

**Resilience: Equipping Houston to Manage Its Next Harvey**  
**Adapting Houston to the New Normal**

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## Introduction

A husband and wife both land their dream jobs requiring the family, including their school-aged children, to move to the Houston area. They find their dream house with all the desired amenities, in the perfect location, and within their price range. The family is settling into a routine when suddenly an unexpected yet devastating once-in-a-lifetime flooding event brings two feet of water inside their dream house – for three consecutive years, and it is outside the floodplain!! They have just experienced urban flooding and rapidly becoming a common occurrence in the Houston-area. According to Sam Brody, Director of Center for Texas Beaches and Shores at Texas A&M University, this area is prone to the most urban flooding incidents in the country over the past forty years (Shaw, Satija and Collier). They are deeply frustrated and have many unanswered questions, but whom do they turn for help?

Unfortunately, the frequency of comparable stories is increasing in the Greater Houston area and often to the same people. According to an analysis performed by the Associated Press, if Harris County were a state, it would rank amongst the top of every category for repeated flood losses. More property loss occurring per capita in this area than anywhere else and the problem is not improving anytime soon. For example, nationwide repeat flood relief payouts average \$3,000 per square mile; in the Greater Houston area, those average payouts are \$500,000 per square mile (NBC News). Harris County Judge Ed Emmett declared, “Three 500-year floods in three years mean either we are free and clear for the next 1,500 years or something has seriously changed” (Kimmelman, Lessons From Hurricane Harvey: Houston's Struggle is America's Tale). So, what’s going on?

The previous statement by Judge Emmett summarizes the discussions and divisions occurring everywhere between residents, city/county staff, elected officials, and pundits from all walks of life regarding the approaches and attitudes during the recent flood events. In the court of public opinion, a part of the population sides with the latter part of that statement and can back it up with studies to back those claims. However, others agree with the former part of that statement saying recent increase in flooding activities are mere coincidences and environmentalists use flawed data and research to make their case.

This paper is written to help answer multiple questions many people within the affected areas and across the country are asking related to Houston's past preparedness during their significant flooding events, including Hurricane Harvey. These questions include (1) why Houston so ill-prepared for Harvey, (2) reasons for the absence of development controls and how it contributed significantly, and (3) why development controls would have made little difference. The closing section of this paper will center on what should be done to prepare Houston for its next flooding event or major hurricane. It will offer potentially innovative solutions from other cities and agencies across the country and the globe to get a better insight into how they are mitigating the damage caused by the flood waters and incorporating those solutions into their respective policies, regulations, and lives. After reading this paper, hopefully the citizens and elected officials of the Houston metropolitan area and experts can hopefully work collaboratively to implement an effective plan. This plan should accomplish viable long-term solutions to diminish the intensity and amount of water and flooding damage caused by these significant flooding events and hurricanes.

### **Why Was Houston So Ill-Prepared for Harvey?**

#### *Facts & Figures*

Before answering the overarching question in this section, let us look at some basic facts for the region. As of mid-2017, the City of Houston has a sprawling area of 599.59 square miles and home to approximately 2.3 million residents; Harris County has a population of 4.6 million (U.S. Census Bureau). How big is Houston? It is the same size as Chicago (234 square miles), Cleveland (82.47 square miles), Detroit (142.9 square miles), and Philadelphia (141.7 square miles) combined (Berke). Houston's Metropolitan Statistical Area (MSA) population is nearly seven million residents and has an approximate area of 9,000 square miles, larger than the entire state of New Jersey (Brian, Merrill and Patterson). Houston is only forty miles from the Gulf Coast, has an elevation of fifty feet above sea level, and "is among the flattest major metropolitan areas in the country sloping less than one foot per mile" (Schaper). In addition to its growth, sprawl, and geographic challenges, the Houston area has "black gumbo" clay-based soil, the least absorptive soil in the county (O'Conner and Kaufman). Combining its size,

geography, location, and the soils found in the region, Houston was already at a significant disadvantage without adding its explosive population growth or weather-related events during unpredictable spring weather and hurricane season. What follows is a review of the implementation of major infrastructure initiatives that led us to the current state.

### *History of Major Infrastructure Implementation*

The City of Houston built many of the existing dams designed to handle the drainage and water retention in the 1930s, long before the establishment of any homes and businesses in the area. In 1938, authorized by the Rivers and Harbors Act (Texas Water Development Board), the U.S. Army Corps of Engineers started building two massive reservoir projects in the western part of Harris County (Mulligan), later named Addicks Reservoir and Barker Reservoir. These reservoirs were a reactive response to reduce the risk of extensive flooding in the downtown area caused by a series of storms in consecutive years during the mid-1930s. (Boburg and Reinhard). At the completion of both reservoirs in the mid-1940s, Houston's population was nearing 400,000, and the city was twenty miles downstream (Kimmelman, *Lessons From Hurricane Harvey: Houston's Struggle is America's Tale*). The reservoirs had a combined design capacity of 411,500 acre-feet or 134 billion gallons and a combined drainage area of 260 square miles (Texas State Historical Association).

Seventy years later, those reservoirs now sit at the center of an "urban agglomeration of six million" (Kimmelman, *Lessons From Hurricane Harvey: Houston's Struggle is America's Tale*). Local officials "allowed development to pave over crucial acres of prairieland that once absorbed huge amounts of rainwater" causing suburban sprawl resulting in water taking longer to drain (Shaw, Satija and Collier). Many people did not know their homes and businesses were in a danger zone that stood in the path designed for water to flow naturally. As a result, the reservoirs built over the last seventy years ago have today "created new flood zones to protect the old ones" (Heisler).

### *Current State of Existing Infrastructure*

Houston never let its hydrology issues prevent it from becoming the fourth-largest city in the country. They continually attempt to engineer man-made solutions to address the constant drainage issues historically using “a network of bayous that run east into Galveston Bay and concrete channels as the main drainage system” (Boburg and Reinhard). This network includes different combinations of bayous, berms, canals, concrete channels, culverts, dams, drains, levees, pumps, reservoirs, and other “gray” infrastructure to patch together a viable solution (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*).

However, in a shocking statement, renowned expert Sam Brody of Texas A&M said, “The stormwater system has never been designed for anything much stronger than a heavy afternoon thunderstorm” with roads built below grade and designed to carry the excess water when storm drains overflow. This may cause a major issue when evacuations are ordered and makes transporting people more difficult as streets become pseudo-rivers (Boburg and Reinhard). Today, the state of that entire infrastructure network is in dire need of upgrade and repair. These repairs and upgrades include the following:

- The Addicks and Barker Reservoirs, which the U.S. Army Corps of Engineers rated “amongst the six most at-risk in the country” (Feldblum);
- Upgrading “old and inadequate drains and pipes that can handle at most up to 1½ inches of rain per hour” (Schaper);
- Widening existing bayous as they are too small to handle recurrent rainstorms and cannot widen nor keep up with new development (Schaper); and,
- Upgrading the Buffalo Bayou as it is virtually unchanged and “is pretty much still a dirt mud channel like you would have seen 100 years ago” (Schaper).

### *Lack of Overall Regional Coordination*

Another factor why Houston was ill-prepared for Harvey was the lack of regional coordination. Harris County has 34 cities and towns within its boundaries and each has independent plans for addressing flooding issues (Boburg and Reinhard). The lack of a comprehensive region-wide plan or coordination often pits cities, neighborhoods, and

subdivisions against each other when battling flooding issues (Feldblum). Even with all the necessary improvements and regional organization, there is something that may be missing. Brody stated, “In new developments where modern drainage systems are installed, they are often treating the symptoms, not addressing the underlying problem” (Gabbatt). What exactly is the underlying problem?

### **Reasons for the Absence of Development Controls & How It Contributed Significantly**

Houston is the biggest city in the country with no zoning laws, which “makes it an interesting case study in limiting government regulations and favoring growth—often at the expense of the environment and a cautionary tale of sidelining science and plain common sense” (Campoy and Yanofsky). Houston has historically been a city with an attitude of “grow first, ask questions later” (Coy, *Houston's Flooding Problem Reflects Shortfalls in City Planning*) and many people think its lack of zoning rules made an unusual weather event even worse (Deshais). Many flooding experts agree “the biggest government failure for the City of Houston came in the years preceding the storm that allowed developers to build new communities with little regard for flooding projections” (Worland). Not segregating incompatible land uses as other cities and not distinguishing between residential densities allowed for increased water runoff to flow at different rates, making the problem worse. Adding to the Wild West development narrative is money-hungry officials and developers encouraging building in low-lying, flood-prone areas without thinking of future risks and strong opposition towards any type of changes to reform the city’s development codes. The section will focus on these reasons as to why these factors contributed significantly to the disaster.

#### *Unenforceable Regulations*

Houston’s light regulations led to disorganized development. The absence of zoning laws stimulated unprecedented property development with little regard to the environmental impact or strain on the current infrastructure (Worland). These regulations lacked any punitive enforcement measures which contributed to more flooding and allowed developers to pave over crucial acres of prairie land that once absorbed enormous amounts of rainwater (Shaw,

Satija and Collier). With no significant penalties, developers often skimmed on flood control and prevention systems (Mulligan). According to a 2015 study by Texas A&M and Houston Advanced Research Center (HARC), between 1990 and 2012 “in less than half of the cases, the developers submitted complete paperwork and in two-thirds of the cases, there was no documentation that any mitigation had happened” (Campoy and Yanofsky).

### *Municipal Utility Districts*

A significant contributor to the uncontrolled growth has been Municipal Utility Districts (MUD). MUDs are special districts functioning as independent, limited governments and give developers an alternative way to finance necessary infrastructure like roads, utilities, drainage, and other services when they are not readily available in those locations. They set a tax rate to reimburse the developer infrastructure costs and have the power to issue debt and increase taxes as needed (City of Austin, Texas). According to the Houston Chronicle, Texas currently has 949 MUDs; Harris (389), Fort Bend (146), and Montgomery (85) counties account for 65% of the overall total (Drew). The locations of MUDs are in the unincorporated parts of counties and each has a set of different standards independent of each other. As they can develop outside the scope of oversight and set their regulations, there is no incentive to coordinate plans, thoroughfare connections, or drainage with each other, which led to today’s sprawl.

### *Overall Attitude*

Another reason the absence of regulations contributed significantly to the disaster is the overall attitude of citizens, developers, and policymakers. Strong opposition is always on the horizon with any intent to reform the city's current development codes (Grabar). Sam Brody of Texas A&M University stated, “Any mention of regulation creates a hostile reaction from people who see that as an infringement on property rights and a deterrent to economic growth” (Boburg and Reinhard). In 2001 after Tropical Storm Allison, the City of Houston tried to change policies, including banning new development in the floodway but it met strong resistance from developers and residents and prompted multiple lawsuits. Years later, those development policies and regulations were either overturned, removed, or severely weakened

due to those lawsuits (Shaw, Satija and Collier). Also, Houston residents have also voted down a zoning code five times in the last 106 years – 1912, 1929, 1948, 1962 and most recently in 1993 (Boburg and Reinhard) & (Buitelaar).

### *Lobby Organizations*

If residents do not intervene, there are organizations, such as the Texas Association of Builders (TAB) and the National Association of Home Builders (NAHB), which continuously lobby against legislation proposing stricter building standards that protect homeowners long-term but affect their bottom line. (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*). All this while the “federal government wants local governments to adopt policies that reduce the cost of disasters, but state and local governments worry about the lost tax revenue” (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*). A study by The Pew Research Center shows upfront spending on stricter standards saves money. That study states, “every dollar invested in mitigating the risk of natural disaster saves \$4 in relief and rebuilding costs” (Worland). If more stringent regulations were in place with more upfront spending on flood prevention and mitigation, it would have saved Houston billions. However, due to the greed of developers and policymakers, the city of Houston has opted for lax regulations.

### *Harris County Flood Control District*

Another reason for the absence of regulations is the arrogance of the top officials at the Harris County Flood Control District (HCFCD), the government agency formed to protect the effects of flooding within Harris County. One example is a 2015 report commissioned by the district indicating that “the restoration of one acre of prairie would offset the extra volume of runoff created by two acres of single-family homes or one acre of commercial property” (Shaw, Satija and Collier). The long-time previous executive director Mike Talbott and his successor Russ Poppe disagree with the study’s findings stating “all development since the mid-1980s have not contributed to any additional flooding” (Shaw, Satija and Collier). Talbott said the recent flooding occurrences are not a new normal and criticized scientists and conservationists

for being anti-development and have an agenda that protects the environment and overrides common sense” (Shaw, Satija and Collier). Having the agency designed to protect citizens from flooding going against their research is concerning and a significant factor to why the attitude and arrogance played a factor.

### *The Grand Parkway*

Recently, the construction of a third outer loop named The Grand Parkway will only incite more sprawl and pave over thousands of acres of precious wetlands in the Katy Prairie. This area lost a quarter of that capacity due to recent development activity (Shaw, Satija and Collier). Within the outer loop is an upcoming multi-billion-dollar master-planned community located outside the 100-year floodplain. However, most of the roads leading into the new proposed development are within the 10-year floodplain, which will make evacuation very difficult during flooding events (Kimmelman, Lessons From Hurricane Harvey: Houston's Struggle is America's Tale). These are just a few known examples of the effects caused by the absence of regulations. Lost wetlands, paving over vacant property, and building in the floodplain increased the impacts of stormwater runoff and flooding issues.

### *The Effects of the Absence of Regulations*

So, what were the effects of their actions? Between 1992-2010, Harris County lost 30% of wetlands (approximately 25,000 acres) while the amount of impervious coverage (i.e., gray infrastructure) increased by 25% from 1996-2011 (Shaw, Satija and Collier). The White Oaks Bayou, in northwest Houston, lost 70% of its original wetlands between 1992 and 2010 (Berke). Between 2000-2015, a total of 360,000 new buildings (Brian, Merrill and Patterson) with at least 7,000 residential (Boburg and Reinhard) and 1,600 nonresidential buildings (Shaw, Satija and Collier) were built in the designated 100-year floodplain. These numbers do not include the 140,000 single-family homes already in the floodplain (Kilgore). In 2001, land developed around the Addicks watershed measured at 28%; nine years later, it increased to 41% (Shaw, Satija and Collier). Over 3,500 homes in the Sims Bayou were subject to flooding because of increased stormwater runoff (Berke). According to calculations through a Texas A&M research

project, “the region has lost the ability to handle nearly four billion gallons of stormwater due to new development activity” (Campoy and Yanofsky). Although that was a fraction of rainfall that Harvey eventually fell on Houston, every bit of unpaved land would have helped reduce or mitigate the expected damages of flooding.

Houston is in a vicious circle. With an increase in population comes a need for additional housing, which leads to more paving, which leads to increased stormwater, which results in more flooding, which ends up affecting more people (Campoy and Yanofsky). With explosive population growth the area is experiencing, there appears to be little incentive to change the status quo. Rob Moore, a senior policy analyst for the Natural Resources Defense Council, stated, “What’s likely to happen is we are going to spend tens of billions of dollars rebuilding Houston exactly like it is now, and then wait for the next one” (Campoy and Yanofsky). Ultimately, “Mother Nature doesn’t really care if you don’t care” (Coy, Houston's Flooding Problem Reflects Shortfalls in City Planning).

### **Why Development Controls Would Have Made Little Difference**

“No land-use planning could have protected an area of 6 ½ million people from the largest downpour in this country’s history” (Hamilton). To quiet critics, Houston Mayor Sylvester Turner sent a message via Twitter five days after Harvey’s landfall while rescue efforts were still ongoing. He tweeted, “Zoning wouldn’t have changed anything. We would have been a city with zoning that flooded” (Turner). There are other factors why any development regulation would have made a slight difference. These factors include climate change, the amount of rainfall, population explosion, development occurring outside the city limits, and the National Flood Insurance Program. Let us explore each one.

#### *Susceptible Location*

As mentioned earlier, Houston sit forty miles from the Gulf Coast making it more susceptible to storms from late spring to early fall. This timeline aligns perfectly with the traditional hurricane season (O’Conner and Kaufman). Data shows ten-inch + downpours happening at twice the rate during the last thirty years (Schaper), a 167% increase in heavy

downpours since the 1950s (O'Conner and Kaufman), and eight once-in-a-lifetime storms since 1989 or one every 3 ½ years (Shaw, Satija and Collier). With Houston's clay-based soils being the nation's least penetrable, it makes flooding more inevitable, causing water to runoff faster or stay stagnant in one location.

### *Climate Change*

The effects of climate change are important but often downplayed in today's political environment. According to The Weather Channel, "A large amount of CO<sub>2</sub> drives the temperature of both the atmosphere and the oceans up, allowing the atmosphere to hold more water vapor" (Alonso III). This increase is called the "Clausius-Clapeyron relation, which says the water-holding capacity of the atmosphere increases about seven percent for each degree Celsius in the temperature (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*). "Hurricanes normally draw in moisture from the ocean, but Harvey dumped so much on Houston that at one point, it was reabsorbing that water from the flooded city and hurling it back down. Heat from the Gulf of Mexico fueled Harvey, so warmer air led to more water and moisture, which lead to more powerful storms" (Gabbatt).

### *Record Rainfall*

During Hurricane Harvey, a record fifty-two inches fell on the region, equivalent to 24-28 trillion gallons of water (Fritz and Samenow), yet no amount of regulation will help a city absorb a year's worth of rainwater in five days. No one questioned the zoning regulations when Hurricane Katrina hit New Orleans in 2005, Hurricane Sandy hit the East Coast in 2012, or when other hurricanes hit more cities along the Gulf Coast. The capacity of the wetlands mentioned in the previous section lost to new development since 1990 would have only absorbed approximately four billion gallons of rainfall, less than one percent of the estimated rain the Harvey dumped in the Houston-area (Beyer).

### *Explosive Growth Patterns*

A more valid cause for criticism could be Houston's explosive overall growth. Many applaud Houston's lack of regulation that allows developers to rapidly fulfill housing and development needs in one of the fastest-growing areas of the country (Deshais). People are moving to this region in record numbers. In the last twenty-five years, Houston has added one million new residents (Mulligan). In fact, from 2008-2015, Harris County added more people than any other county in the U.S. (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*). According to population projections, the Houston metro area population will increase from 6½ million to ten million by 2040 (Berke). However, much of the criticized sprawl development is occurring outside the city limits. Since 2010, an increase of 200,000 took place inside the Houston city limits with the remaining 800,000 in the booming suburbs, such as Katy and Sugarland and those municipalities have zoning codes that discourage density (Beyer). With much growth occurring, there is an unprecedented demand for housing with other ancillary services and not enough land and time to accommodate these demands. The irony is that Houston, because of its looser regulations, will tolerate dense development in contrast with other flood-prone cities, like New Orleans, where much of its housing is in floodplains, but where zoning laws restrict construction in more affluent areas having higher elevations (Beyer).

### [National Flood Insurance Program](#)

[Another reason development regulations would not have made any difference is the National Flood Insurance Program \(NFIP\).](#) A recent distribution breakdown in federal aid shows 53% allocated to replace the loss of property, 22% helping people rebuild and 7% to hazard mitigation or prevention (Gelinias). [The FEMA program](#) altered settlement patterns by subsidizing many developers to build more houses in the floodplain, near bayous or in floodplains. However, the damage might have been less extensive if the government did not subsidize those developments. The NFIP underwrites the risk people assume by living in an area prone to storm surge damage (Powell and Magness). According to a recent study, between fifteen to twenty percent of NFIP policyholders receive subsidies that reduce their premium costs by approximately sixty percent (Powell and Magness). Due to the recent hurricanes,

Congress will be under intense pressure to increase funding for the NFIP, but Congress should instead get rid of the program as it encourages poor choices, which produce bad results, as seen in Houston and other flood-prone areas. Ironically, what this means is it is not the lack of regulation that exposed many of Harvey's victims to catastrophic loss; it was government policy.

### **Potential Solutions to Assist the Greater Houston Area**

The question of whether the lack of stricter regulations played a significant role in the flooding that took place in the aftermath of Harvey in the Greater Houston area will be a highly-contested debate for many years. Although the fingerpointing continues, this section will focus on possible solutions that will assist this region when similar events occur in the future. The first section will cover domestic solutions, and their results and the next will focus on international solutions and the success they have had with those initiatives.

#### *Higher Freeboard Regulations*

One of the first solutions that would make an immediate impact are higher freeboard regulations. Many local governments require a specific minimum elevation requirement for all structures to protect them from possible flooding. Currently, Houston has a freeboard requirement of one foot, but it is not enough for an area notoriously known for flooding and poor drainage (Brian, Merrill and Patterson). Brazoria County, located south of Houston, adopted a freeboard of two feet in 2007. In 1979, Nashville passed a freeboard requirement of four feet, which helped tremendously during the 2010 city-wide flooding and prevented further damage (Brian, Merrill and Patterson). Sam Brody suggests a freeboard requirement of three feet for the Houston metro area. (Gelinias). He also proposed any regulation to increase the freeboard should apply to new and rebuilt homes caused by previous flooding events.

#### *Norfolk, Virginia*

Norfolk, Virginia adopted a unique long-term solution due to its location along the Atlantic Coast. In a proactive effort to reduce and prevent further risk of flooding, government

officials split the city into low-risk and high-risk flood areas. Low-risk areas will transition into high-density mixed-income communities. High-risk areas with established neighborhoods “will gradually retreat from shorelines with housing buyouts, while key sewer and water utilities and roads will be maintained rather than expanded” (Berke). The intent is the higher densities in low-risk areas will help offset the established densities in the high-risk areas.

### *Boulder, Colorado*

Another example is found in Boulder, Colorado. Following extensive flooding in 2013, the city started to redesign infrastructure with permeable surfaces which, unlike concrete, can absorb water into the ground (Shaw, Satija and Collier). For a city that doesn’t flood often, they are proactive in implementing permeable surfaces outside the 100-year floodplain and leaving more open space undeveloped. Boulder is taking the initiative to ensure they are not caught flat-footed again. Katherine Hayhoe, a climate scientist, stated, “They (Boulder) are still preparing because they know in a warmer world, the chance of heavier rainfall is greater” (Shaw, Satija and Collier).

### *Buyout Programs*

Another domestic solution, albeit an expensive one, is a buyout program. In buyout programs, governments purchase homes and properties and convert it back to green space allowing natural water absorption to occur. One successful example is the flood-prone Onion Creek neighborhood in Austin. The City of Austin used a combination of bonds and citywide drainage utility fees totaling \$100 million along with a federal contribution of \$40 million to buy out 823 homes (Song, Shaw and Satija).

In Milwaukee, as part of its 2035 Vision, the Metropolitan Sewage District plans to have “zero homes in the floodplain, acquire an additional 10,000 acres of river buffers through Greenseams®, use green infrastructure to capture the first ½-inch inch of rainfall, and harvest the first ¼-gallon per square foot of area of rainfall” (Milwaukee Metropolitan Sewerage District). After Hurricane Harvey Sam Brody predicted that, the Harris County Flood Control

District would be overwhelmed by the demand; so many people who should be brought out, and they are never going to get to them” (Song, Shaw and Satija).

### *Singapore*

Internationally, Singapore is a model Houston could emulate as monsoons continuously hit the city-state with minimal effects. Although their population has doubled since the 1980s, it has managed to increase the area of land with green cover from 35% to 46% (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*). It is not a quick fix solution but a strategy that will require patience and likely require the work of a generation (Coy and Flavelle, *Harvey Wasn't Just Bad Weather. It was Bad City Planning*).

### *The Netherlands*

The Netherlands serve as another great model and considered the global gold standard for water management. In response to the 1990s flooding that caused the evacuation of hundreds of thousands of residents, the Dutch rethought their approach and decided to “give back to the rivers some of the room we had taken” (Kimmelman, *Lessons From Hurricane Harvey: Houston's Struggle is America's Tale*). Much of the country sits below sea level and gradually sinking. The City of Rotterdam is 90% below sea level but are “pioneering solutions to flooding entail living with the water” (Berke). Due to their location, only 20% of the population is eligible for evacuation (Kimmelman, *The Dutch Have Solutions to Rising Seas. The World Is Watching*) so there had to be creative solutions. Some of their solutions include “underground garages, green roofs that absorb water, and water plazas that serve as a kind of aquatic town square, while acting as huge storage reservoirs when extreme rainfall occurs” (Berke). In fact, many cities from around the world including Jakarta, Ho Chi Minh City, New York and New Orleans visit this city and hire Dutch engineering firms as consultants to help manage their own flooding problems and come up with innovative solutions that will help (Kimmelman, *The Dutch Have Solutions to Rising Seas. The World Is Watching*). If there is a foreign solution for Houston to model itself after, they should go with the Dutch’s engineering solutions based on their history of adapting to Mother Nature.

### *Houston's Attempts*

To Houston's credit, they have not just sat on their hands trying to come up with innovative solutions. In 2010, Houston voters approved a proposition, led by Mayor Analise Parker, to create a dedicated fund for drainage improvements at a cost of \$5 per month to the average resident, but some residents challenged the wording in that referendum and it currently still sits in the courts (Shaw, Satija and Collier). In early 2018, that fund had \$250 million with a projected increase to \$600 million by 2030; imagine the number of improvement projects those monies could fund if the courts sided with the city (Feldblum).

In January 2017, nine months before Hurricane Harvey, the Houston City Council approved an initial \$10 million to reduce drainage problems along three of its bayous. (Brian, Merrill and Patterson). During the 2017 State's legislative cycle, Governor Abbott vetoed a bill that would have allowed Harris County to issue a citation equivalent to a parking ticket for violating floodplain regulations (Kimmelman, Lessons From Hurricane Harvey: Houston's Struggle is America's Tale). Harris County Judge Emmett probably said it best stating, "Looking back, should we have spent more to avoid some of the flooding? Sure. Did taxpayers want to pay more to do those things? No" (Kimmelman, Lessons From Hurricane Harvey: Houston's Struggle is America's Tale).

However, all that changed on August 25, 2018. One year to the date that Hurricane Harvey unleashed its fury on Houston, Harris County residents approved a \$2.5 billion flood bond passing with over 85% supporting it (Despart). In the same article, "the bond allows the Harris County Flood Control District to build at least 230 projects over the next ten to fifteen years with the key to access more than \$2 billion in matching federal dollars" (Despart). Hopefully, the overall attitude has changed in Houston and this is the first step in a series designed to get everyone onboard and on the same page in being more proactive when it comes to flood control and prevention.

### **Conclusion**

In conclusion, the purpose of this paper was to briefly answer various questions people had about the preparedness of the City of Houston during its past significant flooding events,

including Hurricane Harvey. We looked at Houston's size, geography, location, and soils as existing factors that could not be changed, aging infrastructure and lack of regional coordination that made Houston ill-prepared for Harvey. We also looked at how an attitude of grow-first ask questions later, the lack of land-use segregation and regulations, the rise of municipal utility districts, property rights oriented citizens and lobbyists challenging or killing new development regulations, the loss of pervious surfaces, and the arrogance of the Harris County Flood Control District as reasons for the absence of development controls and how it contributed significantly. We looked at reasons why development controls would have made little difference by examining some of the effects of climate change, the amount of rain that fell was not predictable, Houston's explosive growth, and the negative effects of the National Flood Insurance Program. We explored innovative regional, national, and international solutions to assist Houston including higher freeboard regulations, giving higher densities to low-risk flood areas, the use of permeable surfaces, buyout programs, increasing green cover, and hiring Dutch engineers who constantly deal with flooding issues as their native country sits below sea level.

Although there will continue to be questions on both sides of the debate, hopefully with this disaster fresh on everyone's minds, people in power and citizens will stop thinking with their wallets and start using their head when it comes to applying common sense and regulations to match it. While it is true that no city could have withstood the effects of Harvey without serious harm, Houston did make itself more vulnerable than necessary by its repeated ignorance that a problem existed and not doing enough to fix it. However, there are still measures Houston can take to lessen future flooding. Houston is consistently flooding and slow to be proactive or reactive when it comes to addressing flooding issues. It is expected after reading this paper, the citizens and elected officials of the Houston metropolitan area and experts can work collaboratively to implement an effective plan to accomplish viable long-term solutions to diminish the intensity and amount of water and flooding damage caused by these significant flooding events and hurricanes. A proactive approach by Houston or Harris County officials may have helped save lives and property. This could include the government bolstering its reservoirs, buying, and preserving wetlands, incentivizing farmers to harvest their land,

rather than sell it to developers, and approving common sense regulations to prevent development in the floodplain. In updating their aging infrastructure, they should immediately hire Dutch engineers who have extensive in engineering solutions to flood-prone areas. They should consider every solution mentioned. Another solution is to start implementing climate change data into their models for more exact projections. As Ken Kunkel, an official at the National Oceanic and Atmospheric Administration stated, “You can build it now for today’s climate, but you may not be quite in tune to what the climate will be in 50 years” (Worland).

Historically and continually, citizens, builders, developers, and government officials have bent the land to its will and serve their own selfish goals and purpose. They have unintentionally imposed the doctrine of Manifest Destiny on nature’s most formidable hurdles to construct its sprawling highways and developments all to achieve their twisted version of the American Dream. If Houston does not change their ways soon, a worse unimaginable event could spell disaster. The worst flooding event has not yet occurred, but conditions are ripe for a future powerful Category 5 hurricane to cause a direct hit, bringing about devastation to refineries in Galveston Bay with unprecedented storm surges causing widespread flooding more severe than experienced with Harvey, which causes ripple effects in the national economy. This is a very imaginable situation if no action starts takes place right now.

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