HURRICANE HARVEY

Impact and Response in Harris County

Harris County Flood Control District, May 2018
In response to the unprecedented event that was Hurricane Harvey, the State of Texas congressional delegation, submitted the following letter to the 115th United States Congress on October 5, 2017. The intent of this letter was to bring attention to the devastation in our region and request funding for relief and infrastructure improvements.

Text of Statement Presented to 115th United States Congress

October 5, 2017

Sen. Thad Cochran
Chairman, Senate Committee on Appropriations
D torrents, and record-setting floods, causing catastrophic damage to Texas' residents and businesses.

In response to this catastrophic event (DR-4352) and following a direct request for supplemental funding from the Administration, Congress acted swiftly, passing legislation to appropriate $15.25 billion in emergency aid. This amount included $74 billion for the Disaster Relief Fund (DRF) within the Federal Emergency Management Agency (FEMA); $540 million for the Disaster Loan Program within the Small Business Administration (SBA); and $7.4 billion for the Community Development Block Grant Disaster Recovery (CDBG-DR) Program. Texas greatly appreciates the appropriations committees' efforts to swiftly provide funds. However, in light of the unprecedented damage from Hurricane Harvey and the historically unprecedented flooding of Houston, Beaumont and surrounding areas, we all recognize that the funding already appropriated is a small fraction of the federal resources needed to help rebuild Texas and reintegrate the American economy.

Community Development Block Grant Disaster Recovery (CDBG-DR):
H.B. 5, the $74 billion for this program, to remain available until expended, for all major disasters declared in 2017. Early estimates from the Texas Regional Economic Impact Study indicate a need of over $40 billion in CDBG-DR funds. Given the projected summer needs of our State, and the impact of Hurricane Harvey and Maria, we strongly urge an additional down payment of CDBG-DR funds in the next emergency supplemental.

REQUEST: $7 billion

State Educational Agencies:
Texas educational institutions at all levels have reported widespread damages to schools and infrastructure as a result of Hurricane Harvey. In the past, emergency supplemental packages have included funding for Local Educational Agencies (LEA), schools and institutions of higher education that were affected by natural disasters. In order to ensure that the education system endures minimal interruption, we request that the appropriations committees consider an allocation that will provide emergency assistance to educational institutions with unexpected expenses as a result of Hurricane Harvey.

REQUEST: $800 million

SBA Disaster Loans Program:
In the wake of a major disaster, the SBA provides low interest disaster loans to businesses, private non-profit organizations, homeowners and renters. SBA loans are often the first form of federal assistance available for individuals and business for disaster recovery. Any additional emergency supplemental should appropriate additional resources for the Disaster Loans Program account.

REQUEST: $450 million

Economic Development Administration:
The Economic Development Administration (EDA), through the Department of Commerce, plays a crucial role in facilitating the delivery of economic assistance to local governments for long-term recovery planning, reconstruction and resiliency in response to presidentially declared disasters or emergencies. EDA grants, awarded through a competitive process, emphasize disaster resiliency to help mitigate the potential for economic hardship as a result of future weather events.

REQUEST: $300 million

Transportation Infrastructures:
In order to address long-term recovery needs, it is vital that transportation infrastructure be reconstructed and rehabilitated to support economic growth and provide access to economic and social services. The U.S. Department of Transportation's Emergency Relief Program and the Public Transportation Emergency Relief Program, respectively, are crucial programs that can provide Texas with immediate resources for transportation infrastructure repairs.

REQUEST: $50 million

Thank you for your consideration of these funding needs and for your efforts to ensure that our State has adequate resources to recover and rebuild.

Respectfully,
United States Senators:
John Cornyn
Ted Cruz
Will Hurd
Sheila Jackson Lee
Sam Johnson
Kenny Marchant
Michael McCaul
Beto O'Rourke
Pete Olson
Ted Poe
John Ratcliffe
Pete Sessions
Lamar Smith
Mac Thornberry
Marc Veasey
Beto O'Rourke
Randy Weber
Roger Williams

Governor, State of Texas:
Greg Abbott
United States Representatives:
Michael C. Burgess, M.D.
John Carter
John Curtis
Bill Flores
Louie Gohmert
Jodey Arrington
Joaquin Castro
Henry Cuellar
Mike Conaway
John Danforth
Lloyd Doggett
Eddie Bernice Johnson
Blake Farenthold
Joaquín Castro
Michael Cloud
John Cornyn
Henry Cuellar
John Danforth
Lloyd Doggett
Eddie Bernice Johnson
Michael C. Burgess, M.D.
John Carter
John Curtis
Bill Flores
Louie Gohmert
Jodey Arrington
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Eddie Bernice Johnson
Hurricanes are recognized all over the world as uniquely self-reliant individuals, and the people of Harris County are no exception. From our beginning as the State of Texas’ first capital, to our booming growth throughout the 20th and 21st centuries, Harris County and its people have met and withstood any challenge thrown their way; we have weathered every storm.

In 2017, our strength was tested like never before when Hurricane Harvey attempted to drown the county in record-setting floodwaters. Harvey’s devastation was beyond anything that could have been imagined, but it could not break us. Together, we got to high ground, quickly dried out our boots, and got to work rebuilding Harris County, the home we love. Now as we recover, we must also prepare for the next storm, because history has taught us that the next threat will come, and it could happen again tomorrow.

“The rain in Harris County was worse than the previous worst-case scenario. If Houston had gotten the equivalent of the worst storm in history, and if it had targeted Harris County like an expert marksman, it still would have fallen several inches shy of Harvey.”

John Nielsen-Gammon, PhD. Regents Professor of Atmospheric Sciences at Texas A&M University and Texas State Climatologist

Introduction

The people of Harris County are no exception. From our beginning as the State of Texas’ first capital, to our booming growth throughout the 20th and 21st centuries, Harris County and its people have met and withstood any challenge thrown their way; we have weathered every storm.

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Hurricane Harvey: An Unprecedented Storm Event

On August 17, 2017, Harvey became the eighth named storm of the 2017 Atlantic hurricane season. It tracked westward, crossing the Yucatan Peninsula on August 20. Upon entering the Gulf of Mexico, Harvey strengthened into the third hurricane of the season on August 24, as it began to turn north toward Texas. Forecast models varied as Harvey loomed on the horizon. In general, models predicted that Harvey would go inland towards Corpus Christi, and the region braced itself for the storm.

Harvey made landfall on August 25 in Rockport, Texas, as a Category 4 Hurricane. After devastating south central Texas, Harvey returned to the Gulf of Mexico, refueling along its way. Harvey was now expected to slowly crawl north along the coast, where it would make landfall and center over the Harris County region for the next five days, producing rainfall amounts unprecedented in our nation’s history.

The Harris County Flood Control District Flood Operations and Hurricane Response Teams were activated on Wednesday, August 23. During a storm event, this team worked twenty-four hours a day to closely monitor the county’s 354 rainfall gauges, collect rainfall and flooding data, and report this data to the public and partnering governmental entities.

The data that Flood Control District engineers and scientists collect during a storm event allows them to anticipate the location and magnitude of the rain’s impact and to advise the public and local officials of areas that may be affected by flooding.

In the early hours of Sunday, August 27, the Flood Control District—alongside millions of Harris County residents—watched as all 22 main channels and bayous in the county spilled over their banks, meaning that each bayou’s watershed in the county was at risk of severe flooding. Never before has every bayou in Harris County flooded at the same time.

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How Much Water Is
1 Trillion Gallons?

Enough to cover Harris County
33 inches deep

The same amount that goes over Niagara Falls in 15 days
Hurricane Harvey: Impact and Response in Harris County

From its birth as a tropical wave in the Atlantic to its rapid development over the Gulf of Mexico and ultimate demise over Louisiana, the storm that came to be known as Hurricane Harvey lasted 16 days. Harvey peaked as a Category 4 Hurricane, and its path of destruction ranged from Corpus Christi, Texas to Cameron, Louisiana. In total, Harvey spent five days pouring over 1 trillion gallons of water onto Harris County. This map depicts Harvey’s path and development.

*Note: All times are listed in U.S. Central Standard Time (local time for Harris County)*

**Hurricane Harvey Facts**

- **Initial Formation:** August 14, 2017
- **Tropical Storm:** August 17, 2017
- **Cat. 1 Hurricane:** August 24, 2017
- **Cat. 4 Hurricane:** August 25, 2017
- **First U.S. Landfall:** August 25, 2017, Rockport, TX
- **First rain bands reach Harris County:** August 26, 2017
- **Total Time Over Harris County:** 4 days

**How Harvey Developed**

- **August 14**
  - The National Hurricane Center (NHC) began monitoring a tropical wave off the west coast of Africa.

- **August 17**
  - By 4 pm the NHC upgraded the wave to a tropical storm.

- **August 20**
  - The NHC began monitoring for redevelopment as the circulation became better defined.

- **August 22**
  - Harvey hit the Texas coast with wind gusts of 130 mph.

- **August 23**
  - Harvey weakened and moved inland, causing widespread flash flooding.

- **August 24**
  - At 1 am Harvey made a second landfall north of Holiday Beach, and by 1 pm it had weakened to a tropical storm.

- **August 25**
  - Harvey made its final landfall just west of Cameron, LA with winds of 130 mph.

- **August 26**
  - Harvey became a Category 4 storm.

- **August 28**
  - Harvey was positioned just off the Texas coast at Matagorda where convection blossomed.

- **August 30**
  - Harvey made its final landfall just west of Cameron, LA with winds of 45 mph.

**August 26-29**

For five days, Harvey dumped an average of 47.4 inches of rain across Harris County, causing widespread and prolonged flooding.

**August 25-10 pm**

Harvey made landfall at peak intensity at Rockport with winds of 130 mph. By 1 am Harvey made a second landfall in Texas just north of Holiday Beach, and by 1 pm it had weakened to a tropical storm. For 2 days Harvey stalled just inland, dropping very heavy rainfall and causing widespread flash flooding.

**August 25, 6 pm**

Harvey became a category 4 storm.

**August 24, 1 am**

The storm was upgraded to a tropical storm. By noon the storm was upgraded to the 3rd hurricane of the season. By 2 pm, it was a category 3 storm.

**August 23, 10 am**

Harvey had developed a well-defined center.

**August 20**

The NHC began monitoring for redevelopment as the circulation became better defined.

**August 19**

Harvey’s presentation began to deteriorate—while it’s low-level center became less organized. By 4 pm Harvey was downgraded to a tropical depression, and only 6 hours later it was declared an open tropical wave.
As part of the Texas gulf coast, Harris County has always faced the threat of tropical events. Its proximity to the Gulf of Mexico, its low-lying, relatively flat land, and clay soils create a naturally flood-prone environment, and this presents an urgent problem when combined with the dense population centers and sprawling development that have occurred in the region over the course of the last century.

The dynamics of flooding, floodplains, and land development were not fully understood until the 1980s. By this time, over 60 percent of the county was already developed, meaning that many homes and businesses were unknowingly built within the 1-percent, or 100-year, floodplain. Every day, as the residents of Harris County went about their daily lives, they faced a hidden risk from the clouds above and the lay of the land below. On any day, any given storm could bring a devastating flood in one or many of Harris County’s 22 watersheds.

From 1836 to 1936 – within the first 100 years of the Allen Brothers’ founding of Houston – Harris County suffered 16 major flood events. In the last 20 years, multiple devastating flood events have occurred, including Tropical Storm Allison in 2001, Hurricane Ike in 2008, the Memorial Day Flood of 2015, the Tax Day Flood of 2016, and most recently Hurricane Harvey. As Harris County residents have recovered from each of these disasters, it is clear that flooding is and will always be a threat to the region. While we cannot control flooding, we can work together to prepare for tomorrow’s storm.
Hurricane Harvey: Impact and Response in Harris County

Three factors influenced the severity of flooding during Harvey:

- the rainfall intensity (inches of rain per hour),
- the widespread distribution of intense rainfall in each watershed (areal distribution), and
- the lengthy duration of the storm.

For Harvey, the intensity was moderate to high most of the time. Due to the long duration of the storm and the numerous rain bands that developed, the similar intense flooding was experienced in most watersheds throughout the county. There was no escaping the impacts of Harvey due to its size, intensity, and duration.

The average rain that fell during any given hour was between 4 to 5 inches, with the maximum rainfall of about 6.8 inches per hour. Total rainfall amounts ranged from 36 to 48 inches across the county over a five-day period, almost 10 inches more than Tropical Storm Allison in 2001. The typical annual total rainfall for Harris County is about 49.8 inches, and Harvey came just a few inches short of that in five days. A total of 1 trillion gallons of water fell across Harris County during Harvey, enough to cover Harris County’s 1,777 square miles with an average of about 3 feet of water.

How Much Water Is 1 Trillion Gallons?

- Enough to fill the Astrodome 3,200 times.
- Enough to cover Harris County 33 inches deep.
- The same amount that goes over Niagara Falls in 15 days.

Harvey Rainfall Compared to Other Record U.S. Storms

1,777 Sq. Miles | 5-Day Duration

- Harvey 2017: 43.68
- Beulah Louisiana Aug. 1940: 29.80
- Claudette Texas Jun. 1979: 29.79
- Carla Texas Jun. 1961: 24.80
- Katrina Louisiana Aug. 2005: 29.80
- Harvey Texas Aug. 2017: 29.80
- Harvey Texas Sep. 2017: 24.80
- Harvey Texas Sep. 2017: 24.22
- Harvey Texas Sep. 2017: 24.22
- Harvey Texas Sep. 2017: 24.22
- Harvey Texas Sep. 2017: 24.22
- Harvey Texas Sep. 2017: 24.22

Flooding from Harvey at W. Lake Houston Parkway at the West Fork of the San Jacinto River.

A family evacuates from their neighborhood due to near constant rain from Hurricane Harvey. (Michael Ciaglo/©Houston Chronicle. Used with permission)
For the Harris County Flood Control District, “infrastructure” primarily refers to the natural and built drainage systems, including channels and detention basins—not streets, storm sewers, or roadside ditches. The Flood Control District’s drainage and flood control infrastructure is extensive, including more than 1,500 channels totaling over 2,500 miles in length. This is about the distance from Los Angeles to New York City.

The Flood Control District’s mission to provide flood damage reduction projects that work, with appropriate regard for community and natural values is accomplished by:

- Devising flood damage reduction plans;
- Implementing the plans; and
- Maintaining the infrastructure.

The Flood Control District utilizes several tools in the name of flood damage reduction. These tools include channel modifications, stormwater detention, and buyout and channel maintenance.

Channel modifications, or conveyance improvements, are man-made changes to a channel, typically for the purpose of reducing flood damage by increasing the channels overall capacity. It can be accomplished by widening and/or deepening the channel, reducing the friction by removing woody vegetation or by lining the channel with various materials. It should be noted that only 6 percent of the channels in the county’s drainage infrastructure inventory are concrete lined, and the Flood Control District is working towards implementing more natural channel designs throughout the county.

Stormwater detention is another tool in the Flood Control District’s toolbox. Stormwater detention basins are areas of land, usually adjacent to channels that are designed to receive and hold above-normal stormwater volumes. Most stormwater detention basins in Harris County are excavated. The detained stormwater then slowly drains, over time, out of the detention basin as the flow in the channel and associated water surface elevations recede. The Flood Control District uses stormwater detention extensively to reduce the risk of flooding throughout the county.

The Flood Control District also uses non-structural tools to maintain the infrastructure in the County. One of the most effective non-structural tools they use involves voluntary buyout and demolishing of structures that were built deep in flood-prone areas, where structural projects to reduce flood levels are impractical. Structures in this situation were typically built years ago before detailed floodplain maps and studies were available and before floodplain management regulations were adopted by the County.

To maintain the integrity of the Flood Control District’s network of flood damage reduction infrastructure, buyouts, channels, and detention basins are regularly maintained. The Flood Control District maintains more than 2,500 miles of predominately grass-lined bayous, creeks and man-made drainage channels, along with dozens of large stormwater detention basin sites, and about 2,300 buyout lots in neighborhoods across Harris County, totaling a total of more than 18,000 acres. The Flood Control District’s regular maintenance program includes mowing, selective clearing, hazardous tree removal, herbicide application, tree pruning, and removing sediment and foreign materials that build up in our channels, potentially affecting their ability to efficiently convey stormwater.
Hurricane Harvey: Impact and Response in Harris County

People wade through chest deep water from Hurricane Harvey. (Michael Ciaglo/©Houston Chronicle. Used with permission)

Water inundates a gas station near the south Sam Houston Tollway. (Mark Mulligan/©Houston Chronicle. Used with permission)

Kayakers fight against the current flowing from an overtopped Brays Bayou. (Mark Mulligan/©Houston Chronicle. Used with permission)

Rescue boats search a Harris County neighborhood for evacuees.
A Major Economic Driver under Water

While Harris County is working to quickly rebound from Hurricane Harvey, it is important to understand the threat that storm events that hit the region present to Harris County, the state, and the nation.

Harris County is the third most populated county in the United States with a 2016 population of approximately 4.6 million people.¹ In 2016, the Houston-Woodlands-Sugar Land Metropolitan Area, of which Harris County is a part, made up 30 percent of Texas’ gross domestic product (GDP), meaning that $3 of every $10 generated in Texas comes from economic activity in the Houston metropolitan area.²,³ The Houston metropolitan area ranks sixth in the nation among leading metropolitan areas contributing to the economy of the United States.⁴

The diverse economy of urban Harris County dominates the region with export economies in a wide range of industrial sectors. Significant employment sectors include oil and gas field machinery and equipment manufacturing; geophysical surveying and mapping services; crude petroleum and natural gas extraction; and pipeline transportation of oil and gas. The dominance of Texas in the nation’s energy industries comes from Harris County. The Port of Houston also supports a robust economy in activities related to water transportation of commodities. Major storms like Harvey have threatened Harris County’s economic engines in the past, and they will continue to threaten Harris County in the future if major actions are not taken to protect the region...

Fast Facts About Harris County

Founded: 1837
Size: 1,777 square miles
2016 population: 4.6 million
Population Density: 2,608/square mile
Median Household Income: $54,457 (2015)
Average Property Value: $10.57/square foot (2016)
All Property Market Value: $502 billion

¹ Source: U.S. Census Bureau, 2016 American Community Survey
² Source: U.S. Bureau of Economic Analysis, 2016 Gross Domestic Product by Metropolitan Area
³ Source: U.S. Bureau of Economic Analysis, 2016 Gross Domestic Product by State
⁴ Source: Economic Development Coalition of Greater Houston, 2017 Economic Report

Port Houston accounted for nearly $137 billion in trade in 2015.

The Texas Medical Center is the world’s largest medical complex.
Harris County ranks No. 1 in Texas and No. 2 in the nation in terms of GDP growth and ranks No. 4 in Texas and No. 9 in the nation for incoming investments. Harris County has over 2.2 million employed persons working in over 100,000 business establishments, with total employment exceeding that of 28 states in the U.S. One-in-five jobs in Texas are located in Harris County, with $154 billion in total earned wages. Wages paid in Harris County exceed the Texas average by 30 percent. The County is home to 18 Fortune 500 companies, and many other Fortune 500 companies maintain U.S. administrative headquarters within the County.

However, Harris County’s economic engines cannot run themselves. The most vulnerable component of the Port of Houston, the energy industries along the Port, and all industrial sectors in Harris County, are the workers themselves who make the engines hum. To fully understand the devastating effects of Hurricane Harvey, we must acknowledge Harris County’s significant contributions to the local, state, and national economies and the many people whose wellbeing relies on these economic contributions. According to news reports, over one-quarter of U.S. refining capacity was shut down in the days following Hurricane Harvey. If another storm event happened in the Harris County region tomorrow, we – as a nation – would not be ready.

- Over 137,000 people are employed in the energy sector in Harris County, earning yearly wages in excess of $21.7 billion.
- $5 Billion State & local tax revenue generated by business activity related to the Port of Houston each year.
- $25 Billion GDP generated by the Texas Medical Center, the 8th largest business district in U.S.
- 1.7 Million Tax accounts maintained by Harris County annually.
Hurricane Harvey: Impact and Response in Harris County

A Record-setting Storm Event

Historical records held by previous massive floods in October 1994, Tropical Storm Allison in 2001, and the 2016 Tax Day Flood, were exceeded by Hurricane Harvey.

Clear Creek, located southwest of downtown Houston, experienced record flooding along the entire channel and major tributaries of Turkey Creek, Chigger Creek, Cowart Creek, and Mary’s Creek, as well as upper Branner Road Ditch.

Greens Bayou, located northeast of downtown Houston, experienced record flooding along Greens Bayou from E. Mount Houston Parkway south (downstream) to the Houston Ship Channel, exceeding previous records set by Tropical Storm Allison.

Buffalo Bayou, located directly through the entire Houston area, experienced record flooding at every single bridge crossing as waters exceeded previous records set during the Tax Day Flood in 2016 and floods during March 1992. Previous records were exceeded by 2 to 7 feet.

In summary, Harvey overwhelmed Harris County’s stormwater drainage system of channels, bayous, and creeks. A flood of this magnitude will strike again, and together we must be prepared.

Total Rainfall By Watershed August 26 – 30, 2017

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Total Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addicks Reservoir</td>
<td>36.3 in.</td>
</tr>
<tr>
<td>Armand Bayou</td>
<td>43.4 in.</td>
</tr>
<tr>
<td>Barker Reservoir</td>
<td>36.5 in.</td>
</tr>
<tr>
<td>Brays Bayou</td>
<td>37.7 in.</td>
</tr>
<tr>
<td>Buffalo Bayou</td>
<td>37.1 in.</td>
</tr>
<tr>
<td>Cypress Creek</td>
<td>35.2 in.</td>
</tr>
<tr>
<td>Greens Bayou</td>
<td>41.3 in.</td>
</tr>
<tr>
<td>HButtonClick Bayou</td>
<td>39.6 in.</td>
</tr>
<tr>
<td>Jackson Bayou</td>
<td>37.5 in.</td>
</tr>
<tr>
<td>Little Cypress Creek</td>
<td>29.8 in.</td>
</tr>
<tr>
<td>Luce Bayou</td>
<td>32.2 in.</td>
</tr>
<tr>
<td>San Jacinto River</td>
<td>33.0 in.</td>
</tr>
<tr>
<td>San Jacinto &amp; Galveston Bay</td>
<td>42.9 in.</td>
</tr>
<tr>
<td>Sims Bayou</td>
<td>37.6 in.</td>
</tr>
<tr>
<td>Spring Creek</td>
<td>29.5 in.</td>
</tr>
<tr>
<td>Spring Gully &amp; Goose Creek</td>
<td>43.9 in.</td>
</tr>
<tr>
<td>Vince Bayou</td>
<td>42.8 in.</td>
</tr>
<tr>
<td>White Oak Bayou</td>
<td>33.2 in.</td>
</tr>
<tr>
<td>Willow Creek</td>
<td>27.3 in.</td>
</tr>
</tbody>
</table>
Notable Floods in Harris County

1900 - Galveston hurricane, Extensive flood damage; Buffalo Bayou flooded.
1933 - Tropical Storm; Record rainfall and floods.
1935 - Army flood damage; Downtown buildings, power station, central water plant inundated; Ship Channel clogged with silt and debris.
1961 - Hurricane Carla; Heavy flooding in S. Southeast Harris county.
1979 - Three major floods, including Tropical Storm Claudette, New U.S. 24-hour rainfall record set in Aiken, TX – 45 inches
1983 - Three major thunderstorms and Hurricane Alicia; Severe flooding across county.
1994 - Major storm in southeast Texas; Many bayous overtopped; More than 3,200 homes flooded.
2001 - Tropical Storm Allison; 73,000+ houses flooded.
2008 - Hurricane Ike.
2015 - Memorial Day Flood; Over 3,000 houses flooded.
2016 - Tax Day Flood; Historic Cypess creek overflow; Over 9,000 houses flooded.
2017 - Hurricane Harvey; Record rainfall event; U.S. Flood Record for many waterways.

A History of Resilience

For over 300 years, Harris County has played a vital role in the history of Texas and the state of Americans. Harris County is the home of the San Jacinto Battleground State Historic Site, where Texas won its independence in 1836. The following year, the City of Houston was founded on the banks of Buffalo Bayou, and, by 1890, it had emerged as the railroad center of Texas.

Following the 1900 Storm, the development of Harris County as an industrial power began in 1911, when voters approved the formation of the Harris County Ship Channel Navigation District. In 1914, the U.S. Army Corps of Engineers finished deepening the existing 50-mile-long channel to 45 feet from the Gulf through Galveston Bay and up the San Jacinto River and Buffalo Bayou to the turning basin at the Port of Houston.

The discovery of the Spindletop oil field in east Texas, near Beaumont, spurred the development of Texas’ petroleum industry. By 1930, the wealth of opportunity in southeast Texas allowed Harris County to become the most populous county in Texas. Located at about 55 feet above sea level at its center, Harris County was comprised of coastal prairie and timberlands with more than 2,500 miles of bayous, creeks, and streams running throughout its 1,777 square miles. Settlers flocked to the region to take advantage of the many opportunities that Harris County offered; however, its flat terrain, clay soils, and an average annual rainfall of 48 inches presented as many challenges then as they do today...

In 1929 and 1935, devastating floods tore through Harris County, leaving hundreds of thousands of dollars in damages in their wake. In response, the Texas Legislature established the Harris County Flood Control District in 1937 to serve as a local partner to local, state, and federal leaders understood that the threat of flooding was always looming, and the next devastating flood event could happen again tomorrow...

In the early years, the Flood Control District was tasked with overseeing rivers, streams, tributaries, and flood waters for domestic, municipal, flood control, irrigation, and other useful purposes. However, as the population of Harris County doubled in the 1950s and the number of industrial buildings tripled, management of flood impacts became more urgent. Infrastructure built within the 1 Percent Floodplain was flooding essentially on a yearly basis at different points throughout the area. As a result, the Flood Control District started to focus on new flood damage reduction projects.

Today, the Flood Control District invests approximately $100 million a year on flood reduction projects in Harris County. Although the Flood Control District’s operations have become more complex over the years, the mission remains the same today: Provide flood damage reduction projects that work, with appropriate regard for community and natural values.

Case Study: Sims Bayou Federal Flood Damage Reduction Project

This project is a shining example of the Flood Control District and the U.S. Army Corps of Engineers’ partnerships working to achieve crucial flood damage reduction for the area.

Construction of the project began in 1990 and was completed in late 2015. The project has steadily reduced the risk of flooding for property owners in the area since its start, and, once floodplain maps are officially updated, the 1 Percent floodplain will be removed from approximately 35,000 houses and 2,000 commercial structures in the Sims Bayou watershed.

This project is a startling example of the Flood Control District and the U.S. Army Corps of Engineers’ partnerships working to achieve crucial flood damage reduction for the area.
Hurricane Harvey: Impact and Response in Harris County

A car is stranded high above floodwaters along Buffalo Bayou near Downtown Houston. (Michael Ciaglo/©Houston Chronicle. Used with permission)

Residents watched bayous overflow their banks from Harvey’s four days of rain. (Jon Shapley/©Houston Chronicle. Used with permission)

A Kingwood resident prepares to leave his home flooded from the San Jacinto River due to Harvey. (Karen Warren/©Houston Chronicle. Used with permission)

A Harris County resident watches as an apartment parking lot fills with floodwater. (Elizabeth Conley/©Houston Chronicle. Used with permission)

An evacuee reaches out to a neighbor as he makes his way out of a north Houston neighborhood. (Elizabeth Conley/©Houston Chronicle. Used with permission)
Hurricane Harvey: Impact and Response in Harris County

It has been estimated that about 70,000 structures flooded in Harris County during Harvey. It is also estimated that over 600,000 vehicles were flooded, many of which were in homes, parking garages, and dealership lots. The Harris County Medical Examiner’s Office has confirmed 36 flood-related deaths. Early damage estimates suggest Hurricane Harvey’s landfall in Texas and flooding across the Harris County region will likely become one of the costliest disasters in U.S. history, on par with Hurricane Katrina’s $160 billion damages in 2005. As of fall 2017, early damage estimates for Harvey ranged from $80-130 billion.

Flooding tens of thousands of homes — homes of plant and port workers, office personnel, first-responders, neighbors, and our own homes — is reflected in lost productivity across the local and regional economies while residents struggle to restore their lives. Harvey’s damage disrupted almost every business in some way in the Houston area, economists say. Some workers needed time to get back to work as businesses allowed them to repair their homes. Others struggled to make it to work after losing their vehicles, compounded by disruptions public transportation. And there’s disruption among employees who have fled Houston for safety in other cities.

Although damages and lost productivity are staggering in scale from Harvey’s catastrophic flooding, the depth and strength of the local economy were revealed. However, the question remains, how many times can Harris County’s economy be tested before the consequences become permanent? Only with appropriate resources and planning will Harris County be ready to face this type of devastating storm again.
Addicks and Barker Dams and Reservoirs

In the 1940s, in response to devastating floods that occurred in Houston in 1929 and 1935, the U.S. Army Corps of Engineers constructed Addicks and Barker Dams on what was then undeveloped prairie land in west Harris and east Fort Bend counties in an area considered to be in the upper watershed of Buffalo Bayou. The reservoirs were built to provide flood damage reduction along Buffalo Bayou downstream of the reservoirs, through the center of the City of Houston, and to the Houston Ship Channel. The concept worked well when the reservoirs were surrounded by prairie and rice fields. But in recent decades, development has encroached from all sides. Today, about 14,000 homes are located inside the reservoirs.

When Harvey made landfall between August 25 and 26, both reservoirs were empty. However, floodwaters behind the Addicks and Barker reservoirs began rising on Friday, August 25, in response to rainfall over the upstream watersheds. Rising water in the reservoirs resulted in widespread flooding of streets and homes upstream. These elevated pool levels impacted surrounding areas behind the dams, flooding over 5,100 homes. *Reservoir gates were opened on Monday, August 28, and surcharge releases of stormwater were begun downstream into Buffalo Bayou to try to prevent uncontrolled releases at the dam’s spillways. Even with the open gates, reservoir pools continued to rise due to tremendous inflow rates from bayous draining into the reservoirs. House flooding occurred in adjacent neighborhoods, and roadways that run through the reservoirs were inundated. Early Tuesday morning, August 29, flood waters inched higher over the north and south spillways of Addicks in an uncontrolled release. Addicks reservoir rose quicker than forecasted and threatened its storage capacity. Pools in both reservoirs were at or near their peaks as of Wednesday, August 30th. By then, officials said Barker was 80 percent full and Addicks was about 100 percent full. The watershed had accumulated 35 inches of rain since Harvey started five days prior.

Many residents and businesses surrounding Addicks and Barker Reservoirs, as well as the Lake Houston and Lake Conroe Dams, flooded as a result of the massive amount of floodwater during Harvey. Many homes and streets downstream of the reservoirs flooded when the combined release rate from the reservoirs exceeded approximately 4,000 cubic feet per second (cfs). However, the combined peak release rate from Harvey was 13,300 cfs, causing thousands of homes to flood — homes that the reservoirs were initially built to protect.

The peak release rate continued until September 20, and only then did floodwaters completely recede from downstream Buffalo Bayou homes, roadways, and businesses. While many properties were devastated by these floodwaters, the dams did not fail and downtown Houston — including the Houston Ship Channel and Port Houston — were protected through Harvey.

Timetable of Events

<table>
<thead>
<tr>
<th>Date</th>
<th>Addicks-Barker Reservoir Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 25, 2017</td>
<td>Rain begins in the Houston Metro area</td>
</tr>
<tr>
<td>August 26, 2017</td>
<td>Rain continues; flood pools behind the reservoirs begin to rise</td>
</tr>
<tr>
<td>August 27, 2017</td>
<td>Rain continues; flooding upstream homes in the flood pool; 5,100 structures flooded upstream</td>
</tr>
<tr>
<td>August 28, 2017</td>
<td>Reservoir gates were opened and surcharge releases of stormwater were made downstream into Buffalo Bayou; flood pools behind the reservoirs continued to rise; house flooding occurred in adjacent neighborhoods; and roadways that run through the reservoirs are submerged. Peak discharge equals 13,300 cubic feet per second (cfs).</td>
</tr>
<tr>
<td>August 29, 2017</td>
<td>Floodwaters begin to flow on uncontrolled releases around the spillway on the north end of Addicks Reservoir; the rain stops.</td>
</tr>
<tr>
<td>August 30, 2017</td>
<td>Pools in both reservoirs were at or near their peaks. Barker was 80 percent full and Addicks was about 100 percent full.</td>
</tr>
<tr>
<td>August 31, 2017</td>
<td>Both reservoirs reach peak elevation; discharge rates remain at peak rates, respectively.</td>
</tr>
<tr>
<td>September 2, 2017</td>
<td>Peak discharge rates continue to be released downstream. Mandatory evacuation order issued by City of Houston.</td>
</tr>
<tr>
<td>September 20, 2017</td>
<td>Peak discharge rates ended</td>
</tr>
</tbody>
</table>

Lake Houston and Lake Conroe Dams

The San Jacinto River watershed is a very large watershed that originates well outside of Harris County, and two large water supply lakes are located along the river: Lake Conroe and Lake Houston. The channels within the watershed drain all or part of Harris, Montgomery, Walker, Waller, Grimes, Liberty and San Jacinto counties, for a total drainage area of approximately 4,500 square miles.

The lower San Jacinto River watershed occupies a rather narrow strip of land in eastern Harris County and joins with the Houston Ship Channel before flowing into Galveston Bay along the southeastern edge of the county. In Harris County alone, the San Jacinto River watershed covers about 487 square miles, and there are about 310 miles of open streams within the watershed, including the primary streams and tributary channels.

The West Fork of the San Jacinto River flows from its headwaters near Huntsville, through Lake Conroe and Lake Houston. The reservoir, operated by the Coastal Water Authority, and Lake Conroe, operated by the San Jacinto River Authority (SJRA), were both developed as water supply reservoirs and therefore do not provide significant storage during flood events.

In the instance of Lake Conroe, SJRA operators have limited discretion in how they operate the spillway gates and are not able to allow “free release” to further reduce downstream flows. There is only about 11 inches of “freeboard” between the top of the spillway gates and the water level at normal lake level. Freeboard is the distance between the water line and the point at which the water would overflow the gate. Operators cannot allow the water to overtop the gates because they are not designed to sustain that type of force. Therefore, the gates must be raised as the lake level rises to allow flood waters to be released through the flood spillway. The lake can rise a maximum of six feet within a flowage easement purchased for the purpose and the reservoir is therefore designed to allow flood releases to a flow level that is below the amount of inflow into the reservoir. Again, this lake is intended to be a water supply reservoir — not flood control infrastructure — and SJRA operators were charged with maintaining the integrity of the structure all Harvey caused rapidly increasing water levels on Lake Conroe.
Hurricane Harvey’s Impacts to Port Houston

The Coast Guard shuttered Port Houston on August 25, 2017 and began reopening it, with restrictions, five days later. Only ships with certain draft sizes were permitted to move during the daylight. Then on Friday, September 1, the Coast Guard lifted the daylight-only restriction and began allowing vessels with drafts of 45 feet to move throughout most of the Houston Ship Channel. The exception was the more inland portion of the channel, from Mitchell’s Point to the Turning Basin. That segment remained closed longer because floodwaters were causing currents and silt and hazardous debris were being washed into the upper channel from the intense flooding. The massive flooding carried silt into the channel and deposited 10 feet of sediment in some places, according to Janiece Longoria, Port Houston Commission Chairman. The Transportation Institute found that the U.S. economy could lose millions of dollars per year due to a reduction in the channel’s depth.

Harvey spared the ports of Houston, Galveston, Texas City, and Freeport from significant damages, but shutting idle had its own costs for companies that depend on the waterway. By one estimate, closing a major port like Port Houston for a week can cause financial losses of up to $2.5 billion from delayed or canceled business transactions, said Maria Burns, director for the Logistics and Transportation Policy Program at the University of Houston.

In 1929 and in 1935, Port Houston was not so lucky. These flood events damaged and interrupted rail service to the port. The flood event in 1935 devastated Harris County and buried the Houston Ship Channel in wastes, silt, and heavy debris. The Port of Houston was brought to a standstill when rail tracks were ripped from the ground, docks were undermined, warehouses and infrastructure were washed away; electrical power plants knocked out of service; and thousands of dollars of commodities were lost to the forces of the flood. “Wild River,” published in 1935 and again in 1951, captures pictorially the magnitude of the damage.

“The ports here are vital to the nation,” said Capt. Kevin Oditt, Captain of the Port for the Great Guard Sector Houston-Galveston and Incident Commander for the Hurricane Harvey response. “We know it’s critical to get them up and running again and to get the Houston Ship Channel open for business again.”

In the instance of Hurricane Harvey, the Harris County region is fortunate that impacts to the Houston Ship Channel and regional ports were not more devastating, as the slow-moving storm did not produce significant storm surge, high-speed winds, and cyclones that are often associated with tropical storm events. In short, the impacts of a storm event to the region’s critical port infrastructure could have been much more intense, and a storm event like this or worse could happen again.

Fast Facts About Port Houston

• Second largest port in the U.S. in annual tonnage handled
• $137 billion worth of goods pass through Port Houston each year
• Nation’s busiest port for foreign waterborne cargo, handling over 234 million tons in 2015
• Largest importer and exporter of petroleum and petroleum products in the U.S.
• Houses more than 150 industrial companies.
• More than 56,000 direct employees move cargo through Port Houston.
Harris County Flood Control District’s Harvey Response and Recovery

Even before the rains stopped, the Harris County Flood Control District began planning and working to recover our county’s drainage infrastructure.

Crews of surveyors began going out into the flooded areas as early as August 30 to gather data on high water marks from bayous and creeks. This critical information feeds Flood Control District storm models and allows the District’s engineers to calibrate for more accurate flood predictions, and develop flood mitigation and infrastructure improvements for the next storm.

As the water receded, the Flood Control District began to assess damages to flood control infrastructure, to conduct infrastructure repairs as necessary, and to remove storm debris blocking the channels. (Debris removal was a priority before the storm as well.) This step is crucial to allow creeks and bayous to drain more quickly without impediments.

Other crews fanned out to repair stormwater gauges damaged during Harvey floods. These gauges transmit important information, such as rainfall amounts and how fast the bayous rise, to the Flood Control District engineers and hydrologists.

Over one-quarter of U.S. refining capacity was shut down in the days following Hurricane Harvey.

Harris County meteorologist Jeff Lindner provided regular weather and flooding updates and became a major public figure during Hurricane Harvey.

Harris County Judge Ed Emmett and US Senator Ted Cruz discuss response to Hurricane Harvey.

A man carries his dry cowboy boots in his backpack as he goes to check his home in Northwest Harris County. (Melissa Phillip/Houston Chronicle. Used with permission)
In addition to maintaining constant communication with Harris County’s inquiring public during the five-day storm event, the Flood Control District responded to hundreds of agency requests for data, as well as thousands of media and public inquiries during Hurricane Harvey, providing information related to rainfall, flooding, emergency services, and resource centers in the area.

The Flood Control District has compiled a preliminary list of $74 million in priority repairs for Harris County’s bayous, creeks, and other drainage infrastructure in the aftermath of Hurricane Harvey, according to a recently completed county-wide assessment that is expected to eventually top $100 million.¹⁴

The Flood Control District has verified approximately 500 additional repair projects totaling more than 150 channel miles across Harris County’s 22 watersheds. Those projects will be submitted to the FEMA and other federal agencies that assist in disaster recovery for reimbursement under the federal Hurricane Harvey disaster declaration. Meanwhile, the Flood Control District continues to review and prioritize more than 4,200 additional reports of sinkholes, slope failures, and erosion for short-term or long-term repair. The Flood Control District has urgently responded the County’s many drainage and infrastructure needs under its jurisdiction, as we all know that time is of the essence and another storm event could happen again.¹⁵
Hurricane Harvey: Impact and Response in Harris County

A Harris County Sheriff's Deputy pauses to listen for people's voices while searching a neighborhood inundated by water. (Jon Shapley/©Houston Chronicle. Used with permission)

Rescue vehicles drive through a neighborhood as floodwaters rise. (Brett Coomer/©Houston Chronicle. Used with permission)

Nearly 10,000 people took shelter at the George R. Brown Convention Center after Harvey. (Michael Ciaglo/©Houston Chronicle. Used with permission)

Flood victims are evacuated by boat from their neighborhood. (Brett Coomer/©Houston Chronicle. Used with permission)

Volunteers used boats to aid first responders in evacuations.

Flood victims are evacuated by boat from their neighborhood. (Brett Coomer/©Houston Chronicle. Used with permission)

Harris County Fire Marshal Assistant Chief Bob Royall, center, and Harris County Sheriff Ed Gonzalez talk to media on August 31, 2017, in Crosby, Texas. (Godofredo A. Vasquez/©Houston Chronicle. Used with permission)
When the Light Broke Through

Even during the height of Harvey’s destruction, the people of Harris County, first responders, local, state, and federal officials began the hard work of saving lives, property, and preparing for recovery. Across the County, friends and neighbors began to mobilize. People cleared drains to keep stormwaters from filling the streets. Social media was used to update communities of high water locations, shelters, and people and pets in need of rescue. First responders worked day and night to rescue trapped families, and volunteers mobilized in everything from boats to dump trucks to help evacuate neighborhoods. Local and county officials worked around the clock to coordinate rescue and public safety efforts with state and federal officials. Every break in the clouds presented an opportunity to get people out of harm’s way. In total, over 16,800 people were rescued by governmental agencies in Harris County, and many more were rescued by private citizens helping to save one another. Over 37,000 people in the region were relocated shelters.

The days following Harvey saw an outpouring of individual and private support from across the county, state, and nation. Those lucky enough to escape the floods donated closets of clothes and pantries of food to those in need. Tens of millions of dollars in personal and corporate donations were made to relief efforts. And now, a conversation about resiliency planning and infrastructure for the County has been renewed… Because, as a community, we recognize that the next storm could happen tomorrow, and we must be ready.

Harvey Relief

<table>
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<th>Harvey Relief by the Numbers</th>
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<td>$122 Thousand</td>
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<td>$37 Million</td>
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<td>$425 Million</td>
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<td>$711 Million</td>
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Governor Greg Abbott, Harris County Judge Ed Emmett and other local officials brief the press on response efforts to Hurricane Harvey.
As Harvey moved on, light broke through the clouds, exposing us to our own vulnerability of living here in Harris County. Some lost homes. Some lost businesses. Some will move on. Some will never be seen again. Harvey’s record flooding will not be forgotten. But, the story of Harvey’s impact does not end here.

The destructive flooding of Harvey presents a new opportunity to rise above and make our region safer, more resilient, and more prosperous than before. History has shown that the people of Harris County are capable of anything they set their minds to. Ordinary citizens, communities, and governmental officials at all levels and from across the country came together in response to the rising waters. Now that the waters have receded, we must all work together to plan and prepare for the storms we know will come in the future.

By working together, planning carefully, and implementing solutions responsibly, we will be better prepared for the Harvey that could come tomorrow.

Harvey Relief by the Numbers

- Federal funds allocated in H.R. 601, Providing relief for Hurricanes Harvey and Irma: $15 Billion
- State funds allocated by Texas Legislature for Harvey relief: $1.8 Billion
- Estimated total damage caused by Hurricane Harvey: $125 Billion

Flooded furniture and debris overwhelmed waste removal services following Harvey.

A couple disposes of soaked carpet after their Baytown home flooded with about three feet of water. (Godofredo A. Vasquez/©Houston Chronicle. Used with permission.)

Jeff Lindner surveys flooded neighborhoods.
About the Harris County Flood Control District

With rapid development and population increases experienced since the 1950s, the role of the Harris County Flood Control District in reducing flood risks has grown increasingly complex over time. Whereas, its original role was to serve as the local partner for major projects with the U.S. Army Corps of Engineers, many other facets of reducing flood risks in Harris County have come into play.

Today, the Flood Control District’s mission of providing flood damage reduction projects that work, with appropriate regard for community and natural values is accomplished by:

• Development of flood risk management plans
• Preparation of construction plans to build flood risk reduction projects
• Construction of flood risk reduction projects
• Maintenance and monitoring of existing Flood Control District infrastructure

The Flood Control District’s drainage and flood control infrastructure is extensive, including 22 major watersheds drained by 22 major bayous and creeks, with numerous tributaries. The bayous and tributary channels serve as the main drainage system for floodwaters out of the county into Galveston Bay. Harris County has more than 3,500 channels totaling about 2,500 miles in length (about the distance from Los Angeles to New York), and each of the 22 primary watersheds in Harris County presents their own unique flooding challenges.

It should be noted that the Flood Control District does not have sole jurisdiction over flood-related matters in Harris County. In fact, there are many other entities involved that have special interests in their particular areas of responsibility. The City of Houston, for example, is one of the local floodplain administrators for the community’s participation in the National Flood Insurance Program (NFIP). The City has its own criteria for design of its drainage systems—primarily the design of storm sewers and street drainage, but also stormwater detention for these systems.

Other incorporated areas are also floodplain administrators and have their own drainage design criteria for their road systems. In unincorporated areas of Harris County, the County Engineer’s office is the floodplain administrator. In all, there are 34 floodplain administrators in the county...And, the Flood Control District is not one of them.

To complete the jurisdictional picture, there are four county commissioners’ precincts, as well. In all, with 34 floodplain administrators reporting to separate entities of government, there are nearly 250 elected officials involved in the administration of drainage and flooding issues in the county, including each municipality’s building permit program.

Together, with the 34 municipalities in Harris County, and other local, state, and federal entities, the Flood Control District has worked relentlessly to better protect and prepare our region for tomorrow’s next flooding event...
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35. Walters, Edgar, “How much has been raised for Harvey relief — and how’s it being spent?” The Texas Tribune, January 30, 2018, https://www.textratribune.org/2018/01/30/how-much-has-been-raised-harvey-relief-and-hows-it-being-spent/

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The sun sets over the Houston skyline as Harvey moves out of the region. (Michael Ciaglo/Houston Chronicle. Used with permission)