The Harvey Data Project:

City of Houston Housing and
Community Development
Department

March 2019

Executive Summary

After Hurricane Harvey, the stakes were high for the City of Houston in correctly accounting for the full costs of the storm on the city's housing. Between 2015 and Harvey in August 2017, Houston experienced five federally-declared flooding disasters, meaning that many Houstonians had yet to recover from previous storms when Harvey struck. The federal disaster recovery framework is based on a calculation of "unmet need" for housing and other factors. However, traditional methods of calculating this need are based on outdated metrics that exclude anyone who didn't apply for, or receive, Federal Emergency Management Agency (FEMA) assistance after the storm. If Houston's unmet need was chronically undercounted, then its recovery was also being chronically under-resourced.

In February 2018, just a few months after the storm, City Council approved an ambitious new approach for assessing housing damage from Harvey. This new methodology would be based on a combination of data sources, predictive data analytics, and a deep understanding of Houston's most vulnerable communities. The Housing and Community Development Department (HCDD) contracted with Civis Analytics to execute the Harvey Data Project. Together with project partners Dewberry Engineers and Houston-based consultants Knudson, LP, the Civis team built a sophisticated data platform for understanding Harvey in Houston.

This report presents key findings from the Harvey Data Project, compares Houston's new methodology to existing methods of calculating residential impact from a storm, and suggests how Houston (and potentially other jurisdictions) can build on the project for the future. The Technical Appendix includes additional information on methodology.

The innovative methods used in this project will be beneficial to plan for and respond to increasingly common and high-impact disasters both in Houston and wherever different jurisdictions interact with Federal disaster recovery programs. The United States is experiencing natural disasters at

Three Years, Five Disasters

Total residential damage: $17.5B

2015 | $525 M Residential Damage

Memorial Day Flood   **Halloween Flood**

2016 | $159 M Residential Damage

Tax Day Flood   **May/June Flood**

2017 | $16 B Residential Damage

Hurricane Harvey

a quickening pace, with impacts stretching from the Atlantic coast to California. To prepare for potential future natural disasters and allocate sufficient resources, communities see the value in understanding how damage from disasters is calculated. Houston's approach is important to understand as the country wrestles with new kinds of disasters, including slow-moving rain events like Harvey.

Houston Flood Photographs by Chron News, **Memorial Day Flood, Halloween Flood, Tax Day Flood,** and the **May/June Flood.** Hurricane Harvey aerial view Photographs by Air National Guard photo by Staff Sgt. Daniel J. Martinez.

Key Findings

In analyzing housing damage from Harvey, the Harvey Data Project revealed three major themes:

The scope of the storm and flooding was drastic and unanticipated. More than 60% of the area within the full-purpose city limits of Houston was covered by some level of floodwater. This amounted to more than 25% of all Houston households facing some impact from storm waters. More than half of the households impacted fell outside of any FEMA-designated floodplain.

The economic impact is not distributed evenly, and some populations are more vulnerable to the fallout. Looking only at places where flooding was most extreme misses that some hard-hit areas have already received large amounts of recovery assistance, while other areas with lower total damage estimates might have more difficulty recovering. Twelve neighborhoods have been identified that suffered heavy damage in addition to being socially vulnerable due to conditions before the storm. In the 59 Census tracts identified as highest-risk, there were 31,000 households that experienced loss of more than 50% of their annual income, with an average of $26,000 in remaining unmet need per household.

Traditional techniques underestimate total damage, hiding a need for further financial support. Total residential damages from Harvey are estimated at $16 billion, almost $13 billion of which is not met by federal recovery programs. Traditional methods estimated that $1.2 billion of damage qualifies as "serious unmet housing need", eligible for extra recovery funds, but the Harvey Data Project shows that in reality $3.1 billion worth of damage meets that same standard.

The following sections include a deeper exploration of these findings, and a discussion of their inception.

1 square = 10% of Houston Residences

1 in 10 households had flooding in the first floor of their house, with an additional 2 in 10 households with some damage to the home. 7 in 10 residences were not directly impacted, however may experience other indirect impacts.
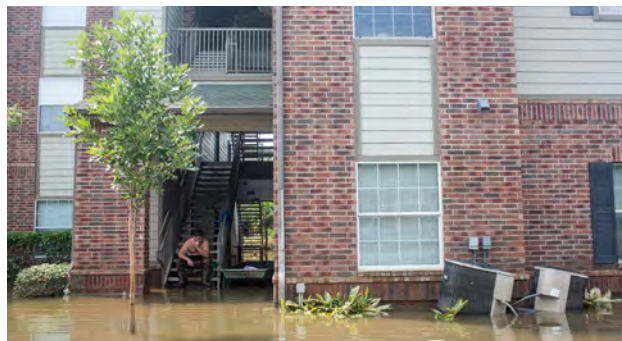
2 in 10 residences were impacted by indirect residential flooding. Even if a home is elevated, structural parts of the home can be damaged if flooding occurs up to the edge of the residence. Soils saturated by flood-water can cause foundation damage. This type of damage puts significant strain on the foundation, and can also cause wear and cracking to window and door frames.

1 in 10 residences were impacted by direct residential flooding. When floodwaters enter the home it can significantly damage many parts of the residence, sometimes beyond repair. Some potentially vulnerable parts of the home include the foundation, insulation, drywall, framing, electrical wiring, appliances, carpets, furniture, and other belongings.

Hurricane Harvey Photographs by: Revolution Messaging. Stekelberg, Aaron et al. (2017, Sept 1). "How water damages a flooded house — and which parts can be saved" **link.**
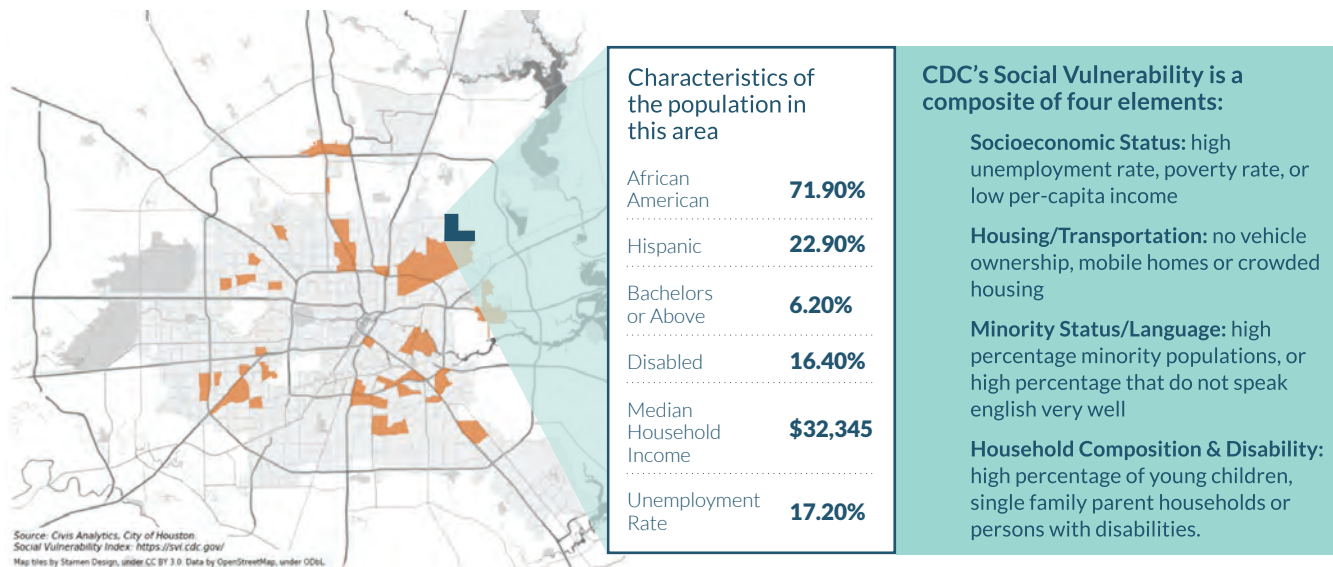
Areas where people are at risk for not recovering from Harvey

How the Harvey Data Project identifies areas with high recovery risk:
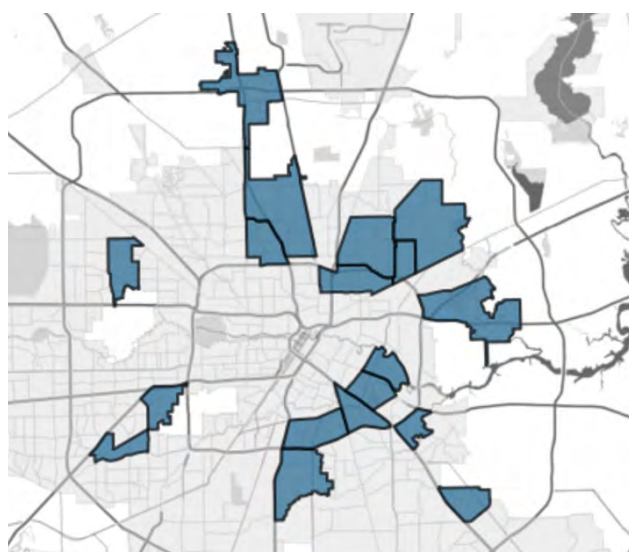
Census tracts within Harris County that are the most Socially Vulnerable. (Top 20% of Social Vulnerability Index)

On average, more than 50% of the tract median income is experienced as loss.

More than 40% of residential buildings were damaged.

Characteristics of the population in this area

African American	**71.90%**
Hispanic	**22.90%**
Bachelors or Above	**6.20%**
Disabled	**16.40%**
Median Household Income	**$32,345**
Unemployment Rate	**17.20%**

Source: Civis Analytics, City of Houston.
Social Vulnerability Index: https://svi.cdc.gov/
Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

CDC's Social Vulnerability is a composite of four elements:

Socioeconomic Status: high unemployment rate, poverty rate, or low per-capita income

Housing/Transportation: no vehicle ownership, mobile homes or crowded housing

Minority Status/Language: high percentage minority populations, or high percentage that do not speak english very well

Household Composition & Disability: high percentage of young children, single family parent households or persons with disabilities.

Key Finding #2: 18 Neighborhoods

More than **25%** of estimated neighborhood households are within one of the identified high recovery risk tracts.

Magnolia Park, Settegast, East Houston, Edgebrook Area, Independence Heights, Park Place, Braeburn, Kashmere Gardens, Northshore, Greater Greenspoint, Greater Ost / South Union, Spring Branch Central, Sunnyside, Gulfton, Gulfgate Riverview / Pine Valley, Trinity / Houston Gardens, Northside/Northline, Lawndale / Wayside

[1] CDC's Social Vulnerability Index (SVI). (2018, September 12). Retrieved February 12, 2019, [2] Census Tracts are defined by the US Census Bureau for statistical purposes. Census tracts are not fully contained within Houston neighborhoods. Source: Civis Analytics, City of Houston. Social Vulnerability Index: **link.**

The scope of the storm and flooding was drastic and unanticipated
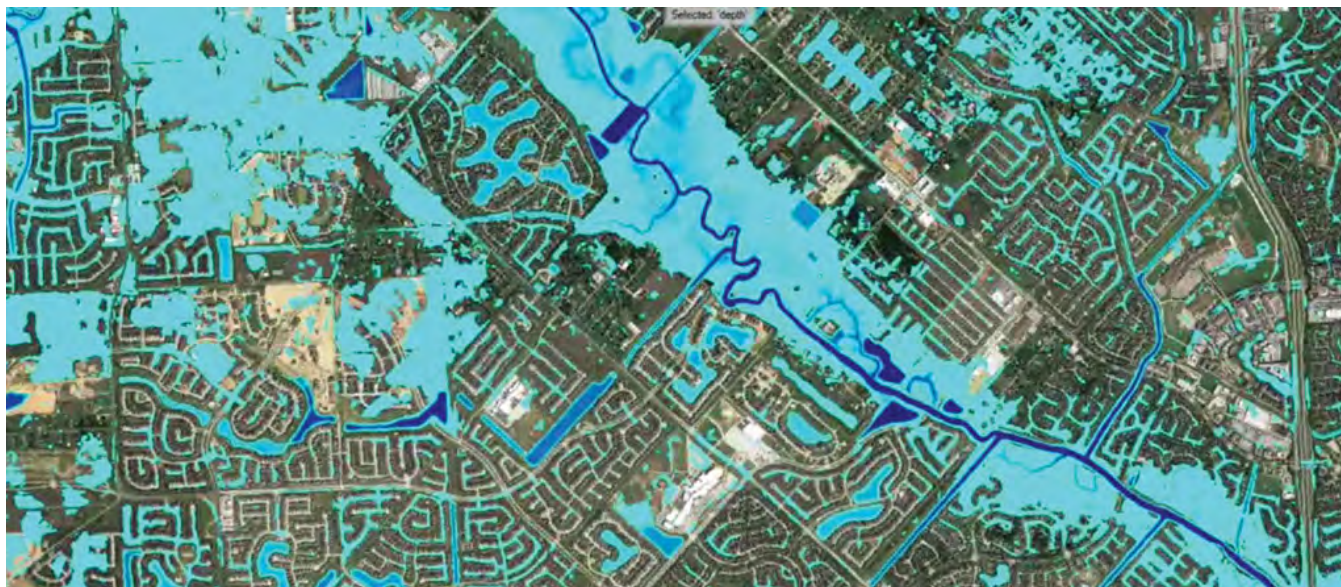
To understand the true scope of flood damage in Houston, the first step was to determine where the flood was. Working with HCDD's GIS team and Dewberry Engineers, a flood inundation model was built to show how deep flood waters reached through the city of Houston and surrounding area during and after the storm. According to the model, **64% of the land area within the full-purpose city limits of Houston were covered by some level of flood water,** far exceeding the 38% of city area that is designated as a flood zone.

FEMA provides projections of flood risk for cities, but the scope of flooding in Houston far exceeded these projections. In most cases of storm preparedness and response, existing models from FEMA show what regions are potentially at risk from extreme or rare floods, either as 100 or 500-year floodplains. But these FEMA designations are based around risk from overflowing in bayous or rivers.

Flooding impact from Hurricane Harvey is an example of "urban flooding". This modern phenomenon refers to heavy, sustained rains pooled and accumulated water over impermeable surfaces

like pavement, or overwhelmed drainage systems that had not been designed with such extreme volume in mind.

The inundation model accounts for this concept by coordinating a significant amount of data from local, state and national sources, including flood gauges, known FEMA claims, satellite imagery, and information about the topography of Houston. By doing so, the Harvey Data Project was able to show where floodwater collected during the five-day period around the storm.
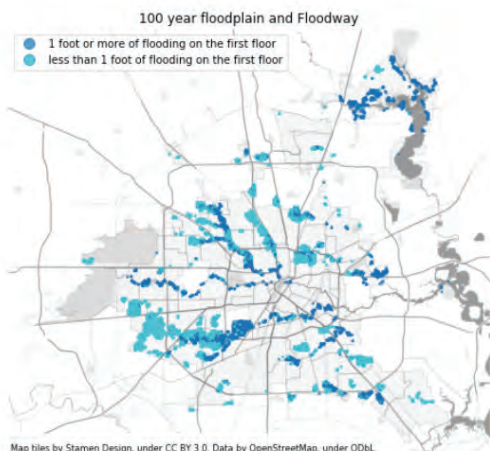
Data from the County Tax Assessor were then overlaid with this to show what properties were in the flooded areas. This analysis showed that approximately **209,000 housing units were impacted by the storm waters,** out of Houston's 771,000 households. According to the deeper inundation areas of the model, **one in ten Houston households had floodwaters inside their homes.** And consistent with the effects suggested by urban flooding researches, the model showed that **more than half of affected residential buildings were outside of any FEMA-designated floodplain.**

Flood Induction Photograph by **Dewberry.**

What are FEMA's Flood Hazard Zones?

The National Flood Insurance Act of 1968 directed the government to identify all flood prone areas in the United States. FEMA (The Federal Emergency Management Agency) conducts flood studies and produces flood maps. A flood study analyzes the terrain and the factors that affect flood prone areas. This information is used to draw the maps that determine floodplain boundaries.
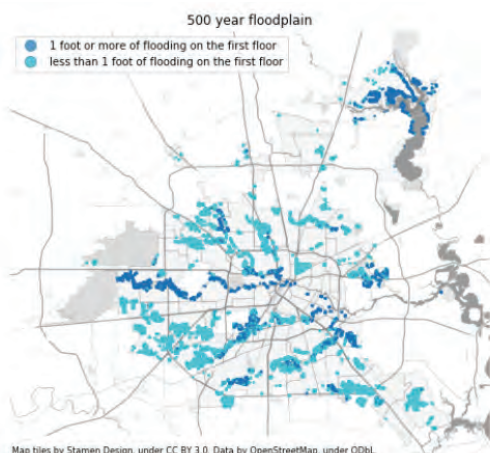
Floodmaps

100 year floodplain and Floodway
- 1 foot or more of flooding on the first floor
- less than 1 foot of flooding on the first floor

Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

Types of Flood Zones

Floodway and 100 year flood zone

Property owners in these areas are required by FEMA to buy federally-backed flood insurance in order to have a mortgage on the property. In these areas there is a 1% chance of river or bayou flooding in any given year.
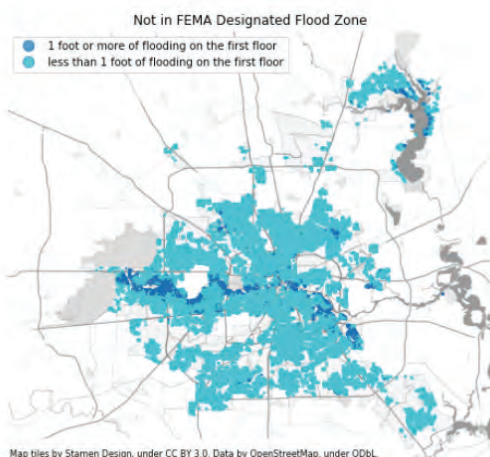
> Approximately **40%** of households in the floodway or 100 year flood zone had direct damage from flooding. **22%** of directly affected households in Houston were in the 100 year floodplain or flood way.

500 year floodplain
- 1 foot or more of flooding on the first floor
- less than 1 foot of flooding on the first floor

Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

500 year flood zone

Property owners in the "500 year floodplain" are not required to buy flood insurance in order to take a mortgage on the property. Homeowners in this area may be aware of flood risk, but they are less likely to take out insurance for it. This zone covers a larger area where river and bayou flooding has an estimated 0.02% chance of happening each year.

> Approximately **30%** of households in the 500 year flood zone had direct damage from flooding. **18%** of directly affected households in Houston were in the 500 year floodplain.

Not in FEMA Designated Flood Zone
- 1 foot or more of flooding on the first floor
- less than 1 foot of flooding on the first floor

Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

Not a FEMA designated flood zone

People who do not reside in one of the FEMA designated flood zones are often the least aware of flood risks in their area.

> Approximately **20%** of households that aren't in a FEMA flood zone had direct damage from flooding. **56%** of the directly affected households are not in a FEMA designated flood zone.

FEMA **link** and IS-9 Managing Floodplain **link.**

The economic impact is not distributed evenly, and some populations are more vulnerable to the fallout from Harvey

In evaluating flood impact to administer relief, it's important to understand not only where the most monetary damage has occurred, but also which areas are still vulnerable and may have a more difficult time recovering. Natural disasters are especially hard on people who are already socially vulnerable, so the Harvey Data Project focused on identifying areas with both significant levels of flood damage and the fewest resources available.

A controlled release of the Addicks and Barker reservoirs by the Army Corps of Engineers exacerbated flooding in some areas. While these neighborhoods with extreme flooding sustained the most damage, they have also received the greatest amount of assistance to date. For example, floodwaters reached depths of more than six feet in the Memorial neighborhood and more than $500 million in federal assistance has already been provided there. That represents approximately 15% of the overall federal assistance received in Houston. The majority of aid in the neighborhood is from federal flood insurance claims as opposed to low-interest loans or other FEMA aid.

When considering the impact of the storm, the team focused not only on the amount of flood damages but also pre-disaster factors that can make it difficult for communities to recover. The Social Vulnerability Index (SVI), a measure developed by the Centers for Disease Control (CDC)[1], identifies areas with lower levels of resiliency to external stresses like natural disasters. Using this metric and the projected damage in each area, the Project identified at-risk areas as those with:

> Very high social vulnerability, meaning the area received a score in the top 20% of social vulnerability on Harris County (above 0.8 on the SVI index)

> Average damages from Harvey totaling more than 50% of the median household income in the area

> More than 40% of residential buildings damaged in Harvey

Using these criteria, 59 Census tracts[2] within the City of Houston were identified as the most at-risk in the recovery process, equivalent to approximately 10% of all tracts in the city. These tracts represent areas where both residents and their communities were affected beyond their means to recover, while also facing pre-disaster socioeconomic, language and other factors which can make recovery difficult.

The Center for Disease Control and Prevention (CDC) states that areas with a higher social vulnerability are more likely to lack the resources needed to prepare for and recover from a disaster. Residents may be more likely to lose their jobs if they must move across town to find new housing, be unable to take time off from work to manage the process of obtaining long-term recovery assistance, or have a harder time accessing resources to assist with the complex recovery process due to language barriers or access to information.

The Harvey Data Project used the approach described above to identify concentrated areas with the highest recovery risk rates. **In the 59 highest risk census tracts, a total of 31,000 households experienced loss on average of more than 50% of the area annual income due to Harvey,** equivalent to a third of all households within these areas.

These at-risk tracts correspond to 18 key, vulnerable neighborhoods of the city: Braeburn, East Houston, Edgebrook Area, Greater Greenspoint, Greater Ost/South Union, Gulfgate Riverview/Pine Valley, Gulfton, Independence Heights, Kashmere Gardens, Lawndale/Wayside, Magnolia Park, Northshore, Northside/Northline, Park Place, Settegast, Spring Branch Central, Sunnyside, and Trinity/Houston Gardens. In each of these neighborhoods, the Project estimated that more than 25% of households are in one of the most at-risk census tracts.

While property values in at-risk areas are generally lower than more affluent parts of the city, **there was still $1.1 billion in damage done in the highest-risk tracts.** As of February 2018, 70% of that need was still unmet by federal sources, for an average of $26,000 un unmet need per impacted household.

Traditional techniques underestimate total damage, hiding a need for further financial support

With the inundation and building information assembled, the Civis team was able to estimate where the city flooded, which buildings were affected and what the total scale of property damage was across all affected residences in the city. In aggregate **these damages totaled $16 billion.**

As of February 2018 only $3.02 billion of that $16 billion has been covered by existing Federal assistance programs in the form of loans, insurance or individual assistance[3]. A majority of the remaining funds will be covered by non-Federal sources, such as private insurance, individual savings or local recovery funds. However, block grant funding from federal agencies to local jurisdictions may occur to support the redevelopment of impacted homes and neighborhoods when programs at the individual household level might not apply.

The U.S. Department of Housing and Urban Development (HUD) may provide block grant funding for any housing recovery needs that are **unmet** (meaning they are not covered by another Federal program) and **serious** (meaning they meet a defined standard of economic impact). The block grants are provided through HUD's Community Development Block Grant - Disaster Recovery (CDBG - DR) Program as a lump-sum to state governments, who then choose how to use funds to rebuild for those who did not receive support from other federal programs. For this program, HUD uses an established process based on FEMA relief applications and assessments to estimate the value of damage that meets the defined criteria of "serious unmet housing

need", and then grants that amount of funding to the city to be spent as the local government's discretion.[4]

With this traditional approach, HUD has identified and granted approximately $1.2 billion in CDBG - DR funds to the City of Houston for Harvey recovery. By combining each of the models and available data sources, Civis can show that the true amount is more than twice as large as what the traditional approach could detect and that in reality, **$3.1 billion of damage meets HUD's standard for serious unmet housing need, meaning that almost $2 billion dollars of additional need meets the same standard that was used for CDBG-DR grants to date.** The correct assessment, measurement and funding of this additional need will be essential in the recovery and rehabilitation of housing in Houston's most seriously affected neighborhoods.

Innovation in the Harvey Data Project Approach

The Harvey Data Project represents a step forward in understanding the cost of a disaster through four key innovations:

> Going beyond FEMA Individual Assistance claims as the basis for a cost calculation, so that those who were excluded from FEMA programs are not undercounted in the HUD programs.

> Identifying seriously damaged homes through objective flood inundation modeling, in addition to subjective dollar value assessments.

> Calculating the cost to repair a specific structure, rather than relying on generic averages.

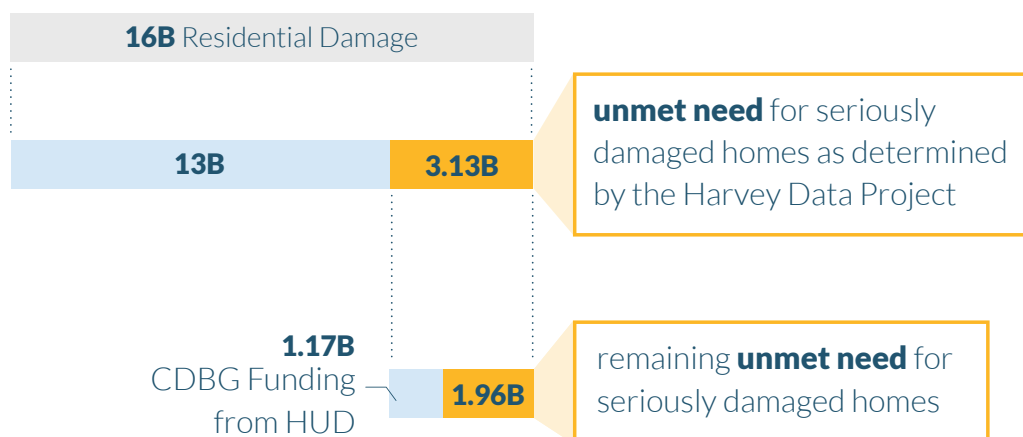> Tracking how funds are being spent and which households are getting (and not getting) assistance.

Beyond FEMA

While FEMA's short-term Individual Assistance (IA) program represents an important source of recovery funds for disaster survivors, it is not designed to be

---

[3] For more detail on the specific federal assistance programs, see Appendix A. [4] For more information, see Appendix A.

Funding from HUD does not cover all of the unmet need for seriously damaged homes

16B Residential Damage	

13B	3.13B

unmet need for seriously damaged homes as determined by the Harvey Data Project

1.17B
CDBG Funding
from HUD

	1.96B

remaining **unmet need** for seriously damaged homes

effective at either funding recovery efforts for the masses or establishing an authoritative total for all types of damage from any given emergency. Typically, HUD estimates the amount of serious unmet housing need based on applications for individual assistance from FEMA. For example, residents can file an application through the FEMA website at **https://www.disasterassistance.gov.** This approach depends on individuals knowing how to apply for FEMA assistance and provide reliable information within a process that is often bureaucratic and disproportionately rejects people of color[5] and lower socioeconomic status[6] or forces them through a lengthy and complicated appeals process.[7]

The FEMA application and appeals process can be long and complicated, with opportunities for households in need to be disqualified or fall through the cracks and fail to advance. For households that do apply for aid, they must coordinate for a FEMA inspector to come for a 30-minute inspection. After Harvey, inspectors were under pressure to conduct many inspections under time and resource constraints. These brief inspections must assess the full scope of verified loss that can be attributed to the storm. Property deemed to be of lower monetary
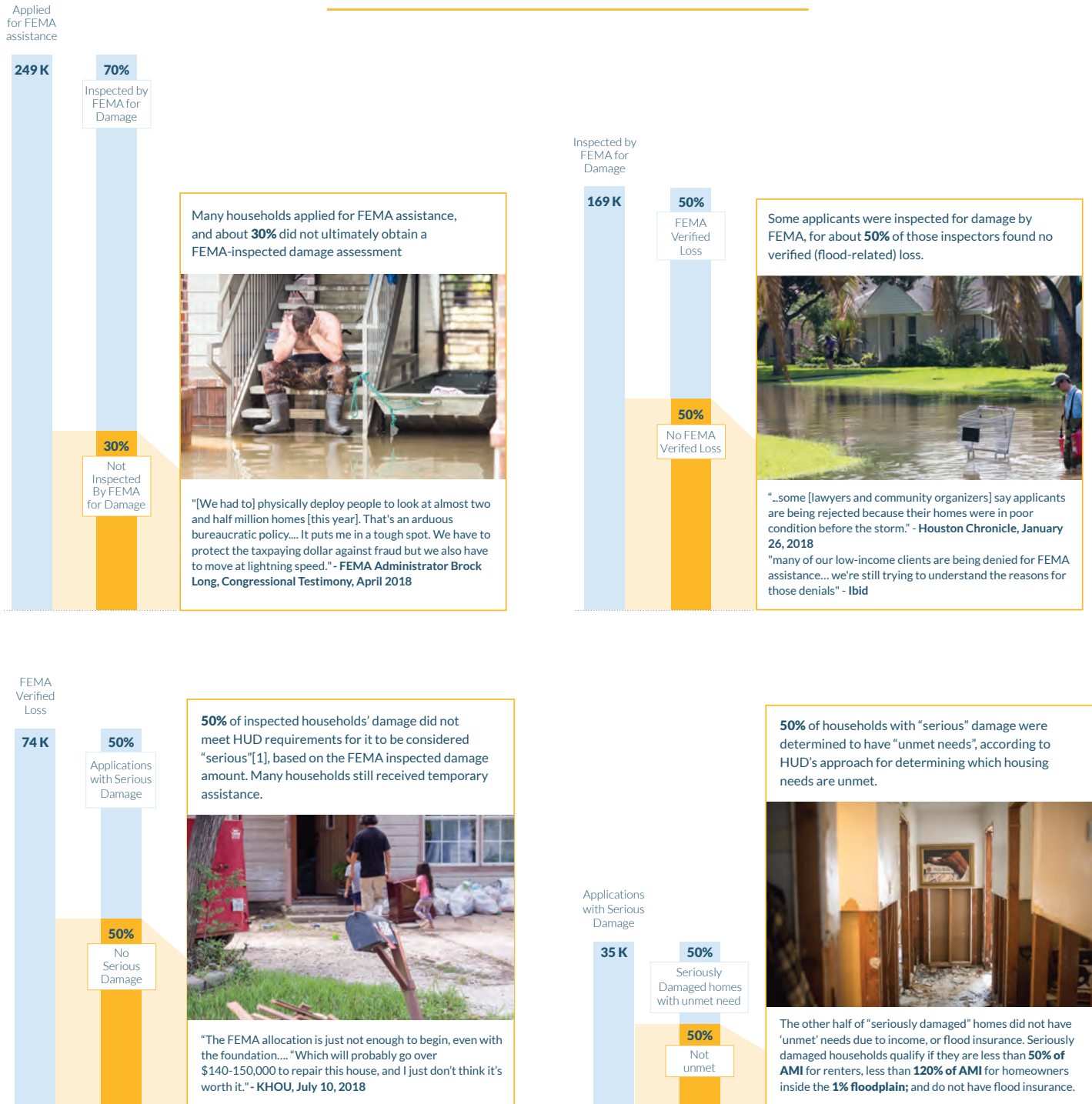
value or in poor repair due to factors before Harvey is often assessed to be of much lower dollar amount than is needed to restore any more than the most basic living conditions. With these assessments, fewer households meet the threshold of $8,000 in FEMA-verified loss for a homeowners' property loss to be considered "serious".

The result is a systematic undercount of the damage estimate, especially within communities of color or those that lack the means or awareness necessary to navigate the full process of applying for and receiving a FEMA assessment. If unaddressed, this discrepancy can prevent communities from getting resources from missing out on significant benefits and can even deepen inequality that existed prior to the disaster.[8]

Despite these limitations, FEMA's IA inspections are a consistent source of post-disaster data in the days and weeks immediately following a storm. HUD has therefore relied on FEMA data to inform its calculations of the long-term costs of recovery. But relying exclusively on data that may exclude low-income and vulnerable communities, presents serious limitations for HUD's long-term recovery formulas.

[5]Sturgis, S. (2018, September 24). Recent disasters reveal racial discrimination in FEMA aid process. Retrieved February 12, 2019, **link.** [6]Adams, A. (2018, November 30). Low-income households disproportionately denied by FEMA is a sign of a system that is failing the most vulnerable, **link.** [7]Martín, C., & Teles, D. (2018, August 15). Disaster aid eligibility processes risk cutting out low-income households in need. Retrieved February 12, 2019, **link.** [8] Howell, J., & Elliott, J. R. (2018, August 14). Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States. Retrieved February 12, 2019, **link.**

Housing Recovery funds from HUD are granted to the jurisdictions based on the what it takes to rebuild an average home using the number of 'seriously damaged' homes determined by FEMA inspections.

Applied for FEMA assistance

249 K | **70%** Inspected by FEMA for Damage

30% Not Inspected By FEMA for Damage

Many households applied for FEMA assistance, and about **30%** did not ultimately obtain a FEMA-inspected damage assessment

"[We had to] physically deploy people to look at almost two and half million homes [this year]. That's an arduous bureaucratic policy.... It puts me in a tough spot. We have to protect the taxpaying dollar against fraud but we also have to move at lightning speed." - **FEMA Administrator Brock Long, Congressional Testimony, April 2018**

Inspected by FEMA for Damage

169 K | **50%** FEMA Verified Loss

50% No FEMA Verifed Loss

Some applicants were inspected for damage by FEMA, for about **50%** of those inspectors found no verified (flood-related) loss.

"...some [lawyers and community organizers] say applicants are being rejected because their homes were in poor condition before the storm." - **Houston Chronicle, January 26, 2018**
"many of our low-income clients are being denied for FEMA assistance... we're still trying to understand the reasons for those denials" - **Ibid**

FEMA Verified Loss

74 K | **50%** Applications with Serious Damage

50% No Serious Damage

50% of inspected households' damage did not meet HUD requirements for it to be considered "serious"[1], based on the FEMA inspected damage amount. Many households still received temporary assistance.

"The FEMA allocation is just not enough to begin, even with the foundation.... "Which will probably go over $140-150,000 to repair this house, and I just don't think it's worth it." - **KHOU, July 10, 2018**

50% of households with "serious" damage were determined to have "unmet needs", according to HUD's approach for determining which housing needs are unmet.

Applications with Serious Damage

35 K | **50%** Seriously Damaged homes with unmet need

50% Not unmet

The other half of "seriously damaged" homes did not have 'unmet' needs due to income, or flood insurance. Seriously damaged households qualify if they are less than **50% of AMI** for renters, less than **120% of AMI** for homeowners inside the **1% floodplain;** and do not have flood insurance.

Hurricane Harvey Photographs by Revolution Messaging. [1]"Serious Damage' is defined by HUD as at least $2,000 in personal property damage for renters, and at least $8,000 in structural damage for homeowners, **link.**
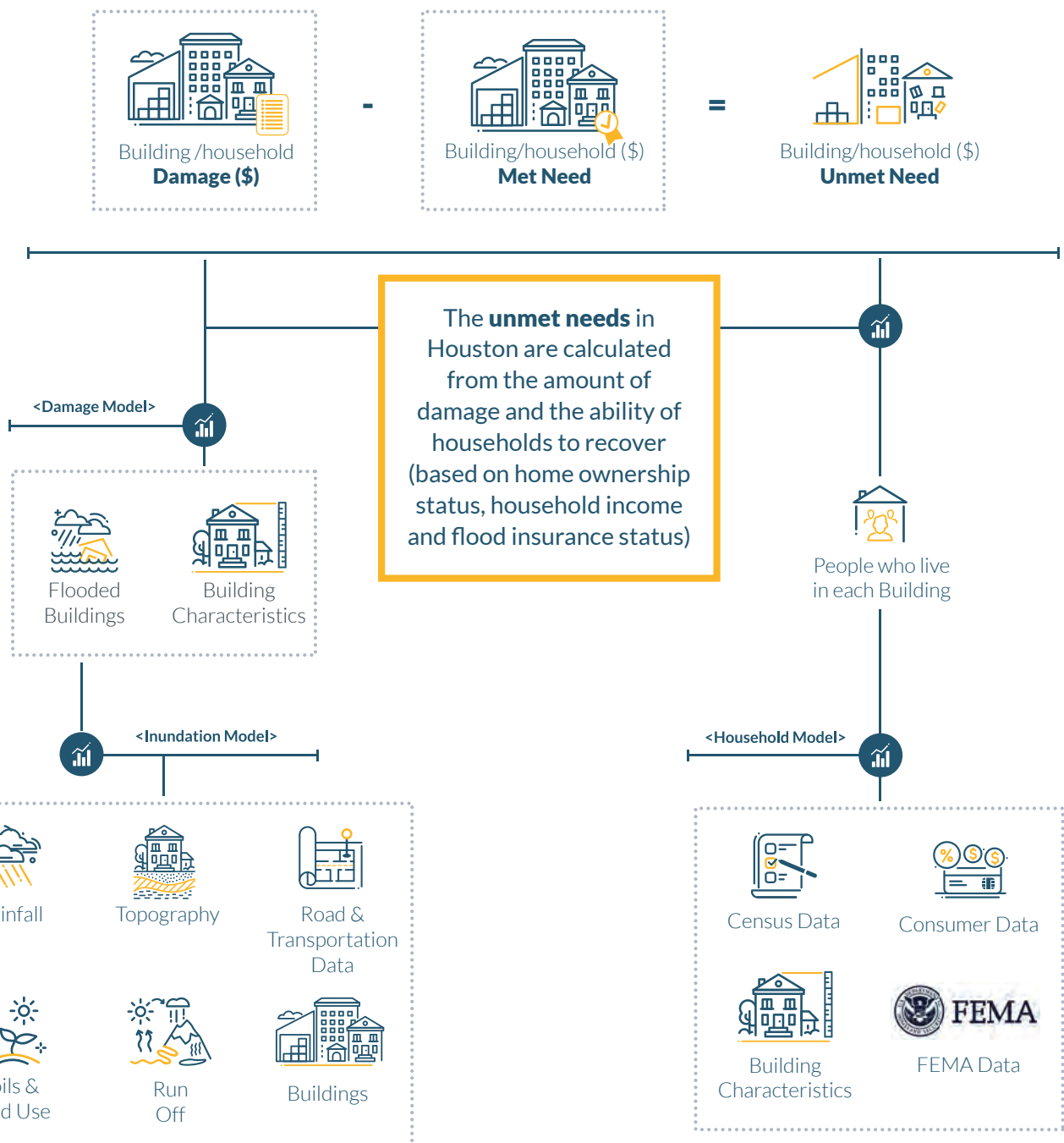
The Harvey Data Project takes important steps in addressing the shortcomings of FEMA data, specifically its ability to calculate unmet housing need, by employing a more comprehensive approach including four models:

A Flood Inundation Model, to see how deeply waters flooded every point in the city,

A Damage Model, to see how flood levels affected each building based on its characteristics,

A Household Model, to see who lived in each of the damaged buildings, and

An Unmet Needs Model, to combine the damage estimates and household information to assess how much additional damage value has not yet been covered.

Building /household **Damage ($)**

−

Building/household ($) **Met Need**

=

Building/household ($) **Unmet Need**

The **unmet needs** in Houston are calculated from the amount of damage and the ability of households to recover (based on home ownership status, household income and flood insurance status)

<Damage Model>

Flooded Buildings

Building Characteristics

People who live in each Building

<Inundation Model>

Rainfall

Topography

Road & Transportation Data

Soils & Land Use

Run Off

Buildings

<Household Model>

Census Data

Consumer Data

Building Characteristics

FEMA Data

As a result, the Harvey Data Project was able to better account for the total scale of both Harvey's impact and the recovery, ensuring that recovery resources were not limited by a lack of available data or broad, imprecise averages that masked local variation within the city. FEMA inspection and assessment results provide information into the model, but they are supplemented with other data sources to show where inspections might underestimate the value of Harvey-related damage.

Objective flood inundation modeling

Where the traditional HUD approach might skip assessing some households entirely if they are ineligible for specific FEMA programs, the Harvey Data Project's citywide model uses the availability of multiple data sources to produce estimates for every area of Houston. Inspections after the storm are dependent on each inspector's assessment of building and content value, and the property

may only be considered eligible for many recovery programs if this verified loss meets HUD's standard for serious damage. By using the Inundation Model to calculate flood depth at the household level, the Harvey Data Project can identify households that meet the standard because they flooded more than 1 foot, regardless of property value.

Specific repair cost modeling, not generic estimates

HUD's traditional approach to calculate the total cost of the disaster uses statewide averages from previous storms. For Harvey, this included a set of average values between $59,000 and $102,000 per household, corresponding to different amounts of damage severity. HUD estimates the total cost by simply multiplying these estimate values by the total number of qualifying applications in each corresponding level of damage severity. This approach does not account for significant differences

Differing Methodologies for Calculating Unmet Need Due to Hurricane Harvey

	HUD unmet Needs Calculation. "Traditional" approach.	Civis estimate of impacted households. Applying HUD statewide Average Damages	Civis estimate of impacted households. Applying Houston Specific Damage Estimates
Total serious unmet housing need in billions	**$1.17** Billion	**$2.04** Billion	**$3.13** Billion
Who is included in the calculation?	**People who** applied for FEMA Individual Assistance, whose homes were inspected and verified loss was found above a threshold.	**People who** are in buildings that were impacted by flooding according to the Civis/Dewberry flood inundation model.	**People who** are in buildings that were impacted by flooding according to the Civis/Dewberry flood inundation model.
How is the amount of unmet need determined?	No. of Applications x Unmet needs for Loss Group = Unmet Needs	Civis estimate of impacted households x Unmet Needs for Loss Group = Unmet Needs	Civis estimated damage of impacted households - Met Needs = Unmet Needs
Loss Group	*Major Low:* $58,956 | *Major High:* $72,961 | *Severe:* $102,046	*N/A*	

in the cost to repair homes depending on their style, size, or location in the city.

The Harvey Data Project's Unmet Needs Model addresses the limitations of a "generic estimates" approach with data specific to each household affected by the storm. Instead of simply mapping a building to an average damage value, the Damage Model produces estimates that are individualized for each building using characteristics unique to that building. It accounts for factors that generic average estimates gloss over, such as building material, elevation of the first floor, age and value of the building, and specific water depth from the Inundation Model.

The result is a better picture of how the extent of damage in Houston was more significant than previous averages could capture. While the highest severity level in the traditional approach approximates $102,000, the median modeled damage for homes severely impacted by Harvey was more than double that Damage Model shows that severely flooded homes from Harvey had a median building damage total was almost double that at $196,000. In addition, the model provides a more precise estimate for each building, enabling more detailed analysis of who suffered damage instead of just a topline number.

Track how funds are being spent

The models from the Harvey Data Project can help track how funds are being spent and what types of residents may still need more help. The modeled framework shows where damages are expected in the city, drawing upon information about who has and has not applied for aid. This application data aligns with information about what areas and populations in the city receive aid from FEMA, HUD or other related government programs. Comparing the overall measures of modeled damage with updated measures of reconstruction and repair spending provides simple contrasts to show if aid is disproportionately failing to reach certain affected populations.

These population/neighborhood-specific insights allow the City of Houston and other recovery jurisdictions to monitor and ensure that recovery from Harvey is equitable. Future spending decisions can compare directly where money has been spent to date and how that compares against an estimate of where need is greatest. This means there can always be an easy means of checking who is falling behind at a systematic, strategic overview. The end result is that city leaders and other stakeholders can make decisions about how to secure and allocate resources with the confidence that none of their constituencies are uncounted or left behind.

Next Steps

The first step of this project was conducting analysis on Harvey's impacts on the population in Houston. Moving forward, the Harvey Data Project will shift its focus to understanding how the City can ensure that recovery funds are spent in an effective and efficient way. Additionally, the project has laid the groundwork to begin preparing for next storm and ensure that future disasters can be faced with better tools already in place.

The future success of the Project, or similar projects in other jurisdictions, hinges on four principles:

> Using data to inform recovery policy and programs.

> The open sharing of data between stakeholders, including those outside the project team.

> Adapting tools and processes to track recovery efforts continuously, not just at a single point in time.

> Readying tools and processes to be always prepared for the next storm.

Informing Program Development

The premise of this project is to convey that post-disaster policy and programs that are informed by data result in more equitable and efficient recovery efforts. The City's HCDD is already using the project's data to inform its outreach strategy

to encourage Houstonians to apply for recovery programs. The models can predict what areas of the city are expected to have a high density of households that are eligible for each program. HCDD can use this information to focus outreach resources and volunteer canvassers in neighborhoods that are likely to have serious damage affecting particular populations, such as households with senior citizens or young children.

The City can manage its recovery programs proactively, going out into the community to solicit more applications instead of waiting for only responding to applications that may not be representative of the needs of the entire community. The data-driven approach of the Harvey Data Project creates new possibilities to efficiently target outreach of existing programs. This approach also presents the city's ongoing needs on a macro level. This combination of approaches allows City leaders to assess recovery and make informed strategic decisions, adjusting policies or developing new approaches as required to stay on-track for an equitable, rebuilt, and fully-serviced city.

Sharing Data with Other Stakeholders

The Harvey Data Project benefited enormously from having access to a multitude of official, quality data sources from many jurisdictions. However, negotiating these data sharing agreements proved to be one of the most cumbersome and time-consuming aspects of the project. Federal agencies have a duty to protect Americans' personally identifiable information (PII), such as name, contact information, and individual-level property and income information.

Any entity with access to PII must maintain the highest standards of data security and ensure that only those with national security clearances are allowed to handle individual data. The need to protect individuals' data must be reconciled with Americans' interest in verifying the responsible and efficient use of significant taxpayer resources

deployed after a disaster. In 2017 alone, Congress appropriated more than $136 billion to disaster-affected jurisdictions from hurricanes Harvey, Irma and Maria, including the California wildfires and other regional disasters.[9]

The project presents new opportunities for those outside of government to track spending and evaluate the effect of post-disaster programs. Other organizations within the City, including municipal agencies, non-profit organization and academic researchers, will be able to learn from the projects models when the resulting data is presented in a clean, intuitive and open manner. Currently, there is a wealth of aggregate information that is ready to share with non-profit and academic partners without compromising PII. But the project partners are still negotiating agreements that would allow further sharing of aggregate data to facilitate future progress without compromising individuals' personal data.

Federal agencies could assist in achieving transparency objectives by appointing a data sharing working group to work with disaster-affected jurisdictions to establish principles for data sharing at different levels, as well as standing data sharing agreements. These agreements would greatly increase the speed of post-disaster analysis in a way that will help jurisdictions recover more quickly.

Other cities facing similar challenges will know well that no single stakeholder or organization can control all aspects of recovering from a disaster of this scale. No single stakeholder can even predict which aspects of recovery will require the most attention. The open and frictionless sharing of both source data and model outputs is critical to ensuring effective cooperation and coordination.

Tracking Progress in the Recovery Effort

The same data and methods that resulted in this report's analysis of Harvey's impact on residential structures in September 2017 can also be used

[9]Painter, W. L. (2018) 2017 Disaster Supplemental Appropriations: Overview (CRS Report No. R45084) Retrieved from Congressional Research Service website, **link.**

to provide ongoing feedback and guidance as the recovery unfolds over the next five years. The Harvey Data Project will use data and maps developed as a baseline against which to track CDBG-DR spending over the City of Houston's six-year grant for Harvey recovery. Using these data and data tools will also allow all stakeholders to understand how CDBG-DR grant funding is impacting the neighborhoods and households with the most need throughout the city, providing greater visibility into who HCDD is serving and how effectively. This will provide an extra level of transparency of spending, so that recovery analysis is not exclusively backwards-looking or frozen on a single point in time.

Preparing for the Next Flooding Event

Throughout this effort, the Harvey Data Project focused on making the process repeatable, building tools and workflows to automate and standardize common analysis tasks. Houston experienced five federally declared disasters between 2015 and 2017. While analysis will still need to be done on a storm-by-storm basis, common elements of collecting, cleaning and processing data from key sources will be applicable to any future flood.

The Project team has provided the City of Houston with access to a secure, cloud-based analysis platform to inspect and manage the data and conclusions from the project. The project created repeatable workflows for ingesting and analyzing federal claims data, flood inundation data, household data, and property assessor data that would be available in the event of a future flood. By designing these tools with reusability in mind, the project has established means for the city to respond with more speed and ease after the next flood, to begin measuring and monitoring impact as soon as possible, and directing recovery aid to where it is needed most.

The specific tools and workflows built by the Harvey Data Project may be adaptable to other cities and jurisdictions as well, but more important is the general practice of building reusable, adjustable processes to combine and understand data before it is urgently needed. Many communities within Houston and across the U.S. will have an interest in disaster damage calculations in the years to come, and well-made, easy-to-understand tools can do much to share knowledge and empower organizations in the pursuit of efficient, effective and equitable recovery.

Aerial photograph of flooding in West Houston, Photograph by Dan Joyce.

Appendix A: Federal Assistance Programs

In the aftermath of a natural disaster, there are three federal programs that provide immediate relief to renters and homeowners.

FEMA Individual Assistance (IA) Program

The FEMA IA program is designed to provide temporary financial assistance or housing assistance to ensure that disaster survivors have a safe place to live in the immediate aftermath. This assistance is intended to help residents rebuild their homes to the point that it is not unsafe for them to stay there, or provide alternate housing, but generally will not cover the full cost of rebuilding a home. As of February 2018, Houston residents received approximately $309 million in FEMA IA housing awards.

FEMA National Flood Insurance Program (NFIP)

This program provides homeowners that have an active NFIP flood insurance policy with up to $250,000 in claim payments that can be used to build the home back to pre-disaster condition. One of the things that occurred in Hurricane Harvey, given the immense amount of damage, is that many homes had damage that outstripped this $250,000 maximum. Approximately 12% of impacted households according to the Harvey Data Project filed an NFIP claim, and as of the end of February 2018, have received approximately $2.48 billion in claims.

The Small Business Administration (SBA) Low-Interest Loan Programs

The SBA provides low-interest loans for qualifying homeowners impacted by disaster. Those who qualify may receive up to $200,000 to build their home back to pre-disaster condition. Renters and homeowners who live in a federally declared disaster area may also apply for up to $40,000 to replace or repair personal property. As of May 2018, Houston residents have received $235 million in SBA loans.

HUD Community Development Block Grant – Disaster Response (CDBG – DR)

The national disaster recovery framework recognizes that some people simply do not have private resources to recover on their own. For this reason, funding from HUD's CDBG - DR Program is focused on low- and moderate-income persons. HUD includes information about which households are included in calculating serious unmet housing need in its Federal Register Notice[10] for housing recovery from Hurricane Harvey. Those with unmet housing need include only homeowners in the 100-year floodplain with incomes below 120% of Area Media Income (AMI) or renters below 50% of AMI, whose needs have not been met by other Federal programs, including flood insurance. Serious damage is determined differently for owners and renters. Renters must have at least $2,000 personal property damage or one foot of water in their homes, and owners must have at least $8,000 in personal property damage or one foot of water in their homes.

[10] **Link.**

CIVIS®

civisanaytics.com