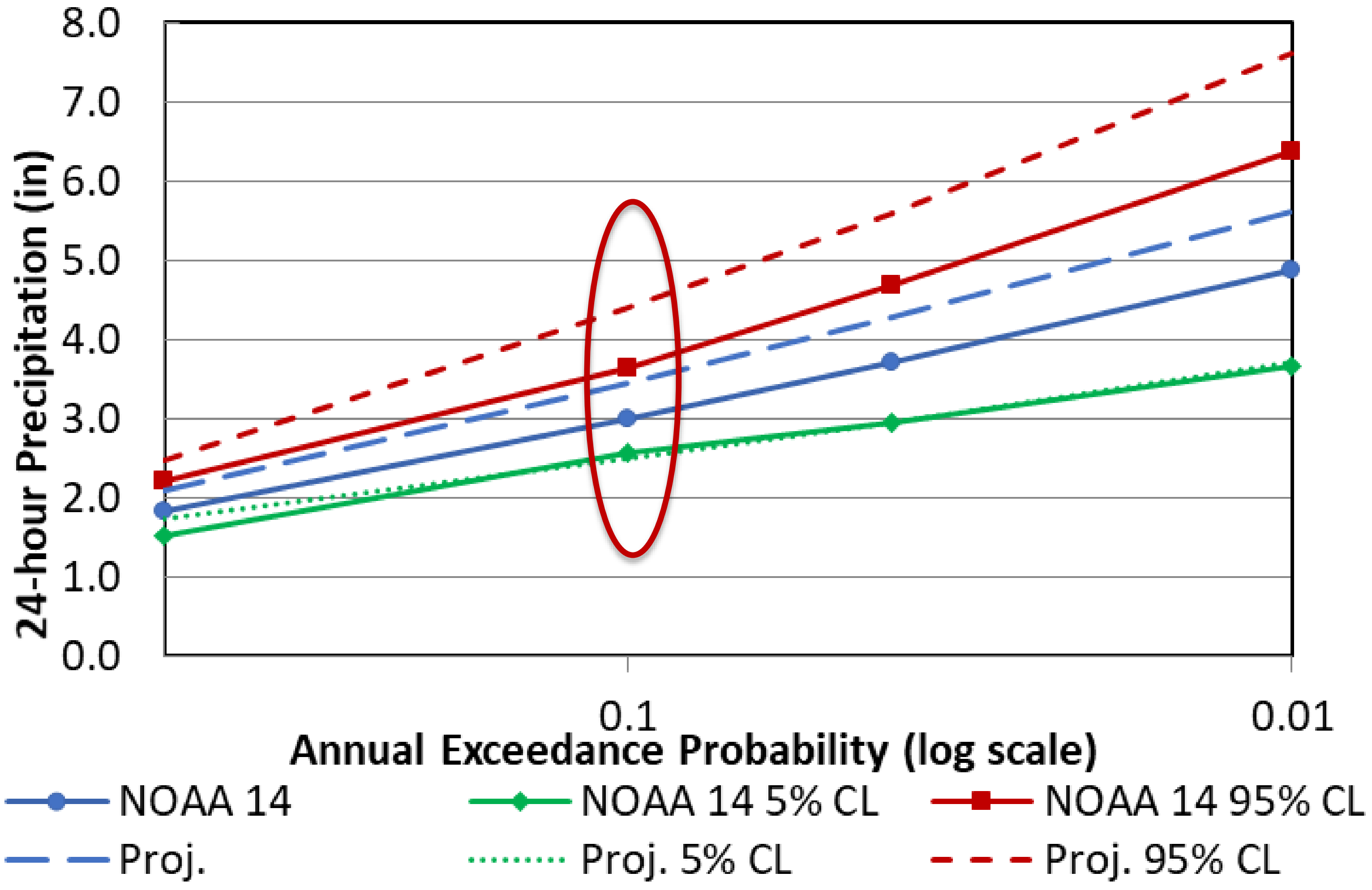
$P_{0.1,P} = P_{0.1,h}\,(R_{0.1}) = 3.00 \times 1.15 = 3.45$ inches

Projected (2050-2099) estimates of the 24-hour precipitation for Denver

Existing

$P_{0.1}$ = 3.00 inches

90% Confidence Interval: 2.46 to 3.65 inches



Projected

$P_{0.1}$ = 3.45 inches

90% Confidence Interval: 2.51 to 4.40 inches

Summary

- Tools exist for projecting precipitation and temperature, e.g. high-resolution climate data from the ***LOCA dataset*** and the ***FHWA CMIP tool***.
- Estimates of ***future 24-hour duration precipitation quantiles*** are available.
- ***Confidence limits*** can be important in evaluating project design.
- More ***complex methods*** are also available.

Remember:

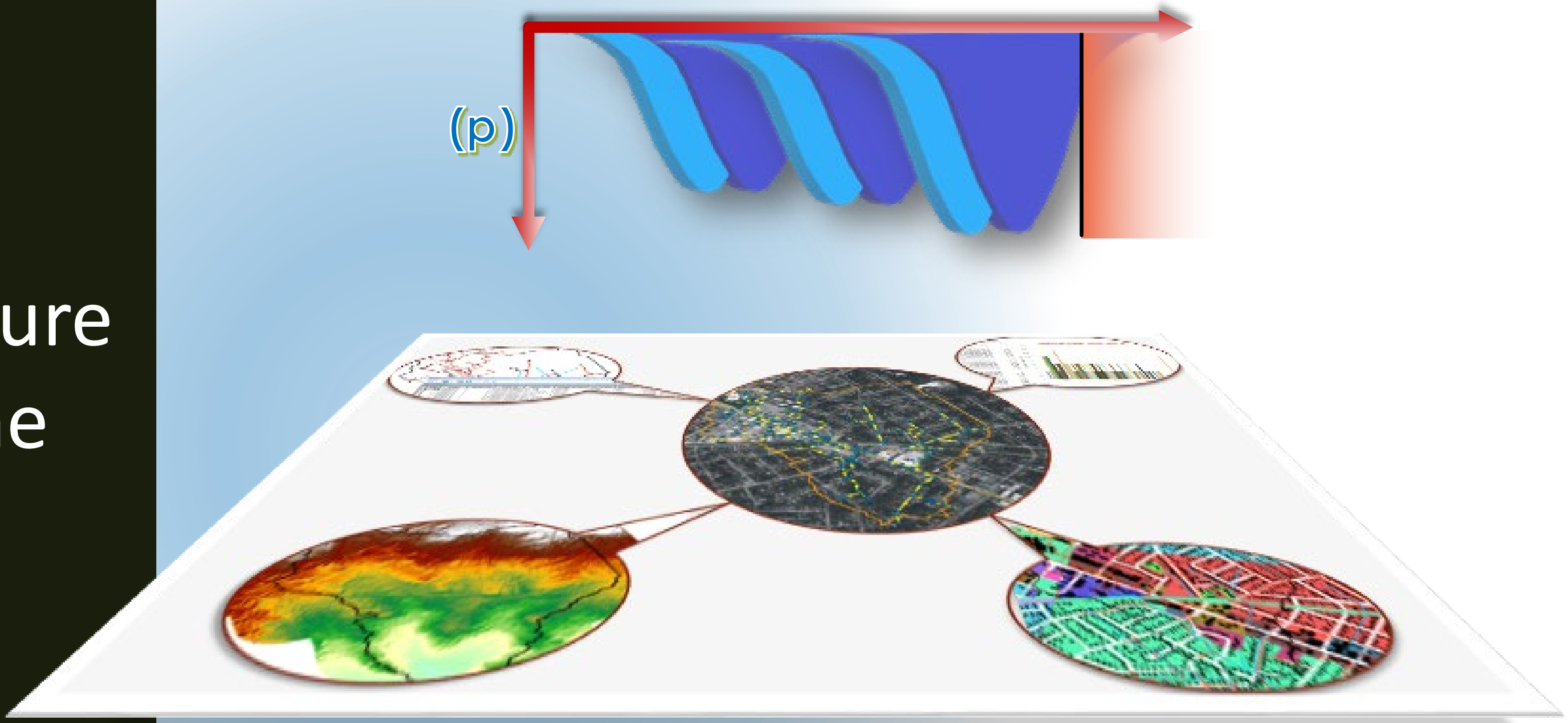
All models are wrong, but some are useful.

Let not the perfect be the enemy of the good.

Additional Information

- FHWA Hydraulic Engineering Circular (HEC) 17 "***Highways in the River Environment – Flood Plains, Extreme Events, Risk, and Resilience***"
- National Cooperative Highway Research Program (NCHRP) Project Number 15-61 "***Applying Climate Change Information to Hydrologic and Hydraulic Design of Transportation Infrastructure***"
- Roger Kilgore (RKilgore@KCMwater.com)

Resilient infrastructure Response to extreme rainfall events



Murari Paudel, PhD, PE

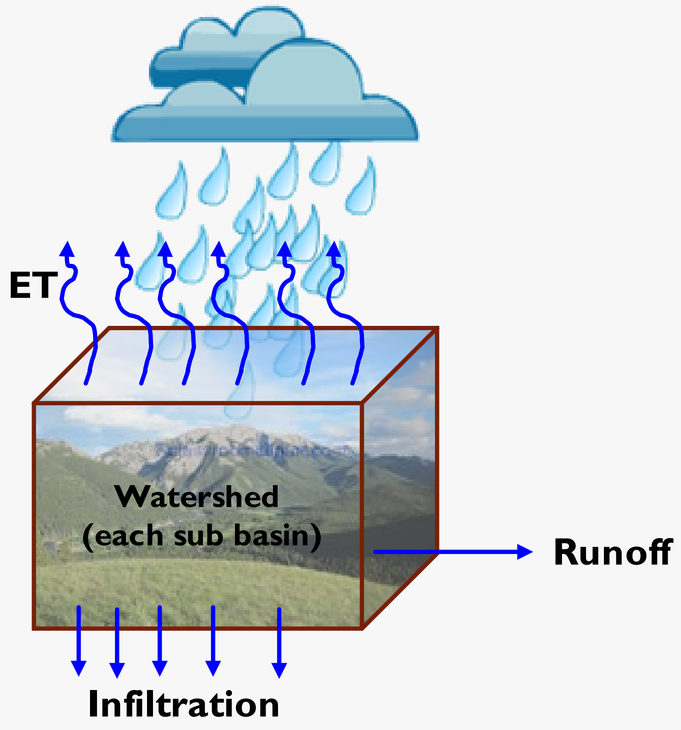
Gamal Hassan, PE

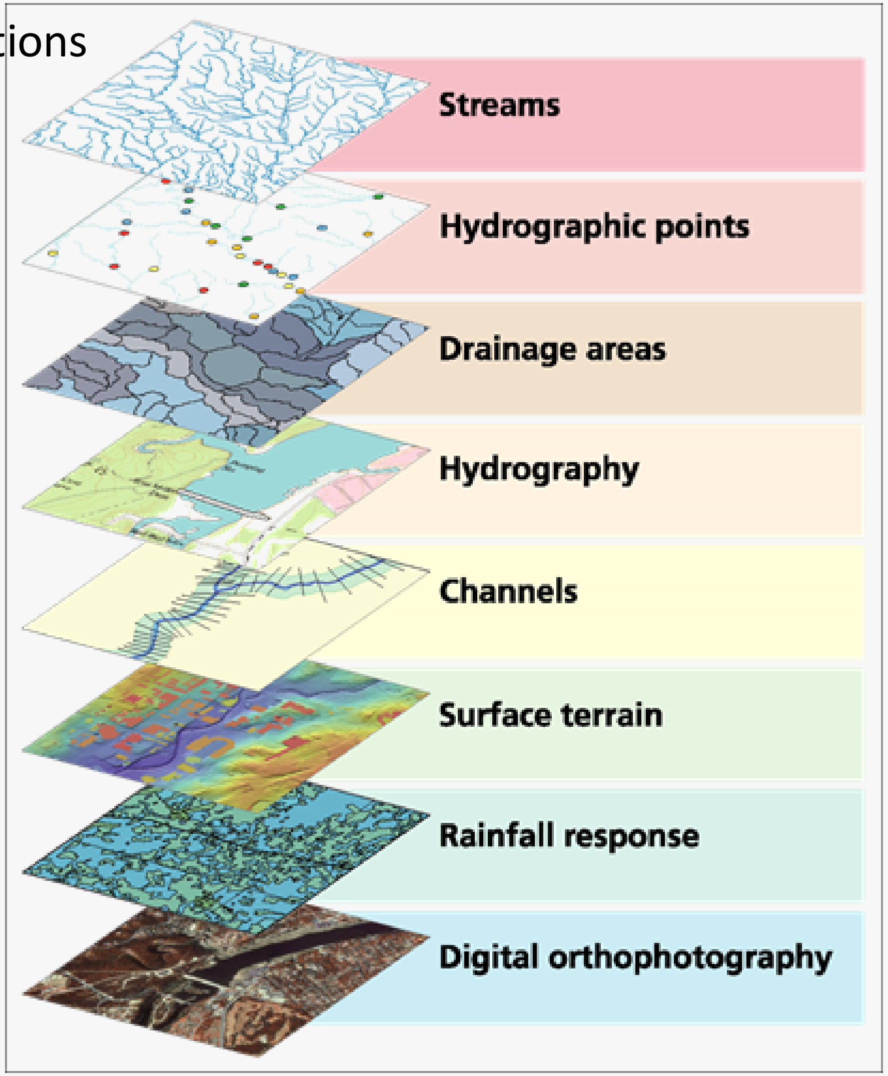
Overview

- Real World Vs Modeling World
- Conventional Modeling Practice
- Forward Looking Alternatives
- Example application
  - VDOT Hampton Roads District R2S2 Model
  - Cleveland Park Drainage Improvement
  - City of Falls Church – Urban Drainage Modeling

Real World Vs Modeling World

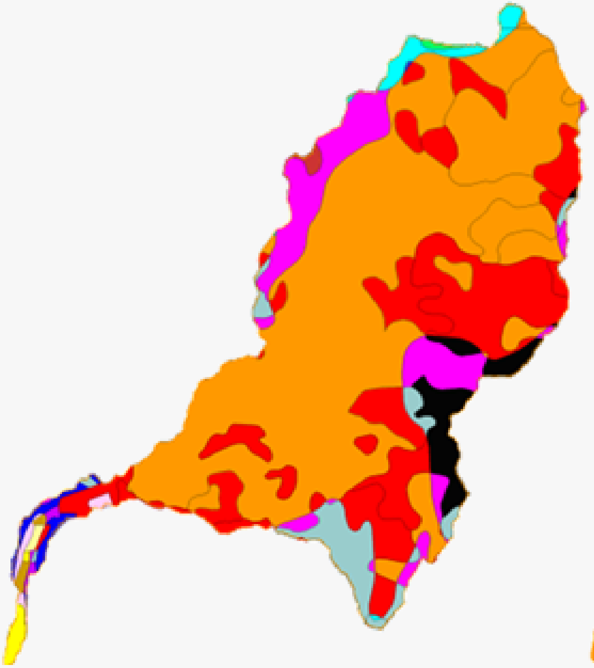
- Real world phenomena are represented by set of mathematical equations
- Watershed characteristics are represented using geo-spatial data



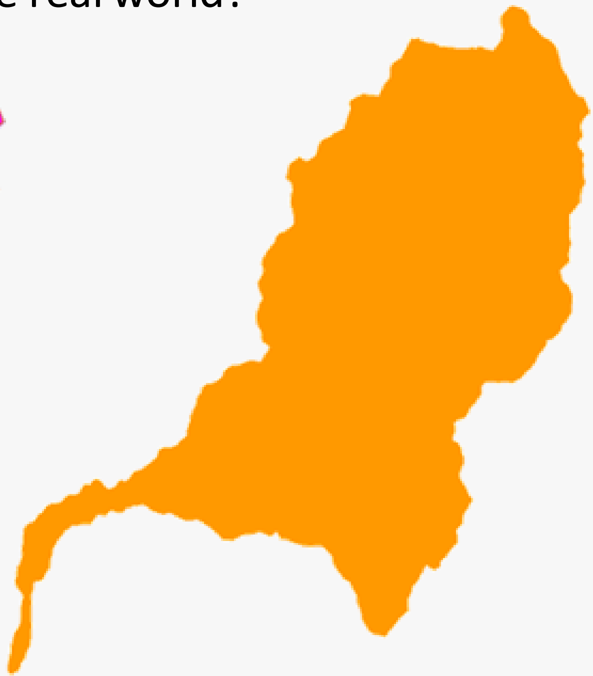


Real World Vs Modeling World

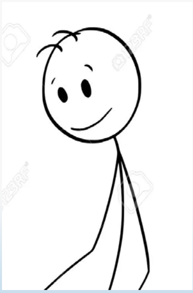
- How do out models see the real world?

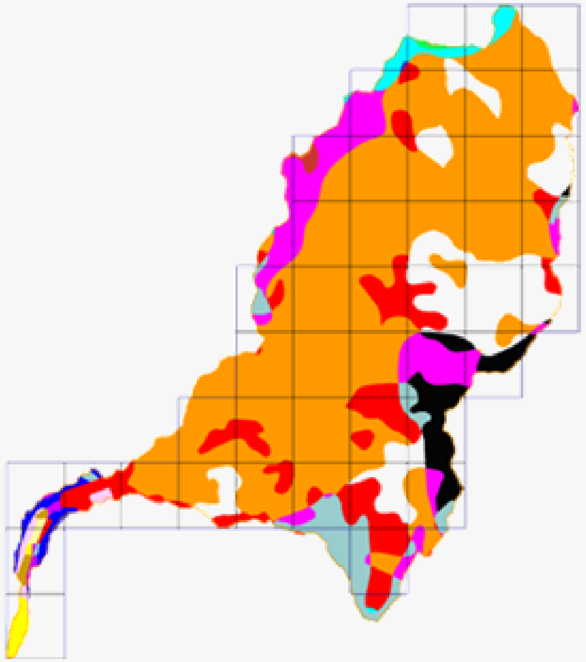


Heterogeneity in the real world

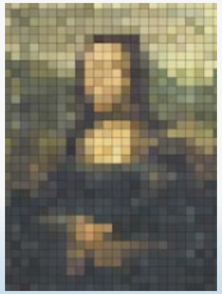


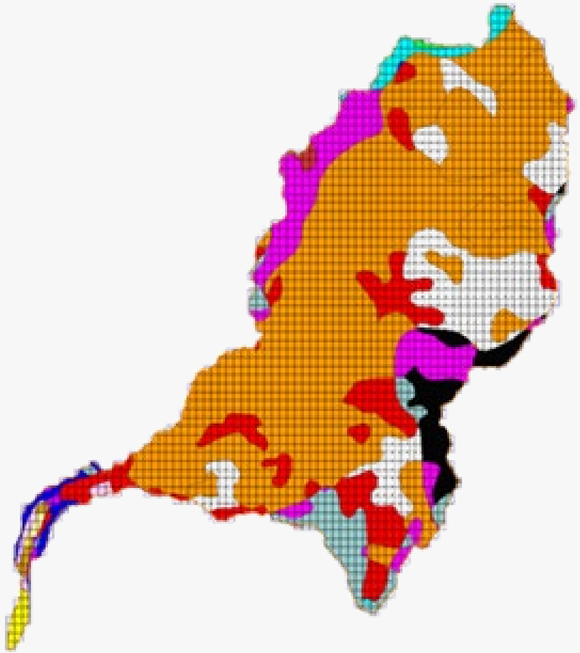
Lumped Model





Semi-Distributed Model

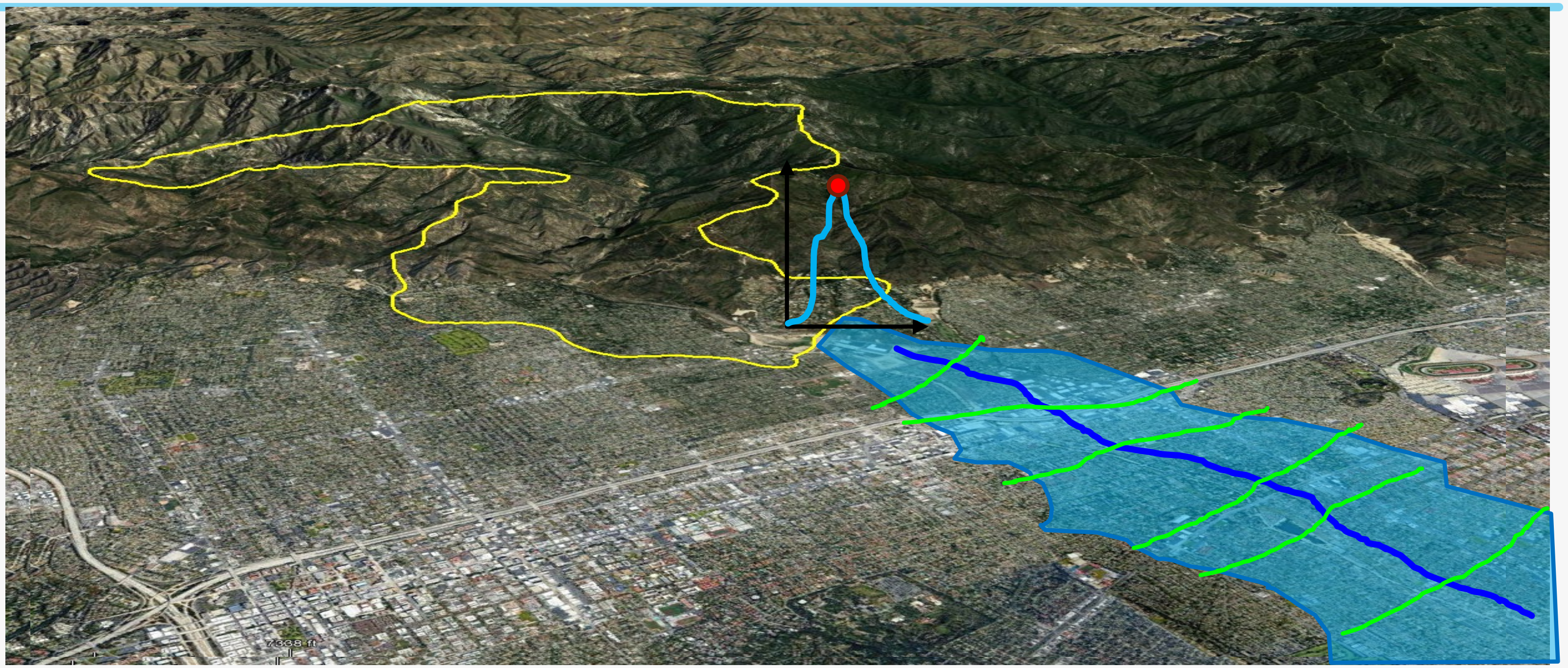


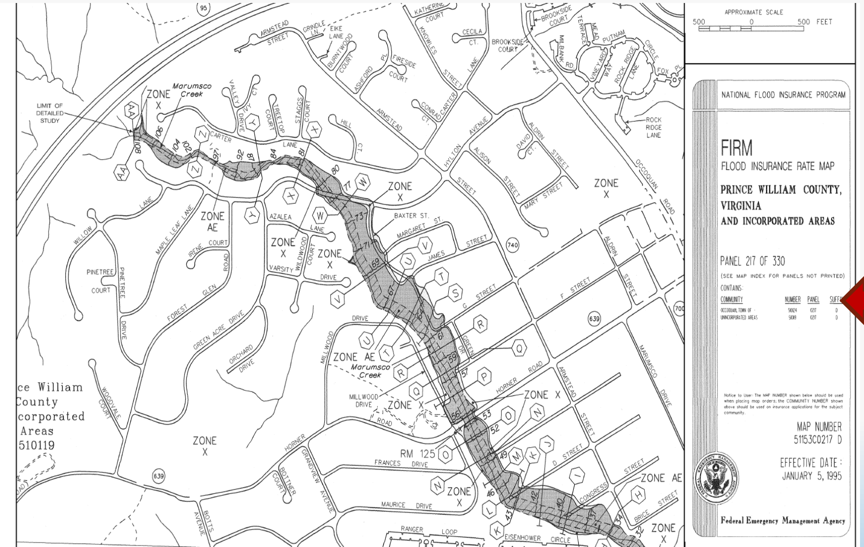


Capture spatial variability

Current Modeling Practice

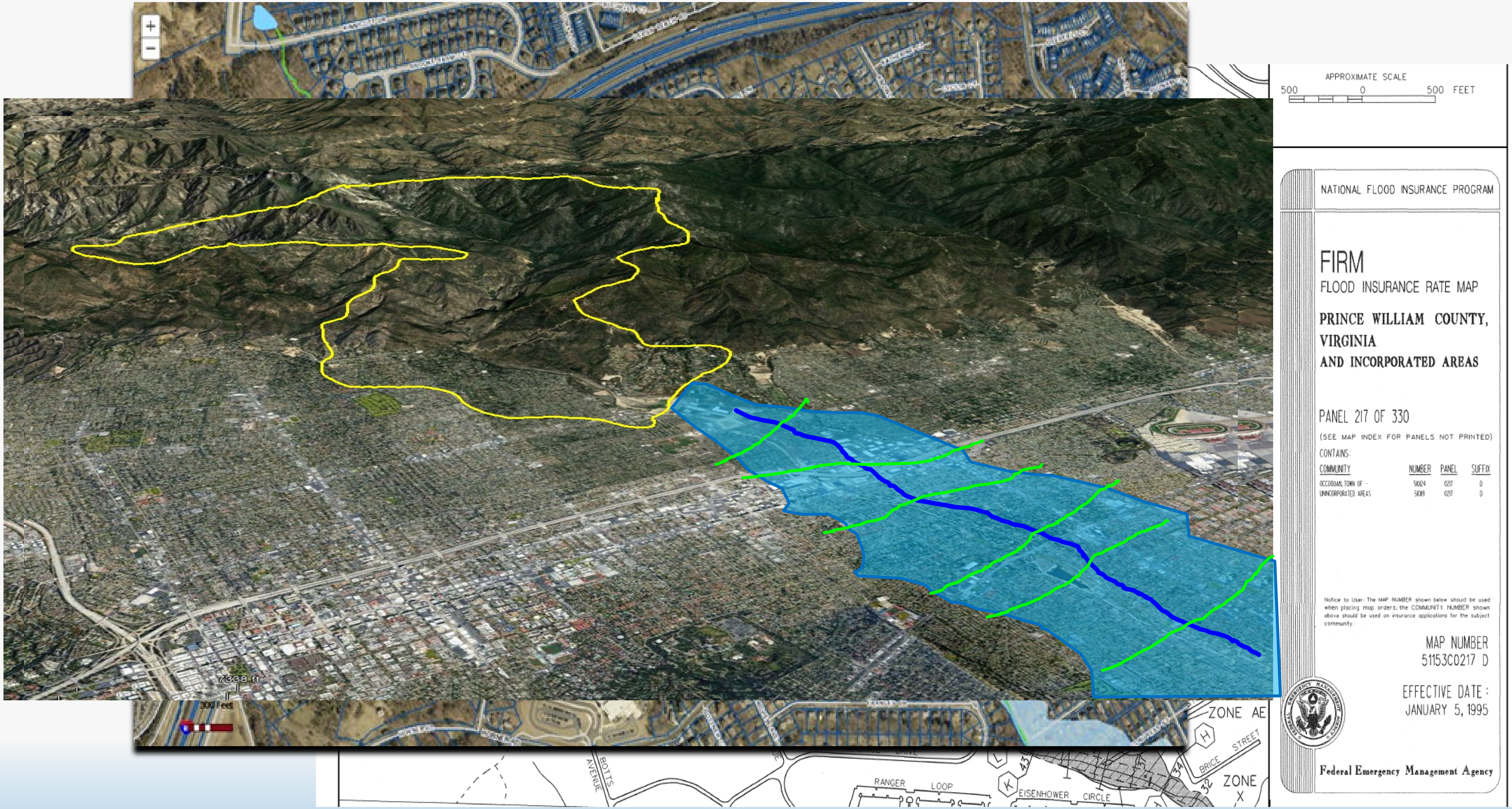
- Current practice to determine flood hazards and risks are not watershed-based
- Fragmented Model
- One-Dimensional Analyses (still)
  - Precipitation
  - Land Use/Cover
  - Soil and Infiltration
- Steady State
  - Peak flow-based design



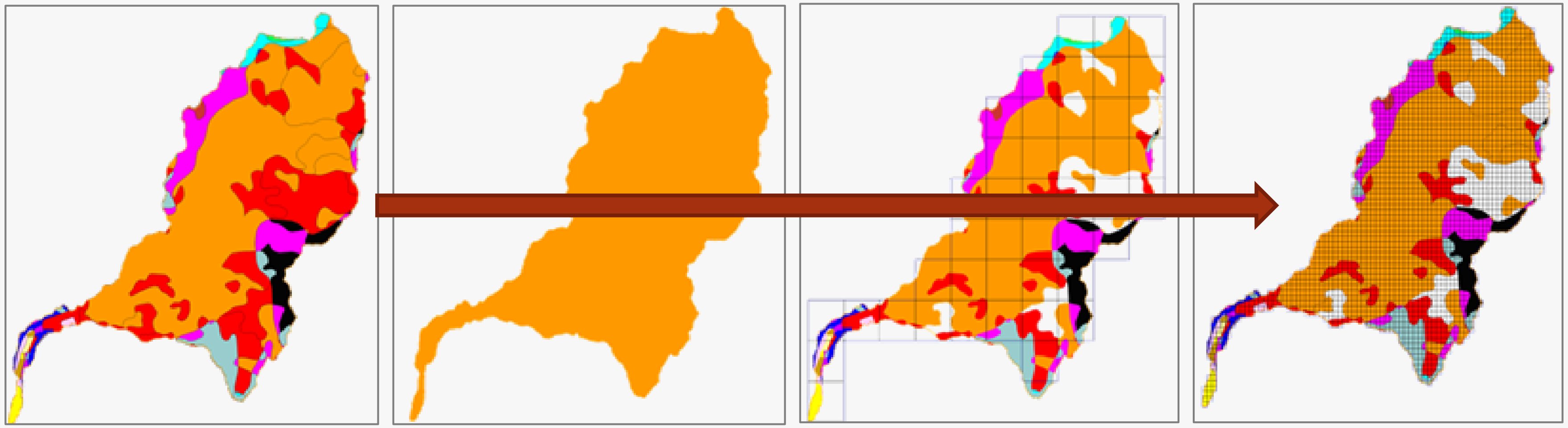


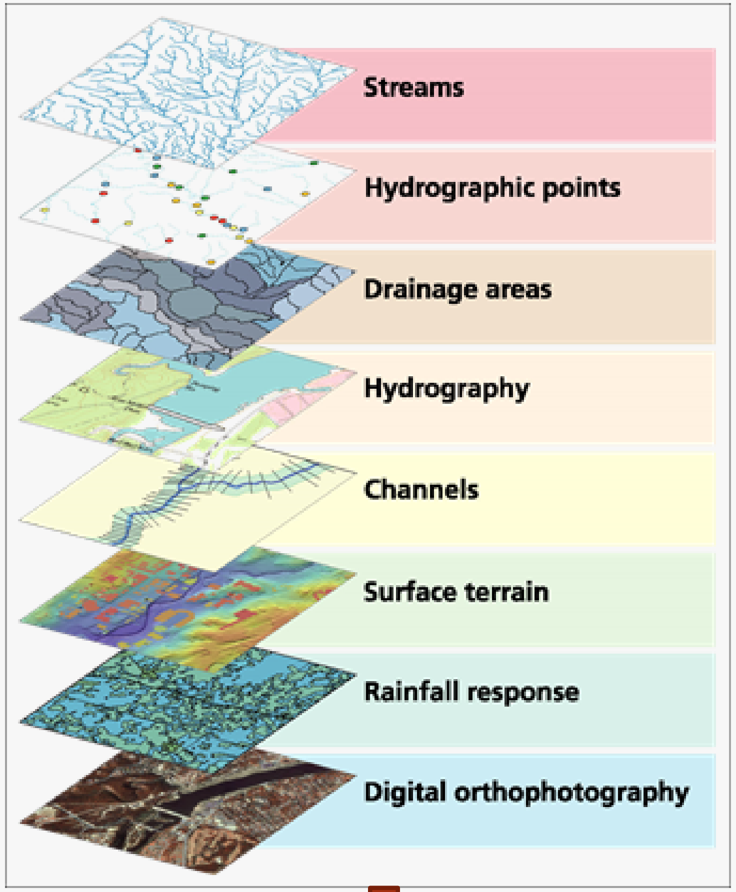
Goal:
Approved FIRM map

Single Use Output



Forward Looking Alternatives



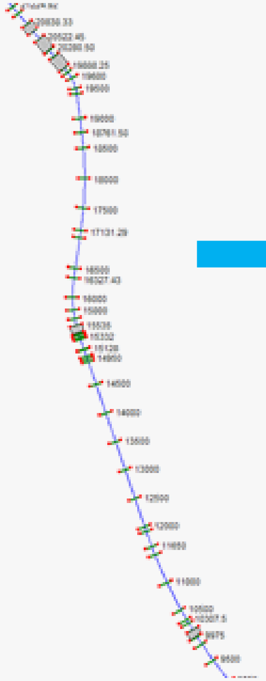


- Integrated watershed response approach instead of river/stream focused approach
- Distributed Model instead of lumped approach
- Abundance of geospatial data available at no cost, at fingertips

  - Models care capable of integrating available data
  - Nowadays, developing Distributed models take less time

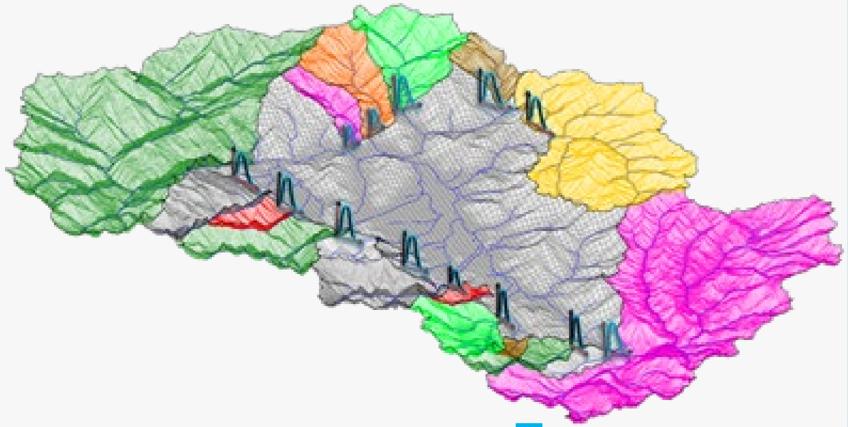
Looking Forward Alternatives

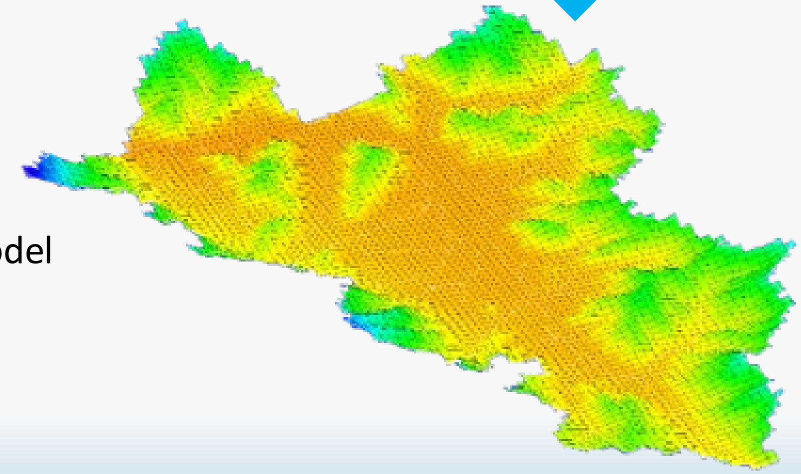
- Develop watershed based integrated response models
  - Distributed models
  - Rain on grid
  - Interconnected watershed-floodplain-riverine system models
- Develop models
  - Not just for map preparation
  - Build them as re-usable tools that can help
    - Identify source of flooding
    - Evaluate future land use scenarios
    - Hydraulic Design of crossings, conveyance and storage facilities
    - Identify source of TMDL
    - and so on…
  - Build scalable models – that can be used at various size watersheds and floodplains
  - Integrated – so that change in one component of the watershed would not break the model
- Let’s discuss three example applications



1D

Semi Distributed

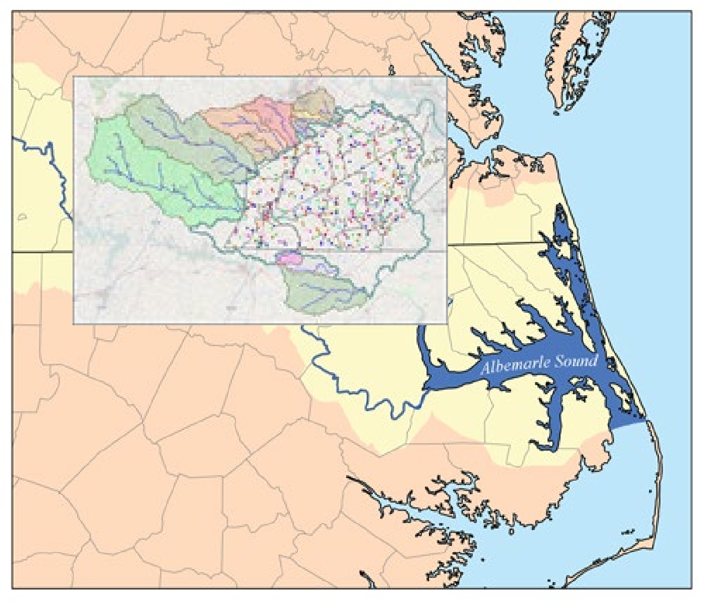




Distributed

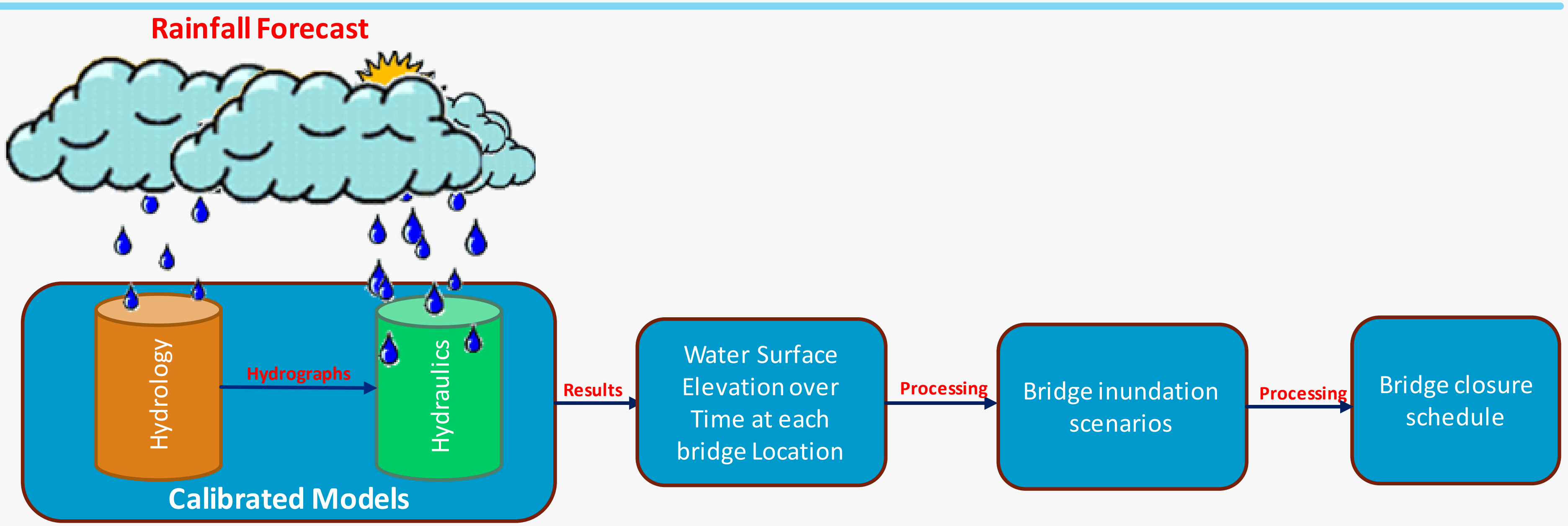
VDOT – Regional River Severe Storm (R2S2) Model

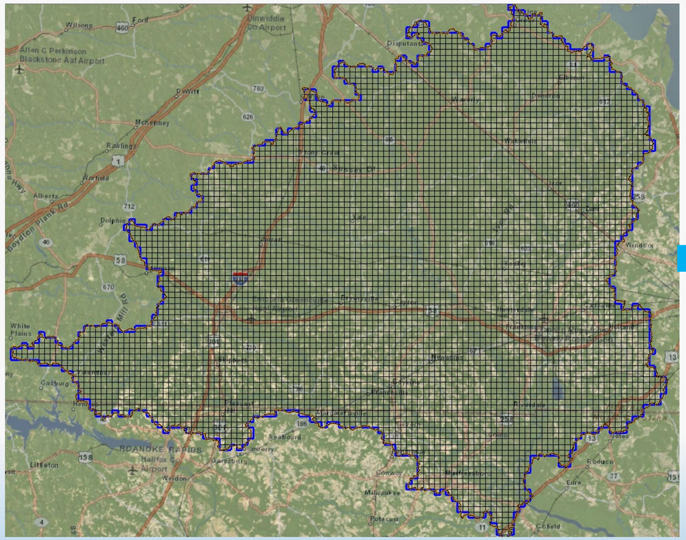
- Developed VDOT – Hampton Roads District, very Large watershed
  - Three River Systems – Nottaway, Meherrin and Blackwater
  - Total watershed area ~ 4,240 sq miles
  - 2D Domain ~ 2,200 sq miles
  - 498 bridges/culverts, 8 meteorological stations, 5 counties
- Integrated Hydrology and Hydraulic Model
  - Distributed
  - Rain On Grid
  - Interconnected Watershed – Floodplain – River
- Primary objective
  - Develop a flood forecasting system to Identify bridges at high flood risk
- Additional usage
  - Identify flood contributors
  - Identify potential solutions
  - Use the model to evaluate impact on the system caused by future development
  - Use the model results in emergency management and planning

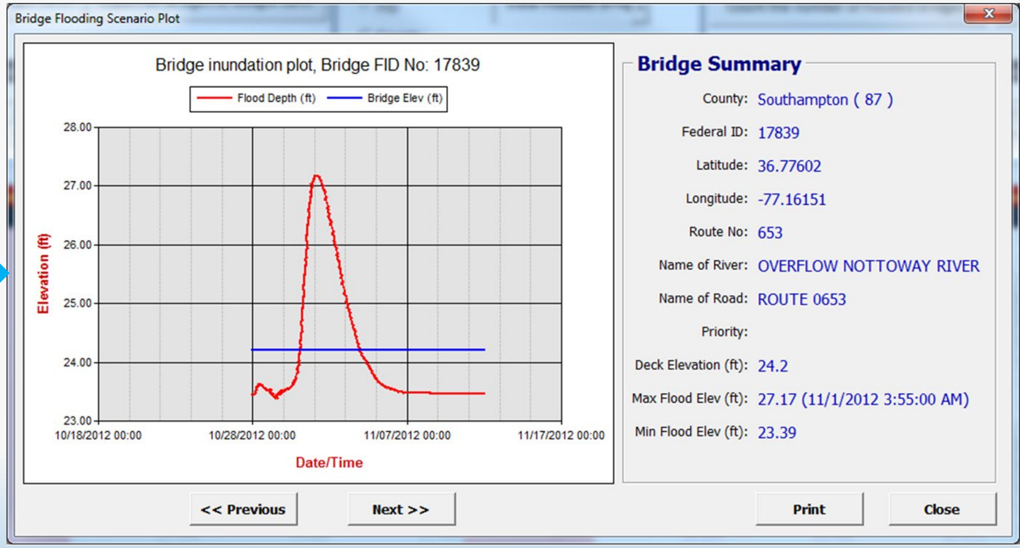


VDOT – R2S2 Model

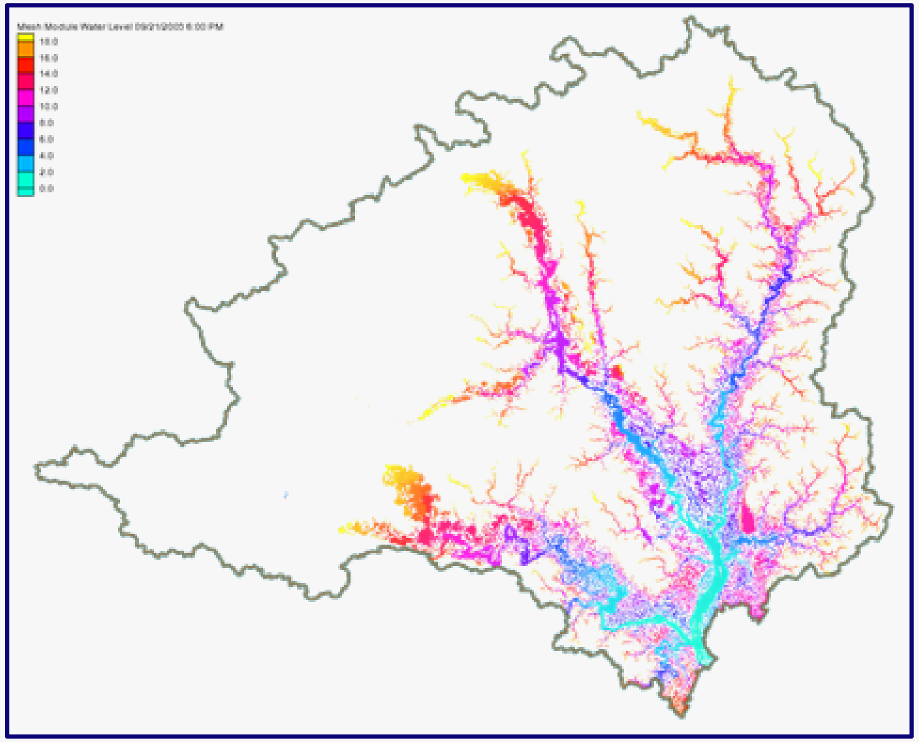
- Hydraulic Model
- 50m grid cells
- 2.3 million cells
- Channel cross sections at each bridge site
- Roadway profile on both side of each bridge
- IDW rainfall grid derived from NOAA rain gage data
- Hydrograph inflow from 11 hydrologic basins
- Spatially varying overland roughness







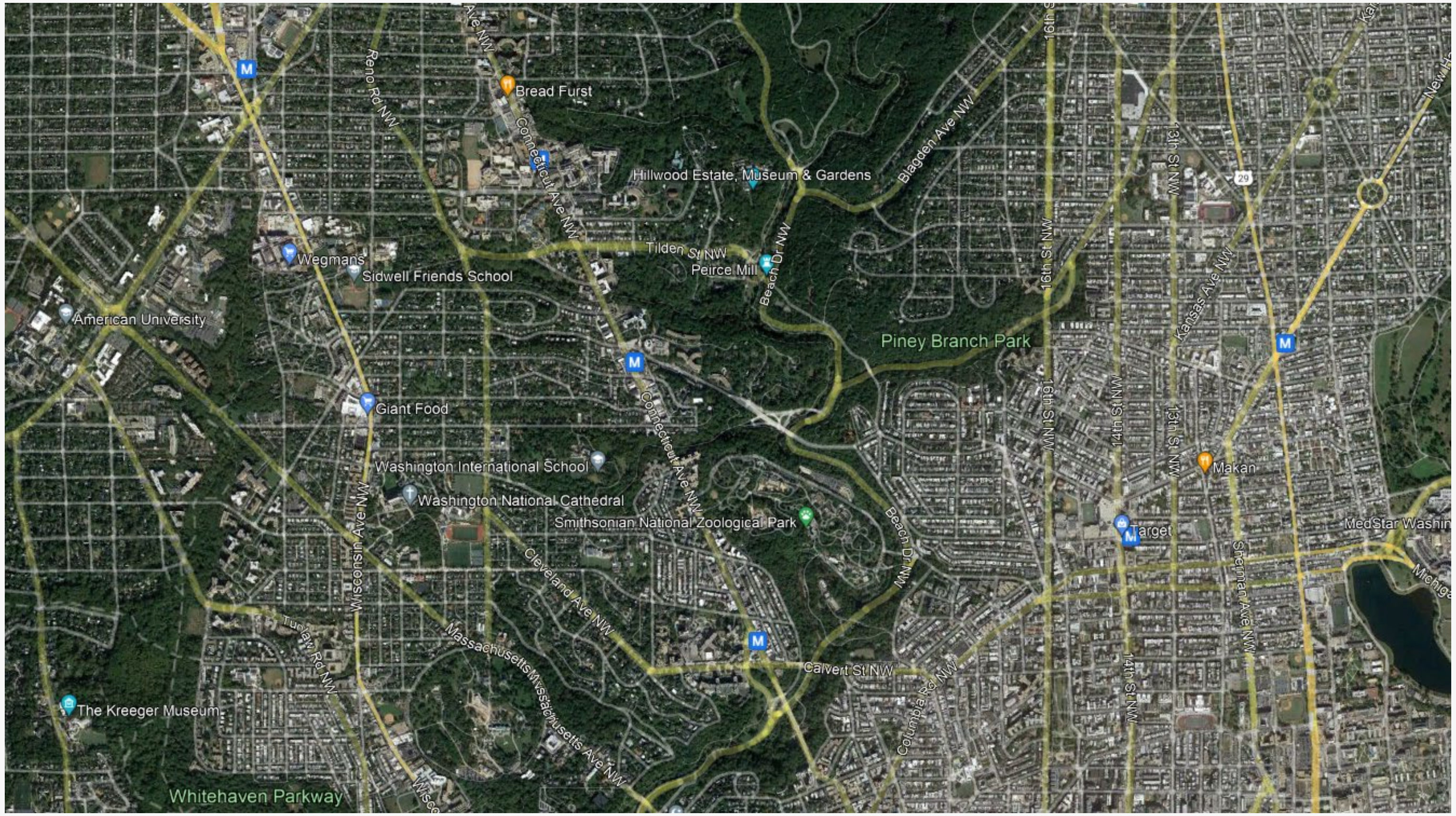
VDOT – R2S2 Model



- Result available everywhere within the model domain
    - Overland flow depth
    - Water Surface Elevation
    - Flow Velocity
    - Flow Direction etc

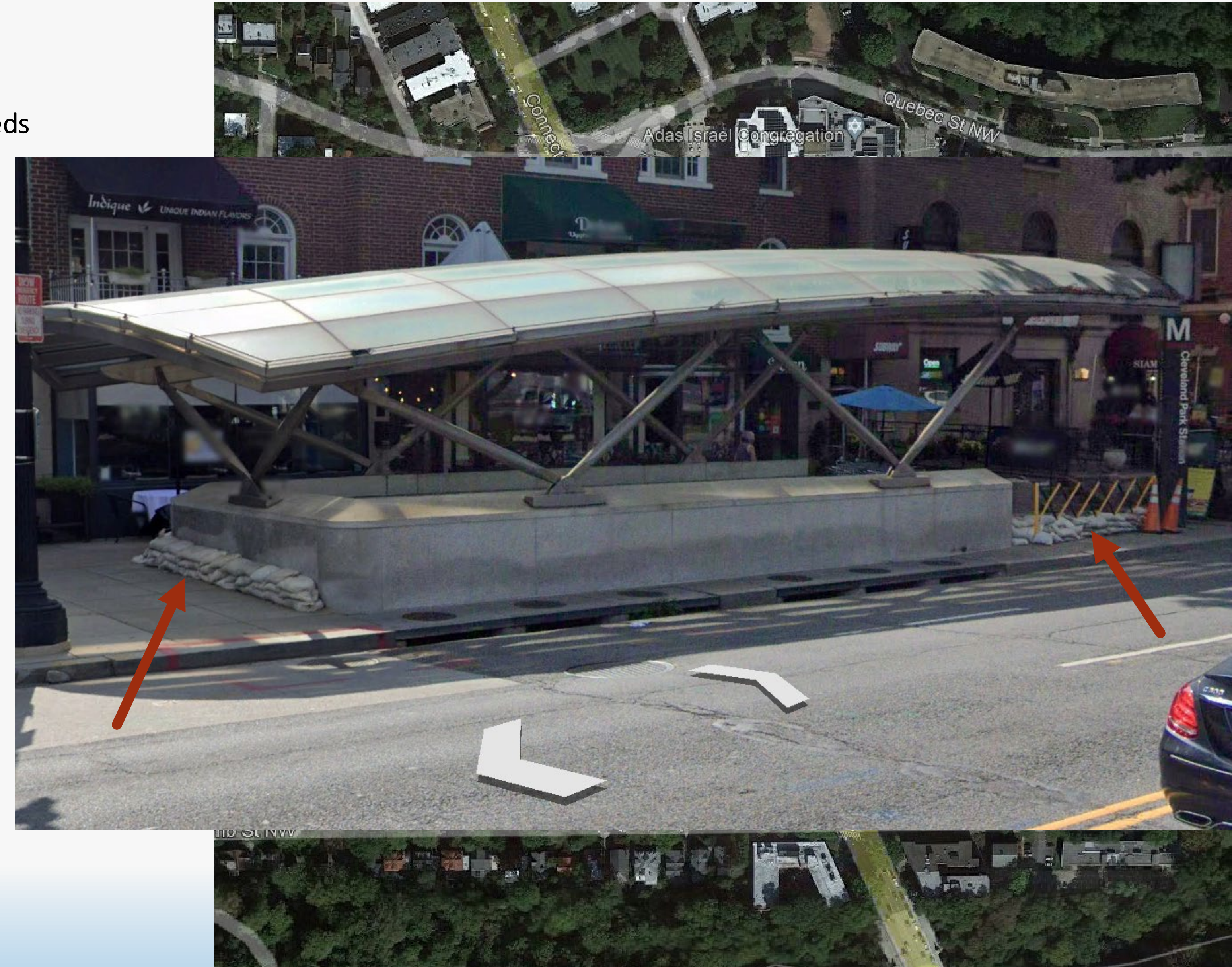
Cleveland Park Drainage Improvement

- Urbanized small watershed – Washington DC
  - Mixed land use
  - Overland and underground drainage driven
  - Large and complex drainage system
- Integrated Hydrology and Hydraulic Model
  - Distributed
  - Rain On Grid
  - Interconnected Watershed – Floodplain – Storm Drain - Creek
- Primary objective
  - Flood mitigation at Metro Station
- Additional usage
  - Identify flood contributors
  - Identify potential solutions, green infrastructure
  - Use the model to evaluate impact on the system caused by future development



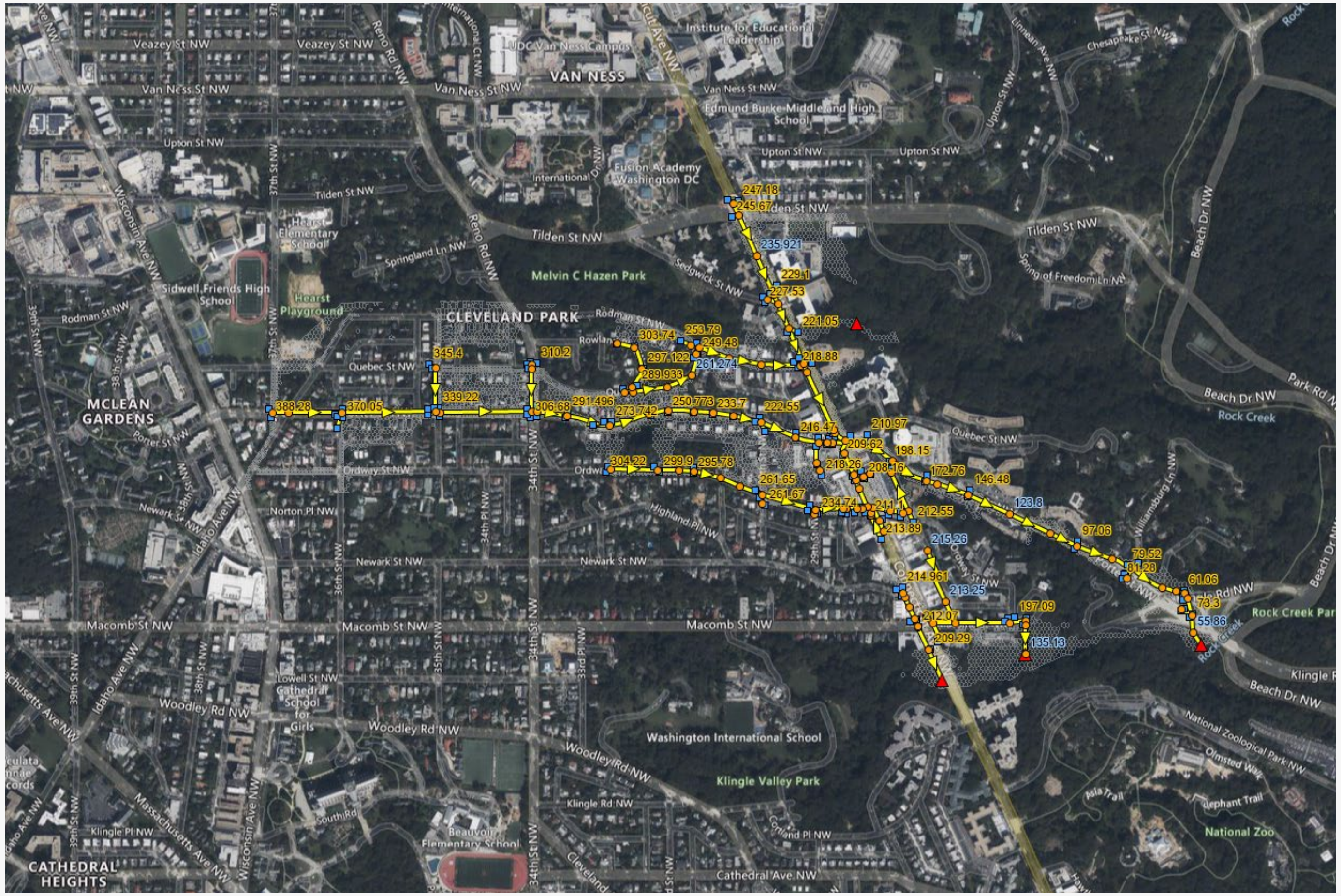
Cleveland Park Drainage Improvement

- Recurring flooding at the metro-station
  - Aged storm drain system
  - Designed to cater several decades old drainage needs
- Source of flooding
  - Insufficient pipe capacity?
  - Insufficient and inefficient inlets?
  - Overland runoff
- Is the design storm the same?
  - Assumption of stationarity
  - Climate change has anything to do?
- Conventional solution?
  - Throw in 5 inlets in a row?
  - Enlarge the pipe wherever you can?
  - Steady state modeling
- Smart Solution
  - Holistic approach, big-picture assessment
  - Green infrastructures



Cleveland Park Drainage Improvement

- Highly Urbanized small watershed – City of Falls Church
  - Mixed land use
  - Overland and underground drainage driven
- Integrated Hydrology and Hydraulic Model
  - Distributed
  - Rain On Grid
  - Interconnected Watershed – Floodplain – Storm Drain - Creek
- Primary objective
  - Flood mitigation
- Additional usage
  - Identify flood contributors
  - Identify potential solutions
  - Use the model to evaluate impact on the system caused by future development



Cleveland Park Drainage Improvement

Terrain Model
- Publicly available LiDAR Data
  - Watershed Delineation
  - Surface characterization

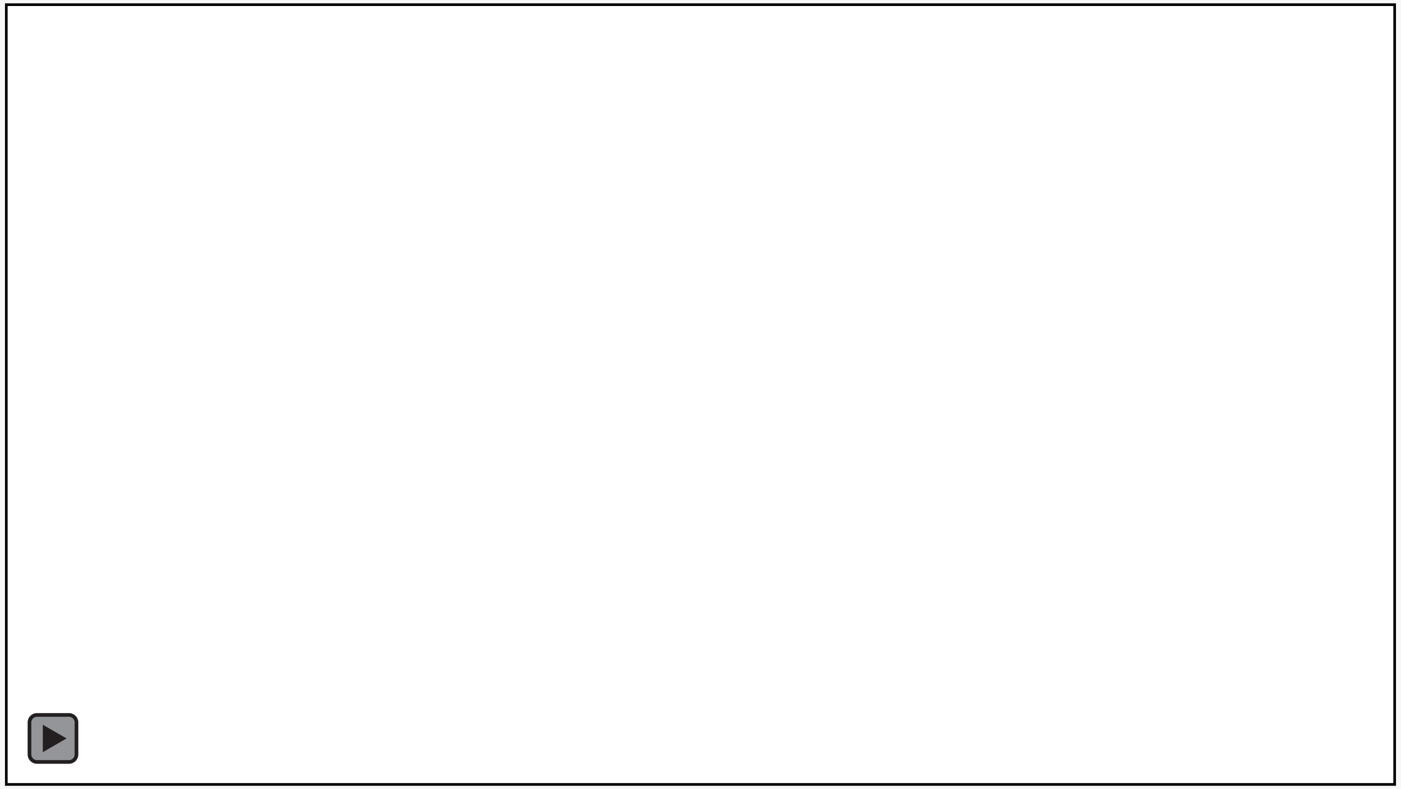
Conveyance System
- Counter maps
- Field Survey
- Aerial Photographs
- LiDAR

System Characteristics
- SSURGO Soil Data
- NLCD Land Cover
- Existing studies

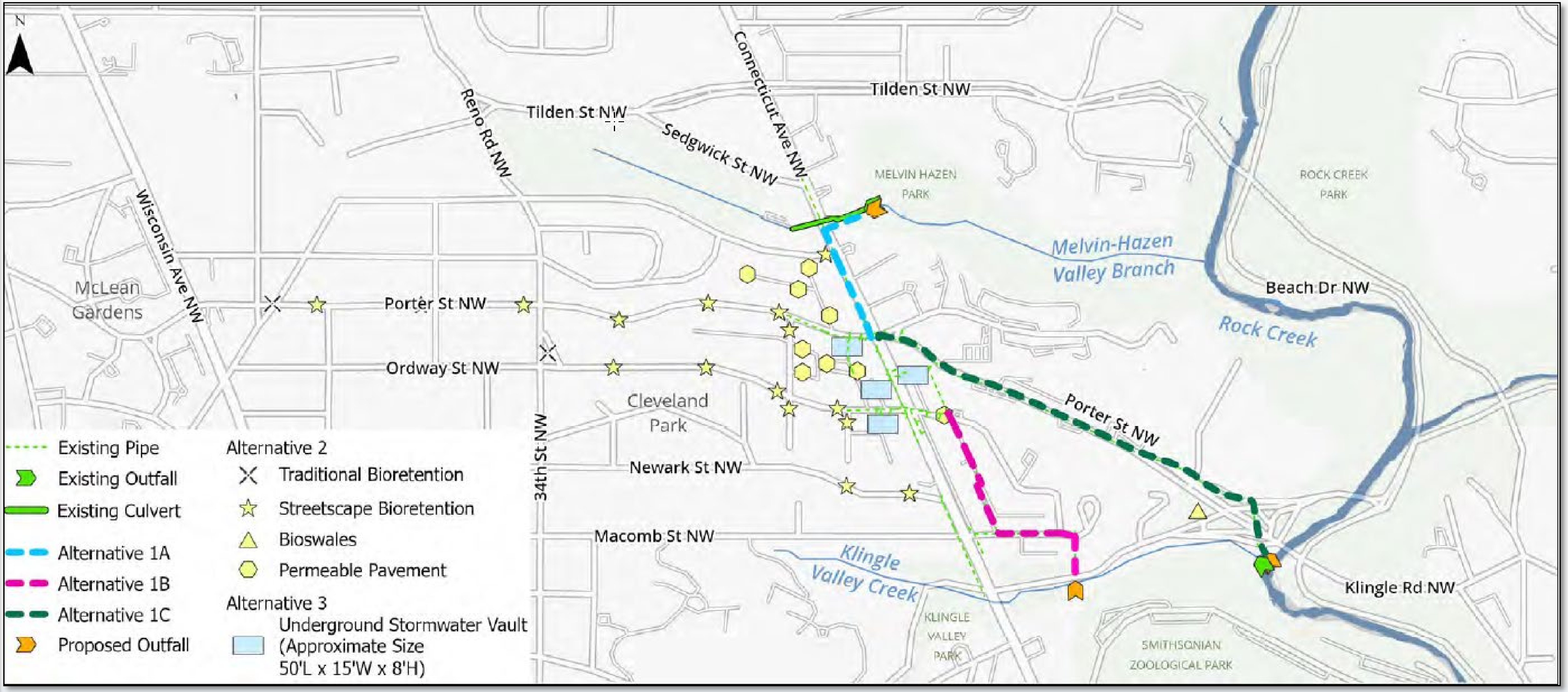
Precipitation
- NOAA Atlas 14 15 year 24 hr

Geospatial Data
- County’s GIS data portal
  - Storm Drain System
  - Existing Waterbodies
  - Building Footprints
  - Outfall locations

- All Publicly available data

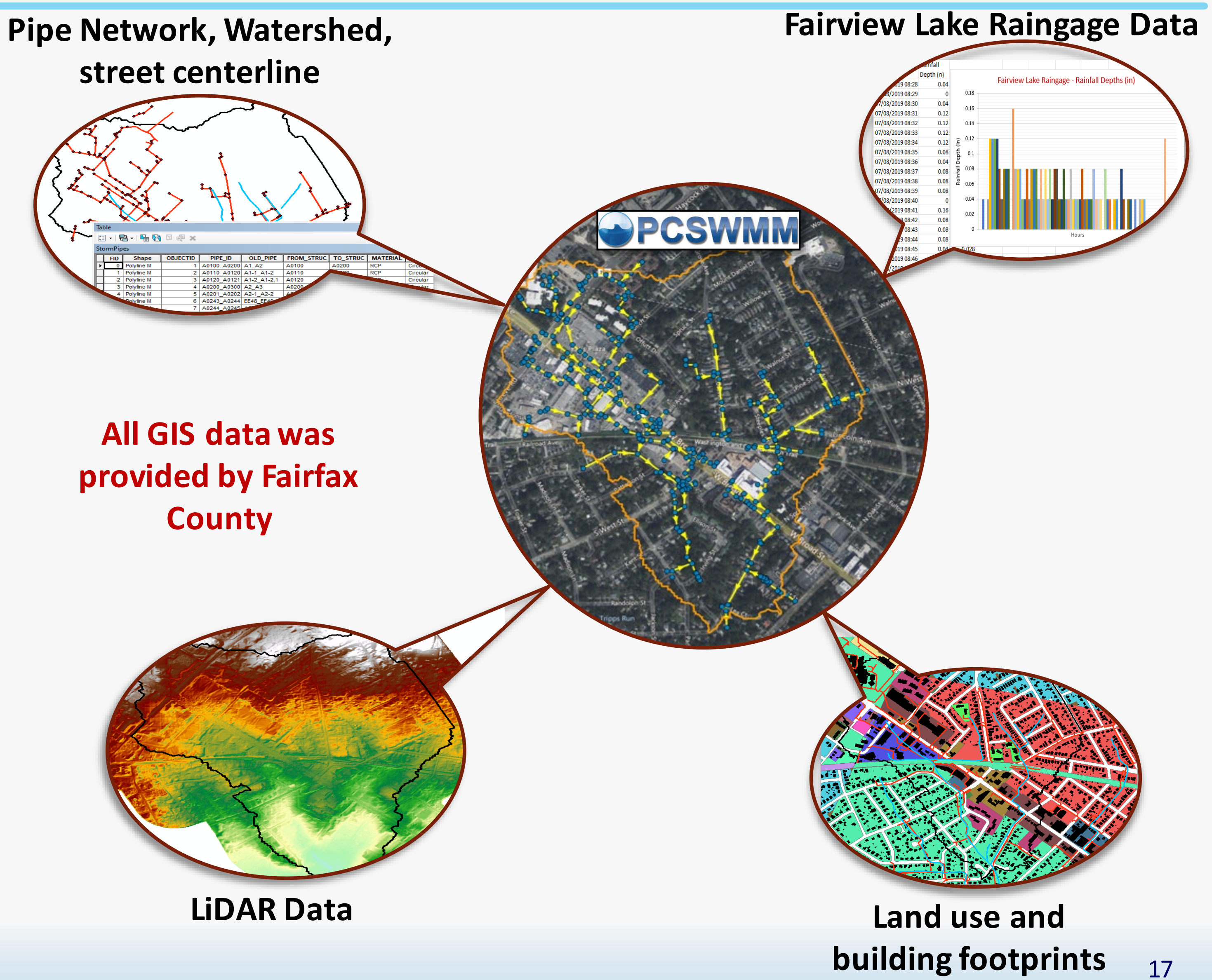


Cleveland Park Drainage Improvement



City of Falls Church – Urban Drainage

- Highly Urbanized small watershed – City of Falls Church
  - Mixed land use
  - Overland and underground drainage driven
- Integrated Hydrology and Hydraulic Model
  - Distributed
  - Rain On Grid
  - Interconnected Watershed – Floodplain – Storm Drain - Creek
- Primary objective
  - Identifying Flooding
- Additional usage
  - Identify flood contributors
  - Identify potential solutions
  - Use the model to evaluate impact on the system caused by future development



City of Falls Church – Urban Drainage

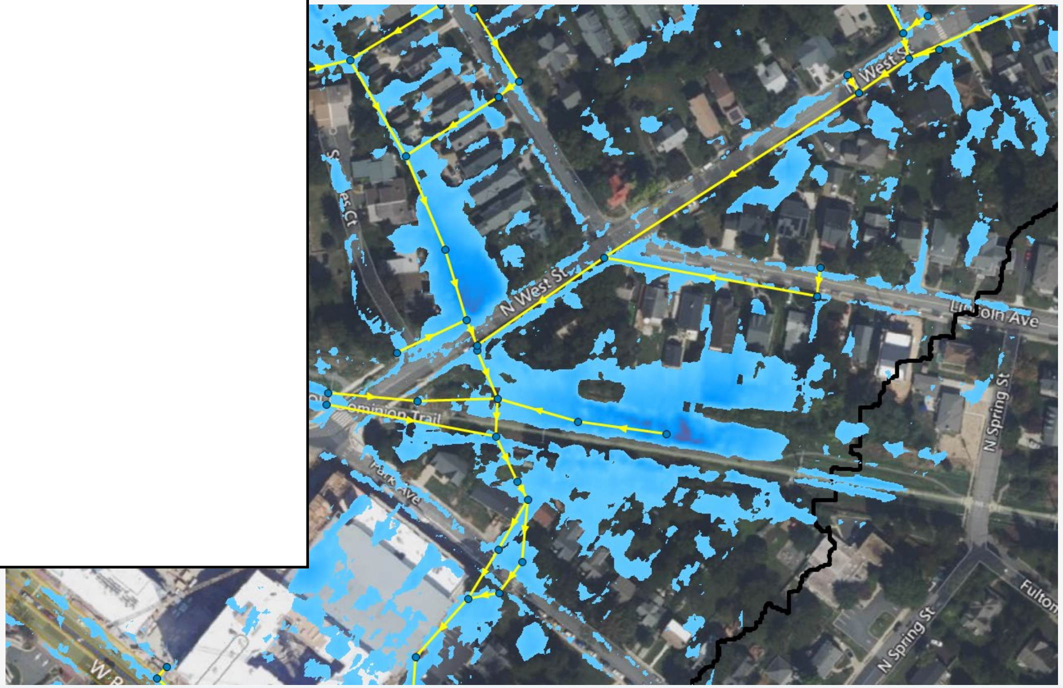
Pipe profile and Hydraulic Grade Line (HGL)

Results from 1D component

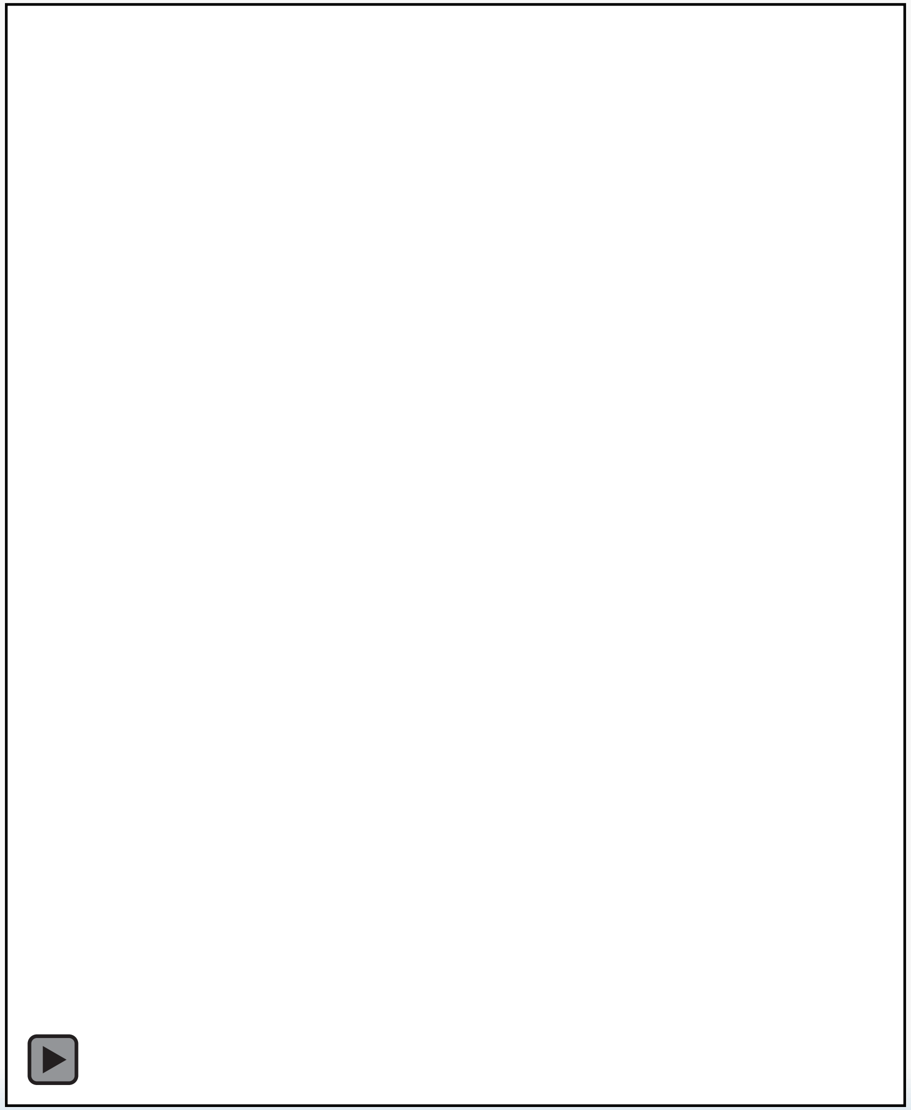
- Storm drain models with 1D node-link can show:
  - Insufficient Pipes
  - Surcharging Inlets and manholes
- But can't tell what happens to the flow once it surcharges onto the overland
- Cannot predict and locate flooding caused by overland flow
- Paints only half the picture

City of Falls Church – Urban Drainage

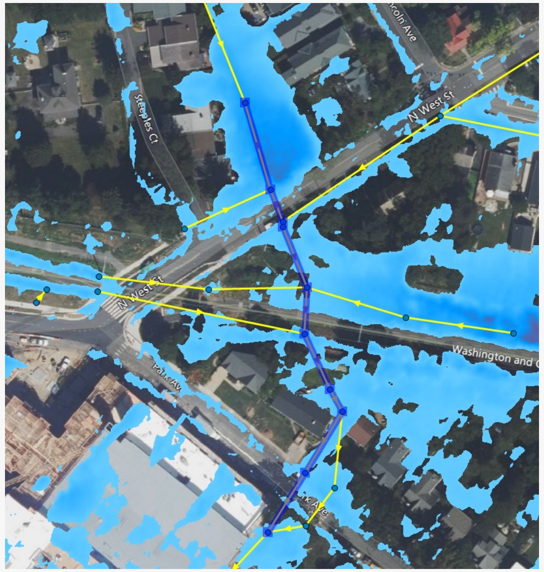
- Identifying source of flooding
  - Pipe surcharge or undersize?
  - Overland flow accumulation?
  - Natural depression – local accumulation?
  - Could we answer all these questions with a simple node/link model?

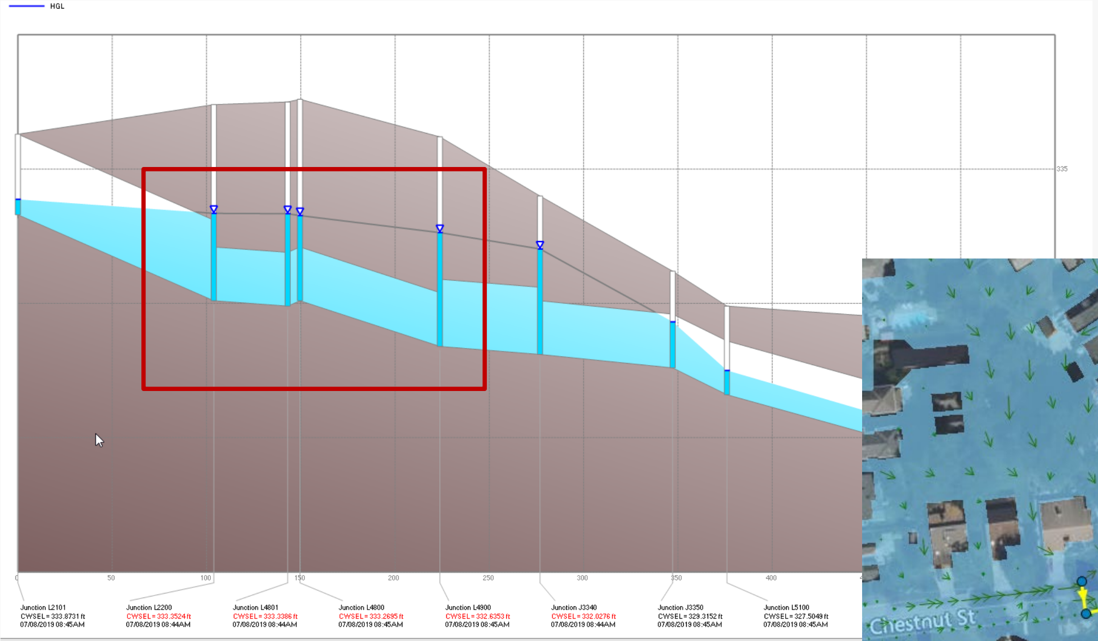


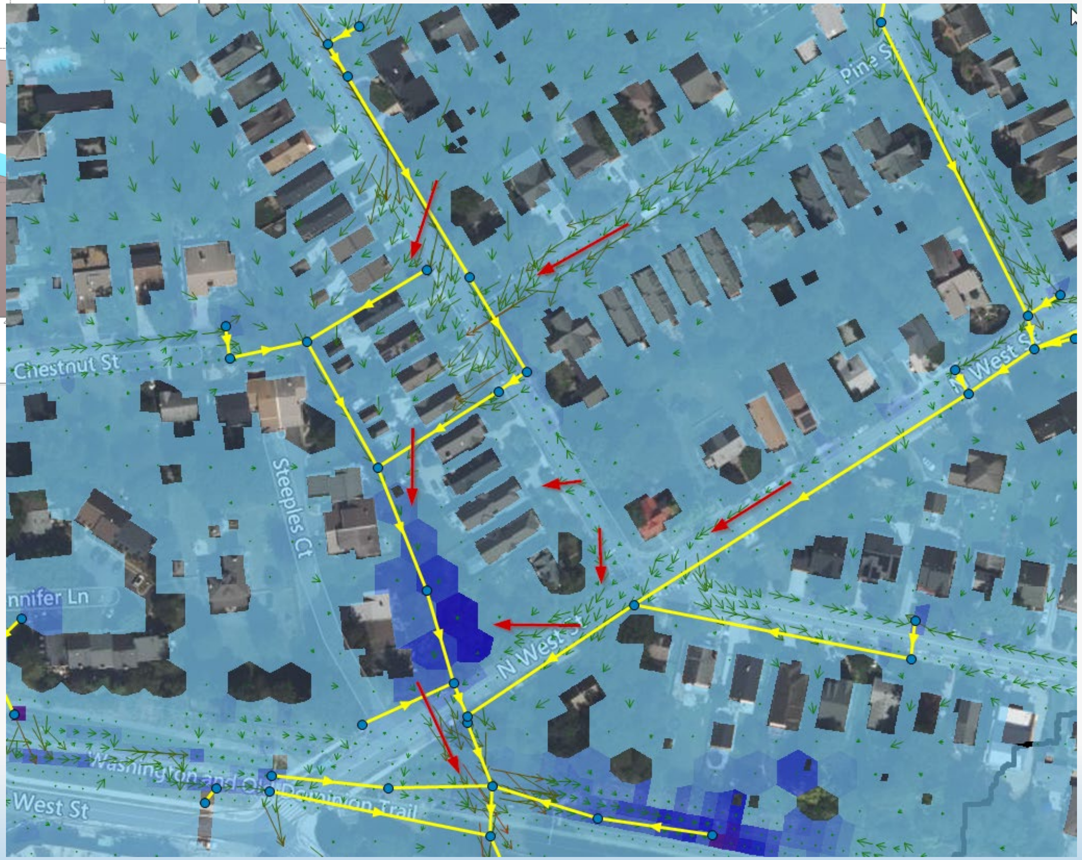
City of Falls Church – Urban Drainage



City of Falls Church – Urban Drainage



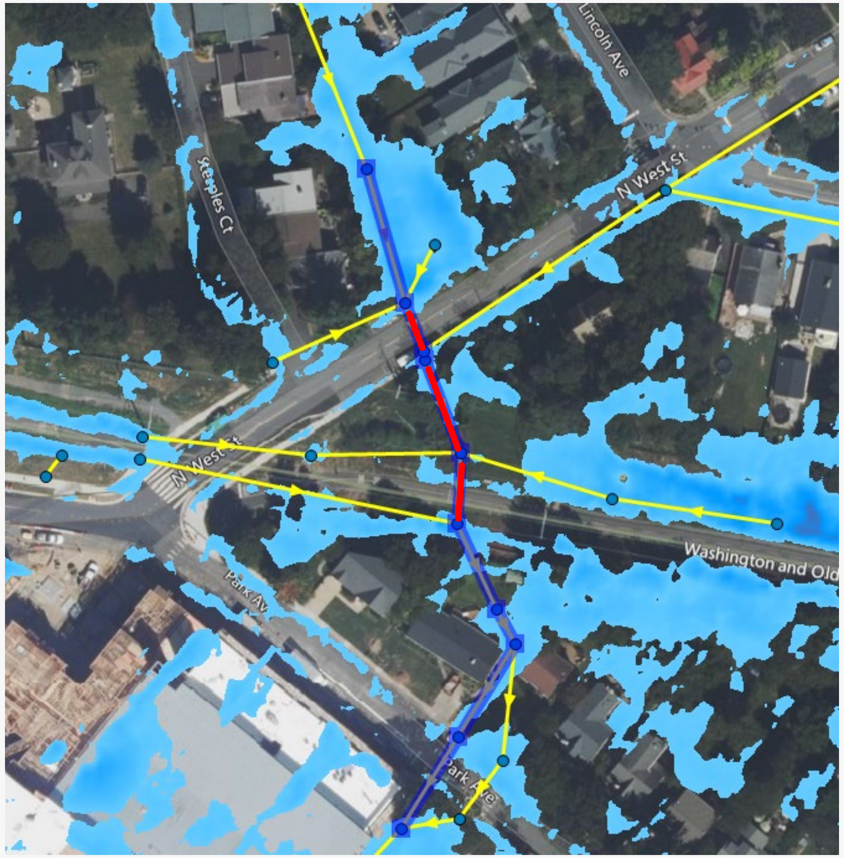


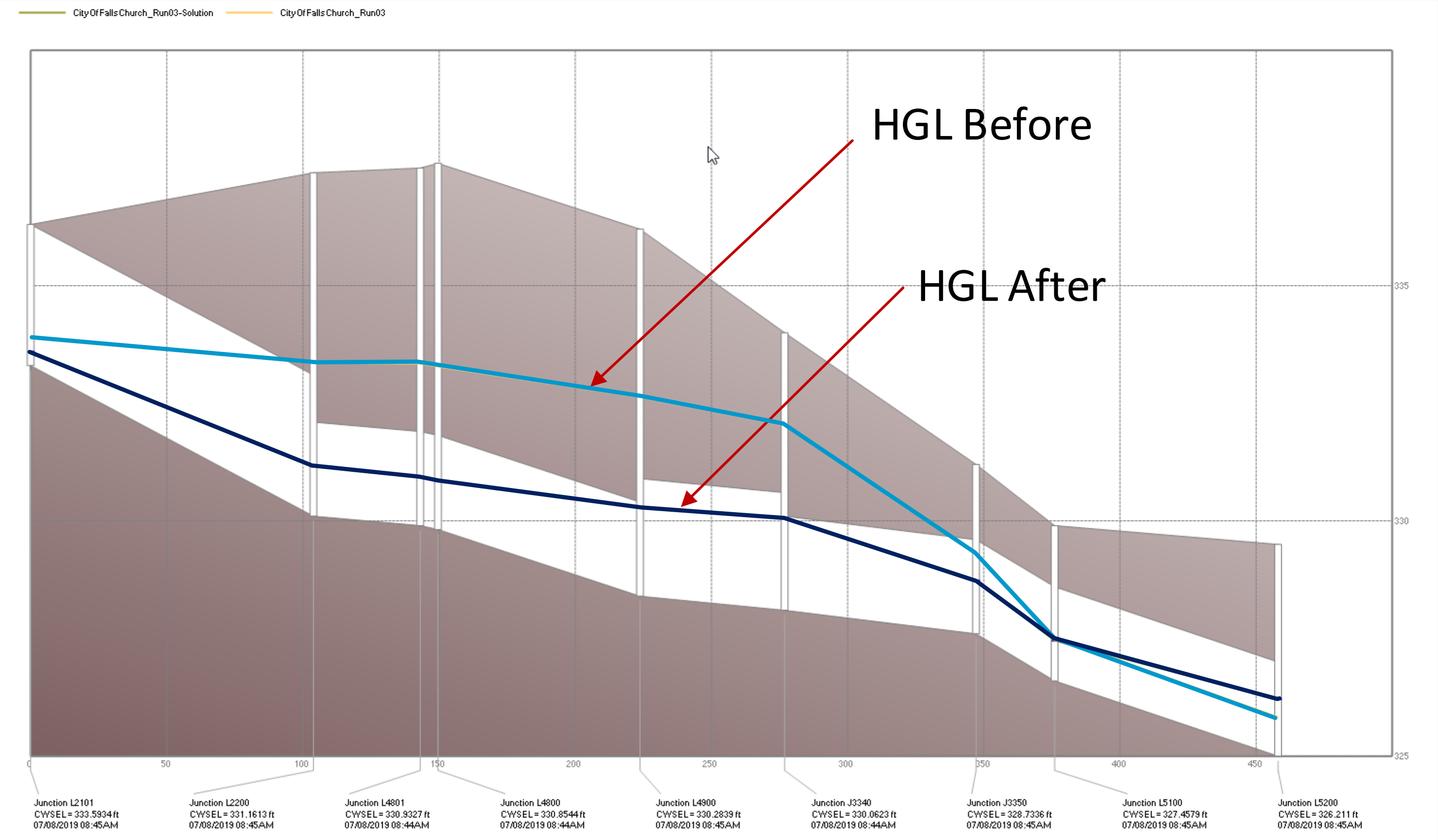


- Dual problem
  - Pipes undersized
  - Overland flow accumulation
- Model as a Tool
  - Run multiple scenarios with alternative mitigation measures
  - Geo-spatial visualization – effectiveness of mitigation

City of Falls Church – Urban Drainage

- Increase Pipe Capacity (additional barrels)
- Add inlet to capture overland accumulation





City of Falls Church – Urban Drainage

Before

After

- Primary source of flooding:
  - Overland flow from Steeples Ct, N West Street and Lincoln Ave
  - Pipe crossing N West St reduces in size as it goes downstream
  - Overland flow accumulation (no inlet to capture the accumulated flow)

- Solution
  - Increase pipe capacity –additional barrels
  - Add an inlet and a lateral
  - Flooding behind those homes reduced from 4ft to 1.1ft

Take away

- Extreme precipitation events and flooding are not going to go away
  - May get worse because of climate change
- We can improve the way we are solving our flooding problems
  - Move beyond flood maps
  - Develop integrated models which are
    - Scalable
    - Reusable
    - GIS integrated
    - Adaptable to new changes
- Distributed modeling with rain on grid
  - Can be applied to various size watersheds with various level of complexities
  - Technology has evolved such that is now easier to set up these models than to stick to node/link model
- Use the geospatial data that's out there!
  - State, County, City – Public GIS data inventories
  - USGS, NWS, NOAA, Universities, Consortiums
- Resilient infrastructure that can
  - Respond to extreme rainfall events
  - Adapt to new climatological and system variables

Questions?

Contact us:

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Floodplain Mitigation and Strategies for Resiliency

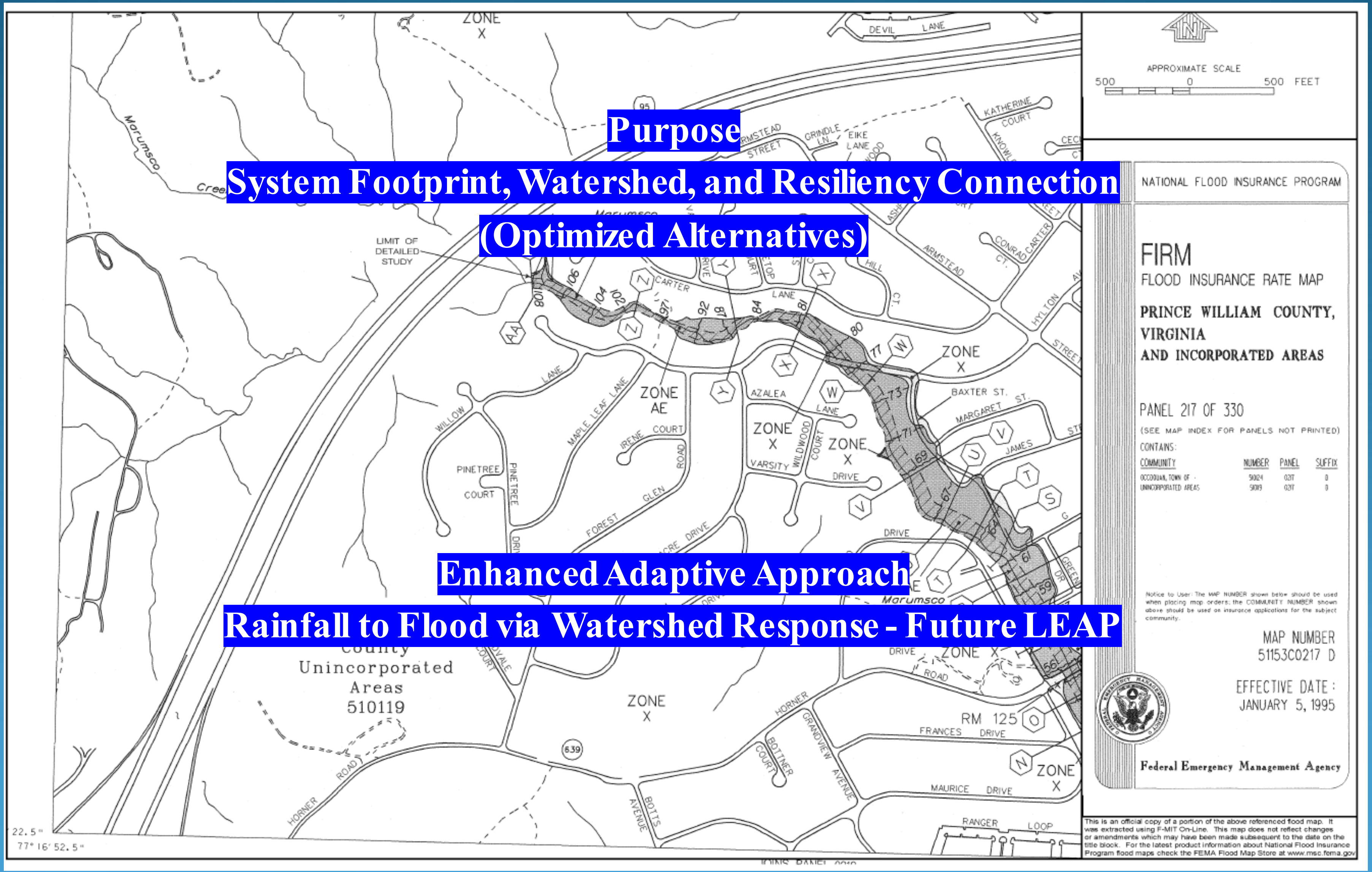
Floodplain Mitigation and Strategies for Resiliency

Flood Resiliency via the sum of mitigative measures throughout the watershed

Purpose

System Footprint, Watershed, and Resiliency Connection

(Optimized Alternatives)



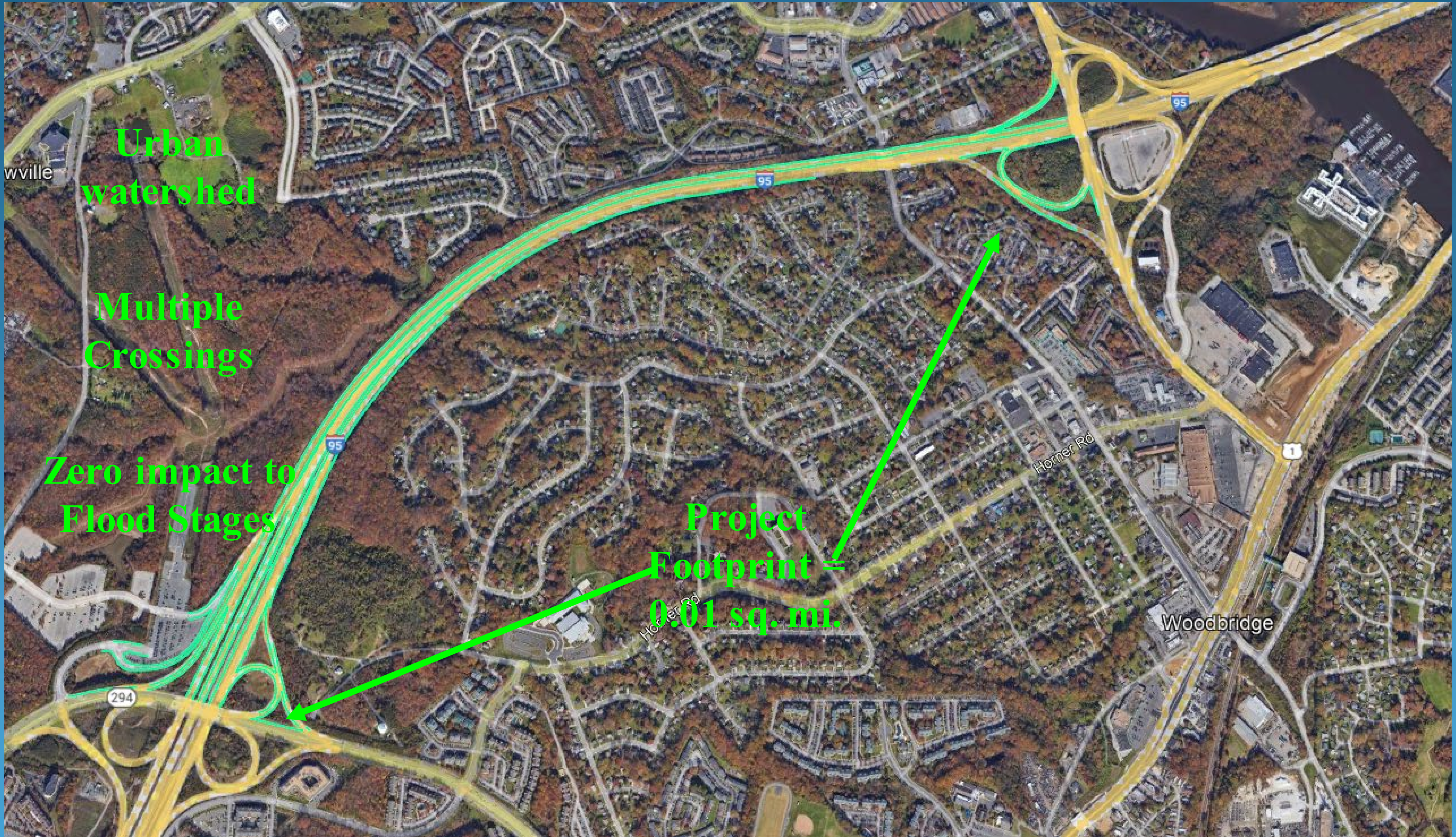
Enhanced Adaptive Approach

Rainfall to Flood via Watershed Response - Future LEAP

Floodplain Mitigation and Strategies for Resiliency

I-95 SOUTHBOUND AUXILIARY LANES

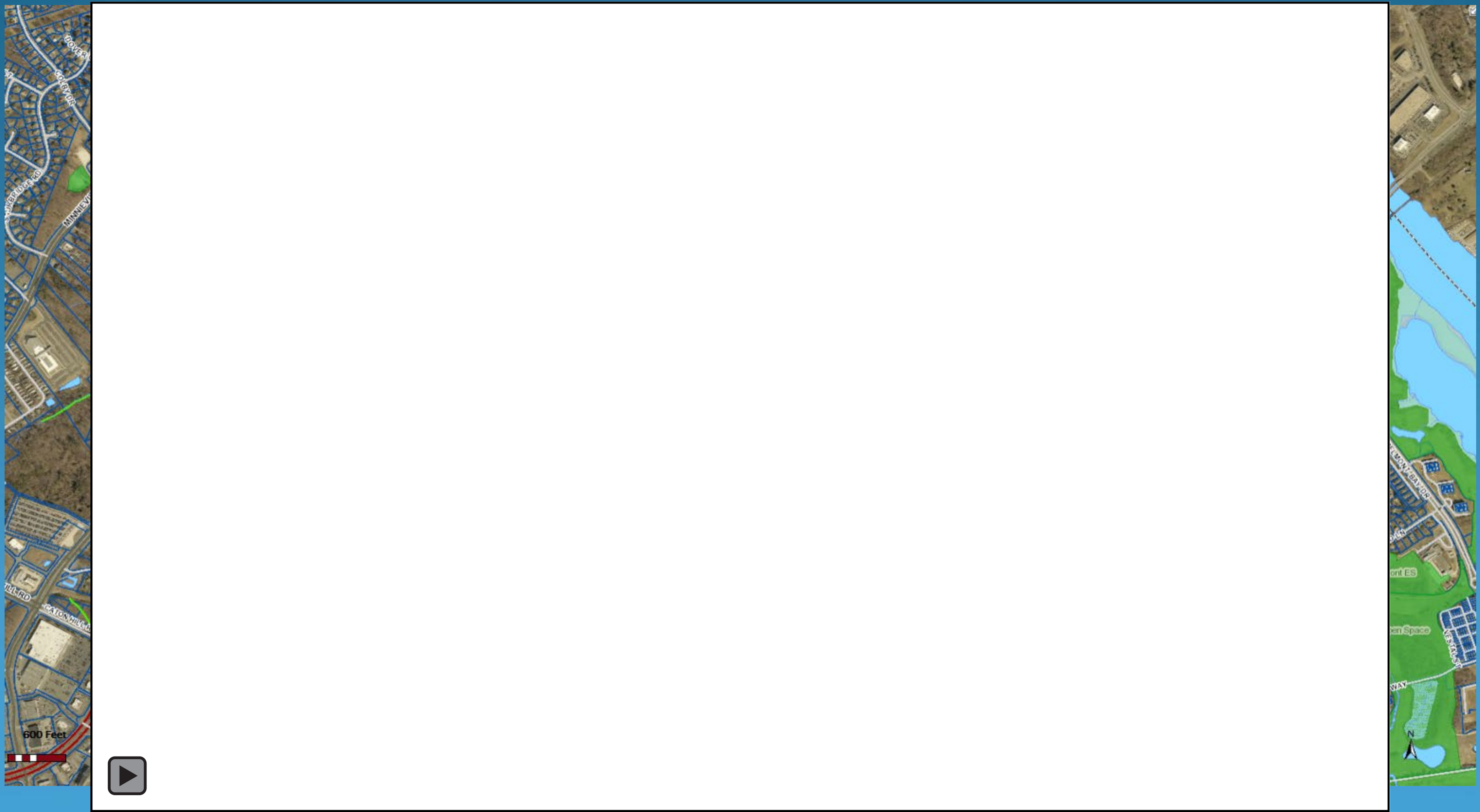
Roadway Widening and Culverts' Extensions over Marumsco Creek



Floodplain Mitigation and Strategies for Resiliency

I-95 SOUTHBOUND AUXILIARY LANES

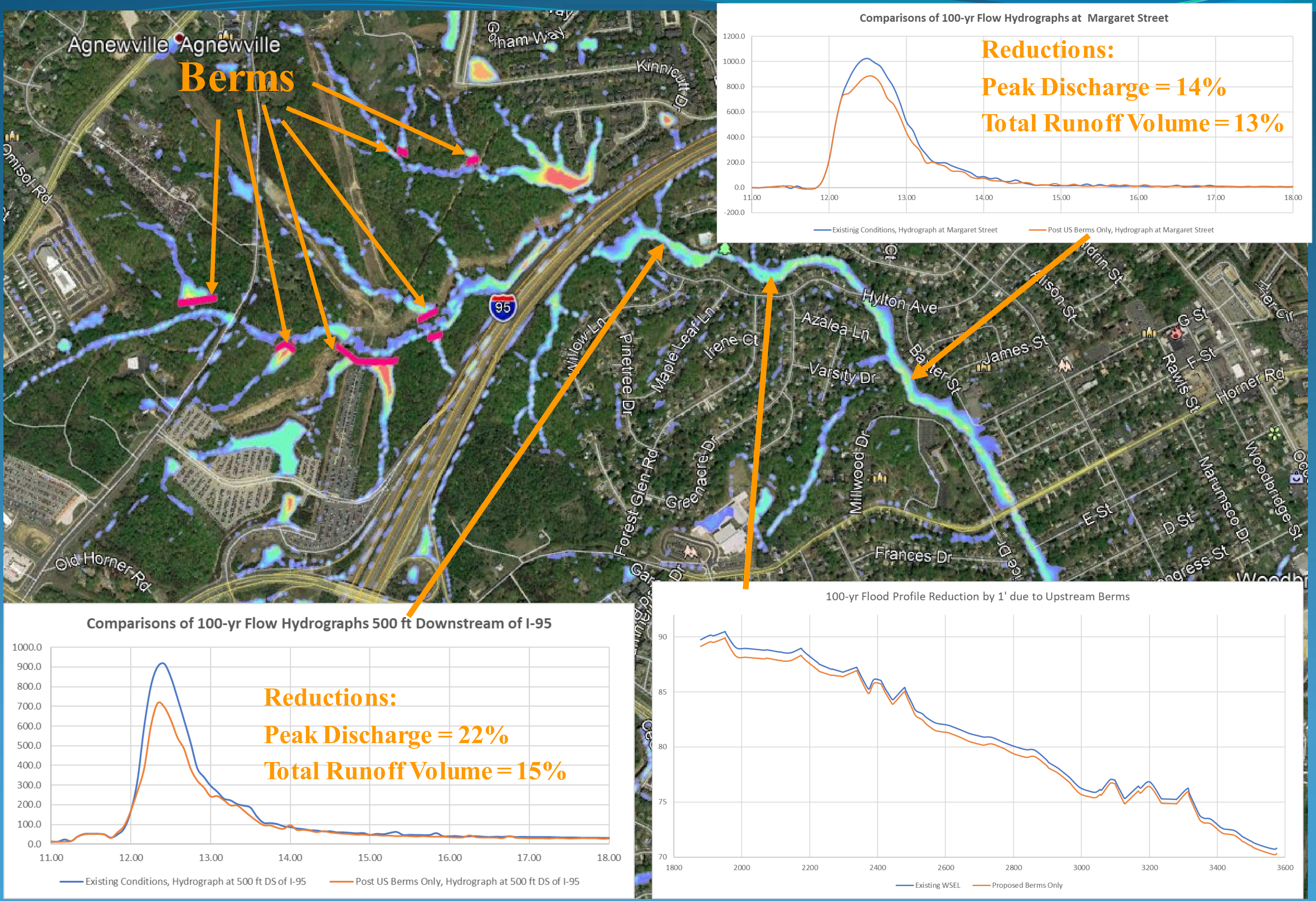
Ground data = Prince William County GIS Portal Site, 2 ft contour



Floodplain Mitigation and Strategies for Resiliency

I-95 SOUTHBOUND AUXILIARY LANES

Floodplain Mitigation and Strategies for Resiliency



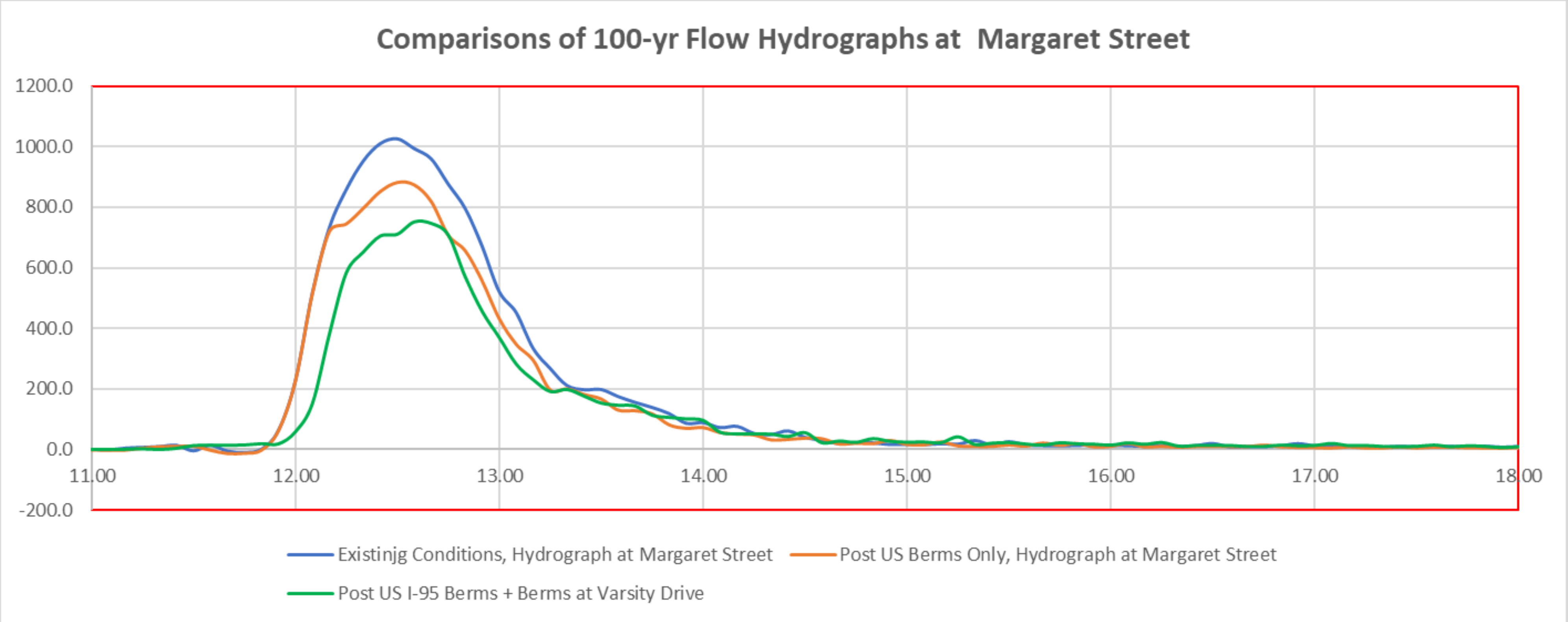
Floodplain Mitigation and Strategies for Resiliency

I-95 SOUTHBOUND AUXILIARY LANES (2019 - 2020)

Zero Impact to Existing Flood Stages

Comprehensive Watershed Floodplain Map, including small streams & tributaries

Flexible flood resiliency optimization



Floodplain and Strategies for Coast Installation Resiliency

Lesner Bridge Replacement Project
City of Virginia Beach, VA (2008 – 2018)

Floodplain and Strategies for Coast Installation Resiliency

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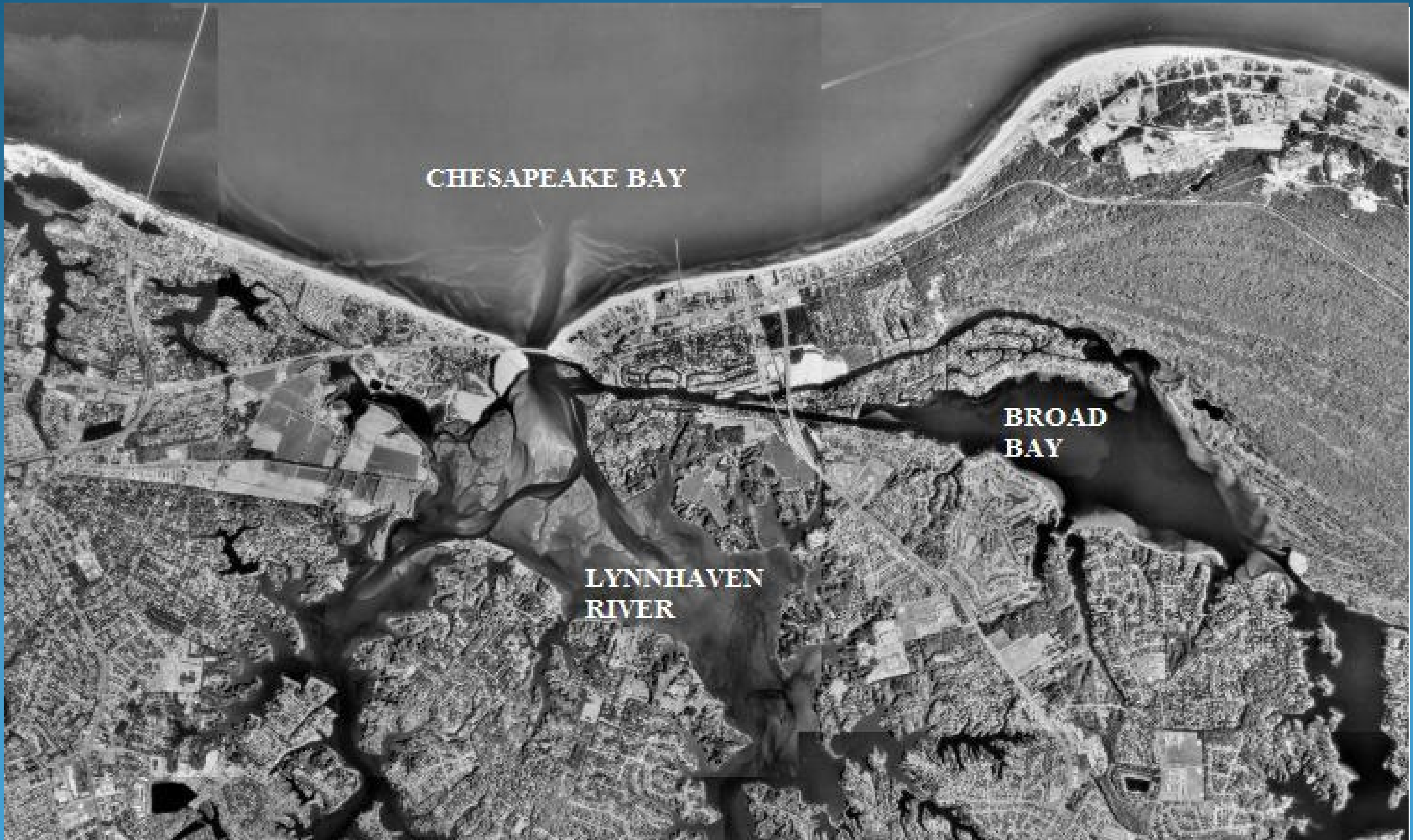
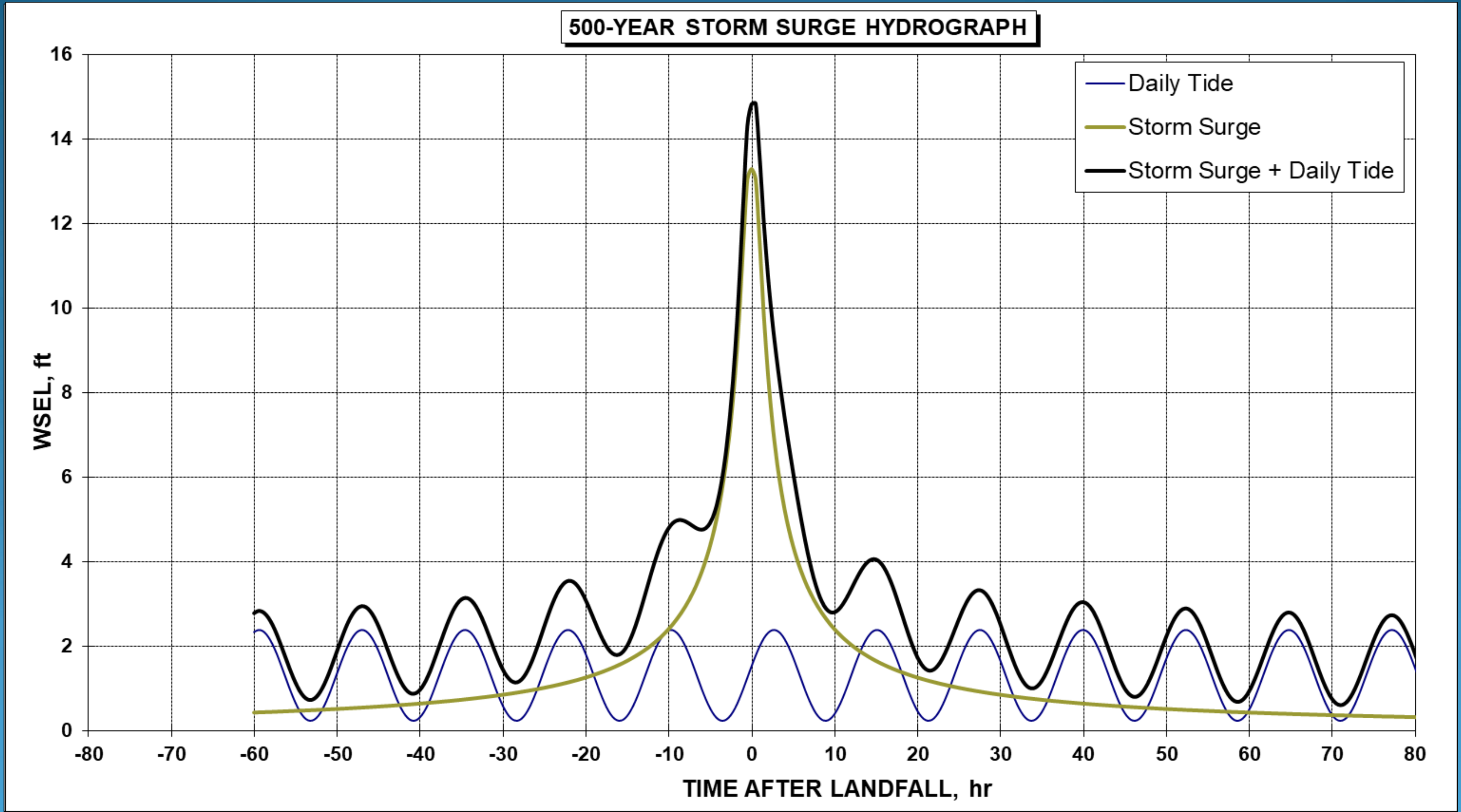
Floodplain and Strategies for Coast Installation Resiliency

Lesner Bridge Replacement Project
City of Virginia Beach, VA (2008 – 2018)



Floodplain and Strategies for Coast Installation Resiliency

Lesner Bridge Replacement Project
Combined Storm Surge + Sea Level Rise (2100)



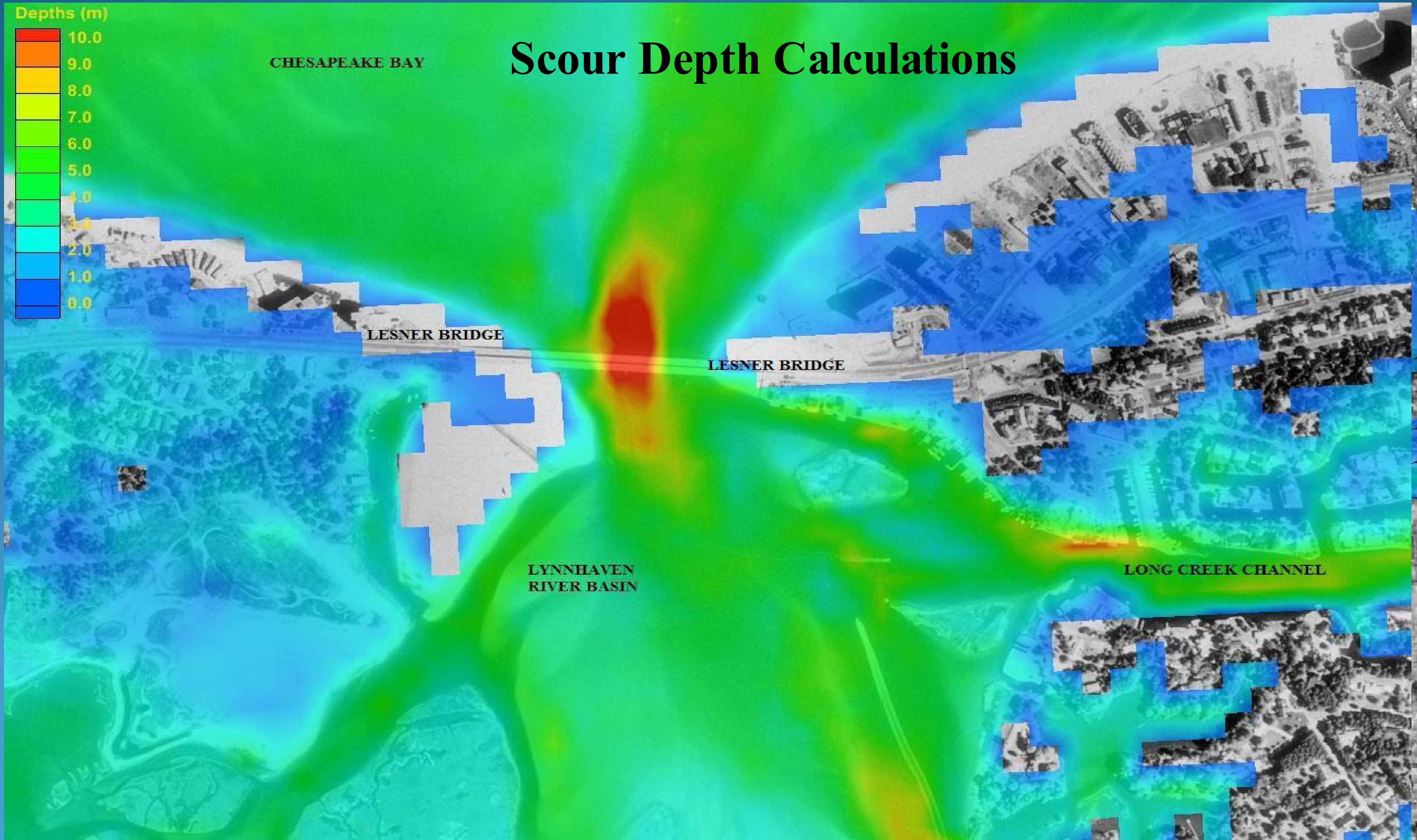
Floodplain and Strategies for Coast Installation Resiliency

Lesner Bridge Replacement Project

System Footprint = 45 sq. mi.

Floodplain and Strategies for Coast Installation Resiliency

Lesner Bridge Replacement Project
City of Virginia Beach, VA (2008 – 2018)



Floodplain and Strategies for Coast Installation Resiliency

Lesner Bridge Replacement Project
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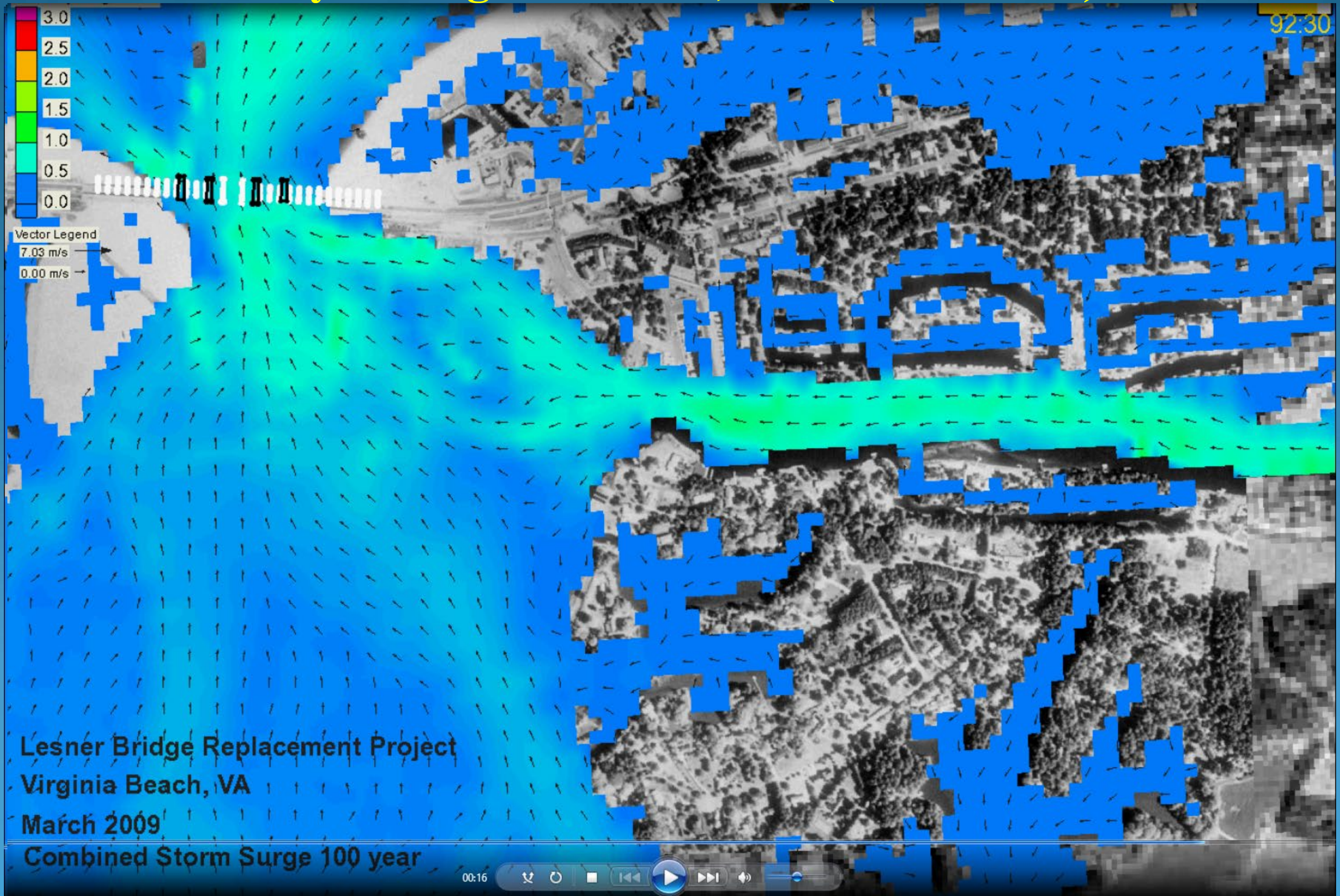
Lesner Bridge Replacement Project
City of Virginia Beach, VA (2008 – 2018)



Floodplain and Strategies for Coast Installation Resiliency

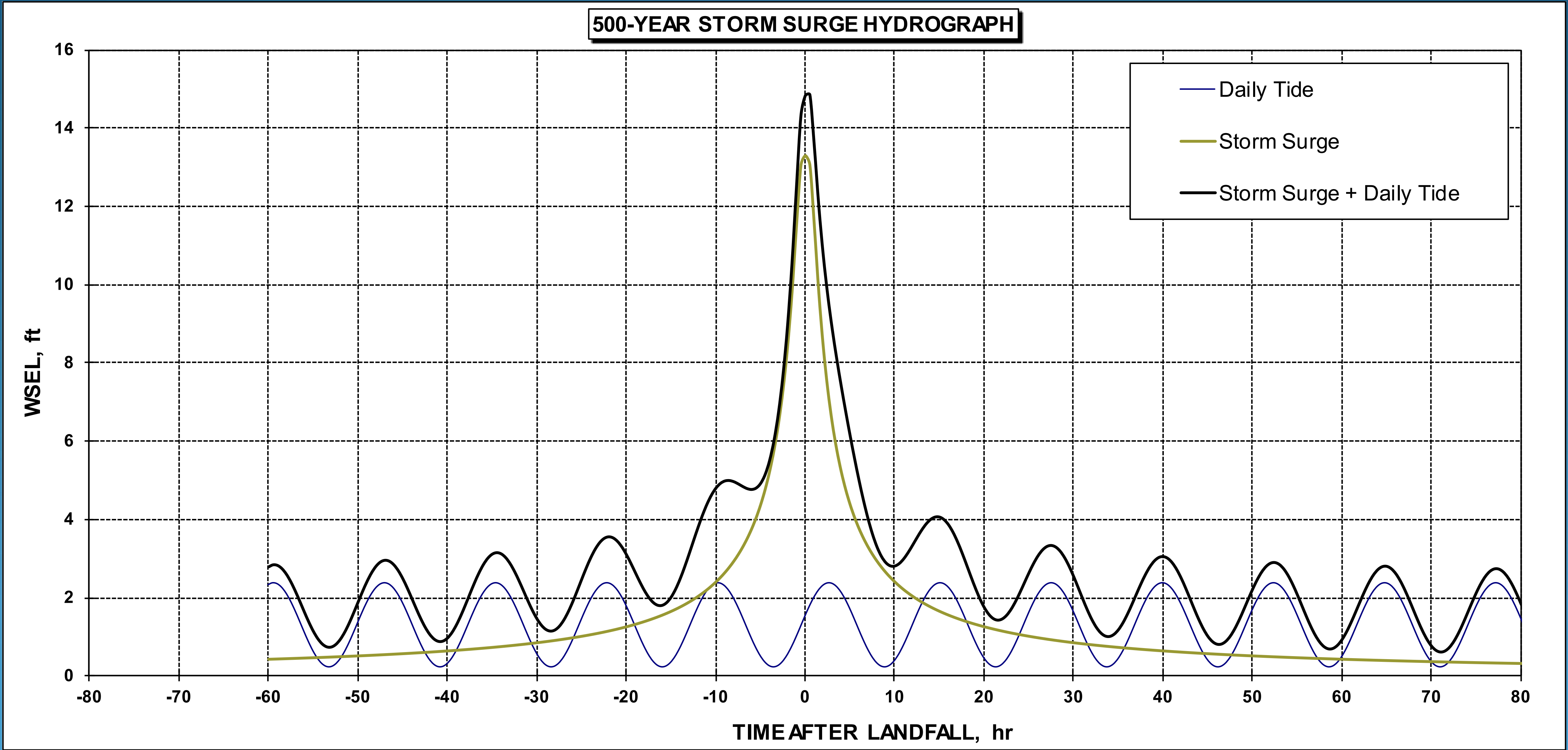
NASA Wallops Flight Facility

Floodplain and Strategies for Coast Installation Resiliency

NASA Wallops Flight Facility

Floodplain and Strategies for Coast Installation Resiliency

NASA Wallops Flight Facility
Wallops, VA (2020 – 2022)



Floodplain and Strategies for Coast Installation Resiliency

NASA Wallops Flight Facility
Wallops, VA (2020 – 2022)

Floodplain and Strategies for Coast Installation Resiliency

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Wallops, VA (2020 – 2022)

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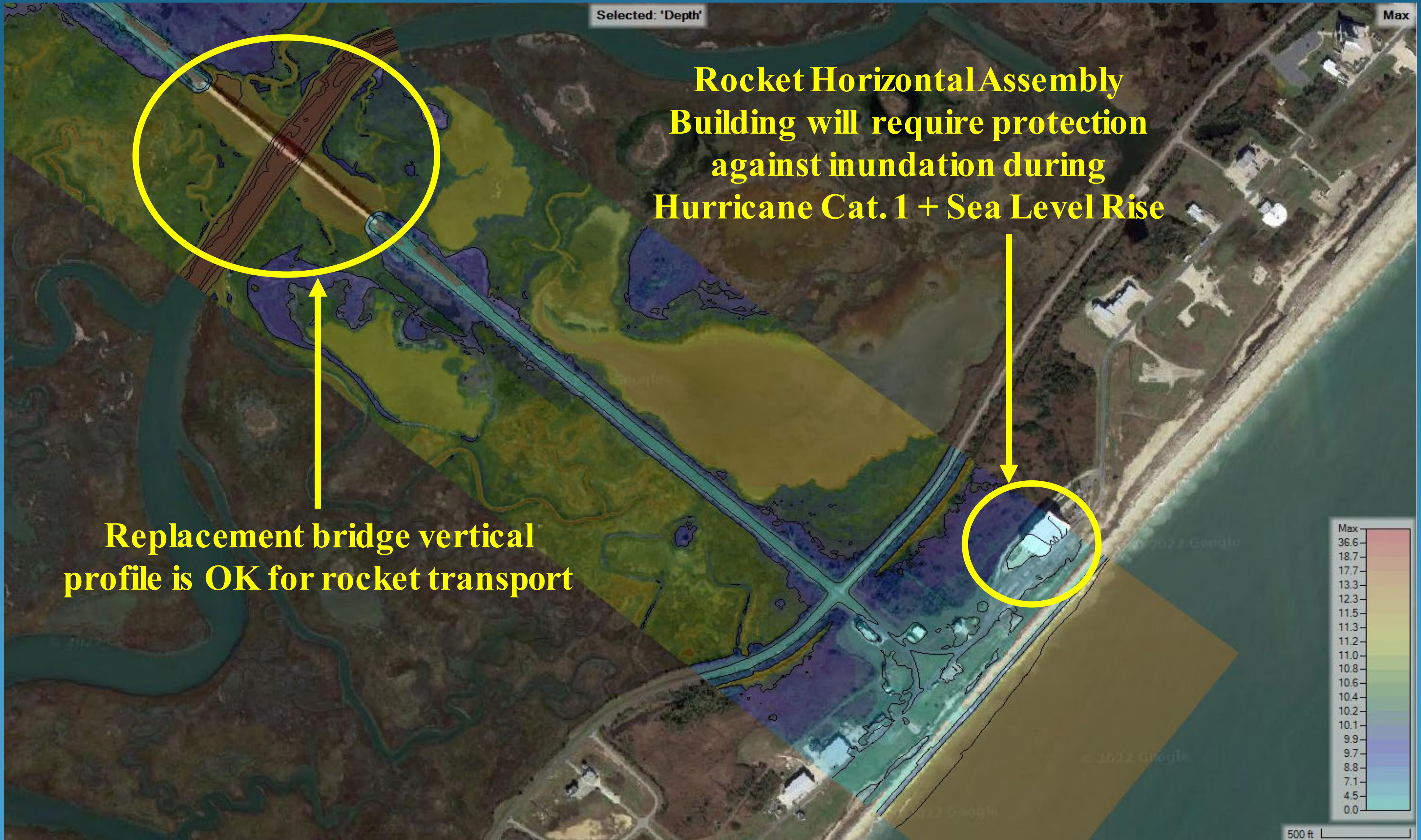
NASA Wallops Flight Facility
Wallops, VA (2020 – 2022)



Floodplain and Strategies for Coast Installation Resiliency

Conclusion

Future LEAP approach enhances flood mitigation and coastal residency

Floodplain and Strategies for Coast Installation Resiliency

Questions

Today's presenters

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TRB Webinar: Withstanding Climate Change—Resilient & Flexible Pavement

November 30

TRB Webinar: State DOTs Perspective on Pavement Resilience

https://www.nationalacademies.org/trb/events

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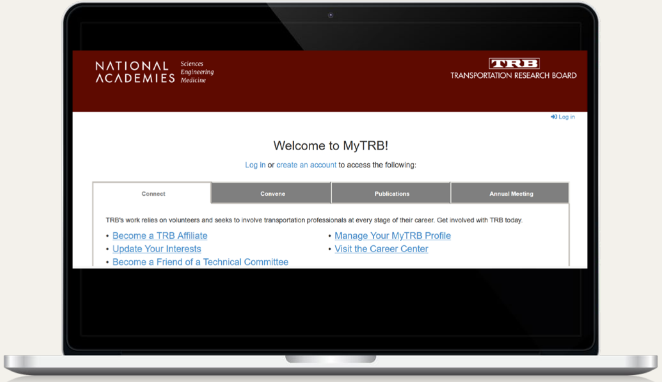

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