UTILITY INFRASTRUCTURE SPECIAL REPORT

Uncovering New Risks from Extreme Floods to Electric Substations in Harris County, TX

Extreme weather events already impact a majority of substations in Harris County. As physical risks from climate change grow, Transmission and Distribution planners must leverage cutting-edge climate analytics to enhance grid reliability.

An Immediate Issue for the Power Sector

Extreme weather events driven by climate change affect the electricity system across all regions of the U.S. and all components related to the production, conversion, delivery, and use of energy.[1] Weather-driven service interruptions represent significant economic impact, with many studies estimating multi-billion-dollar annual losses to the U.S. economy.[2] To adapt to these physical risks, stakeholders within the power sector—including utilities, regulators, and policymakers—must evaluate future resilience investments by quantitatively assessing the exposure of their asset portfolios and understanding the evolution of such risks over time.

Jupiter Study Reveals Greater Flood Risk—and Greater Need for Resiliency

This report shows probable current and future flood risk for Harris County, Texas, substations using both geospatial information for infrastructure and Jupiter Intelligence's high-resolution, forward-looking climate analytics.

"Our models show that a majority of electrical substations in Harris County are already at risk, today, of flooding of at least one foot (0.3m) from extreme weather—whether a hurricane, storm surge, or prolonged rainfall—driven by climate change," says Rich Sorkin, CEO and co-founder of Jupiter Intelligence. "What's as alarming is the real possibility, if not probability, that utility operators who rely on FEMA data are either ignoring or badly underestimating the scope of the actual flood risk they face."

To better illustrate the current and future flood vulnerability of electric substations in Harris County, one of the most climate-vulnerable regions in the U.S., between the present year and 2030, Jupiter uses a small subset of available data to show that:

- Jupiter's best-in-science approach produces results materially different from that of the FEMA National Flood Insurance Program (NFIP). Substations designed to FEMA data in the past will require an updated assessment of current and future flood risk.
- Many substations designed to FEMA data will see more exceedances to their design tolerance within the next 5-10 years (if not already), which requires timely resilience intervention. This coincides with many Jupiter customers reporting their substations seem to be flooding more frequently.

This report covers 257 substations[3] within Harris County and compares flood depth levels from Jupiter's FloodScore™ Planning product[4] at 0.2% annual occurrence probability (equivalent to a 1-in-500-year flood) in 2020 and 2030. It bases the event probability and time horizon of interest on federal recommendations[5] and the typical service life[6] of electric substations.

Although these projections take the form of 1-in-500-year probabilities, events of these magnitudes are already happening with increasing regularity. For example, Houston, the Harris County seat, experienced three 1-in-500-year floods between 2015 and 2017, according to The Washington Post.

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>
> *—Rich Sorkin, Jupiter co-founder & CEO*

More Substations to be Affected by Deeper Floodwaters

Notably, the study shows that, by 2030:

- The number of substation locations experiencing 4 feet or more of flooding will increase by 75%, from 12 to 21.
- The number of substations that will experience over 8 feet of flooding will triple, from one to three.
- The number of locations experiencing 2 to 3 feet of flooding will rise by 50%, from 12 to 18; what's more, all of these locations currently expect less than 1 foot of flooding.

The report consists of two parts:

Part 1 uses Jupiter FloodScore™ to model each electric substation and summarizes the portfolio's expected flood depth change between 2020 and 2030. Analytics include absolute flood depth, change in flood depth from 2020 to 2030, and whether the flooding exceeds the illustrative one-foot flood tolerance threshold.

Part 2 compares results from Part 1 with flood zone information from FEMA's NFIP Flood Insurance Rate Maps (FIRMs) for discrepancies in present-year flood risks.

Part 1 Results: Change in Flood Risk From 2020 to 2030

- As shown in Figure 1, 60% (148) of substations located within Harris County are already at risk of at least one foot of flooding during an extreme event in the current year; 40% (104) are subject to one-foot flooding in 2020 and increasing expected flood depth in 2030 (upper right quadrant).

- With business-as-usual emissions, not only will the number of locations experiencing acute flooding (≥4 feet) increase by 75% from 12 to 21, the average flood depth at the 148 currently flood-prone sites will increase from 1.9 to 2.3 feet during an extreme event. Figure 2 maps the substations based on the four-quadrant color code shown in Figure 1. Most of the vulnerable substations are at coastal locations or along rivers, and thus subject to flooding caused by storm surge and overland precipitation. These vulnerable sites include infrastructure belonging to electric utility, chemicals, oil and gas, and water utility companies, indicating impact across residential and large commercial/industrial users.

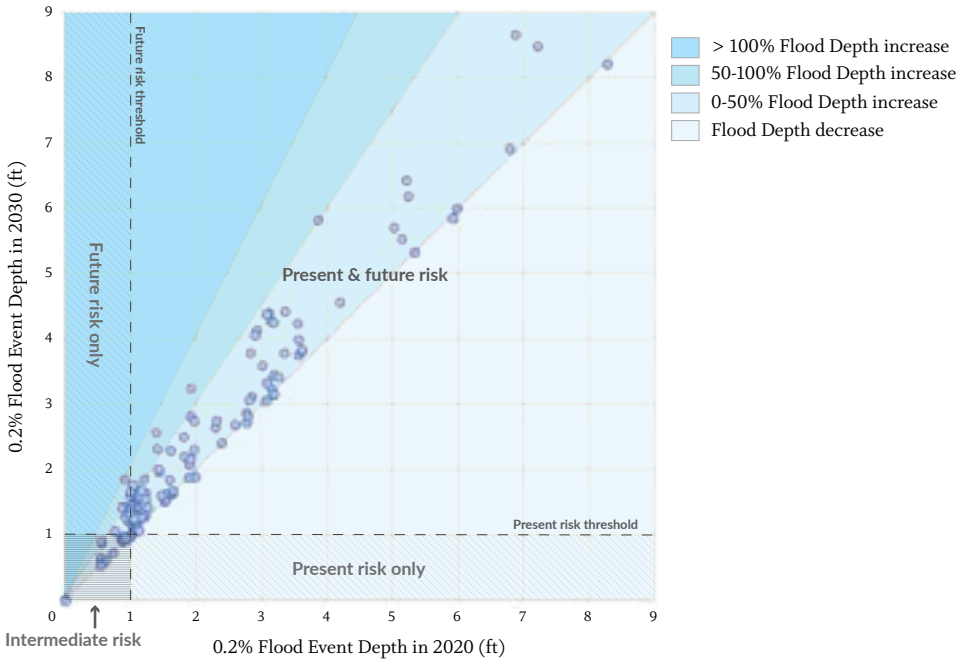

Figure 1 Flood depths during a 0.2% flood at 257 substations in present-year and 2030 under a business-as-usual scenario.

Figure 2 Select Harris County substations by 0.2% flood depth threshold exceedance during present-year and 2030 under a business-as-usual scenario.

Part 2 Results: Comparison to FEMA FIRM Flood Zones

- 90 (35%) of Harris County substations shown flooded by Jupiter analytics are located outside of FIRM flood zones.
- FIRMs underestimate flood risk or provide insufficient information for almost 60% of substations in Harris County.
- 40% of Zone A substations have base flood elevations (BFEs) below Jupiter flood depths during a 1% flood; 76% of Zone X substations—though within Jupiter's 0.2% flood area—lack BFE data from FIRMs needed for planning or resilience investments.

FIRM Estimates	FIRM Designation		
	100-yr Flood Plain[i]	500-yr Flood Plain[ii]	Outside Flood Plain
Underestimation†	12 (5%)	58 (23%)	90 (35%)
Consistent with Jupiter modeling‡	18 (7%)	15 (6%)	94 (37%)

† BFE < Jupiter modeled flood depth or location not in Jupiter flood plain
‡ BFE ≥ Jupiter modeled flood depth or location not in Jupiter flood plain

Figure 3 Number of substations (and share of portfolio) by FIRM flood zone designations and flood depth comparison with Jupiter flood modeling for the present year.

This discrepancy can be attributed to Jupiter's unique approach to flood modeling:

- FIRMs do not consider fluvial flooding (the impact of rain falling on the ground) and the effects of climate change
- Jupiter's digital elevation data (terrain) is more up to date.
- Jupiter runs more simulations of rainfall and coastal storm events than FEMA does.

Importantly, these results reflect portfolio flood exposure based on one specific illustrative set of parameters and assumptions (i.e. 0.2% probability, one-foot depth tolerance, a 10-year timeframe, business as usual emissions, and no investments in resilience). Jupiter's customers can choose multiple other parameters and/or focus on specific assets that are most vulnerable.

> *Electrical utilities who designed their substations to FEMA's data, whether years ago or months ago, should take a deeper look at the actual risk these assets face.*
>
> *—Rich Sorkin, Jupiter co-founder & CEO*

Key Takeaways

This report shows that the majority of Harris County's fleet of substations are already at risk of flooding during extreme weather events. Substations that are vulnerable today are expected to experience deeper floods within just a decade, in many instances well within the useful life of most equipment. Perhaps more importantly, historical data widely used for decision-making, such as the Flood Insurance Rate Maps, is a poor representation of both current and future flood risks given evolving atmospheric conditions.

Accurate insights into future extreme weather risks are critical for screening high-risk assets, developing service interruption and emergency response plans, updating engineering design standards, allocating capital investments, and responding to regulatory and investor scrutiny.

"Best-in-science flood risk data like Jupiter's indicate that FEMA's data are inadequate at best in projecting the probable flood impacts of extreme weather events on the utility infrastructure," Jupiter's Sorkin says. "Electrical utilities who designed their substations to FEMA's data, whether years ago or months ago, should take a deeper look at the actual risk these assets face. Anecdotally, some utilities are already reporting that 'their substations seem to be flooding more frequently,' and our data indicates that flood depths are only expected to increase."

The impact of extreme weather will be felt across sectors, as vulnerable substations serve residential as well as large commercial and industrial customers. With the latest scientific modeling, T&D asset owners and operators can gain a quantitative understanding of the severity and timing of extreme weather risks and develop a targeted, prioritized climate resilience strategy.

While this report focuses on changes in flooding above and below one foot (0.3m), Jupiter's customers can pick any time horizon, threshold, and return period relevant to their business needs. The 2030 projection is based on the increasingly accepted business-as-usual scenario.[7] Jupiter's modeling encompasses major relevant flood drivers in the region, including sea-level rise, hurricanes, precipitation, and riverine and overland flooding.

About Jupiter

Jupiter Intelligence brings together the latest climate modeling methodologies and scientific research to provide actionable insights for climate resilience. Contact info@jupiterintel.com to learn more.

1 Department of Energy (2015). Climate Change and the U.S. Energy Sector: Regional Vulnerabilities and Resilience Solutions.

2 Executive Office of the President (2013). Economic Benefits of Increasing Electric Grid Resilience to Weather Outages.

3 Substation location data retrieved from Department of Homeland Security (2019). Homeland Infrastructure Foundation-Level Data.

4 FSP provides probabilistic outlooks for long-term flood hazard from 6 months to 50-plus-years in the future using Jupiter's proprietary models that capture the complex interaction between flood drivers such as changes in regional sea level, precipitation, storm surge, and the built-environment. For more information, please visit jupiterintel.com/services/

5 See Executive Order 11988 on Floodplain Management and associated regulations at 44 CFR 9.4 and 9.11, which require that FEMA support protection of critical facilities to the 0.2 percent chance flood level. FEMA considers critical facilities to include "public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during and after a flood." FEMA guidance also recommends that communities protect critical facilities at or above the 0.2 percent chance flood level. See FEMA Guidance on "Managing Floodplain Development Through The National Flood Insurance Program" at 6-18 to 6-20, available at https://www.fema.gov/media-library-data/20130726-1535-20490-8858/is_9_complete.pdf (last accessed on Feb. 13, 2020

6 Service lives for transformers and substations for utilities vary, but typically range from 40 to 60 years based on utility depreciation studies. However, retirements of transformers are often earlier and primarily caused by storm damage, deterioration, fire or third-party damage, capacity or loading issues, etc. For utility operators and managers who expect the life characteristics of transformers to be similar in the future as they have been in the past, extreme weather events are likely to exert downward pressure on the expected service life if no incremental resilience measures are taken.

7 The climate change scenario used in this study is aligned with RCP 8.5 released by the IPCC.

i. Includes substations in Zone A according to the National Flood Hazard Layer released by FEMA in June 2018. All Zone A locations in this study are either in Zone AE or Zone AO. FEMA guidelines specify the definitions of flood zones as the following:

> *Zone A*: The Special Flood Hazard Area (except coastal V Zones) shown on a community's Flood Insurance Rate Map. Note that there are five types of A Zones and the area of study only consist of Zones AE and AO.
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> *Zone AE*: SFHA where base flood elevations are provided. AE Zone delineations are now used on new FIRMs instead of A# Zones.
>
> *Zone AO*: SFHA with sheet flow, ponding, or shallow flooding. Base flood depths (feet above grade) are provided.

ii. Includes substations in Zone A and Zone X according to the National Flood Hazard Layer released by FEMA in June 2018. FEMA guidelines specify the definitions of flood zones as the following:

> *Zone X*: Area of moderate or minimal flood hazard, usually depicted on Flood Insurance Rate Maps as between the limits of the base and 500-year floods or above the 500-year flood level.