BEFORE THE WATER GETS TOO HIGH

TEXAS AND THE FIGHT AGAINST SEA LEVEL RISE

HONORS THESIS

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by

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ABSTRACT

The Texas Gulf coast totes 365 miles of shoreline and over 6 million residents; however, many do not realize the rate at which sea-level is rising. Between 1950 and 2016, Texas experienced 18.56 inches of sea-level rise[1]. The U.S. Army Corps of Engineers predicts it will rise six more inches by 2031[2]. As the situation escalates in Texas, communities are exploring shoreline mitigation techniques for future protection and sustainability. This project is a long-form multimedia story about the sea-level rise in Texas; specifically, it investigates what two very different coastal communities are doing to adapt to impending change. I conducted the two "case studies" examining mitigation tactics proposed and employed in the Galveston area and along South Padre Island, respectively. This was primarily done by interviewing community leaders, residents and organizations invested in the problem. Additionally, I include data journalism and video to create a complete story package hosted online at high-water.hollyhearn.com. The aim of this project is to contrast sea-level rise situations in Galveston and South Padre Island respectively through digital storytelling.

ABOUT THIS PROJECT

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[1] National Oceanic Atmospheric Administration, *Tides & Currents,* 2016, https://tidesandcurrents.noaa.gov/waterlevels.html?id=8771450&units=standard&bdate=19500101&edate=20171231&timezone=GMT&datum=MSL&interval=m&action=data.

[2] U.S. Army Corps of Engineers, *Sea-Level Change Curve Calculator (Version 2019.21),* 2019, http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html.

Rather than a traditional research-based written thesis, this thesis primarily lives online as a multimedia journalism project. Multimedia means to use more than one medium for expression or communication. The online thesis includes video, data and images to communicate how two Texas coastal communities are responding to sea level rise. This final product is the culmination of four months of research, traveling, interviews, video editing, journalism and coding. Travel to some locations was funded by the Undergraduate Research Fellowship. For the full-effect of the project, please visit high-water.hollyhearn.com.

I. A climate crisis that cannot be ignored

Sea level rise and flooding are increasing across the United States, leaving coastal communities particularly vulnerable. NASA collects data from coastal tide gauges across the globe as part of the Global Climate Change research program. Data shows that since 1950, the sea level has risen 6.5 inches; however, half of it (3 inches) has occurred in the last 20 years[3]. This acceleration has caused a 200-400% increase in flooding across the United States, resulting in displaced Americans, disrupted ecological systems, and billions of dollars in damage according to the National Oceanic and Atmospheric Administration (NOAA)[4].

In addition to mitigating the effects of climate change, actions must be taken to assure long term global sustainability according to the UN Intergovernmental Panel on Climate Change (IPCC)[5]. Environmental scientists recommend largely reducing greenhouse gas emissions to slow the warming of Earth's atmosphere. Island and coastal communities are facing displacement due to rising sea levels and many argue that it would be generationally unjust for this event to go on ignored.

According to the IPCC, sea level can change, both globally and locally due to four main causes:

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[3] National Aeronautics and Space Administration, *Global Climate Change: Vital Signs of the Planet,* December 2018, https://climate.nasa.gov/vital-signs/sea-level/.
[4] William V. Sweet, Doug Marcy, Gregory Dusek, John J. Marra, Matt Pendleton, "2017 State of the U.S. High Tide Flooding with 2018 Outlook," *NOAA Office of Coastal Management,* June 6, 2018, https://www.ncdc.noaa.gov/monitoring-content/sotc/national/2018/may/2017_State_of_US_High_Tide_Flooding.pdf.
[5] IPCC, *SR15 Special Report,* October 2018, https://www.ipcc.ch/sr15/.

1. **Ice melt** causes about two-thirds of global sea level rise. 1,700 trillion pounds of ice is melting from Antarctica (550 trillion), Greenland (700 trillion), and mountain glaciers (450 trillion) each year.
2. **Thermal expansion** causes about one-third of global sea level rise. As the ocean gets warmer, water expands and pushes the sea level higher.
3. **Changing ocean basins and a slowing gulf stream** increases sea levels in some areas. The melting ice from glaciers adds tons of fresh water to the gulf stream, disrupting its usual flow with so much low-density fresh water. The slowing gulf stream is leaving more ocean water on the American East Coast, contributing the the relative sea level rise there.
4. **Sinking land** increases sea level rise in some areas. Water pumped from underground causes the land above to sink down, and sea levels to rise. This is the case in Texas leading some areas to restrict groundwater and oil extraction practices according to the Texas Water Development Board[6].

Thomas Ballinger is an assistant professor of geography at Texas State University in San Marcos, Texas. He specializes in Arctic change and studied ice melt in Greenland in 2013.

"The Arctic component of sea level rise is probably the biggest," said Ballinger. "The meltdown of the Greenland ice sheet and some of the smaller ice caps in the Arctic is the main contributor to global sea level rise right now."

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[6] Texas Water Development Board, *Vulnerability of Texas Aquifers, 2016,* http://www.twdb.texas.gov/groundwater/models/research/subsidence/subsidence.asp.

While in Greenland, Ballinger noted the effect the melting ice was having on the residents. Many live in isolated communities without connections via road.

"They get back and forth by boat or by dog sled," said Ballinger. "Boat in the summer, spring, early fall and dog sled over the ice in the winter. The ice is now so thin and so fragile, that people have been hesitant to take those trips. That's one manifestation-transportation."

Scientists have studied Arctic ice melt for decades; however, relative sea level rise can occur from a combination of causes. Scientists and governmental organizations continually observe and analyze local coastal changes across the country. The NOAA keeps tabs on tides, currents and water levels by collecting data from gauges along the coast of the United States. Below is a chart with sea level data going back to 1950 for five high-risk states along the Atlantic coast and Gulf of Mexico. In total, the states are looking to spend over $21 billion on sea level mitigation techniques.

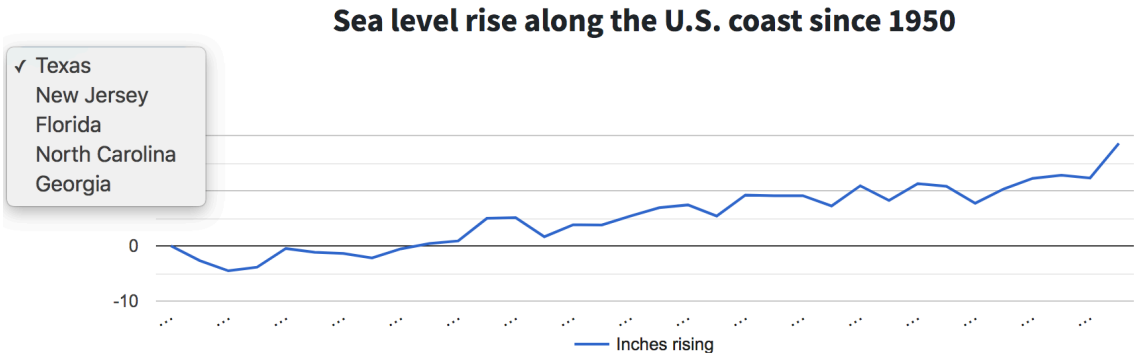

Figure 1 An interactive chart found in the multimedia story displaying sea level rise along the U.S. coast since 1950. Source: National Oceanic Atmospheric Administration, Tides and Currents, 2018.

II. Danger in the Gulf

Data from the NOAA Galveston Area Tide Gauge reveals an 18" sea level rise since 1950. Texas sea level rise is mostly due to sinking land, also known as subsidence. Texas pumps large volumes of fresh water from aquifers deep within the Earth for drinking and municipal uses. Additionally, oil operations along the coast extracted tons of material, causing the land to sink and fill the empty space. As the land continues to drop, the most probable solution involves filling the underground spaces; however, the effects in the meantime are proving extremely damaging and costly. Sea level rise results in more severe coastal flooding, beach erosion, submerging of wetlands and dry land and a critical impact on ecological systems and native species. Texas plans to spend over $12 billion on mitigating the effects of sea level rise including storm surge protection, drainage and erosion control and flood mitigation projects.

Between 1996-2016, there was an average of 6” of sea level rise along the Texas Coast. The U.S. Army Corps of Engineers (USACE) predicts 6 more inches of sea level rise by 2031.

In addition to a damaged ecosystem, coastal communities have to navigate major property degradation due to sea level rise. Beaches act as a barrier to storm flooding, but as the sea levels rise, the sand erodes and leaves communities vulnerable to floods. Infrastructure and buildings are structurally compromised which poses significant health and safety risks. Flood damage to coastal property is particularly devastating after major weather events, which are happening more frequently according to sources such

as Scientific American and the Environmental protection agency (EPA)[7][8]. The Texas coast is lined with barrier islands with willful residents who expect and prepare for hurricane season every year. Following damage from major weather events, some Galveston-area residents are evaluating their respective futures on the Texas coast.

III. Galveston, Bolivar and the bay

The historic district on Galveston Island, Texas boasts hundred-year-old homes with the high water marks to prove it. In 2008, Hurricane Ike pushed a twelve-foot storm surge over the island. Many of the century-old homes suffered damage while others narrowly escaped by only two-to-three inches. With the estimated rate of relative sea level rise, those lucky historic homes may not be so fortunate in the future.

Hal Needham started the U-Surge project to document historic storm surge along United States coast from Texas to Maine. Needham noted that there have been about three inches of sea level rise every 12 years over the last century, and this knowledge must inform understandings of major storms.

"If the same Hurricane Ike happens in the year 2020, the same storm, all of a sudden these houses that were dry by two-to-three inches, they go from dry to wet," Needham said. "That's because of sea level rise difference. That's where even a couple inches make a big difference when you think about it that way."

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[7] Chelsea Harvey, "Extreme Weather Will Occur More Frequently Worldwide," *Scientific American,* February 15, 2018, https://www.scientificamerican.com/article/extreme-weather-will-occur-more-frequently-worldwide/.

[8] EPA, "Climate Change Indicators: Tropical Cyclone Activity," January 19, 2017, https://www.epa.gov/climate-indicators/climate-change-indicators-tropical-cyclone-activity.

Galveston Island is 27 miles long and is home to nearly 50,000 permanent residents with 5.4 million visitors throughout the year. Just a short ferry ride north is another barrier island known as the Bolivar Peninsula. Both of these barrier islands are tasked with protecting one of Texas and the United States most valuable shipping assets, the Port of Houston. However, historical data and modeling indicates that the sea level is rising and the shoreline is suffering. Below is the U.S. Army Corps of Engineers sea level rise projections from 2016-2050 for four Texas coastal communities.

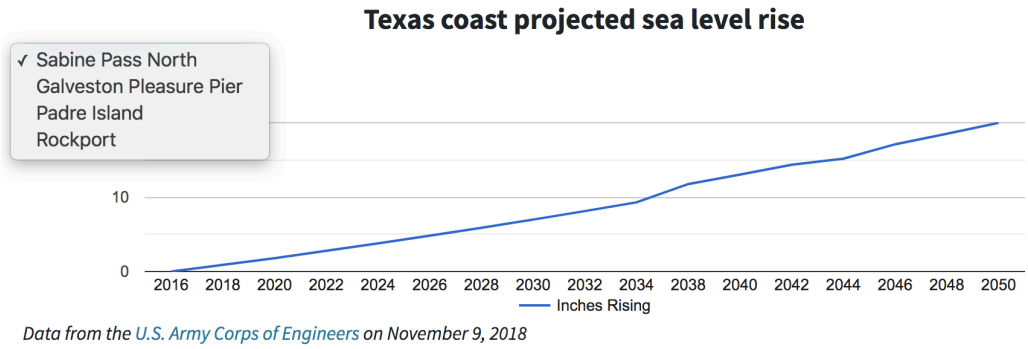

Figure 2 Interactive chart found on the multimedia story displaying Texas coast projected sea level rise. Source: U.S. Army Corps of Engineers, Sea-Level Change Curve Calculator, 2018

The sea level on the Galveston Island Pleasure Pier is expected to rise 21.56 inches, leading those who depend on the island to formulate adaptation solutions. The Galveston Bay Foundation is a non-profit organization that addresses issues and concerns related to the multi-use bay. Haille Leija is the Habitat Restoration Manager for Galveston Bay Foundation and explained Galveston's shoreline situation as a combination problem.

"Anecdotally, in our area I've seen an increase in the high tides- frequency and the length and height of them," said Leija. "On some of our properties where we do a lot of work I've noticed that the high tides stay there longer and are more extreme. In addition to the subsidence in this area, we really see these extreme changes happening."

Over just the past few years, Leija has seen the geography of Galveston Bay change dramatically. The organization works to make the shorelines more resilient and restore them with natural processes.

“We’re working on a project right now with some partners to restore historic bird islands that are completely under water, and just 10 years ago they weren’t,” said Leija. “By planting marsh grass and having an offshore breakwater system you can get that marsh grass growing which will then stabilize the sediment. But as sea level rises, it will migrate if you allow it to- if you don’t have that bulkhead in place to prevent it.”

There are a few options for combating an eroding shoreline. Galveston Bay Foundation invests in living shorelines, land conservation, oyster reef restoration and wetlands restoration. A living shoreline helps stabilize the earth that can be washed away daily and during storms. Leija said that living shorelines are an attractive, effective and more natural approach to shoreline mitigation.

“At Galveston Bay Foundation we promote a more natural approach instead of doing a bulk head,” said Leija. “By creating things like living shorelines we can work with the ecosystems to help them protect our shoreline rather than building so many hard structures like sea walls and bulk heads that are just going to fail and erode the shoreline further.”

The video below is a living shoreline project at the Texas City Prairie Preserve. The Galveston Bay Foundation worked with volunteers from UT Dallas to plant spartina alterniflora, or cordgrass, grown by the the U.S. Department of Agriculture's Natural Resources Conservation Service.

Figure 3 Video of Galveston Bay Foundation planting cordgrass. Source: https://www.youtube.com/watch?v=-FRuUhmjfs4

While Galveston Bay Foundation utilizes natural processes for long-term mitigation, there are other man-made options for coastal protection. Following the destruction of Hurricane Ike in 2008, Texas A&M at Galveston professor, Dr. William J. Merrell proposed a coastal barrier that would extend the existing Galveston sea wall in either direction. He called the barrier the "Ike Dike," after the destructive 2008 hurricane that leveled two-thirds of the homes on Bolivar Peninsula.

Merrell modeled the coastal spine after projects in the Netherlands where they are known for cutting edge coastal mitigation techniques. In an interview with the Texas A&M Foundation, Merrell said that the barrier could protect Galveston, Bolivar Peninsula, Houston, and the refineries and port infrastructure along the ship channel[9].

[9] Jeannie Ralston, "Ike Dike to the Rescue," *Texas A&M Foundation,* May 15, 2017, https://www.txamfoundation.com/News/Ike-Dike-To-The-Rescue.aspx.

"This is preventive medicine," said Merrell. "The concept is easy. You stop the storm surge at the coast so that you protect everyone."

The USACE is considering the coastal barrier spine as part of the Coastal Texas Protection and Restoration Feasibility Study, a comprehensive study of the entire Texas coast. In October 2018, USACE released a 442-page draft report that includes more ambitious plans for the barrier, which would stretch 76 miles long from one tip of Galveston to the other end of Bolivar Peninsula[10]. Additionally, it includes a proposal for storm risk management and ecosystem restoration features along the entire Texas coast.

When Merrell initially proposed the project, it was projected to cost $12 billion, but with the USACE additions, it would cost an estimated $21 billion-$31 billion. A project of this magnitude does not happen overnight. If approved by Congress in 2021, the barrier could take anywhere from 10-50 years to construct according to USACE project manager Kelly Burks-Copes.

At 17-feet-tall, the structure is supposed to offer protection for island residents and business in the port of Houston. During Hurricane Harvey, the port of Houston was closed for 6 days, costing industries roughly $1 billion said Maria Burns, director of the University of Houston's College of Technology in an interview with the Houston Chronicle[11].

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[10] U.S. Army Corps of Engineers, "Coastal Texas Protection and Restoration Feasibility Study," October 2018, https://www.swg.usace.army.mil/Portals/26/docs/Planning/Public%20Notices-Civil%20Works/Coastal-TX%20DIFR-EIS/Coastal%20Texas%20DIFR-EIS_Oct2018.pdf?ver=2018-10-24-162409-300.

[11] Andrea Leinfelder, Jordan Blum, "Houston Ship Channel closure could cost energy industry $1 billion," *Houston Chronicle,* March 25, 2019, https://www.houstonchronicle.com/business/energy/article/Houston-Ship-Channel-closure-could-cost-energy-13716058.php.

As storms become more frequent and costly, the benefits of storm protection are fueling a sense of urgency for many Texans. The chart below outlines six most major weather events to hit the Texas coast since 2001.

Damage from top five storms since 2001

	Weather incident	County most effected	Total damage	Total mortality	Beach erosion
1	2001 Tropical Storm Allison	Harris County	$5.2 billion	23 deaths	minimal
2	2005 Hurricane Rita	Jefferson County	$18.5 billion	59 deaths	moderate
3	2007 Tropical Storm Erin	Harris County	$45 million	16 deaths	minimal
4	2008 Hurricane Ike	Galveston County	$38 billion	74 deaths	severe
5	2010 Tropical Storm Hermine	Cameron County	$240 million	7 deaths	moderate
6	2017 Hurricane Harvey	Harris County	$127 billion	68 deaths	severe

Data from The National Oceanic and Atmospheric Administration on November 9, 2018

Figure 4 Table displaying the five most major weather events to impact the Texas coast since 2001. Source: National Oceanic Atmospheric Administration, OceanReports, 2019

Although residents recognize the threat of storm surge and agree that coastal mitigation is necessary, many on Galveston island and Bolivar Peninsula are opposed to the barrier.

Matt Pace is an insurance agent who has owned property on Bolivar Peninsula since 1987. In December 2018, Pace conducted a poll on a Coastal Barrier Information page on Facebook to gauge where fellow residents stood on the issue. 522 did not want any barrier on the peninsula, 31 were in favor if it was built along the dunes and three were in favor of the current proposal to build it along Highway 87.

The coastal barrier spine is proposed to run straight down the center of Bolivar Peninsula along Highway 87 to protect residents from major storm surges like they experienced in Hurricane Ike. However, Pace said this would leave residents on the sea side of the island at risk and he questions who would really benefit from the barrier.

“The main reason you see stated as reasons for building the dike in the first place is to protect the Houston ship channel, port of Houston, and those really nice

communities at the upper end of Galveston Bay," said Pace. "If you want to protect the Houston ship channel and the refineries and such up there-by the way, none of them actually suffered any damage in Ike from storm surge- there are other alternatives."

Although many on the peninsula are part-time residents, tourism is essential for the economy of the small community. Beautiful vacation homes and peaceful beaches line the coast, but Pace is concerned about what the barrier may do to property value.

"If you build this large coastal barrier down this peninsula, there's no telling what it's going to do to real estate values and no telling what it's going to do to tourism," said Pace. I'm safe to tell you, the majority of people on this peninsula do not want a barrier built anywhere along the peninsula."

Not only would the barrier put those on the sea side at risk in a storm event, but those on the bay are also at risk. In events like Hurricane Harvey where 40-50 inches of rain fell around the Houston-metro area, the water needed to drain to the coast as quick as possible and Hal Needham said he is concerned about any kind of obstruction at the mouth of Galveston Bay. Additionally, Needham said that the swirling motion of storm winds can cause water to surge on both sides of the island.

"I'm really concerned about Galveston Bay being that close to the barrier," said Needham. "Everyone thinks they're safe, then you get category 5 winds across Galveston Bay and I think you could see a 12, 13, 14-foot surge. There's this false sense of security that people would be safe when that is not necessarily true."

Azure Bevington is a coastal wetland ecologist and environmental consultant on projects near the sea. She brings scientific expertise and rigor to projects for many non profits and has worked in North Carolina, Virginia, Louisiana and Texas. Bevington

currently lives on Bolivar Peninsula and said she was surprised when she heard about the coastal barrier proposal.

"I never thought that this would get as far as it did," said Bevington. "This isn't going to protect everyone, and even if it was built and could protect everyone we would sacrifice the beach, the ecosystem health and everything that we love about Galveston Bay."

Bevington explained that there are varying approaches to shoreline protection from a completely natural system, to sparse gates and levees, to the construction of giant gates and walls. She considers the coastal barrier spine a somewhat aggressive approach.

"It was really concerning ecologically and from a community standpoint that it went right down the highway," said Bevington. "I didn't actually think that something that extreme would happen because there are a lot of reasons not to go that extreme from a scientific standpoint, but also from an engineering and cost standpoint."

In response to the coastal barrier spine, the Severe Storm Prediction, Education, & Evacuation from Disasters (SSPEED) Center at Rice University developed the Galveston Bay Park plan to protect Galveston and the Port of Houston. Needham, Bevington and Pace all believe it is a more viable alternative. The plan includes multiple lines of defense such as extending levee systems into Galveston Bay, raising roadways, utilizing sand berms and restoring oyster reefs. Phase one is estimated to cost $2.8 billion and offers immediate protection as soon as three years after construction begins[12].

[12] Severe Storm Prediction, Education & Evacuation from Disasters Center, "Galeston Bay Park Plan," *Rice University,* 2018, http://docs.wixstatic.com/ugd/d29356_5cde1ed3665a42d78ed7e4ac2b3bfea5.pdf.

Galveston Island and the bay are ecologically invaluable and serve an important role protecting Texas from storm surges. With billions of dollars on the line, many economic and intellectual resources are being dedicated to combat the issue of sea level rise and related storm surge. However, this degree of federal commitment is not the case for every Texas coastal community. 360 miles south, another coastal community is facing sea level rise and finding more localized solutions.

IV. South Padre Island

South Padre Island is a small coastal town nearly on the tip of Texas. It sits on the end of Padre Island, a barrier island which stretches 113 miles north to Corpus Christi Bay. Unfortunately, much like everywhere else along the Texas coast, South Padre Island is facing the effects of sea level rise and assessing options for mitigation.

The U.S. Army Corps of Engineers intermediate forecast projects 17.28 inches of sea level rise in the South Padre Island area by 2050[13]. This would have drastic effects on storm surge according to Hal Needham. Needham documented historic storm surge in South Padre Island at the request of the city, which questioned FEMA's 100-year storm assessment. A "100-year storm" is the estimated probability of a particular intensity storm event occurring in any given year. This varies by location and is estimated using modeling rather than historic data. Needham's data-driven 100-year water levels are typically two-to-four feet higher than FEMA's for most cities.

"South Padre Island came to me a couple years ago and they were concerned that the new FEMA flood maps were really underestimating their risk levels," said Needham.

[13] U.S. Army Corps of Engineers, *Sea-Level Change Curve Calculator (Version 2019.21)*, 2019, http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html.

“We developed a historic dataset for them and did a risk analysis and we did find that according to a data-driven approach-meaning that you’re actually looking at all the high water marks on record-the flood risk was higher than what the FEMA models were indicating.”

While the Galveston 100-year storm surge sits around twelve feet, Needham estimates South Padre Island's to be just four feet. This may not seem like much, but if the USACE forecast is correct, the four-foot estimate turns into 5.5 feet. This could be devastating for the small town that is not equipped with manmade barriers like the Galveston seawall.

There are 5,000 year-round residents on the South Padre Island, but tourism is the primary industry with nearly 5 million visitors annually. With so much dependent on the pristine beaches and beautiful views, the South Padre community collectively takes responsibility for the future of the island according to Brandon Hill, shoreline manager for the City of South Padre Island.

“When it comes to shoreline management of any community, I think the challenge is balance,” said Hill. “You have to balance the natural conservation of our ecology, you have to balance access for the public and the residents, you have to balance the tourism. There’s also the fact that people want to come to the beach to enjoy it, but you also want to make sure that when they come, they enjoy it responsibly.”

The vegetative sand dunes are a point of attraction for beach-goers. Additionally, they serve an important purpose for shoreline mitigation. Dune grass and other plants take root in the sand and gradually build up a barrier that protects homes on the other

side. Below is an interview with Hill where he talks about the importance of sand dunes to South Padre Island and all coastal communities.

Figure 5 Video with South Padre Island's Shoreline Director discussing community mitigation strategies. Source: https://www.youtube.com/watch?v=ZZ4LmhxsADU

Sand dunes are the first line of defense for South Padre Island. Hill said the money and sand are nonrenewable resources necessary to keep the city safe. To keep an affordable influx of sand, South Padre Island buys sand that has been dredged from the Brazos-Santiago Pass by the USACE to supplement and build up dunes on the island. This is a sustainable practice that could be used in the Galveston Bay area where the ship channels are dredged 24/7 but the material is dumped in landfills[14].

As part of the Coastal Texas Protection and Restoration Feasibility Study, the USACE recommends building dune berms in front of the existing dunes to protect South

[14] John Burnett, "Houston Ship Channel and Galveston Bay Digging Out After Harvey," *National Public Radio,* December 10, 2017, https://www.npr.org/2017/12/10/569463500/houston-ship-channel-and-galveston-bay-digging-out-after-harvey

Padre Island's shoreline[15]. This largely protects the economically viable parts of the city, but not the entire island. Although the majority of South Padre Island's economic hub is concentrated toward the south of the island, Hill believes approaches to mitigation need to be holistic to have long-term success.

"We have to make sure that not only what we're doing works, but that it works the best for the community," Hill said. "Sand and money are our two primary factors when it comes to non-renewable resources and we really need to make sure we are getting the maximum potential out of both. It's that sort of thinking that will help make sure that our island is here for generations to come."

The localized approach to shoreline mitigation is not unlike some efforts in the Galveston bay area; however, the city of South Padre Island seems to have a stronger commitment to natural resiliency tactics.

V. Going Forward

Flooding is a costly occurrence in terms of lives and in dollar amounts. Texas must take steps to prepare for flooding events. This could mean adaptive measures such as installing pumps and raising roads as Miami has done. Replenishing beaches that have eroded is another ecologically sound way to create a barrier against storm surges. However, these are temporary solutions to an ongoing problem bigger than the state of Texas. Even the most resilient shorelines can suffer major losses as storms become more frequent and 100-year storms turn into 25-year storms. It is imperative that Texas invests economically and intellectually in its coast and the people living there. Between locally

[15] U.S. Army Corps of Engineers, "Coastal Texas Protection & Restoration Feasibility Study," October 2018, https://www.swg.usace.army.mil/Business-With-Us/Planning-Environmental-Branch/Documents-for-Public-Review/.

formulated solutions and technological advances, the future of shorelines is looking brighter and drier.