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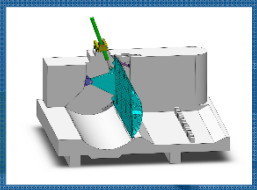
A Hurricane Surge Barrier for Washington DC



A barrier to protect communities on the Potomac River from flooding due to future hurricanes and sea level rise

Presented To:
Washington DC Silver Jackets Team

February 24, 2015

Outline

- Introductions
- What is the threat (Surge, Climate Change: SLR and Rainfall IDF)
- Vulnerable facilities and assets
- Types of Flood Barriers
- Design Considerations
- Potential comprehensive regional solution
- Barrier Alignment Concepts
- Preliminary Modeling Results
- Costs
- Discussion

A surge barrier could protect billons in assets, spur on economic development and provide resilience from future Superstorm Sandy's and sea level change

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Why We Are Here…

- To discuss how similar communities around the globe have addressed flooding and hurricane surge issues
- Discuss CH2M HILL's experience in designing and constructing flood control solutions
- Review potential concept options for regional flood control due to storm surge and sea level rise in the Washington DC region
- Provide real world, hands-on experience with operating flood control structures
- Discuss costs and benefits associated with these structures

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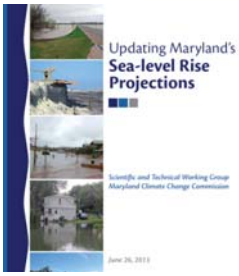
The threat: sea level rise of about 3.7 ft by 2100 and future hurricane surge



Maryland Relative Sea-level Rise	Relative SLR meters	Relative SLR feet
2050 best	0.4	1.4
2050 low	0.3	0.9
2050 high	0.7	2.1
2100 best	1.1	3.7
2100 low	0.7	2.1
2100 high	1.7	5.7

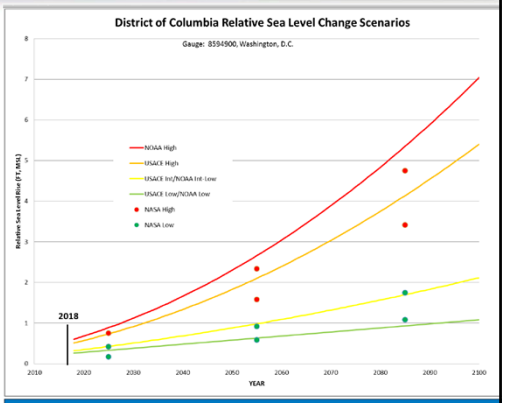


Figure 6. Relative Sea Level Change for the District of Columbia (NASA 2012 D.C. Climate Data), and for Gauge 8594900 in Washington, D.C., for USACE and NOAA Scenarios.

North Atlantic Coast Comprehensive Study (Jan, 2015)

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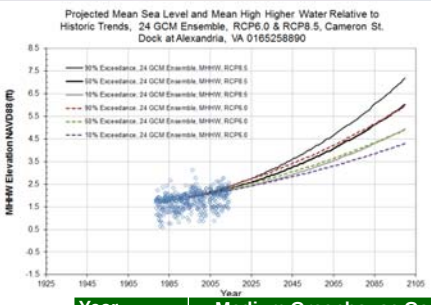
Projected Relative Sea Level Change at Alexandria: High Tide (MHHW) in 2100 could range from 4.3 to 7.1 ft, an increase of 2.4 to 5.2 ft



Source: *CH2M HILL analysis of IPCC CMIP5 GCM Data, translated to Washington DC (2014)*

Year	Medium Greenhouse Gas Scenario (RCP6.0)			High Greenhouse Gas Scenario (RCP8.5)		
	Low Estimate (10% non-exceedance)	Median Estimate	High Estimate (90% non-exceedance)	Low Estimate (10% non-exceedance)	Median Estimate	High Estimate (90% non-exceedance)
1995	1.9	1.9	1.9	1.9	1.9	1.9
2050	2.9	3.2	3.6	3.0	3.4	3.8
2100	4.3	4.9	5.9	4.9	6.0	7.1

Note: All elevations are in feet, relative to North American Vertical Datum (NAVD88)

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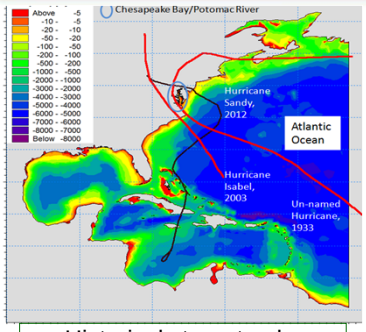
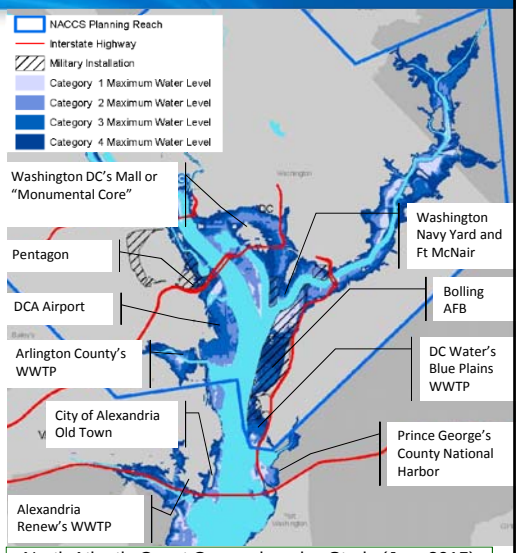
The threat: Current studies show that sea level rise coupled with storm surge will inundate areas of critical infrastructure up & down the Potomac watershed



Historical storm tracks



North Atlantic Coast Comprehensive Study (Jan, 2015)

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The risk of flooding from hurricane surge is real and will increase with climate change because of future sea level rise. Low probability, but high consequences)

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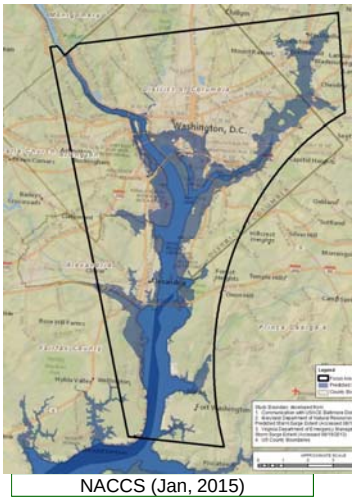
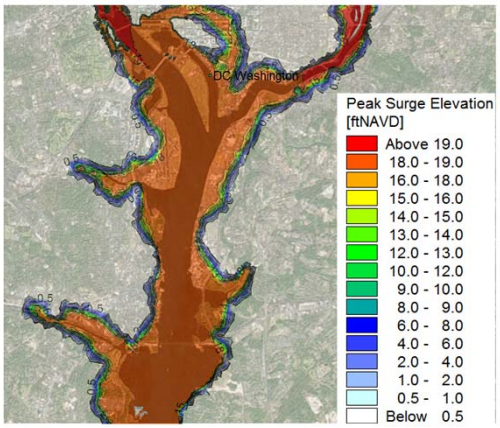
Surge, if coupled with riverine flooding and sea level change could increase risk



NACCS (Jan, 2015)



500-yr peak surge, with SLC (Sc.4 from NACCS at Boundary), with coincident peak discharge from Hurricane Sandy (CH2M HILL, MIKE21 Model, Feb.2015)

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Updated extreme water level analysis for Potomac River based on historical records show higher risk for 1% and 0.2% (100-year and 500-year) events

Washington, D.C. NOAA tide station 8594900 annual maximum tide elevation (NAVD88) return periods for period of records indicated published by FEMA (2010) and by CH2M Hill using statistical (L-Moments) analysis.

Return Interval (Year)	FEMA Revised Water Level Elevation (ft.) 1932-2003	CH2M HILL Analysis Water Level Elev. (ft.) 1931-2013
2	-	3.7
5	-	4.8
10	5.8	5.7
20	-	7.4
50	8.9	9.0
100	**10.5**	**11.0**
500	**14.7**	**17.7**

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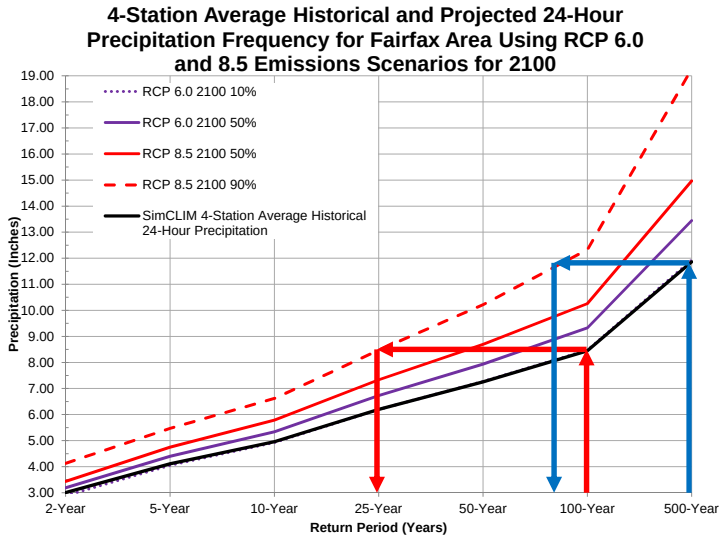
The threat: more frequent storms could increase risk due to rainfall from 1% to 4% (100-yr storm becomes 25-yr), or 0.2% to >1% (500-yr becomes less than 100-yr)



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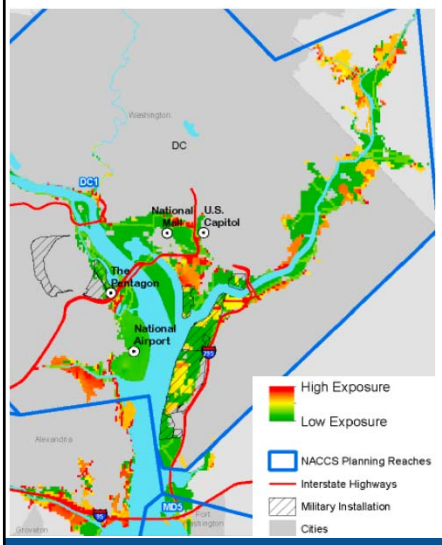
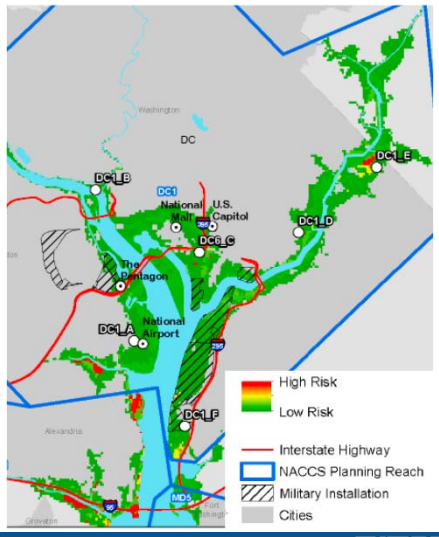
Exposure and Risk Assessments (NACCS, Jan.2015)





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Global Flood Barriers

Europe

- Delta Works (Netherlands)
  - IJssel Barrier (1958)
  - Haringvliet (1971)
  - Eastern Scheldte (1986)
  - Hartel Barrier (1997)
  - Maeslant Barrier (1997)
- Hull flood barrier (UK) (1980)
- Thames Barrier (UK) (1982)
- St Petersburg Flood Defense Barrier (Russia) (2012)
- MOSE Barrier (Venice, Italy) (2017)

USA

- Fox Point Hurricane Barrier, Independence, Rhode Island (1966)
- New Bedford Harbor Hurricane Barrier, Massachusetts (1966)
- Hurricane Barrier, Stamford, Connecticutt (1969)
- IHNC Lake Borgne Surge Barrier, New Orleans (2012)

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Example Flood Barrier Projects

Tees Barrage, England
230ft long with 4 no. gates,
$149 million

Thames Barrier, London
1,700ft long with 4 no.
200ft wide and 6 no. 100ft
wide gates, $2.59 billion

Hull Impoundment, England
100ft wide with 1 no. gate,
$345 million

- Flood elevations
- Navigation
- Location and land ownership

- Neighborhood impact
- Potential future projects
- Effect of diverted waters

- Operations and maintenance
- Life cycle cost

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Example Flood Barrier Projects

St. Petersburg, Russia
16 miles long with 650ft
wide sector gate and 340ft
wide lift gate, $6.4 billion

New Bedford Harbor, MA
1.8 miles long with single 100ft
wide gate, $200 million

Intracoastal Waterway,
New Orleans 1.8 miles long,
$1.24 billion

- Flood elevations
- Navigation
- Location and land ownership

- Neighborhood impact
- Potential future projects
- Effect of diverted waters

- Operations and maintenance
- Life cycle cost

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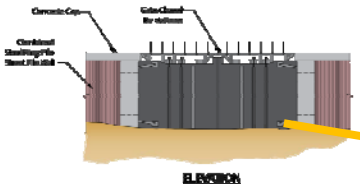
CH2M HILL Flood Barrier Design Projects in New York City



Howard Beach Flood Barrier

The "Big U" - Manhattan

Newtown Creek Flood Barrier

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Flood Barrier and Gate Design Criteria

- Primary Functional Requirements (engineering)
  - Moves (to open and close) on demand
  - Strength to withstand design event
- Secondary Functional Requirements (engineering)
  - Design life and Risk, Reliability & Consequence
  - Maintenance of structures and MEICA
  - Buildability
  - Maintenance of navigation channel
- Secondary Functional Requirements (soft sciences)
  - Aesthetics (views and obstructions)
  - Operability
  - Environmental
  - Ecological

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Types of Flood Gates

Lifting gate lowered into defense position, significant air draft to allow navigation

Lifting gate lowered into defense position, significant air draft to allow navigation

Lifting gate lowered into defense position, prevents navigation

Drop gate raised into defense position from its sea bed chamber

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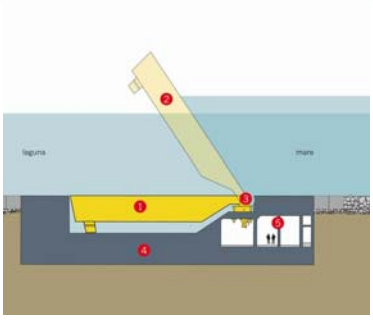
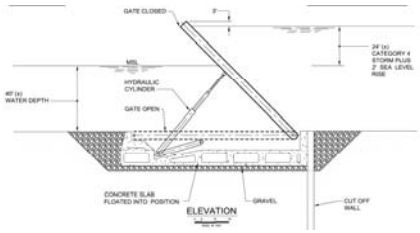
Types of Flood Gates



Flap gates – driven to surface by dewatering of the flap 'fingers' using compressed air

Flap gates – driven to surface by hydraulic cylinders



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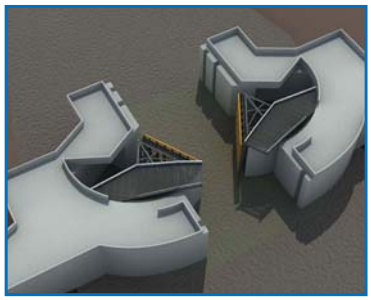
Types of Flood Gates

Mitre gates - span normally limited to circa 100 ft with concrete pier between



Sector gates – substantial land take to accommodate gates in open position

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Types of Flood Gates

Rising sector gates raised for defense

Radial sector gates lowered for defense

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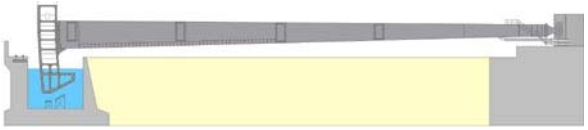
Types of Flood Gates

Main gates in permanent dry dock when gate is open. Floated into defense position and ballasted down

Gap remains between and under gates



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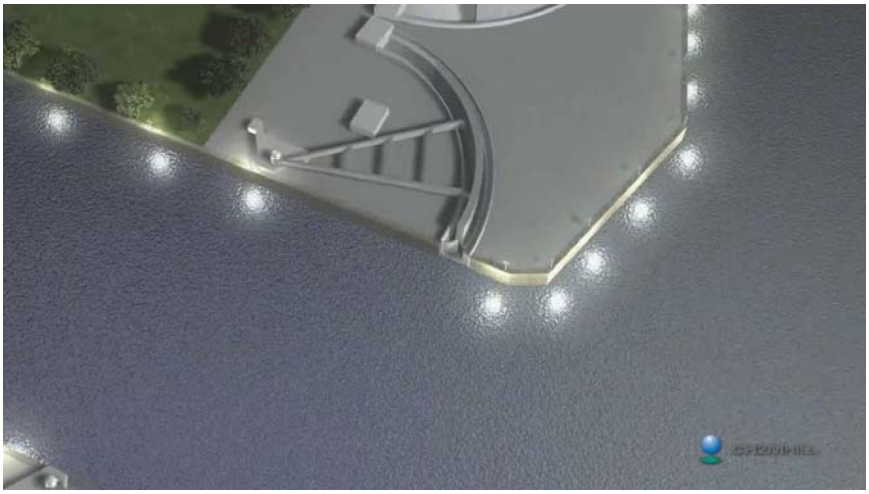
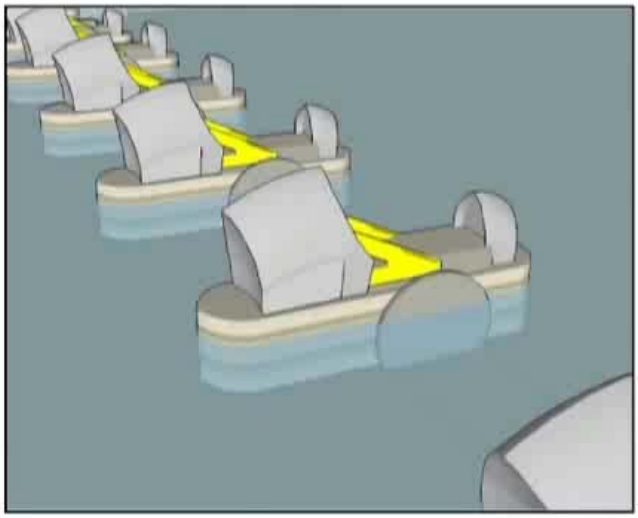
Flood Barrier Concept Visual Simulation



Flood Barrier Concept Visual Simulation

Potential Thames River Video Clip



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Conditions Affecting Types and Locations of Barriers

- Community impacts
- Land use
- Bathymetry
- Topography
- Geotechnical
- Hydrodynamic
- Environmental
- Operational control
- Funding sources
- Capital and O&M costs
- Maritime operations

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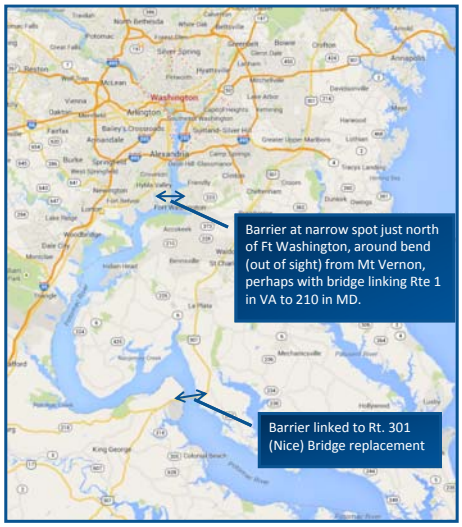
A hurricane surge barrier provides potential comprehensive regional solution – concepts developed at two locations offered for illustrative purposes



- Similar in design and operating conditions to existing barriers
  - St. Petersburg and Thames barrier already operated successfully
- Supports roadway (or rail)
  - Could provide much-needed traffic artery
  - Could be eligible for transportation funding

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Local Topography/Bathymetry Conditions at South Location – 8,400 ft width (at 0 ft NAVD), 14,400 ft at 22.3ft crest elevation

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Local Topography/Bathymetry Conditions at North Location – 3,800 ft width, with 1,000 ft gated channel, and 2,800 ft levee/

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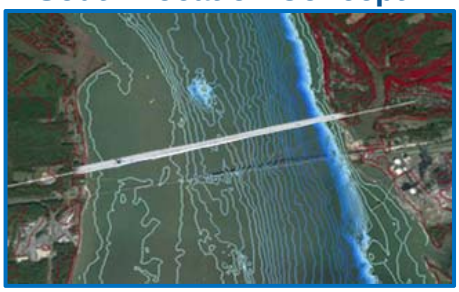
Potential Barrier and Gate Alignments

South Location Concept



North Location Concept

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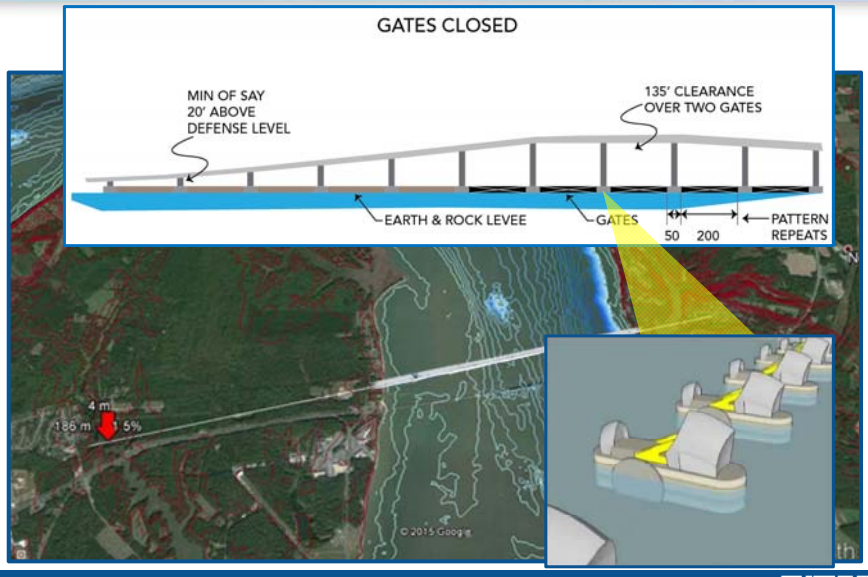
Concept – South Location



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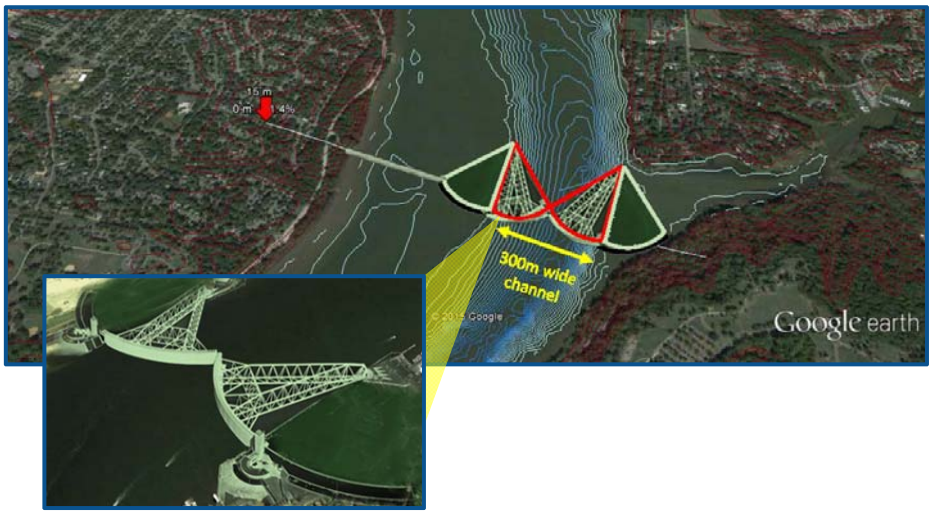
Concept – North Location



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How does the barrier effect local water flow ?

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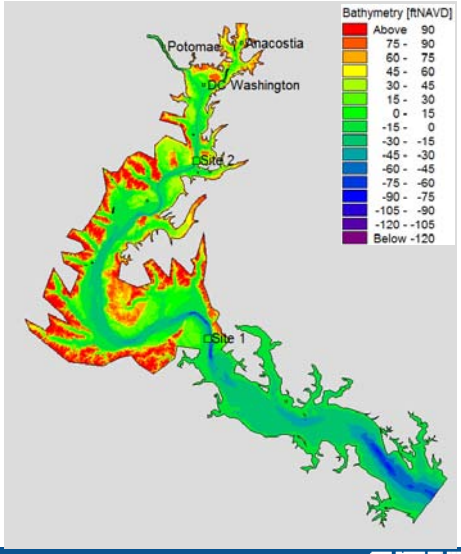
Preliminary hydrodynamic modeling of surge, with sea level rise, and with/without riverine storm flows

Potomac River model domain including upstream stretches of Potomac and Anacostia Rivers and abutting bank areas

Model includes:
- Tide
- Surge
- Wind
- Time varying surge level boundary applied at downstream
- Time varying river discharge boundary applied at upstream

Model can be used to:
- Evaluate impacts of barrier on water levels, current speeds / patterns
- Provide design conditions



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Model refinement for Washington's Monumental Core

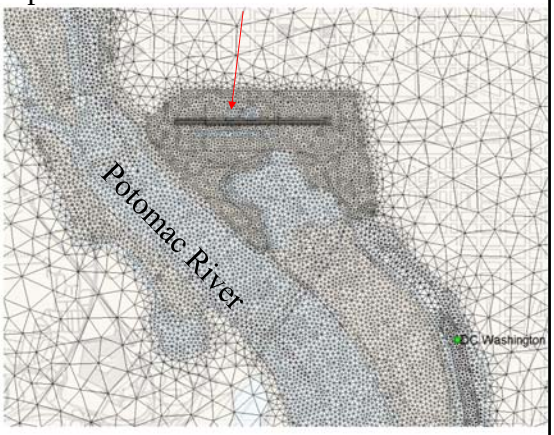
Model grid refined around Washington DC area

Run for 500yr extreme surge event

Requires validation with site-specific data

- Water levels
- Currents

Refined rectangular grid for recently completed 17th street levee



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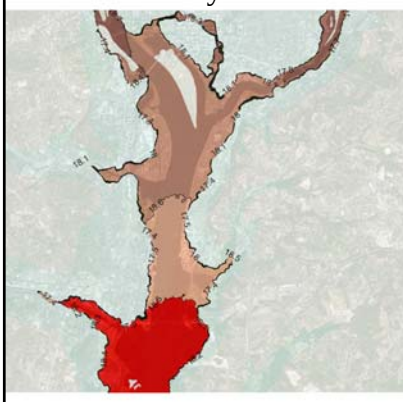
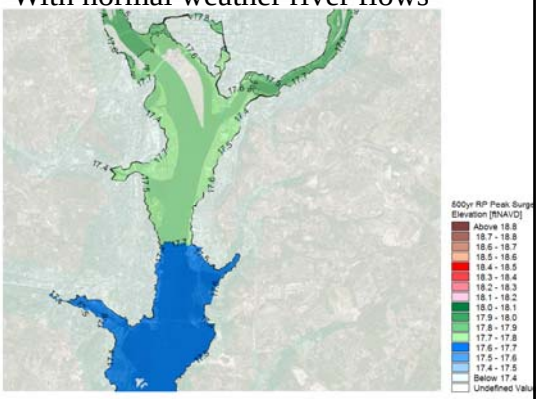
Preliminary Surge water levels – no flood barrier (500-yr surge, plus Sea Level Change)

With Hur. Sandy river flows



With normal weather river flows



Note that the left figure differs from that in Slide 8. Slide 8 is based on a more refined mesh in the DC Washington Core Area + the 17th Levee, and conversion of the two islands into water domain, which is shown as flooded in Slide 8.

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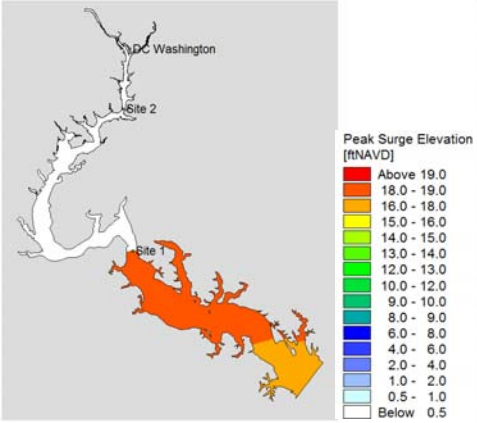
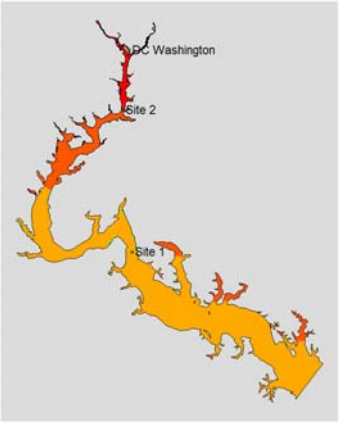
Difference in peak surge water levels: flood barrier 1 closed vs no barrier (regional view)

Site 1



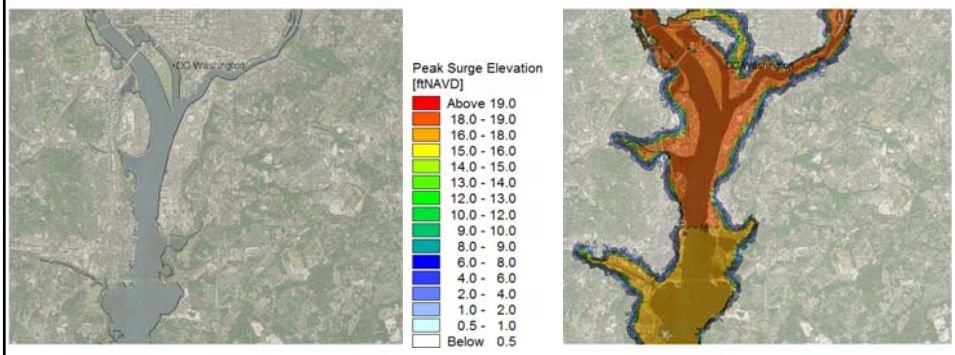
No barrier



Difference in peak surge water levels: flood barrier 1 closed vs no barrier (sub-regional view)

Surge Barrier at Site 1

No barrier



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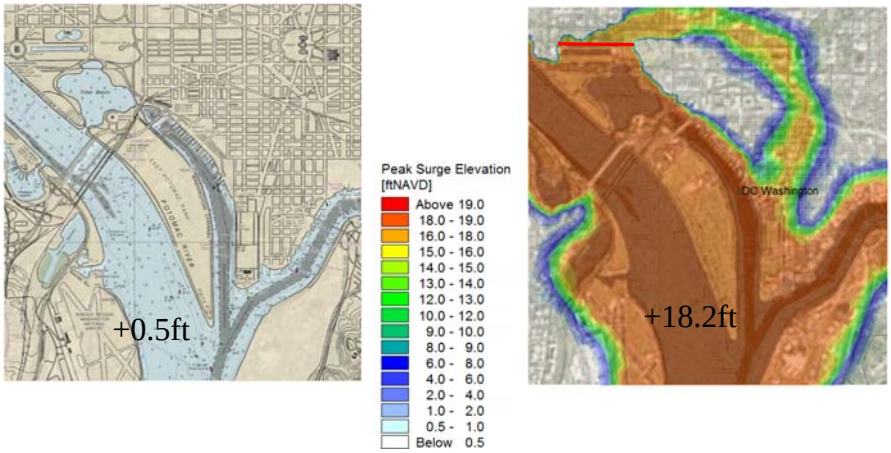
Difference in peak surge water levels: flood barrier 1 closed vs no barrier (local view)

Site 1

No barrier



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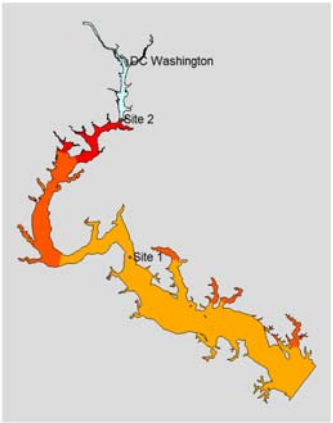
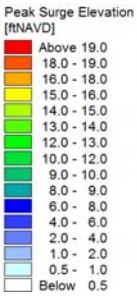
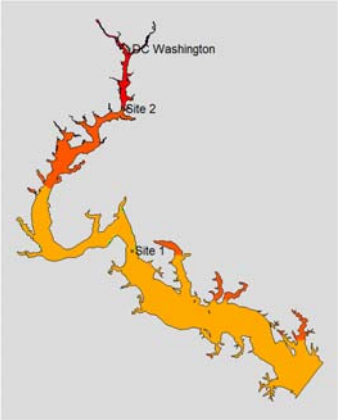
Difference in peak surge water levels: flood barrier 2 closed vs no barrier (regional view)

Site 2





No barrier



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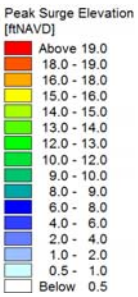
Difference in peak surge water levels: flood barrier 2 closed vs no barrier (sub-regional view)

Site 2



No barrier

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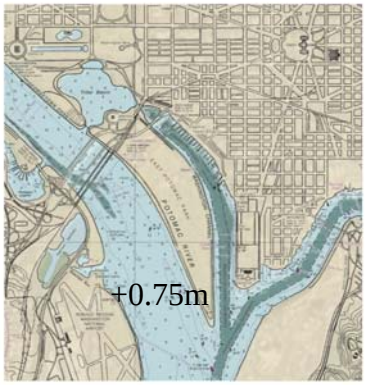
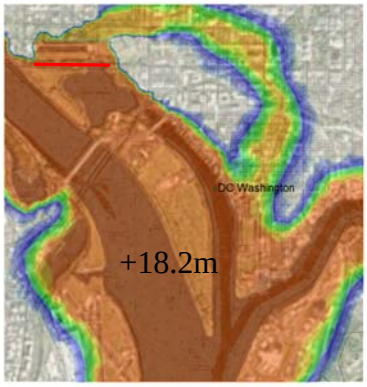
Difference in peak surge water levels: flood barrier 2 closed vs no barrier (Local view)

Site 2



No barrier



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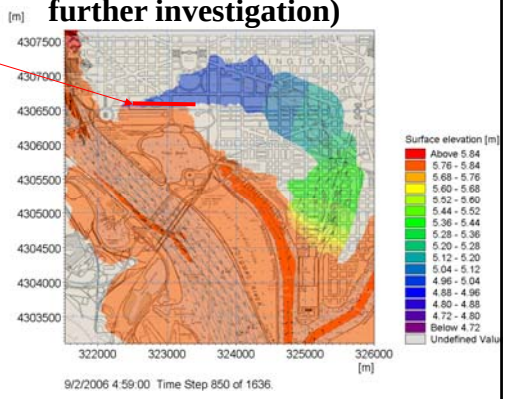
Impact of the recently completed 17th St Levee

Spatial Extent of Peak surge elevation

17th St Levee

Snapshot of current vector illustrating potential for backside flooding (needs further investigation)



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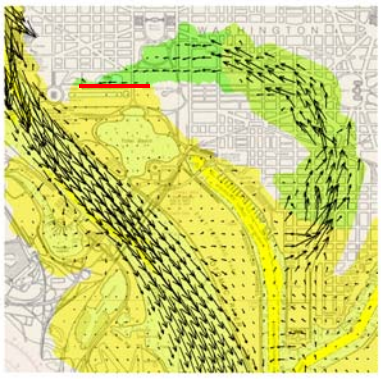
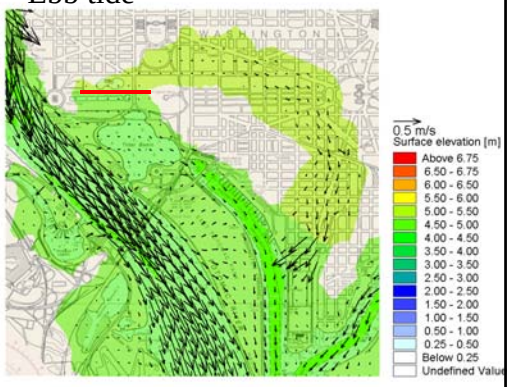
Preliminary Current speeds – no flood barrier

Flood tide



Ebb tide



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Ecological and Water Quality Impacts

- Migratory Fish
- Salinity Distribution
- Sediment distribution
  - Altered flow of water
    - Need to assess scour and siltation
  - Dredging impacts
    - Dredging analysis to identify change in materials and quantities
- Flushing
  - Assess whether flows will be reduced / impeded
    - Less effective at transporting point and non-point discharges
      - Most critical when barriers are closed during heavy rains
      - Detailed modeling required
    - Trapping of harbor debris ?

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Concept Costs

Option 1: North Location near Ft Washington – Radial gates with 1000 ft wide channel, and 2800 ft earth/rock levee barrier	
Base capital costs for barrier and gate	$594,150,000
Option 2: South Location near MD 301 (Nice) Bridge at Dahlgren MD – Rising Sector Gates (16) spanning 4000 ft wide channel, with 4,400 ft earth/rock levee barrier, and 14,400 ft 4-lane bridge.	
Base capital costs for barrier and gate	$7,405,200,000
Base capital costs for bridge	$2,253,620,000
Sub-total	$9,658,820,000

Note: Cost Estimates are Class V: -25% to +50%

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Project Benefits

Investments in flood protection will generate numerous benefits for Washington DC, VA, and MD communities and Federal Facilities on the Potomac

- Multiple Communities and Facilities protected under 1 project
- Reduced property damage
- Potentially lower insurance costs
- Higher property values & tax ratables from current properties
- Reduced need for future response and recovery investments
- Enhanced desirability to those wishing access to DC regional jobs
- Economic Development
- Construction jobs

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What else would we need to do for evaluation of the concept of a regional surge barrier for Washington DC

- Define benefits (direct and indirect costs of no action)
- Siting study
- Modeling of sediment transport, scour, and hydrodynamics
- Conceptual engineering and design of the barrier structures
- Enhance geotechnical data review
- Constructability review
- Refine cost estimates
- Select a preferred alignment
- Develop rendering of the flood barrier
- Discussion with regulators

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Frequently-Voiced Concerns

"It costs too much!"

- Compared to what?
- Sandy (2012): NJ damage estimated at $10B
- Irene (2011): cost $1 billion
- Forecast return period for Cat 1 hurricanes = 19 years
- In 50 year period
  - 1 in 7 chance of a hurricane strike
  - 1 in 30 chance of an intense hurricane (Cat 3 or greater) strike

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Conclusions

- A surge flood barrier system is conceptually feasible, and can be based on proven technology
- Benefit to cost ratio could be very favorable considering magnitude of storm damage avoided
- Creating and operating a surge flood barrier system will require consensus and cooperation from the federal, state, and local government
- Further engineering-led investigations are required to improve certainty and plan risk mitigations
- Grant money is available now!

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