

National Weather Service Flood Class



2019 Season



SKYWARN

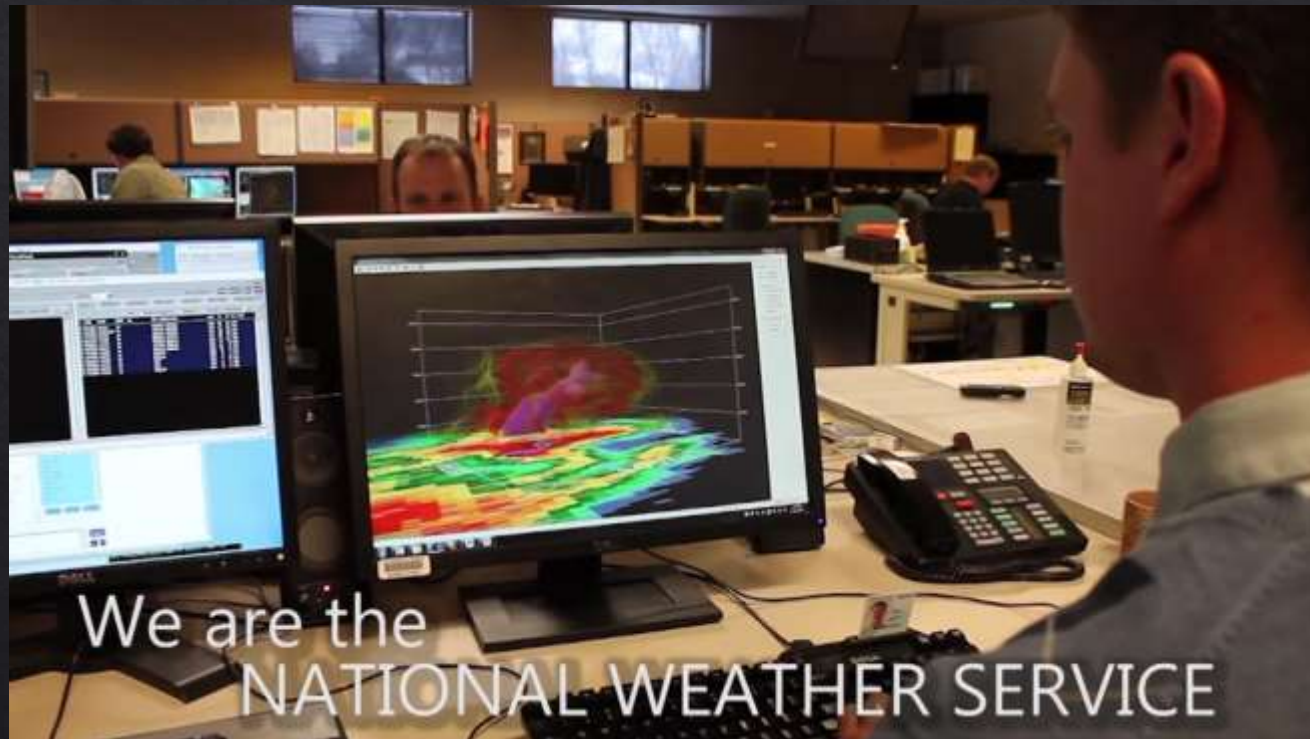
Tonight's Topics

- ◇ NWS Hydrology Overview
- ◇ Flood Facts & Flood Safety
- ◇ "Hydrology 101"
- ◇ Rainfall Forecasting / Meteorology
- ◇ Types of Flooding
- ◇ **Break**
- ◇ NWS Products
- ◇ Observations
- ◇ What to Report
- ◇ Event Reviews
- ◇ Review / Q&A



National Weather Service Mission

- ◇ Provide weather, **water**, and climate **data, forecasts and warnings for the protection of life and property** and enhancement of the national economy.



The National Weather Service is Local!



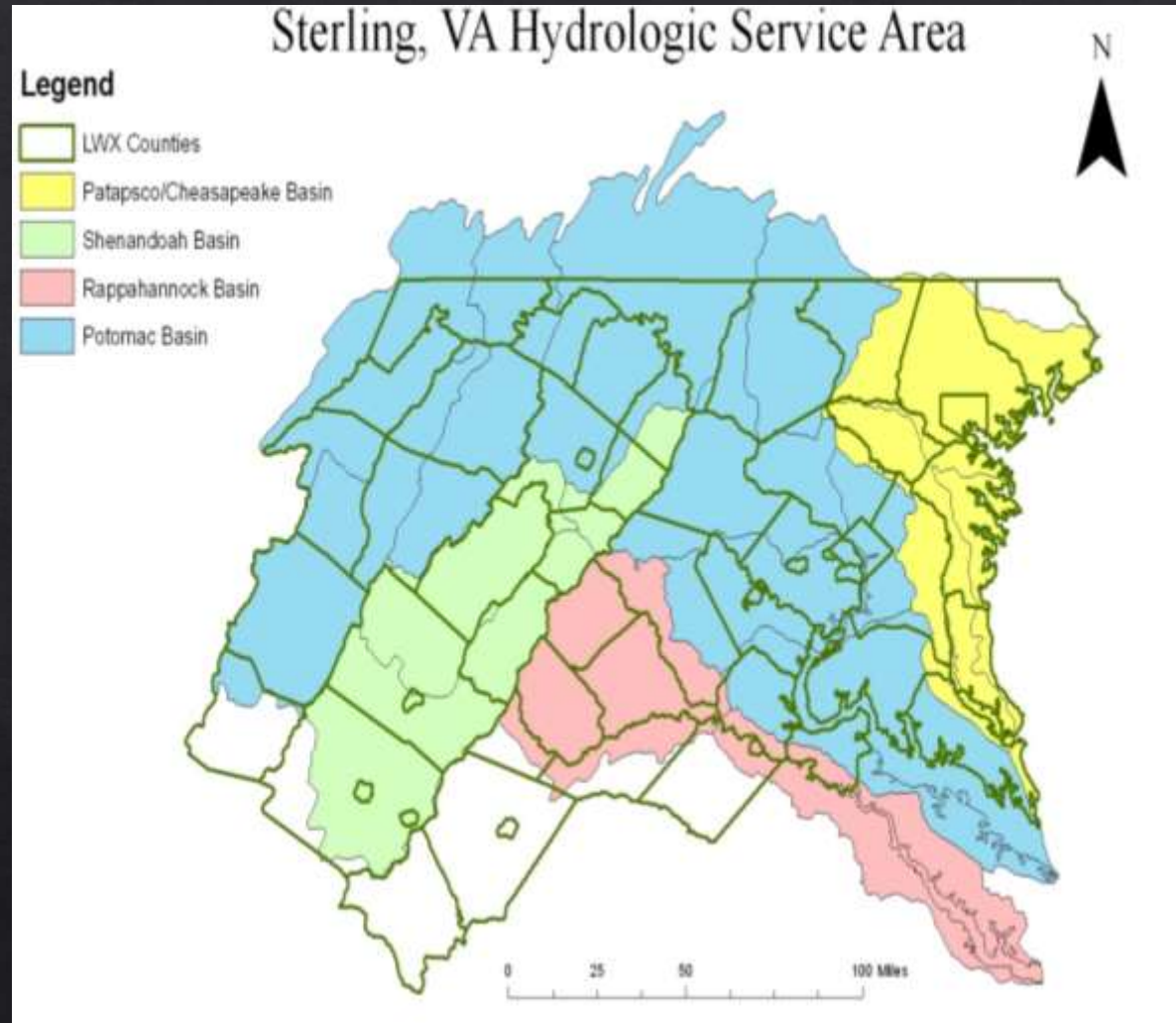
Areas of Responsibility

◇ County Warning Area (CWA) Flash Flood

- ◇ 43 Counties in 3 states
- ◇ District of Columbia
- ◇ 12 Independent Cities
- ◇ MD Chesapeake Bay

◇ Hydrologic Service Area (HSA) River Flood

- ◇ Potomac Basin
- ◇ Shenandoah Basin
- ◇ Rappahannock Basin
- ◇ West Chesapeake

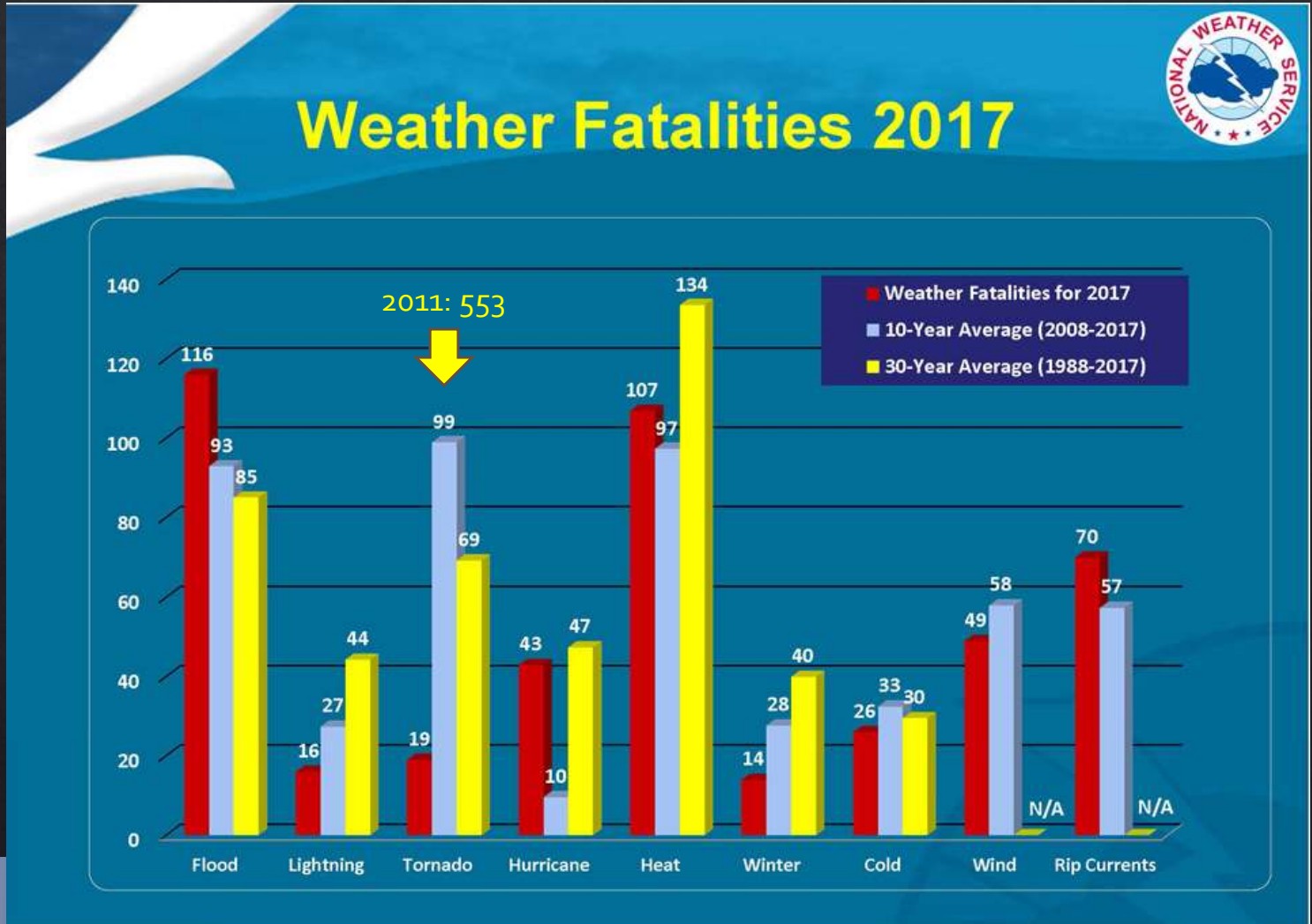


Don't let this be you! (Or anyone you know.)



Floods – a major weather killer

- ❖ On a long-term basis, floods are the #2 cause of death when weather plays a role, behind heat. *(2018 data not yet finalized)*



Flood Facts

- ◇ Most flood fatalities:
 - ◇ occur in cars
 - ◇ occur at night
 - ◇ *are the result of bad decisions*

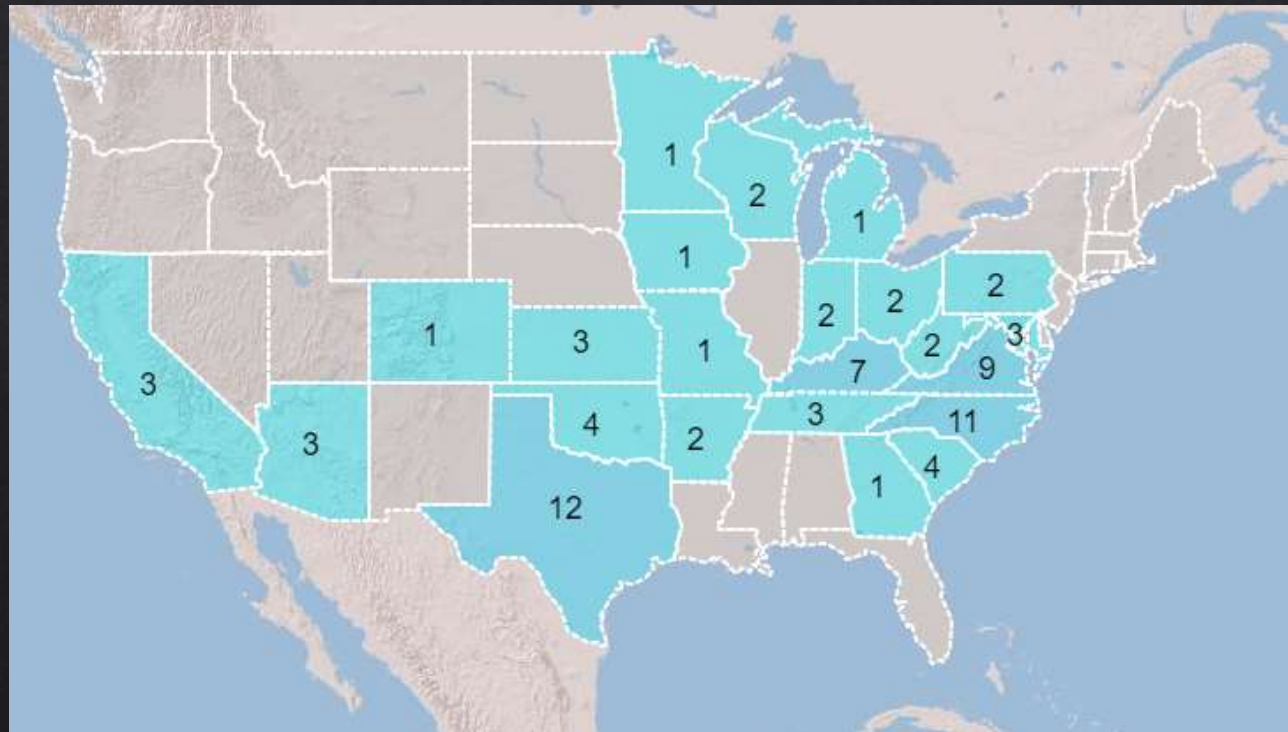
*Upper Marlboro, MD &
Fairfax, VA – Sept. 2011*



Flood Fatalities

- ◆ In 2018, there were 83 flood fatalities (right around the long-term average).
- ◆ Nearly two-thirds (65%) were male and over two-thirds (69%) were vehicle-related

This is consistent year after year



Flood Damages

- ◇ 10 year average: \$10 billion per year!
 - ◇ *2017: \$61.4 billion!*
- ◇ Most Presidentially-declared disasters are at least in part flood-related



Ellicott City, MD
2016



Flood Safety

- ◆ **Take Appropriate Action!**
- ◆ Never try to drive, swim, walk, or run through a flooded area.
- ◆ Know the flood prone areas on your daily commute – and avoid them if they're flooded! (Know at least one alternate route that doesn't flood!)
- ◆ Plan ahead – Identify where to go if told to evacuate. Choose several places (a friend's home or a hotel, or a designated shelter)
- ◆ Children should not play in or near flooded areas, especially in ditches or moving water



**Fall Hill Road, Fredericksburg, VA
June 2018**

Photo courtesy City of Fredericksburg



Turn Around, Don't Drown!

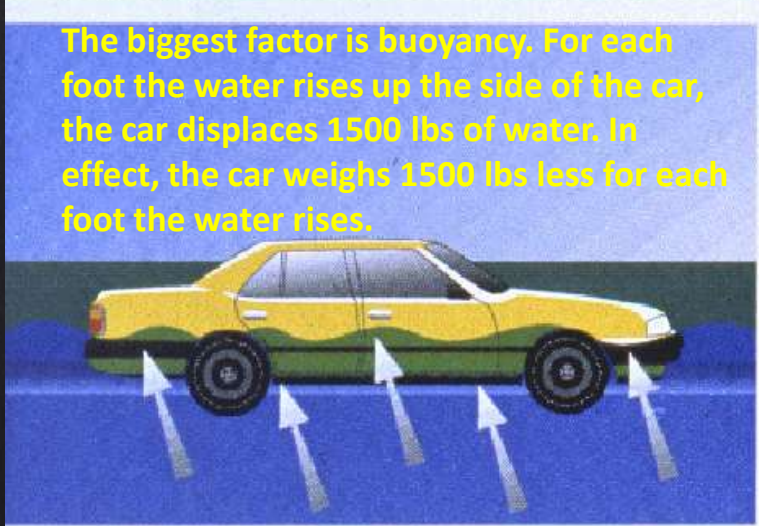
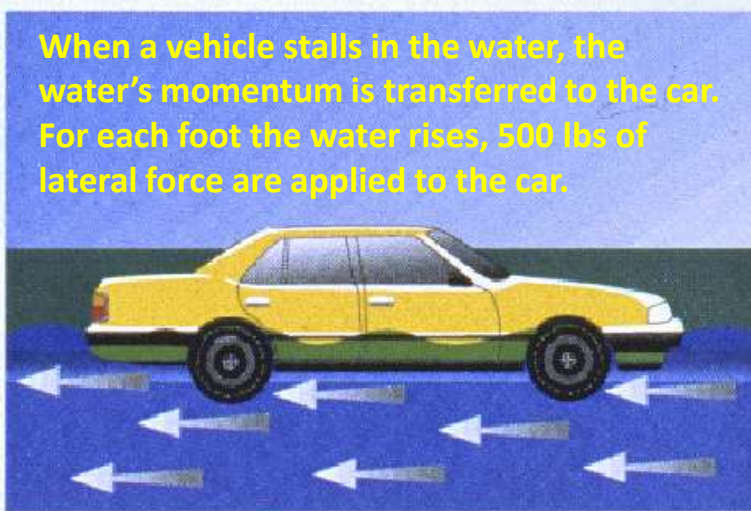
- ◇ If you come upon flood waters, **STOP! TURN AROUND AND GO ANOTHER WAY!**
- ◇ Only 6 inches of fast-moving water can knock you off your feet
- ◇ 2 feet of moving water will float almost any vehicle...*less water for smaller cars*
- ◇ The road under the water might be compromised
- ◇ **Bottom line: never assume there is a safe way to drive through water**





The Physics of Floating Cars

- Vehicle weights:**
- Mitsubishi Mirage: 1,973 pounds
 - Ford Fiesta: 2,537 pounds
 - Toyota Corolla: 2,800 pounds
 - Honda Accord: 3,336 pounds
 - Ford F-150: 4,850 pounds
 - Chevy Suburban: 5,808 pounds



The Physics of Floating Cars



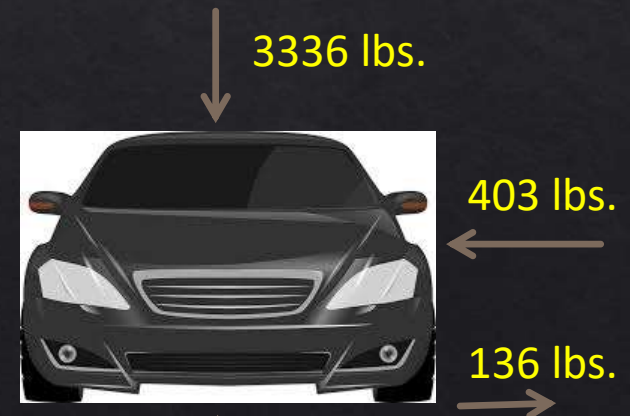
- The Honda Accord weighs 3,336 pounds
- 1 foot of water displaced by this vehicle weighs $(6 * 16 * 1 * 62.4) = 5990$ pounds

- ▶ Water Depth = 1 foot
- ▶ Width: 6 feet
- ▶ Length: 16 feet
- ▶ Clearance: 6 inches
- ▶ Weight: 3,336 pounds
- ▶ Net Depth = 0.50 foot

Net Weight : $3,336 \text{ lbs} - 2,995 \text{ lbs} = 341 \text{ lbs}$

Friction Force: $0.4 \times 341 \text{ lbs} = 136 \text{ lbs}$

136 lbs is LESS than the 403 lbs of stream force, so unless you and all the extra things in your vehicle weigh 267 pounds, your car will begin to be carried downstream!



If this number \rightarrow is greater than the weight of your car, it's floating!

Not Just Hazards for Cars



WFTS-TV

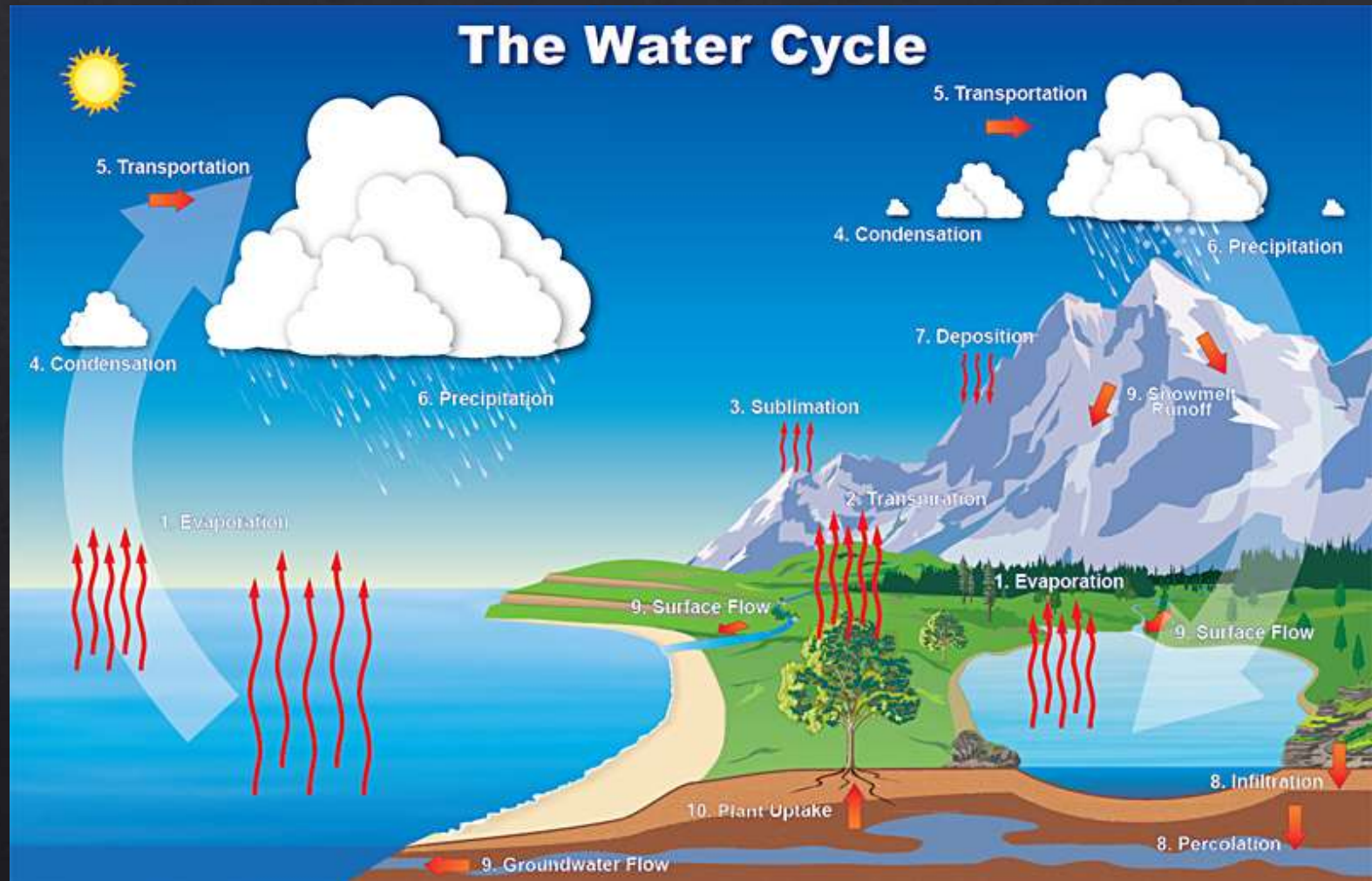


Know Your Risk

- ◇ Check the FEMA Flood Maps to see if you are in a flood zone...
 - ◇ **Maryland:** <http://www.mdfloodmaps.net>
 - ◇ **Virginia:** <http://cmap2.vims.edu/VaFloodRisk/vfris2.html>
 - ◇ **West Virginia:** <http://www.mapwv.gov/flood/>
 - ◇ **DC:** <https://doee.dc.gov/floodplainmap>
 - ◇ **National:** <https://www.floodsmart.gov>
- ◇ Flooding is not limited to these flood zones!
Always consider flood insurance!



Basic Hydrology

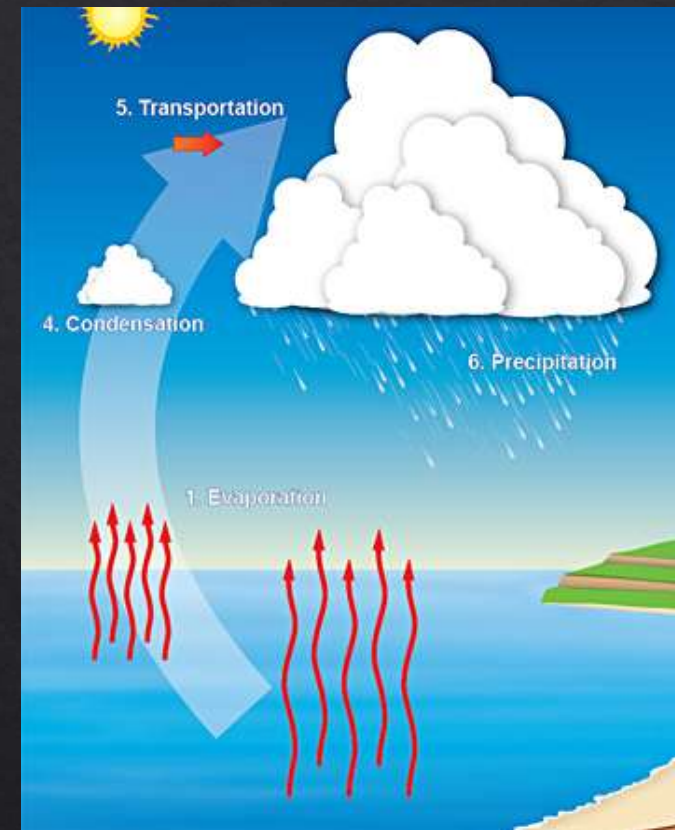


<http://polaris.umuc.edu/cvu/envm/hydro/hydrologic.swf>



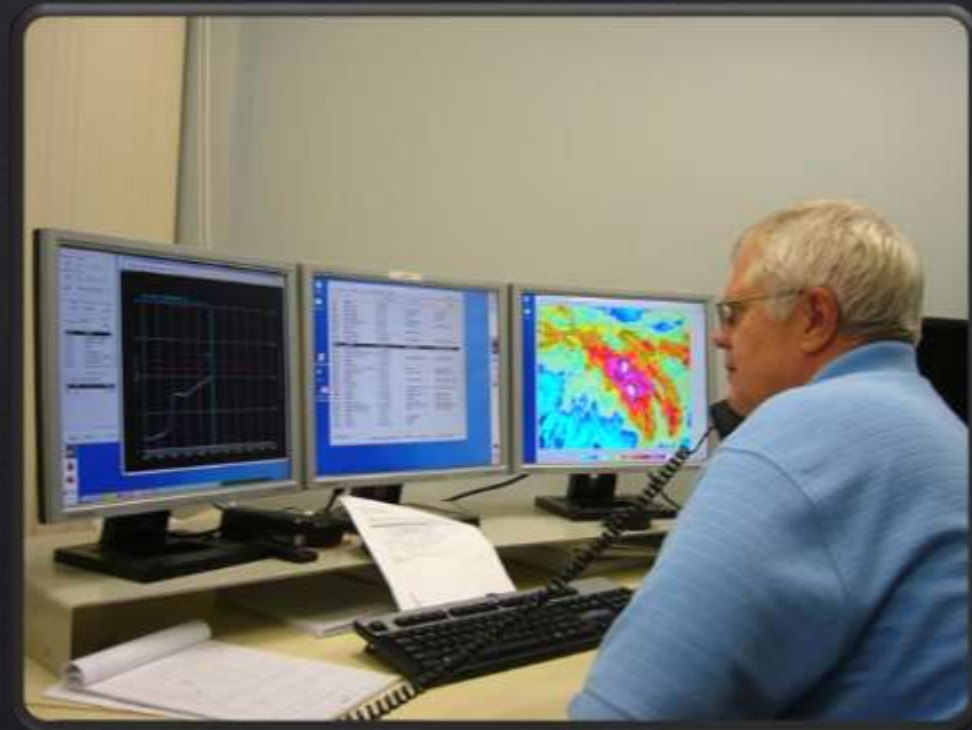
Precipitation in the Water Cycle

- ❖ The air must be nearly saturated. (100% RH)
- ❖ Cloud droplets or ice crystals form through condensation on small particles (often minerals in the air)
- ❖ These droplets/crystals then grow in size
- ❖ For precipitation to occur, cloud elements must get so large that their falling speeds exceed the upward motion in the air
- ❖ Also, the precipitation must be able to fall through any drier air that exists between the cloud and the ground.



How do we forecast flood potential?

- ◆ Pre-event assessment "*antecedent conditions*"
- ◆ Consider areas more prone to flooding
- ◆ Forecast expected rainfall
- ◆ Put it all together!

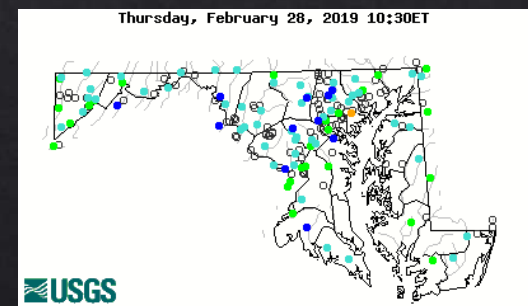
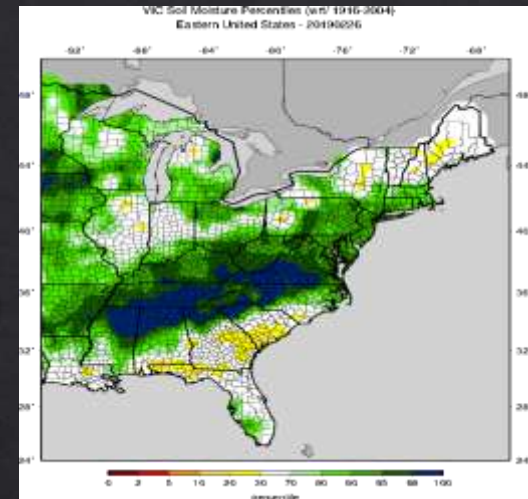


Pre-event assessment

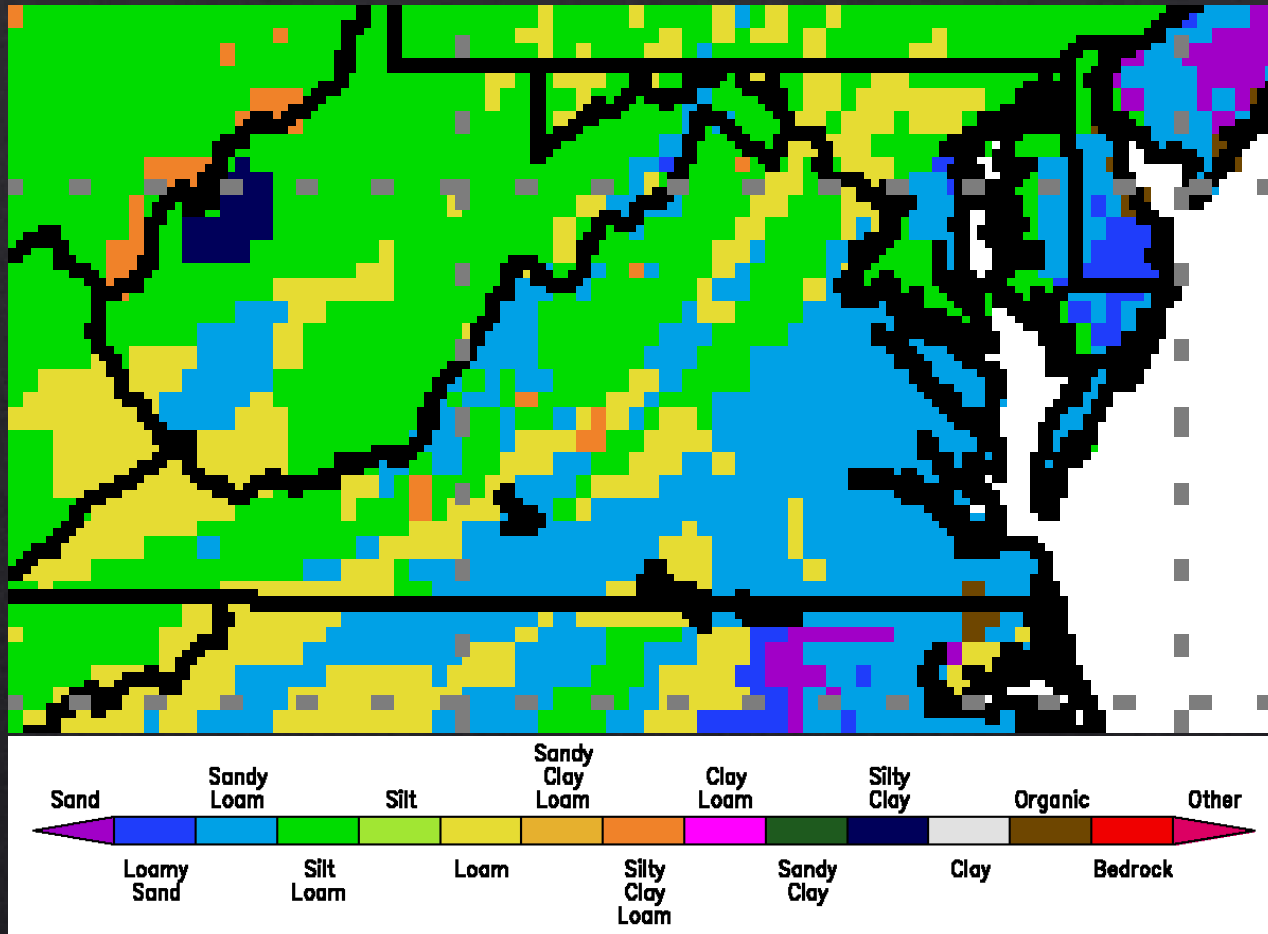
Questions to ask / items to check:

- ◇ Is the ground/soil wet or dry?
- ◇ What type of soil exists? (sandy, clay, frozen)
- ◇ Are streams at baseflow or elevated?
- ◇ What is the topography of the area?

- ◇ **More questions based on time of year**
 - ◇ Have the trees leafed out yet?
 - ◇ Is there snow on the ground? Will the snow melt?
 - ◇ Could plowed snow or fallen leaves clog drainage systems?

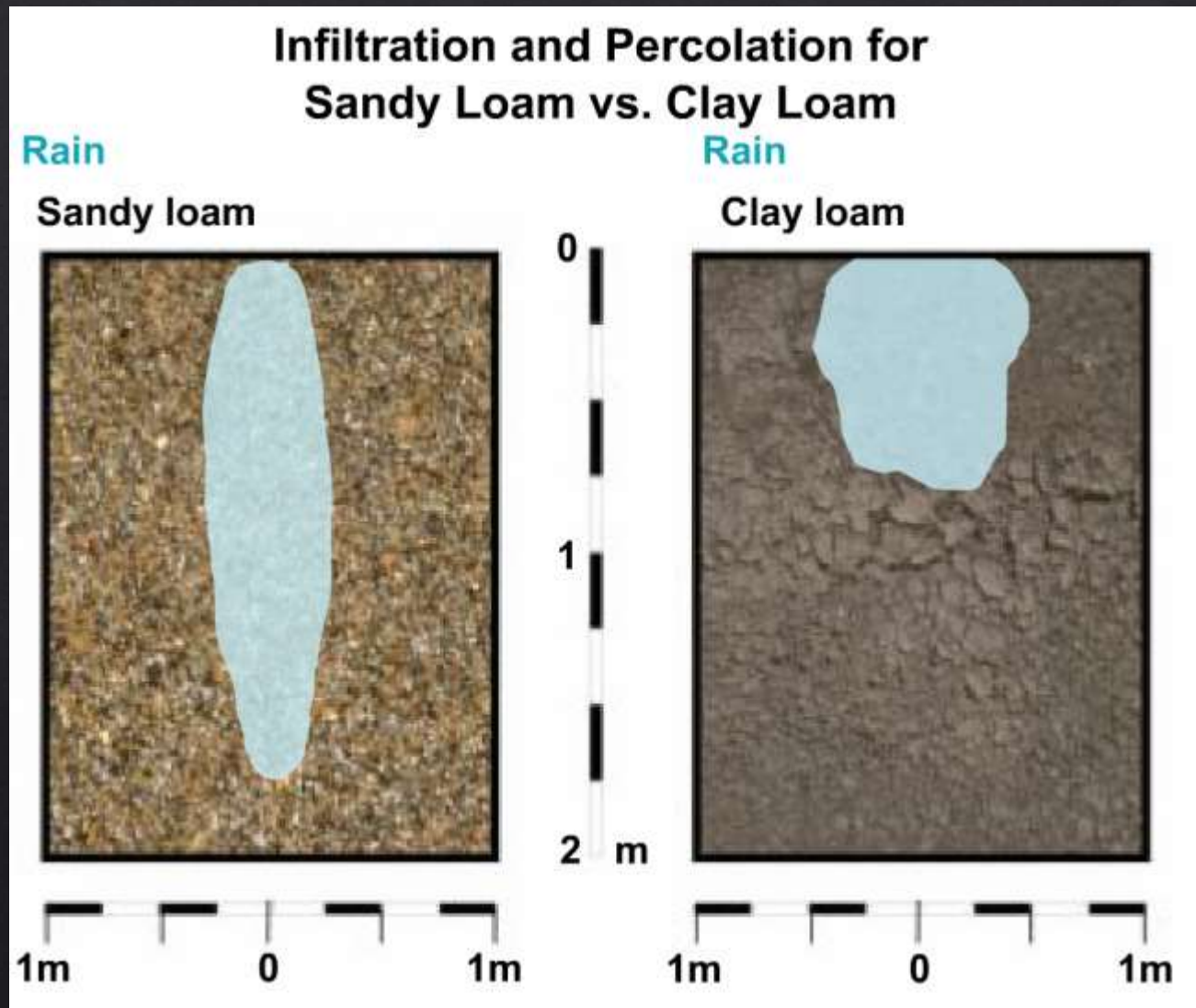


Soil Types



Soil Type Effects

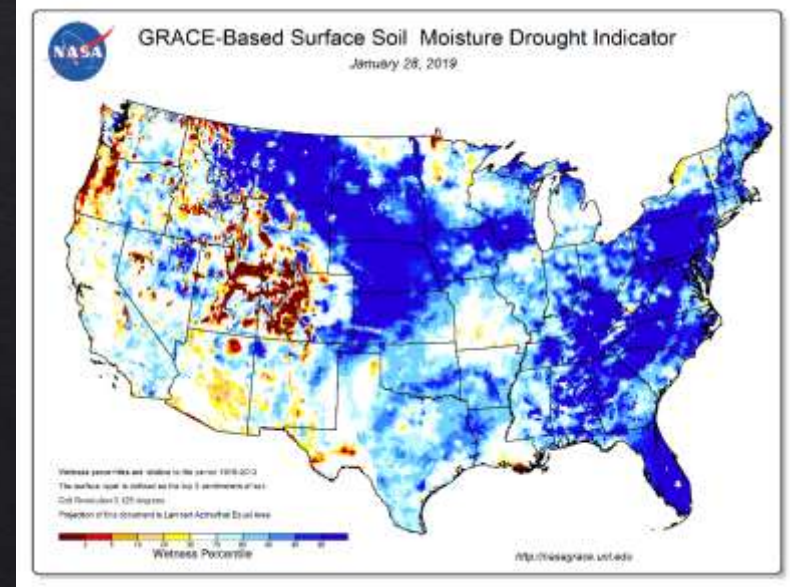
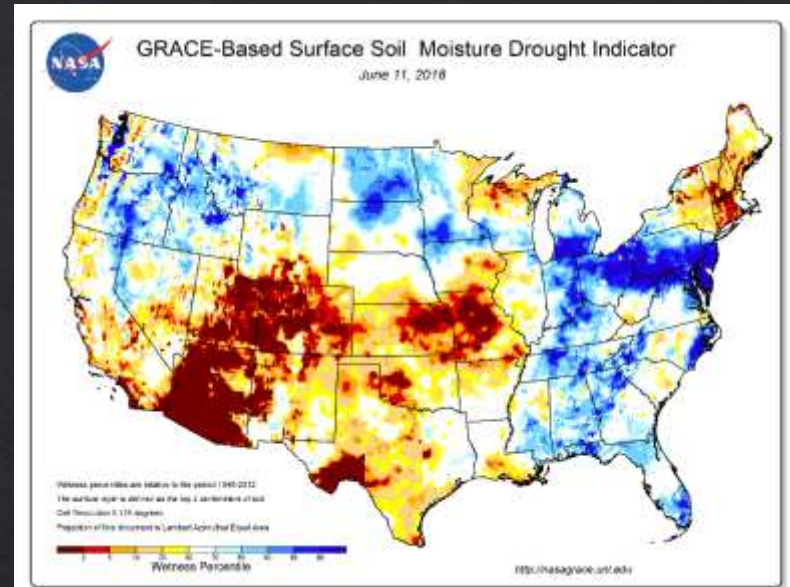
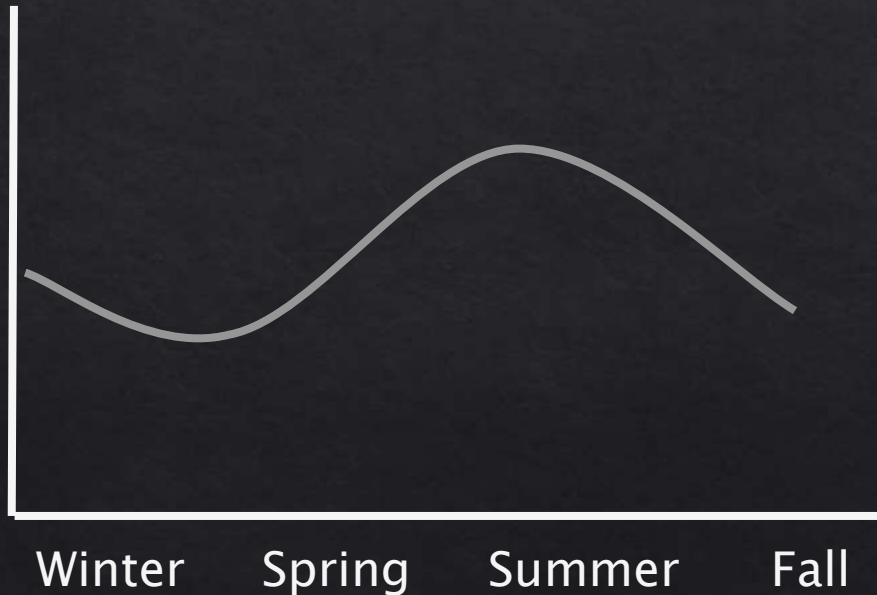
- ◇ Sandy soils accept rainwater deeper into the ground faster, thus taking longer to approach saturation and leading to less flood susceptibility.



Soils

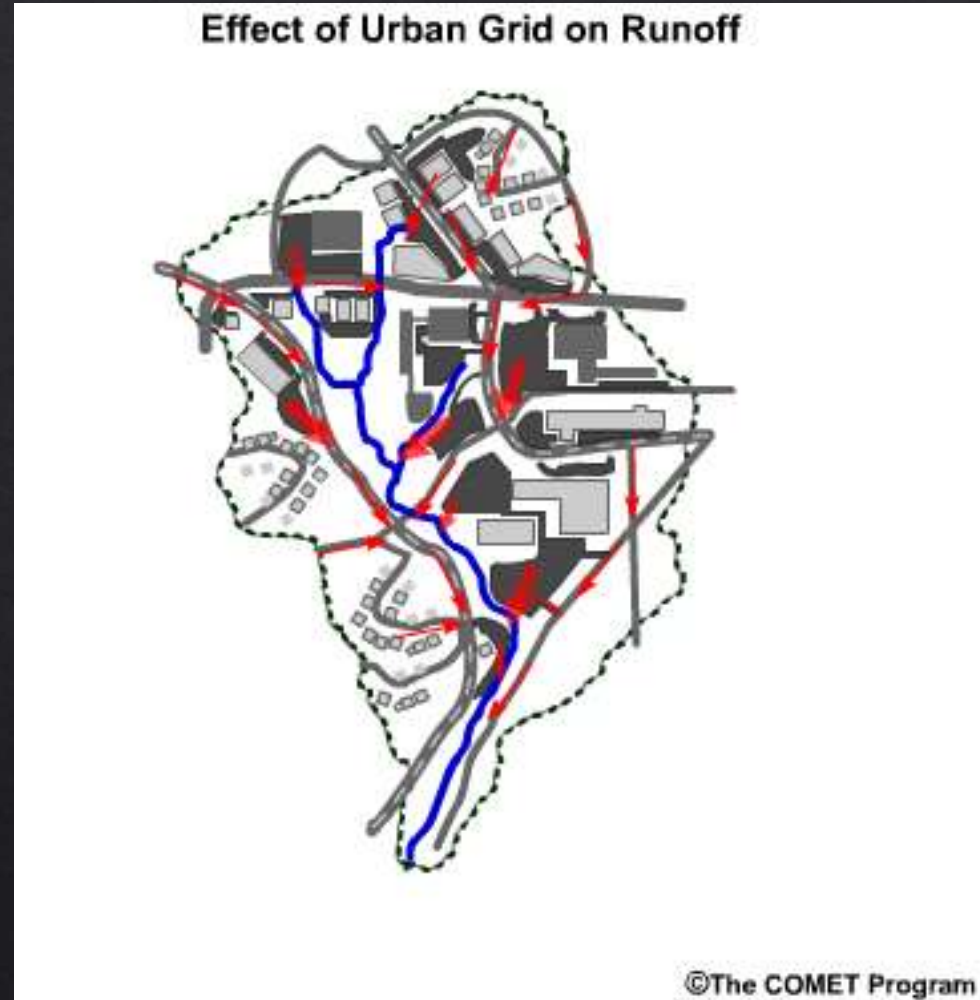
- ◇ But also: Soil infiltration rate changes with the season. This impacts flood potential!

Mean Infiltration rate



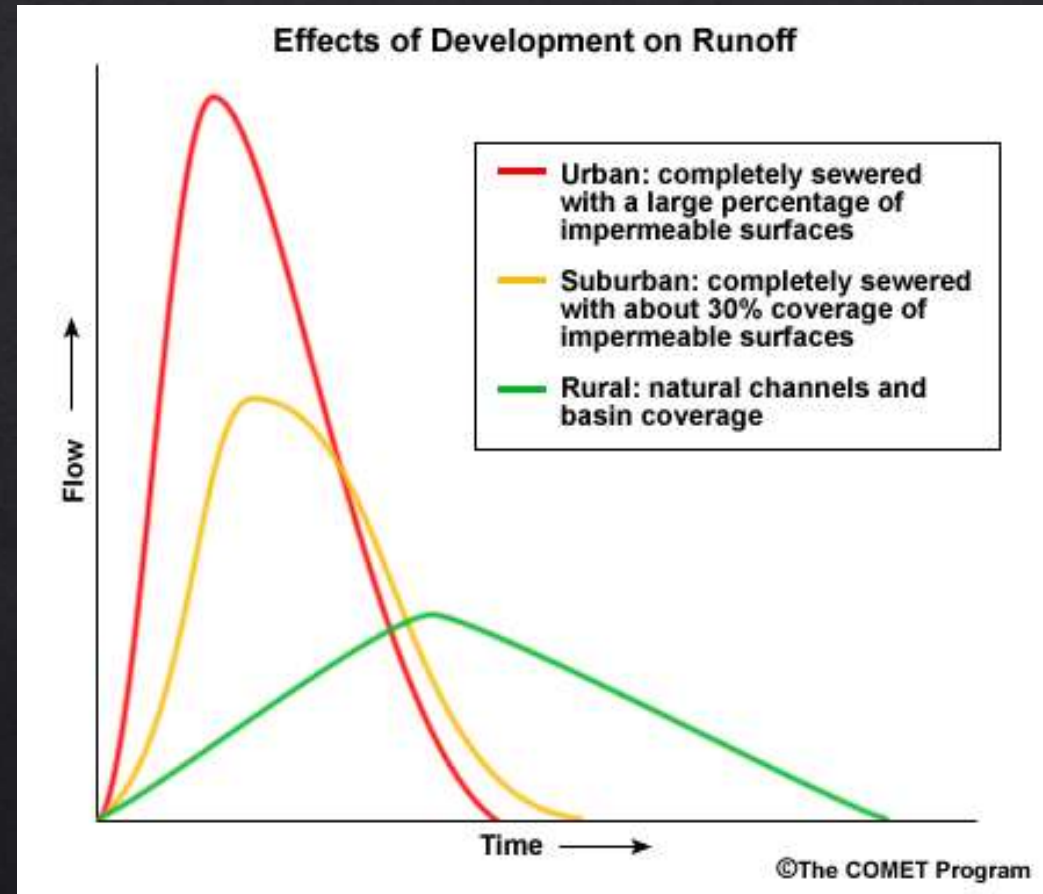
How Urbanization Effects Flooding

- Anything that cannot be absorbed into the soil becomes *runoff*.
- In an urban area, where surfaces like concrete and asphalt are impermeable, everything becomes runoff!



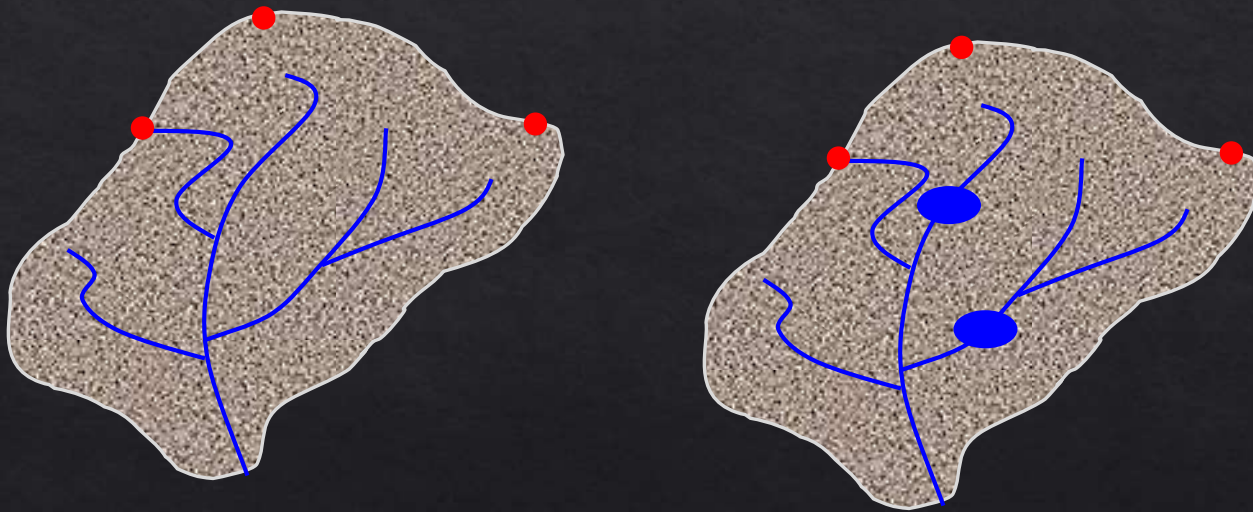
Bigger, Faster, Better?

- ◇ The good:
 - ◇ The stream reacts faster, and thus may be less susceptible to a prolonged event.
- ◇ The bad:
 - ◇ The stream rises higher due to runoff, and thus may be more susceptible to a high intensity (but relatively short duration) event.



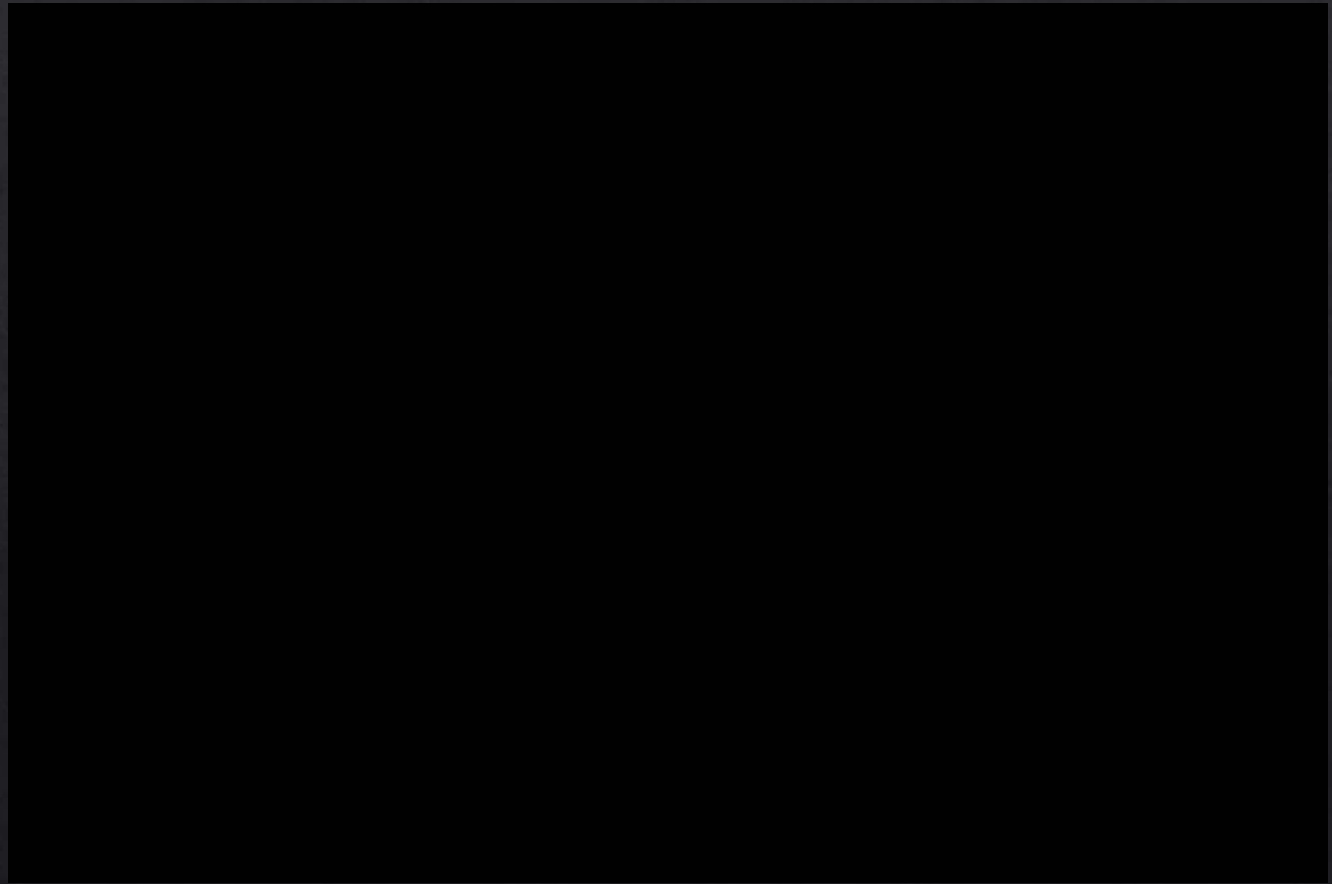
Why Dams Can Be Helpful

Key point: Lakes and flood control basins are important to locate



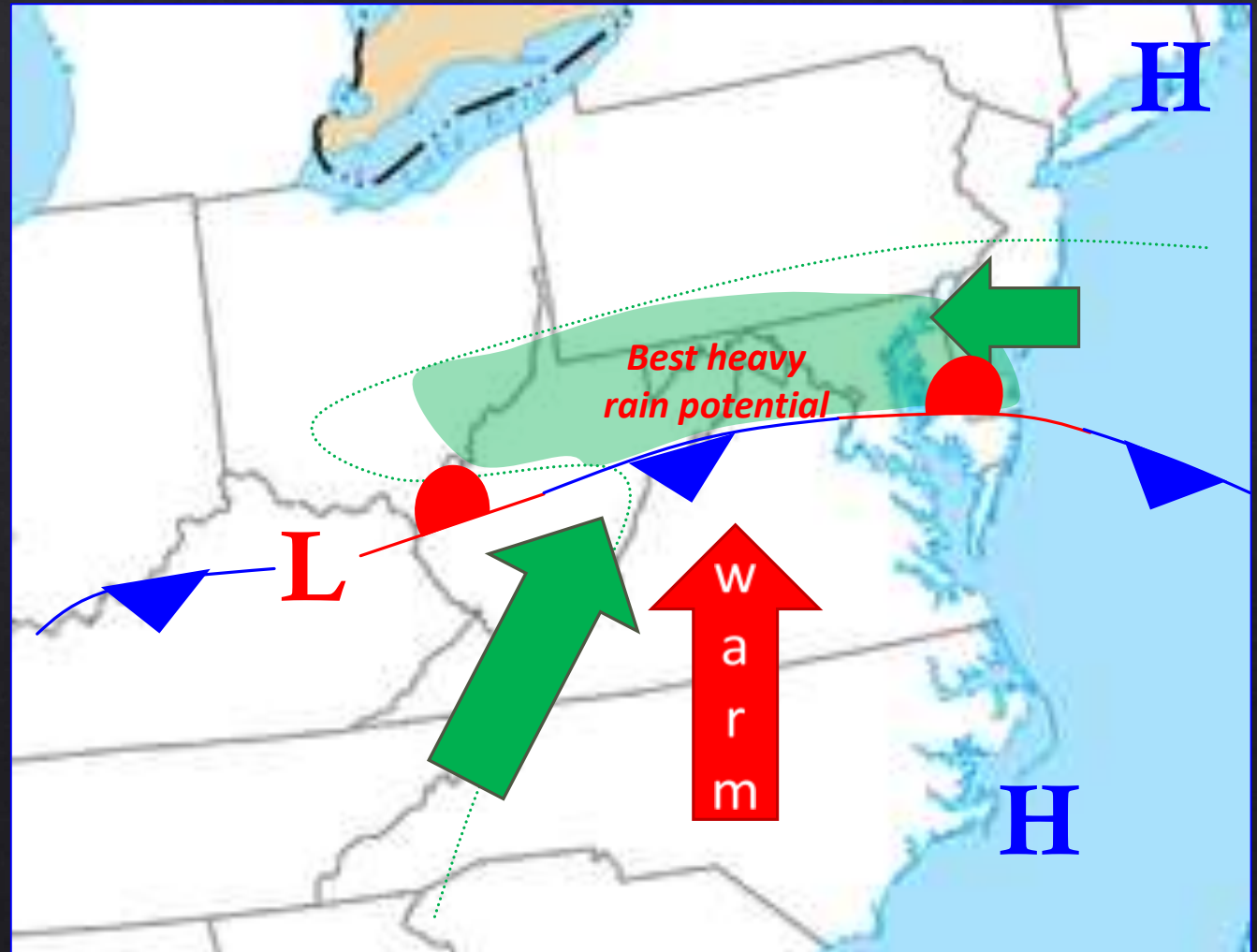
Why Dams Can Be Harmful

- ◇ Although it's rare, sometimes (due to a variety of factors) a dam could fail. If it does, downstream flooding can be catastrophic.

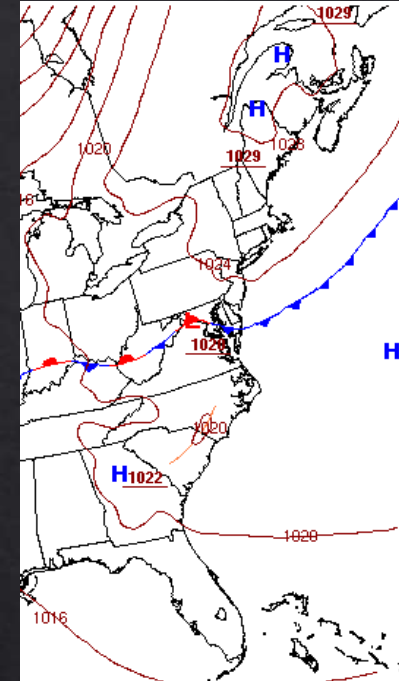
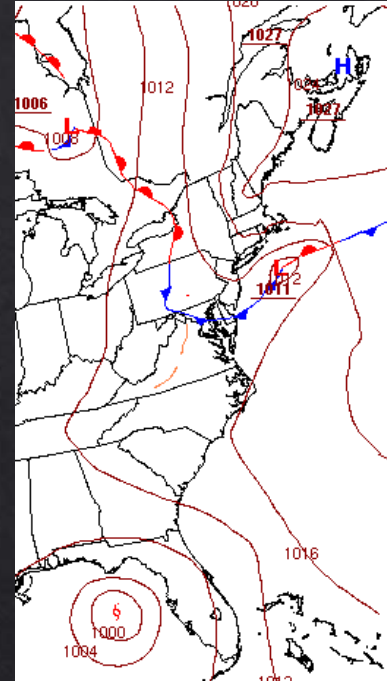
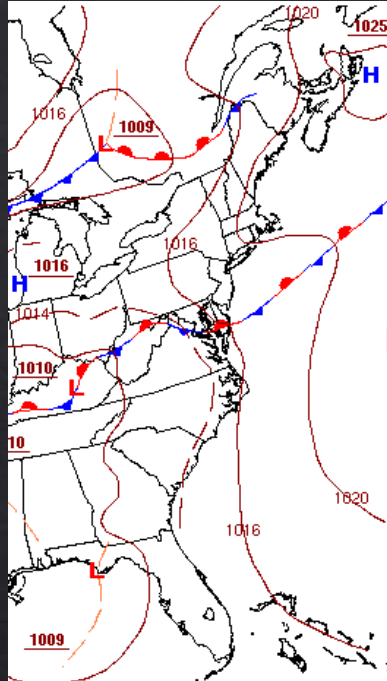
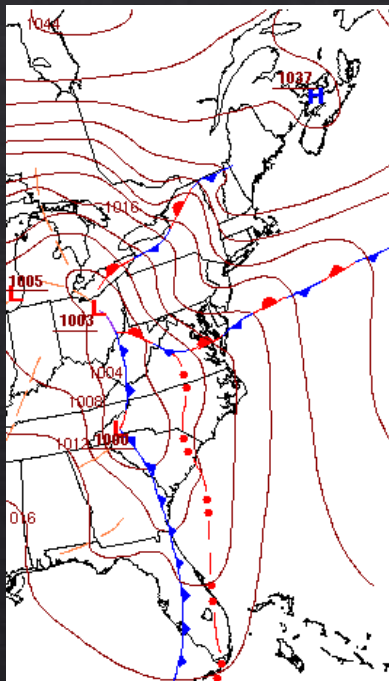


Favorable Weather Patterns

- ◇ Slow-moving or Stationary Fronts



How common is it?

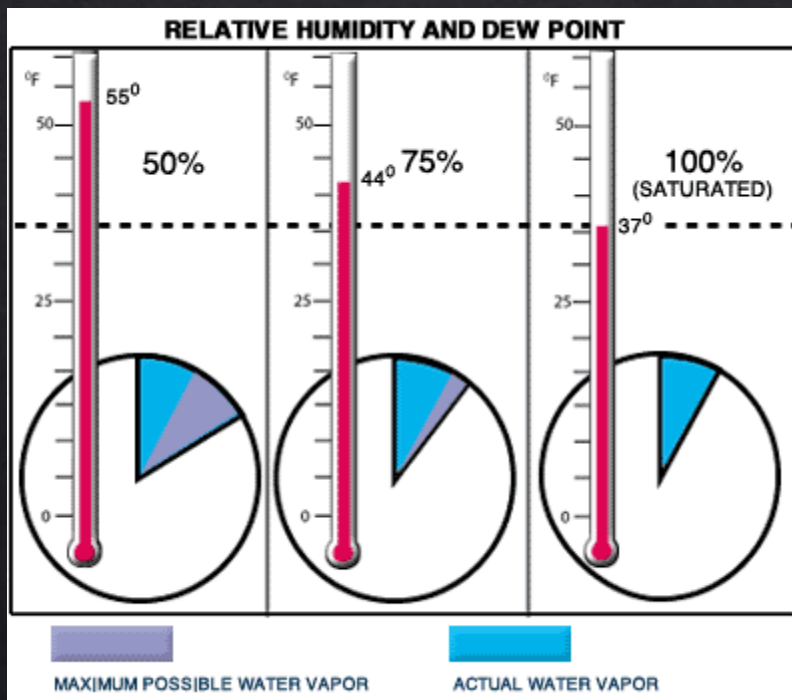


- ◆ These four events (among many others) caused flooding locally in 2018. (April 15-16, Frederick MD, Ellicott City, Harford County)

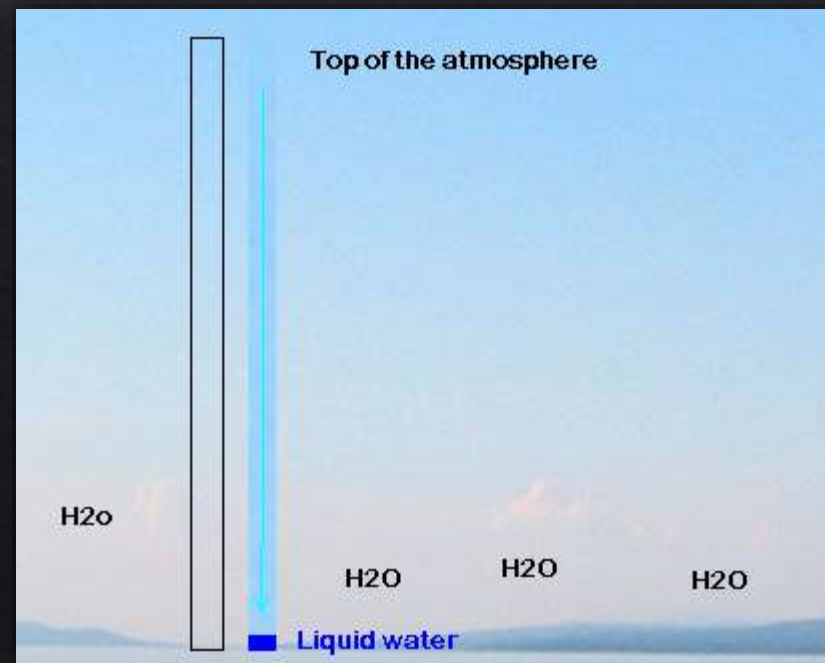
Favorable Weather Patterns

◇ High Moisture Content

Dewpoint

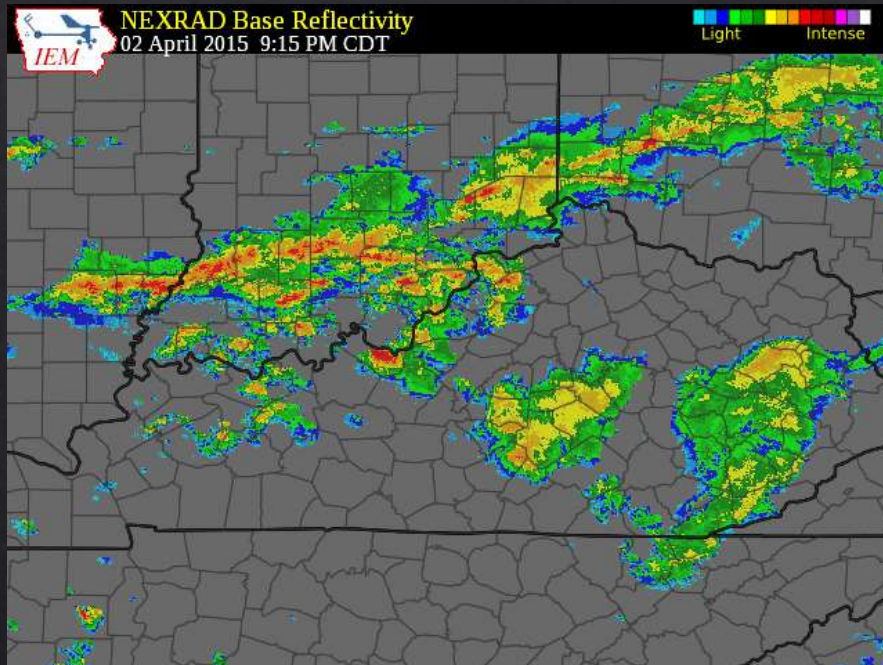


Precipitable Water

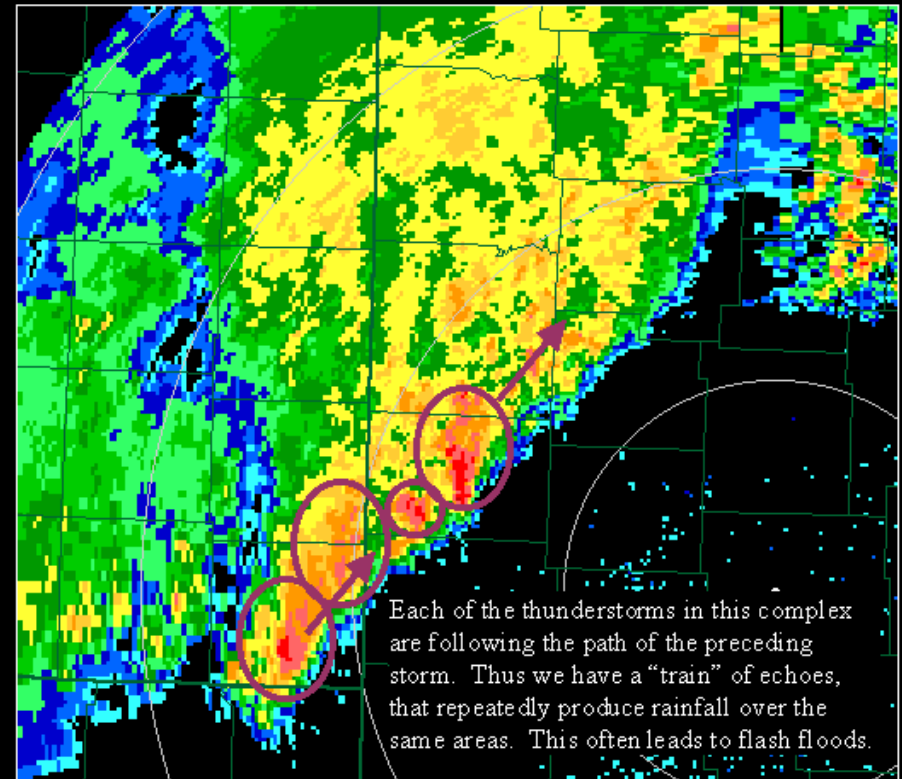


Favorable Weather Patterns

◇ Slow-moving & Training (Repeating) Thunderstorms

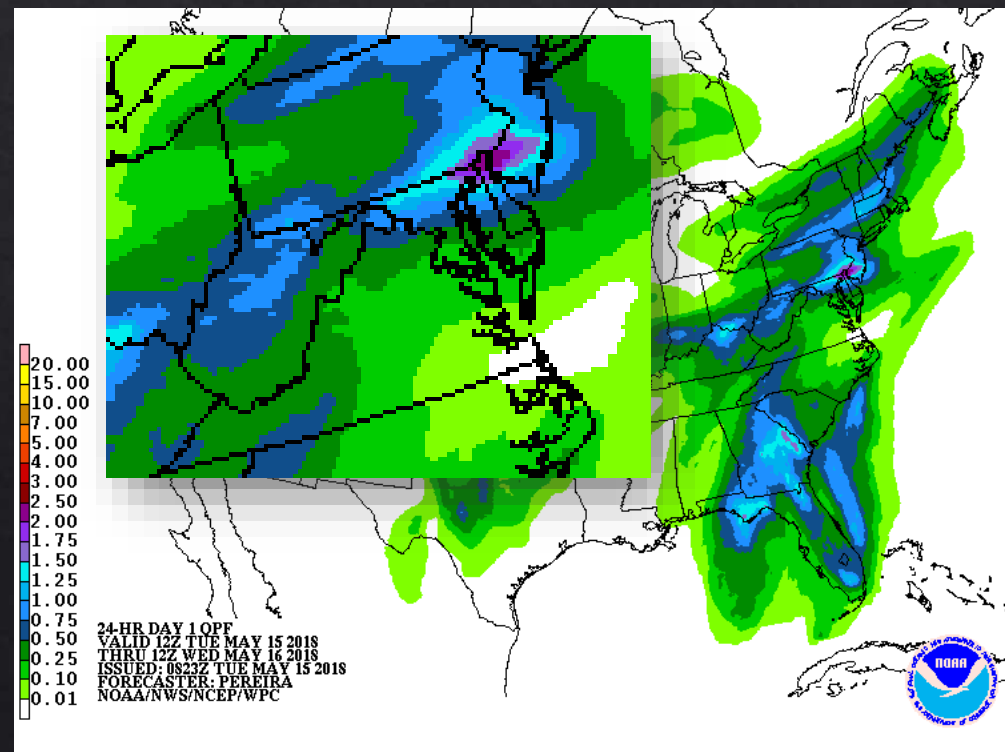
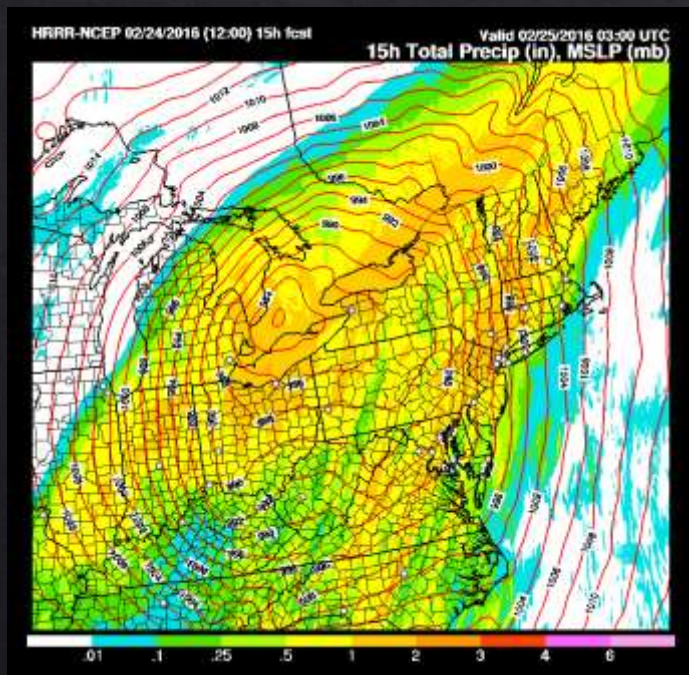


Training Echoes Example



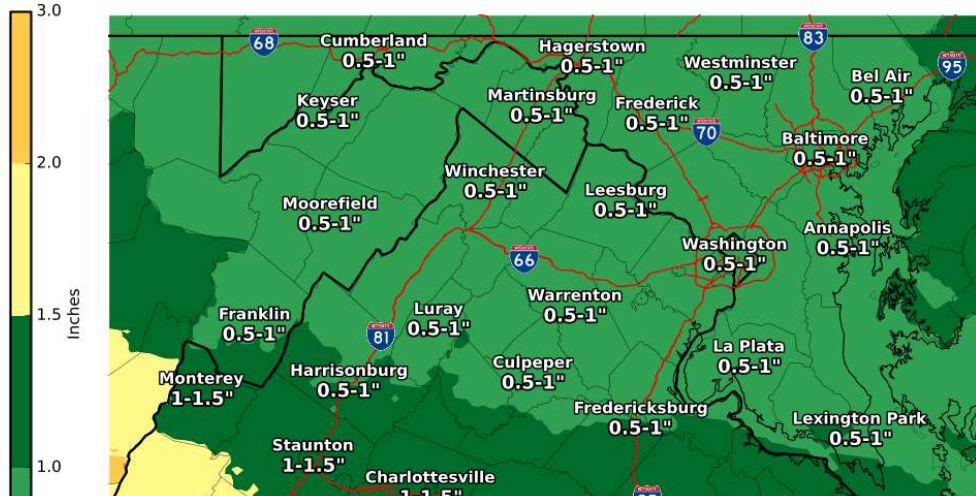
Making a Rainfall Forecast

- ❖ We begin with national precipitation forecasts from the NWS Weather Prediction Center (WPC).
- ❖ We then localize this – especially in the first 6-12 hours as we get the best idea of where the heaviest rain will occur.



It's Not Just One Number!

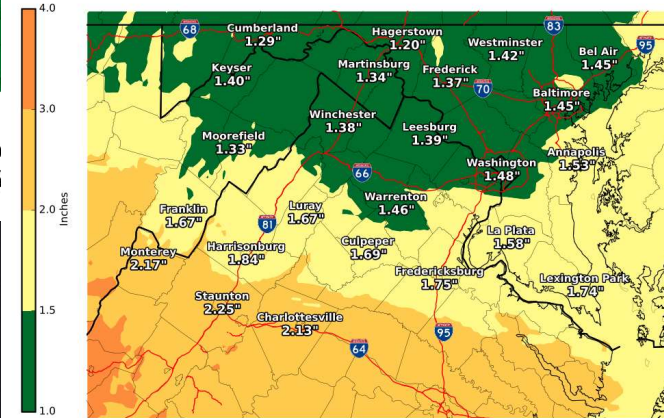
Expected Liquid Precip - Official NWS Forecast
Valid: 02/21/2019 09:00 PM - 02/24/2019 07:00 PM



Low End Amount - 9 in 10 Chance (90%) of Higher Liquid Precipitation
Valid: 02/21/2019 09:00 PM - 02/24/2019 07:00 PM



High End Amount - 1 in 10 Chance (10%) of Higher Liquid Precipitation
Valid: 02/21/2019 09:00 PM - 02/24/2019 07:00 PM



**National Weather Service
Baltimore/Washington**
02/21/2019 09:21 PM EST

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National Weather Service
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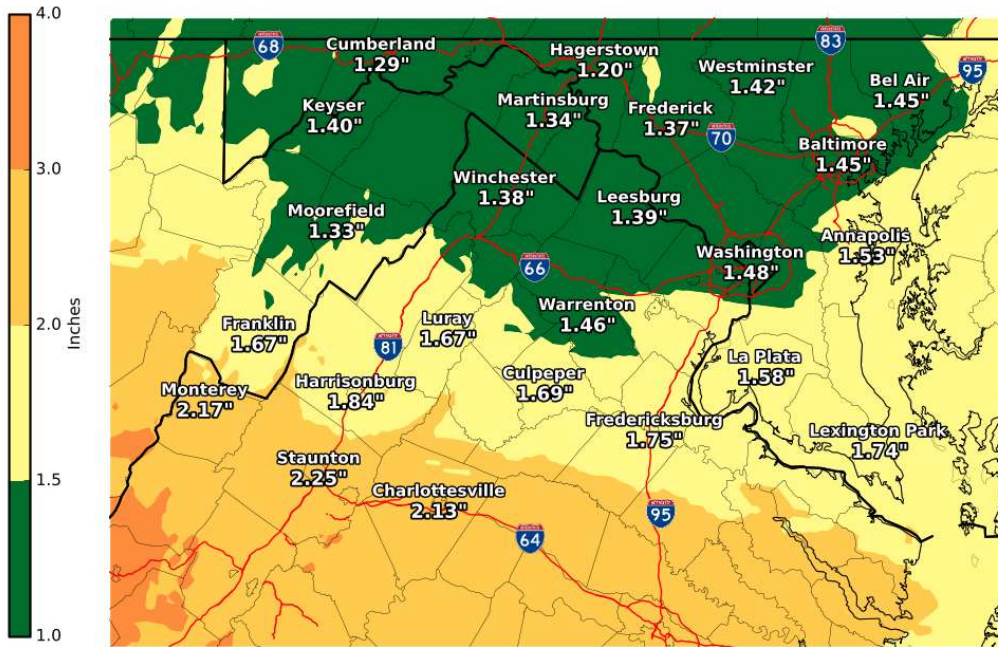
National Weather Service
Baltimore/Washington
02/21/2019 09:24 PM EST
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Summer Storms Exceed "High End"

High End Amount - 1 in 10 Chance (10%) of Higher Liquid Precipitation

Valid: 02/21/2019 09:00 PM - 02/24/2019 07:00 PM



National Weather Service
Baltimore/Washington
02/21/2019 09:24 PM EST

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Putting It All Together

- ◆ Once we have forecast an expected amount and range of rainfall expected...we have to combine this forecast with the antecedent conditions, as well as how quickly the rain is expected to fall.



Flood vs. Flash Flood

- ❖ **Flash Flood** - a *rapid and extreme* flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, *which requires immediate action to protect life and property* (e.g., intense rainfall, dam failure, ice jam). Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters.
- ❖ **Flood** - any high flow, overflow, or inundation by water which causes or threatens damage.

Source: NWS Instructions 10-950 and 10-922



What makes a flash flood?

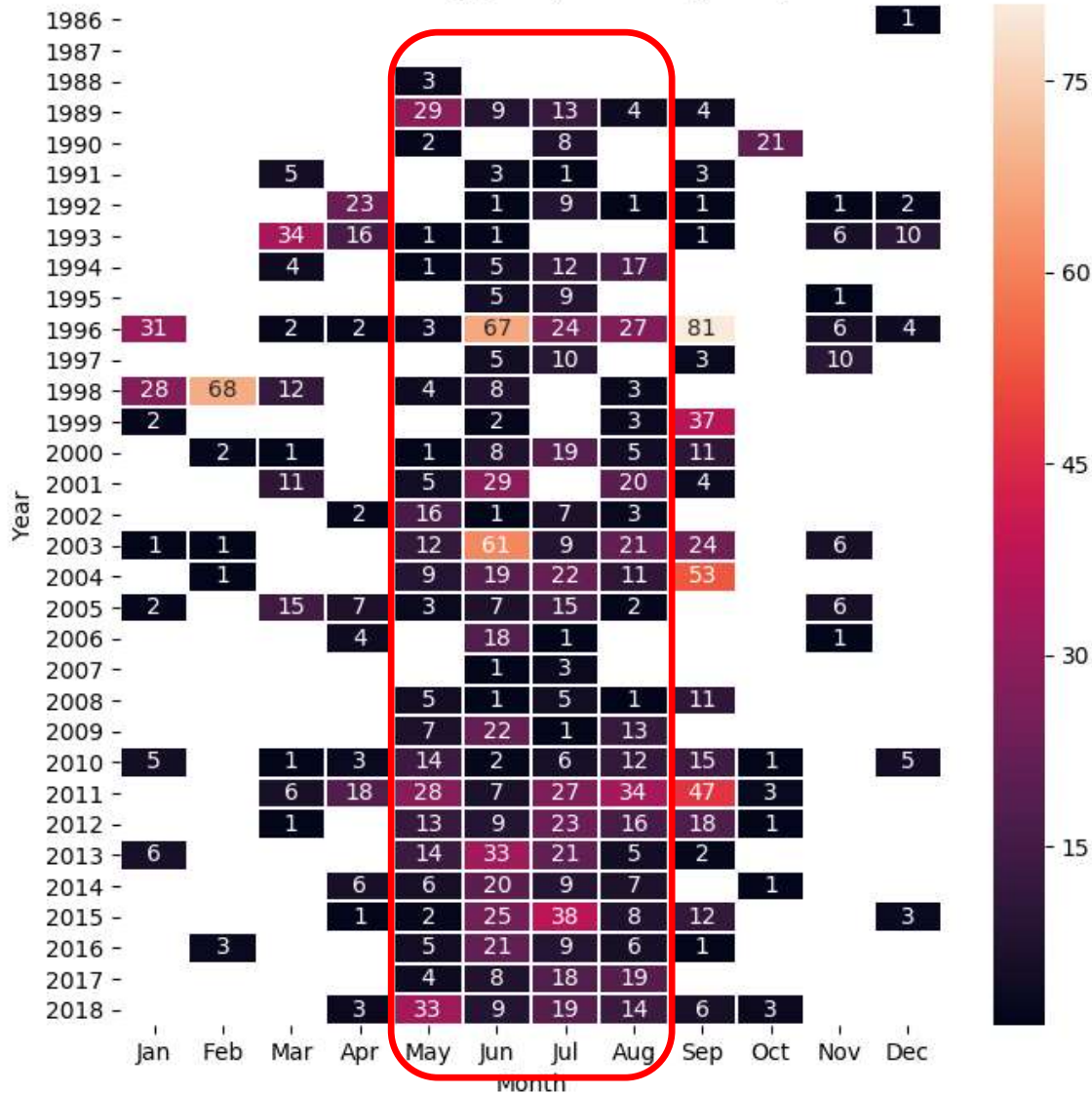
- ❖ Caused by convection (thunderstorms or intense showers)
- ❖ More isolated compared to flooding
- ❖ Response time is short, usually 1-2 hours, but as little as 15 mins. in urban areas (compared to 6-12 hours for flooding)
- ❖ Swift Water Rescues, road closures, creeks and streams flood within an hour or two of the causative event

**Maryland Route 180 after a
Flash Flood – May 2018**

Photo from MD Lt. Gov. Boyd Rutherford



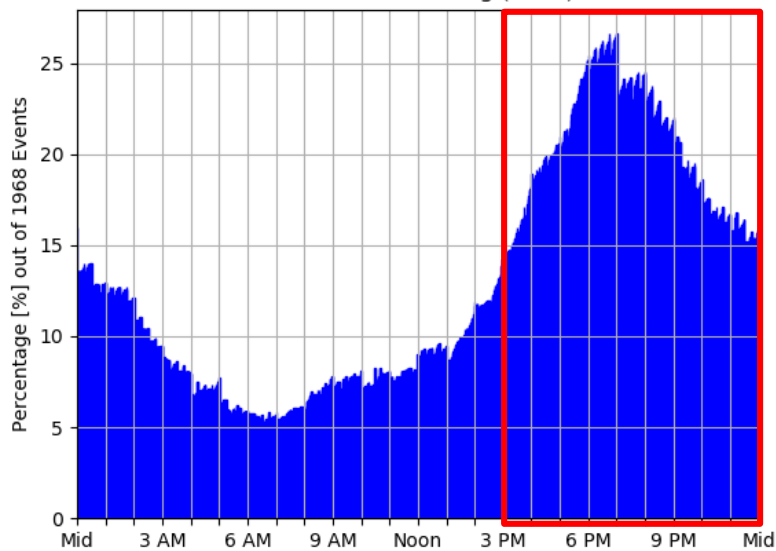
NWS Baltimore Md/ Washington Dc Flash Flood Warning (FF.W) Issued by Year,Month



When does flash flooding occur?

- ◇ Can occur anytime – day or night.
- ◇ Approximately two-thirds of all flash flooding occurs at night.
- ◇ Most flash flood fatalities occur at night!

[LWX] Baltimore Md/ Washington Dc :: Time of Day Frequency
Flash Flood Warning (FF.W)



Generated at 27 Feb 2019 12:56 PM CST in 2.69s IEM Autoplot App #72



Special Cases – Debris Jams

- ❖ Occasionally, floating debris or ice can accumulate at a natural or man-made obstruction and restrict the flow of water.
- ❖ Water held back by the ice jam or debris dam can cause flooding upstream.
- ❖ Subsequent flash flooding can occur downstream if the obstruction should suddenly release.



Special Cases – Ice Jams



Chunks of ice collect in river channels and may ultimately stop the flow of water.

Ice can collect at a bridge and create an ice jam.

Water backs up behind the ice jam and subsequent flooding results.



Special Cases – Ice Jams



Special Cases – Mudslides/Landslides

- ◆ In significant rain events in higher terrain, a mudslide or landslide can be triggered.
- ◆ This isn't the rain rushing down the slope; it's the land rushing down the slope.



Photo courtesy TN Dept. of Transportation; landslide map from USGS



Landslide Incidence and Susceptibility	
Red	High incidence
Orange	High susceptibility, moderate incidence
Yellow-orange	High susceptibility, low incidence
Yellow	Moderate incidence
Light yellow	Moderate susceptibility, low incidence
Very light yellow	Low incidence

What's this "Areal" Flood?

- ◇ **NOT** = "a real" flood
- ◇ **NOT** = "aerial" flood

- ◇ Flooding that covers an area.
- ◇ Flash Flooding typically affects a *very* small area very quickly. Areal flooding is slower to rise or develop and often affects more or larger areas.

- ◇ But...other than the time constraint, the severity and effects can be exactly the same.

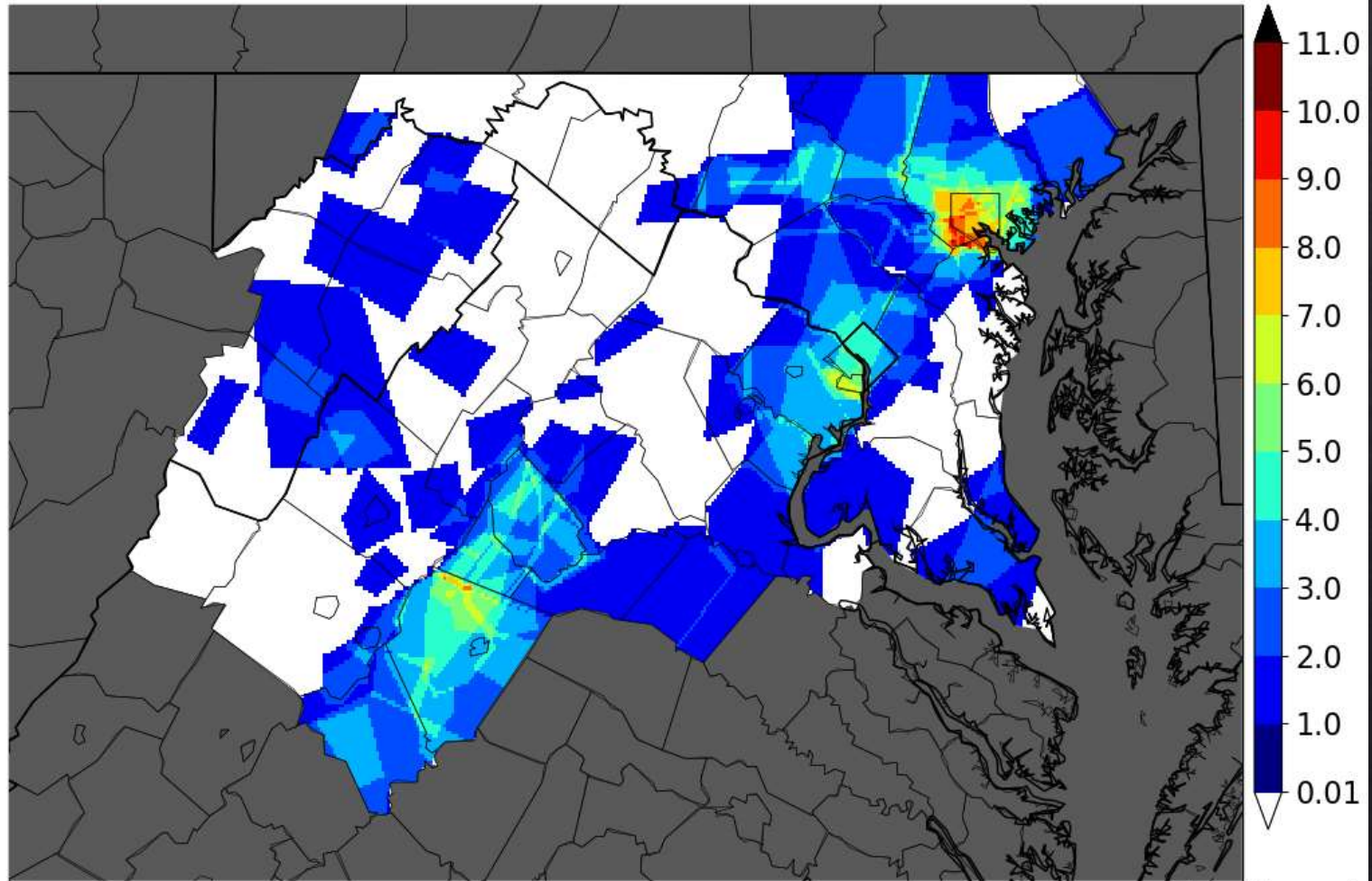


Flash Floods vs. Areal Floods (2018)



Count for 2018 Flash Flood Warning (FF.W)

Plotted for Baltimore Md/ Washington Dc (LWX), based on IEM Archives



data units :: count
IEM Autoplot App #90

Generated at 1 Mar 2019 9:59 AM CST in 2.51s



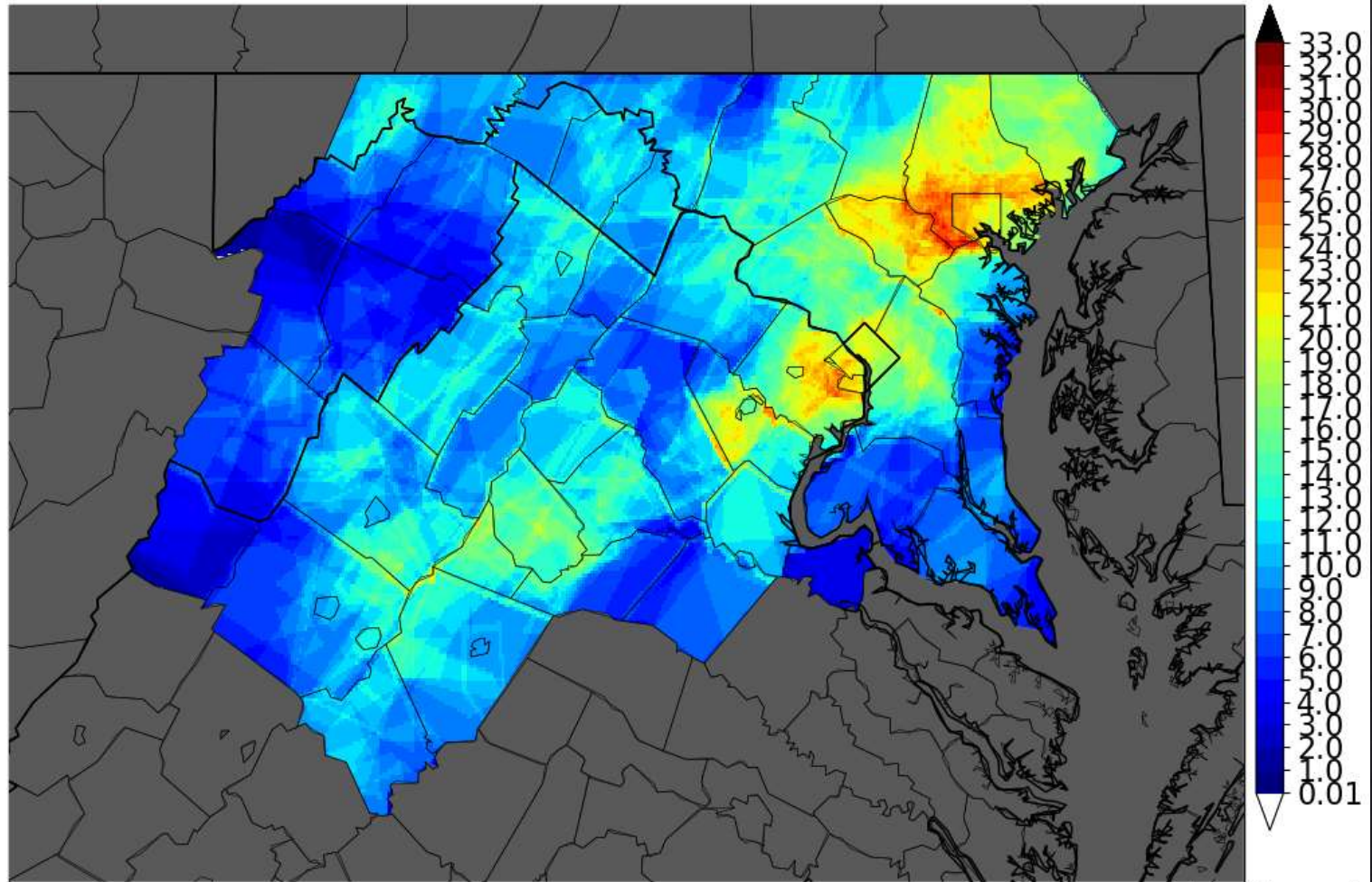
National Weather Service Baltimore/Washington

Flash Floods vs. Areal Floods (2018)



Count for 2018 Areal Flood Warning (FA.W)

Plotted for Baltimore Md/ Washington Dc (LWX), based on IEM Archives



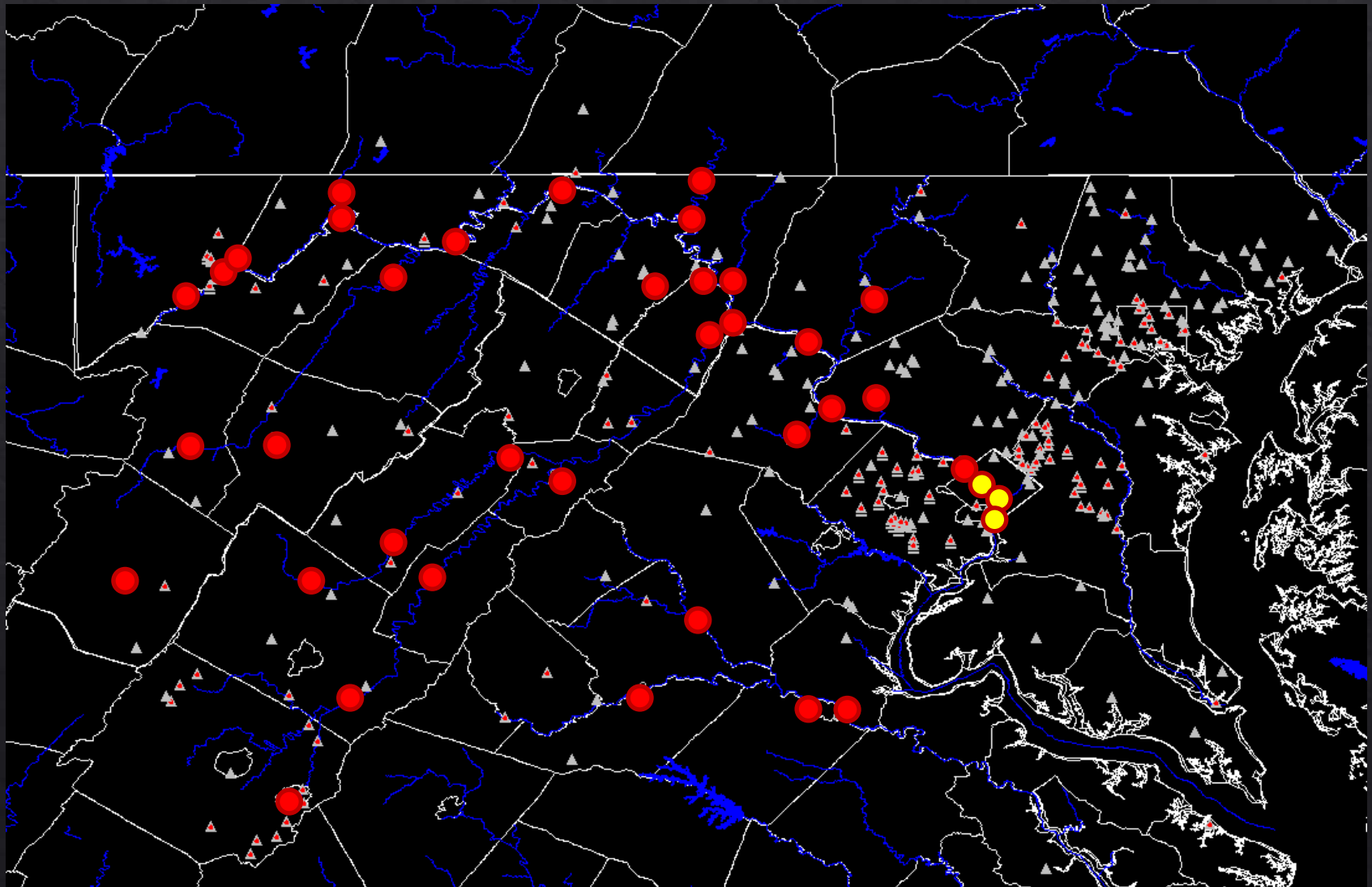
data units :: count
IEM Autoplot App #90

Generated at 1 Mar 2019 10:00 AM CST in 3.99s

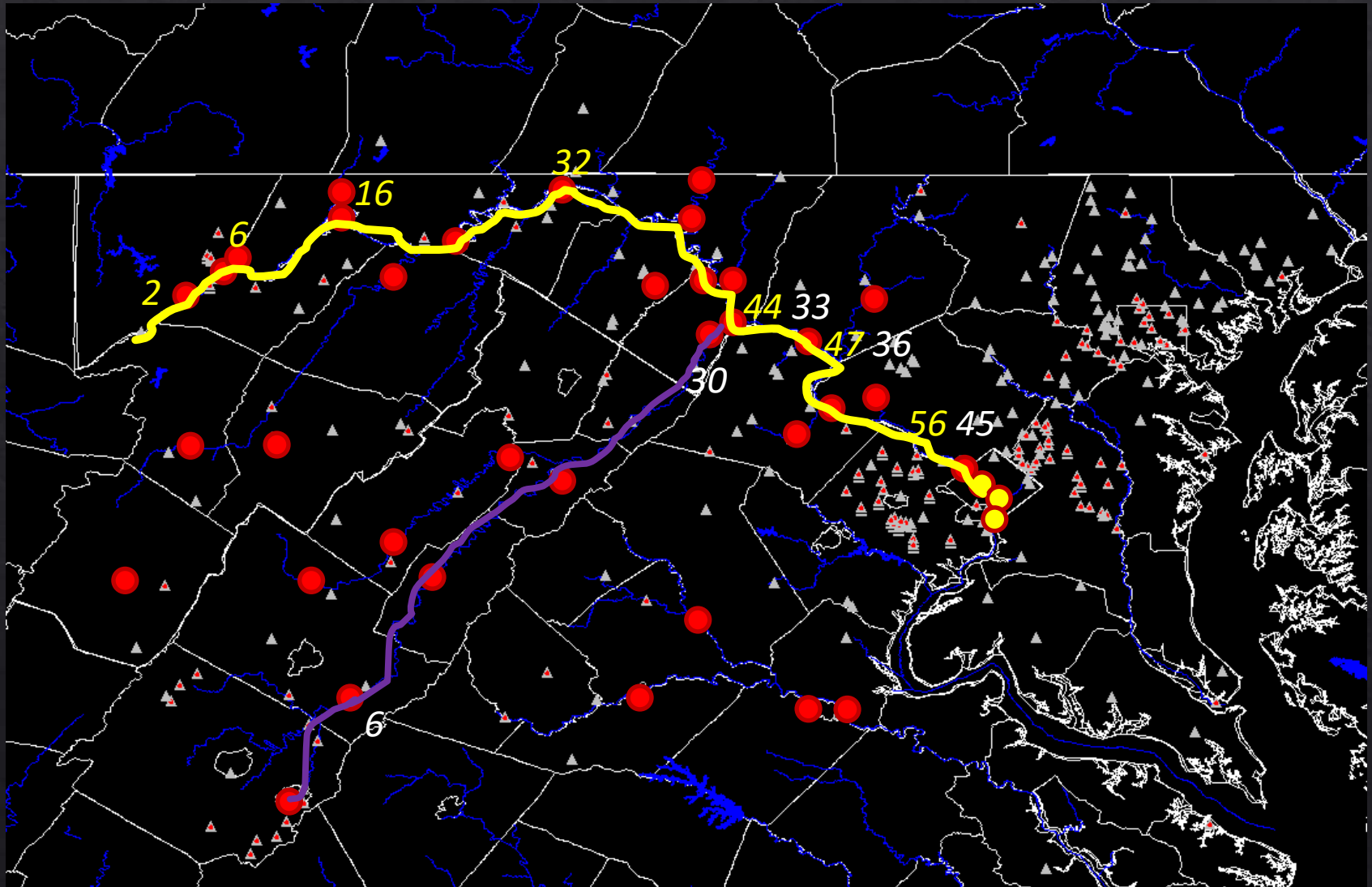


National Weather Service Baltimore/Washington

River Flood Forecast Points



Travel Times (in hours)

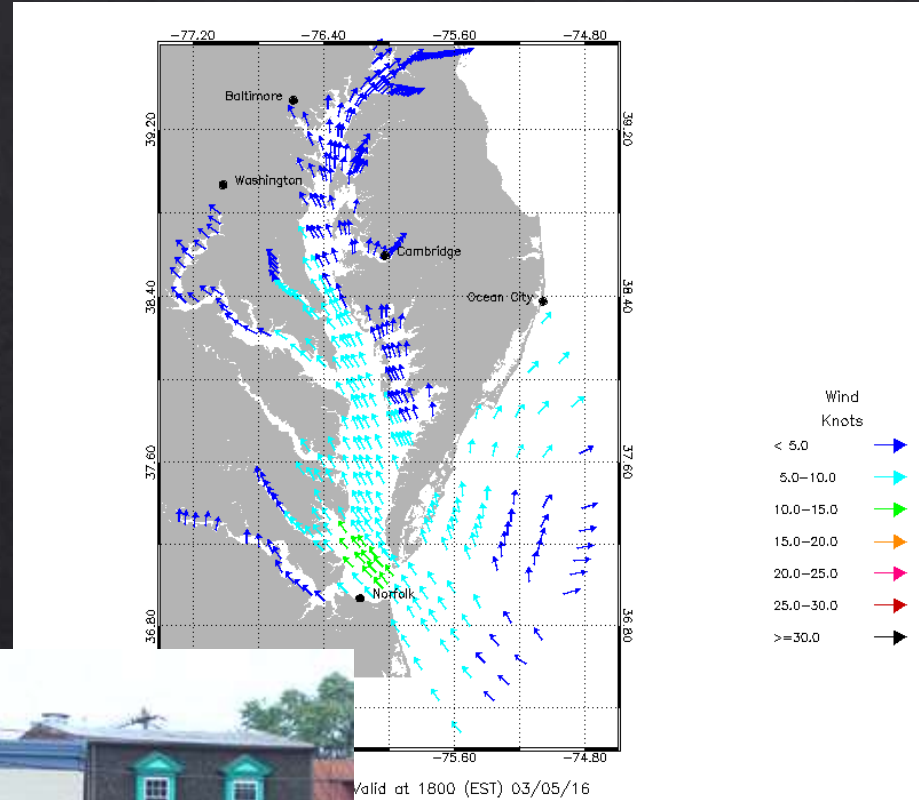


Coastal Flooding

- ◇ Prolonged onshore flow
- ◇ Storm Surge from Tropical Systems



Annapolis, MD



Coastal Flooding

- ◇ Although coastal flooding happens often – it's usually not much more than this...

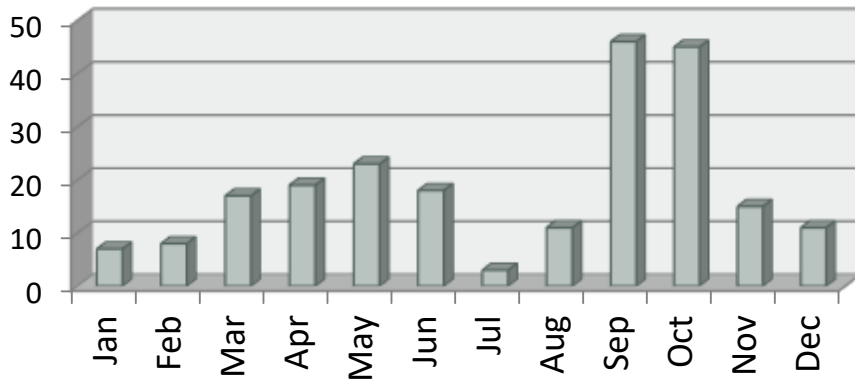
Minor Coastal Flooding at the US Naval Academy



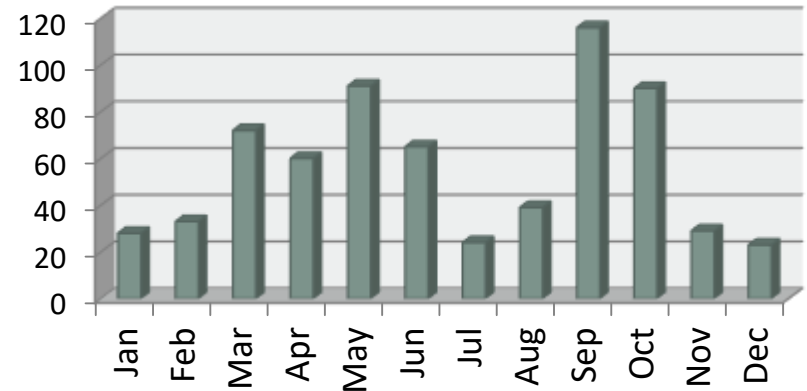
Coastal Flooding

- ◇ Two distinct peaks for positive departures
May/June & September/October
- ◇ September stands out due to tropical systems

Number of Flood Occurrences by Month (1996-2015) in Baltimore, MD



Number of Flood Occurrences by Month (1996-2015) in Washington, DC



Coastal Flooding

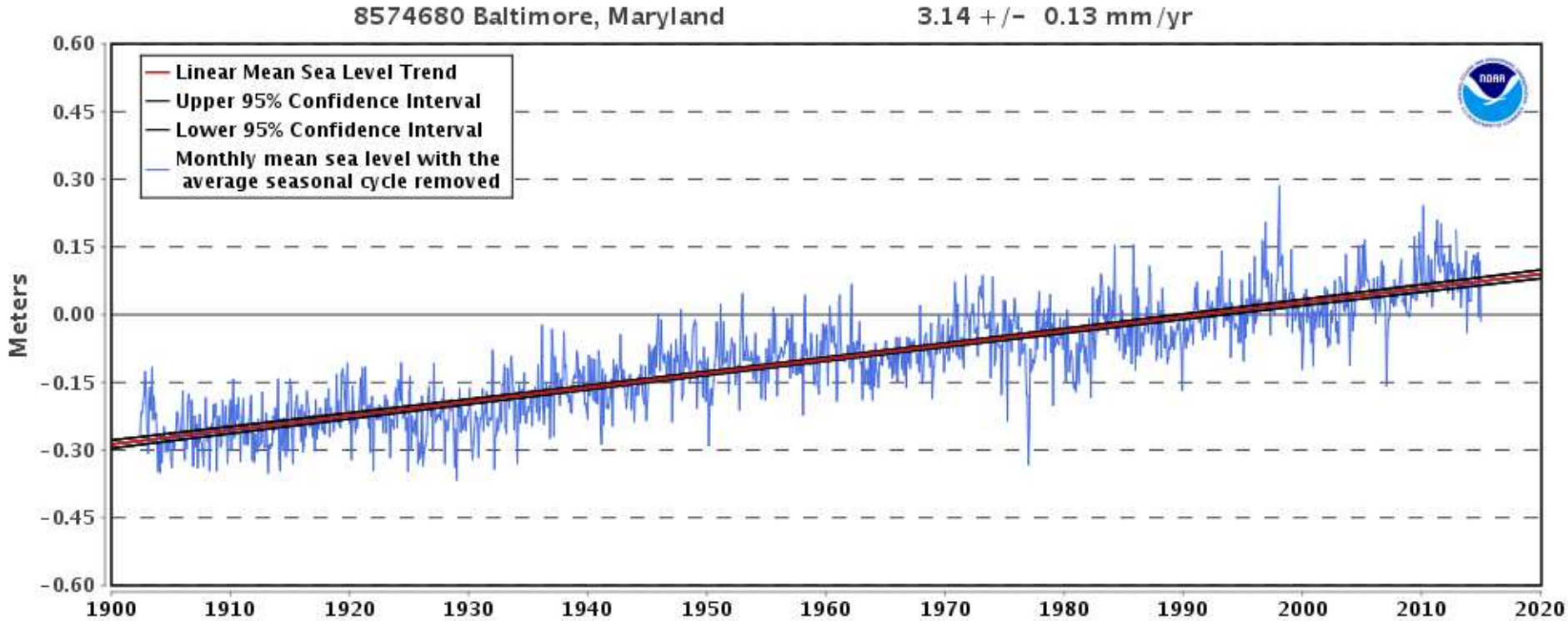


Baltimore
Inner Harbor



On the Rise

- ◇ Mean Sea Level (MSL) is steadily rising...
(average rate ~1 foot/century)



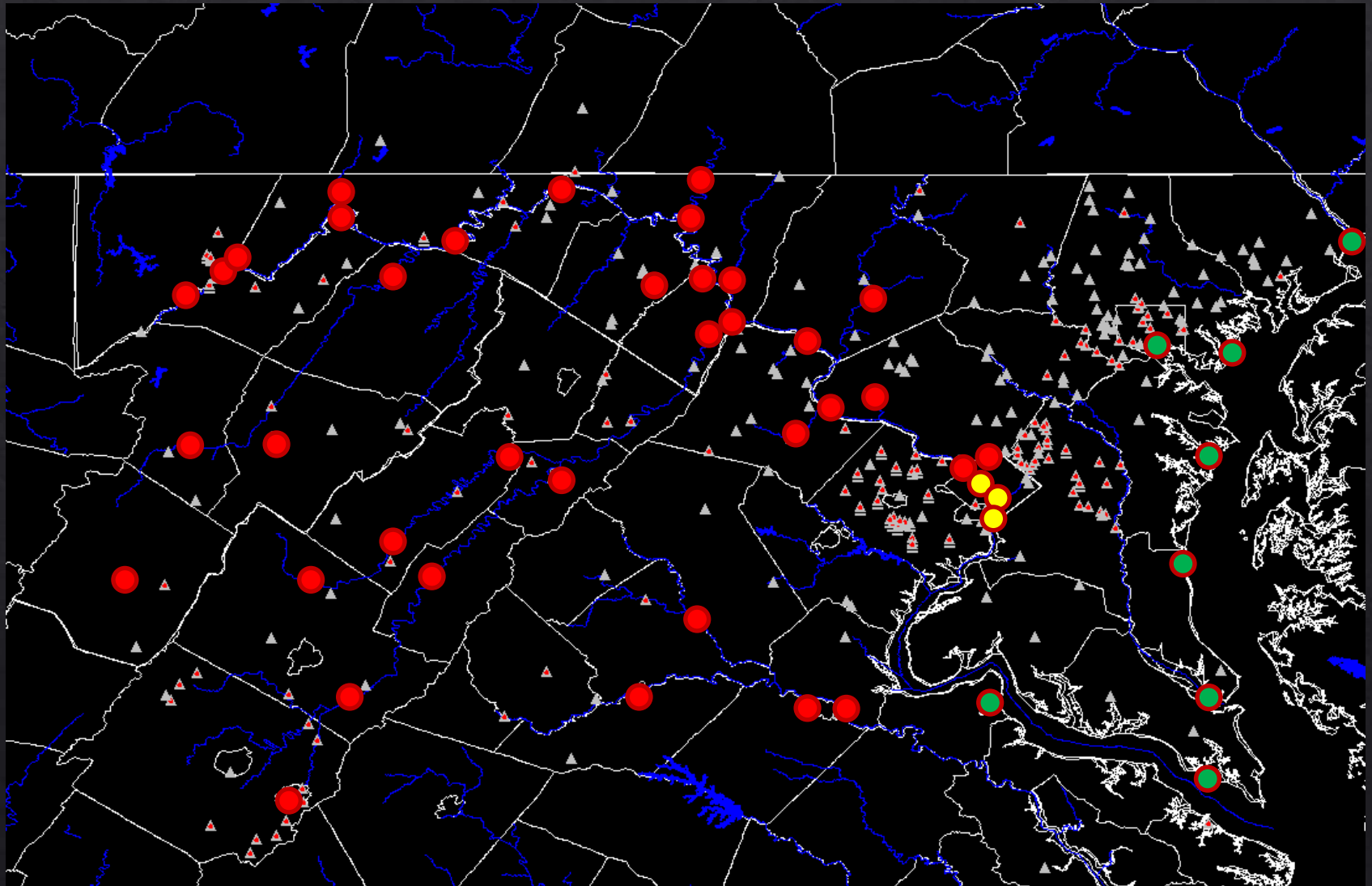
More of a Nuisance

- ◆ A NOAA study finds that nuisance flooding (defined as reaching our NWS 'minor flood' level) has substantially increased in the last 50 years.
- ◆ This is due to a rise in the base water level, not due to increased storms.

City	Average nuisance flood days (1957-63)	Average nuisance flood days (2007-13)	Percent increase
Annapolis	3.8	39.3	925%
Baltimore	1.3	13.1	922%
Washington	6.3	29.7	373%



Flood Forecast Points



Flood Type Summary

- ◇ In a single event, we must consider:
 - ◇ Flash Flooding
 - ◇ Areal Flooding
 - ◇ Nuisance Flooding
 - ◇ Tidal Flooding
- ◇ ...often all at the same time...and at the same time as severe weather or other hazardous weather...
- ◇ ...and ensure the public is properly notified of any/all of these threats that may affect them!



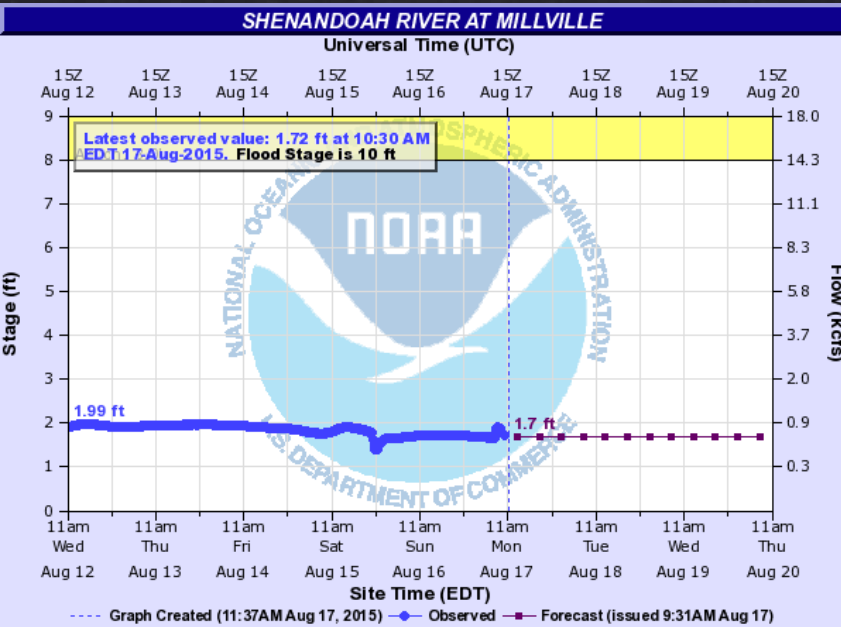
When reporting flooding to us...

- ◆ Don't worry about characterizing the type of flooding. Just give the facts, as specifically as possible, and we can do the characterization.
- ◆ More on that in a little bit!



Viewing live river data & forecasts

<http://water.weather.gov>



National Weather Service
Advanced Hydrologic Prediction Service

Home News Organization

Referal Observations BYC Observations

Weather Forecast Office (Baltimore/Washington) Sterling, VA Middle Atlantic River Forecast Center

River Observations River Forecasts Experimental Long-Range Flood Risk Precipitation Download

Auto Refresh: OFF Print this map Permalink Bookmarks

395 total gauges 0 gauges in flood

Legend:

- Forecast available
- Probability and forecasts available
- Observations only available
- Major Flooding
- Extreme Flooding
- Minor Flooding
- Near Flood Stage
- No Flooding
- Observations: No Fast Current
- Out of Service
- Flood Category Not Defined
- At or Below Low Water Threshold

WHEN FLOODED TURN AROUND DON'T DROWN

MILW2(plotting HGIRG) "Gage 0" Datum: 293.32'

Observations courtesy of US Geological Survey

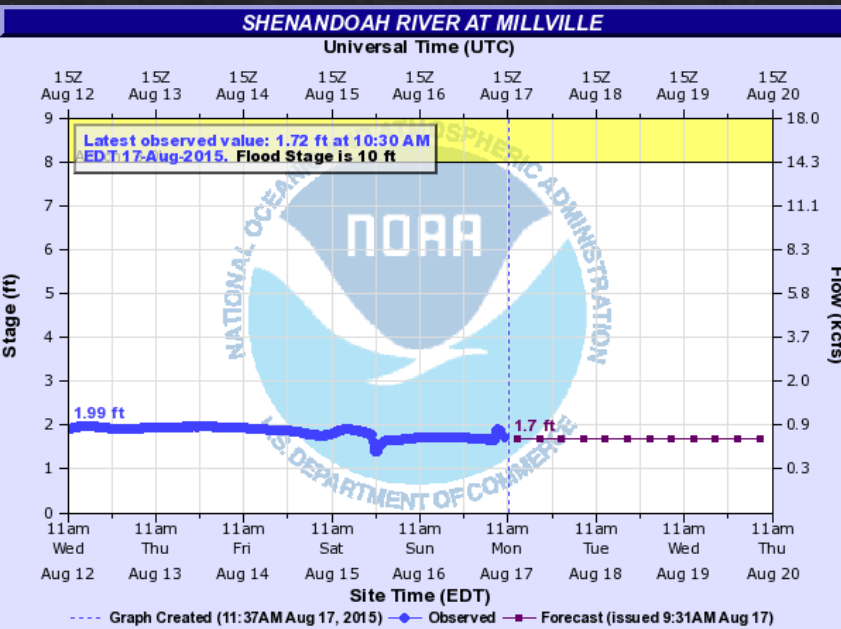
Break time!

Please return in 5 minutes



Viewing live river data & forecasts

<http://water.weather.gov>



National Weather Service
Advanced Hydrologic Prediction Service

Home News Organization

Local weather forecast by "City, ST"

City, ST [] Go

Adjacent Areas: [Map navigation icons]

National Conditions: Rivers, Satellite, Climate, Observed Precip

Local Conditions: Warnings, Weather, Forecast, Radar

AHPS Documentation: User Guide, User Brochure

What is AHPS? Facts, Our Partners

Feedback/Questions: Provide Feedback, Ask Questions

WHEN FLOODED TURN AROUND DON'T DROWN

National Weather Service
Advanced Hydrologic Prediction Service

Home News Organization

Referal Observations NYC Observations

Weather Forecast Office (Baltimore/Washington) Sterling, VA Middle Atlantic River Forecast Center

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Auto Refresh: OFF [Refresh icon]

Print this map Permalink Bookmarks [Social media icons]

395 total gauges 0 gauges in flood

[Map navigation icons]

Forecast available

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Observations only available

Major Flooding

Extreme Flooding

Minor Flooding

Near Flood Stage

No Flooding

Observations: No Fast Current

Out of Service

Flood Category Not Defined

At or Below Low Water Threshold

Last map update: 03/16/2015 at 01:21:38 am EDT
03/16/2017 at 17:21:38 UTC

What is UTC time? Map map

Disclaimer

USGS esri

MILW2(plotting HGIRG) "Gage 0" Datum: 293.32'

Observations courtesy of US Geological Survey

Our Products

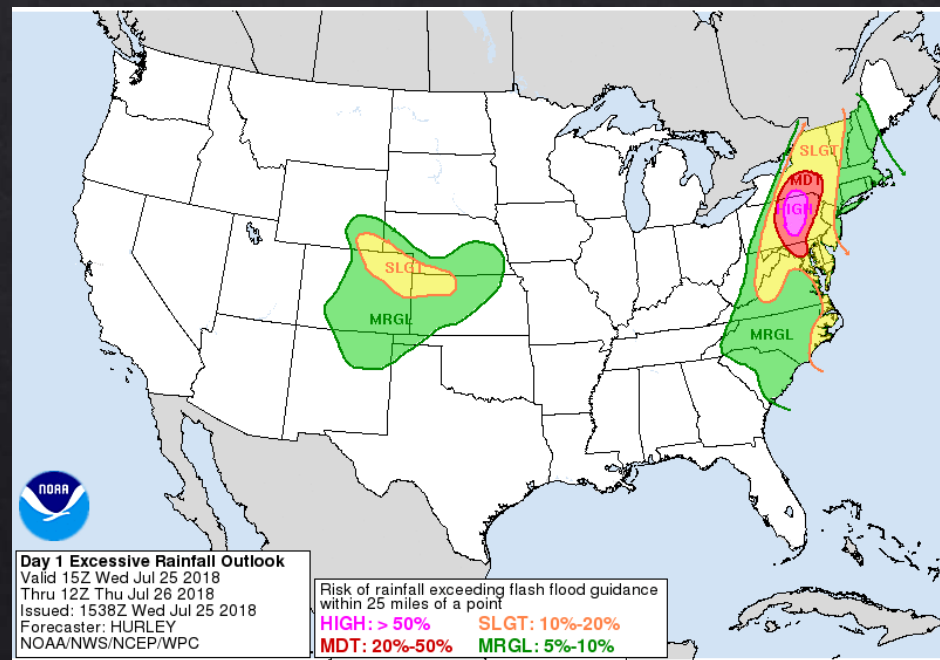


Outlook Phase

- ◆ The Hazardous Weather Outlook will mention:
 - ◆ Flood potential in the Day 3-7 period
 - ◆ Flood potential in the first 48-72 hours, if confidence is too low for a watch
 - ◆ Coastal flood potential for moderate flooding or greater only at any time in the seven day forecast.

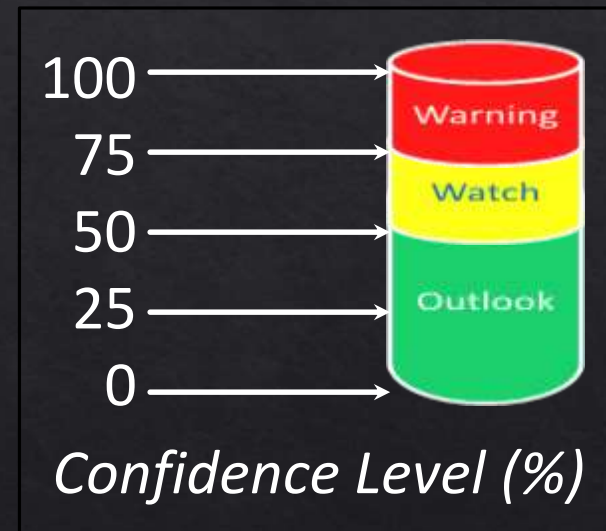
- ◆ The Weather Prediction Center (WPC) issues Excessive Rainfall Outlooks for Days 1-3. These are not an indication of expected flood coverage, not severity!

- ◆ HIGH risks matter!



Watch vs. Warning

- ◇ **WATCH:** Conditions are favorable for flooding to occur (>50% chance). Be alert for possible flooding during the watch period.
- ◇ **WARNING:** Flooding is occurring or is extremely likely to occur (>75% chance). Stay out of low areas and seek higher ground if necessary!
- ◇ Note: A watch does not necessarily precede a warning, especially for river flooding.



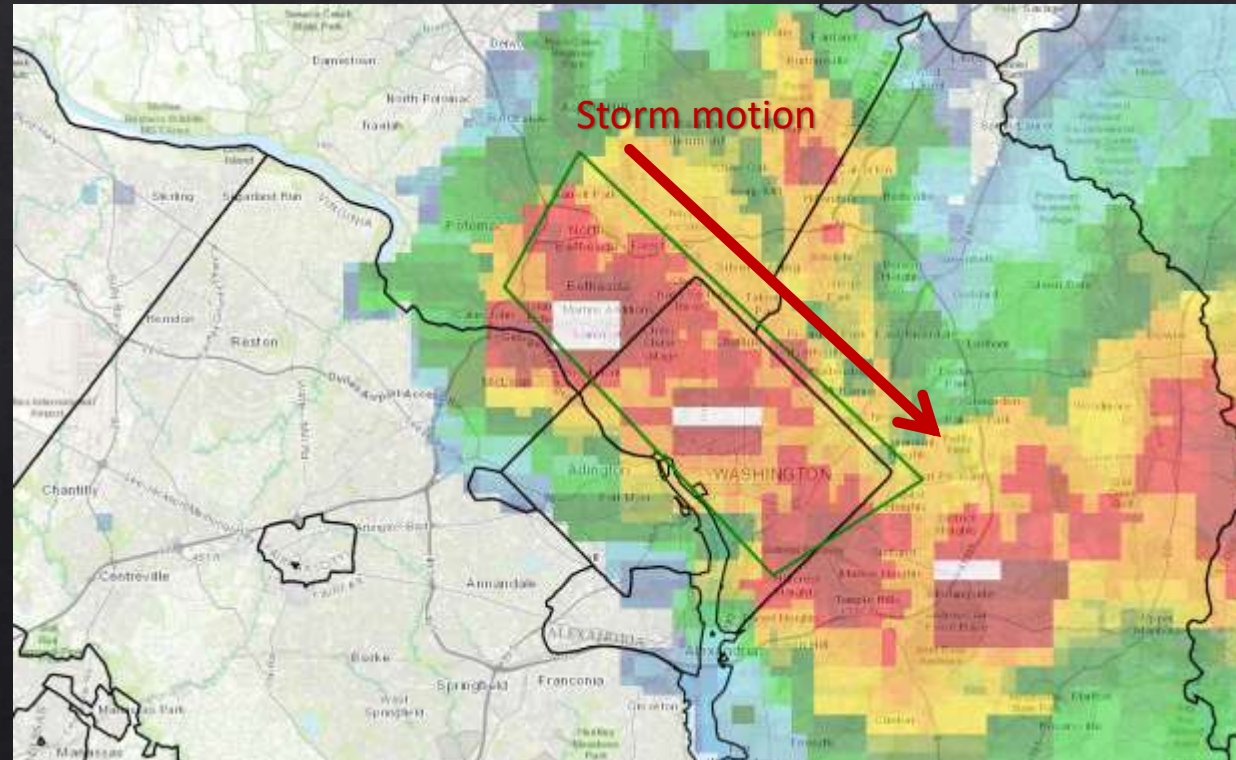
Flood Warning vs. Flash Flood Warning

- ❖ **FLOOD WARNING:** Flooding is expected during the period of the warning. This flooding will generally be slower to develop (water might not be moving as quickly) but could ultimately become just as significant/severe as a flash flood.
- ❖ **FLASH FLOOD WARNING:** Rapid and extreme flooding is expected during the warning period. You will have little, if any, time to react, and swift moving water will occur in some spots. Other locations may experience less impactful flooding.
- ❖ **FLASH FLOOD EMERGENCY:** Rapid and extreme flooding is occurring and is causing significant damage or threat to life RIGHT NOW. There is no time to wait; action must be taken immediately and a certain spot (or spots) within the warning area are in grave danger. Other locations may experience less impactful flooding.



Basin-Based Warnings

- ◇ Our goal is to warn for:
 - ◇ Where the rain is going to go
 - ◇ Where the water is going to flow
- ◇ This means we may warn for places where it will not even rain!



Respect the Polygon!

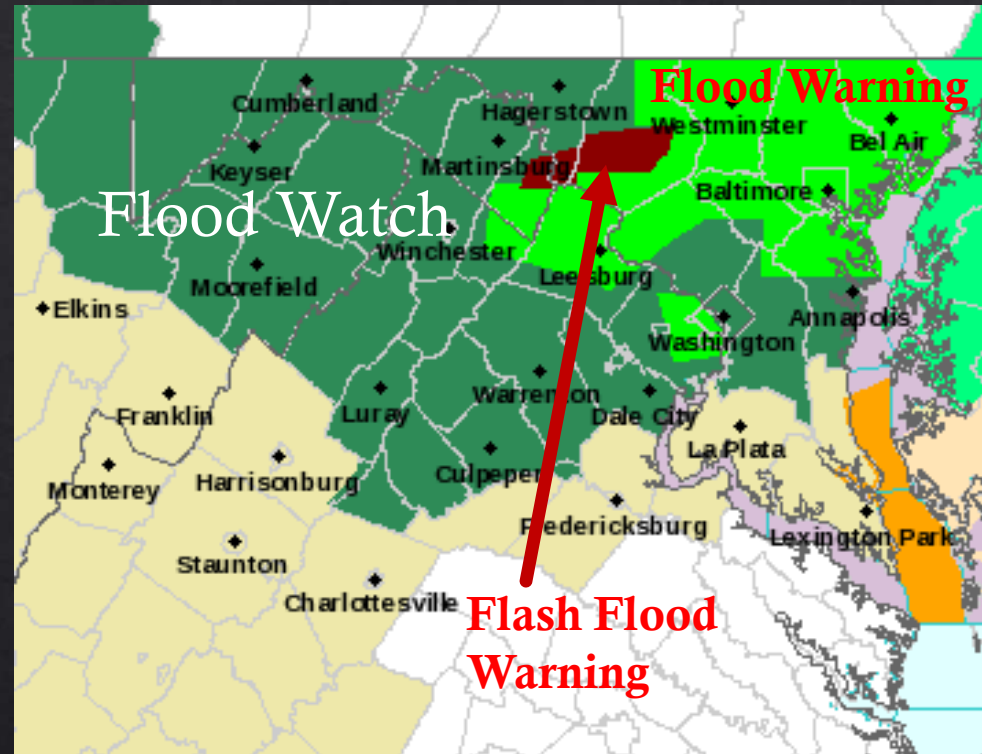
- ◇ All flood warnings (except coastal flood) are issued as polygons.

- ◇ Limits the area covered by a watch or warning

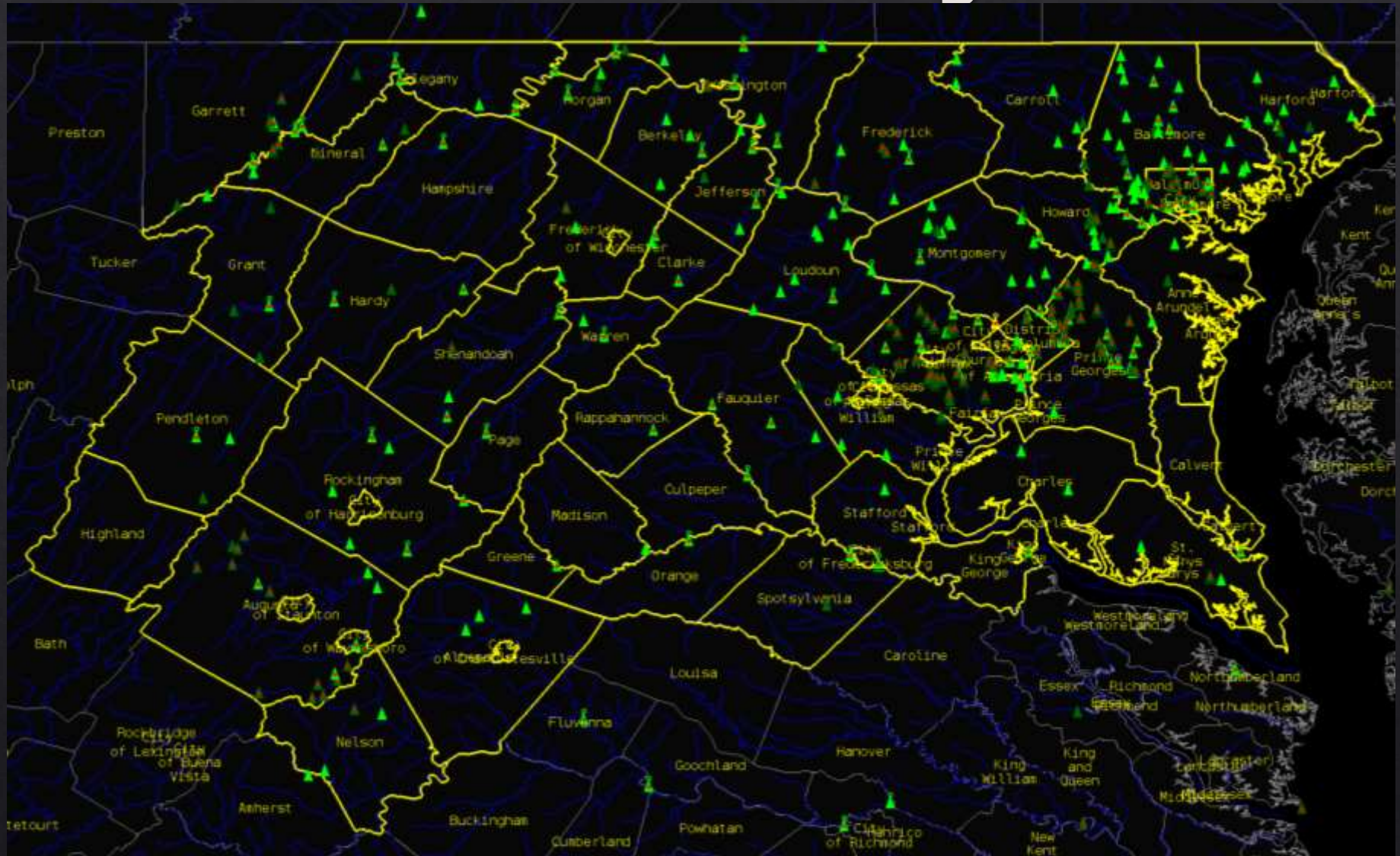
- ◇ If you're not in a box, we believe your threat is low!

- ◇ For watches, only river flood watches are issued as polygons.

- ◇ Reminder: While all areas in the polygon are perceived to have an imminent flood threat, in many cases only a few small areas will actually experience flooding.



River & Lake Gauges

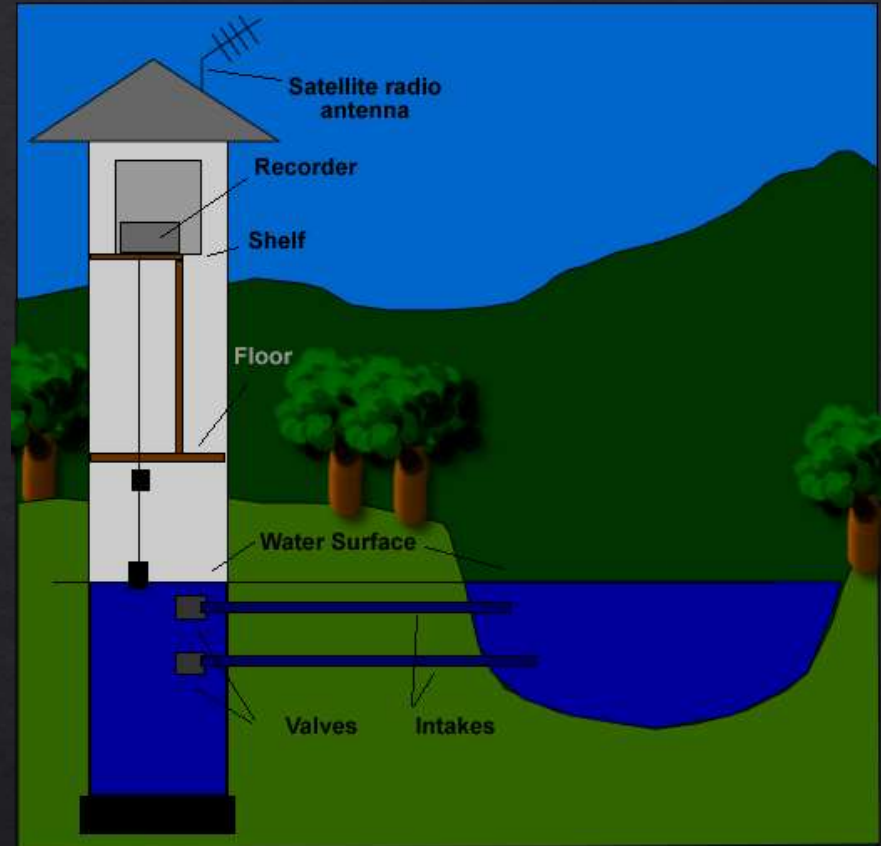


Where does it flood most often?

- ◇ **Cacapon River near Great Cacapon, WV (GCPW2) – 2.3x / year** *Morgan County*
- ◇ **Opequon Creek near Martinsburg, WV (MBGW2) – 2.3x / year** *Berkeley & Jefferson Counties*
- ◇ **Robinson River near Locust Dale, VA (LOCV2) – 1.9x / year** *Madison & Culpeper Counties*
- ◇ **Western Branch at Upper Marlboro, MD (UPRM2) – 1.8x / year** *Prince George's County*
- ◇ **Whitemarsh Run at White Marsh, MD (WHMM2) – 1.7x / year** *Baltimore County*
- ◇ **Shenandoah River near Millville, WV (MILW2) – 1.7x / year** *Jefferson & Clarke Counties*
- ◇ **Mechums River near White Hall, VA (MECV2) – 1.6x / year** *Albemarle County*
- ◇ **Seneca Creek at Dawsonville, MD (DAWM2) – 1.6x / year** *Montgomery County*
- ◇ **Otter Point Creek at Edgewood, MD (EDGM2) – 1.6x / year** *Harford County*
- ◇ **St. Mary's River at Great Mills, MD (GMRM2) – 1.4x / year** *St. Mary's County*
- ◇ **Monocacy River at Bridgeport, MD (BDGM2) – 1.4x / year** *Frederick County MD*



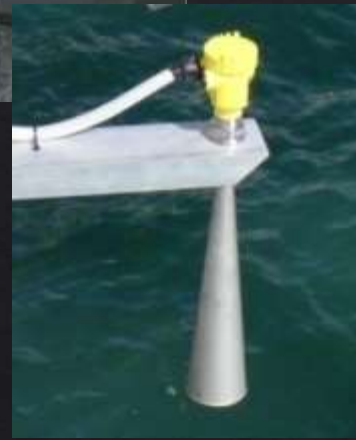
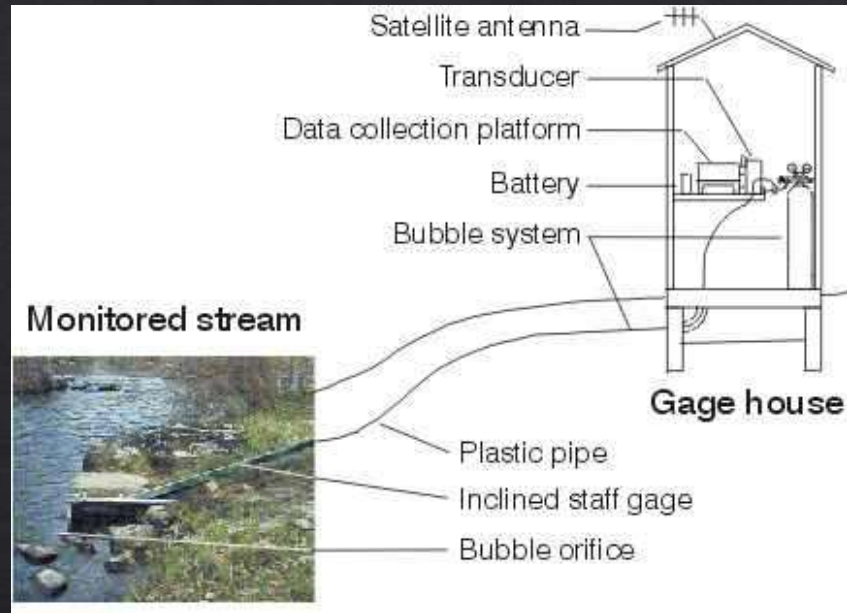
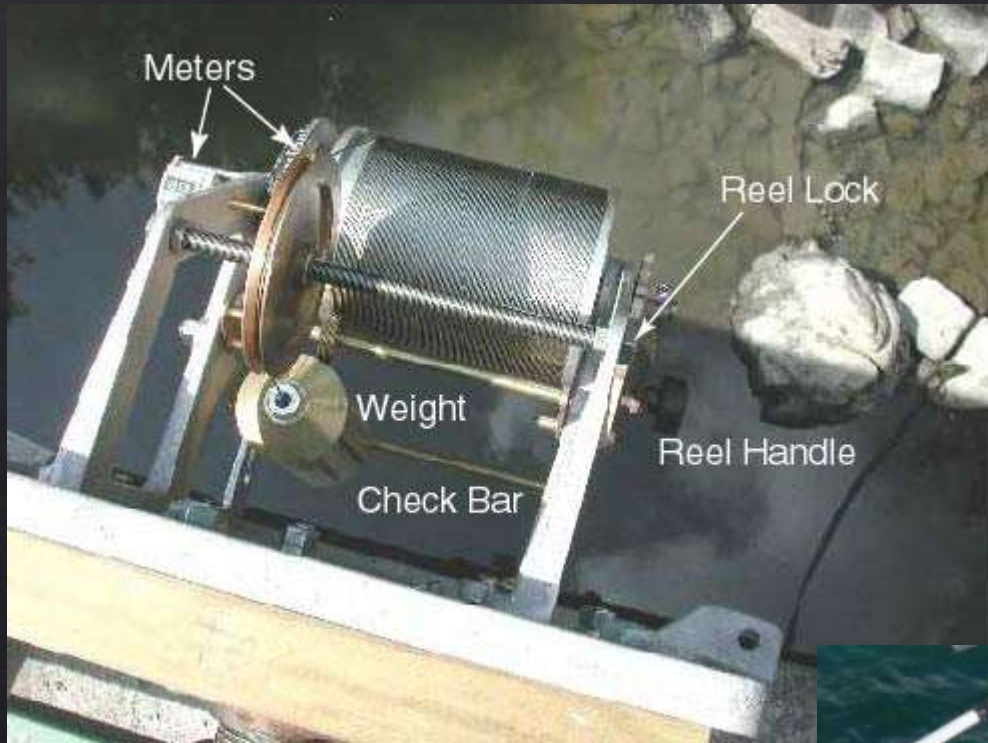
How are water levels measured?



From left:
Staff Gauge
Crest Gauge
Stilling Well / Float



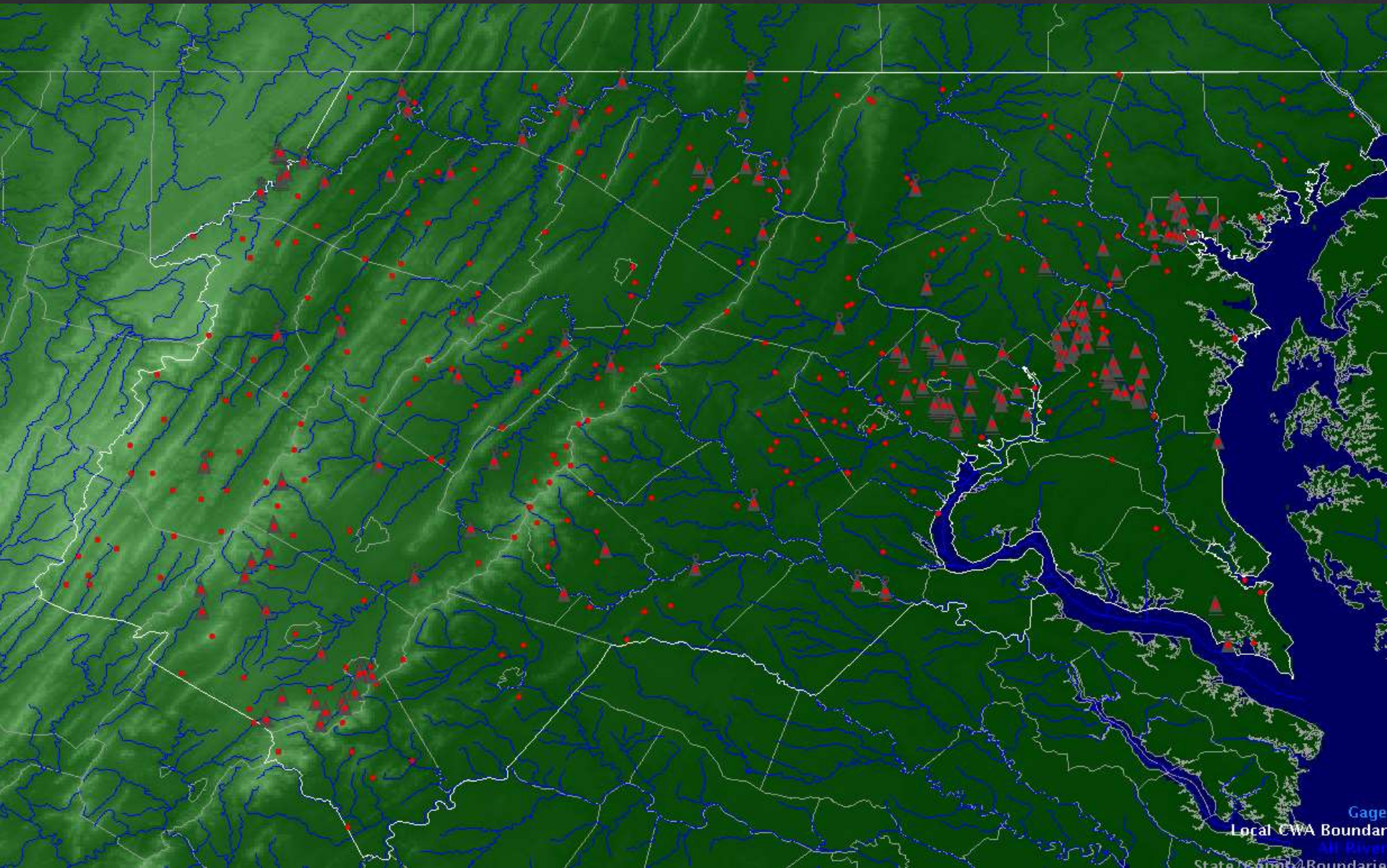
How are water levels measured?



From left:
Wire Weight Gauge
Radar Gauge
Pressure Transducer /
"Bubbler"



Precipitation Monitoring



Observations during heavy rain

- ◇ Ground truth
 - ◇ Nothing ever beats an eye in the field!
 - ◇ Rainfall measurement / flood report / stream measurement
 - ◇ Safety is always key!



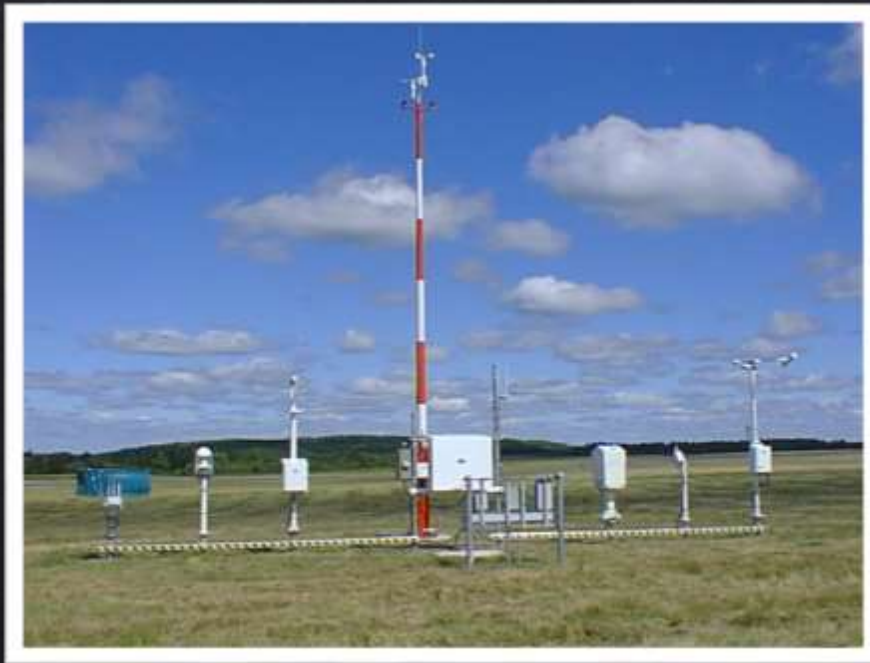
Photo courtesy Prince George's County EMS

**US 301 / MD 4
Prince George's Co., MD**



Observations during heavy rain

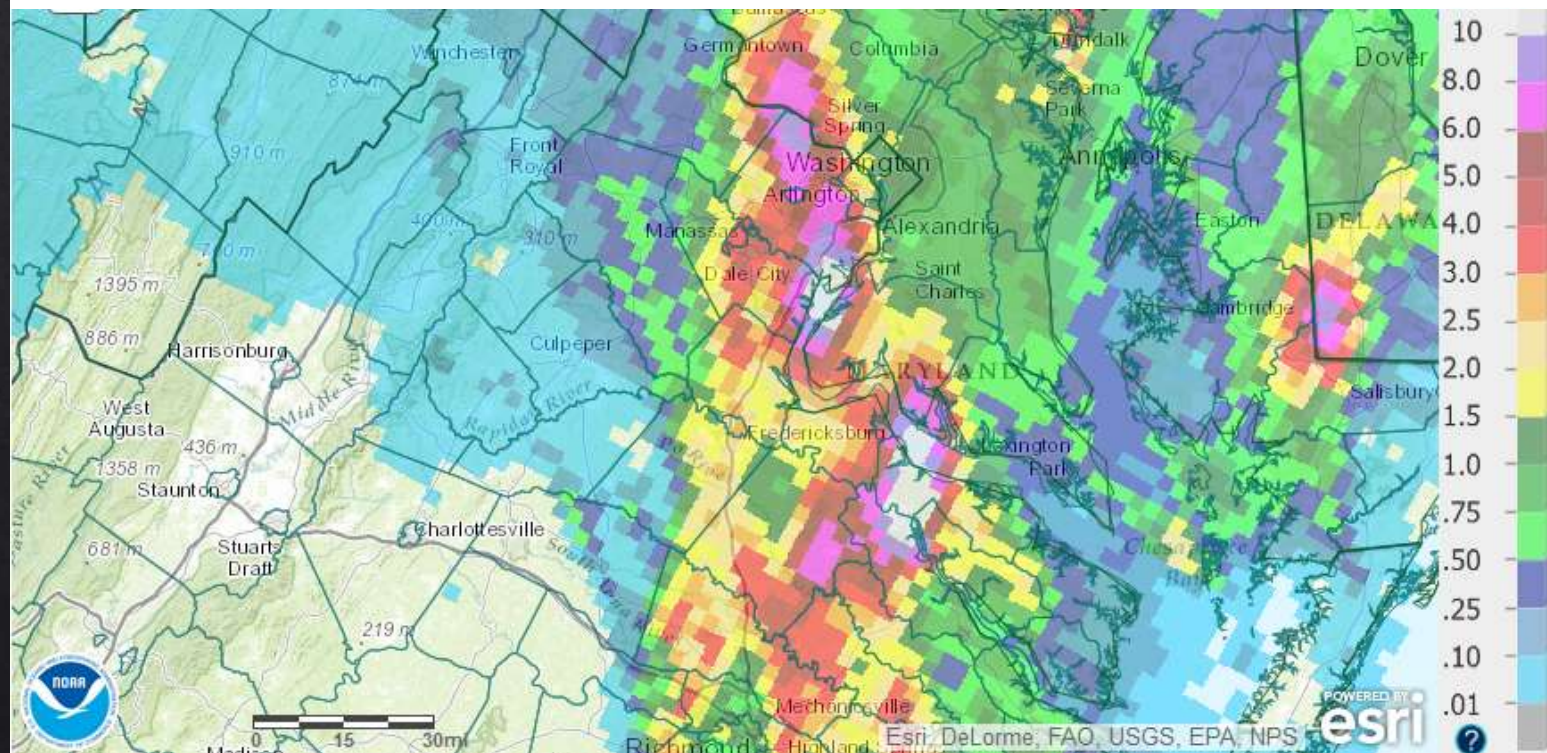
- ◇ Automated observations
 - ◇ Near-real time, but...
 - ◇ Subject to error/clogging/freezing
 - ◇ No measurement of how much of the fallen rain is being soaked into the ground, and how much is running into streams



Precipitation Estimates

- ◇ Remote Sensing
 - ◇ Radar
 - ◇ Satellite

Baltimore/Washington, VA (LWX): 9/9/2011 1-Day Observed Precipitation
Valid at 9/9/2011 1200 UTC- Created 9/11/11 23:31 UTC



The “Ultimate Combo”

- ◇ Ground truth observations
- ◇ Radar & satellite estimates skewed by ground truth
- ◇ Gaps filled in by radar & satellite

- ◇ Spotter reports are vital!
 - ◇ Rain amounts
 - ◇ River level status
 - ◇ Is there water over the road?
 - ◇ (We’ll talk more about this later...)



Ellicott City, MD

Photos by Craig Coyne



Why Do We Need Spotters?

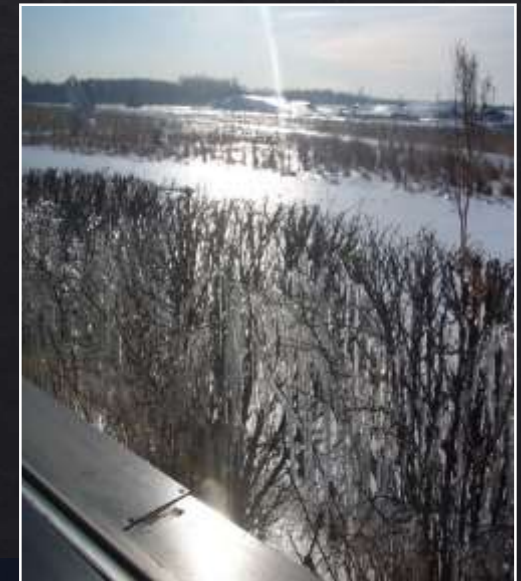
- ◇ All one team!
 - ◇ Emergency Managers
 - ◇ Other Government Agencies
 - ◇ Broadcast and Print Media
 - ◇ SKYWARN Spotters
 - ◇ Amateur Radio Operators
 - ◇ Cooperative Observers



Spotter Reports

◆ Answer the 4 Ws:

- ◆ Who are you?
- ◆ What is your report?
- ◆ When did this happen?
- ◆ Where did this happen?



Tips:

Give us your spotter number & name

Be descriptive about what you see

(pictures are great, but be safe!)

Be as specific about location as possible



Why Specificity Matters

◆ Floods are not created equal!



VS.

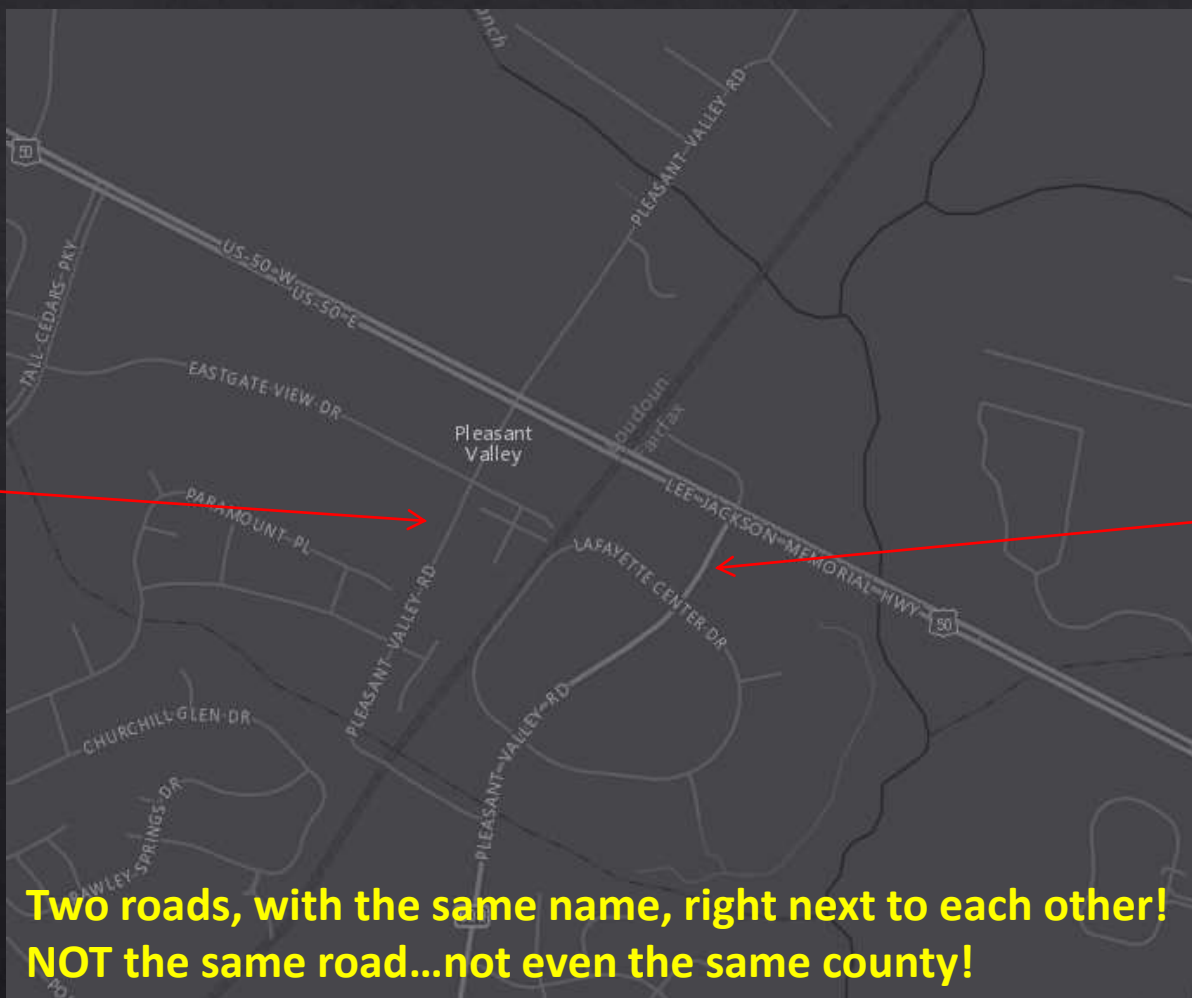


Why Specificity Matters

◆ Location...location...location!

Pleasant Valley Rd
(Loudoun Co.)

Pleasant Valley Rd
(Fairfax Co.)



Floods – What to Report

- ◇ River or stream flows out of banks and is a threat to life or property.
- ◇ Person or vehicle swept away by flowing water **from runoff that inundates** adjacent grounds.
- ◇ A maintained county or state road closed by high water.
- ◇ Approximately **six inches or more of flowing water** over a road or bridge.
 - ◇ This includes low water crossings in a heavy rain event that is more than localized (i.e., radar and observer reports indicate flooding in nearby locations) and poses a threat to life or property.



See water where it doesn't belong, but it doesn't meet these criteria? Report it anyway, but be as descriptive as you can! We don't want to issue warnings when they aren't really needed!



Floods – What to Report

- ◇ Dam break or ice jam release causes dangerous out of bank stream flows or inundates normally dry areas creating a hazard to life or property.
- ◇ Any amount of water in contact, flowing into or causing damage of an **above ground** residence or public building and is **runoff from adjacent grounds**.
- ◇ **Three feet or more of ponded water** that poses a threat to life or property.
- ◇ Mud or rock slide caused by rainfall (could possibly occur in a burned area with only light-moderate rainfall).

See water where it doesn't belong, but it doesn't meet these criteria? Report it anyway, but be as descriptive as you can! We don't want to issue warnings when they aren't really needed!



What to Report

- ◆ **Heavy Rain** – measured 1" or more (we prefer to get periodic reports & a storm total at end)
- ◆ **Rainfall Rate** –
Rainfall in inches per hour
(**Warning:** automated weather stations often provide an “instantaneous rain rate” which can sometimes be 10+ in/hr... this is not what we are looking for!)



What to Report

- ◆ **Flooding & Flash Flooding** – Streams, creeks or rivers out of banks or flooding of roads

Things to look for:

- ◆ Is the water still or flowing?
- ◆ How deep is the water?
- ◆ What is the source of the water? (stream? drainage ditch? poor drainage?)
- ◆ If a road is impacted, lat/lon or block #
- ◆ Are any structures impacted (including outbuildings)?
- ◆ Can you safely get any pictures?



Terminology Reminders

◆ **By NWS Definition** –

A flood/flash flood must impact life or property!

- ◆ Water over the banks of a stream but not affecting anything is technically not a flood...but we'd still like to know! Let us know that "(name of stream) is bankfull" or "just over bankfull".

◆ **Low Water Crossings** –

We have many of these in this area. They are designed to be covered by water while the stream is entirely within its banks. (Not a flood!) If the "flood" is of a low water bridge, please say so!



Flood Spotter Safety Reminder

- ◆ **Don't become a statistic!**

Practice what we preach!

If you come across a flooded road,
that is a report! Don't drive through
it looking for more flooded roads!



Winter Reports

- ◇ **Ice Accretion** – Any glaze on surfaces (or more) →
- ◇ **Snow Accumulation** – Every 2" and a storm total, or any accumulation not reflected in the forecast



Average Ice Accretion
5/16" = 0.3"

Bonus points 😊:

Snow Water Equivalent – melt your snow down to see how much water is within it

Snow Measurement Guidelines:

https://madis-data.noaa.gov/snow_measurements.html



Setting Up for Snow Reports



Ideally, a snowboard is the best measuring surface.

- Can be as simple as a 2 ft square piece of plywood painted white
- May want to place flags/markers near the board to help locate during snowy weather
- You can measure snow on a table if you don't have a board

- Do NOT clean off the snowboard more frequently than every **six hours**.



Non-Flood spotter reports

- ◆ Although we don't go into severe reports here, if you're already a spotter by having taken our Basic course, you certainly can report that too!
- ◆ If you want to provide tornado/funnel cloud reports, you should attend Basic first!



How to Report Hail



Hail reports are the most difficult to gather. The hail shaft can be very narrow and short lived.

“Marble Size” hail is ambiguous. Do not report hail as marble sized.



How to Report Hail



Please
sports

ns or
uler.

Hail should be measured along the longest dimension. It is best to use a ruler or tape measure.



How to report

- ◇ Call NWS as soon as you see something (and it's safe):
(800) 253-7091
- ◇ You can email delayed reports or pictures to:
LWX-Report@noaa.gov
- ◇ Contact local Emergency Management
- ◇ Amateur Radio (when activated)
- ◇ **Rain & Snow Reports can be sent via our online form**
- ◇ If you see signs of flooding after the event, let us know!
Immediate reports are best; but no report is too late!
- ◇ If a report is second-hand (not directly from you), please let us know that.



Best way to report

VERY IMPORTANT INFORMATION:

- ❖ Please DO NOT send flooding reports by email, unless you see it after the fact, have a picture, or can't get to a phone!
- ❖ This is very time critical information that needs to be relayed to forecasters immediately.
- ❖ Best means to get information to the NWS quickly is via the telephone or Amateur Radio.
- ❖ Rainfall/snowfall observations via email/web form are fine unless you think we need to know more urgently.

PLEASE DON'T WAIT FOR US TO CALL YOU! (we will...)



Additional Reports

If you have a rain gauge or automated weather station:

- ◇ We would love to have your reports routinely!
- ◇ Rain gauge or automated weather station must be well-sited (not attached to side of house, not under trees, etc.)



How can I join?

Five easy steps

Simply sign-up on the CoCoRaHS web page: www.cocorahs.org

Obtain a 4" plastic rain gauge

View the on-line "training slide show"

Set-up the gauge in a "good" location in your yard

Start observing precipitation and report on-line daily



Flood History

◇ Did you know?

The first recorded floods in this region were in **1748!**

- ◇ *A teenaged George Washington, working as a land surveyor, could not cross the Potomac River at Berkeley Springs due to flooding from snowmelt. Washington instead spent time at the "Medicinal Springs" (today's Berkeley Springs).*
- ◇ *As the flood (maybe the same one, we're not sure) moved down the Potomac, Robert Harper – the namesake of Harpers Ferry – had to leave his log cabin and move into a barn up on the hill.*

<http://www.weather.gov/washington/FloodTimeline>



March 17-19, 1936

- ◇ Still, to this day, the record flood on the Potomac.
- ◇ The record flood on the Shenandoah is 1942



What Causes Floods Here?

- ◇ Stalled fronts
(with more extreme floods near them in the summer)
- ◇ Coastal Lows
- ◇ Tropical storms / hurricanes
- ◇ Snowmelt
- ◇ Unusually high tides (sometimes not from hurricanes)

Now let's look at cases of these in more detail...



Stalled Fronts

◇ **June 27, 1995**

◇ **Madison County, VA**

◇ **June 10, 2014**

◇ **College Park, MD**

◇ **June 12, 2014**

◇ **Clear Spring, MD**

◇ **July 30, 2016 & May 30, 2018**

◇ **Ellicott City, MD**



June 27, 1995

- ◆ Affected foothills of central Virginia
- ◆ 24" rain within 24 hours
- ◆ 3 fatalities
- ◆ Mud/Debris slides
- ◆ All bridges in and out of Madison County were washed out or damaged except for U.S. Route 29 South.

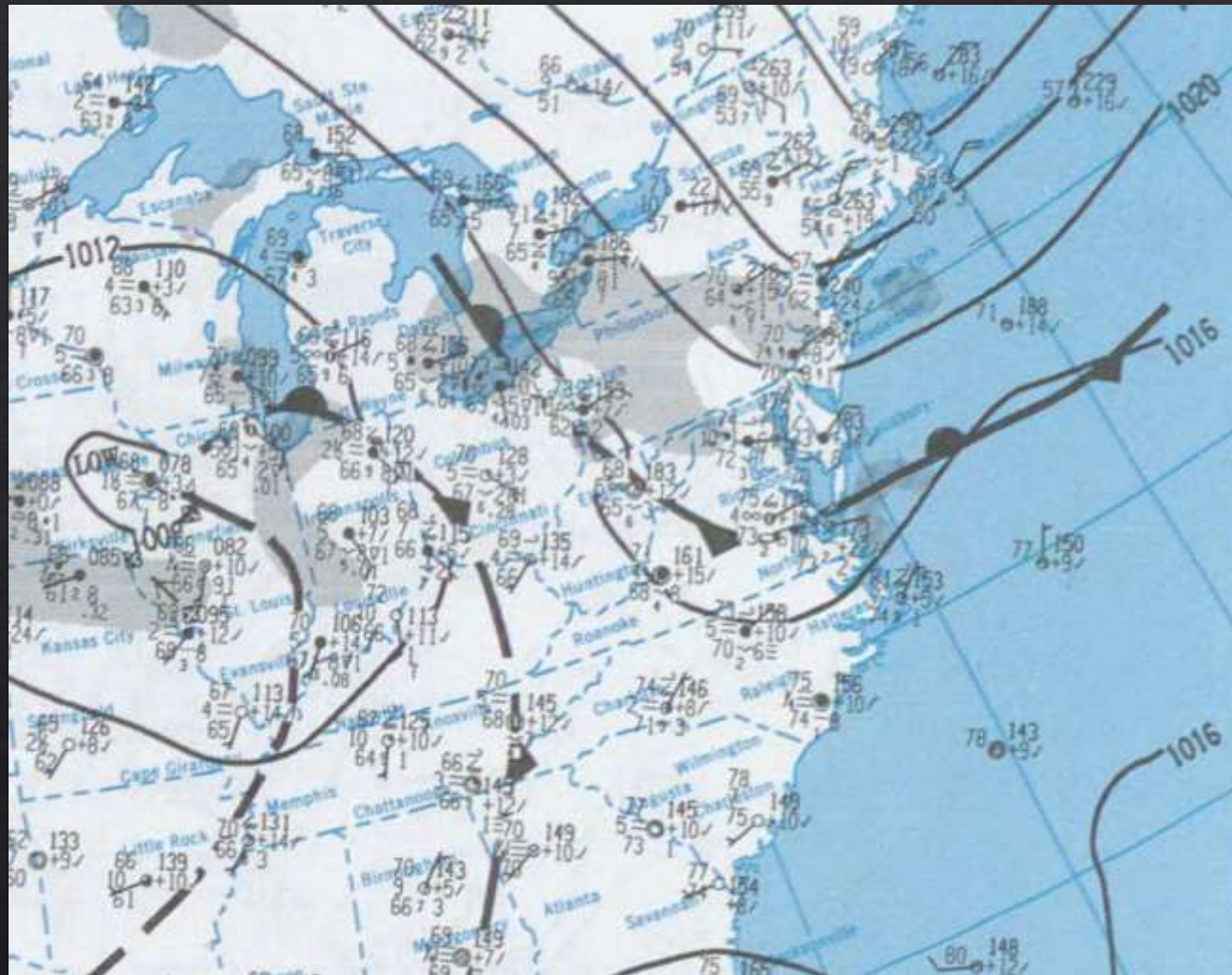


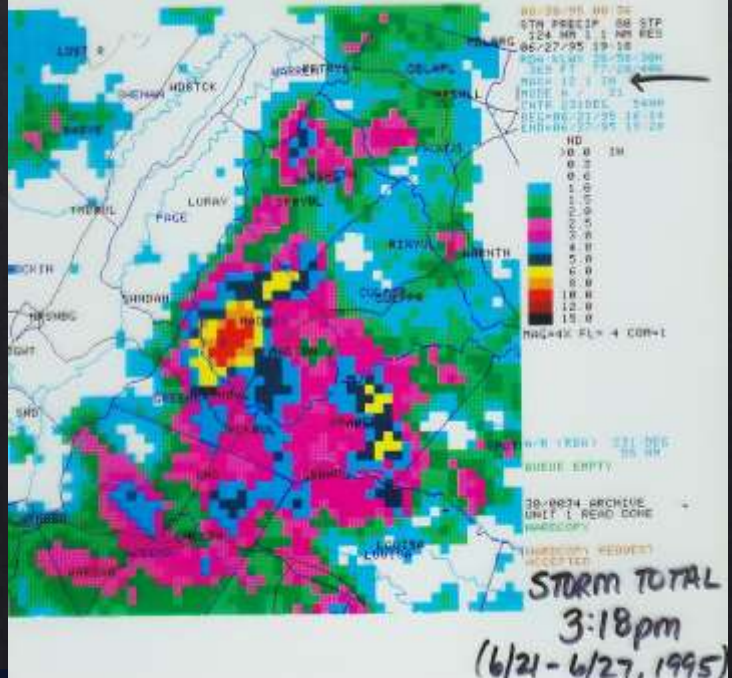
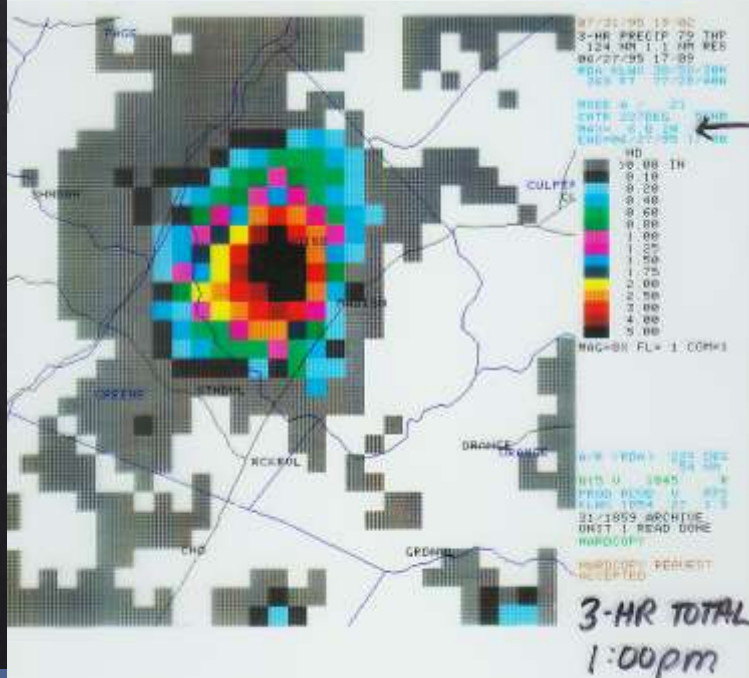
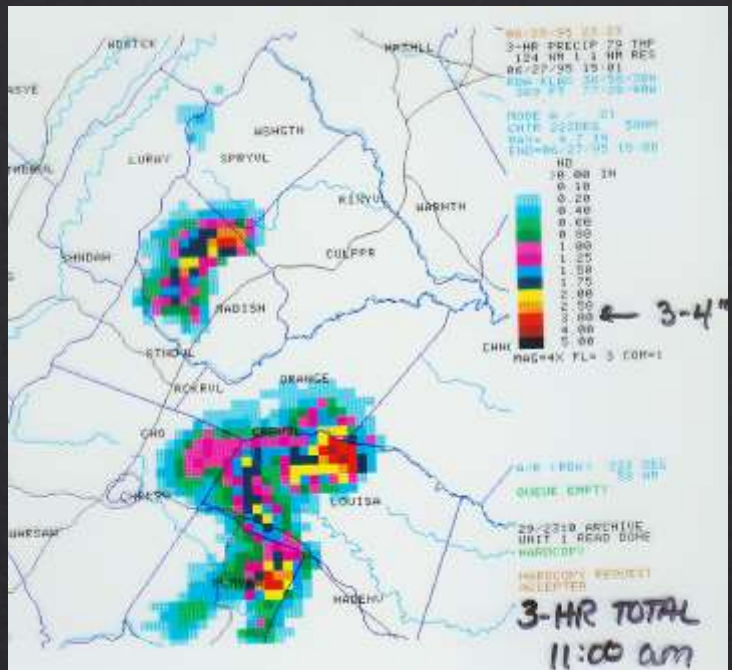
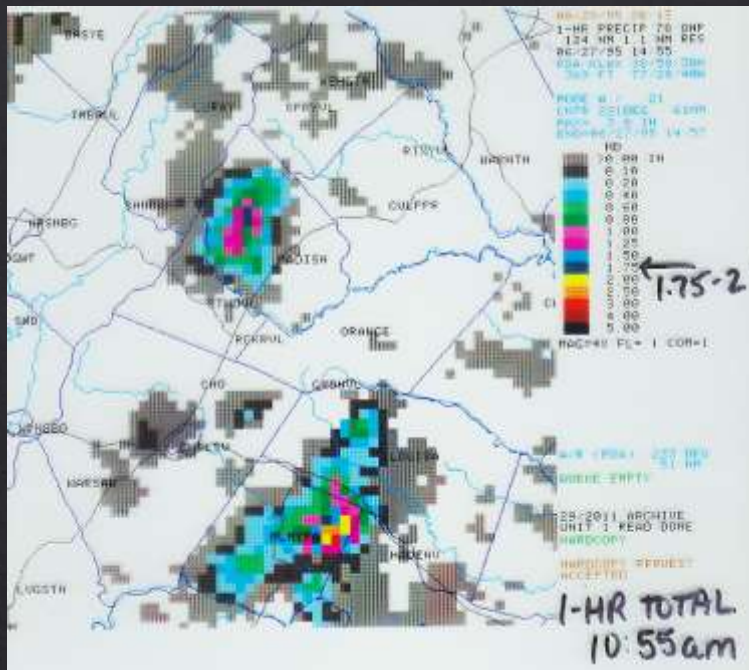
Rt. 29 @ Madison/Greene County Line

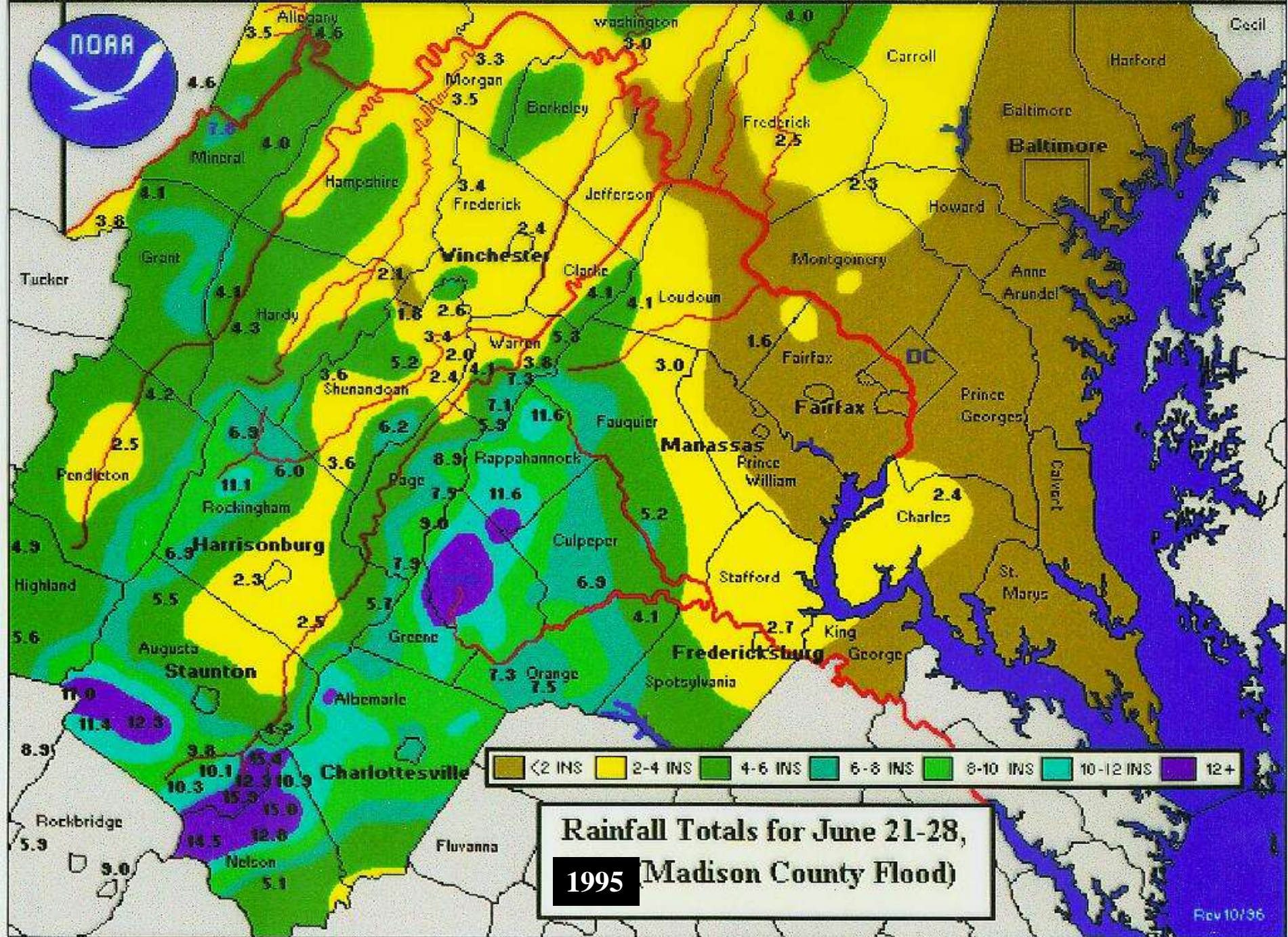


Rapidan River poured over U.S. Rt 29 at the border of Madison & Greene counties

How it Happened



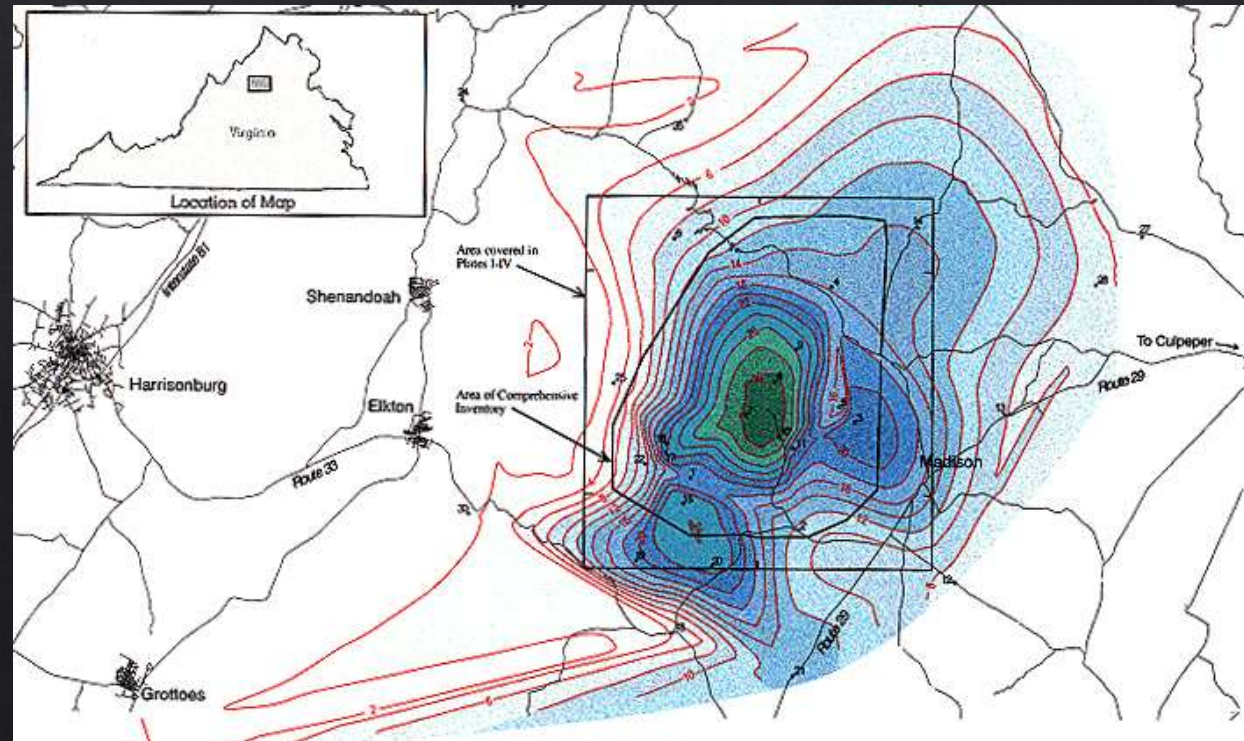




Rainfall Totals for June 21-28, 1995 (Madison County Flood)

Madison County (VA) Flash Flood

- ❖ Precipitable water before the event from the Dulles sounding was 1.97", near record high for the date.
- ❖ The Rapidan River was flowing at 125 times its normal rate – 37 billion gallons per hour!
- ❖ Rainfall of 20 to 30 inches over quite a large area



Madison County (VA) Flash Flood

- ❖ Radar was underestimating rainfall - ratio of ground truth to radar estimates was 1.8 : 1.
- ❖ As flooding became more severe, communications were lost.
- ❖ Skywarn amateur radio spotters provided the first ground-truth report from Madison County.
- ❖ At 2PM, Etlan reported 10", with 5" falling between 10AM & 2PM.
- ❖ Record Flooding along the Rapidan River near Ruckersville and Culpeper

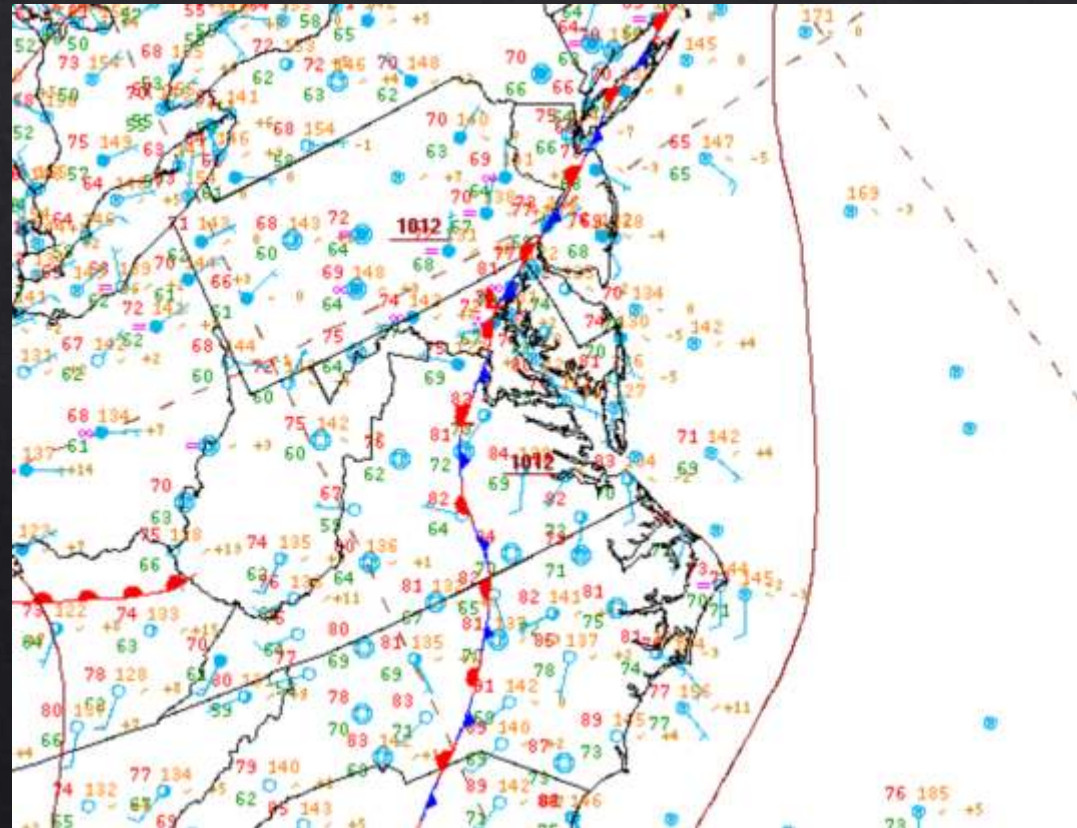
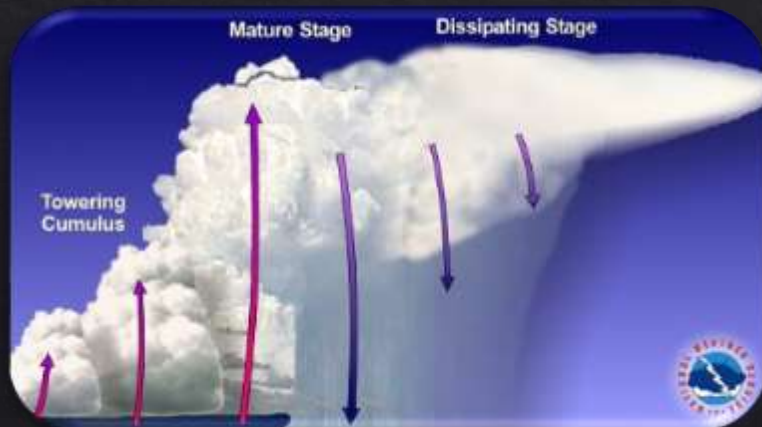


June 10, 2014

◇ Not as typical of a case as the last one:

◇ Often in these events, they occur in the evening.
But this time, storms formed in the morning

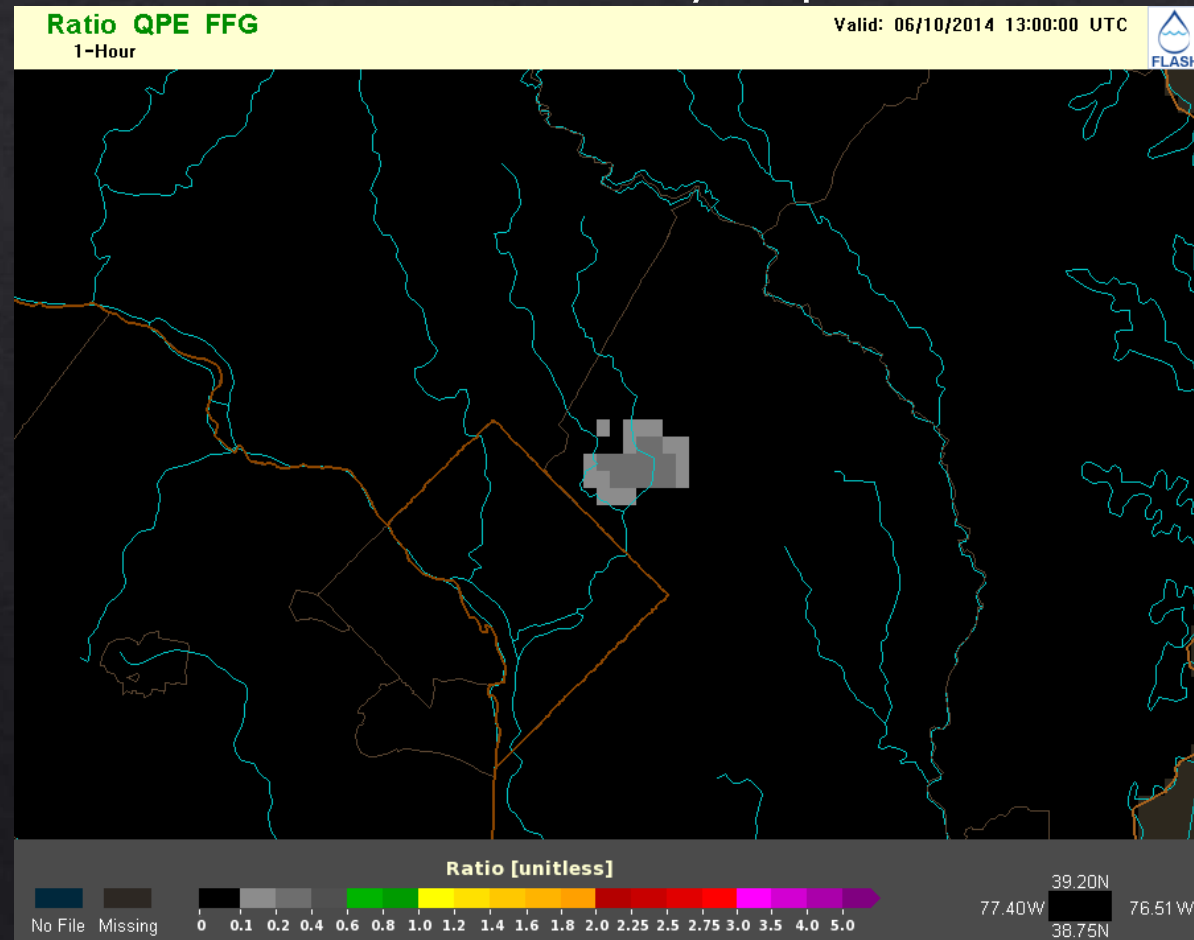
◇ And did this...



College Park Flood – 6/10/2014

Our goal is to provide a one-hour (actually 65 minute) advance notice of a flash flood. Sometimes this is literally impossible.

- * Image is from 9am
- * Flooding began by 9:57am, with water rescues before 10:00am.



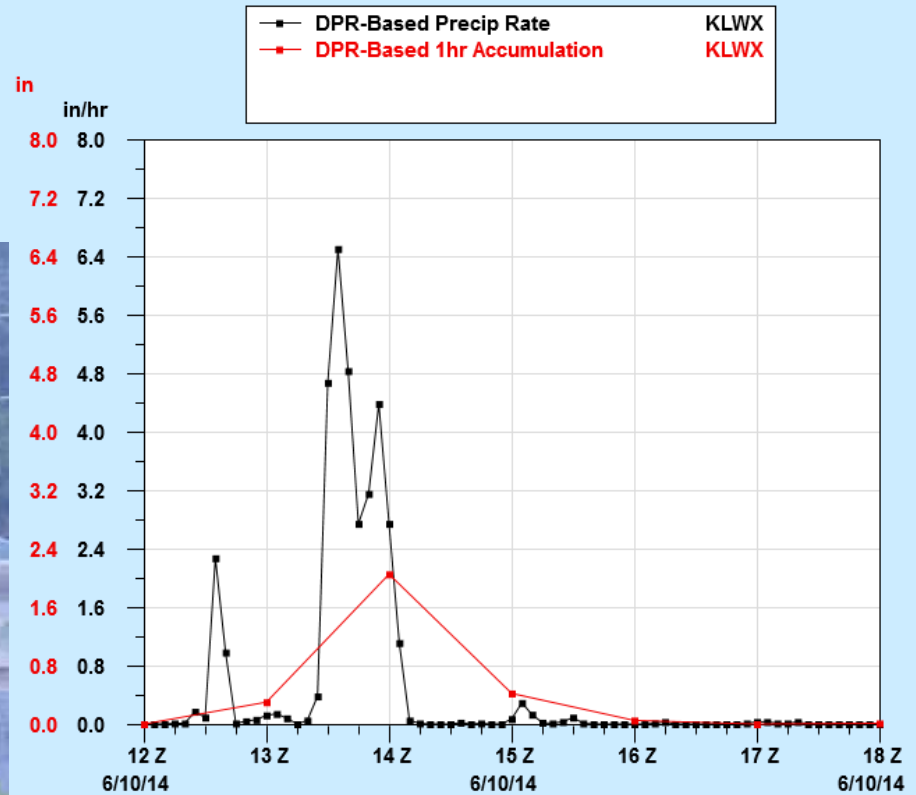
College Park Flood – 6/10/2014

That 20-30% on the last slide was from a previous shower!

Really, it didn't even begin raining hard until 9:30am!



Map Location: Lat **38.97** Lon **-76.93**

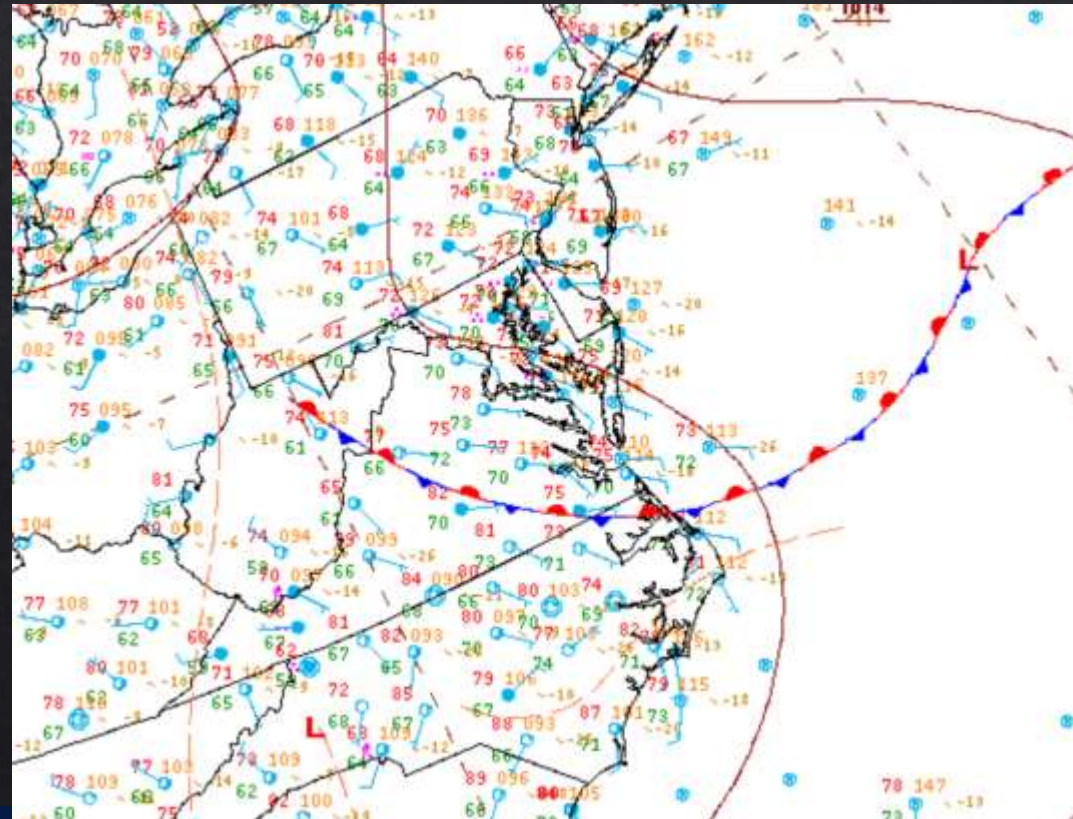


East-West Highway in Riverdale, MD
Photo from Anand Parikh



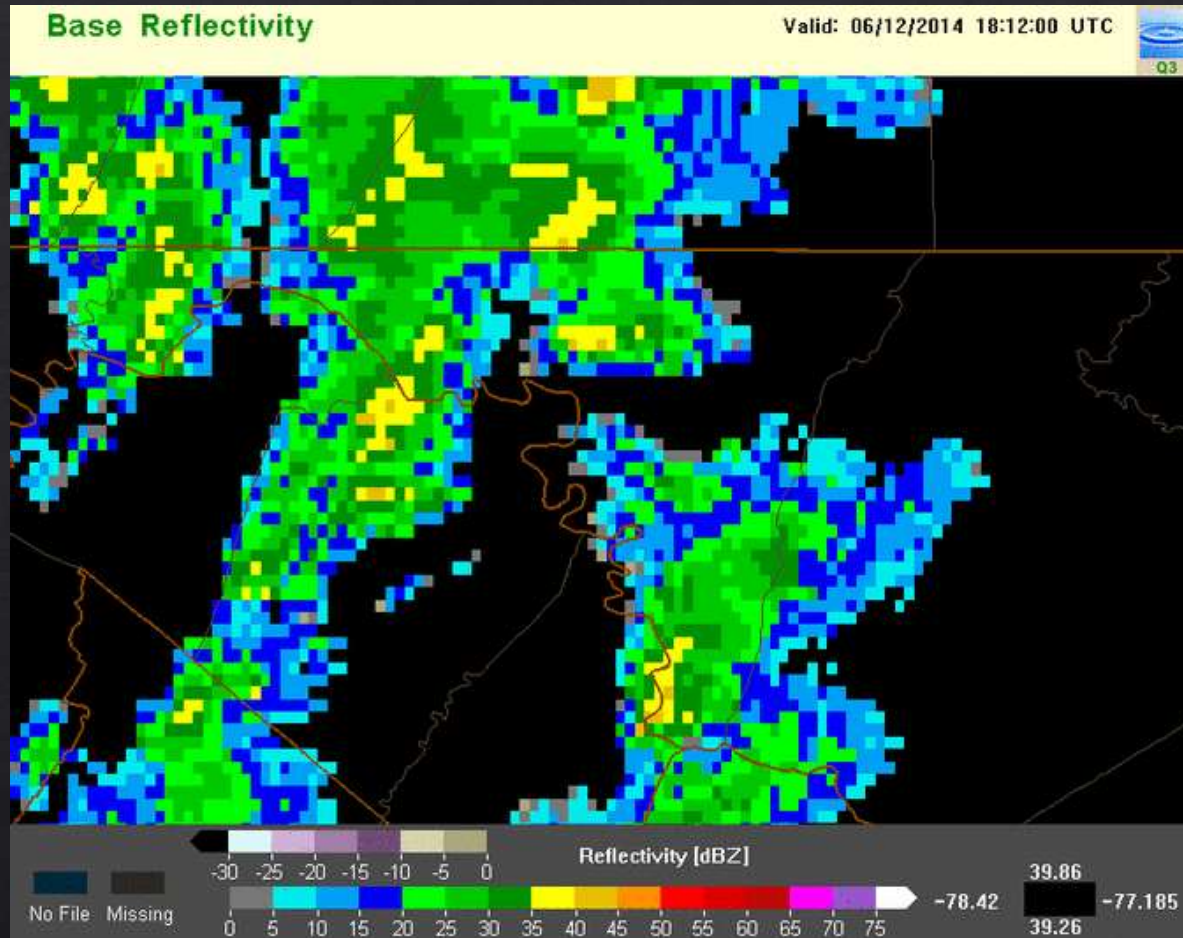
June 12, 2014 – Clear Spring, MD

- ◇ You might have noticed...this is only two days after the College Park event we just talked about.
- ◇ The stalled front...now stalled elsewhere. (But there's still a boundary.)
- ◇ Deep easterly flow off the Atlantic →
- ◇ Typical afternoon & evening storms



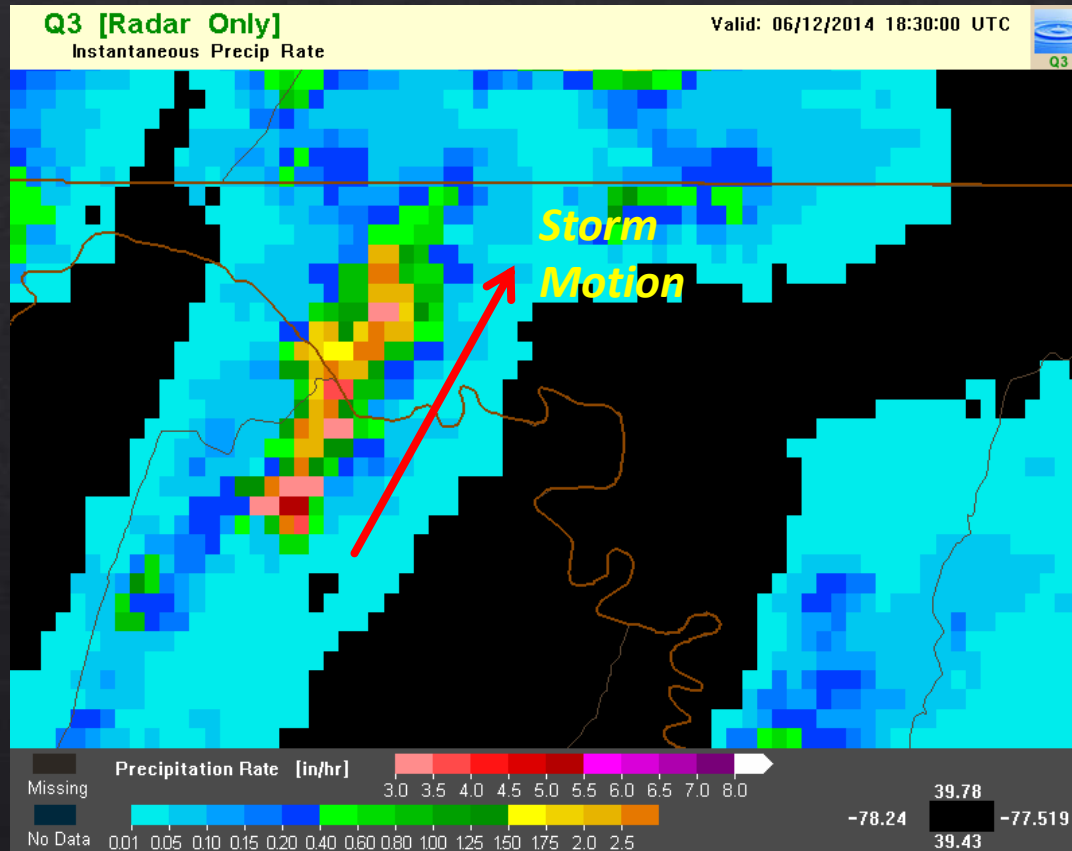
Clear Spring – 6/12/2014

◇ Radar Base Reflectivity 2:12pm – 3:00pm:



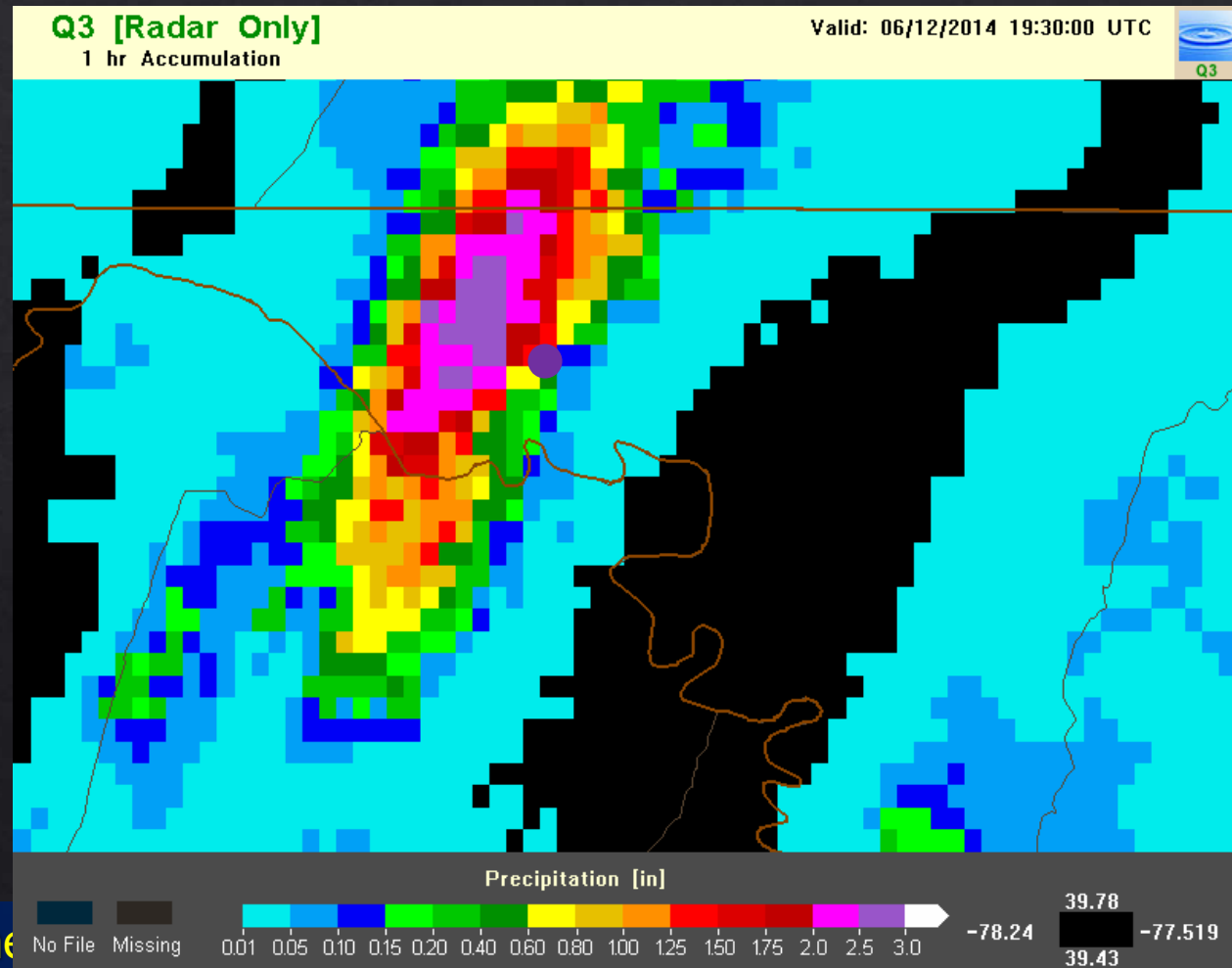
Clear Spring – 6/12/2014

◆ Instantaneous Rain Rate product at 2:30pm:



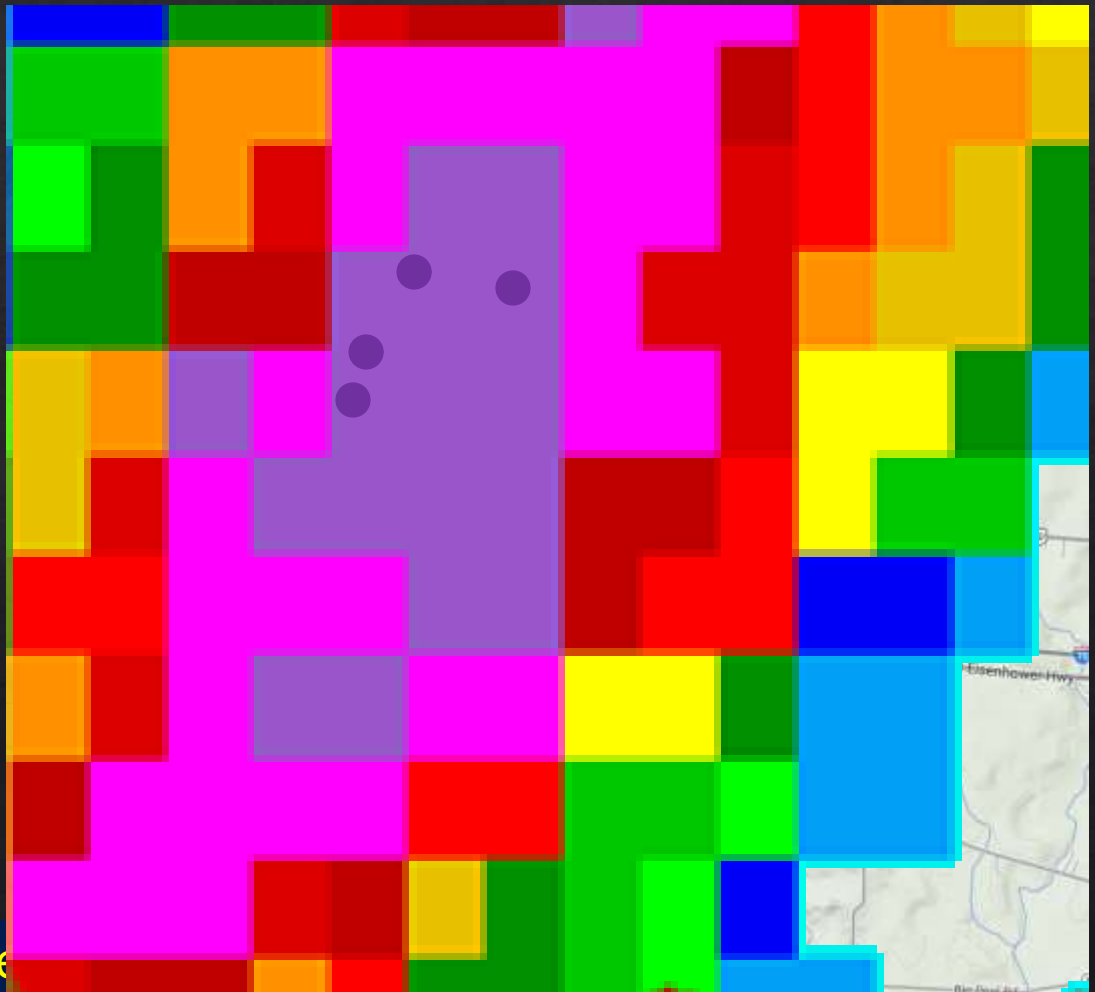
Clear Spring – 6/12/2014

- ◆ One Hour Precip at 3:30pm:
- ◆ Note where Clear Spring is!



Clear Spring – 6/12/2014

- ◆ We must always warn for where the rain's going to go and where the water is going to flow!



Clear Spring – 6/12/2014



Flooding in Clear Spring, MD (photo from Hagerstown Herald-Mail)

Clear Spring – 6/12/2014



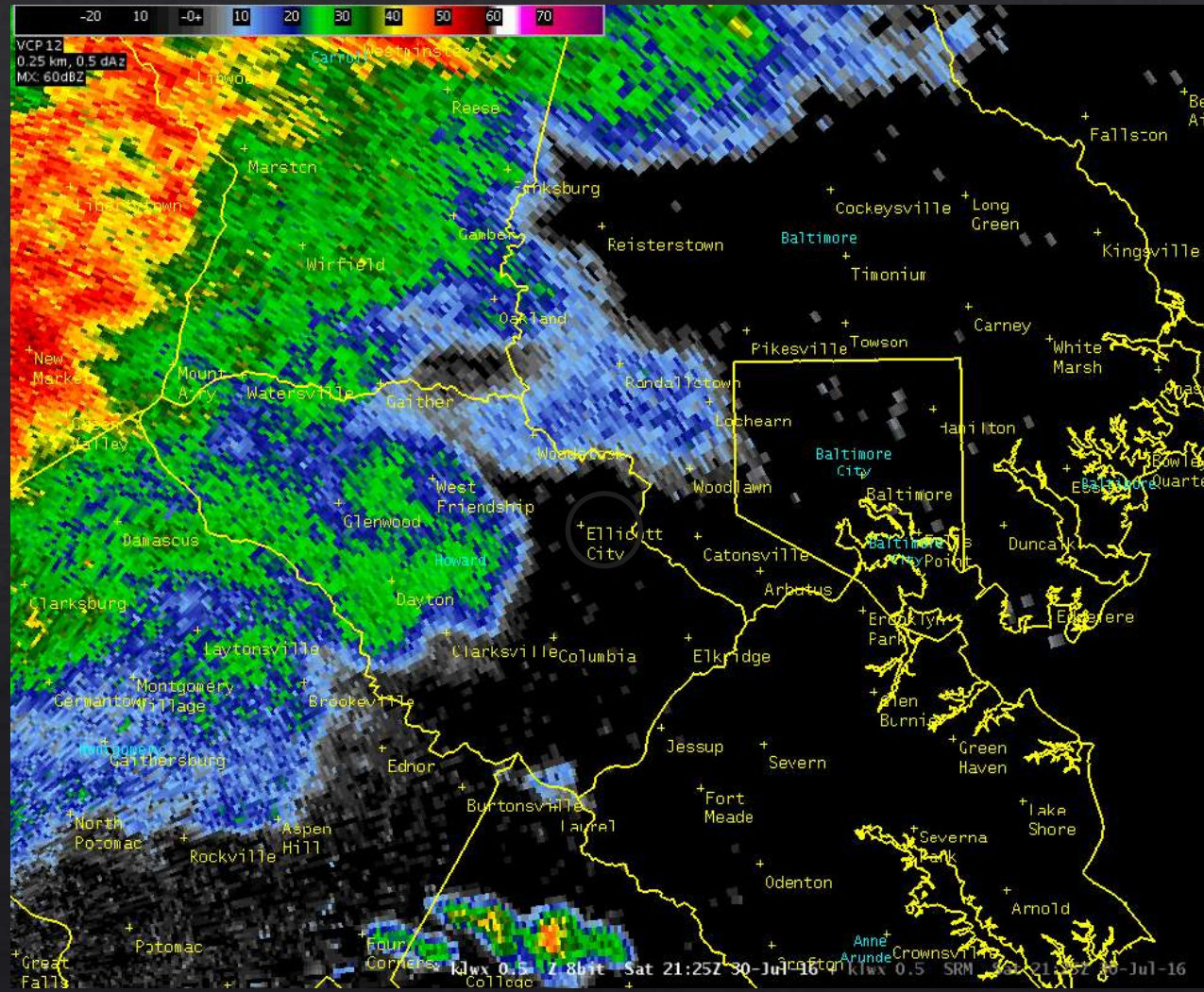
Flooding in Clear Spring, MD
(photo from Hagerstown Herald-Mail)



Ellicott City Flood Overview

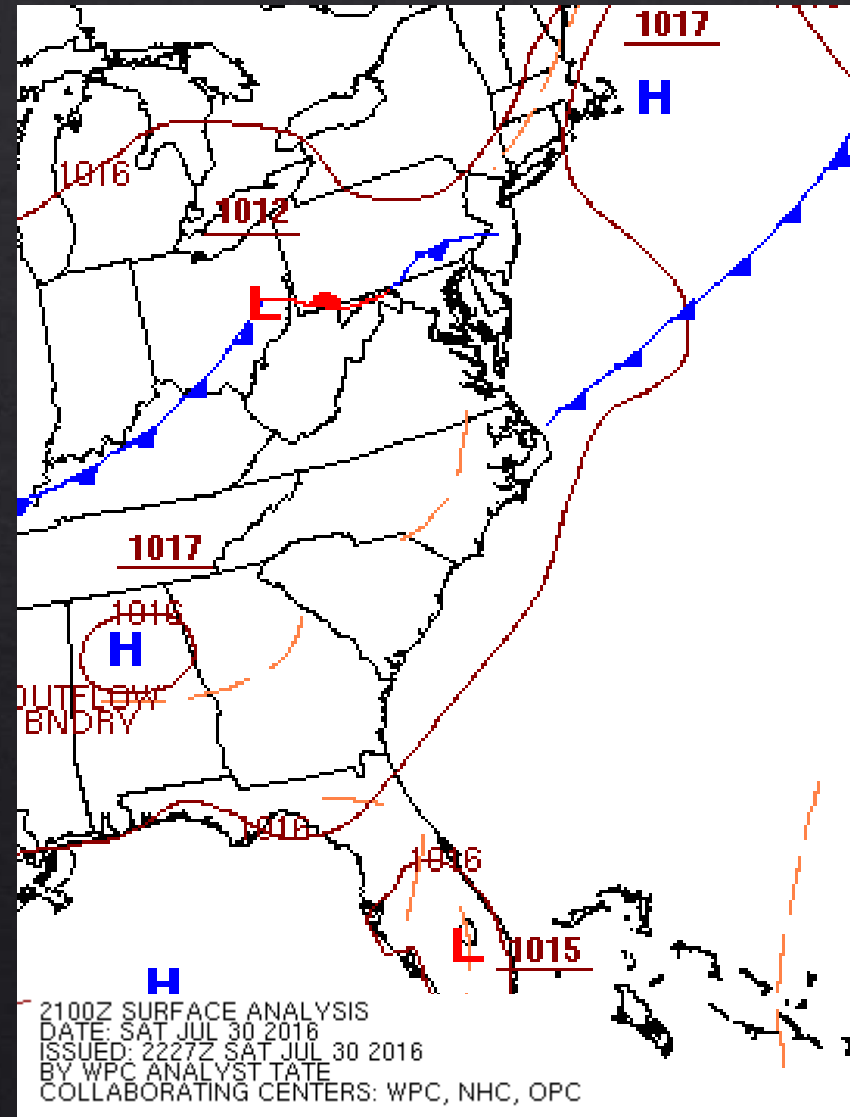
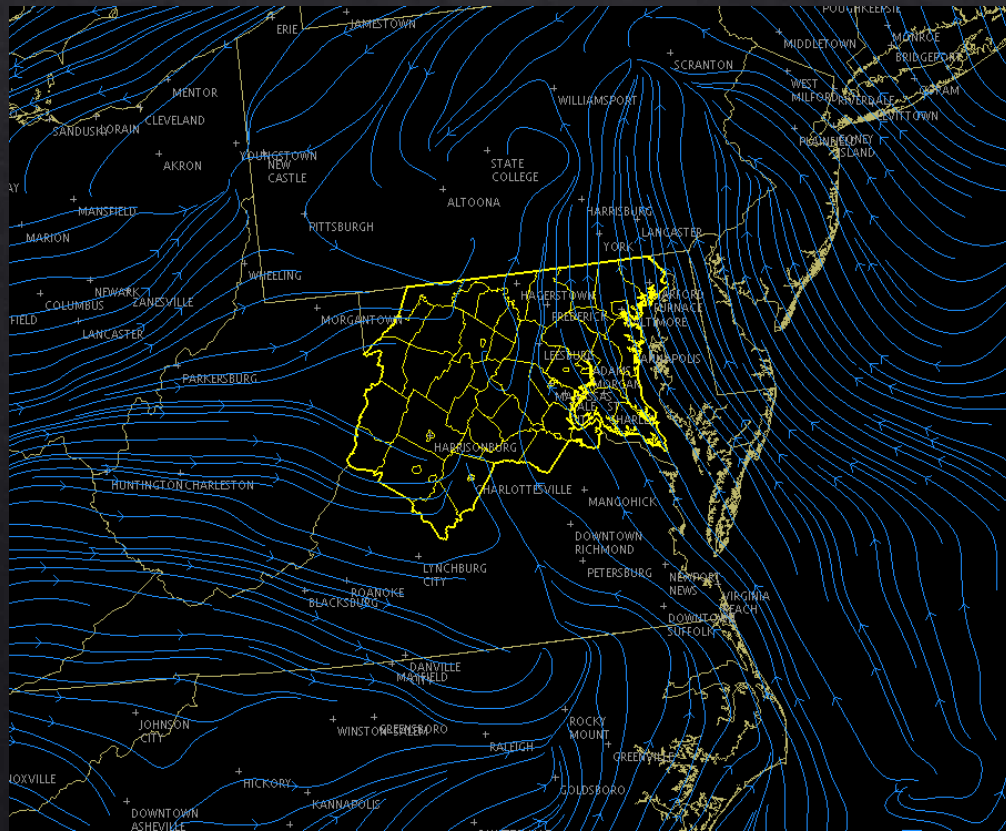
On the evening of July 30, 2016, heavy rain formed into a persistent band affecting a small multi-county area in central Maryland.

KLWX Radar loop from 2125 UTC 30 July to 0102 UTC 31 July

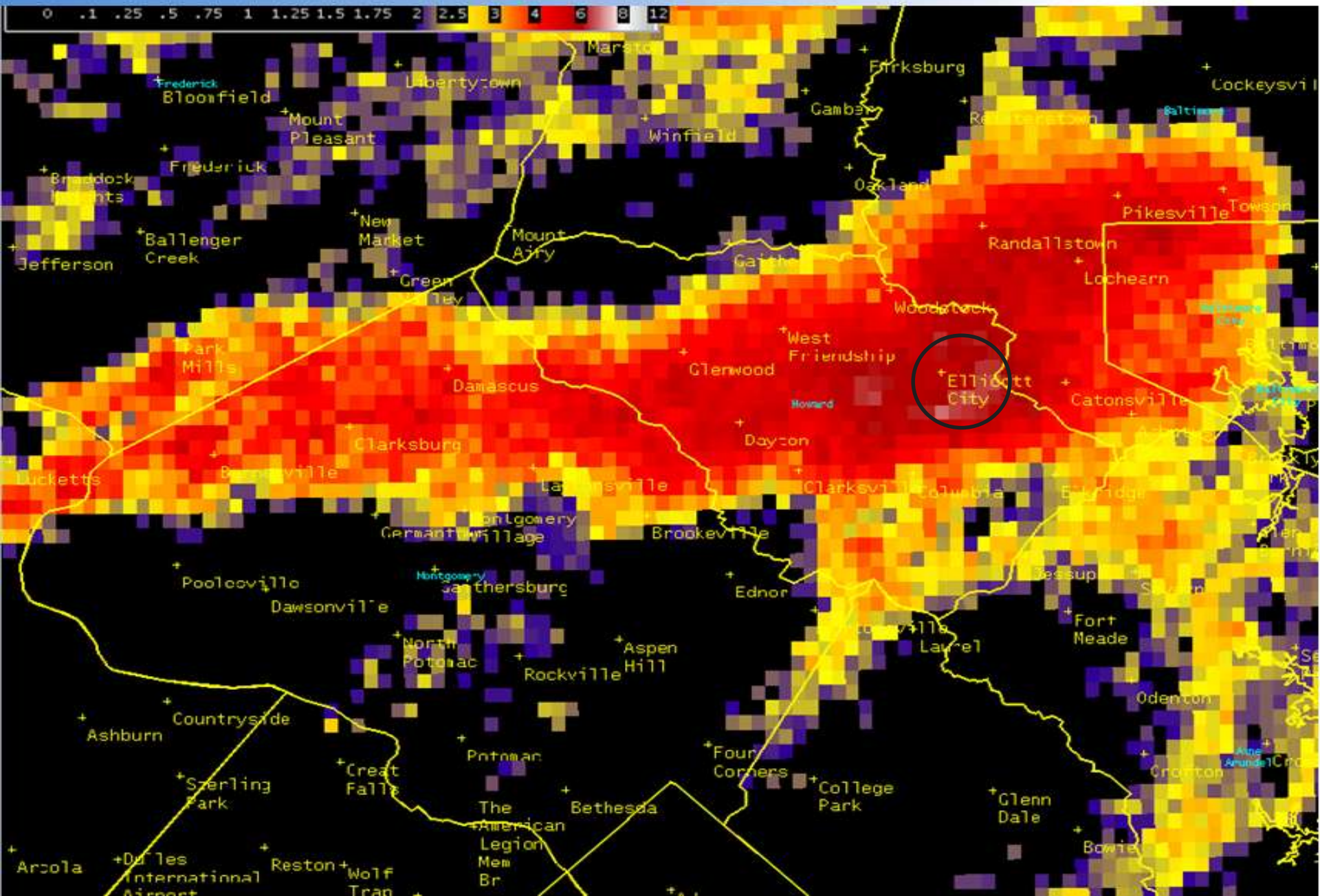


Synoptic Setup

SFC boundary near Mason-Dixon Line
Strong low-level inflow off Atlantic



Precipitation Estimates – July 30, 2016

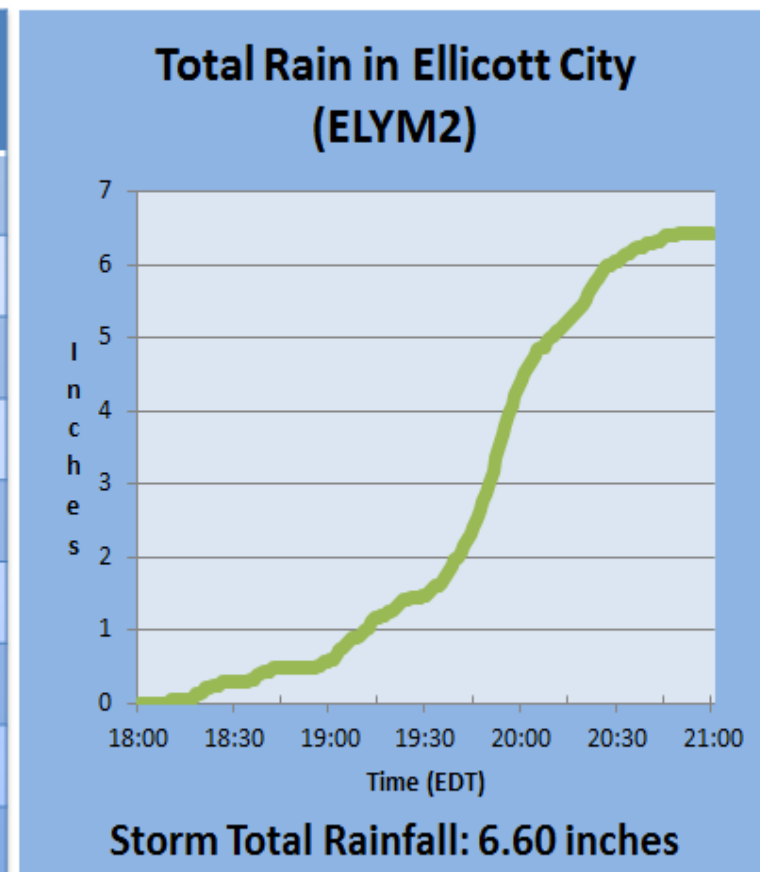


Extreme Precipitation

Historic Rainfall in Ellicott City, Maryland – July 30, 2016

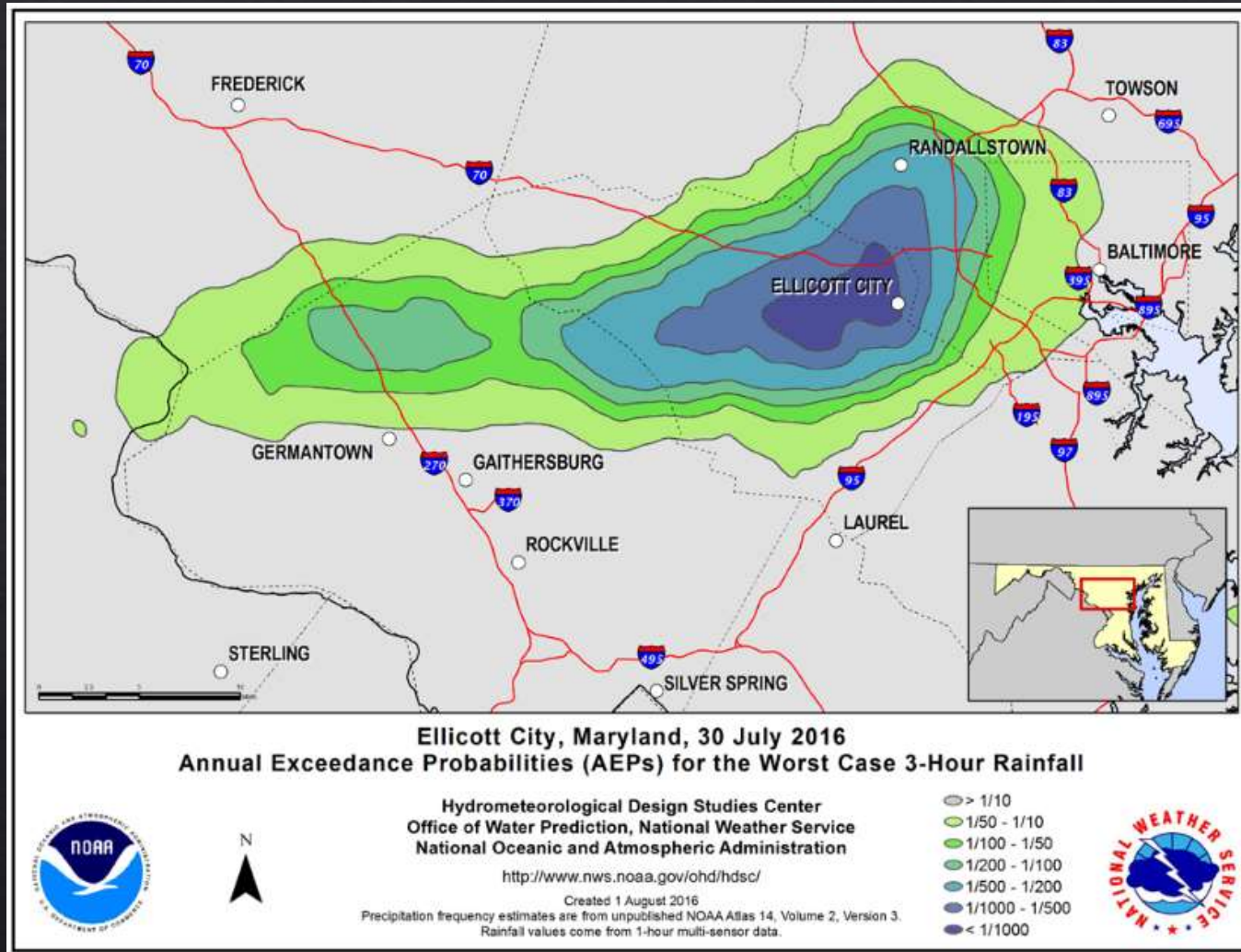


Duration	Max Rainfall in Duration	Time of Occurrence
1 minute	0.20"	7:52pm-7:53pm
5 minutes	0.80"	7:50pm-7:55pm
10 minutes	1.44"	7:50pm-8:00pm
15 minutes	2.04"	7:46pm-8:01pm
20 minutes	2.44"	7:44pm-8:04pm
30 minutes	3.20"	7:36pm-8:06pm
60 minutes	4.56"	7:30pm-8:30pm
90 minutes	5.48"	7:00pm-8:30pm
2 hours	5.96"	6:50pm-8:50pm



*Information obtained from the Ellicott City (ELYM2) rain gauge.
This gauge reports in 0.04" increments.*

Precipitation Annual Exceedance



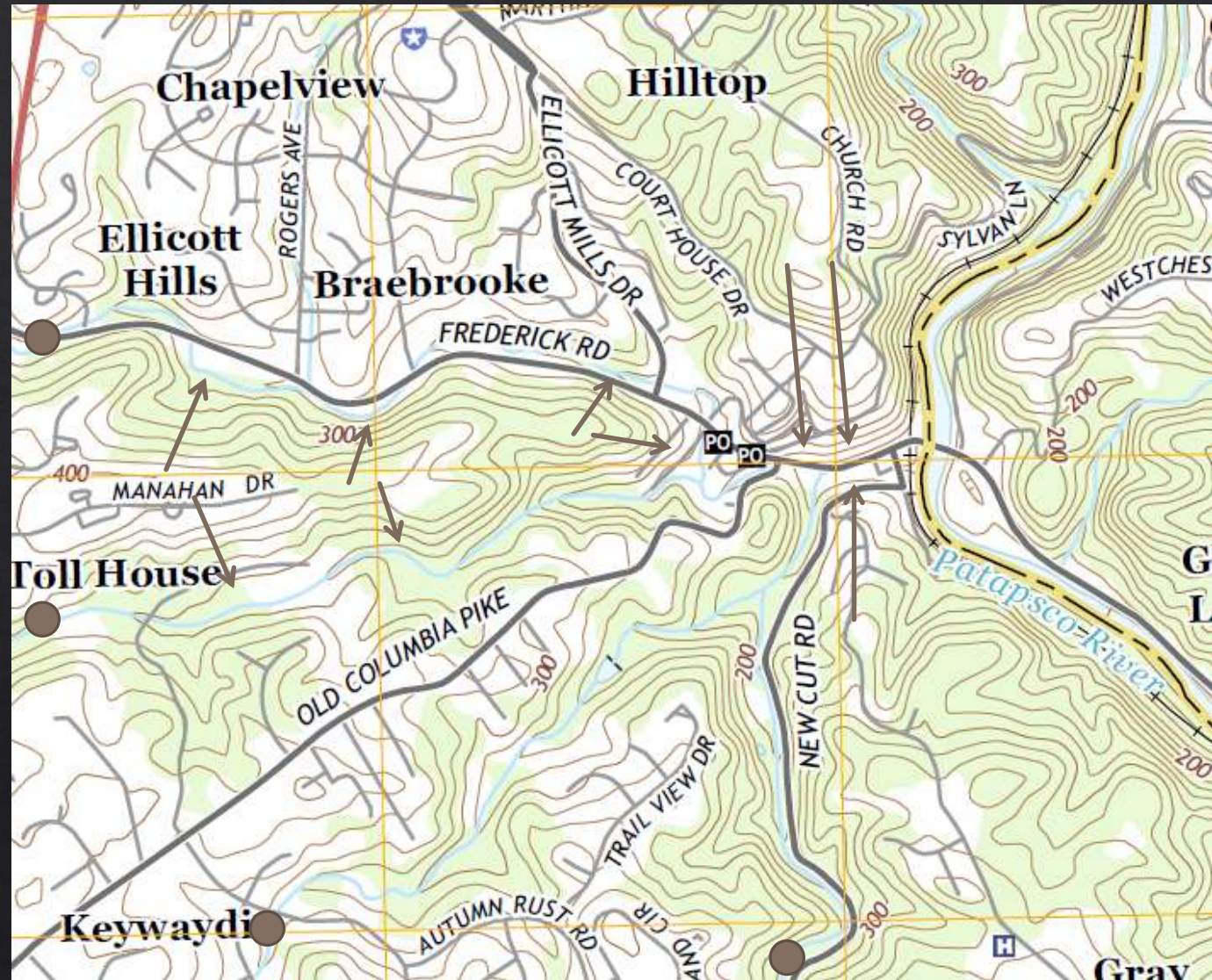
http://www.nws.noaa.gov/ohd/hdsc/aep_storm_analysis/

National Weather Service Baltimore/Washington

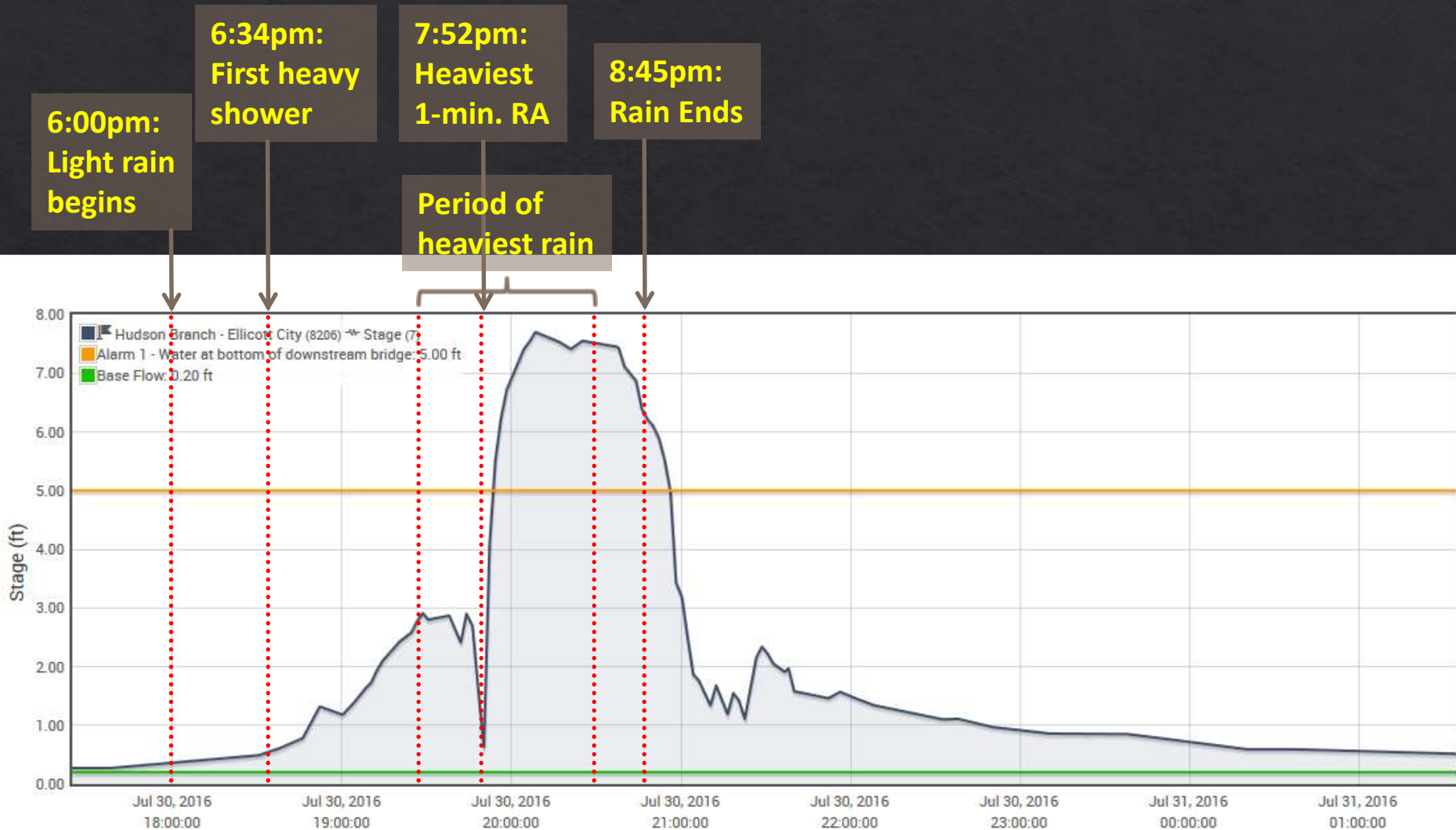


Geography – Terrain & Streams

In addition to the four streams, local runoff can also occur off relatively steep terrain throughout the watershed. (Much of which is solid rock)



Hudson Branch Hydrograph



Hudson Branch Hydrograph

USGS computations:

Bridge opening at gauge location can pass 525 cfs

Estimated flow on 30 July 2016 = 2750 cfs \pm 20%



**Patapsco River
at Hollofield:
22800 cfs
(peak at 9:37pm)**

**Hudson Branch
2750 cfs (est.)
(peak 8:04-8:37pm)**

**Patapsco River
at Ellicott City:
elevation 128.05
(peak at 8:57pm)**

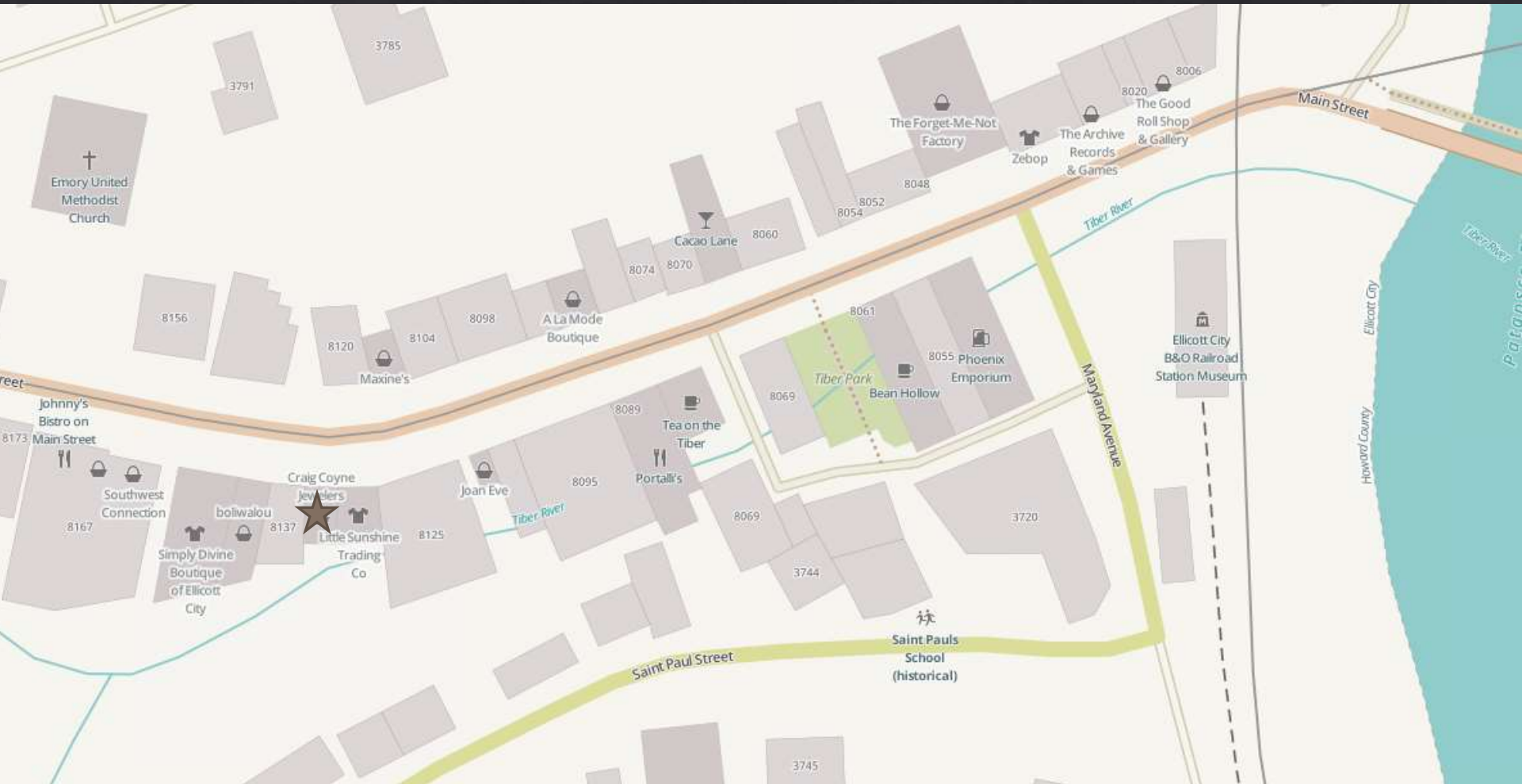
**Catrock Branch (Tiber)
2100 cfs (est.)**

**New Cut Branch
3320 cfs (est.)**

**Patapsco River at
Catonsville:
25500 cfs
(peak at 9:15pm)**

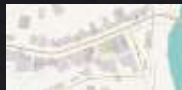


Tiber River



Ellicott City Flood – July 30, 2016

- ◆ Security camera footage (used with permission)
Craig Coyne Jewelers, Ellicott City

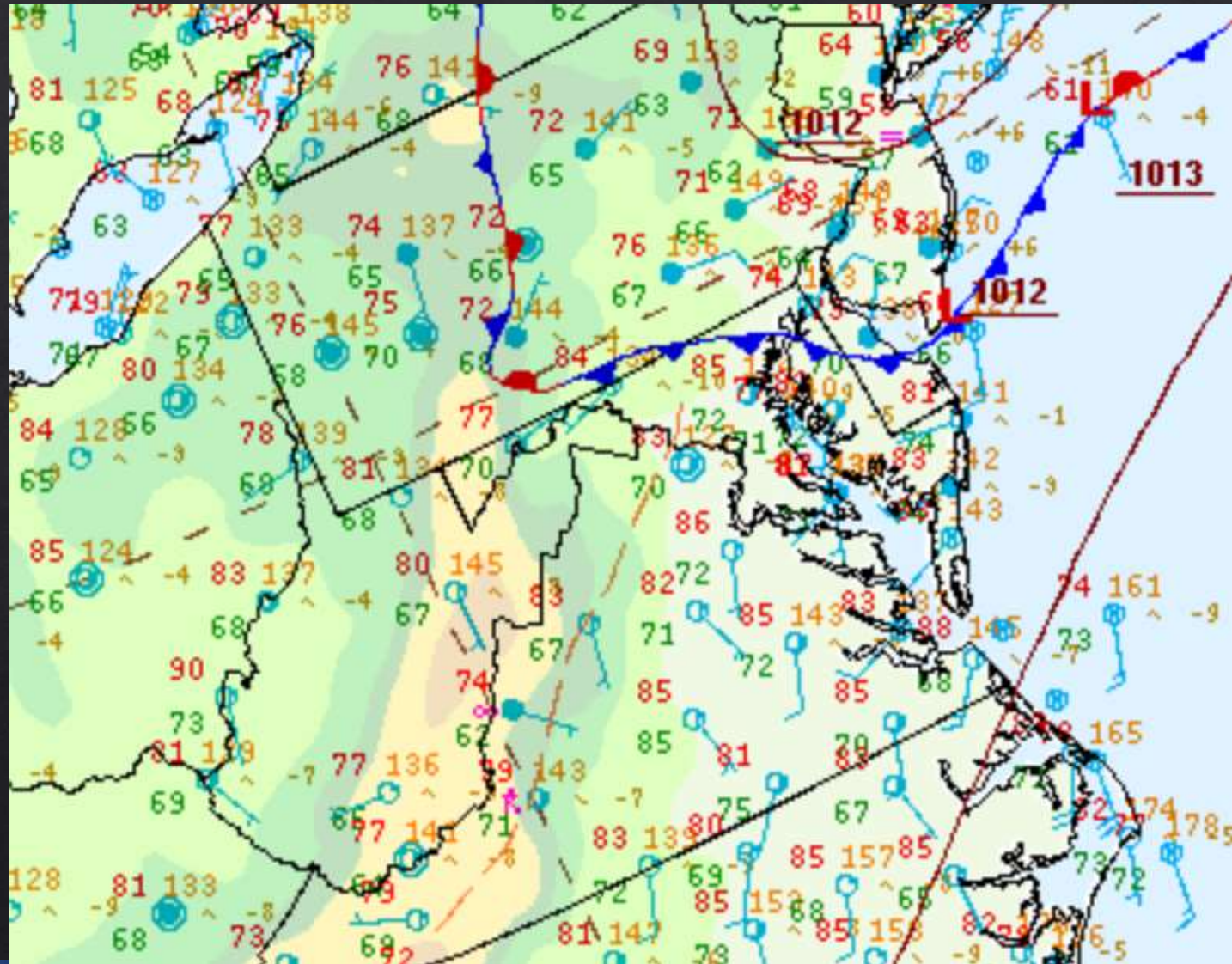


And then it happened again!

North of Front:

Temps 58-76

Dewpoints 57-67



South of Front:

Temps 80-86

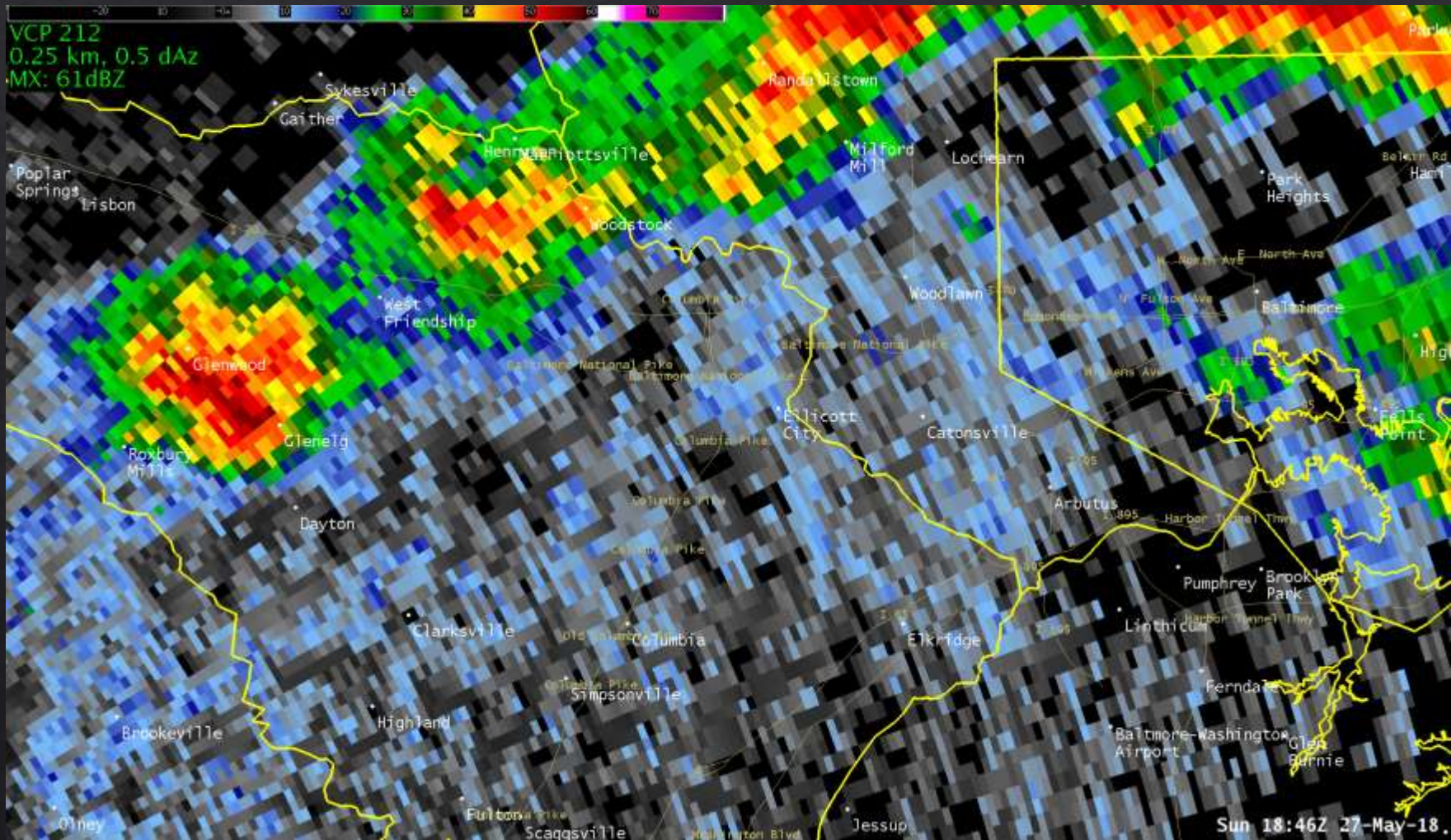
Dewpoints 70+



National Weather Service Baltimore/Washington

May 27, 2018 Radar

◇ 2:46pm – 7:59pm



Sun 18:46Z 27-May-18



National Weather Service Baltimore/Washington

Flood Time Lapse



National Weather Service Baltimore/Washington

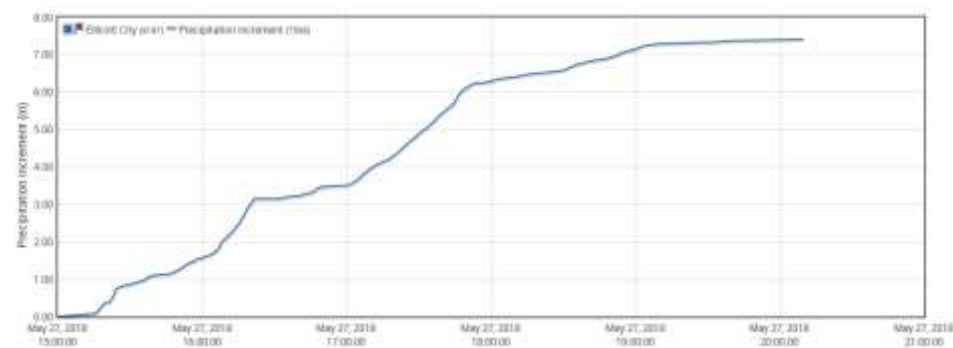
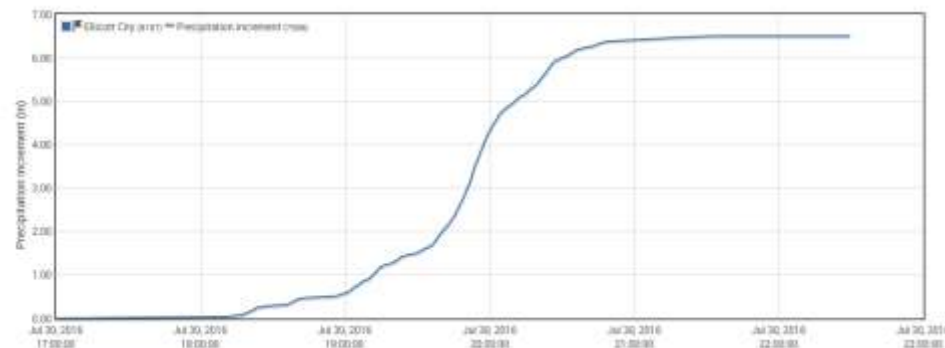
What made this one different?

2016

Duration	Max Rainfall in Duration	Time of Occurrence
1 minute	0.20"	7:52pm-7:53pm
5 minutes	0.80"	7:50pm-7:55pm
10 minutes	1.44"	7:50pm-8:00pm
15 minutes	2.04"	7:46pm-8:01pm
20 minutes	2.44"	7:44pm-8:04pm
30 minutes	3.20"	7:36pm-8:06pm
60 minutes	4.56"	7:30pm-8:30pm
90 minutes	5.48"	7:00pm-8:30pm
2 hours	5.96"	6:50pm-8:50pm

2018

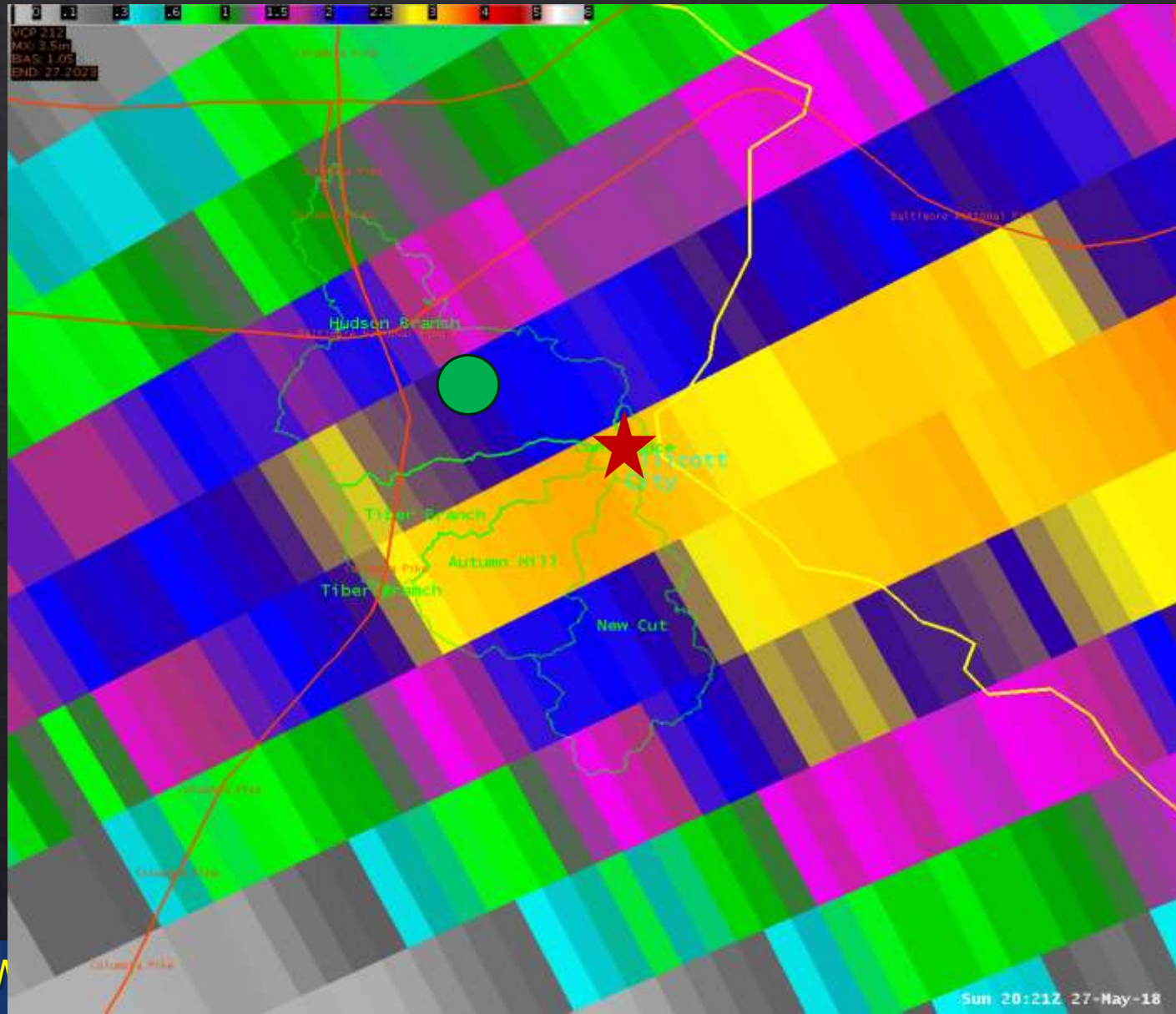
Duration	Max Rainfall in Duration	Time of Occurrence
1 minute	0.16"	4:15pm-4:16pm
5 minutes	0.56"	4:15pm-4:20pm
10 minutes	0.96"	4:11pm-4:21pm
15 minutes	1.44"	4:06pm-4:21pm
30 minutes	1.84"	3:53pm-4:22pm
60 minutes	2.68"	3:20pm-4:20pm
2 hours	5.00"	3:53pm-5:53pm
3 hours	6.56"	3:15pm-6:15pm



Estimated Rainfall

One hour
estimated
rainfall
ending at
4:21pm

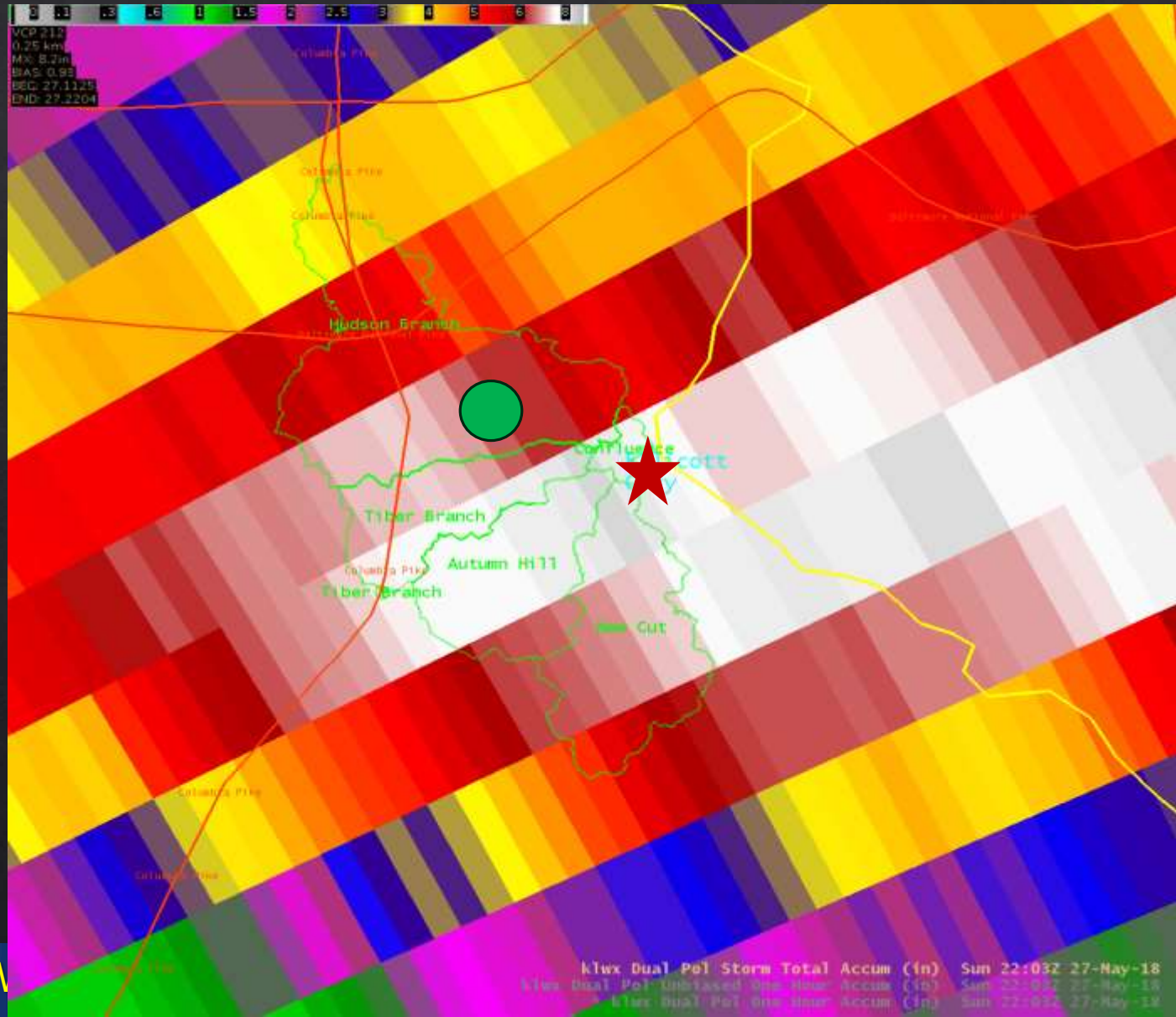
(Most was
between
3:50-4:20)



Estimated Rainfall

Three hour
estimated
rainfall
ending at
6:03pm

In northern
half of
watershed,
rain fell in
two rounds
with a break



So was it a “1000-Year Flood”?

- ◇ Short answer: No!
- ◇ Image from 4:35pm →
- ◇ Rainfall through 4:25pm:
 - ◇ 30 minute rain: 1.1” – 1.7”
 - ◇ 60 minute rain: 2.1” – 3.2”
(amounts from radar estimates & gauges)
- ◇ Rain of this intensity is not uncommon and occurred in every significant flood in the Baltimore/Washington area in 2018!

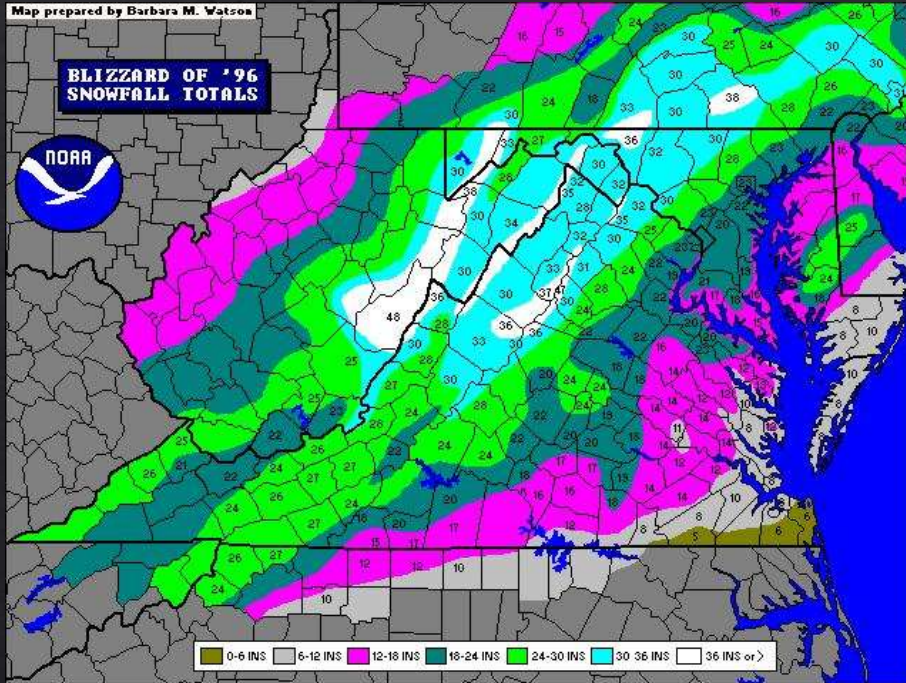


Snowmelt

◇ January 1996 Blizzard

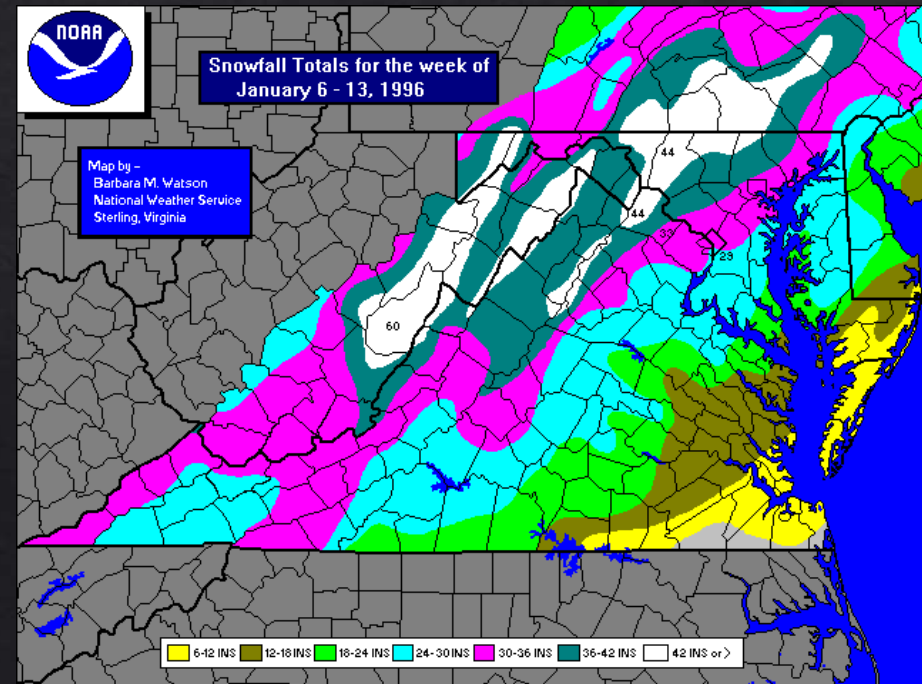


January 6-13, 1996



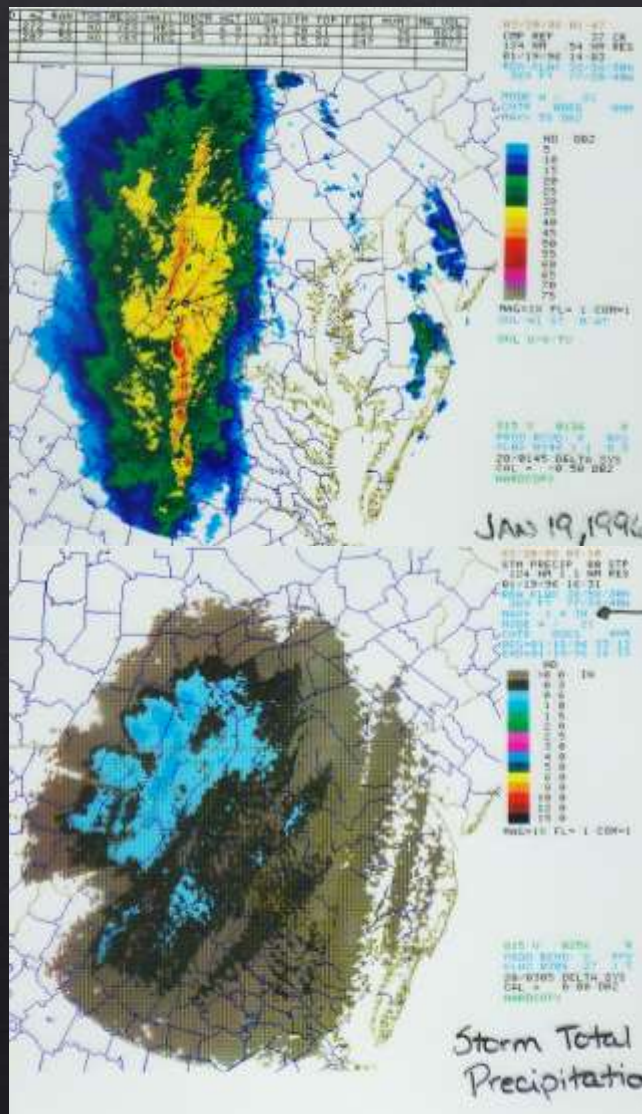
Snowfall from January 6-8, 1996
Blizzard

Additional snow fell January
12th. Snowfall totals for the week
January 6-13, 1996



January 19, 1996

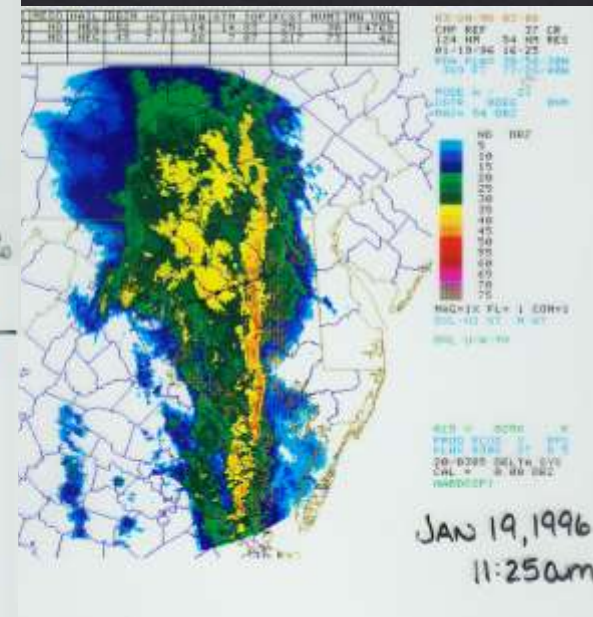
Snowfall at Dulles Int'l Airport (IAD)		
Date	New Snow	Snow on ground (7 am)
6	1.4	0
7	19.8	7
8	3.4	24
9	0.2	24
10	T	21
11	0	18
12	6.1	19
13	0	23
14	0	20
15	0	14
16	0	12
17	0	11
18	0	9
19	0	T
20	0	T
21	T	T



Radar images on Jan 19th...

-9:03 am (left)

-11:25 am (below)



Radar estimated total rainfall – max 1.4 inches



January 1996 event

- ◇ 2 – 3 feet snowfall early
- ◇ Additional snow a week later (less than 1' East & 3' West)
- ◇ Water equivalent of snow pack 2-3" (17th & 18th)
- ◇ Additional 1 – 3" rain, locally up to 5"



Above: Shenandoah Street in Harpers Ferry flooded in January 1996

Left: Flood Markers on Whites Ferry General Store include the January 1996 flood

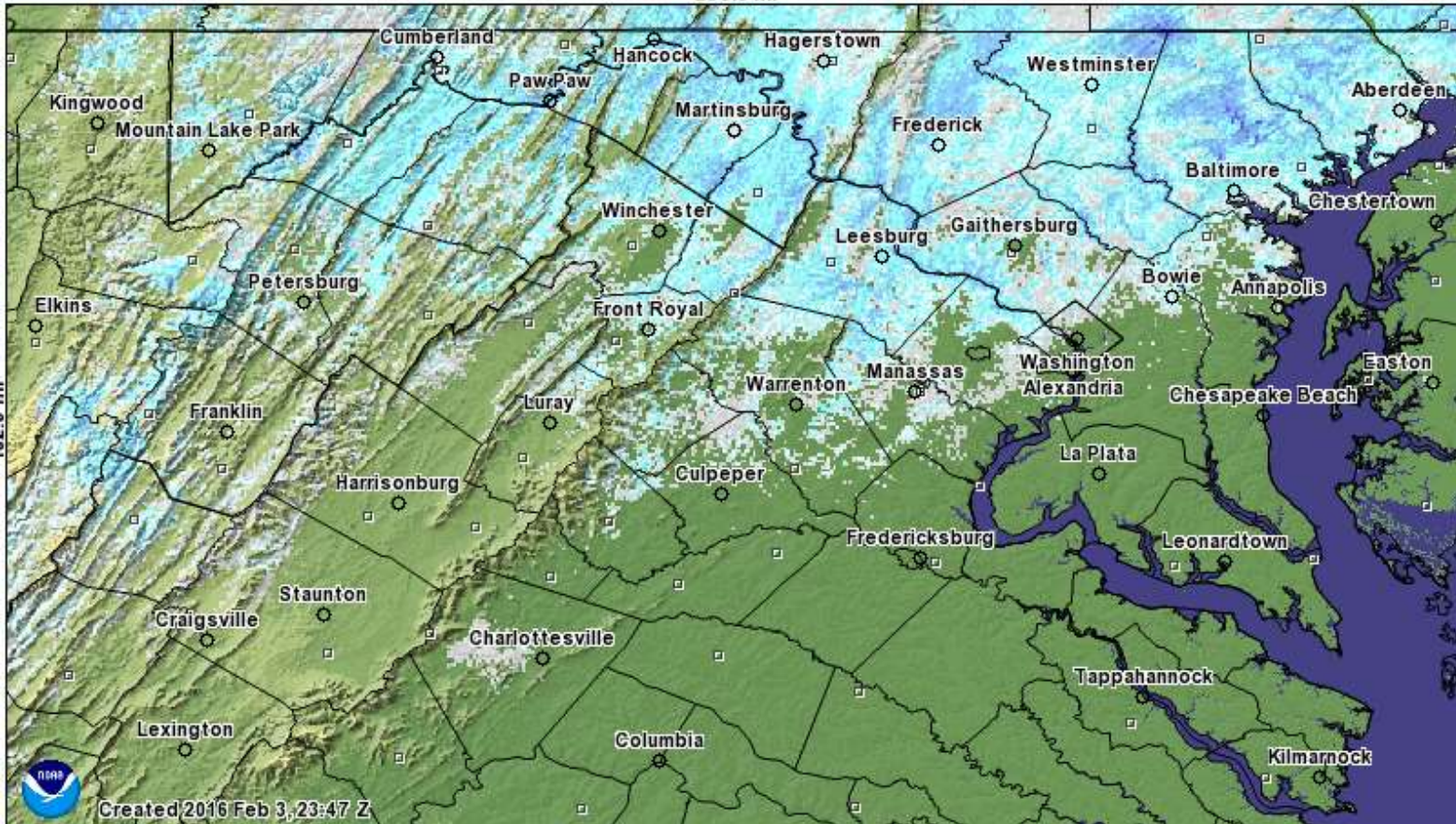


1996 Blizzard vs. 2016 Blizzard

Why no flood this time??

Modeled Snow Depth for 2016 February 3, 12:00 UTC

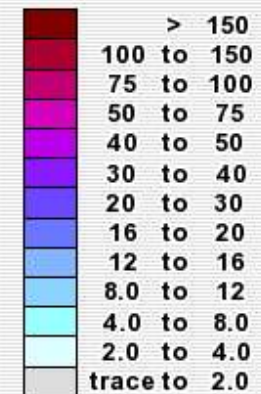
209.8 mi



216.3 mi

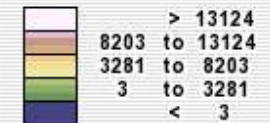


Inches of depth



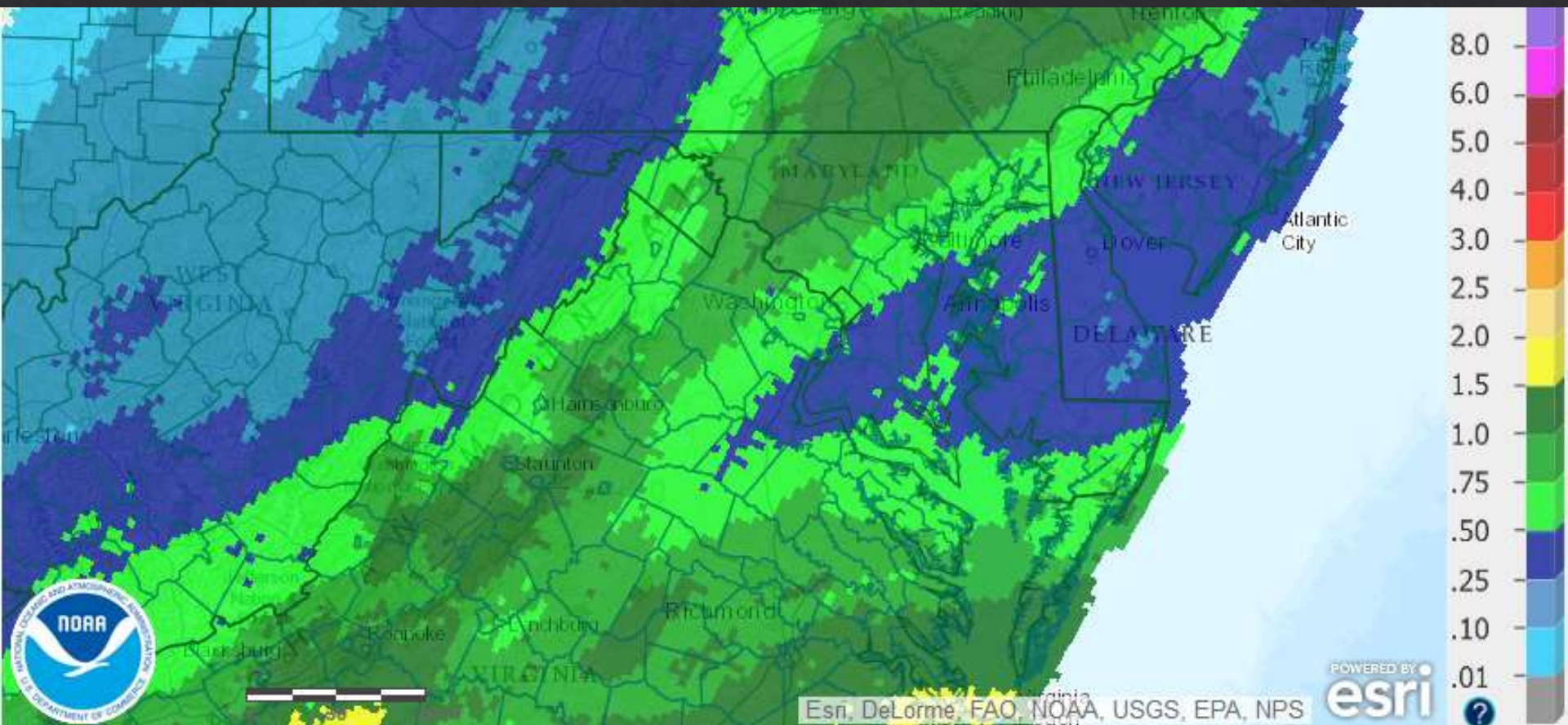
Not Estimated

Elevation in feet



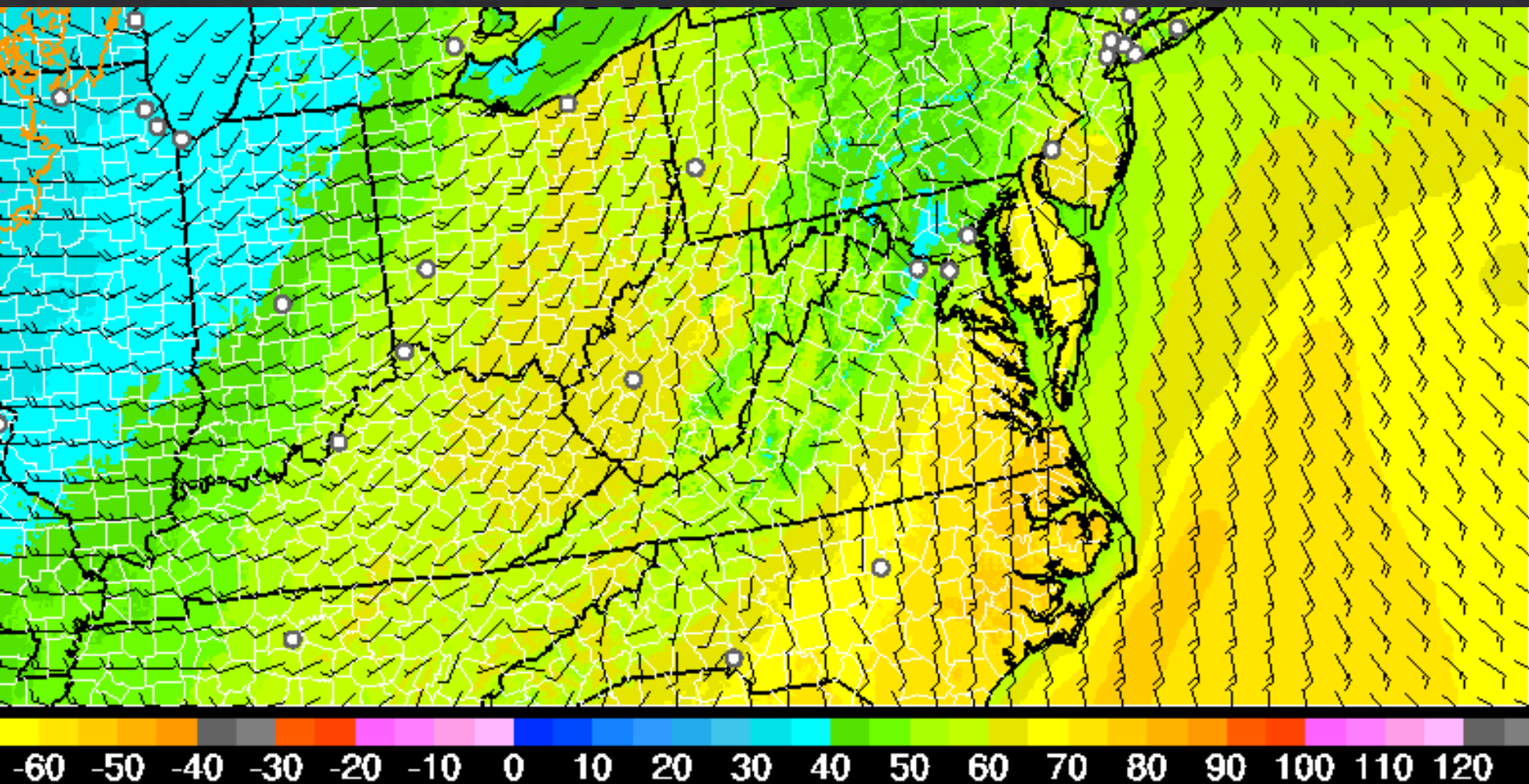
1996 Blizzard vs. 2016 Blizzard

Why no flood this time??



1996 Blizzard vs. 2016 Blizzard

Why no flood this time??

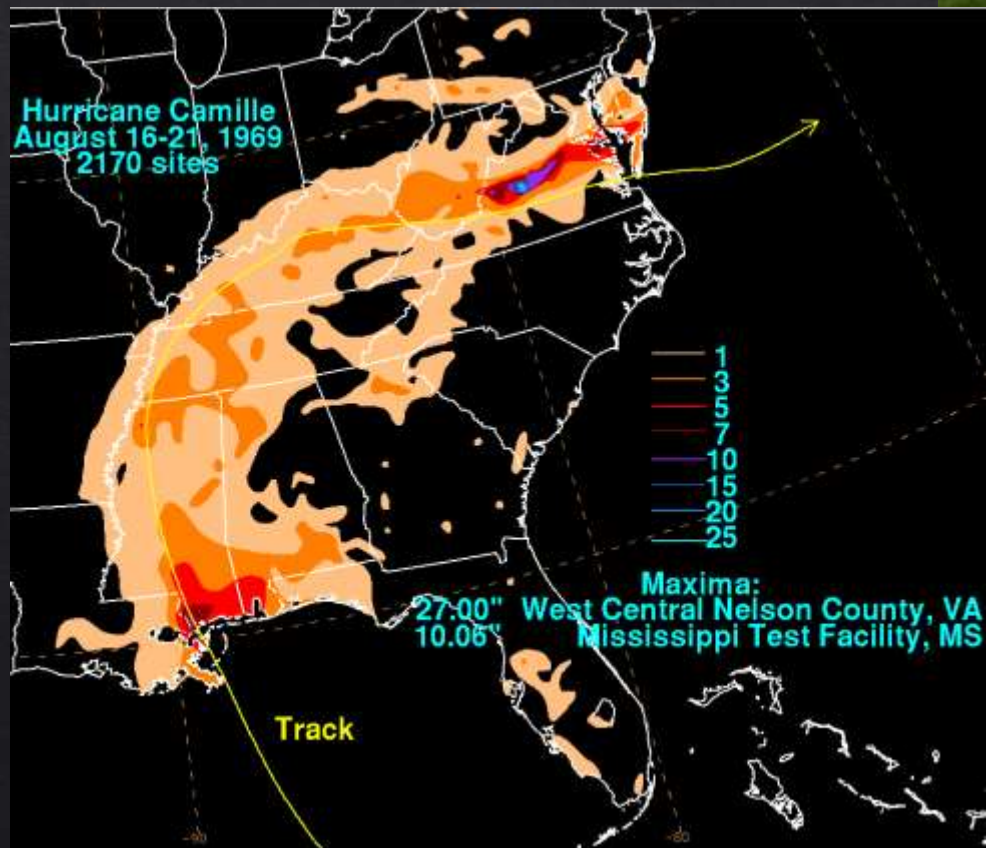


Tropical Storms / Hurricanes

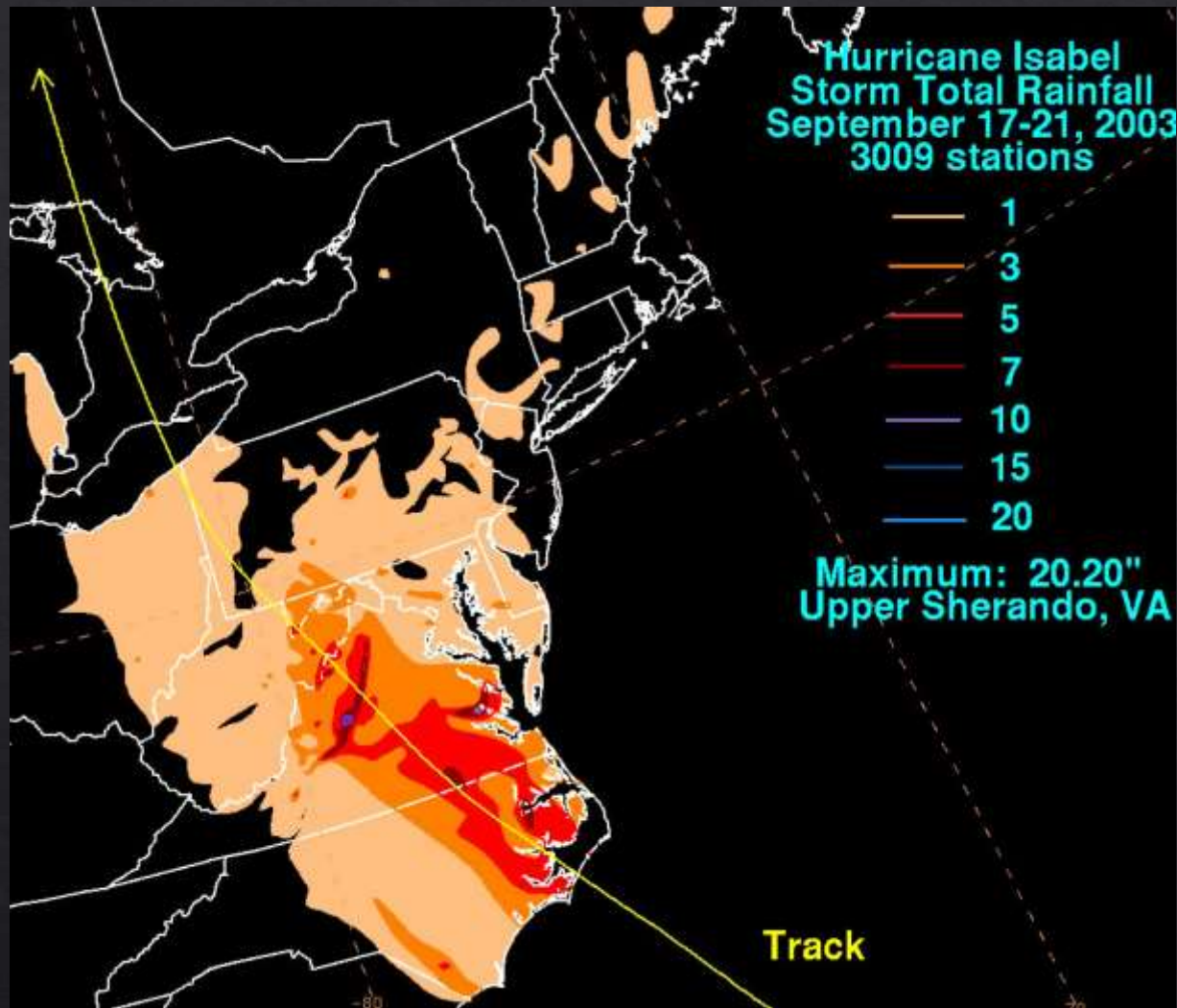
- ◆ **Camille (1969)**
- ◆ **Isabel (2003)**
- ◆ **2011 Tropical Systems**
 - ◆ **Irene & Lee**



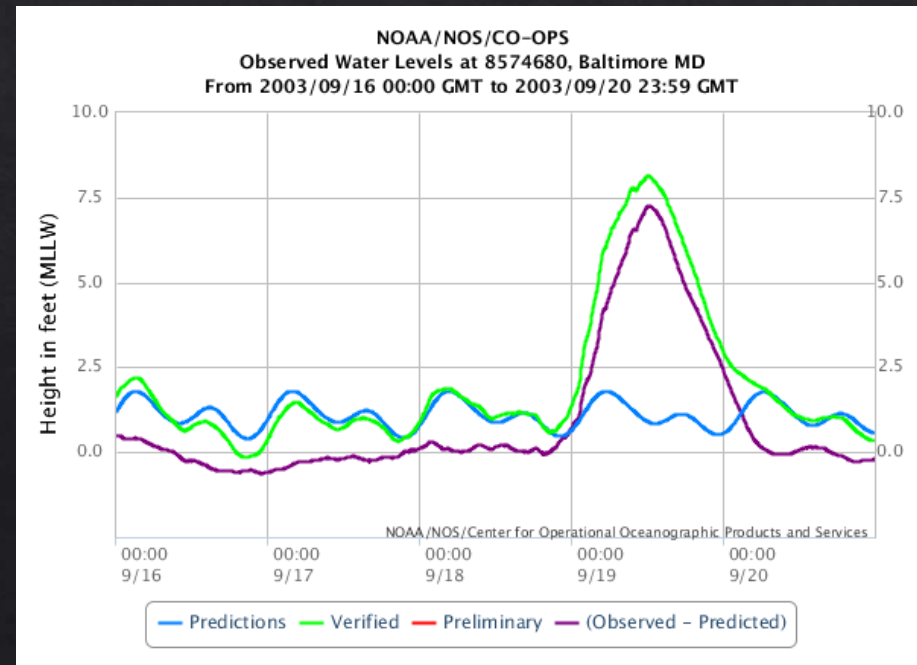
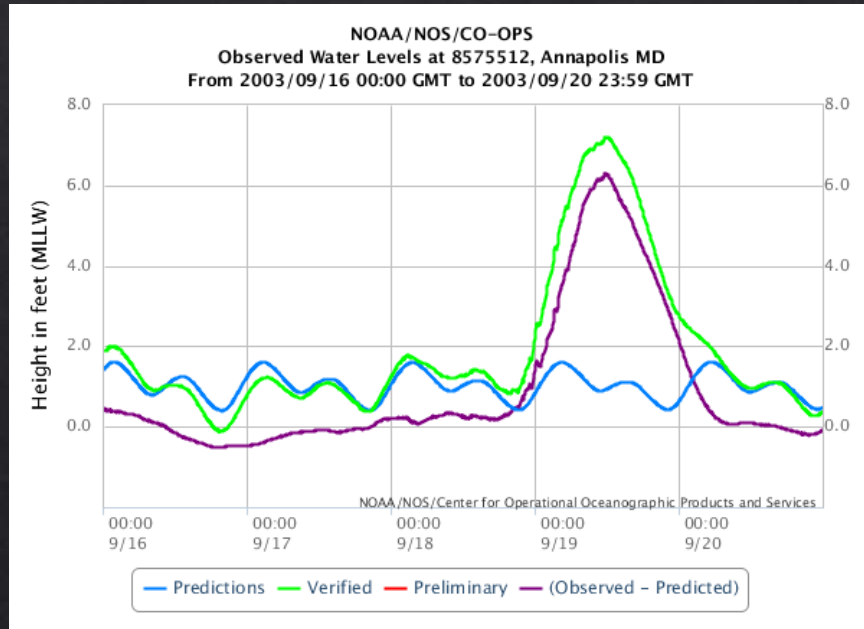
Camille (1969)



Isabel (2003)

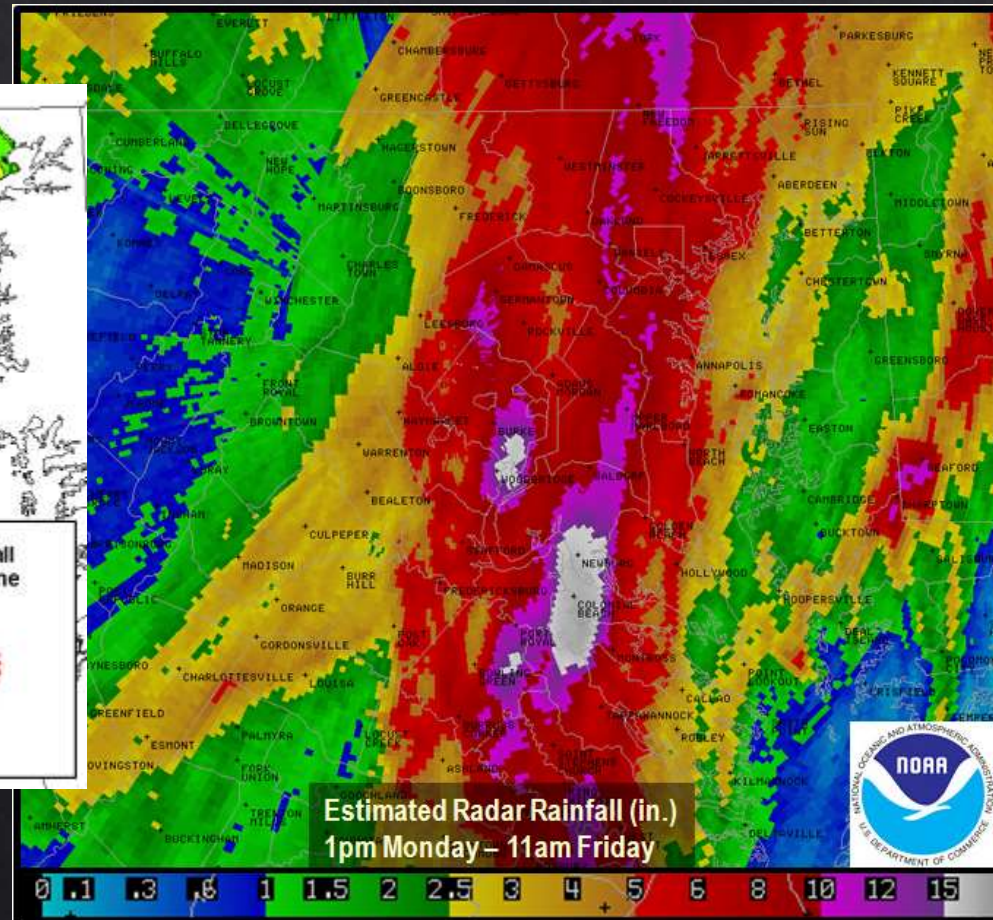
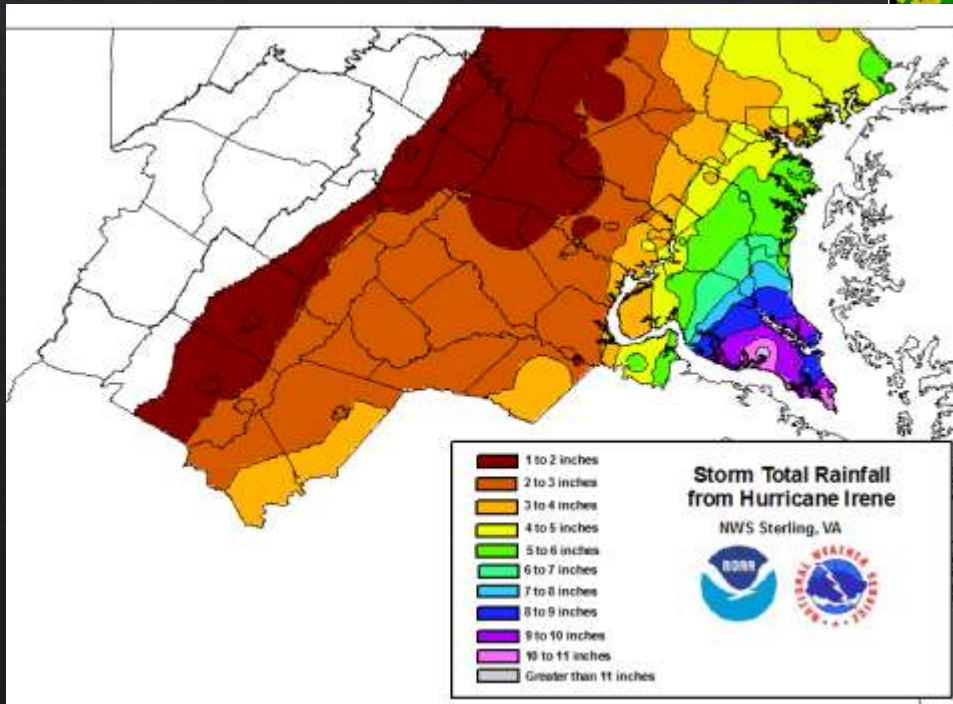


Isabel (2003) – Record Tides



2011 Tropical Systems

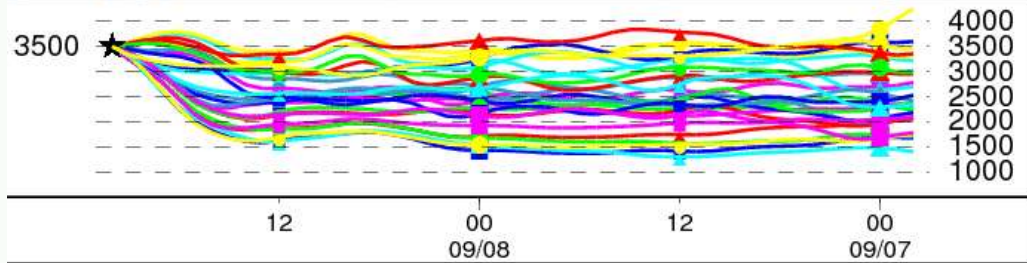
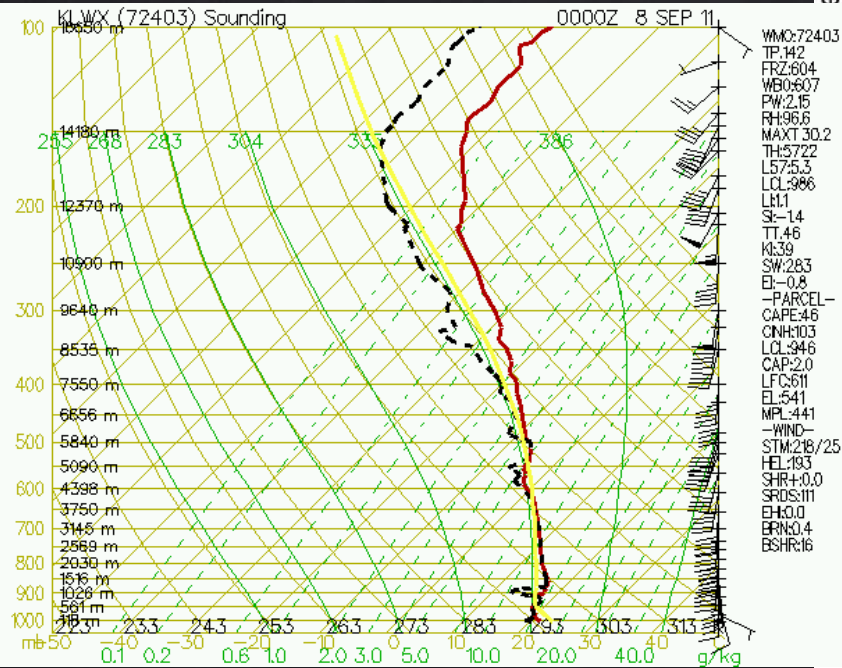
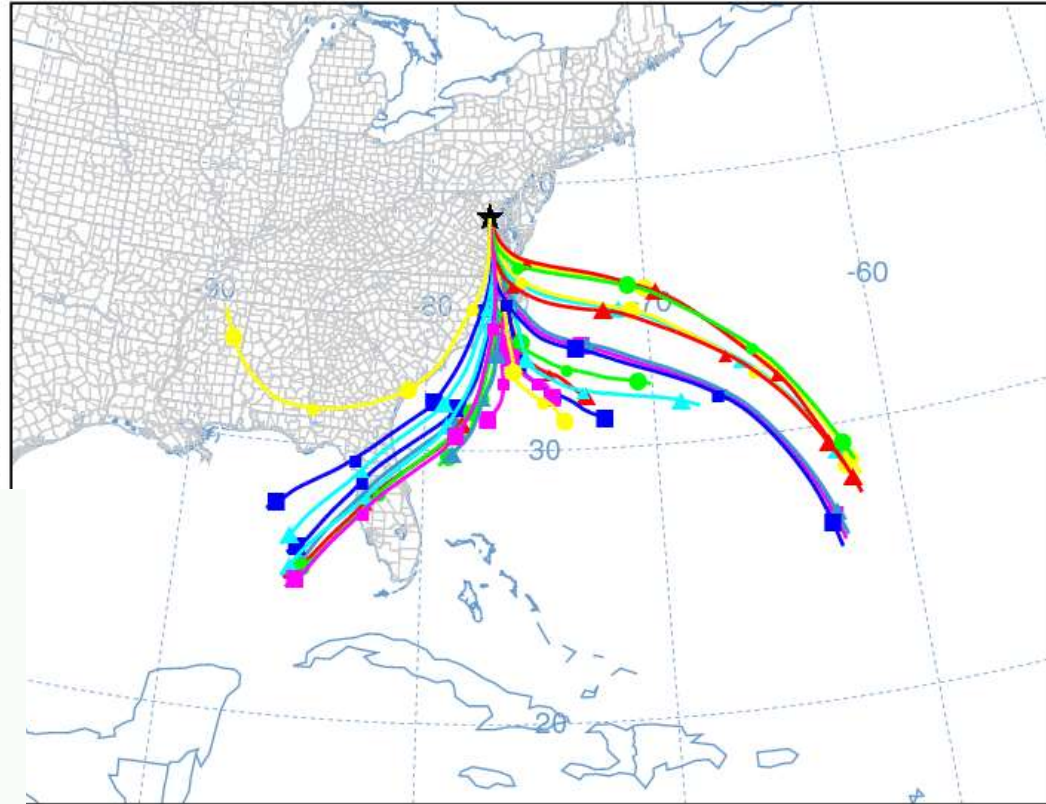
◊ Below: Irene
Right: Lee



Th

◇ Combination of airmasses from the Tropical Atlantic and Gulf of Mexico

★ at 38.72 N 77.18 W



This is not a NOAA product. It was produced by a web user.
 Job ID: 351135 Job Start: Tue Sep 11 14:41:29 UTC 2012
 Source 1 lat.: 38.72 lon.: -77.18 height: 3500 m AGL
 Trajectory Direction: Backward Duration: 48 hrs
 Vertical Motion Calculation Method: Model Vertical Velocity
 Meteorology: 0000Z 08 Sep 2011 - GDAS1



“Lee” Rainfall Totals

◇ Fort Belvoir, VA	13.52”
◇ Newington, VA	13.48”
◇ Franconia, VA	12.56”
◇ Reston, VA	11.97”
◇ Waldorf, MD	11.66”
◇ Ellicott City, MD	11.36”
◇ Crofton, MD	10.21”
◇ Quantico, VA	9.39”
◇ Andrews AFB, MD	9.20”
◇ Oakton, VA	7.21”



September 2011 flooding – Fairfax Co.

◆ Giles Run at Lorton Road



◆ Reston Park & Ride →



September 2011 flooding – Ellicott City



The Last Word

- ◇ At least one major flash flood happens here almost every year:
 - 2018 – Ellicott City, MD (again); Frederick, MD; Charlottesville, VA; Greene & Madison Counties, VA; Harford County, MD; Fulks Run, VA; Berkeley Springs, WV (again); and more!!!
 - 2017 – we got lucky!*
 - 2016 – Ellicott City, MD
 - 2015 – Woodstock, VA
 - 2014 – Clear Spring, MD & BWI Airport
 - 2013 – Laurel, MD
 - 2012 – Berkeley Springs, WV
 - 2011 – (widespread flooding from Lee)
- ◇ **But...**
 - ◇ Last Major Tidal Flood: 2003
 - ◇ Last Major Potomac Freshwater: 1996
- ◇ The Potomac floods, on average, every 6-7 years.
We are overdue!!



Review

◇ Stay informed via the NWS website.

weather.gov/washington

or

weather.gov/baltimore

Or use...

mobile.weather.gov

for cell phone display

The screenshot shows the National Weather Service website for the Baltimore/Washington office. The page features a navigation bar with links for HOME, FORECAST, PAST WEATHER, SAFETY, INFORMATION, EDUCATION, NEWS, SEARCH, and ABOUT. Below the navigation bar, there is a section for "Local Forecast by City, ST or ZIP code" with a search box and a "Go" button. To the right, there are "News Headlines" with links to "NOW AVAILABLE - Experimental Days 6.7 Winter Storm Threat outlook" and "Upcoming SKYWARN Class Schedule - Basic, Flood, Convective, and Tropical Classes all scheduled!". The main heading is "NWS Forecast Office Baltimore/Washington" with the location "Sterling, VA" and "Weather Forecast Office". Below this, there are links for "Current Hazards", "Current Conditions", "Radar", "Forecasts", "Rivers and Lakes", "Climate and Past Weather", and "Local Programs". A map is displayed with the instruction "Click on the map below to zoom in." and a "Last Map Update: Wed, Mar 9, 2011 at 12:13:15 pm EST". To the right of the map, there are links for "Watch, Warning & Advisory", "Special Weather Statement", and "Hazardous Weather Outlook". At the bottom, there are icons for "Radar", "Current Weather", "Rivers & Lakes", "Satellite", "Weather Information Outlook", and "Forecast Maps". Red arrows point to the "News Headlines", "Rivers and Lakes" link, and the "Rivers & Lakes" icon.



Watch & Warning Review

- ◇ **Hazardous Weather Outlook**
 - Detail on flooding potential through day seven.
- ◇ **Flood Watch**
 - Conditions are favorable for flooding. Check the product for threat details (river/flash/areal)
- ◇ **Flood Warning**
 - Flooding is imminent or nearly certain to occur. Take action now!!!



Review

- ◇ Remember...FLOODING KILLS!
- ◇ When a warning has been issued for your area, or you observe signs of imminent flooding, YOU must make the decision to leave flood prone areas and seek higher ground.
- ◇ If you are driving and come to a flooded roadway, STOP! TURN AROUND AND GO ANOTHER WAY.
(Yes...even if you are a spotter!)



Review – What to Report

- ❖ **Heavy Rain** – measured 1” or more (we like getting periodic reports & a storm total at end)
- ❖ **Flooding & Flash Flooding** – Streams, creeks or rivers out of banks or flooding of roads from poor drainage



Terminology:

- * Water over banks but not affecting anything – “bankfull/just over bankfull”
- * Water affecting farmland, roads, property out of floodplain – “flooding”



Review – What to report

- ❖ **Ice Accumulation** – Any glaze on surfaces (or more)
- ❖ **Snow Accumulation** – Every 2” and a storm total, or any accumulation not reflected in the forecast



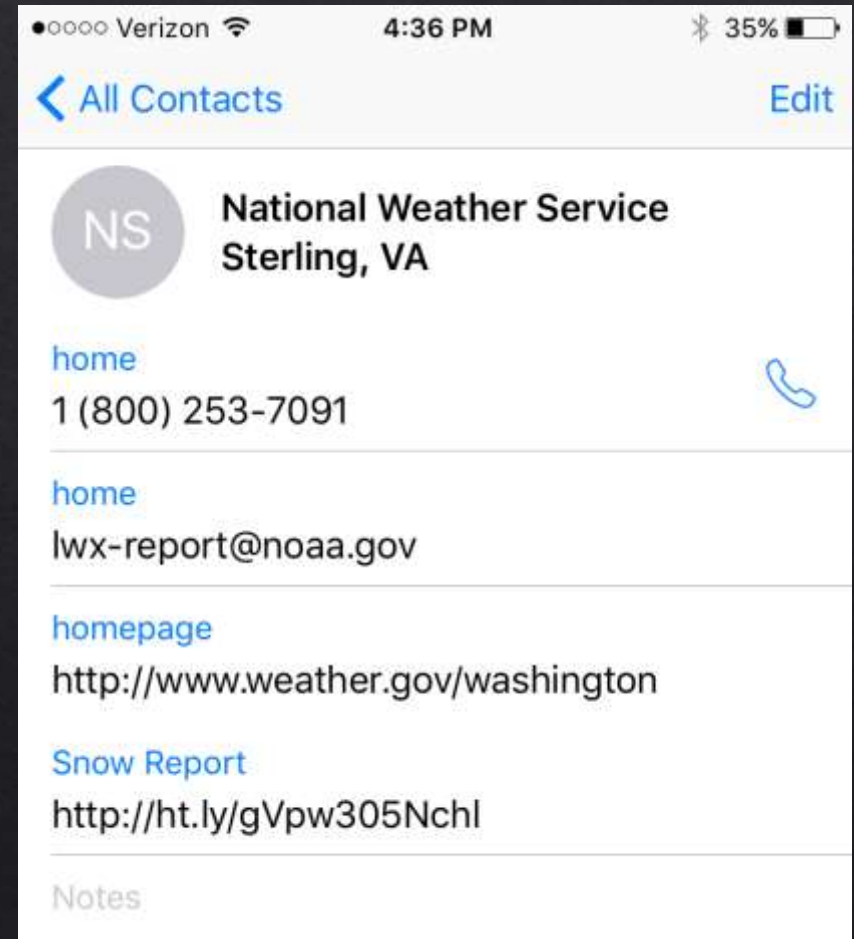
If half the ground has 2.0” and half the ground is bare, report 1.0” as your total depth.



If more than half the ground is bare report “T” (trace) and mention the range of depths in your comments.

Review – How to report

- ◇ Call NWS Sterling as soon as you see something:
(800) 253-7091
- ◇ You can email delayed reports or pictures to:
LWX-Report@noaa.gov
- ◇ Contact local Emergency Management
- ◇ Amateur Radio (when activated)
- ◇ If you see storm damage after the event, let us know! *Immediate reports are best; but no report is too late!*



Questions?

◆ **Jason Elliott**
Senior Service Hydrologist
NWS Sterling, VA

◆ jason.elliott@noaa.gov

