National Capital Planning Commission

Interior Flooding in the District of Columbia

Urban Stormwater Workgroup Meeting

February 20, 2018

Presentation Outline

1. Washington, DC's History of Flooding
2. Mapping Interior Flooding
3. Next Steps

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Three Types of Flooding

Three Types of Flooding

1. Riverine

Pennsylvania Avenue – River Flooding

1889

Source: Library of Congress

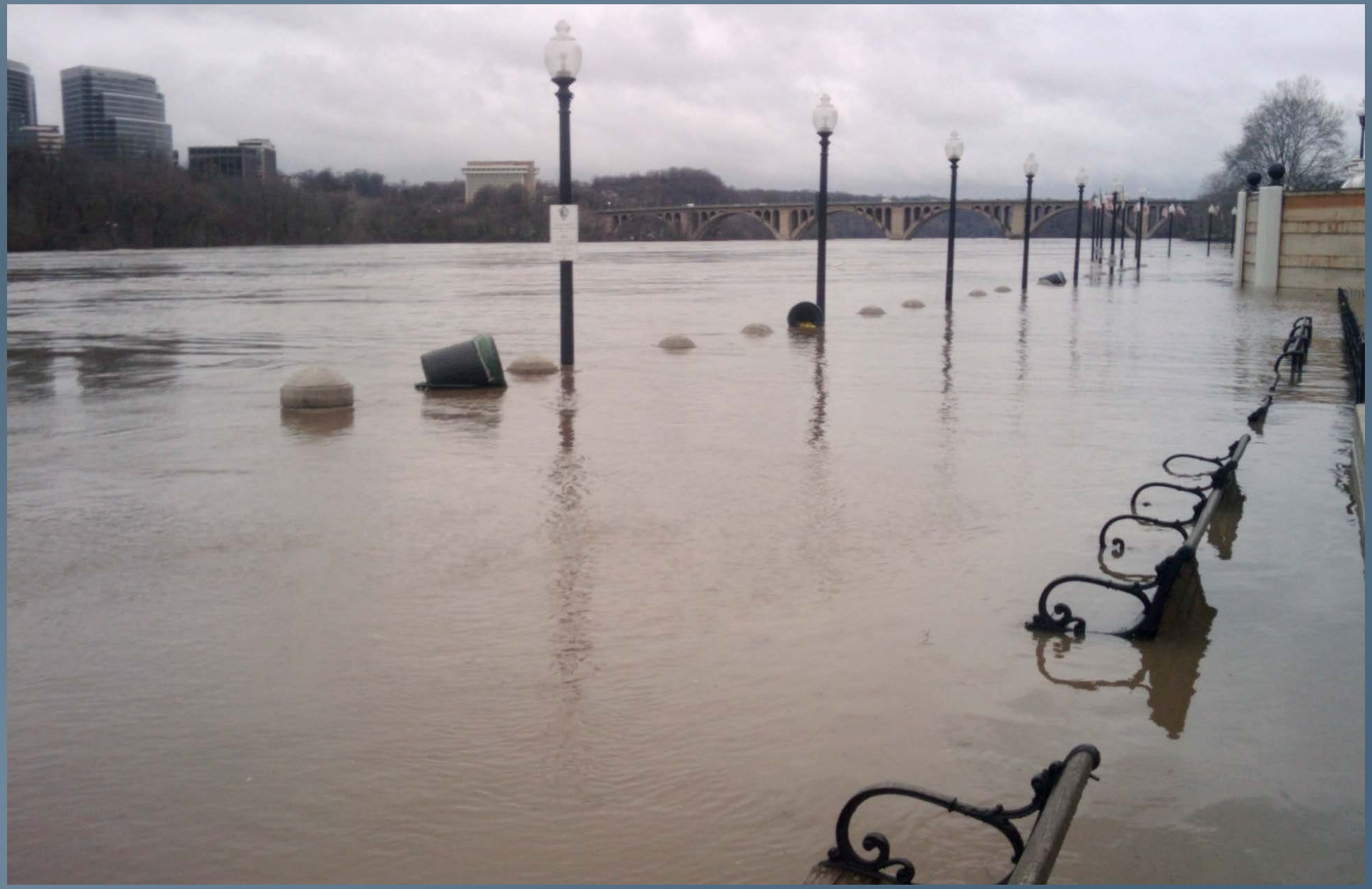
River Flooding

1936

Source: National Archives

Georgetown – River Flooding

2010



Source: Flickr user brownpau

Three Types of Flooding

1. Riverine
2. Coastal

Hurricane Isabel – Storm Surge Flooding

2003

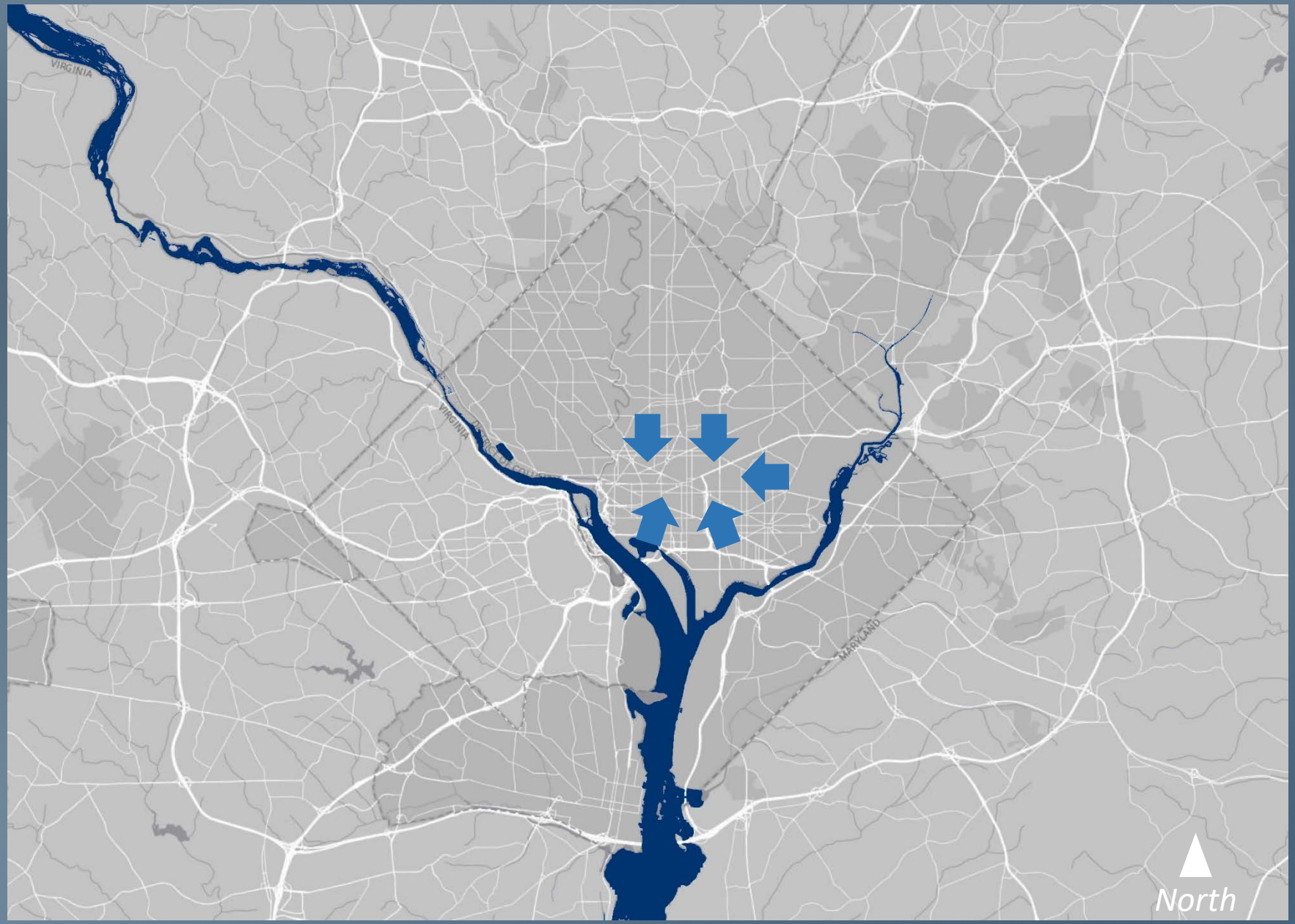
From: Washington Post

Tidal Basin Flooding at High Tide

2015

Source: Courtney Elkins

Three Types of Flooding



1. Riverine
2. Coastal
3. **Interior**

Federal Triangle – Interior Flooding

2006

Source: General Services Administration

Federal Triangle – Interior Flooding

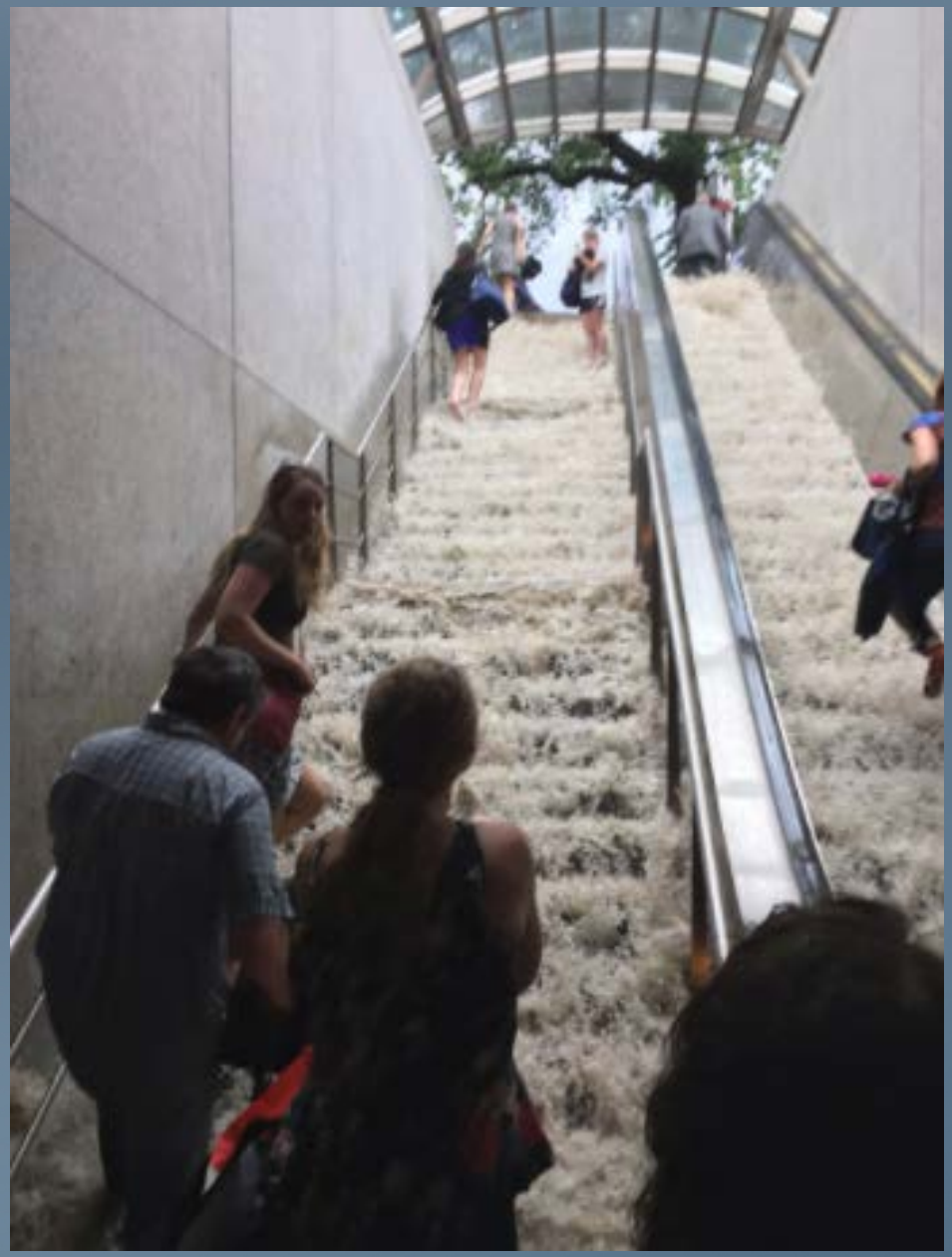
2006

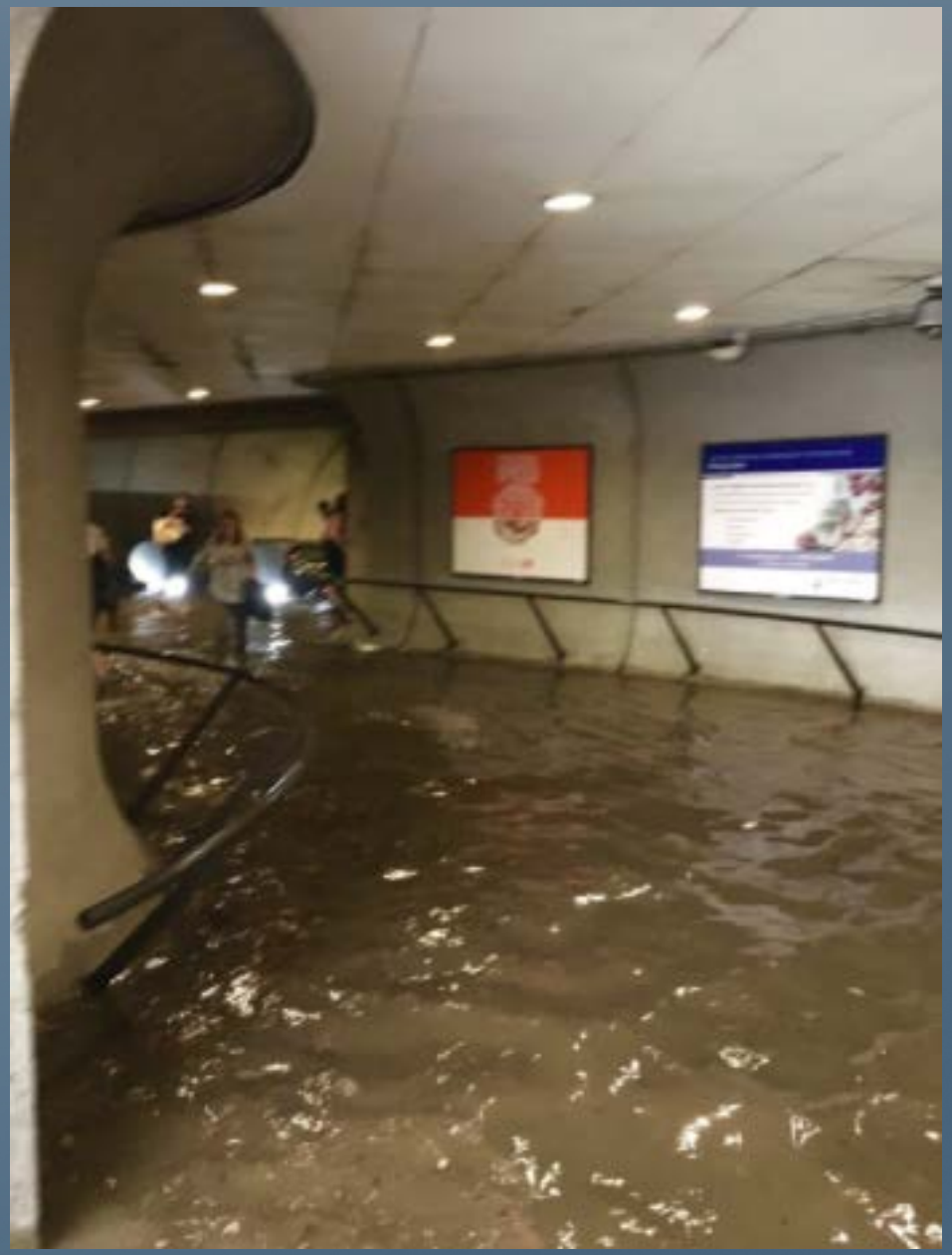
Bloomingdale – Interior Flooding

2012

Source: Bloomingdale Neighborhood Blog

Cleveland Park Metro– Interior Flooding





2016

Source: Christin Fernandez

National Mall – Interior Flooding

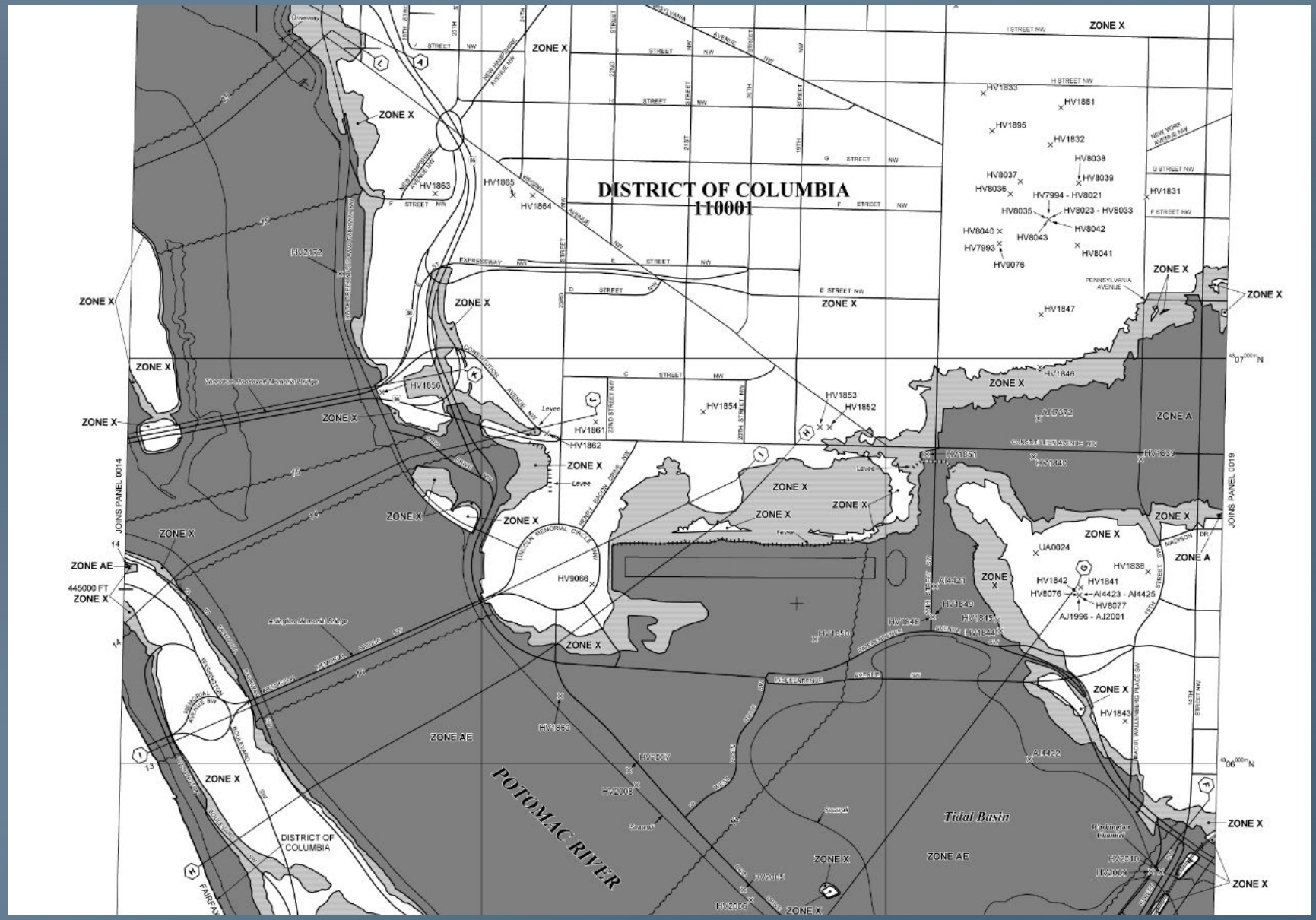
Today

Presentation Outline

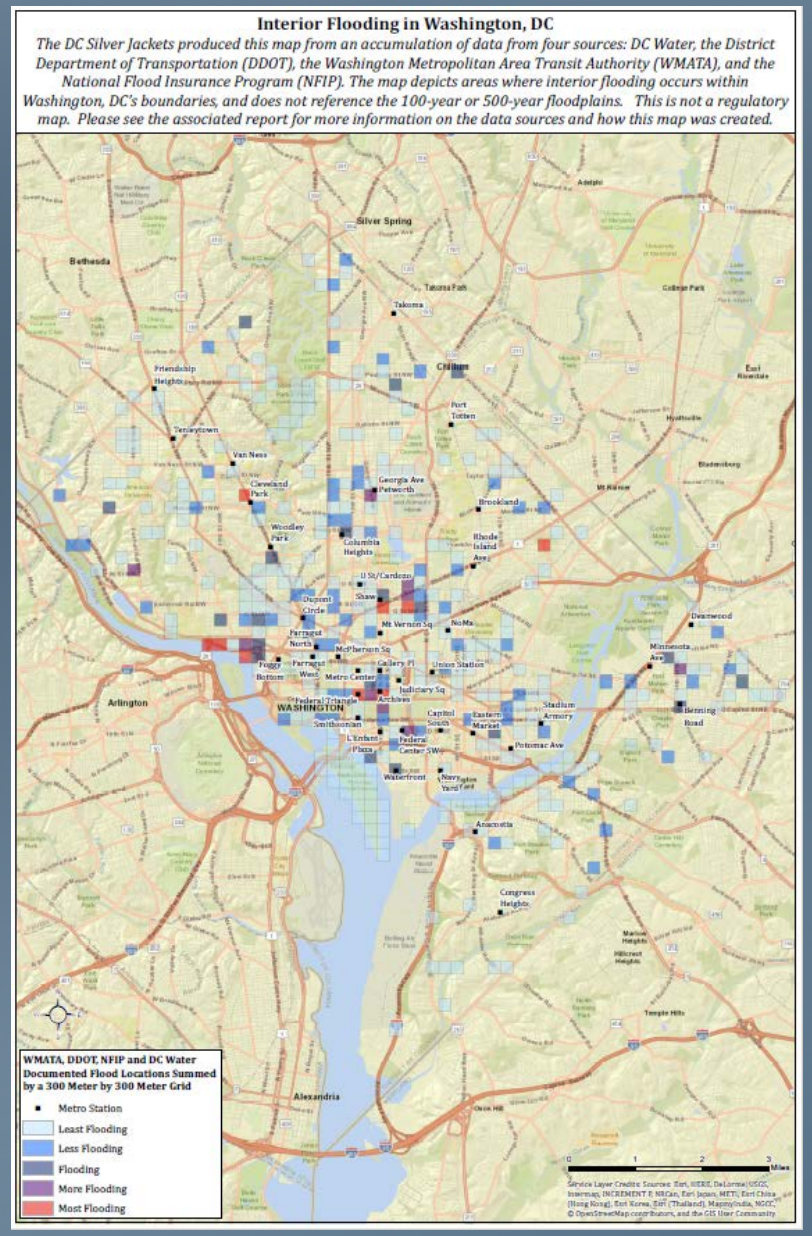
1. Washington, DC's History of Flooding
2. **Mapping Interior Flooding**
3. Next Steps

National Capital Planning Commission

Can we Create Something like the Flood Insurance Rate Maps?

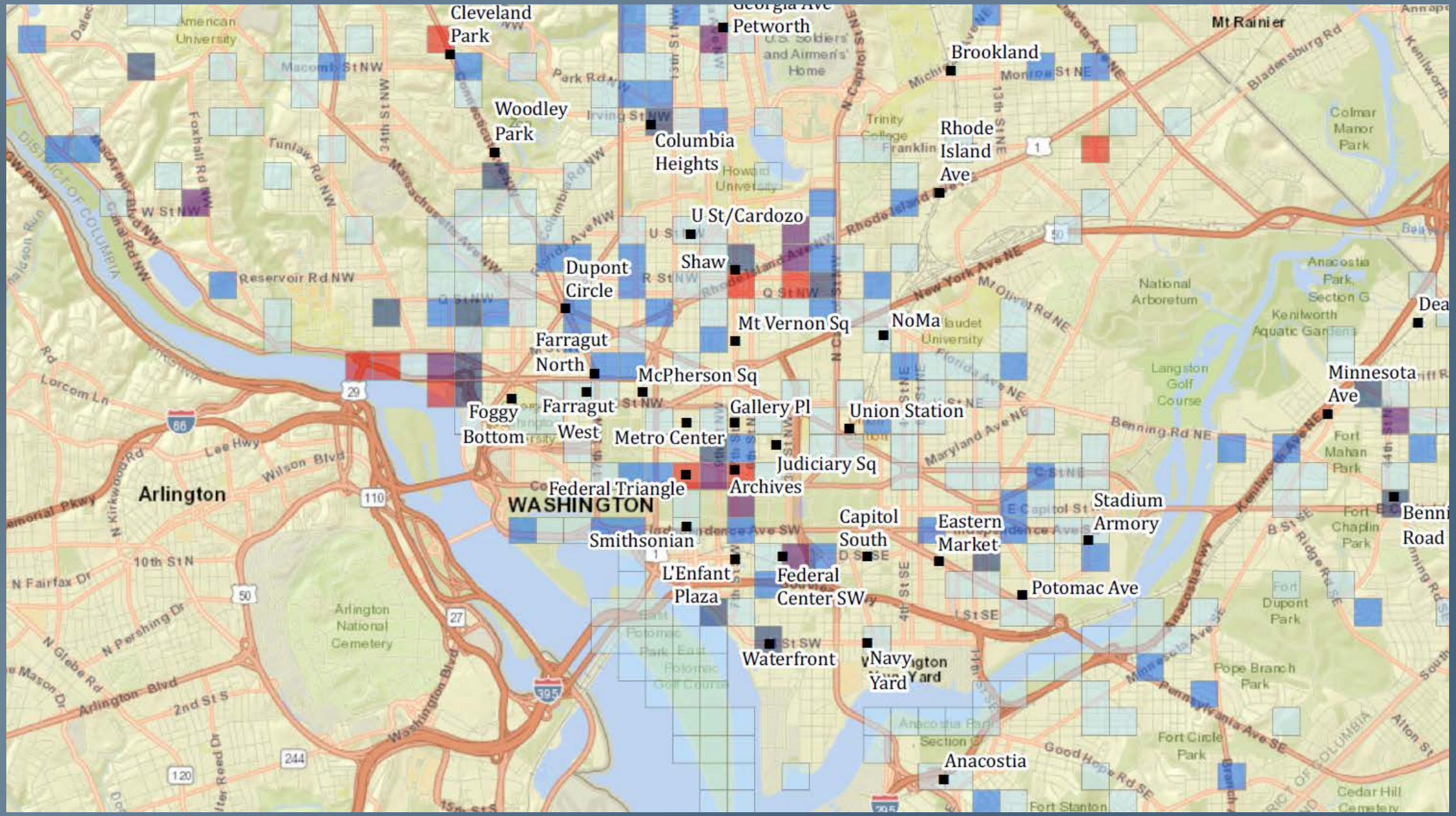


Creating a Map from Proxy Data

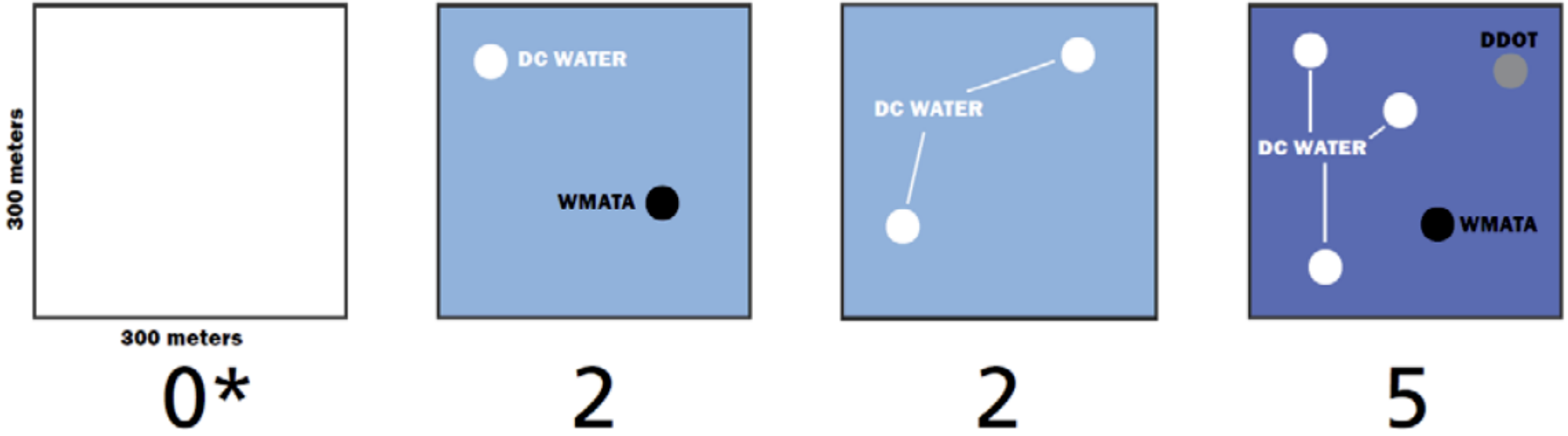


1. **DC Water Utility**
   - Calls for Service from Standing Water
2. **District Department of Transportation**
   - Known Areas of Flooding
3. **WMATA (Metro System)**
   - Recorded Flood Incidents
4. **National Flood Insurance Program**
   - Properties with active policy and claim

Mapping Interior Flooding



How flood locations are summed in each 300m x 300 m grid

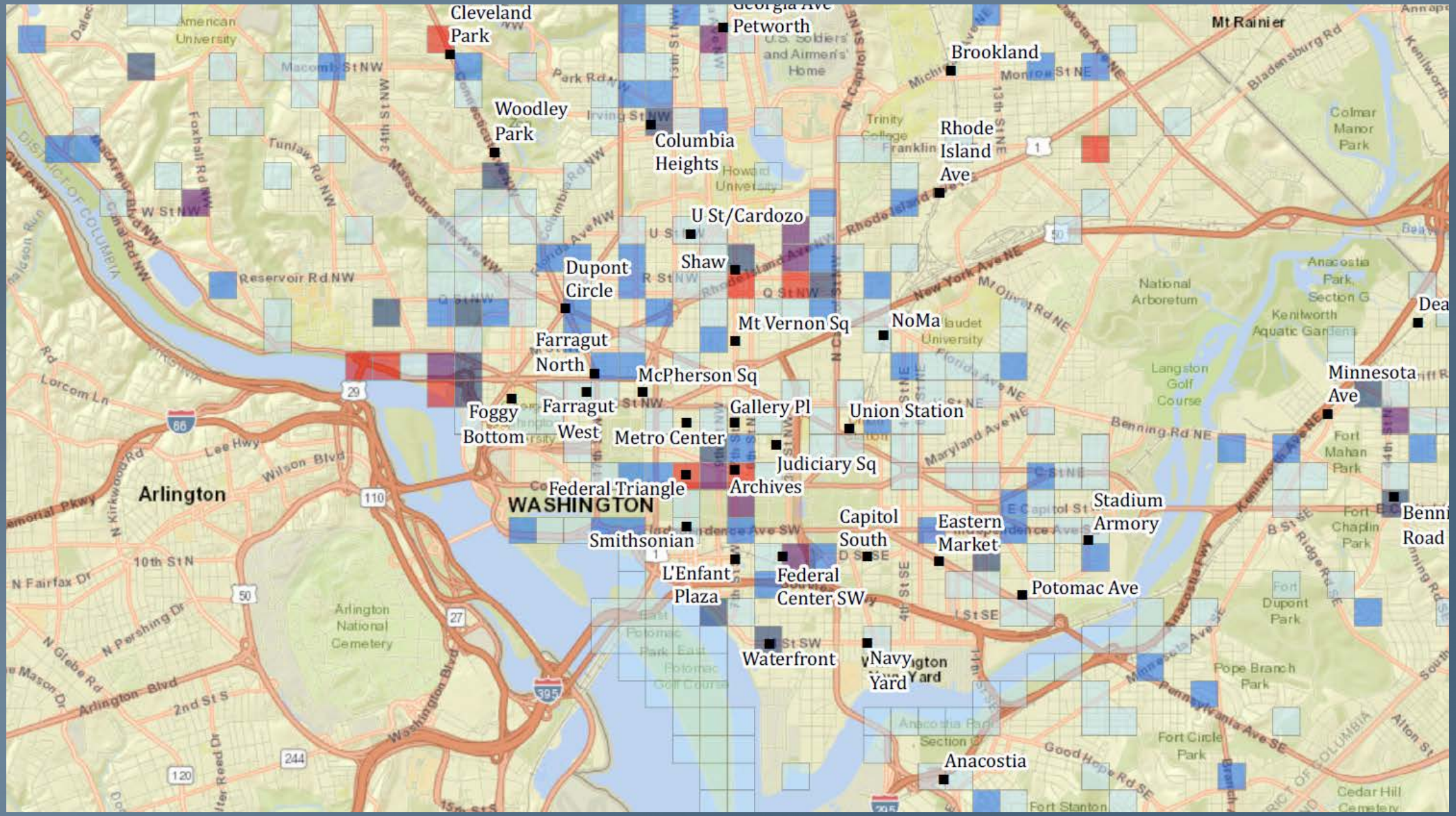


0* 2 2 5

● Represents 1 flood location identified by the four data sources.

* The number below the grids represent the sum of flood locations in each grid. The colors of the grids in this diagram and their corresponding number do not translate to the colors in the map.

Mapping Interior Flooding



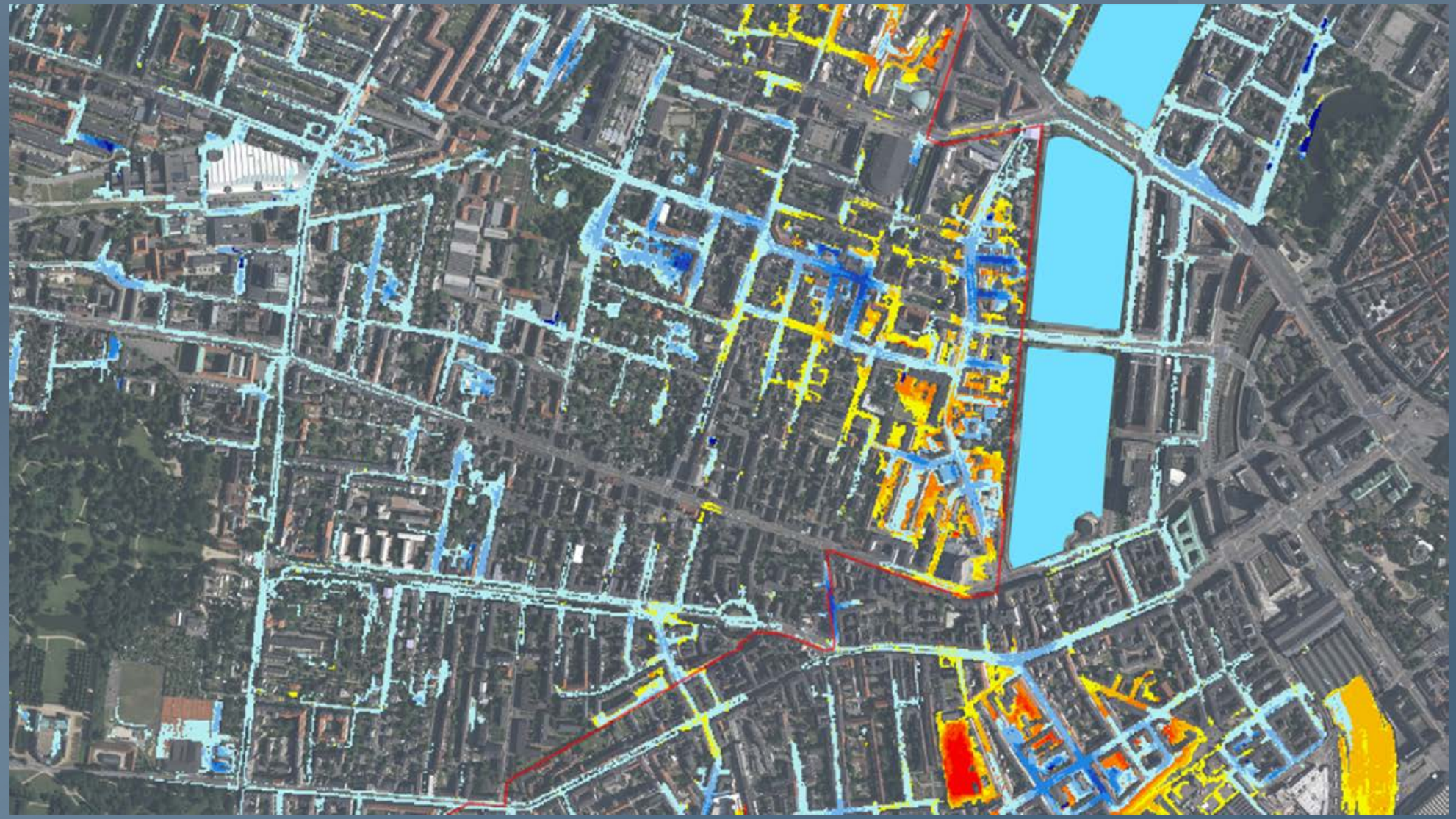
Notes when Using the Map

1. Datasets are at different timescales
2. Datasets use different definitions of flooding
3. Just because no one called, doesn't mean it doesn't flood!

Presentation Outline

1. Washington, DC's History of Flooding
2. Mapping Interior Flooding
3. **Next Steps**

Federal Triangle Workshops Summer 2018



Citywide Integrated Flood Model like Copenhagen?

Thank you!

Read the Interior Flooding Report:

https://silverjackets.nfrmp.us/Portals/0/doc/DC/Interior_Flooding_Report_20170825.pdf?ver=2017-09-01-175909-267

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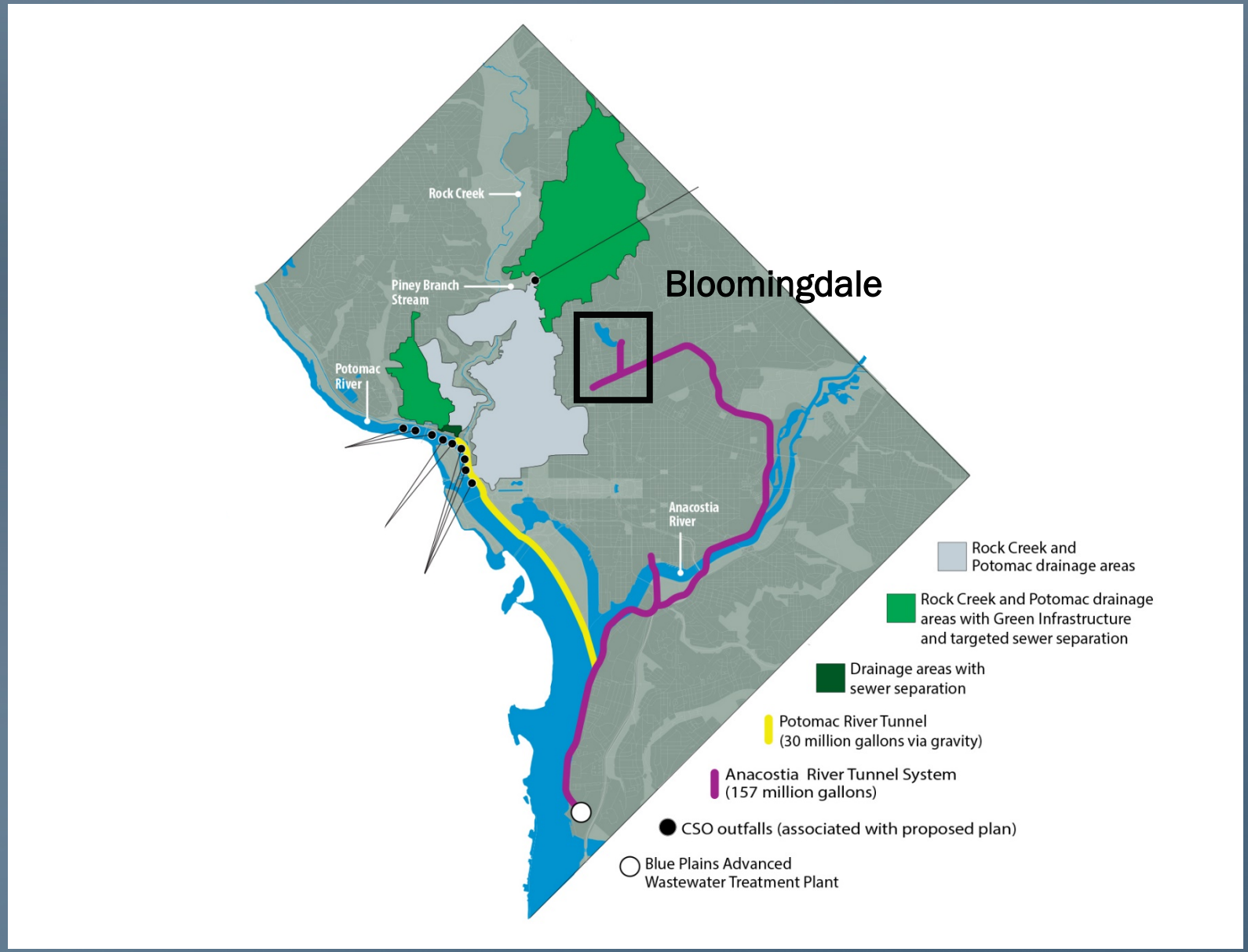
National Capital Planning Commission

Extra Slides

DC Clean Rivers Project



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https://www.ncpc.gov/docs/Flood_Risk_Management_Planning_Resources_January_2018.pdf

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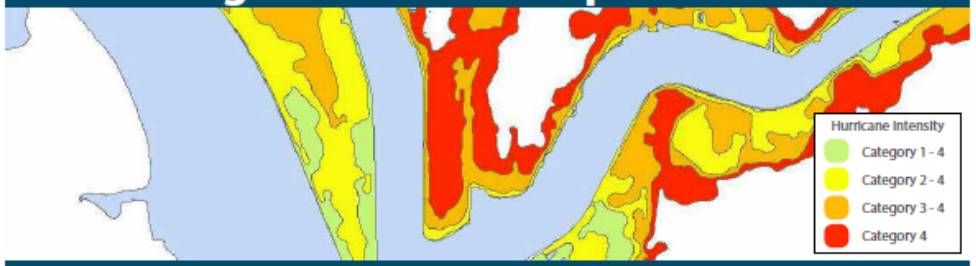
Storm Surge Inundation Maps



U.S. Army Corps of Engineers (USACE)

Purpose: Determine the reasonable worst-case (peak) storm surge from the various intensities of hurricanes that could strike the region. The end product includes worst-case scenario storm surge mapping for each category hurricane (i.e., categories 1, 2, 3, and 4) that are used in Hurricane Evacuation Studies.

Flood Type

- Riverine
- Interior
- **Coastal**

Tool Type

- Projection
- **Map**
- Report

Key Facts

2014
SLOSH modeling

2016
Map Published

Available in many locations; This page refers only to the Washington, DC study.

Links

Online Map Viewer (DOEE)
http://doee.dc.gov/floodplainmap
(In Layers, check box for "Storm Surge")

Explanation of SLOSH
http://www.nhc.noaa.gov/surge/slosh.php
(Refer to "Composite Approach")

Underlying Data and Modeling

Modeling: Water surface elevations for worst case storm surges are generated by a 2014 SLOSH model run for the Chesapeake Basin (CP5), which are developed by NOAA's National Hurricane Center. The surges are added to the mean higher high water (MHHW) elevations. USACE overlaid these surge plus MHHW elevations from the SLOSH grid on a DEM to create the extent and depth of flooding.

Accuracy: The underlying DEM is from 1 meter LIDAR data obtained in 2008 that was resampled to 10 feet. SLOSH grid cells range in size and are approximately 500 meters in the Washington, DC area.

NCR Specific: The 17th Street Levee Closure and the Anacostia Levee System are not shown as providing protection.

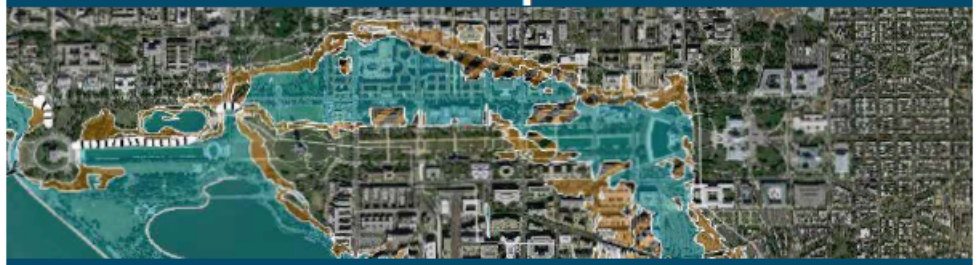
Discussion

Best Uses: The primary purpose of this data is to support hurricane emergency management planning activities, including identification of evacuation zones. The map is meant to show the areas that are at risk for each hurricane category. For example, if the NWS predicts that a Category 4 (CAT4) hurricane is approaching Washington, DC, facility managers can refer to these maps to understand what areas might be flooded. In the event that the area experiences a CAT4 hurricane, it is likely that some areas identified in the maps as being inundated may actually experience less flooding since the maps represent the worst-case. The maps are useful in showing the areas that do not have storm surge flood risk (outside CAT4).

Limitations: This tool is only available as GIS shapefiles and there are no risk percentages (such as 1% annual chance) associated with the layers in this map. The map does not account for increased sea levels or for riverine flooding.

Comparisons: Compare to "Flood Insurance Rate Maps" on page 16 and "Flood Inundation Mapping Tool" on page 17. Instead of layers created by annual risk (FIRMs) or by elevation (FIMs) this tool has layers corresponding to Hurricane strength. This tool is an update to a previous study in 2009: https://www.ncpc.gov/docs/2009_USACE_Hurricane_SSIM.pdf. The following document futher describes how these maps compare with FIRMs: http://nhma.info/uploads/resources/flood/CoastalFloodMapsFactsheet_Final.pdf

Flood Insurance Rate Maps



Federal Emergency Management Agency (FEMA)

Purpose: Provide maps that show the 1% annual chance (100-year) and 0.2% annual chance (500-year) floods. The maps are used by the local jurisdictions to regulate development in floodplains and are used by the National Flood Insurance Program to determine flood insurance requirements.

Flood Type

- Riverine
- Interior
- Coastal

Tool Type

- Projection
- Map
- Report

Key Facts

2004
Topographic Data

2010
Maps Published

Available nationwide, though this page refers only to the DC maps

Links

Online Map Viewer and DC Resources
https://msc.fema.gov/portal/search?AddressQuery=washington%20dc

2010 Flood Insurance Study
https://www.ncpc.gov/docs/DC_Flood_Insurance_Study_Pre-17th_Street_Levee.pdf

Underlying Data and Modeling

Modeling: The maps are created through a complex process that is detailed in chapter "3. Mapping Current Flood Risk" on page 28. The process combines historical data analysis contained in the 2010 Flood Insurance Study with the USACE HEC-RAS software to model the water flow.

Accuracy: Washington, DC's floodmaps are derived from LIDAR data obtained in 1999, used to create a Digital Elevation Model (DEM) with 1 meter contours.

NCR Specific: Washington, DC's maps were recently updated to show the 17th Street Levee Closure as protecting against the 1% annual chance (but not the 0.2% annual chance) riverine or coastal flood. Much of the Federal Triangle area is still in the 1% annual chance floodplain because interior flooding risk remains. Federal Triangle is the only location in Washington, DC where interior flooding is mapped. The original 2010 Flood Insurance Rate Maps (FIRMs) and associated Flood insurance Study did not analyze interior flooding.

Discussion

Best Uses: This tool is best used for screening of assets at a master planning level. It is unique because it shows inundation from an extreme water level perspective, with layers for the 1% annual chance (100-year) flood and the 0.2% annual chance (500-year) flood.

Limitations: The underlying DEM data and resulting limited horizontal resolution means that this tool should only be used for high-level screening. This tool does not incorporate future flood risks and projections of the 100 and 500-year floods are based on existing conditions as of the effective date of the FIRM.

Comparisons: Compare to "Surging Seas Risk Finder" on page 21, which can provide annualized risk from a different perspective. The user determines the height of flooding from 1 to 10 feet, and the viewer will provide the probablity that the selected flood will occur.

Section 2 - Flood Risk Management Resources

Flood Type

- Riverine
- Interior
- Coastal

Tool Type

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- Map
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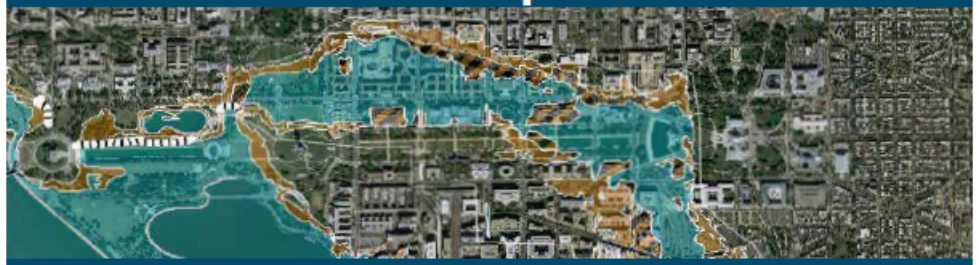

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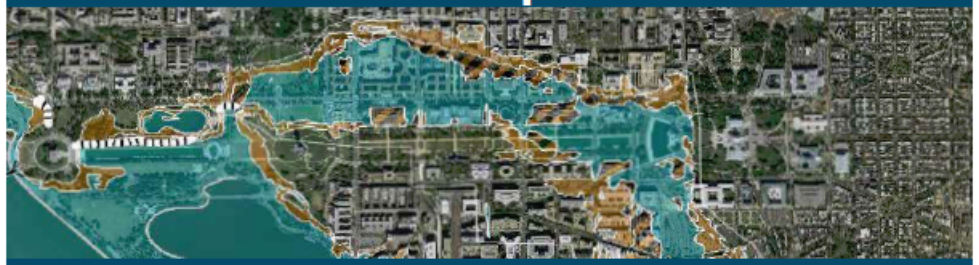

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← Underlying Data and Modeling

← Discussion

Flood Risk Management Resources for Washington, DC

The 11 resources described in this guide are listed below. Attributes of each study, Flood Type and Tool Type, are shown on page 13. Markers under **Flood Type** indicate that resource is useful for the specified types of flooding; riverine, interior, or coastal. Markers under **Tool Type** indicate what kind of resource to expect: "Projection" indicates that the resource has predictions about future climate conditions like sea level rise or precipitation, "Map" indicates that the resource includes a map or a model that can be used to visualize flood impacts, and "Report" indicates that the resource includes a written report with useful information on flood risk management.

Page #	Resource Name	Last Update	Flood Type			Tool Type		
			Riverine	Interior	Coastal	Projection	Map	Report
16	Flood Insurance Rate Maps (FEMA)	2010	●		●		●	
17	Flood Inundation Mapping Tool (USACE)	2016	●		●		●	
18	North Atlantic Coast Comprehensive Study (USACE)	2015			●	●	●	●
19	Storm Surge Inundation Maps (USACE)	2016			●		●	
20	Sea Level Rise Viewer (NOAA)	2017			●		●	
21	Surging Seas Risk Finder (Climate Central)	2017			●	●	●	●
22	Sea Level Change Curve Calculator (USACE)	2017			●	●		
23	Precipitation Modeling (DOEE)	2015		●		●		●
24	Federal Triangle Flood Study 2008	2008		●			●	●
25	Federal Triangle Flood Study 2011	2011		●			●	●
26	CMIP Climate Data Processing Tool (DOT)	2010		●		●		

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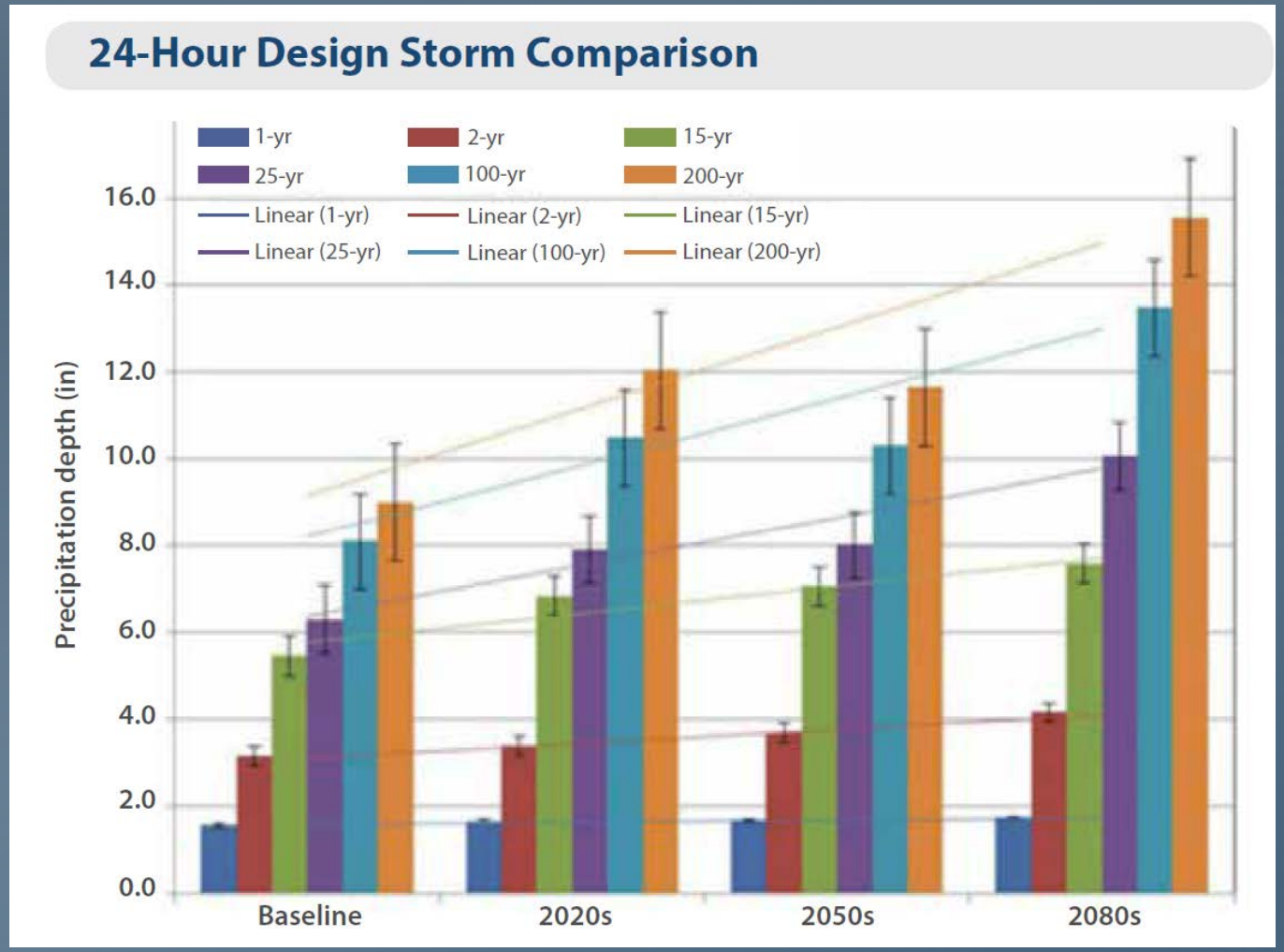
How will these change in the future, and how can we model them?


24-Hour Design Storm Comparison
1-yr
2-yr
15-yr
25-yr
100-yr
200-yr
Linear (1-yr)
Linear (2-yr)
Linear (15-yr)
Linear (25-yr)
Linear (100-yr)
Linear (200-yr)
Precipitation depth (in)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Baseline
2020s
2050s
2080s

Relative Sea Level (RSL) Projections for Washington, DC

Relative sea level (RSL) projections specific to Washington, DC are summarized below. All RSL projections start with a global model that projects global mean sea level (GMSL). These GMSL projections are then modified by one or more local factors to create RSL projections. GMSL projections that underly RSL projections are noted under "Global Factors." The chart simplifies a very complex process of how projections are created, which typically involves consideration of a combination of historical data, output from climate models, and expert judgement. The chart should not be used to determine which projection is best, but as an "apples-to-apples" comparison of all local projections and their underlying global models available as of December 2017.

Note on Projections: Only lowest and highest projections are shown for 2050 and 2100, though many of the RSL projections include intermediate scenarios as well. Projections that follow with a year in superscript indicate a particular study that did not publish projections for the years 2050 or 2100, and used an alternate time horizon instead. For example, NASA's low projection of "+0.2m (2050s)" indicates that NASA projects +0.2m of sea level rise in the years 2050-2059. All projections in this chart are standarized to start at zero in 1992. This year is often used because it is the mid-year of the NOAA National Tidal Datum Epoch (NTDE) of 1983–2001. Pojections are rounded to one decimal place.

		RSL Projections =		Global Factors					+ Local Factors		
		2050 Low / High	2100 Low / High	GMSL Projection (see page 55)	Thermal Expansion	Land-Water Storage	Glaciers & Ice Caps	Greenland & Antarctic Ice	Vertical Land Motion	Ocean Dynamics	Ice-Melt Fingerprinting
NASA (2012)	NASA's RSL projections are based on NASA's own GMSL projections that incorporate 7 global climate models and 3 emissions scenarios. Only the high GMSL projections incorporate rapid ice-melt. Local sea level changes due to ocean dynamics were derived from the global models. Vertical land motion data was derived from the Peltier database.	+0.2m (2050s) / +0.7m (2050s)	+0.3m (2080s) / +1.4m (2080s)	NASA (2012)	●		●	●	●	●	
USACE (2013)	USACE's RSL projections for the low scenario are based on the historic rate of GMSL rise. Intermediate and high GMSL projections are from the 1987 NRC report that USACE modified using the most recent IPCC and NRC projections. GMSL projections are localized with vertical land motion based on data from NOAA's Sea Level Trends website. (This text represents the default settings)	+0.2m / +0.6m	+0.3m / +1.7m	NRC (1987)	●	●	●	●*	●		
NOAA (2013)	NOAA's RSL projections are found on the USACE SLC curve calculator by modifying the default settings (which show USACE 2013 RSL). Select "NOAA" as output agency and "Regionally Corrected" as SLC Rate. GMSL projections are based on the NOAA 2012 report and then localized with vertical land motion based on data from a 2013 NOAA technical report.	+0.2m / +0.7m	+0.3m / +2.1m	NOAA (2012)	●		●	●	●		
Maryland (2013)	The Maryland Climate Change Commission's RSL projections use the GMSL projections from the 2012 NRC report as a starting point. The GMSL projections are then adjusted for local factors by the Scientific and Technical Working Group using peer reviewed science that uses data appropriate to Maryland's location.	+0.3m / +0.7m	+0.7m / +1.7m	NRC (2012)	●		●	●	●	●	●
Climate Central (2017)	Climate Central (CC) allows users to view RSL projections based on six global models (NRC 2012, NOAA 2012 (National Climate Assessment), IPCC 2013, Kopp et al. 2014, Kopp et al. 2017, and NOAA 2017). CC then localizes the projections that aren't already localized. Projections at right are CC's localization of GMSL projections in the NOAA 2012 report.	+0.2m / +0.6m	+0.4m / +2.0m	Multiple	●	●*	●	●	●	●*	●*
CARSWG (2016)	RSL projections for DOD installations by the Coastal Assessment Regional Scenario Working Group (CARSWG) used GMSL projections in the NOAA 2012 report and then localized them with peer reviewed science and local data. Only the process for creating RSL projections is publically available in the CARSWG Report. DC projections shown here were provided as an exception.	+0.2m (2035) / +0.5m (2035)	+0.3m / +2.4m	NOAA (2012)	●	●	●	●	●	●	●
NOAA (2017)	The process for creating NOAA's RSL projections as well as the actual GMSL projections they derive from are described in the NOAA 2017 report. The regionalization process is similar to that used in CARSWG 2016 but differs by using new data sets slightly modified from Kopp et al. 2014. Data (.csv format) for multiple locations is provided in low, medium, and high scenarios.	+0.2m / +1.1m	+0.3m / +3.6m	NOAA (2017)	●	●	●	●	●	●	●

*Projections do not include rapid ice-melt scenarios

*Depends on which model selected