# Reported Flood Inundation due to Hurricane Harvey in Houston, TX

A LOOK AT THE AVAILABILITY AND APPLICABILITY OF CROWD-SOURCED FLOOD REPORTS IN UNDERSTANDING HURRICANE HARVEY FLOOD EVENTS

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# 1. Introduction

Hurricanes and resultant flooding entail some of the deadliest natural disasters in the United States, attributing to thousands of deaths and devastation to communities on the hurricane coast (Blake & Landsea, 2011). Impacts to life, livelihoods, infrastructure, and the economy will continue to exacerbate in the future, as the population on the US hurricane coast continues to grow rapidly (Cutter & Emrich, 2006). Flooding is the primary factor in hurricane related deaths. During Hurricane Katrina, flood water depth in a parish was directly associated with mortalities (Cutter & Emrich, 2006). The current flood mapping system does not predict inundation in areas outside of the floodplain, leaving emergency personnel and potential evacuees stranded in dangerous flood waters. An understanding of inundation during major storms will allow better planning for, and response to future storms.

### 1.1 Hurricane Harvey in Houston

Hurricane Harvey's recent impact on Houston, Texas caused unprecedented flood levels through the area (HCFCD - Hurricane Harvey, 2017). Harvey's immense rainfall named it the storm of record for the Houston area (Lerner, 2017) and flooded 136,000 structures within Harris County (HCFCD - Hurricane Harvey, 2017). As Harvey set new records for flooding, rainfall, and damage in the Houston area, it also demonstrated unforeseen challenges for local officials and emergency management to manage relief efforts from modelled flood levels. Insurance companies, officials, and citizens rely upon floodplain guidelines.

However, many of the severely affected areas during and after Harvey lay outside of the delineated floodplain, i.e. the areas were pluvially, not fluvially inundated. Emergency management did not have a way to predict or track flooding in neighborhoods, and could not preemptively evacuate residents. As storms of this magnitude become the norm, rather than the exception, it is imperative that accurate estimates of flood levels are available for the safety of citizens, infrastructure, and the economy. Flood events such as Harvey call for more sophisticated and practical models of severe flooding in urban areas. This project aims to consider non-traditional methods of data accumulation, by using social media and crowd-sourced information to track and understand flooding situation throughout the temporal and spatial extent of a storm. These data are compared to traditional flood metrics, such as floodplains, high water marks, and peak river stages, gathered from Houston-area stations during and immediately after Hurricane Harvey.

# 2. Available Data

The two available datasets for flood reports and rescue requests came from the City of Houston 311 database, and a Facebook group entitled "Hurricane Harvey 2017 - Together We Will Make It; TOGETHER WE WILL REBUILD."

The City of Houston data was extracted from August 24 to September 2, 2017 from the 311 database (MyCity Houston Open Data Portal, 2017). It was filtered for reports of floodwater, yielding 1395 flood reports across the time period. As this data came from a government agency, it is well organized and relatively complete, proving to be simple and reputable to include as part of this analysis. However, the spatial range (including only areas officially designated as part of the City of Houston), limits its use over the entire area affected by Hurricane Harvey. At this time, data from affected Houston suburbs, such as Sugar Land, has not been considered.

The Facebook dataset is a stellar example of the power of social media to bring together communities and people in times of hardship. The group was started by Jennifer Cardenas, in an effort to connect people wanting to help to those needing it. She was recognized by Facebook and local news stations (Covington, 2017) for her insight and commitment to helping Houstonians. A feature of interest in the Facebook group is the link to a Google My Maps application (Hurricane Harvey Rescue Application, 2017), where flood victims could specify their location and danger, prompting rescue efforts. The application recorded 4816 rescue requests from its inception on August 27 to September 1, at which point all rescue operations were taken over by government agencies. Although 2558 of these requests are in the Beaumont area, this additional data serves to fill in the gaps of knowledge of flood endangerment in Houston during Harvey.

A major limitation of this data is the lack of standardization of the input table. As the rescue requests came in various forms – from the Google Forms app, from text messages, and from Facebook posts – the data does not follow a specific format. Significant effort was put into extracting time stamps from the data points, yielding nearly 80% success.

Other data was extracted from various sources. USGS Flood Event was used to obtain Hurricane Harvey peak summary data for Harris, Montgomery, and Fort Bend counties (US Geological Survey, 2017). Floodplain data, which included river channels, as well as 100- and 500- year floodplains, was obtained from ArcGIS Online Portal (ArcGIS Online Portal, 2012). A more precise data source was not found. The high water mark data was accessed through the ArcGIS online portal, but reflected data gathered from the USGS (US Geological Survey). The stormwater line data was also accessed from the ArcGIS online portal, but published by MyCity Houston (MyCity Houston).

# 3. Analysis and Results

## 3.1 Crowd Sourced Inundation metrics

The two datasets yielded thousands of points, reflecting residents across the Houston area needing rescue efforts and/or flood relief. As these data are not verified, it is not valid to extrapolate any information from individual data points. However, trends in the data over time and space are seen clearly as the storm progressed. The Point Density tool in ArcGIS converted the point shapefiles into a raster of the density of points in each area. The default cell size and radius setting were used in each of the following maps. The following figures show the results from the Point Density tool for the aggregated Facebook and City of Houston 311 data, as well as the data for each day from August 26 – August 29. The remaining three days of data were not included, as they primarily recorded points in Beaumont, TX. The Point Density function did not notice any significant trends in the Greater Houston area during this time period.

The complete set of point data, shown in Figure 1, identified two areas of major inundation: southwest Houston, near Sugar Land, and northeast Houston, near Kingwood. Other noticeable areas affected include those in west Houston, near Memorial and Katy.

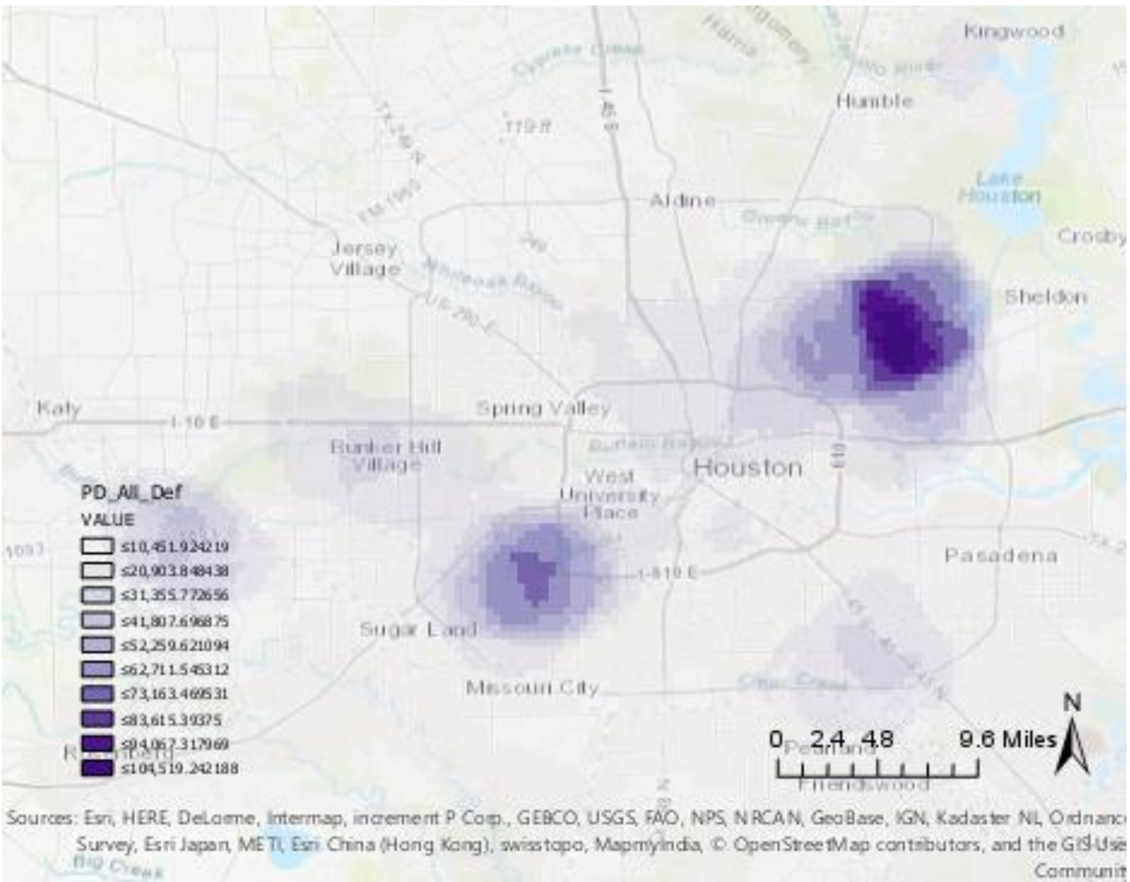


*Figure 1. Point Density of All Collected Points*

Figure 2 shows the Point Density function results for each day with significant flood reports in the Greater Houston area. This is useful to see how the flooding situation changed across the time period of the storm and in the days after.

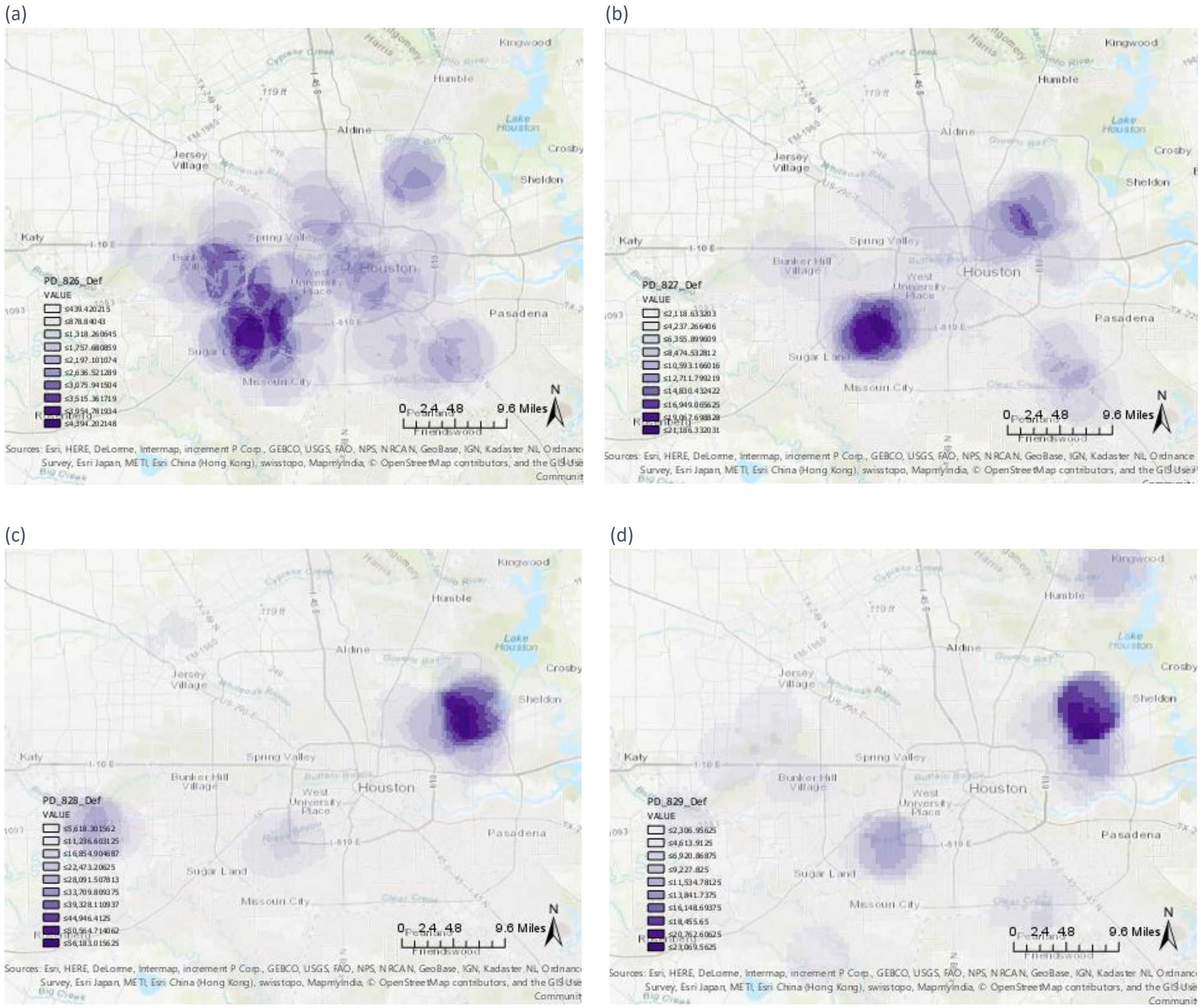


*Figure 2: Point Density of Daily Recorded Points (a) August 26 (b) August 27 (c) August 28 (d) August 29*

### 3.2 USGS River Peak Summary Comparison

The USGS Peak Summary data during Hurricane Harvey contained data about the peak stage value and time across the stream gages in Houston. Creating Thiessen polygons across the Houston area showed times of peak stream stages. Although more refined time data is available, the peaks were summarized by day to compare to the flood report data. Only one day (August 29, 2017) overlapped with significant point density and peak stage times, and is shown in light blue in Figure 3. There is no clear spatial correlation between the river channels reaching the peak of the flood wave and neighboring inundation reports. However, this is expected for this storm, as most of the flooding proved pluvial rather than fluvial in nature.

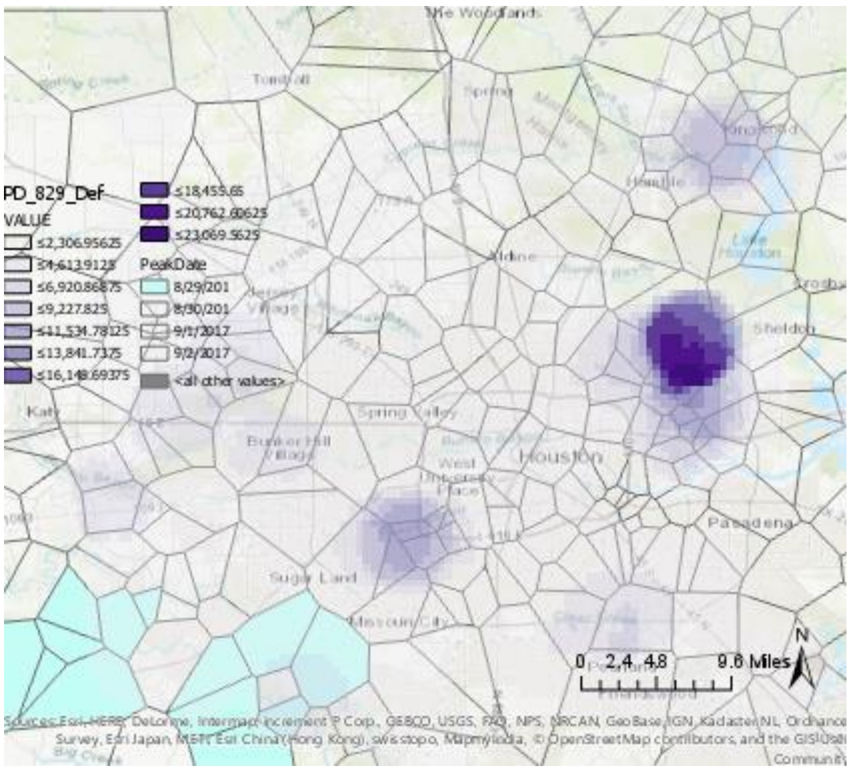


*Figure 3: USGS Peak Summary Days as Thiessen Polygons*

### 3.3 Fluvial Floodplain Comparison

Similarly, a comparison of the entire suite of flood reports to the floodplain for the region yields small overlap. However, both the floodplain mapping and flood reports show flooding in the southwest portions of Houston, near Sugar Land and Missouri City, as can be seen in Figure 4. These areas are known to have severe flooding during the storm, and it validates both the floodplain and the effectiveness of the crowd-sourced data.

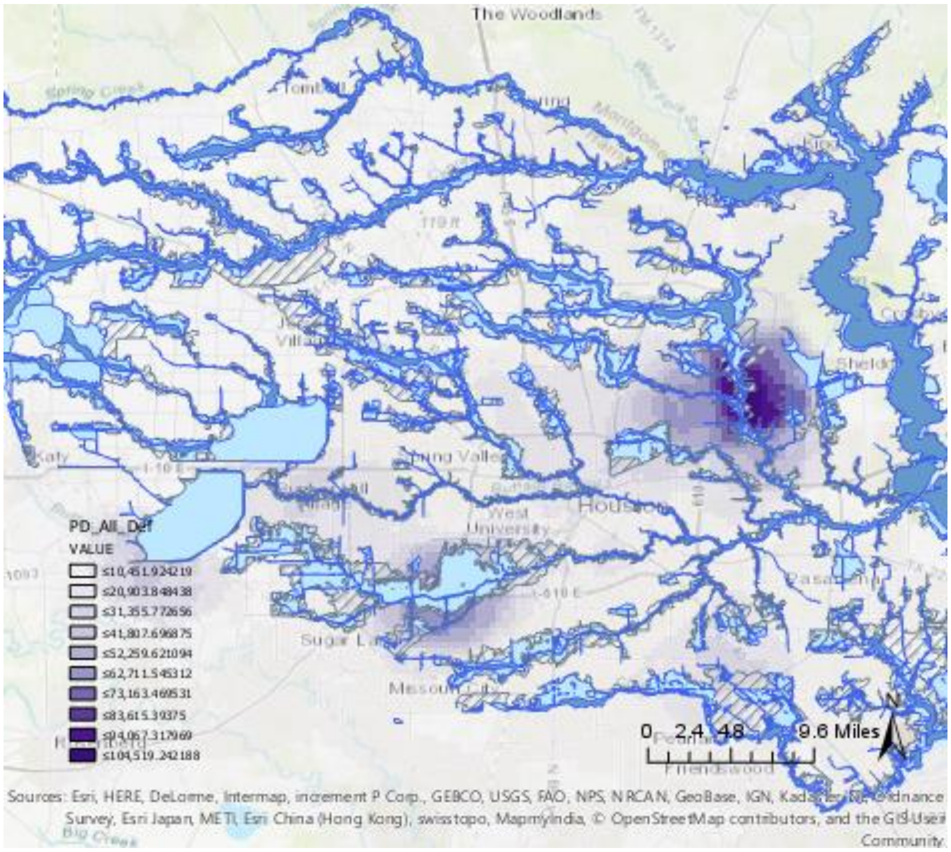


*Figure 4. Floodplain and Point Density*

### 3.4 USGS High Water Mark Comparison

Using the USGS High Water Mark data, a TIN surface was created, with hopes of showing higher water elevation recorded in areas with more reported flooding. However, the only major trend discernible in the resulting TIN raster (Figure 5) is that of the natural elevation change from the inner areas to the coastal boundaries.

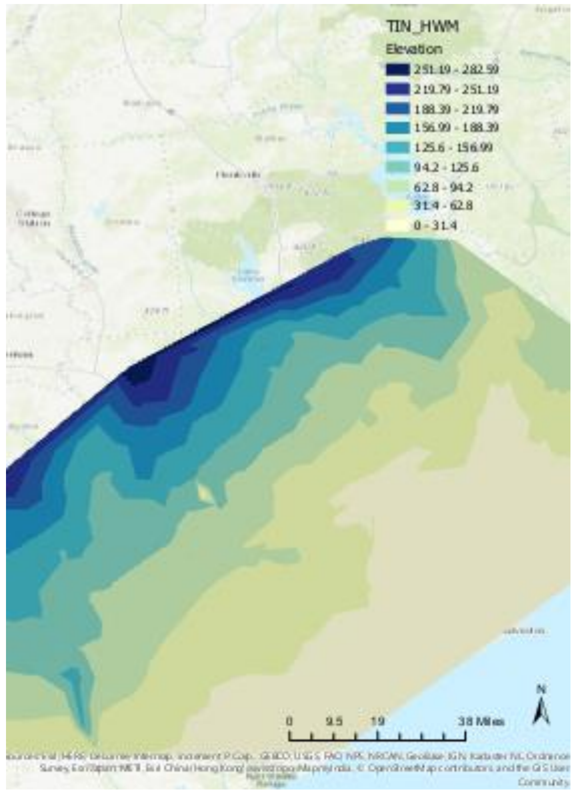


*Figure 5. TIN Surface Raster for High Water Marks*

## 3.5 Stormwater Drainage Network Comparison

As it can be shown that much of the Hurricane Harvey flooding occurred outside of the floodplain, it is imperative that more attention is given to future pluvial flooding possibilities. A critical component of managing rainfall runoff is an urban stormwater drainage network. Houston is notorious for its lax rules on urban drainage systems, and therefore lacks thorough stormwater infrastructure. The comparison of reported inundation points to the availability of a stormwater network is shown in Figure 6 below. This figure focuses on a neighborhood in Kingwood, TX, near Lake Houston. This analysis proved inconclusive, as the stormwater network is too dense to examine qualitatively on a broader scale.


*Figure 6. Stormwater Network in Kingwood and Reported Flooding Points*

## 4. Conclusion

This project examined two sets of flood and rescue report data, from the City of Houston 311 calls, and a social media platform connecting victims and helpers during the devastation of Hurricane Harvey. Creating a single dataset with both types of data proved incredibly time-intensive, but in the end a dataset with latitude, longitude, and (most) time stamps was extracted for 6,211 points. This dataset was compared with various measures of fluvial inundation, including the delineated floodplain, the peak flood waves at various stations along rivers, and the high water marks across the region. This primary analysis highlighted the failure in fluvial inundation prediction during Hurricane Harvey, and the need for better pluvial inundation measurement and prediction techniques. The stormwater drainage system was obtained in order to compare to areas of high and low pluvial inundation, but the density of this data made it difficult to assess within the scope of this project.

The primary takeaway from this semester project is the use of crowd-sourced emergency management data in future research and governmental applications. A simple smartphone application, developed prior to such an event, would have provided a streamlined way for affected citizens, emergency personnel, government agencies, and future researchers to record, rescue, and plan for future events. In today’s world, every one travels around with a high-quality camera, a built in GPS, and the ability to record and transmit information through their smartphones. It would be worthwhile and useful to create an official method of recording flood levels and starting rescue efforts through a smartphone app. Crowd-sourcing information could yield a more useful, dense, and time-sensitive dataset than that of traditional sensing methods.

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