



Tidal Flooding: The Shoreline Threat

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Outline



- ▶ Definitions
- ▶ Methodology
- ▶ Products/Thresholds
- ▶ Scenario
- ▶ Future Plans



What is Coastal Flooding?



- ▶ The inundation of people, buildings, and coastal structures on land at locations that, under normal conditions, are above the level of high tide.
- ▶ The Baltimore/Washington Coastal Flood program encompasses flooding of coastal areas along the tidal Potomac River and western shoreline of the Chesapeake Bay due to...
 - ▶ storm surge
 - ▶ tidal departures above astronomical predictions.





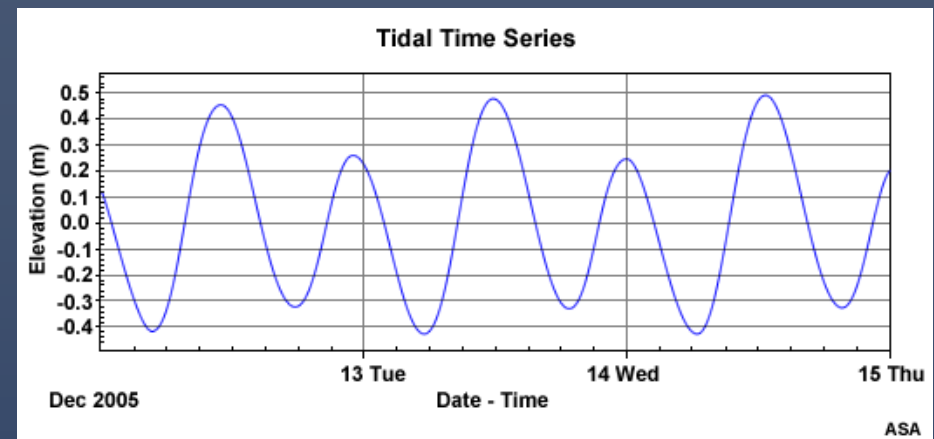
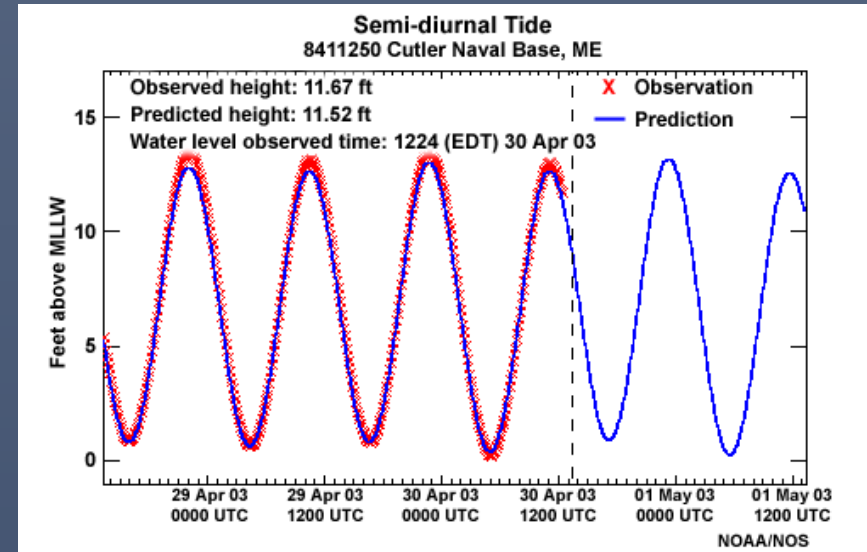
Tide Definitions

- ▶ **Astronomical Tides:** The rise and fall of water due to gravity/effects of the Sun and Moon.
 - ▶ **Meteorological Tides:** the rise and fall of water due to weather.
 - ▶ **Spring Tides:** Occur near new and full moons, when the Earth, Sun, and Moon are aligned. Results in the highest astronomical tides of the cycle.
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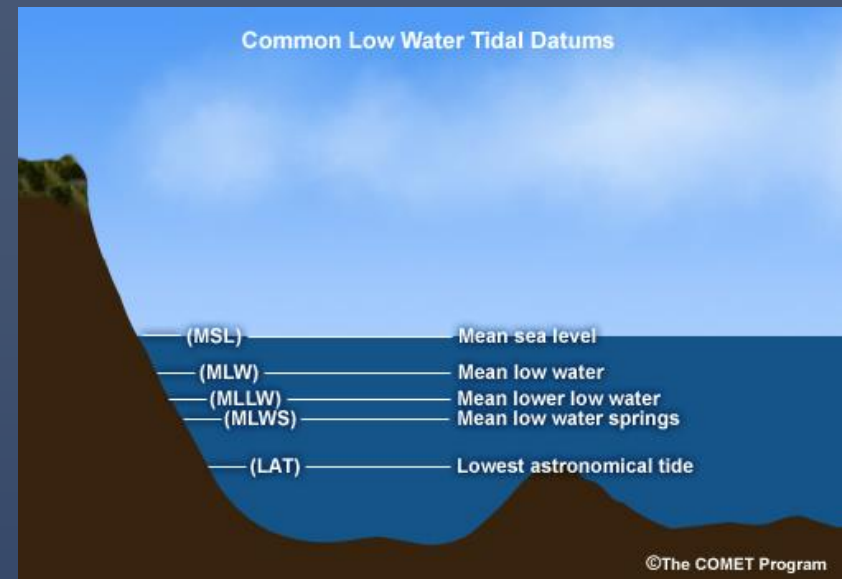
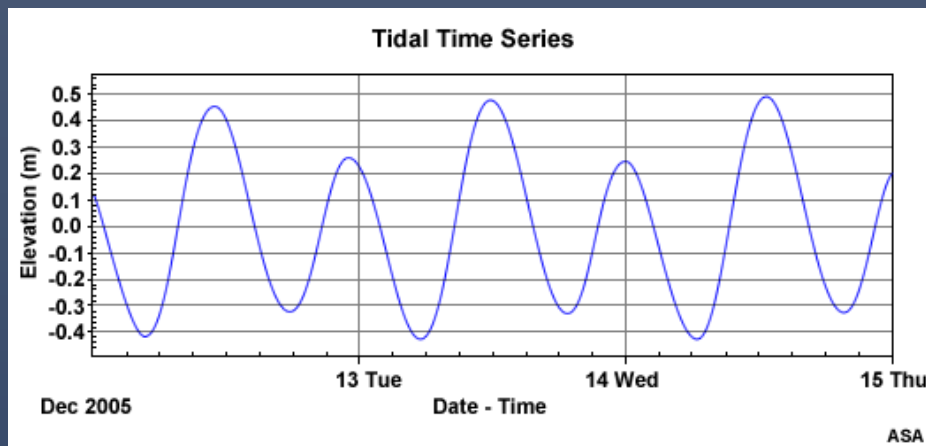
Tide Definitions

- ▶ Typical tide cycle in the Chesapeake Bay and Tidal Potomac River is either the *semidiurnal tidal cycle* or the *mixed tidal cycle*
 - ▶ Semidiurnal tides are nearly the same height. [DC]
 - ▶ Mixed tides are offset-- have a higher and lower high and low tide each day. [Most of the Maryland Chesapeake and tidal Potomac River]



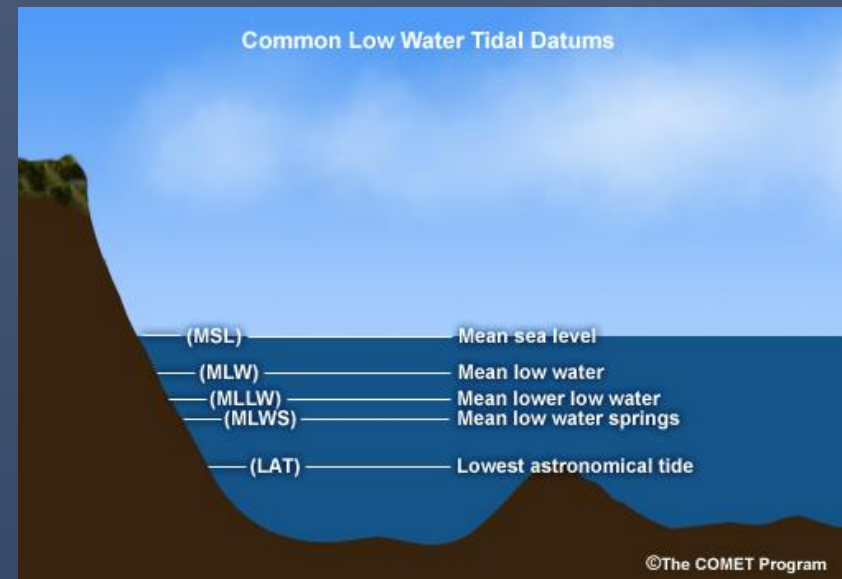
Datums

- ▶ The horizontal plane, unique to each individual tidal station, to which soundings, ground elevations, or water surface elevations for that station are referred.
- ▶ Since most sites locally have mixed tides, they report in Mean Lower Low Water. Those are the heights referenced in NWS products.



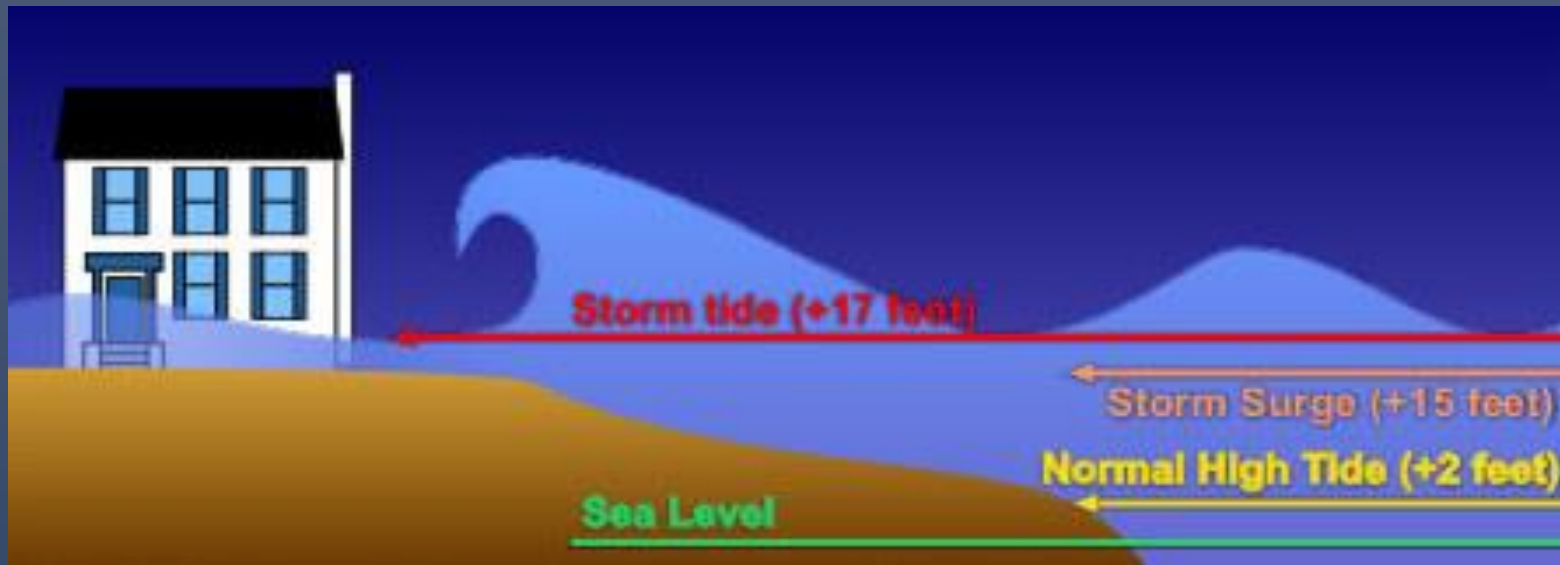
Datums

- ▶ There are plenty of other datums out there...
 - ▶ Mean Higher High Water
 - ▶ Mean Sea Level
 - ▶ NGVD29
 - ▶ NAVD88 (North American Vertical Datum of 1988— based off of a single point in Canada)
 - ▶ Washington Mean Low Water



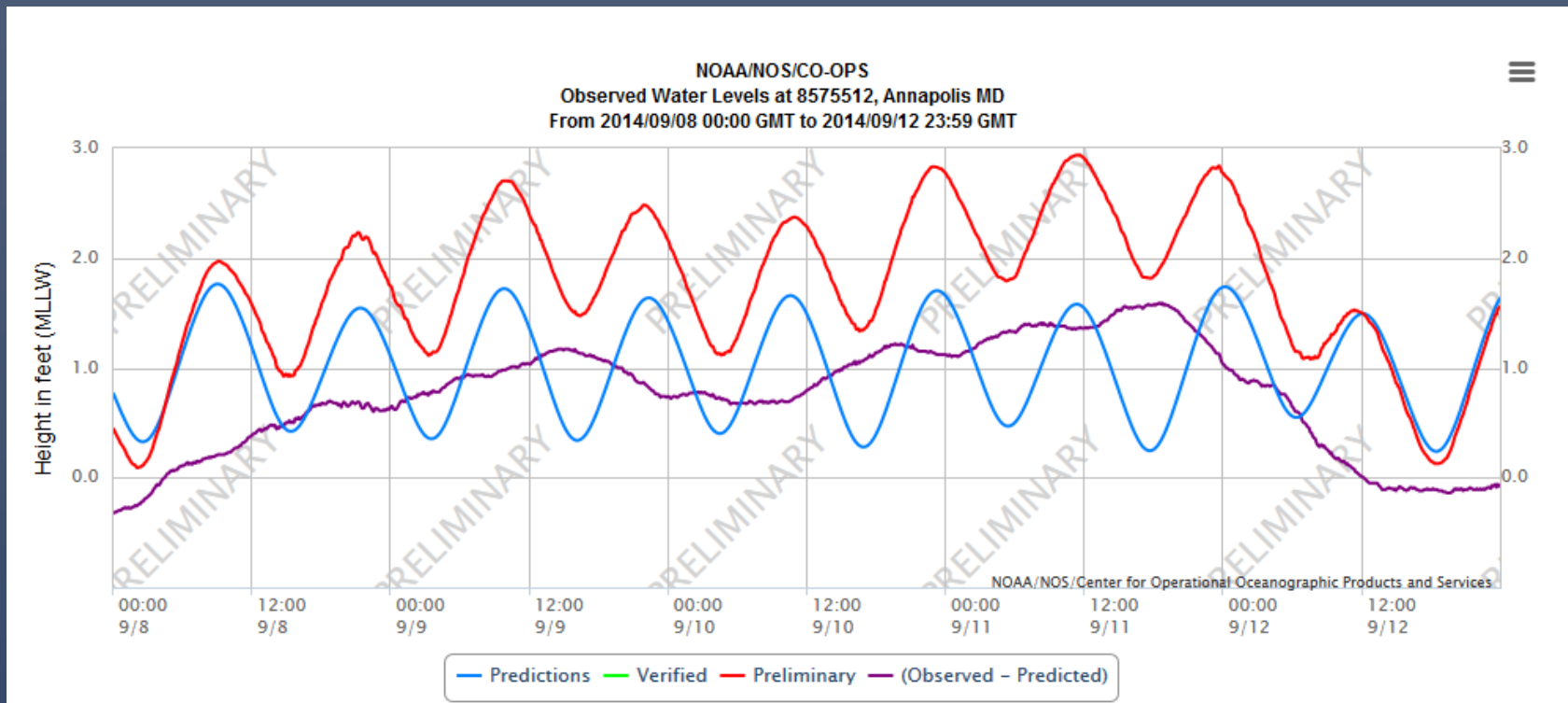
Tidal Anomalies

- ▶ **Storm surge:** A rise above the normal water level along a shore that is caused by a storm. The surge height is the difference of the observed water level minus the predicted tide.



Tidal Anomalies

- ▶ The big events are a result of either tropical systems or Nor'easters
- ▶ More frequently for us, tidal departures develop over time.





Coastal Flood Categories

- ▶ Minor flooding occurs when a few roads/parking lots are flooded at sensitive locations, or there is incidental property damage, such as yards being partially submerged. We issue **Coastal Flood Advisories** for minor flooding.
 - ▶ Moderate flooding takes place when major roads affected, property damage begins, sandbagging efforts are required, or evacuations become possible. If we expect moderate or higher flooding, we will issue a **Coastal Flood Warning**.
 - ▶ Major Flooding causes significant property damage and evacuations affecting larger populations.
-



Products



Beyond 48 hours

- Hazardous Weather Outlook (HWO)
- Area Forecast Discussion (AFD)

12-48 hours

- **Moderate Flooding Possible:** Coastal Flood Watch (along with HWO and AFD)
- **Minor Flooding:** Hazardous Weather Outlook

Within 12-24 hours

- **Moderate/Major Flooding:** Coastal Flood Warning (*will issue more than 12 hours in advance when lead time is important; will extend 24+ out when confident*)
- **Minor Flooding:** Coastal Flood Advisory (*will extend 24-36 hours out when confident*)

Warnings are NWR Tone Alerted, and will generate a "heads-up" email; Advisories do not.

Threshold Summary (Chesapeake Bay)



County	Location	Critical Minor	Critical Moderate	Critical Major
Harford	Havre de Grace <HDGM2>	4.0	5.5	7.0
	Edgewood <LTQM2>			
Baltimore County *	Bowley Bar	3.0	3.8	
Baltimore City *	Inner Harbor/Fells Point <BLTM2; also FORM2 & GFAM2>	3.0	5.0	6.0
Anne Arundel	Annapolis <APAM2>	2.4	3.3	6.0
Calvert	North Beach <NBCM2>	2.75	4.0	5.0
	Solomons <SLIM2>	2.75	4.0	5.0
St. Mary's (bayside)	--			

NOTE: Baltimore City and County are in the same zone, so the lower number will drive advisory/warning.

Threshold Summary (Tidal Potomac River)



County	Location	Critical Minor	Critical Moderate	Critical Major
Washington DC	SW Waterfront (Maine Ave.) <WASD2>	4.2	5.3	7.0
	Georgetown <GTND2>	6.0 WMLW	7.0 WMLW	10.0 WMLW
Arlington*		9.5	11.0	
Alexandria	Old Town (Cameron St Dock) <AXTV2 > [also ALEV2]	4.5 (3.1 NAVD88)	5.9 (4.5 NAVD88)	8.0 (6.6 NAVD88)
Fairfax	New Alexandria/Belle Haven <NADV2,APSV2,ATGV2>	5.9 (5.5 NGVD29)	6.9 (6.5 NGVD29)	7.9 (7.5 NGVD29)
	Huntington <HPKV2>	5.9 (5.5 NGVD29)	7.4 (7.0 NGVD29)	9.4 (9.0 NGVD29)
St. Mary's	St. George Island <SGIM2, SGSM2>	2.7	3.5	

NOTE: Arlington in same zone with Alexandria, which will almost always dictate the headline decisions



Thresholds Under Development

- ▶ Middle Tidal Potomac River
 - ▶ Prince George Co.
 - ▶ National Harbor/ “The Awakening” (4.5’ but unsure how well it relates to the big picture)
 - ▶ One other neighborhood road north of Piscataway Creek
 - ▶ Charles Co.
 - ▶ Marshall Hall: 5-ish
 - ▶ Pope’s Creek Road
 - ▶ Cobb Island
 - ▶ Tidal Patuxent River
 - ▶ Prince William Co.
 - ▶ Inlets from Occoquan Bay (5-ish)
 - ▶ Stafford Co.
 - ▶ Aquia Harbor?
 - ▶ King George Co.
 - ▶ Fairview Beach?
- ▶ Chesapeake Bay side of St. Mary’s Co.





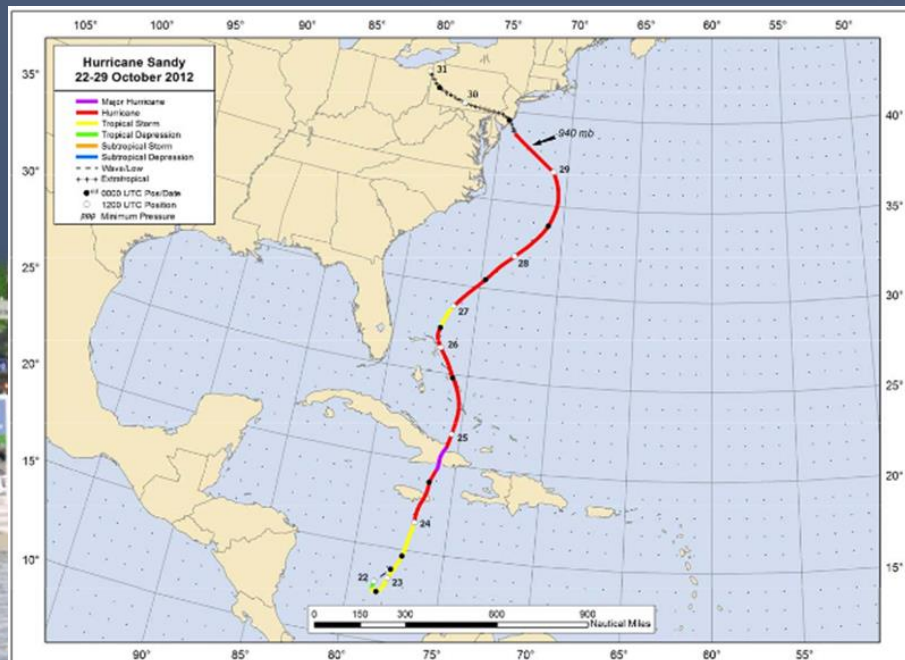
Scenario

What if Sandy happened here?

Making the case

- ▶ Its been over a decade (Isabel) since a significant tidal flooding event occurred
 - ▶ Event amnesia

- ▶ Post-tropical Storm (“Super Storm”) Sandy brought a catastrophic storm surge to metro NYC/New Jersey in late October 2012



- ▶ Preliminary damage estimates in the US \$50B*
 - ▶ 2nd costliest in history
 - ▶ 72 deaths* in the Mid-Atlantic/northeast US
 - ▶ Most since Agnes

▶ *CREDIT: Tropical Cyclone Report, Hurricane Sandy (AL182012), 22 – 29 October 2012
Eric S. Blake, Todd B. Kimberlain, Robert J. Berg, John P. Cangialosi and John L. Beven II; National Hurricane Center; 12 February 2013

Making the case



Twitter @Mark Hughes

via <http://animalnewyork.com/2012/hurricane-sandy-the-aftermath-in-photos/>



CNN.com



Twitter @Michelle Charlesworth

via <http://animalnewyork.com/2012/hurricane-sandy-the-aftermath-in-photos/>



Master Sgt. Mark C. Olsen/U.S. Air Force/New Jersey National Guard – [Flickr](#) Via Wikipedia



What if it happened here?

- ▶ SSH conducted a “What-if” study for metro DC
 - ▶ Using GIS mapping, observed surge values from NYC were placed on top of DC astronomical tides
- ▶ We have inundation mapping for Annapolis
 - ▶ We’ll use the same methodology
 - ▶ 7.6 ft is worst-case available
- ▶ Can make rough estimates elsewhere
- ▶ *Discussion*
 - ▶ *Explanation of methodology*
 - ▶ *Presentation of results*
 - ▶ *Our actions.*
 - ▶ *Your actions?*





DC Methodology

- ▶ The numbers in New York City:

Location	Storm Tide	Max Anomaly ("Storm Surge")	Tide cycle
The Battery, NYC	14.04 ft MLLW (11.27 ft NAVD88)	9.34 feet	High
Bergen Point	14.56 ft MLLW (11.64 ft NAVD88)	9.56 feet	High
Kings Point	14.30 ft MLLW	12.64 feet	Low

- ▶ Storm tide in NYC about 4 ft higher than what was observed during Isabel
- ▶ Tidal ranges are much higher in NYC than DC
 - ▶ Comparable surge will result in a lower storm tide
- ▶ Highest-possible astronomical high tide during tropical season is 3.7 feet MLLW (taken from NOAA Tide Tables)
 - ▶ Hypothetical storm surge 9.3 ft = hypothetical storm tide 13 ft





By the numbers...

	Washington DC (southwest Waterfront)		Annapolis (US Naval Academy)		Baltimore City (Inner Harbor)	
Minor	4.2 ft		2.4 ft		3.0 ft	
Moderate	5.3 ft		3.3 ft		5.0 ft	
Major	7.0 ft		6.0 ft		6.0 ft	
Record	11.05 ft (fresh)					
	Isabel (tidal)		Isabel		Isabel	
“Isabel”	10.28 ft	+8.10	7.28 ft		8.15 ft	
Hypothetical “Sandy” (9.3 ft surge)	<u>Storm Tide</u> ~13 ft	<u>Astro Tide</u> (3.7)	<u>Storm Tide</u> ~11.1 ft	<u>Astro Tide</u> (1.8)	<u>Storm Tide</u> ~11.4 ft	<u>Astro Tide</u> (2.1)

Storm Surge Warning is coming!



Metropolitan Washington results



What's not affected:

Orange outlined area:
protected by 17th St. levee (12
ft NAVD88)

Blue outline: Joint Base
Anacostia/Bolling protected
by levees/floodwalls

▶ Shaded region is approximately below 11.6 ft NAVD88 (=13 ft MLLW), the determined elevation which would equal a Sandy-like surge atop the highest high tide of tropical season

Metropolitan Washington results

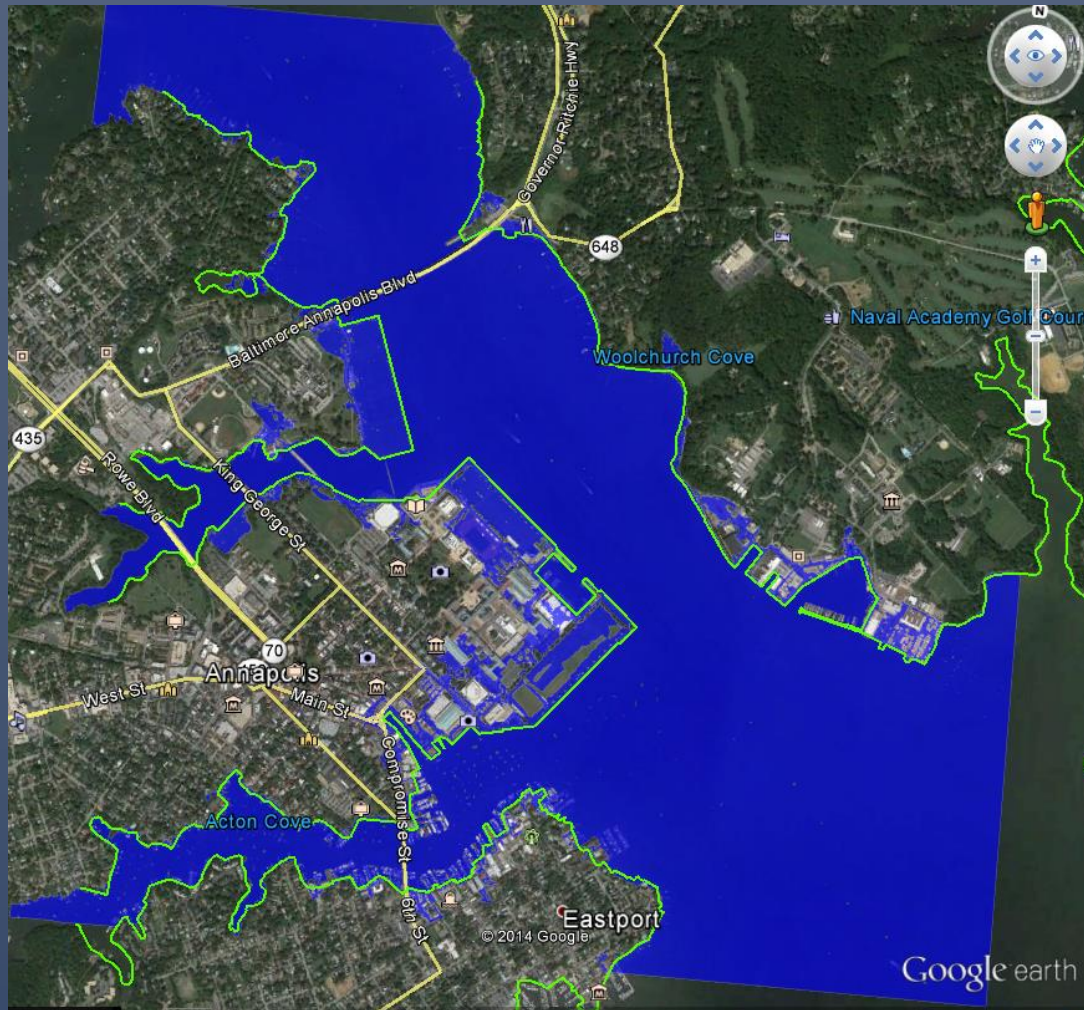


Impacted:

- East Potomac Park
- Part of west Potomac Park, incl. Jefferson/FDR/MLK memorials
- Tidal Basin → 17th St SW → Constitution Ave → WWII memorial and Reflecting Pool
- Water St SW (both ends)
- Shoreline near Ft. McNair
- Levee at Anacostia Park overtopped → I-295, Suitland Pkwy, & I-695
- Parts of DCA/GW Pkwy
- Roosevelt Island
- Georgetown waterfront (mitigated by floodwalls)
- Old Town Alexandria (2 blocks inland)

▶ Shaded region is approximately below 11.6 ft NAVD88 (=13 ft MLLW), the determined elevation which would equal a Sandy-like surge atop the highest high tide of tropical season

Annapolis results



Isabel resulted in significant damage in the City Dock area as well as on the campus of the Naval Academy.

One would think that the impact of an additional 3 ½ feet would be extensive.

Isabel isn't necessarily the worst-case scenario; planning shouldn't be based upon it!

▶ Shoreline in green; shaded region represents inundation to 7.6 ft MLLW. This is the worst-case illustration we have access to. **Actual inundation would be 3.5 ft higher (11.1 ft MLLW)!!**

Metro Baltimore possibilities

- ▶ **From “Storm Data” for Isabel:**
 - ▶ Coastal properties below 10 feet MSL [were] exposed to wave action
 - ▶ BaltCo: Residential areas of Millers Island, Edgemere, North Point, Bowley Quarters and Turners Station were hard hit with more than 400 people being rescued from their homes and over 300 buildings destroyed.
 - ▶ Water flooded Baltimore's Inner Harbor and Fells Point area causing millions of dollars damage to waterfront property. The Baltimore Museum of Industry alone received \$1.5 million in damage.
 - ▶ Harford: [Inundation] up the Bush River and the waterfront at Havre de Grace. About 55 people were evacuated from Abingdon, Edgewood and Perryman along the Bush River and about a dozen people were evacuated in Havre de Grace.



Isabel storm tide 8.15 ft
Baltimore

Think what a hypothetical
storm tide of 11+ ft would
do.

(9.3 ft surge + 2.1 ft astro
tide = 11.4 ft storm tide)

Inundation would be 3 or 4
ft deeper than Isabel!



Southern Maryland/northern Piedmont Virginia possibilities



▶ From “Storm Data” for Isabel:

- ▶ Calvert County: 4 to 5 foot waves crashed into the towns of North Beach and Solomons. In North Beach, a house was moved off its foundation. The pier at Solomons Island was lost with the storm surge causing extensive damage to the shoreline.
- ▶ St Mary's County: residents saw 6 foot waves crashing onto shore and some homes were literally flattened. On St. George Island, 20 homes were destroyed and water covered much of the island at high tide for a week. The bridge to the island washed out as early as 3:45 pm on Thursday.
- ▶ Charles County: \$2 million in damage to roads. Cobb Island was hit hard with two homes destroyed and others damaged.
- ▶ King George County: four homes and 20 businesses had major damage.
- ▶ Prince William County: seven homes were destroyed and 24 homes and 3 businesses had major damage. The storm surge washed away 20 feet of embankment along the Potomac which caused one of the CSX tracks to collapse along the Cherry Hill Peninsula. Damages at Quantico Marine Base were significant; flooding destroyed their marina.
- ▶ Stafford County: many boats at the docks broke free. Five marinas were destroyed.

Isabel was (estimated to be) a 5 to 9 ft storm surge.

The surge took out the gauges at Solomon's Island and Colonial Beach, so we'll never know the storm tide for sure.

Think about what a 9 ft storm surge/ 11 ft storm tide would do.

(9.3 ft surge + 1.8 ft astro tide = 11.1 ft storm tide)

Inundation would be 2-4 ft deeper, penetrate further inland than Isabel!





Questions?

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