Development of a Comprehensive Gauge-Based Flood Frequency Analysis for the National Weather Service Baltimore/Washington Hydrologic Service Area

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Introduction / Motivation

- Beginning in 2011, staff from the National Weather Service Baltimore/ Washington office began a multi-year project to determine critical flood thresholds at over 200 stream gauge locations which had no such thresholds determined.
- In conjunction with this project, a study was conducted to determine weather patterns favorable for extreme rainfall as well as stream flooding, and the frequency with which flooding occurs.

Extreme Rainfall History

Top 10 Raindays

Washington DC		Baltimore	
6.39	8/23/1933 (1933 hurricane)	7.62	8/23/1933 (1933 hurricane)
6.14	8/2/1944 (1944 hurricane)	6.30	8/12/2014 (onshore flow)
6.11	6/21/1972 (Agnes)	6.02	9/30/2010 (Nicole)
5.97	8/11/1928 (TS remnants)	5.97	9/24/1912 (onshore flow)
5.44	8/12/1955 (Connie)	5.85	7/8/1952 (onshore flow)
5.19	6/25/2006 (Federal Triangle) *	5.51	10/29/2012 (Sandy)
5.16	9/2/1922 (onshore flow)	5.02	9/16/1999 (Floyd)
4.92	8/12/1898 (strong cold front)	5.00	9/27/1985 (Gloria)
4.83	8/20/1963 (overrunning)	4.91	8/12/1955 (Connie) **
4.76	9/16/1976 (subtropical #3)	4.76	9/6/1895 (onshore flow)

** The Federal Triangle flood was the highest two-day rainfall at DC (9.41")*
*** Connie was the highest two-day rainfall at Baltimore (8.50")*

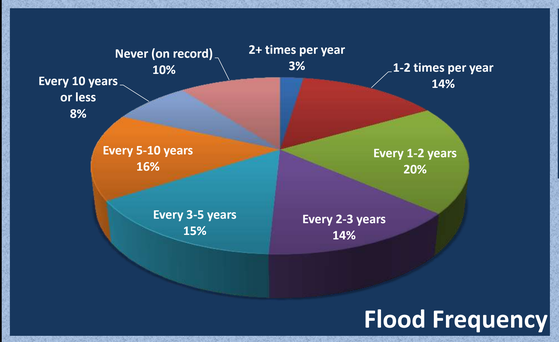
35 of the 36 wettest days in Baltimore and 39 of the 40 wettest days in DC are between June 2nd and October 11th (exception in both cases: Sandy)

- The extreme rainfall analysis indicates that the heaviest rains are fairly localized, and all occur in the June to October timeframe in the Washington and Baltimore metro areas. Further inland (not shown), extreme rainfall cases are spread throughout the year, and more associated with coastal lows.
- A river flood frequency analysis from the Middle Atlantic River Forecast Center indicates that larger rivers are most likely to flood in the January through April timeframe. This is a reminder that it does not take the most extreme rain amounts to cause larger rivers to flood.

Methodology

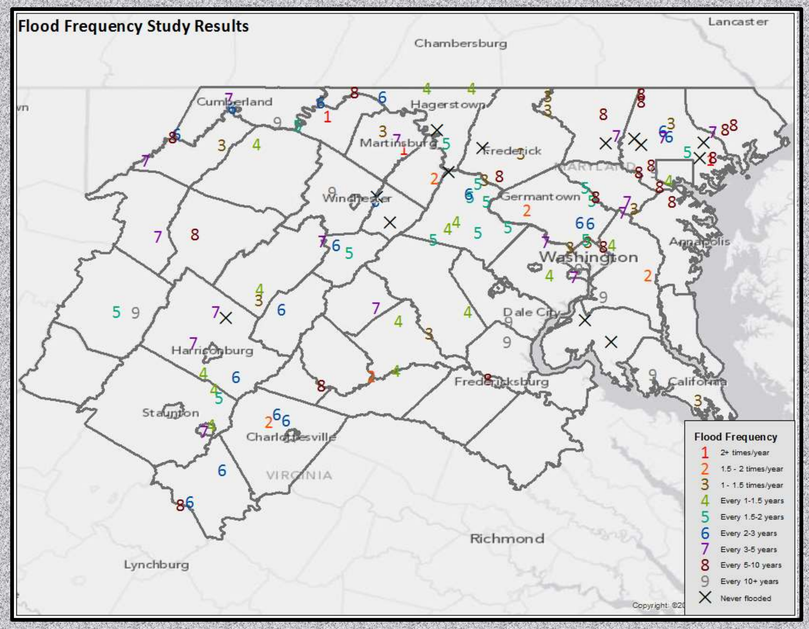
- Over a multi-year period, staff from the National Weather Service used a combination of field surveys, FEMA flood maps, USGS station descriptions, state bridge elevation data, and flood history to determine flood stages at locations which did not have them throughout the HSA. These flood stages were not set to bankfull, but were set to be a meaningful level where a road, building, or other substantial property was affected. Choosing this as the flood stage allows it to be a trigger point and verification point for Flood Warnings to the public.
- Historical stage and flow data was obtained from the USGS for all available currently-active locations. Then the peak values were compared to the determined flood stage and a frequency determined based on the period of record at the site. Changes in site and/or datum were also factored into the analysis.
- Some sites did not have a sufficient period of record to determine a flood frequency. Others, through field surveys and other information, were determined to have little or no flood threat and were also not included in the frequency study.

Results



% of sites without flood levels before this project	
2+ times per year	33%
1-2 times per year	67%
Every 1-2 years	80%
Every 2-3 years	67%
Every 3-5 years	63%

- Just over half of the 136 locations in this study flood at least once every 3 years. Of these, 70% are not river forecast points and did not have known flood levels before this project.
- Of the sites that average at least one flood per year, 62% are not river forecast points and did not have known flood levels before this project.
- Among the sites that average at least one flood per year, all but one have lengthy periods of record of 35 years or more, making their flood frequency significant.



Conclusions

- Gauge data can help us detect and verify flooding, but only if we know what critical flood thresholds are at each gauged location.
- When flood thresholds exist for dozens of sites, it becomes difficult for a meteorologist/hydrologist to prioritize which sites to monitor more closely.
- The development of a flood frequency analysis allows for a 'ranking' of sites based on their flood occurrence, so persons working the hydrology desk can see which sites flood more frequently and give those sites the most attention when heavy rain occurs in those areas.

Favorable Weather Patterns

- 31 locations in the Baltimore/Washington Hydrologic Service Area have at least 65 years of record or longer (date back to 1950). Using the record one-day rain events from these locations, composite charts of typical surface and upper air weather patterns were developed.

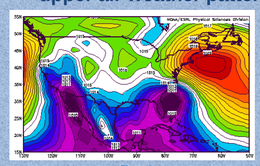


Figure 1

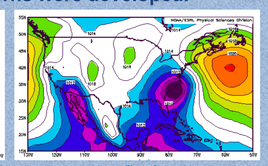


Figure 2

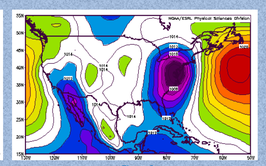


Figure 3

The graphics above show composite mean sea level pressure for (from left to right) a three-day sequence centered on the date of the record one-day rain at all 31 sites.

- Note the strong high pressure east of New England, which slowly shifts eastward as low pressure moves up the Atlantic coast.
- When tropical cyclones are factored out of this analysis, more of a synoptic signal exists west of the Great Lakes, and the composite surface low is inland, rather than just off the coast.

Figure 4, at right, represents the same time as Figure 2 above, but with all tropical events removed.

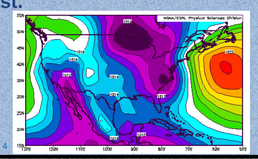


Figure 4

- A connection to Atlantic and/or Gulf of Mexico moisture is a key factor in heavy rain events in the mid-Atlantic region. Using the same events as noted at left, composite charts of precipitable water were also developed.

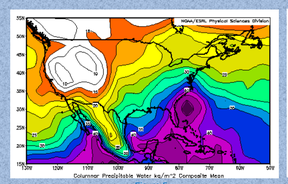


Figure 5

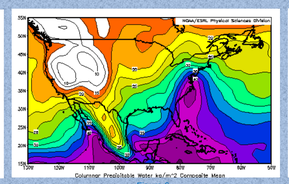


Figure 6

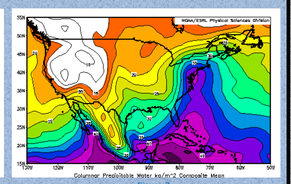
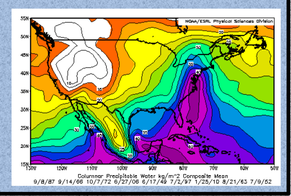


Figure 7

The graphics above show composite precipitable water (in mm, from left to right) for a three-day sequence centered on the date of the record one-day rain at all 31 sites.

- Average precipitable water values of 1.50 – 2.00 inches are noted south of the mid-Atlantic, with a gradient to the north. Over time, this higher moisture content shifts northward, but the region – on average – is more so in the gradient of high precipitable water values than actually in the maximum. The non-tropical case is again shown at right, but it looks very similar.



Future Work

- Flood frequency alone does not necessarily tell the entire story of flood threat. There are many cases in this study where two sites have the same flood frequency, but one floods in several hours while another may take 1-2 days to flood. There are also cases in this study where a location floods many times with minor impact, while other sites may reach flood less frequently but impact more when they do flood.
- For this reason, the next step in this study is to use basin characteristics and the time it takes for a given location to flood, as well as an analysis of what is specifically impacted, to create a *flood threat score*. This will allow more rapidly-flooding streams to be ranked above a stream where interests may have 1-2 days to prepare. It will also allow sites where significant damage occurs frequently to be ranked above sites where not as much is impacted. This flood threat score can be used by forecasters to give them knowledge of which locations are of greatest overall threat, not just frequency.

Acknowledgments

United States Geological Survey, Virginia Water Science Center
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Middle Atlantic River Forecast Center
National Climatic Data Center