Using 311-Call Data to Measure Flood Risk and Impacts: the case of Harris County TX

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Introduction

The impacts of flooding in the United States (U.S.) are becoming more ubiquitous, costly, and widespread. As a result, decision makers are searching for more timely and representative data to better understand and plan for flooding events, particularly in large populated urban areas. Current damage assessment techniques rely on satellite imagery at very coarse scales, windshield damage surveys, and forensic analysis using limited amounts of high-water marks, insurance claims, or other flood-loss payouts. Planners, first responders, and recovery experts are increasingly in need of information at a fine spatial scale, generated closer to real-time storm events, that better represents the risk of and impact from flooding.

Recent studies analyzing “user-generated content” based on social media, crowdsourcing platforms, and other citizen inputs have showed early promise as complementary or alternative data streams to better identify and reduce the impacts of flooding events (Li et al., 2018). The vast majority of this work examines data from social media platforms, such as Twitter, Instagram, and Flickr. These data sources have the advantage of being generated through direct observation, near real-time, and sometimes at a specific x and y coordinate. However, one pervasive, but under-evaluated data stream that can more systematically provide information on the scale and extent of flood events before traditional damage assessments are generated is local 311 calls. This source of data is already being used by many urban municipalities around the country to assess and respond to problems, ranging from trash pick-up to troublesome potholes.

These data are continuously being collected, mapped, and assessed in a near real-time environment by city/county departments and first response agencies, and can play a critical role in assessing vulnerabilities of 311 callers to flood hazards and their impacts (Zobel et al., 2017).

This study examines the potential of 311 calls to help capture the risk and impact of flooding through high-resolution, parcel-level, observational data that can complement traditional data streams like high water marks, satellite imagery, on-site surveys, etc. Specifically, we spatially and descriptively examine 19,680 calls during Hurricane Harvey (2017) in Houston, Texas - one of the most widespread and impactful urban flood events in U.S. history- across multiple parameters. Using exploratory data and spatial analysis, this study seeks to: (1) assess the relevance of flood-relate 311 calls as a citizen-generated dataset in measuring flood impacts; and (2) evaluate the built environment and socioeconomic composition of 311 call origins relative to other objective measures of flood impacts. Results indicate the usefulness of these data to identify flood risk and more proactively mitigate the rising costs of floods for Houston and other metropolitan areas across the U.S.

The following section covers the existing literature and case studies on user-generated content to signify flood impacts. Next, we describe research methods, such as study sample, variable measurement, and data analysis. Results are then reported descriptively across multiple parameters, including physical/spatial, built environment, socioeconomic, and federally-paid flood losses. Following this section, we present a discussion of the results and make recommendations for integrating citizen-generated data into flood mitigation practices. We conclude the paper with research limitations and direction for future work on the topic.

Using Citizen-Generated Data to Identify and Respond to Flood Events

Information on and geographic representations of flood risk are traditionally produced using hydraulic and hydrologic models, remote sensing imagery, or aerial photos. These methods often prove problematic for decision makers working in a near real-time environment surrounding a particular flood event. Hydrologic models, such as those underlying FEMA risk maps require detailed data on local physical conditions, large amounts computational time, and years to complete. Managers who need information on actual flood conditions directly before, during, and after an event cannot effectively use these products.

Physics-based models like the FEMA 100-year floodplain boundaries also lack accuracy for several reasons. Measurement error (Patterson and Doyle 2009), limited hydrometeorological observations (Apel et al. 2004), spatial-temporal variations in precipitation (Morss et al. 2005), and changes in climate (Hirsch et al. 2004) all confound the level of accuracy needed for managers to prepare for and respond to floods. Hydraulic and hydrologic models also do not always account for changing local land use, socioeconomic, and natural conditions. Blessing et al. (2017) illustrated the potential lack of precision of these approaches when they found that 75% of insured losses in a watershed south of Houston during an 11-year period were located outside of the predetermined FEMA 100-year floodplain.

Remotely-sensed data from satellites or images from over flights can provide more timely estimates of flood impacts, but take hours to process at only one point in time at large spatial scales (Mason et al., 2012; Schumann et al., 2009). More recently, household-level insurance claims and federal flood loss payouts have been analyzed to identify flood impacts (Brody et al., 2018) and risk in general (Mobley et al., 2021). But, this work is done forensically months and sometimes years after an event, and is of little use to decision makers who need more timely information.

In response to the lack of widely available, near real-time flood impact data at the parcel level, researchers are beginning to examine “user-generated content,” a term used to describe data input from the general public engaging in localized events through social media and crowdsourcing platforms. These data sources include Twitter, Facebook, Instagram, Flickr, and city service helplines, including SOS, 911, and 311 calls. Individuals reporting on these platforms can potentially assist local government agencies in collecting, analyzing, and distributing vital information, such as flooding (Li et al. 2018). This ground-up approach, coined “citizen-as-sensors,” captures high-resolution, spatial information essential to understanding and reacting to developing disaster conditions (Zhang et al., 2018). In relation to flooding, data extracted from user-generated content have shown promising results in identifying locations of inundation and provide a more suitable framework for incident management than that of forecasting applications (Smith et al., 2017). These data can improve situational awareness during disaster response, provide direction for rescue personnel, and help managers communicate to residents living in flood-prone areas in advance of a storm event (Brouwer et al., 2018).

The majority of flood-related research relying on user-generated content focuses on data harvested from Twitter. Li et al. (2018), for example, found that mapping Tweets in South Carolina "could provide a consistent and comparable estimation of the flood situation in near real time, which provided a continuous picture of the flooding situation within the whole study area and was able to capture flooded areas that were not mapped by the official map." (pg. 97). Other researchers have used this data source to predict flood risk by recording water depth information from photos (Fohringer et al., 2015), extracting data to detect flood events early in the Philippines and Pakistan (Jongman et al., 2015), and creating more accurate flood probability maps in Indonesia when users detail the exact location of flooding. When a specific location is mentioned in a Tweet, locational accuracy reaches approximately 90 percent, far greater than hydraulically-based FEMA maps (Eilander et al., 2016). While not without its drawbacks, the general consensus from the literature is that social media platforms like Twitter could effectively provide a primary or complementary tool to assist in the planning and response to urban flooding (Wang et al., 2018).

An underrecognized, but promising user-generated data source for flood mitigation and response comes from service helpline call centers, also known as 311. Local governments are adopting these call systems as a way to systematically collect citizen-reported non-emergency service issues, ranging from trash pick-up to flooding. The municipal 311 system was initially put in place as a means of alleviating 911 congestion resulting from high numbers of nonemergency calls that were delaying the delivery of emergency services. In 1997, the U.S. Federal Communications Commission (FCC) established the abbreviated telephone number 311 for non-emergency local government services (Schwester et al., 2009). Baltimore was the first city to implement a 311 system to divert non-emergency calls away from 911 and is still being used to this day (Mazerolle et al., 2001). As of 2017, there were over 70 cities and counties in the United States and 18 cities in Canada offering 311 non-emergency services (Xu et al., 2017). Many of these datasets are open to the public where they can be queried and mapped across local jurisdictions. In 2020, the city Chicago alone received approximately 2.8 million 311 calls (https://www.chicago.gov/city/en/depts/311/supp_info/311hist.html). New Yorkers called the 311 system 37,998 times in the week after Hurricane Sandy in 2012 compared to 4,111 times the previous week (Faber, 2015).

Utilizing 311 information, as suggested in prior studies, proves to be beneficial in determining proper resource allocation (Schellong and Langenberg, 2007), long-term planning initiatives (Xu et al., 2017), and can serve as a means of providing primary or even complementary data for urban flooding events (Wang et al., 2018). For example, an analysis of almost 35,000 311 calls in Miami during Hurricane Wilma in 2005 demonstrated this platform's ability to continuously map citizen notification about damage that was used to assist the County and other agencies (i.e. FEMA, Army Corp of Engineer's) in allocating response resources (Schellong and Langenberg, 2007).

While initial work supports the effectiveness of 311 call data in providing a geographically precise, continuous measure of citizens experience (White and Trump, 2018), little, if any, parcel-level spatial analysis has been done on the degree to which these data can capture flood risk.

Research Methods

Study Area

On the evening of August 25, 2017, Hurricane Harvey made landfall on the central gulf coast of Texas. Moving up the coastline and towards the heavily imperious landscape of Houston, Texas, Harvey's intensity slowed, dumping vast amounts of rain for over a week straight. According to (Blake and Zelinsky, 2017), direct and indirect losses caused by Hurricane Harvey resulted in an estimated $125 billion in damage. Federal payouts through the National Flood Insurance Program (NFIP) and Individual Assistance (IA) grants, both operated by the Federal Emergency Management Agency (FEMA), amounted to over $10.4 billion in direct losses (GCRT, 2018). Approximately 200,000 structures in the Houston/Harris County area alone were inundated. Despite these staggering losses, the actual impact of the storm may never be known because many structures and homes that experienced damage were not covered by flood insurance due to their presumed risk being near zero - according to Flood Insurance Rate Maps (FIRM) from FEMA. In accordance with FEMA regulations, structures and homes located within the designated 100-year floodplain are required to own and maintain flood insurance. The Houston area most impacted by Hurricane Harvey provides an ideal study area and large-scale urban flood event to better understand the degree to which 311 calls, as user-generated content, inform the nature of flood hazards.

Study Sample and Variable Measurement

Using open source 311 data provided by the city of Houston (https://www.houstontx.gov/311/), we statistically and spatially analyzed flood-related calls during the period of Hurricane Harvey impact in 2017. The city established its 311 Houston Service Help-line in 2001, a consolidated call center designed to assist residents reporting non-emergency concerns. Multiple departments within the 311 are responsible for responding to service requests, such as water leaks, property nuisances, as well as flooding, storm drainage, and storm debris collection. In 2020 alone, the call center received over 373,000 service requests.

Our study sample was based on a total of 77,600 311 service request calls made between August 23, 2017 and October 25, 2017, which is the time period considered by the city as being impacted from Hurricane Harvey. Similar to Wu et al. (2017), we selected requests under the following categories: 1) flooding, 2) drainage, 3) storm debris collection, 4) street hazard, 5) crisis cleanup, 6) sewer wastewater backup, and 7) water leak. We analyzed data across numerous related categories to obtain the fullest possible understanding of the storm impact. These impacts, as interpreted by the caller, include not just inundation, but also debris, street flooding, water leaks in the house, etc. Distinguishing between flood-related categories also provided the opportunity to examine the type and timing of different impacts.

Calls were joined to a parcel using the geo-reference identifier (X and Y Coordinates) provided in the 311 data set. Calls located outside of a parcel, or had no geo-reference identifier, were eliminated from the sample, resulting in a total of 25,540 flood-related 311 service request calls during the study period. After spatially joining the calls to a residential parcel located in Harris County, we generated a study sample of 19,680 311 service requests within 15,275 residential parcels. The difference between these two numbers signify there were residential parcels that made multiple 311 service request calls related to flooding.

Variable Measurement

The sample of Hurricane Harvey 311 calls were spatially measured and analyzed across the following categories: physical/environmental, built/structural, *socioeconomic*, and federally-paid flood losses (see Table 1 for an overview of variables and data sources). Variable measures were derived by joining call attributes to a residential parcel dataset for Harris County.

Physical landscape and environmental markers were measured to gain a better understanding of how a resident's geographic position may influence the amount and type of call. Percentage of calls were categorized by name of watershed and FEMA-defined flood zone (Floodway, 100-year, 500-year, and outside 500-year). Average distance from each FEMA flood zone and nearest stream segment were also recorded. Elevation of each call was measured using a United States Geological Survey (USGS) 10-m digital elevation model (DEM). Finally, the level of inundation for each parcel with a call was measured based on the official (also used by the state in the *Eye of the Storm* report) USGS flood model that indicates how much water covered the site during the storm period.

Built environment variables provide information on the type of residential structure associated with 311 service requests. For each parcel, we measured the age of structure and its assessed value using data obtained from ATTOM Data Solutions, Inc. The average values for these variables were also compared to those of Harris County based on U.S. Census Block Group ACS 5-year Estimates to better understand the degree to which calls represent built environment characteristics for the broader residential county population.

Multiple socioeconomic variables were also measured to describe characteristics of the caller responding to flood event. Estimates were obtained from the U.S. Census ACS 1-year and 5-year Estimates on median age, household income, home ownership, and percent education for the population 25 years and over for each request. Measures were based on the U.S. Census Block Group level, the lowest available spatial scale. Each socioeconomic variable was also compared to overall county estimates.

Lastly, we measured several variables based on federally-paid flood losses to estimate the degree of damage incurred by callers in the sample. Total payments under both the National

Flood Insurance Program (NFIP) and the Individual Assistance (IA) program were calculated for each parcel. These federal financial relief programs, both administered by FEMA, provide information on residential structures that accrued damages caused by flooding from Hurricane Harvey. These two datasets detail the presence of a claim for federal funding, estimated damage amount, and total payout amount. Structures insured by NFIP can be covered up to $250,000 for structural damage and up to $100,000 for content damage as a result of flooding (FEMA, 2018). On the other hand, IA relief funds are not meant to cover the full extent of home damage, but can provide up to $33,000 (adjusted each year) for basic home repairs, replacement of essential household items and/or temporary housing (Lindsay, 2017). These point-level data provided a key opportunity to better understand how calls aligned with economic losses at a level of detail never seen before.

Table 1. Variables and Sources of Data

Dependent Variable	Source	Measurement
311 Service Request Calls	www.houstontx.gov/311/	
Physical Environment		
Watershed Boundaries	HCFCD	
Flood zone Features	FEMA	Meters
Major River and Streams	H-GAC CRP	Meters
Elevation (meters)	USGS	Meters
Flood Inundation Level	USGS H&H Model	Feet
Built Environment		
Building Age (years)	ATTOM	Years (#)
Building Assessed Value ($)	ATTOM & U.S. Census ACS 5-year Estimate	Dollars ($)
Socioeconomic		
Median Age (years)	U.S. Census ACS 1-year Estimate	Years (#)
Education	U.S. Census ACS 5-year Estimate (Pop. 25 years and over)	
Median Household Income ($)	U.S. Census ACS 1-year Estimate	Dollars ($)
Home Ownership	U.S. Census ACS 5-year Estimate	
Federally-Paid Flood Loss		
National Flood Insurance Program (NFIP) ($)	FEMA	Dollars ($)
Individual Assistance (IA) ($)	FEMA	Dollars ($)

Data Analysis

Spatial data were analyzed descriptively using means, medians, and frequencies. Multiple variables were also compared to county estimates to provide insight into the degree to which requests are representative of the larger population or possibly some biased subsets. GIS-based maps were also produced to exemplify spatial patterns of data when appropriate.

Results

Table 2 shows the number of total 311 service request calls made for each of the seven 311 service categories. A daily temporal distribution of each flood-related 311 service request call by service category across the nine-day timeframe of Hurricane Harvey are illustrated in Figure 1. The majority of 311 service request calls were to report storm debris and flooding, respectively. Most 311 service request calls associated to flooding were made at the beginning of the storm between days 1 and 4 when the inundation first occurred. In contrast, calls associated with storm debris collection were more prevalent during days 3 through 6 after the damage had already been done.

Table 2: 311 service request calls made by service type

Service Type	Number of 311 Calls Made	Percent of Total
Drainage	1,265	6.43%
Flooding	3,567	18.13%
Sewer Wastewater	2,847	14.47%
Storm Damage	181	0.92%
Storm Debris Collection	8,326	42.31%
Street Hazard	982	4.99%
Water Leak	2,512	12.76%
Total	**19,680**	**100%**

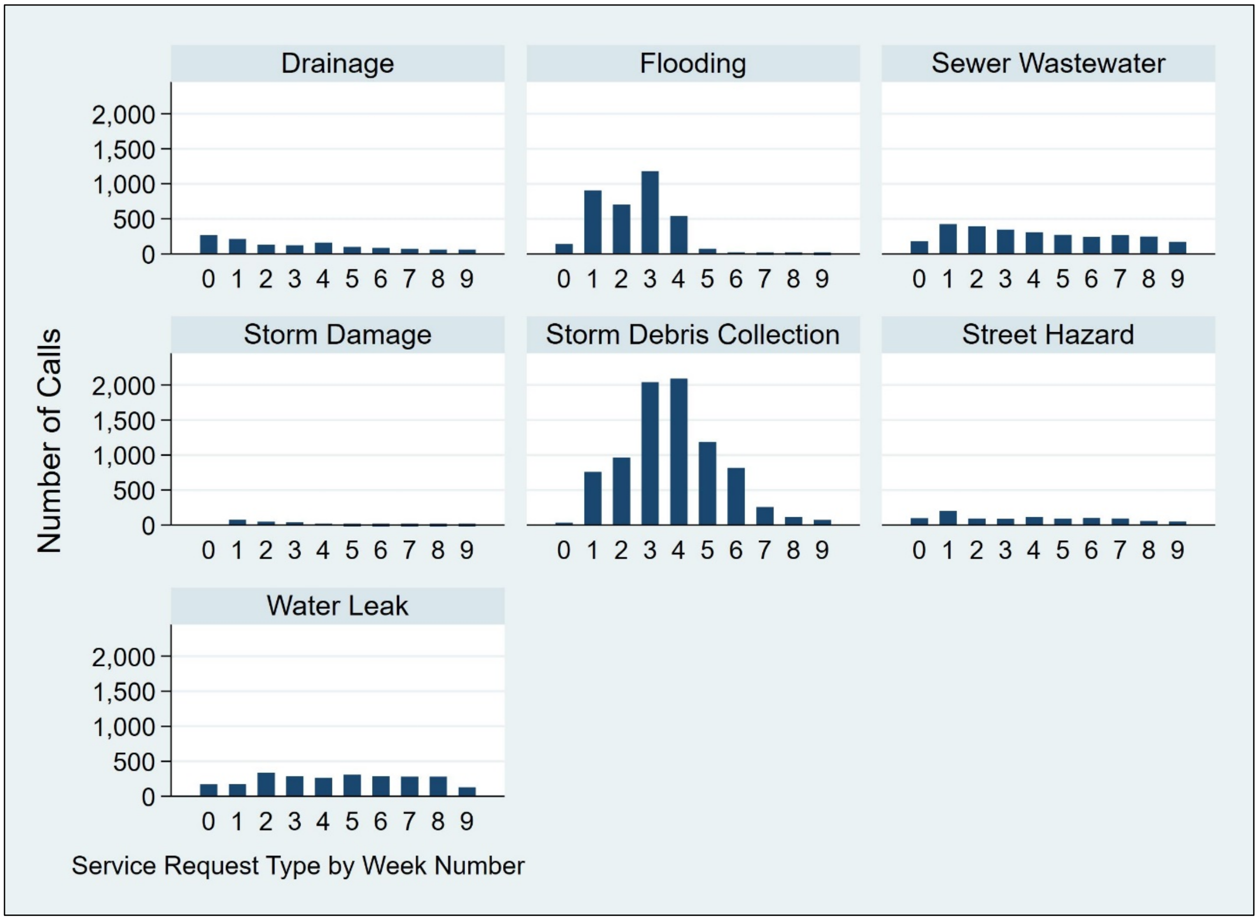

Figure 1: Temporal distribution of 311 calls by service category

The following sections disaggregate the Hurricane Harvey data by spatially examining the 15,275 residential parcels that experienced at least one flood-related 311 service request call across multiple contextual characteristics. By doing so, we form a better understanding of what these calls represent and if they are sound predictors of flood hazard.

Physical/Spatial Markers

The vast majority (75 percent) of flood-related 311 service request calls were located within the following 5 of the 19 Harris County watersheds: Brays Bayou (25.66%), Buffalo Bayou (21.46%), Sims Bayou (15.02%), White Oak Bayou (13.68%), and Greens Bayou (10.09%). As shown in Table 3 and Figure 2, the majority of calls were concentrated in Brays Bayou to the southwest of downtown Houston. Residents have struggled with chronic and severe flooding in this area for decades (Bass et al., 2017). Hundreds of millions of dollars in federal insurance claims have been paid out in Meyerland, Bellaire, and other neighborhoods surrounding the Bayou. Most recently, the USACE completed a long-term, $500 million project to increase the channel's capacity for drainage purposes (Juan et al., 2020). Buffalo Bayou, received the second highest number of calls largely due to a controlled release of Addicks Reservoir upstream that resulted in the flooding of approximately 4,000 additional homes during the storm event (Sebastian et al., 2017). Residents along this Bayou were not historically accustomed to flooding to the same degree as Brays, resulting in a record number of 311 calls from this area.

Table 3: Percentage of 311 Calls by Watershed

Rank	Watershed Name	Number of Residential Parcels	Percentage of Residential Parcels
1	Brays Bayou	3,920	25.66%
2	Buffalo Bayou	3,278	21.46%
3	Sims Bayou	2,294	15.02%
4	White Oak Bayou	2,089	13.68%
5	Greens Bayou	1,542	10.09%
6	Hunting Bayou	731	4.79%
7	San Jacinto River	584	3.82%
8	Clear Creek	530	3.47%
9	Armond Bayou	153	1.0%
10	Addicks Reservoir	97	0.64%
11	Cypress Creek	27	0.18%
12	Luce Bayou	9	0.06%
13	Barker Reservoir	7	0.05%
14	Carpenters Bayou	6	0.04%
15	Not Associated	3	0.02%
16	Spring Creek	2	0.01%
17	Cedar Bayou	1	0.01%
18	Vince Bayou	1	0.01%
19	Willow Creek	1	0.01%
	Total	**15,275**	**100%**

While over 75% of residential parcels with at least one flood-related 311 service calls were concentrated in just 5 watersheds, even more revealing is that over 55% of these residential parcels are located completely outside FEMA-designated floodplains (Figure 3). Calls within the 100-year floodplain accounted for 3,515 (23%) of residential parcels in the sample; similarly, there were 2,921 (19.14%) calls located in the 500-year floodplain. A total of 8,599 (56.29%) residential parcels with at least one flood-related 311 service request call were located in the FEMA X-Zone, traditionally considered very low risk for flooding.

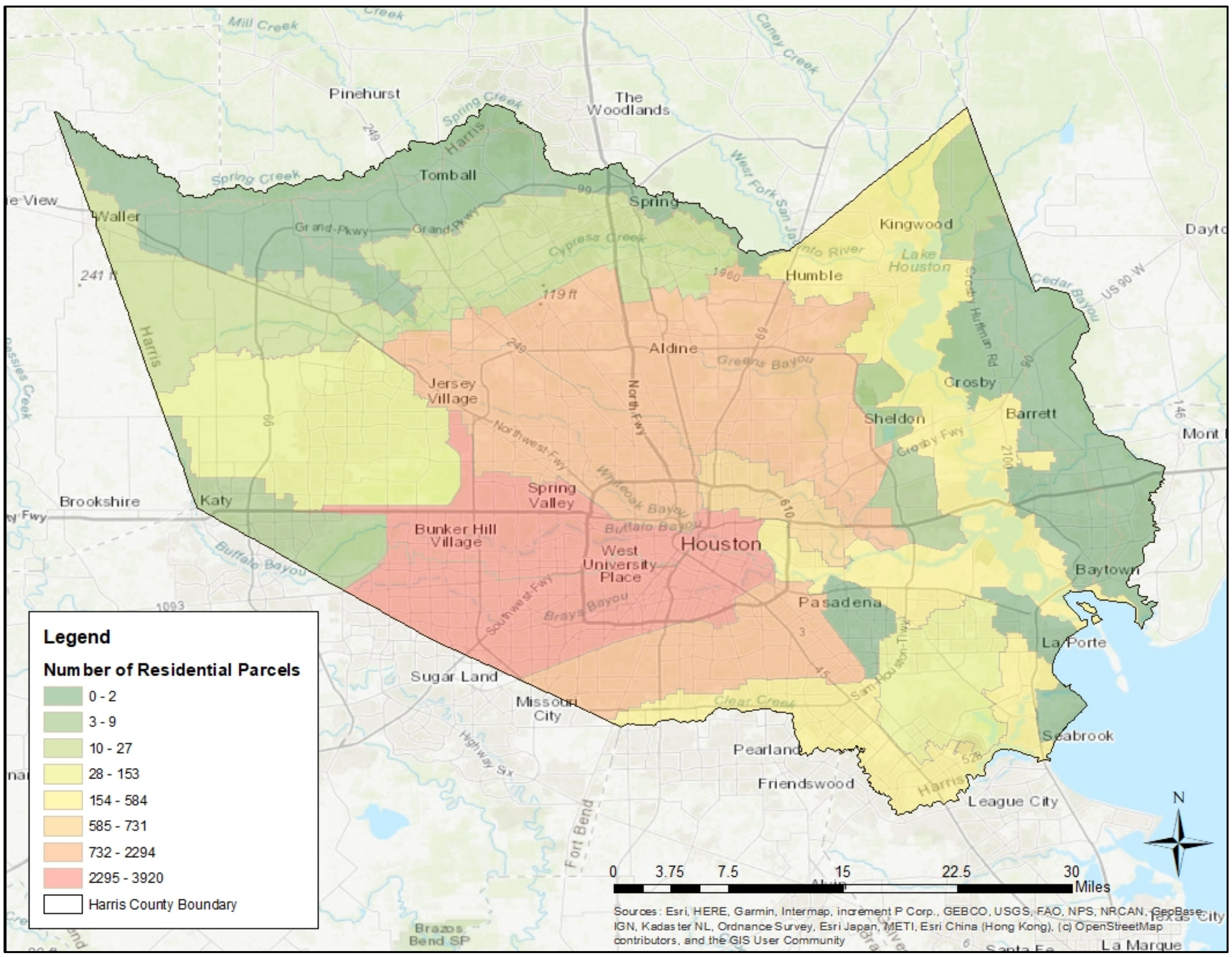

Figure 2: Number of 311 Calls by Watershed in Harris County, TX

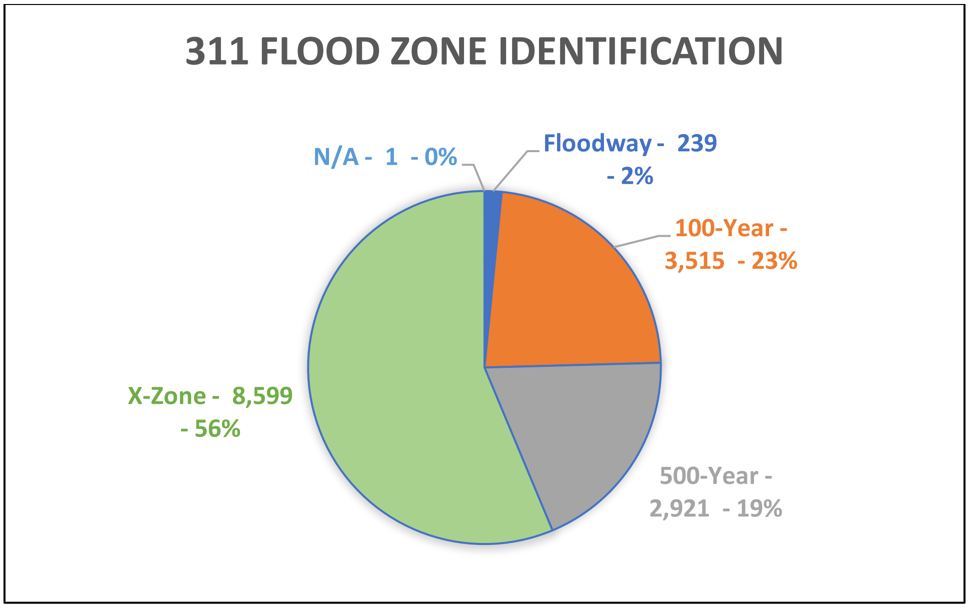

Figure 3: Percentage of 311 Calls by FEMA Flood Zone

Because such a large percentage of flood losses have historically occurred outside FEMA-designated floodplain, particularly during Hurricane Harvey, we also calculated the distance of each call from FEMA floodplain boundaries. This analytical approach also indicates the geographic extent of concern and potential impacts of the flood event. As show in Table 4, calls originating outside of the FEMA 100-year floodplain were, on average, over 600 meters away from this boundary in planar distance. Calls from outside the 500-year floodplain were similarly almost 600 meters away from a 0.2 percent change of inundation. Some calls were upwards of half a mile away.

We also calculated distance of all calls from the nearest stream segment. On average, all calls whether inside or out of a FEMA floodplain designation, were located over 440 meters from a water body prone to flooding from excessive runoff. Measuring the elevation above sea level for each residential parcel with a 311 call during Hurricane Harvey provided an indicator of inundation risk even within an overall low-lying landscape. The average elevation of callers was significantly lower at 17.13 meters, compared an average of 43 meters county-wide. Lastly, we calculated the level of surface water inundation during the height of the storm calculated by the USGS and used as an official dataset for the state after action report. Callers eventually had, on average, approximately 15.5 inches of flood waters on their property, ranging from 0 to 41 inches.

Table 4: Distance of 311 Calls from Physical Markers of Flood Risk

Physical/Spatial Markers	Observations	Mean	Std. Dev.	Min	Max
Floodplain Distance (m)	11,521	600.28	569.04	0.015	2769.21
500-year Flood Zone Distance (m)	8,600	598.16	536.99	0.094	2564.21
Stream Distance	15,275	440.25	428.89	1.9	3020.35
Elevation (m)	15,275	17.13	5.3	1.08	52.78
Flood Inundation Level (in)	15,275	15.59	6.68	0	41

Built Environment Markers

Structural characteristics, such as structure age and value were also calculated for the sample of 311 call (Table 5). Of the 15,275 residential parcels available for analysis, mean structure age is 51 years with a median assessed value of $137,519. In general, calls were made from older residences with lower assessed values compared to Harris County overall.

Table 5: Built Environment Characteristics of 311 Calls

Built Environment Variable	Residential Parcels with a 311 call	Harris County Average
Mean Structure Age	51	36
Median Assessed Value	$137,519	$174,000

Socioeconomic Markers

Socioeconomic characteristics were also calculated at the U.S. Census Block Group level related for the sample of 311 calls. These variables, including median age, education, median household income, and home ownership descriptively provide an indication of household composition concerned about or adversely impacted by the storm event (Table 6). Level of education generally tracks with the overall county average, except a larger percentage of household making 311 calls for flooding had less than 9th grade completion (12.35 vs. 10.4 percent). The median age, collected from the U.S. Census ACS 1-year Estimate, was 36.4 compared to the Harris County average of 33.7. The median household income of residential parcels with a 311 call was $63,801 compared to the Harris County median of $60,232. Lastly, the average rate of home ownership was 56.65 percent for 311 callers, very similar to the county-level within which they were located. In general, the sample of callers were socioeconomically similar to the overall Harris County population.

Table 6: Household Socioeconomic Characteristics at Block Group Level

Socioeconomic Variables	Residential Parcels with a 311 call	Harris County Average
Less than 9th Grade	12.35%	10.40%
9th to 12th Grade; No Diploma	9.25%	8.20%
High School Diploma	22.79%	23.40%
Some College; No Degree	18.60%	19.60%
Associates Degree	5.34%	6.70%
Bachelor's Degree	19.40%	19.90%
Graduate or Professional Degree	12.27%	11.70%
Median Age	36.4	33.7
Median Household Income	$63,801	$60,232
Home Ownership	54.65%	54.10%

Federally-Paid Flood Loss

One of the important aspects of assessing how 311 calls capture flood impacts is the degree to which they coincide with federal payouts to cover losses. Parcel-level claims paid under the NFIP and IA programs provide a rare opportunity to spatially connect observed with perceived or experienced impacts. A total of 3,936 NFIP claims were subsequently made from the 15,275 residential parcels with estimated damage of $664,566,366, and total payout of $632,628,281. There were 6,405 IA claims with estimated damage of $112,783,208, and total payout of $42,867,715.

As shown in Table 7, over 24 percent of residences making calls eventually received some level of federal financial assistance based on actual damage to their homes. Only 6.8 percent of the sample filed an NFIP claim, mostly for flood inundation, storm damage, and debris collection. In contrast, almost double this amount filed an IA claim associated with the same service request types.

Table 7: Federally-Paid Flood Loss Claims by Service Request Type

Service Request Type	Percent NFIP Claims	Percent IA	Percent Both	Percent Neither
Drainage	4.19%	13.44%	10.04%	72.33%
Flooding	9.45%	28.37%	32.02%	30.17%
Sewer Wastewater	4.12%	8.54%	4.78%	82.58%
Storm Damage	8.29%	25.41%	23.76%	42.54%
Storm Debris Collection	8.80%	21.37%	29.07%	40.76%
Street Hazard	4.58%	11.41%	10.49%	73.52%
Water Leak	3.18%	8.72%	7.01%	81.09%
All Services (19,680 311 calls)	**6.80%**	**17.46%**	**18.97%**	**56.77%**

Discussion

This study assesses the potential of using flood-related 311 service request calls to better understand flood hazards and impacts. These calls reflect the real-time experience of residents being impacted by storms rather than hindsight inspections or forensic investigations months after the fact. First, 311 calls record a much broader scope of flood impact rather than solely water inundation that results in property damage. For example, over 42 percent of calls during Hurricane Harvey were related to troublesome storm debris, something hydrologic models or insurance claims fail to detect. If flood impact analysis was based only on flood category calls (around 18 percent of all storm-related calls), a comprehensive understanding of the storm's impact would have been missed.

Second, 311-service request calls can be used to inform local and regional officials on where watershed-level projects are needed, as well as prioritize funding applications for HMGP, BRIC, and other federal programs. Our results show that over 75% of calls were located in just 5 of the 19 watersheds intersecting Houston. Being able to track and measure both acute and chronic flood issues experienced by residents over time would help localities better articulate the need for project funding and implement plans that most appropriate address flood impact hotspots.

Third, 311-service calls effectively capture impacts outside of traditional FEMA-defined flood zones traditionally considered the main marker of risk. Over 56 percent of all calls in the sample were located outside of both the FEMA 100 and 500-year floodplain boundaries. These results are very close to official county-level forensic analyses of building damages from Hurricane Harvey. The ability of the 311-call dataset to detect impacts disconnected from bayou overflow is important because development is increasingly driving flood losses far away from traditional floodplains and into neighborhoods once thought to be safe from inundation. Recording trends of flood impacts in x-zones would enable local decision makers to understand and prepare for flooding caused by expanding urban development.

Lastly, only about a quarter of 311 calls during Hurricane Harvey were later linked to either an NFIP or IA claim. This finding indicates that using federal payouts to residents as a way to measure the impact of a flood event (see: Highfield and Brody, 2017; Blessing et a., 2017; Brody et al., 2018) is not sufficient. Given the low insurance penetration rate and the sporadic nature of individual assistance claims, using these traditional data will not capture the true impact of a flood, particularly one as large as Hurricane Harvey. Another indicator of the usefulness of using 311 calls to capture structural flood loss is the distribution of water depth during the storm. Approximate 62 percent (9,455 calls) of our sample had at least 14.5 inches of scientifically-measured water on the site. Over 32 percent (3,070 calls) led to NFIP claims and almost 39 percent (3,670 calls) resulted in an IA claim. The majority of calls had enough water depth to result in flood losses, which is backed up by the large amount of federal assistance requested. The results suggest that researchers and decision makers alike should consider near real-time data streams based on human sensors and experiences to better understand how to respond to and mitigate these events in the future.

Conclusion

This study is one of the first to spatially analyze parcel-level 311 calls across multiple characteristics of flood risk and impact for one of the largest flood events in U.S. history. Findings suggest that these data could not only be utilized for effective resource allocation in active and for future events, but also improve flood modeling, flood risk maps, and promote general awareness of available services to the public. While this work provides important insights into using human sensor data to understand and respond to flood events, it should only be considered a starting point for more extensive analyses. First, this study analyzes just one historic storm within a single jurisdiction. Future work should consider longer time-frames, both chronic and acute events, and multiple jurisdictions with 311 call centers. There are localities producing geocoded datasets all over the U.S. that would enable an insightful comparative analysis. Second, 311 calls are entirely voluntary and should be treated as such. Just because a parcel or area does not receive a 311-service request call does not mean that the hazard or risk of flooding did not occur. Future research should integrate multiple data streams, both experienced/perceived flood impact and inspected loss after the fact to better understand the nature of flooding in urban landscapes. Finally, this study was purely descriptive. More work needs to be done on explaining the factors contributing to 311 flood calls and the statistical relationship between these data and other types of flood impact measures.

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