Data and Bias, Part 2:

Next Year's 100-Year Storm

by Kevin Loney

In the first article in this series, the focus was on algorithmic use of input values we do not fully explore (credit scores) to institutionalize societal effects we do not intend. Those impacts hit individuals and protected populations, and without adjusting for upstream bias there is no hope of remediating its downstream effects.

In this article the focus is on actual *streams*: the inland rivers of the US and way we measure, report, and plan for their flooding. Before we build another bridge, we should understand what the data means, what's expected going forward, and how we talk about it. This discussion will start in Texas, with **the 100-year flood** — an engineering and insurance planning term now in common misuse — and work toward a clearer metric to use for the bulk of the population.

To illustrate the data and issues behind what that metric is trying to convey, this story starts on the west coast of Mexico, near the end of 2018 hurricane season:

In October of 2018, Hurricane Sergio struck the Pacific coast of the Baja California peninsula, moved eastward across it while decreasing in power, then crossed the Gulf of California and made a second landfall in mainland Mexico. Continuing northeast, it caused localized flooding and tornadoes before it dissipated, hitting Texas with heavy rains on October 12 & 13.

Texas's Llano River had already flooded earlier that week, with floods from heavy rains on October 8 obliterating an RV park. The new rains led to additional flooding with the Llano destroying the RM 2900 bridge as captured on live TV: https://youtu.be/EY45z_vXbSQ (*still from video shown*). Watch even two minutes of that to clarify the scope for this discussion.

Local headlines recited the storm risk as if it were the expected storm frequency there: "Built for 50-year storms, Kingsland bridge lasted 49 years" read the headline in The Statesman (https://www.statesman.com/news/20181016/built-for-50-year-storms-kingsland-bridge-lasted-49-years). The metric misuse in the headline contrasted with the details in the article (emphasis added) highlight the difficulty of using the "*N-year storm*" metric for general discussions:

"Most bridges on Texas Department of Transportation-constructed roads are built to withstand 25- or 50-year storms, while interstate highways are designed to withstand 100-year storms, said Travis Attanasio, a civil engineer in the Fort Worth area and an officer with the American Society of Civil Engineers. Some large Texas cities in recent years have started requiring bridges to be designed to withstand 100-year floods.
A 100-year storm is a rain event that has a 1 percent chance of occurring in any given year based on federal weather data. Those data, however, are being re-evaluated to reflect higher rainfall totals in recent years. ***Texas, for instance, has seen 500-year floods in each of the last three years."***

That closing sentence illustrates the problem with using these terms outside of urban planning. The US Geological Survey (see https://pubs.usgs.gov/gip/106/pdf/100-year-flood_041210web.pdf) published a full-page poster just to try to explain what the terms mean:
A 100-year storm's flood has a 1% chance of occurring each year, regardless of last year.
A 50-year flood is above flood stage, but lower than the 100-year storm's level. It has a 2% chance of occurrence every year.
A 25-year flood is lower. It has a 4% chance of occurrence every year.
And a 500-year storm's flood level is higher than the 100-year storm's. It has 0.2% chance of occurrence every year.
We should be able to convey that without confusing the issue.

But which 100 years are they measuring? It's complicated.

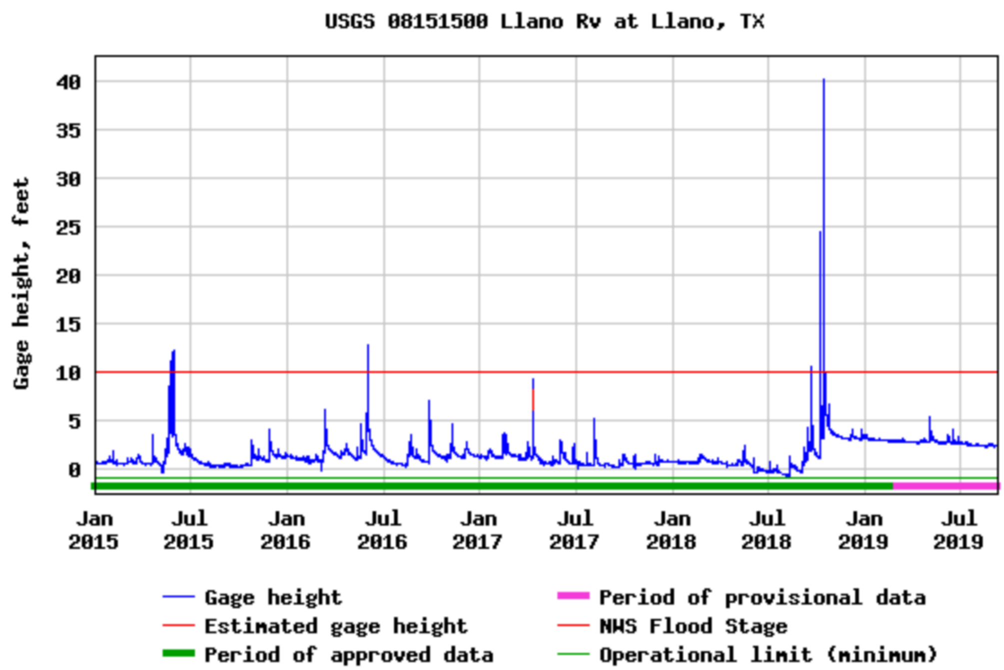
Climate change has changed storm intensities, storm frequencies, and the structure of rivers. While many climate-related discussions have focused on the need for seawalls around sinking islands (https://www.dw.com/en/can-a-wall-protect-tangier-island-from-rising-seas/a-46056726) or vulnerable cities, the inland rivers in the continental US have been subjected to increasingly severe storms and changes. For example, in 2012 the USGS (see "Watershed Scale Response to Climate Change—Black Earth Creek Basin, Wisconsin," https://pubs.usgs.gov/fs/2011/3129/FS11-3129_508.pdf) noted that as upper midwestern winters became warmer, there would be a smaller snowpack and the streams' flows would change in the timing, temperature, and sources of their water. "*Thus, the characterization of upper-midwestern streams as being spring snowmelt-dominated may not hold if these emission scenarios of climate change are representative of future conditions. Rather, the hydrology would closer resemble more southerly United States streams*."

The changes to the structure and flow of the rivers force the reevaluation of their flooding potential. A 100-year storm has a 1% chance of occurring each year, so it is possible to have 100-year storms in consecutive years. When the climate changes and the percentages change, we have to revise what those numbers mean quickly and consistently.

As noted in the Statesman article, there have been multiple floodings of the Llano River in the past decade. The following chart shows the depth of the Llano River since 1/1/15, including the flood stage level. (*link to reload chart data:* https://nwis.waterdata.usgs.gov/tx/nwis/uv/?cb_00060=on&cb_00065=on&format=gif_default&site_no=08151500&period=&begin_date=2015-01-01&end_date=2019-09-11)

Gage height, feet

Most recent instantaneous value: 2.37 09-11-2019 15:00 CDT



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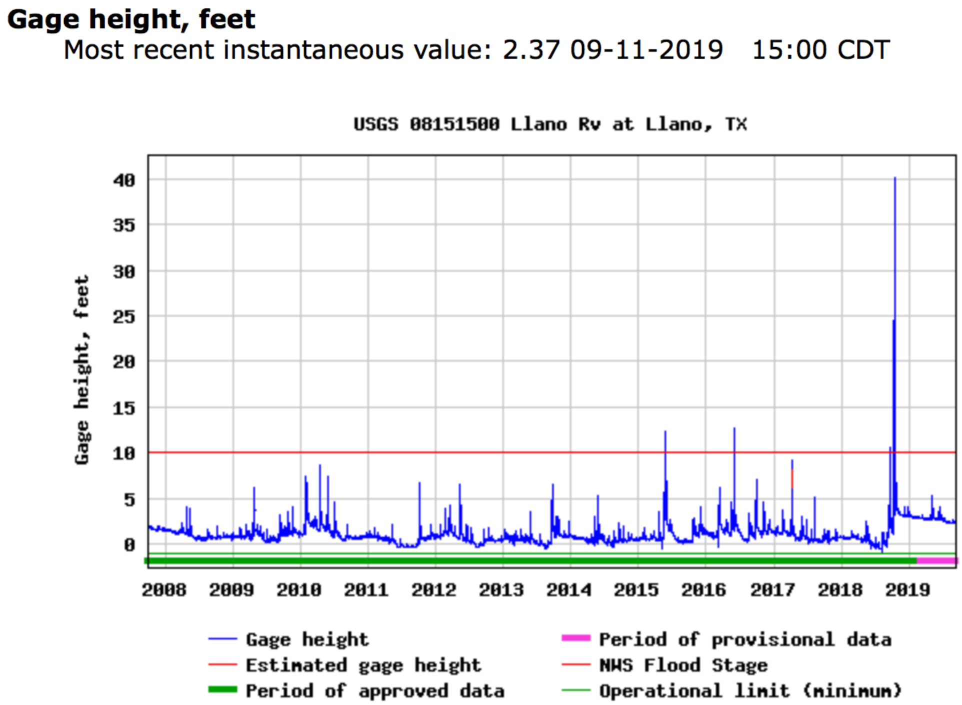
The first flood shown in that graph, in the first half of 2015, looks like it was just above flood stage. But this is the issue with flood forecasting — it's not like forecasting the usage on a computer server that will slow down, or the throughput at an airport security gate that will backup. There are no minor floods. Floods uproot trees and fling them against buildings and bridge supports. That line that hit 13 feet in 2015 represents the Memorial Day flood that demolished the bridge in Wimberley, Texas. (*still from drone video shown. You should see the full video:* https://youtu.be/o-Y8HbCM-Vc)

What happened before 2015? The online USGS data, available back to 2008, shows that the flood events exceeding 10 feet at this location are a recent phenomenon:



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Given today's climate, the catastrophic nature of floods, the past decade's data, and the most recent five years: if it were your job to predict the water levels for 2020, what would you predict? Where would you establish the flood stage?
What metric would be the best way to express that estimate and its range of uncertainty to someone who lived there? What would they care about?

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Revising the Target: Atlas 14

NOAA initiated a study, Atlas 14, to collect country-wide rainfall values through 2017, reflecting changes in climate, population, and building patterns since the last full study in the mid-1990s. The analysis is published per region (https://www.nws.noaa.gov/oh/hdsc/index.html) as sections are completed. Austin's Watershed Protection Department (WPD) coordinated its response to the Atlas 14 findings for Texas — changes to building codes, floodwall heights, and storm drains (http://www.austintexas.gov/page/atlas-14-and-austin).

For further reading:
Atlas 14 Citation and version history: This documentation and associated artifacts such as maps, grids, and point-and-click results from the PFDS are part of a whole with a single version number and can be referenced as:

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite (2018). NOAA Atlas 14 Volume 11 Version 2, Precipitation-Frequency Atlas of the United States, Texas. NOAA, National Weather Service, Silver Spring, MD.

From the Austin WPD's summary:

"Before the study, we believed that, in any given year, there was a 1 percent chance of 10.2 inches of rain falling in 24 hours in Austin. This was the official definition of the 100-year storm. The Atlas 14 study shows that this amount of rainfall is now likely to occur more frequently. The new 100-year storm will be closer to 13 inches of rain in some parts of Austin. This resembles the current 500-year storm."

Probability of Occurrence in any Given Year	Storm Level	Current Rainfall Intensity (24-hour storm)	Atlas 14 Rainfall Intensity (24-hour storm)
4%	25-year	7.6 inches	Up to 9 inches
1%	100-year	10.2 inches	Up to 13+ inches
0.2%	500-year	13.5 inches	Up to 19.5 inches

In Austin's new rating values, what had previously been called a 500-year storm is now 5 times as likely to occur, and is called a 100-year storm. The prior value for a 100-year storm is now close to the new rating of a 25-year storm.

So the new official estimate is that for Austin next year, there is a 4% chance of having a rain event that brings 9 inches of rain in 24 hours, and a 1% chance of a storm that brings up to 13 inches of rain — plus or minus 10%, as these calculations use confidence intervals. There is a 0.2% chance of a storm bringing 20 inches of rain in 24 hours.

If the Constant is now Variable, Provide the Context

Based on the changed values, the Austin WPD estimated that the number of buildings now at risk in its 100-year flood plain increased from 4,000 to 7,200. Those buildings will need to be evaluated both from a suitability aspect and from an insurance perspective. (Note: Canada's approach toward dealing with buildings in the flood plain favors removing the buildings and capping funds for rebuilds, recognizing the floods will reoccur more frequently given changed climate conditions. Since 2005, the province of Quebec "*has prohibited building new homes or rebuilding flood-damaged ones, in the 20-year floodplain*" according to the New York Times https://www.nytimes.com/2019/09/10/climate/canada-flood-homes-buyout.html).

The change to the storm metric highlights its variable nature. The 100-year storm value had been treated as a constant for years until the changes in the temperature, water volume and flow forced it to be altered. Having a common national atlas establishes a common baseline study across the watersheds, and the study name or year should be added to the metric to clarify its data source. Thus, the 100-year storm value should be referenced as the *Atlas 14* 100-year storm value. There is no reason to assume subsequent studies would not be needed on a more frequent basis, and data is not published for the entire country at once. The study and publication performed for the Atlas 14 compilation has taken years — the northeast states' data was published in 2015, which preceded the Texas floods shown earlier. Until all data is published, the metrics should include the study references for clarity.

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From the Red to the Cedar, the norm is much higher

In other areas of the country, bridges whose approaches are in low-lying areas are scheduled for redesigns or moves. In some cities, inland bridges are too close to the water they cross and may effectively dam floods during storms. In Des Moines, Iowa, for example, the Red River Bridge, a railway bridge converted to a popular pedestrian and cycling venue, had been fully renovated in 2007. When the Iowa data from Atlas 14 was released, the city got bad news about the bridge they had built just a decade earlier: it was too low. To meet the new flood level guidelines, the bridge would have to be removed or elevated just ten years after it had been rebuilt. The city opted to raise it 4.5 feet, slowly lifting the million-pound structure to its new elevation (see https://www.stanleyconsultants.com/markets-we-serve/transportation/highways-and-bridges/des-moines-iconic-red-bridge-raised/).

As noted at the time, (https://apnews.com/552ec81f352f475ba2c80624d8a720f8) the impact in Des Moines was also seen in Cedar Rapids, Iowa (emphasis added):

"*It was like a bomb was dropped off in our lap," [Des Moines] City Engineer Pam Cooksey said of the revised flood forecasts from the Army Corps of Engineers. The findings suggested that the bridge could act as a dam during bad storms, sending waves of backed-up floodwater into the refurbished business district…*
River level forecasts have increased in Cedar Rapids, Iowa, since tropic-like rainstorms in 2008 caused the normally placid Cedar River to climb higher than anyone thought possible, eventually ***topping the previous record flood by 11 feet*** *(3.4 meters). More than 1,100 blocks in Iowa's second-largest city wound up underwater.*
Afterward, the Corps of Engineers raised Cedar Rapids' projections for a 100-year flood by 8 percent. *As part of a massive flood-control project, the city decided to raise its Eighth Avenue Bridge by 14 feet (4.3 meters), putting it 28 feet (8.6 meters) above the average water surface.*
"What used to be the norm is no longer the norm," said Rob Davis, the city's flood-control program manager. "The norm is much higher."

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Seeking Higher Ground

The metric used to communicate these changes had been the "100-year storm" — which considers both the rainfall and the discharge generated from the retention areas (since higher velocity discharges can scour support areas under bridges and other structures). As shown in these examples, the collection of water level measurements takes place across years, and any discussion requires knowing if you're using old values or recent values for all related waterways. And you keep having to explain the metric as it is used. When talking about its impact on homes or bridges, a different metric entirely would be used (feet above flood stage, or above the existing flood protections). *So stop using the metric that's not fit for purpose.*

The core problem with this metric is that it is not a measure representing the impact to the user. It puts the event in terms abstracted from individual experience, and then attempts to use those terms to discuss critical issues with impacted individuals.

We don't use this kind of language for other measurements of events with impacts for people; we don't tell diners at a restaurant that the seating time for their table will be delayed because of a "25-year restaurant event" that is relevant only to the restaurant staff. Rather, we put the data into metrics relevant to the diners, provide the range estimate and assumptions, and add context for clarity if needed:
"*There will be a 30 minute wait, plus or minus 5; we're a lot busier on weekends during the state fair, so our wait times are not the same as they were last month*. *You're fifth on the list to be seated*."

The vast majority of flood data users are homeowners or news channel watchers who want to know how likely it is their area will be flooded this year (or during this week's storm) based on justifiable projections. <u>The answer to that is a percentage</u>. That percentage should include its assumptions or range of error. It should reference its testing method and test dates as justification. If there are extenuating circumstances, call them out to support the current value or set the stage for potential changes to it.

For instance:

"*There is a 4% chance of going two inches over the floodwall here, using the Atlas 14 numbers, and that will flood this whole block like it did last year. The storm sewer construction project will finish in June, then the chance will drop to 1%*."
or
"*There is a 2% chance of flooding here, using the pre-Atlas 14 rainfall numbers. But we expect that likelihood of flooding to go up when this region's data is published, since the cumulative rainfall here has increased every year for the last 5 years*. *It's probably closer to 6% chance*."
or
"*This is in the 1% floodplain. Before the new flood forecasts came out from the Army Corps of Engineers we had considered it the 0.2% floodplain*. *We had a flood last August. and revisited all the rainfall numbers in the state.*"

For those in the project management business, this is starting to sound like a project estimate, with a range of values, statement of assumptions/dependencies, and projected future actions that would change the anticipated outcomes. In which case: <u>Awesome</u>. That message would be relevant, correct, and quantifiable. Changing the message and telling the same people they live in a 50-year storm zone leaves out critical data and does not communicate the same clarity for information they need to know to build, plan, and survive.

- Kevin Loney, September 2019.