



The “500-year” flood, explained: why Houston was so underprepared for Hurricane Harvey

It’s the city’s third “500-year” flood in the past three years.

By Dara Lind | dara@vox.com | Aug 28, 2017, 9:40am EDT



Photo by Scott Olson/Getty Images

It’s difficult to comprehend the scale of the flooding and devastation that Hurricane Harvey and its aftermath are wreaking on the Houston area. Weather experts call the storm **unprecedented**, and note that it’s gone beyond even the most **pessimistic forecasts**. In the final reckoning, it’s certain that Harvey will be classified a 500-year flood — and maybe even a 1,000-year flood.

But those terms can be a bit misleading — especially when high-profile people, like the president of the United States, **confuse the issue** by calling Harvey “a once in 500 year flood.”

In theory, a 500-year flood is something that has a 1-in-500 shot of happening in any given year — in other words, the sort of event that’s so rare that it might not make sense to plan around the possibility of it happening. The problem is that 500-year floods are happening more often than probability predicts — especially in Houston. And, especially in Houston,

prevention planning hasn’t evolved to acknowledge that a “500-year” flood isn’t really a 1-in-500 chance anymore.

“500-year” floods are based not on history, but on probability

The severity of floods tends to get put in terms of years: a 100-year flood, a 500-year flood, a 1,000-year flood. But this isn’t an assessment of “the worst flood in” that time — places like Houston don’t actually have detailed weather records going back to 1017 AD, after all.

The lack of hundreds of years’ worth of flood data is actually the reason we have the term **“100-year” flood** to begin with. When the government decided to map flood-prone areas to improve the National Flood Insurance Program in the early 1970s, the maps couldn’t just use the worst flood ever recorded in a given area to judge what a “bad flood” would look like — because some areas had more records than others, and besides, just because a bad flood hadn’t happened yet didn’t mean it couldn’t.

Instead, the standard set for mapping flood-prone areas was a compromise between the existing Army Corps of Engineers standards for dams and levees, and the (much more modest) standards that most communities had set for flood prevention. The areas deemed at risk of a bad flood were the areas that had about a 1 percent chance of flooding in any given year: in other words, the areas that would flood approximately one year out of every 100.

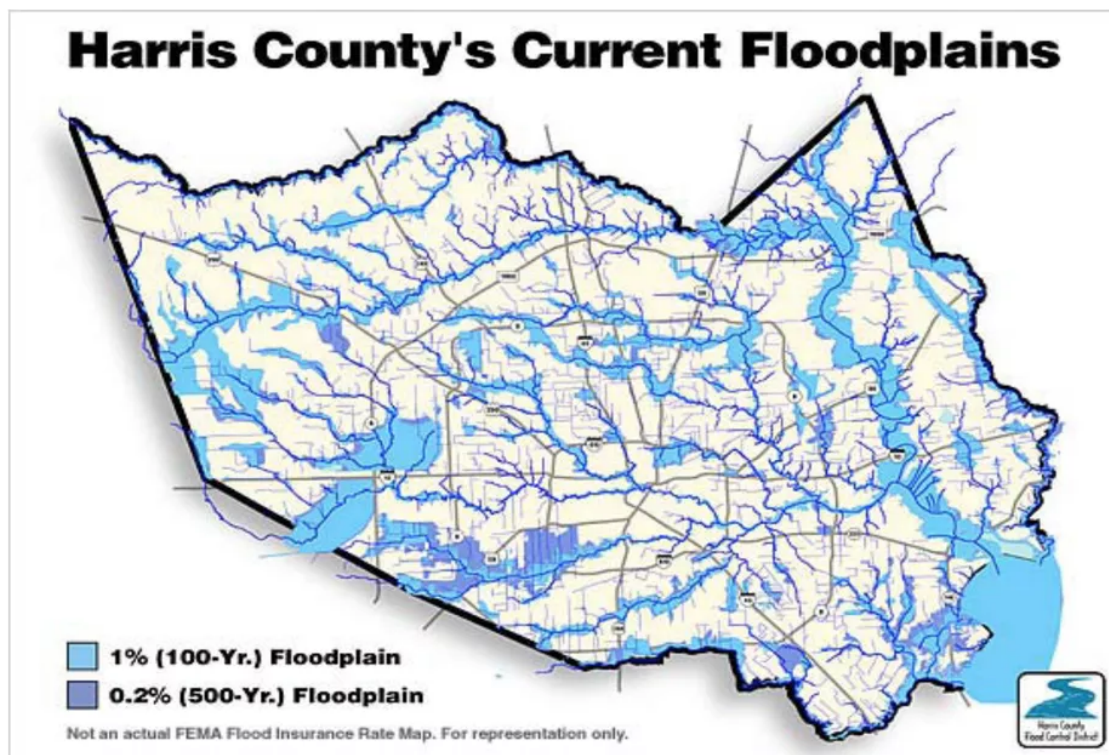
A 500-year flood is based on the same principle: Experts estimate that in any given year, there’s a 1-in-500 (0.2 percent) chance a flood this bad will strike a particular area. In theory, that means that over 500 years, that will happen once: so there will be one flood that bad over a 500-year period.

Of course, different areas flood at different frequencies. So how bad a flood has to get to qualify as a 1-in-500-year flood is going to vary depending on where you’re judging it — and a flood will probably qualify as a “500-year” occurrence in some locations but not others. This table, for example, shows the flooding in various locations in the Houston area in April 2016. You can see that the flood reached 500-year levels in certain places, but in others it was the sort of event meteorologists would predict to happen every 10 years.

Watershed	Bridge	Gage Elevation	Flood Frequency	Previous Record	Previous Record Date
Cypress Creek	Huffmeister	132.79	~0.2%(500-yr)	131.63	Oct. 1998
Cypress Creek	Eldridge	128.71	~0.2%(500-yr)	126.10	Oct. 1994
Cypress Creek	Grant	127.52	~0.2%(500-yr)	125.40	Oct. 1994
Cypress Creek	SH 249	120.51	~1%(100-yr)	120.50	June 2001
Cypress Creek	Stuebner-Airline	110.02	~1%(100-yr)	109.70	June 2001
Cypress Creek	Kuykendahl	101.35	~2%(50-yr)	101.30	May 1989
Langham Creek	W Little York	112.84	~0.2%(500-yr)	110.70	April 2009
Lt Cypress Creek	Becker	197.62	~1%(100-yr)	197.20	July 2012
Lt Cypress Creek	Cypress Rosehill	161.62	~0.2%(500-yr)	160.40	July 2012
Lt Cypress Creek	Kluge	136.84	~0.2%(500-yr)	136.30	Oct. 1994
S Mayde Creek	Peek	141.36	~10%(10-yr)	142.90	Oct. 1998
S Mayde Creek	Morton	123.74	~2%(50-yr)	118.62	Sept. 2008
Bear Creek	Clay	114.86	~0.2%(500-yr)	114.40	April 2009
Horsepen Creek	Trailside	118.50	~1%(100-yr)	112.80	Oct. 2009
Cane Island	Hwy 90	137.88	~1%(100-yr)	134.30	April 2009
Mason Creek	Prince Creek	106.30	~1%(100-yr)	106.10	April 2009

Harris County Flood Control District

When it comes to planning for future floods, you have to get a little more abstract. So FEMA maps out 100- and 500-year “floodplains” — the places that would get flooded by the kind of rainfall that has a 1 percent chance (or 0.2 percent chance) of falling on an area in any given year.



A 2013 map of the estimated 100-year and 500-year floodplains for Harris County, where Houston is located. | Army Corps of Engineers, “National Economic Development: Flood Risk Management,” 2013.

But probability never works out perfectly in practice (as you know if you’ve ever flipped a coin twice and gotten heads or tails both times). And it’s especially hard to get the probability of an event perfect when the circumstances keep changing — as they do when we’re talking about weather events, which become more or less common depending on the underlying climate. And current climate change trends could easily increase the chance of bad flooding — there’s more **water vapor in the atmosphere** now (ready to condense into storm clouds and precipitation), for example, than there was 70 years ago.

As a result, FEMA has to keep updating its assessments of the floodplains — i.e., which locations should think of flooding as a 1 percent possibility, and which should think of it as something with a 0.2 percent chance of happening in any given year. The FEMA maps for Harris County had just been updated in late 2016. However, the city of Houston itself is working off a Hazard Mitigation Plan it developed in 2012 — based on where FEMA was *then* saying the city’s 100-year and 500-year floodplains were located.

In the meantime, the reality of Houston’s flooding has already shown the old models to be out of date. An area of West Houston called Memorial City, for example, was outside Houston’s 500-year floodplain but **flooded three times in the past decade**: in 2009, 2015, and 2016.

It’s hard to design policy around preventing damage for something with a 1-in-500 chance of occurring...

Anti-flood policy tends to focus on 100-year floods, not 500-year ones. Many mortgage lenders require any homeowner living in a 100-year floodplain to buy flood insurance (homeowners with federally backed mortgages have to have flood insurance, as well). But homeowners living in a 500-year floodplain don’t typically have to purchase flood insurance — after all, 500-to-1 odds are pretty long odds.

Similarly, it’s hard to make city policies to prepare for remote events. In Houston, for example, the city’s current Hazard Mitigation Plan calls to discourage people from building homes in the 100-year floodplain, but it doesn’t say anything about the 500-year floodplain.

There’s a simple, probability-based reason for this. Everything that a person (or city) can do carries some amount of risk, and if a city prevents any activity that might be risky, it won’t be able to allow people to build new houses at all. So if something really only has a 1-in-500 chance of occurring, it’s not necessarily logical to force people to change their plans because of it.

...but certain areas are seeing “500-year” floods pretty frequently these days

What if storms happen more often than probability suggests they would, though? What if a place gets hit with more than one 100-year storm over a 10-year period — or even in consecutive years?

The US appears to be getting hit with major storms with unusual frequency. From August 2015 to August 2016, there were eight 500-year flood events recorded by the National Weather Service. There were six “1,000-year” floods in the US over the five years from 2010 to 2014; in 2015 and 2016, though, there were at least three each year.

Looking at the US as a whole can be a bit misleading — it’s a big country, and probability suggests that if there are a few thousand flood-prone locations around the country, a few places a year will experience 1-in-1,000 events. But what’s more suggestive are the places that keep getting hit with the kind of severe flooding that’s supposed to be uncommon — places like Houston.

Tomball, Texas, Public Works director David Esquivel **told a local paper there this year** that the Houston area had “two 500-year storms back to back”: over Memorial Day weekend of 2015 and early April 2016. That means that Hurricane Harvey constitutes the third “500-year” flood in three years.



Flooding in Richmond, Texas, a city in the Houston area, in 2016. | Photo by Bob Levey/Getty Images

Theoretically, the odds of a 1-in-500 event occurring three straight times are one in 125 million. Because Houston is a big city and the same spots aren’t necessarily reaching 500-year levels each time, those odds don’t *quite* apply — but we’re still, as the Memorial City example shows, talking about events that FEMA estimates to be vanishingly unlikely.

Either Houston is incredibly unlucky or the risk of severe flooding is a lot more serious than the FEMA modeling has predicted — and the odds of a flood as bad as the ones Houston

has seen for the past few years are actually much higher than 1 in 500.

Houston isn't the only city to get hit by “historic” floods with rapid frequency. Cedar Rapids, Iowa, got hit with a 500-year flood in 2008, followed by a 100-year flood in 2016.

After the 2008 flood, the city **worked to develop a central greenway** that could be used to protect residents from future floods, and a plan to put up temporary barriers. That plan worked to mitigate the damage done by the 100-year flood of 2016. But **city officials acknowledged** that if they'd been hit with a second 500-year flood in nine years, their planning wouldn't have been sufficient to protect them.

Houston wasn't even prepared for a 15-year flood

Houston is not Cedar Rapids. For nearly a decade — ever since Hurricane Ike narrowly missed Houston in 2008 — city and state officials and experts have been warning that Houston wasn't even prepared for a 15-year storm.

In 2016, **ProPublica and the Texas Tribune** collaborated on a project detailing how bad the damage from an Ike-caliber storm would be — and how little Houston had done to mitigate it. “We've done nothing to shore up the coastline, to add resiliency ... to do anything,” Phil Bedient, a Rice University professor who co-directs the Storm Surge Prediction, Education, and Evacuation from Disasters (SSPEED) Center, told ProPublica.

Even the things the city of Houston was trying to do weren't working — the mitigation plan called to discourage building within the 100-year floodplain, but 7,000 homes were built since 2010 in low-lying areas of the city. And while the Army Corps of Engineers and Harris County had **launched a partnership** to widen channels and build bridges in the Brays Bayou area to reduce the impact of flooding, the city was unable to muster the resources to build new seawall or floodgates — which Bedient and other experts agreed would be needed to mitigate the damage of a 100-year or 500-year storm.

In April 2017, George P. Bush, the commissioner of the Texas General Land Office, **wrote to the White House** asking President Trump to allocate \$15 billion for a “coastal barrier system” to protect Houston and Galveston — what the press called a “hurricane wall.”

The proposed system was designed to a “100-year-flood” standard, not a 500-year-flood one. But it still likely would have been better than what the city currently has.

In 2015, Bedient **told the Atlantic’s David Graham** that “I’m actually fairly optimistic that something will be done, because it needs to be done.” But when Graham **interviewed him the week before Harvey hit**, Bedient conceded that “something” hadn’t turned into much. “I don’t think much has been done to mitigate flooding in the past two years,” he told Graham.

In other words, for two years in a row, Houston saw 500-year floods and didn’t do enough to prepare for the next one. Now it’s dealing with what could be a 1,000-year flood — the sort of storm that no city could ever prepare for, but that could absolutely cripple a city that wasn’t even prepared for a much smaller and more common disaster.

If 500-year floods actually came only once every 500 years, Houston’s reaction would be understandable. But it’s clear that something is deeply wrong with how the US judges flooding risk. And when floods are hitting a city 500 times more often than probability predicts, it’s reasonable to expect that local and federal officials will start taking the possibility of the next “500-year” storm as something that could come next year.

CLARIFICATION: This article has been updated to more accurately reflect the chronology of the National Flood Insurance Program; the NFIP itself was created in 1968, but flood maps weren’t developed until the 1970s.

