Flash flood July 30 in Ellicott City, MD a One-in-1,000-Yr. Event

"The massive rainfall that caused a devastating flash flood in Ellicott City, Md., was a rare 1-in-1,000-year event that has been happening with unprecedented frequency in recent years, meteorologists said.

The storm, which killed two people, dumped 6.5 inches of rain on Ellicott City in only about 3 hours, with 5.5 inches falling in just 90 minutes, the National Weather Service said. One nearby spot recorded 8.22 inches, amounts that weather service meteorologist Greg Carbin called 'off the charts...'

A 1-in-1,000-year rainfall event is a statistical way of expressing the probability of such a massive rainfall occurring in any given year in a given location, according to the National Center for Environmental Information, which is part of the National Oceanic and Atmospheric Administration. In other words, this flood had a 1 in 1,000 chance of occurring in Ellicott City in any year."

The storm, which killed two people, dumped 6.5 inches of rain on Ellicott City in only about 3 hours, with 5.5 inches falling in just 90 minutes, the NWS said. Ellicott City picked up almost twice its monthly average rainfall of 3.50 inches Saturday night.

This is at least the ninth "1-in-1,000" year rain event across the U.S. since 2010, and the third this year. Flooding in Houston in April killed eight people and then in June, 23 died in West Virginia flood caused by heavy rain. So many "1-in-1,000 year" rainfalls appear unprecedented. "The number of these types of events has seemingly become more pronounced in recent years," meteorologist Steve Bowen of a global reinsurance firm Aon Benfield said in a tweet Monday. The world record for a one-minute rainfall happened in Maryland 60 years ago, according to the World Meteorological Organization. On July 4, 1956, 1.23 inches of rain fell in Unionville, Md., in the state's Eastern Shore region.

The meteorological cause of Ellicott City's epic flood was complex, a mixture of high humidity, unstable air, southerly wind flow, a nearby warm front and other factors as noted by *The Washington Post*'s Capital Weather Gang.

The small town's main street turned into a raging river, carrying away cars and other debris and forcing dramatic rescues of people trapped in the flood. The two victims were found early Sunday. The flood also tore away portions of the street and many storefronts, leaving the quaint shopping district in a shambles.

It's a highly vulnerable spot, an urbanized strip along the bottom of a deep valley through which the Patapsco River flows. Historic Ellicott City, Md., has seen plenty of serious floods: 1868, 1923, and 1952. More recently, the remnants of Hurricane Agnes (1972) left an extreme high-water mark, measured in many feet. The Great Mid-Atlantic Flood of June 2006, once again drowned parts of the town.

July 30th what the NWS is calling an "Once in one thousand year rainfall event (in terms of recurrence interval) created a harrowing drama involving 120 swift-water rescues, dozens of ruined cars, demolished businesses and two fatalities.

The air mass had destabilized, humidity was approaching historically high levels, and air currents were beginning to converge across MD — in a manner that would literally squeeze moisture out of the atmosphere. The best any meteorologist could do was portray the threat region in broad strokes. The reason: Summertime flash floods almost always issue forth from highly localized convective storms, dropping vast amounts of water on small locations. Flash flood warning essentially becomes a "nowcasting" exercise: Once those storms have formed, you try to stay ahead of where they will track and how long they will persist. There is almost always never any lead time.

The meteorology behind Saturday night's flood

The highly localized, convective nature of Saturday's flood is underscored in the following image, which depicts radar estimated rainfall in and around Ellicott City.



Doppler estimated rainfall, Howard County, July 30. (RadarScope)

Compare this five-inch estimate of rainfall, with the analysis from the National Weather Service's Greg Carbin, which showed up to 8.2 inches of had fallen in just three hours, from 6 to 9 p.m. As is often the case, the radar will indicate significantly less rain than gauges, due to many factors. These include distance from the radar, width of the radar beam, the time it takes to scan a storm repeatedly, and the theoretical framework describing how scattered microwave energy translates into actual drops on the ground.



The convective system that dumped on Ellicott City left behind a swath of heavy rain extending from Parr's Ridge (Damascus) in upper Montgomery County to the western suburbs of Baltimore.

To get rainfall so extreme, there must be abundant moisture. Indeed this was the case, as the next figure shows. This is a map depicting total precipitable water, which vertically integrates the total mass of water vapor from top of the troposphere to the surface — expressing the result as an equivalent depth of rainwater. Total precipitable water values were in the 2 to 2.2-inch-range across central Maryland, thanks to southerly flow pumping low-level, humid air off the Atlantic.



Weather map depicting conditions favorable for flash flooding July 30. (National Weather Service)

Total precipitable water tells only part of the story. Values this large raise the prospect of flash flooding, but much more water vapor can be made available to a convective storm when the airflow converges.

When air streams converge, humid air is fed into a storm complex from a large, surrounding area. This explains why the rain totals can exceed total precipitable water values by a factor of two to three, or more.

The figure below is an analysis at 5 p.m. that shows how air streams (heavy red, dashed arrows) at the 5,000foot level were converging over Maryland. The air flow converged thanks to an area of low pressure over western Pennsylvania and high pressure off Long Island.



Weather map analysis for flash flood event July 30. (National Weather Service, adapted by Jeff Halverson)

But there's more to this figure that's important.

First, note the thin red lines, which show contours of convective available potential energy (CAPE) — a measure of the buoyant energy feeding convective updrafts. The greater this energy, the more water vapor is lofted into the clouds and processed as rain. A tongue of significant CAPE (1500 J/kg) was feeding northward into central Maryland, in the region of convergent airflow — sustaining vigorous thunderstorms.

Second, I have annotated the position of a warm front on this diagram (red dashed line, oriented along the Mason-Dixon Line). This frontal zone was pushing north across the region during the day. With slightly cooler air to the north of the boundary, the convergent air flow was also rising along this sloped thermal boundary, from south to north. This helped cool the air to saturation. The combination of converging and up-gliding air focused very intense ascent over central Maryland.

Third, you'll note the words "back-building convection" within the flash flood threat region (green, scalloped lines). This refers to the tendency for larger convective clusters to remain stationary (or nearly so) for hours. This happens when individual convective cells form repeatedly over the same locations. Winds carry off the older cells while new cells pop up to replace them. The larger complex of cells stays put, leading to steadily accumulating rain.

My review of the radar loop from the event revealed the back-building process over Ellicott City, for part of the time — as a giant convective cluster congealed and moved very, very slowly toward the east.

Earlier in the evening, before the main back-building complex took shape, Ellicott City was over-swept by three separate convective cells, moving rapidly from the south. The repeated passage of discrete storm cells is called training. Each of these cells dumped a quick a half-inch to one inch of rain, before the main, back-building cluster congealed.

Prospects for better prediction?

Of all the hydrometeorological hazards in the United States, flash floods are the No. 1 killer. When compared to tornadoes, derechos and hailstorms, it does seem somewhat ironic: Humble rain, often gentle, is life-sustaining, nourishing and thus benign 99 percent of the time. But what we take for granted sometimes quickly turns deadly.

To understand flash flooding, you need to examine the behavior of the smallest convective storm cells: Are they training? Are they developing into a larger, nearly-stationary complex? Computer models, even the highest resolution simulations, cannot yet resolve these details. Until they do, unfortunately, most flash flood warnings will only be issued once the heavy rain is already underway.

By 5 p.m., meteorologists at the National Weather Service cautioned that a large area extending from Northern Virginia northeast through Pennsylvania and Connecticut was under the gun for heavy rainfall.

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Ellicott City is a highly vulnerable spot, an urbanized strip along the bottom of a deep valley through which the Patapsco River flows.

This place, historic Ellicott City, Md., has seen plenty of serious floods:

1868

1923

1952

More recently, the remnants of Hurricane Agnes (1972) left an extreme high-water mark, measured in many feet.

The Great Mid-Atlantic Flood of June 2006, once again drowned parts of the town

ELLICOTT CITY, MD. — Kelly Secret realized something was wrong Saturday night when the creaking sound outside her second-floor Main Street apartment grew louder.

Kelly Secret did not know it yet, but she and her boyfriend were trapped.

On one side of their building, a creek had flooded, and on the other, a torrent of raging, brown water was devouring Ellicott City's historic downtown.

"The whole house shook," she said. "We thought we were gone." In two hours, nearly six inches of rain had fallen, an event so extraordinary that the National Weather Service said it should, statistically, occur there just once every 1,000 years.

By Sunday morning, as Gov. Larry Hogan (R) prepared to declare a state of emergency, images and videos of the carnage would spread on social media: bricks torn from sidewalks, streets caved in, cars overturned, foundations obliterated, storefronts gashed, ground floors gutted.



Sources: USGS, Google Earth

LARIS KARKLIS/THE WASHINGTON POST

But before the TV cameras arrived, before officials determined that 200 buildings had sustained damage, before the discovery of two bodies that had been swept downriver into Baltimore County, Secret needed to escape.

She had watched the surge push four cars down Main Street, pinning one against a telephone pole. Secret and her boyfriend ran to the front door but discovered that the steps had disappeared. Beneath them, an eight-foot sinkhole had formed in the ground.

Secret, who is in her 40s, could not believe it. Five years ago, she had lost everything when another Main Street flood ravaged her ground-floor apartment, prompting her to move to a second-story home. But now, here she was again, and this time, Secret did not know whether she would survive.

Helpless, she and her boyfriend retreated to their apartment. Then, suddenly, they heard a cracking noise. Emergency workers armed with axes had climbed onto the roof of a building and kicked in the window of a neighboring antiques store. They then chopped a hole in Secret's wall, allowing her and her boyfriend to climb out.

"I don't think," she said, "I'll ever live on Main Street again."

Baltimore County police identified the two victims as Jessica Watsula, 35, of Lebanon, Pa., and Joseph Anthony Blevins, 38, of Windsor Mill in Baltimore County.

Watsula and her family, tourists to the area, were in their car when the flash flood struck, police said. The other occupants escaped and were rescued before being taken to Howard County General Hospital. Watsula's body was later found 200 yards from the Ilchester Bridge.

Blevins and his girlfriend were also driving through town when the gush of water caught their car. She climbed out and found rescue, but he could not break free from the current. His body was found Sunday morning by a hiker who spotted it on the shore of the Patapsco River near the Howard County line.

Among the 200 damaged buildings, police said, five have been classified as destroyed. About 170 cars must be towed from the streets or pulled from the Patapsco.

"We've got a long road ahead of us," said Hogan, who toured the wreckage with U.S. Rep. Elijah E. Cummings (D-Md.) on Sunday morning. "We are going to do everything we can to immediately help people, make sure there is housing, and get things back on track."

Howard County Executive Allan Kittleman, who vowed that Ellicott City would recover, described the 244-year-old town's epicenter as "a scene from a disaster movie."

In another harrowing episode, three men formed a human chain through the furious current to reach a woman trapped inside her car.



"I can't do this," the woman yelled as she crawled halfway out.

"You have to," someone shouted back. The man closest to her was Jason Barnes, whose business, All Time Toys, was being wrecked by floodwaters. He stretched out his arm, but he could not reach the woman. So he let go of the chain and stumbled forward. Just seconds after he had fallen and was nearly submerged, he took the driver in his arms and carried her to safety.

"Jason was incredibly brave and a little bit reckless to wade out to that," said David Dempster, co-owner of Main Street's Still Life Gallery. "When he went down, I thought that was it for Jason. I thought he would be swept away to his death."

Saturday's disaster was not the first to befall the town.

"It seems," the Baltimore Sun wrote in 2012, "that Ellicott City has come in for an inordinate amount of disasters from floods, fires and railroad wrecks since its founding in 1772."

The unincorporated town of 68,000 has endured at least four major floods, according to the Maryland Historic District's web site, including a pair in the 1970s, another in 1923 and one in 1868 that "wiped out most of early industry in the valley sparing only the flour mill."

Ellicott City's geography makes it particularly vulnerable, said Jason Elliott, a National Weather Service hydrologist.

It is bordered by the Patapsco and by areas of higher elevation, which means heavy rain could trigger flooding from two directions, as it did in this case.

On Sunday, officials asked residents to remain patient as emergency crews assess the damage and work to ensure structures are safe. Hogan and other elected officials said the county, state and federal governments will work together to make sure the affected area is rebuilt.

"This is not going to be cleared up in a day or two," Kittleman said.

Hundreds Offered Condolences on Social Media.

When the rain began, Karry Brown, 42, was enjoying dinner with his wife at the Phoenix Emporium on Main Street. As the weather worsened, restaurant staff moved the 50 or so guests up to a third floor.

"We were just watching in disbelief at how the water was sweeping cars away," said Brown, of Odenton, Md. "It was pretty dramatic."

His wife's car was nearly among those washed away. She had parked it on Maryland Avenue, perpendicular to Main Street, which sustained the worst flooding. The water pushed the car out of its parking spot and into the road.

Once they left the restaurant, they managed to start the vehicle and drive slowly out of town. But soon, Brown said, "the dashboard lit up like a Christmas tree," and the engine died, forcing them to call a tow truck that arrived about two hours later.

Shannon Tolley, 45, of Manheim, Pa., had stopped with a friend in the basement of Ellicott Mills Brewing Co. Soon, she said, a flash flood warning appeared on her phone, and water began to leak into the bar. Patrons were moved up to the first floor, then the second and the third.

"The water was just rushing down the street," she said, "like a big river." By about 9 p.m., the water had receded enough for Tolley, a music teacher, to venture outside. She waded through ankle-deep water to her car, which had been parked high enough on a hill to prevent it from being lost. "I've never seen anything like this in my life," Tolley said.

One Ellicott City man named Kirk Cummings, who lives outside downtown, was watching a movie with his family when it began to rain. "I knew it was going to be awful," said Cummings, 44. He got into his

Toyota 4Runner and drove toward the flooding. Before he picked up a man and two women who had been stranded, Cummings watched the cars being pushed and pulled down his town's most beloved street.

Martin Weil, Eddy Palanzo and Theresa Vargas contributed to this report.





Flooding in historic Ellicott City, Md., causes road closures and building damage July 30. (Howard County)



See what the scene looks like after flooding in historic Ellicott City

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Cleanup begins after a night of flooding damages Ellicott City, Md., and surrounding areas













Historic Rainfall and Flash Flooding Saturday Night in Ellicott City, Maryland

Duration	Rainfall Total	Time
1 minute	0.20″	7:51-7:52 pm
5 minutes	0.80″	7:50-7:55 pm
10 minutes	1.44"	7:50-8:00 pm
15 minutes	2.04"	7:46:8:01 pm
20 minutes	2.48"	7:44-8:04 pm
30 minutes	3.16"	7:36-8:06 pm
60 minutes	4.56″	7:30-8:30 pm
90 minutes	5.52″	7:00-8:30 pm
2 hours	5.92″	6:45-8:45pm

The storm total rainfall at Ellicott City was 6.50 inches. Based on the preliminary precipitation frequency estimates in NOAA Atlas 14 from the nearest location, the rainfall amounts with duration 10 minutes to 2 hours statistically have a less 0.1% chance of occurring in any given year, or a 1 in 1000 year event.



The convective system that dumped on Ellicott City left behind a swath of heavy rain extending from Parr's Ridge (Damascus) in upper Montgomery County to the western suburbs of Baltimore (shown below).



Doppler estimated rainfall for flash flood event July 30. (Jordan Tessler)