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Safety and environmental review of Plaquemines LNG

Critical analysis of risks from climate-driven hurricanes, extreme weather events, and sea level rise

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FOR THE SIERRA CLUB

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I. Introduction and Qualifications

My name is Ivor van Heerden. I hold a doctorate degree in Marine Sciences and am the former deputy director of the Louisiana State University Hurricane Center. I am also the former director of the Center for the Study of Public Health Impacts of Hurricanes. I am a former Associate Professor of the Department of Civil and Environmental Engineering at LSU.

I have been asked by Sierra Club to review and give an opinion on the Venture Global proposal for a new liquefaction plant, marine and terminal site and pipeline system along the Mississippi River in Plaquemines Parish, Louisiana. The documents I reviewed and references I relied on are set forth in the following report, and the attached list of References, and include:

- Venture Global Gator Express, LLC's Plaquemines LNG and Gator Express Pipeline Project Joint Permit Application, submitted to the Louisiana Department of Natural Resources Office of Coastal Management and U.S. Corps of Engineers (June, 2017) –

- March 26, 2018 Joint Public Notice, New Marine and Terminal Site and Pipeline System Within and Along the Mississippi River in Plaquemines Parish;

- Federal Energy Regulatory Commission's Final Environmental Impact Statement, FERC/EIS – 0286F (May 2019).

- Memorandum of Record, Department of the Army Environmental Assessment and Statement of Findings for the Above-Referenced Standard Individual Permit, CE MVN-ODR-E (File Number, MVN 2015-2098-EPP) (May 16, 2019).

This report contains my expert opinions, which I hold to a reasonable degree of scientific certainty. The opinions expressed herein are based upon my review and analysis of these pertinent materials in an effort to assist Sierra Club in fully evaluating and understanding the factual implications of this project. My opinions are based on my application of professional judgment and expertise to sufficient facts or data, consisting specifically of a review of the regulations and documents discussed in report. These are facts and data typically and reasonably relied upon by experts in my field.

For the reasons described below, my expert opinion is that:

a) This project whose purpose is "to construct a New Marine and Terminal Site and Pipeline System within and along the Mississippi River, Plaquemines Parish" will in fact inevitably, irreparably, and significantly harm surge-reducing wetlands, the local community, and the flora and fauna of the area, and will pose a major risk of contaminants escaping the facility during passage of a major hurricane.

b) There is a high probability that the LNG site will be flooded by a hurricane in the foreseeable future, even if the proposed ring dike levee is constructed.

c) The proposed Plaquemines LNG site was flooded during Hurricane Ida in 2021, and recent hurricane seasons emphasize the extreme risk posed by constructing such a facility at the proposed site.

d) Substantial design flaws in the proposed storm wall and construction process pose substantial risk of a levee failure. Failure of any levee and especially the I-wall ring dike will result in catastrophic release of chemical contaminants towards Barataria Bay impacting wetlands as well as the waters of the Bay. The impact to wetland fauna and flora would be immense.

II. Risks from Climate-driven Hurricanes, Extreme Weather Events, and Sea Level Rise Have Increased Since 2020

It is my opinion that the authors of the permit application as well as the reviewing agencies have to date failed to adequately consider and even ignored three very important and pertinent phenomena that characterize coastal Louisiana, namely: climate change and accelerating sea level rise; hurricanes and their associated surges; and thunderstorms "on steroids." Louisiana has the highest relative rise in sea level of anywhere in the US. Storms and hurricanes are common in Louisiana and could happen at any time, as aptly demonstrated by the 2020 and 2021 Hurricane Seasons (discussions to follow). As demonstrated during Hurricane Ida, the LNG Facility is at risk of serious flooding. Consequently, there is a significant risk of flood waters inundating the site, which would pollute adjacent wetlands with construction materials and petro-chemicals, thus harming water quality, severely stressing the coastal wetlands, and endangering surrounding residents and communities.

Climate change is real and manifests in robust precipitation events followed by extended dry spells. Major weather events in the Mississippi Basin such as the record setting floods in 2019, record breaking tropical episodes, and stalled storm systems (e.g., the 2016 Baton Rouge flood), will become far more common and are strong evidence of global warming and its climate change consequences. Recent science suggests that relative sea level rise for coastal Louisiana (due to both ocean warming and coastal subsidence in Louisiana) is between 4 and 6 feet per century and is accelerating. Sea level rise is one of the factors responsible for Louisiana's alarming loss of its coastal wetlands, the natural apron that protects its residents from storm surges. These climate change factors, as described below, exacerbate the environmental impacts of the proposed LNG Facility.

It is my opinion that the LDNR did not sufficiently evaluate the environmental effects of the project in light of hurricanes. Each year there are an average of 12 named storms and 6 hurricanes, including 3 major storms that are Category 3 or greater.[1] As predicted by NOAA, 2020 resulted in an above-normal Atlantic hurricane season (June 1 through November 30). In fact, 2020 was the most active and seventh costliest, with 31 tropical cyclones all but one of which became a named storm. The 2021 hurricane season, with 21 named storms, was the third- most productive Atlantic season on record. The LNG Facility site is vulnerable to storm surges when they make landfall in Louisiana, as discussed in Section III.a. The 2020 and 2021 seasons will be discussed in depth below.

Ocean temperatures are rapidly rising especially along the Atlantic Hurricane formation pathway including the Gulf of Mexico. In 2019, the oceans hit their highest temperature ever

[1] Insurance Information Institute, Fact + Statistics: Hurricanes, https://www.iii.org/fact-statistic/facts-statistics-hurricanes (last visited Feb 4, 2021).

recorded and the rise is accelerating; 2020 was not far off. All the data for 2021 are not available, but the global mean temperature in 2021, to date, make it the 6th to 7th warmest year ever recorded. On average the world's oceans absorb more than 90% of the heat trapped by the greenhouse gases emitted by fossil fuel burning, forests destruction and other human activities. The oceans' heat supplies the energy for hurricanes to metastasize and research has shown there will be more intense, stronger hurricanes (major hurricanes – Category 3 to 5) than in the past. <u>As discussed below in Section III.a, there is a high probability that the LNG site will be flooded by a hurricane in the foreseeable future, even if the proposed ring dike levee is constructed.</u>

Tropical cyclones will also increase in number and strength. These storms pose a severe risk to natural systems, personal property, and public infrastructure in the Gulf Coast region, and this risk will likely be exacerbated as the temperature of atmosphere and sea surface increase. Whereas loss of life from hurricanes has decreased in recent decades, property losses due to rapid population growth and economic development of coastal areas has increased. Hurricanes have their greatest impact at the coastal margin where they make landfall and sustain their greatest strength. Severe beach erosion, surge overwash, inland flooding, and windfall casualties are exacted on both cultural and natural resources.

The kinetic energy of tropical storms and hurricanes is fueled from the heat exchange in warm tropical waters. An increase in sea surface temperature (SST) from global climate change is likely to increase the probability of higher sustained winds per tropical storm circulation (Emanuel, 1987; Knutson et al, 1998). Sea surface temperature has increased significantly in the main hurricane development region of the North Atlantic during the past century (Bell et al., 2007) as well as in the Gulf of Mexico (Smith and Reynolds, 2004).

Santer et al. (2006) used 22 climate models to study the possible causes of increased SST changes in the Atlantic and Pacific tropical cyclogenesis region, where SST increased from 0.32 °C to 0.67 °C (0. 57 – 1.21 °F) over the 20th century. These results and those from similar studies suggest that as radiative forcing and SST continue to increase, hurricanes will be more likely to form in the Atlantic and Pacific Basins and more likely to intensify in their destructive capacity. In its Fourth Assessment Report, the IPCC (2007) concludes that there is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures (Keim etal, 2008). These authors also show that an increase of one to two hurricanes above the historical frequency can be expected by year 2050 and up to four added hurricanes by year 2100. The potential gain of four hurricanes over the next century from a 20 percent increase in storm intensities nearly doubles the strike probability of the historical record. Not only will hurricane incidence increase under these assumptions, but individual storms will be stronger such that more catastrophic storms are likely to develop regardless of landfall location.

Moreover, intense rainfall was not considered as contributing to the project's environmental impacts. Scientists in Louisiana have stated that many rainfall events in the last 10 years or so appear to be "Showers on Steroids" whether of tropical origin or a stalled cold front or just summer convection.[2] Present day showers, on average, are more intense and deposit their rain loads more quickly than they did about 40 years ago. The cause is the very high temperatures of the Gulf of Mexico, which are a consequence of global warming, which in turn is an outcome of an overabundant release of greenhouse gases into the atmosphere. Rainfall events could regularly exceed 10 inches.

Increasing extreme rainfall is one of the clearest observed signals of climate change, and the fingerprint of global warming has been firmly identified in the global trend of increasing extreme precipitation. Back-to-back years of extreme August rainfall events are consistent with the global trend of increasingly frequent extreme and record-breaking rainfall events.

The Corps recently admitted that its levee designs and post-Katrina repairs were built too low given global warming induced sea level rise.[3] Building a facility at an elevation of -5 feet NAVD 88 in close proximity to Barateria Bay that is in turn connected to the Gulf of Mexico with its killer storm surges and on the west side of the Mississippi River, is a recipe for a catastrophe.

a. The 2020 Hurricane Season

The 2020 Atlantic hurricane season was the most active and the seventh costliest Atlantic hurricane season on record. In addition, it was the fifth consecutive above-average Atlantic hurricane season from 2016 onward, though it was the first extremely active season since 2017. The season featured a total of 31 (sub)tropical cyclones, all but one of which became a named storm. Of the 30 named storms, 13 developed into hurricanes, and six further intensified into major hurricanes, with one, Hurricane Iota, attaining Category 5 strength (winds greater than 157 mph) on the Saffir–Simpson scale.

It was the second season to use the Greek letter storm naming system (ran out of English alphabet letters), the first being 2005. Of the 30 named storms, 12 made landfall in the contiguous United States, breaking the record of nine set in 1916. The season was also the fifth consecutive season in which at least one Category 5 hurricane formed. During the season, 27 tropical storms established a new record for the earliest formation by storm number. This season also featured a record 10 tropical cyclones that underwent rapid intensification, tying it with 1995. This unprecedented activity was fueled by a La Niña (for an explanation of El Nino and La Nina see https://oceanservice.noaa.gov/facts/ninonina.html) that developed in the summer months of 2020. Twelve of those storms made landfall in the continental U.S., breaking the previous record of nine set in 1916, according to theNOAA.

Five storms made landfall in Louisiana this hurricane season, breaking the state record for the most strikes in a single season. Hurricane Zeta was the 5th named storm and the 2nd Greek-

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[2] Charles Lussier, *Why is Louisiana seeing more 'showers on steroids,' intense downpours these days?*, The Advocate (Aug. 11, 2019), https://www.theadvocate.com/baton_rouge/news/weather_traffic/article_418dfcc8-b2ff-11e9-ad50-9b94c47fa8d2.html.

[3] Thomas Frank, *After a $14-Billion Upgrade, New Orleans' Levees Are Sinking*, E&E NEWS Apr. 11, 2019, https://www.scientificamerican.com/article/after-a-14-billion-upgrade-new-orleans-levees-are-sinking/ (last visited Feb 4, 2021).

named hurricane to hit Louisiana in 2020. The five storms that hit Louisiana in chronological order were:

- Tropical Storm Cristobal
- Tropical Storm Marco
- Hurricane Laura
- Hurricane Delta
- Hurricane Zeta

Tropical Storm Cristobal was the earliest third-named storm in the North Atlantic Ocean on record, breaking the record set by Tropical Storm Colin in 2016 which formed on June 5. It is also the first Atlantic tropical cyclone to form in the month of June since Cindy in 2017, and the first June tropical cyclone to make landfall in Mexico since Danielle in 2016. The third named storm of the extremely active 2020 Atlantic hurricane season, Cristobal formed on June 1 over the Bay of Campeche from the remnants of Tropical Storm Amanda in the Eastern Pacific. Cristobal then made landfall in the state of Campeche on June 3, 2020, with sustained winds of 60 mph, causing torrential rainfall throughout the region. It slowly curved northward over Mexico and progressed into the Gulf of Mexico. Cristobal then made a second landfall over southeastern Louisiana on June 7, becoming the second-earliest tropical cyclone to make landfall in Louisiana. In Louisiana, 5 feet of surge was reported at Grande Isle. At the LNG site, 4-5 inches of rain was predicted by the NWS (Figure 1).

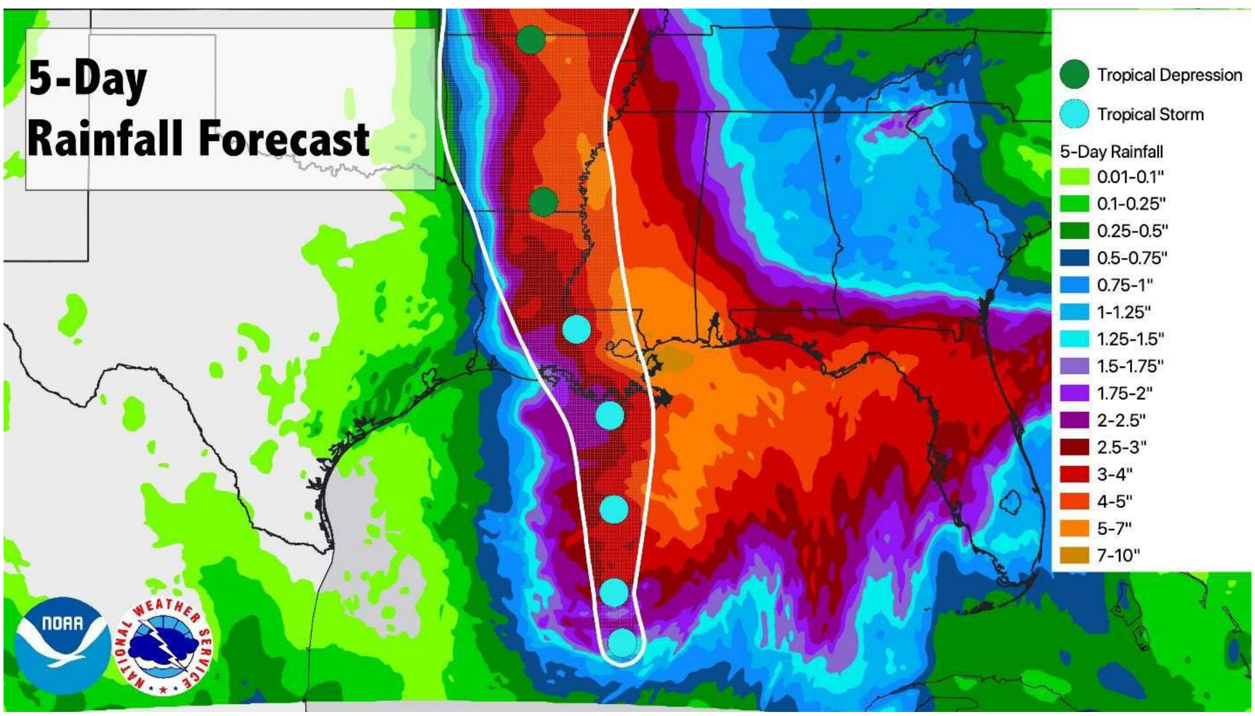

Figure 1. Predicted rainfall for Tropical Storm Cristobal

Hurricane Marco was the first of two tropical cyclones to threaten the Gulf Coast of the United

States[4] within a three-day period, with the other being Hurricane Laura. The thirteenth named storm[5] and third hurricane of the record-breaking 2020 Atlantic hurricane season, fortunately Marco lost a lot of its power prior to landfall and there was not excessive rainfall in Louisiana.

Hurricane Laura was a deadly and destructive Category 4 hurricane that tied with the 1856 Last Island hurricane as the strongest hurricane on record to make landfall in Louisiana, as measured by maximum sustained winds of 150 mph. This was the twelfth named storm, fourth hurricane, and first major hurricane of the record-breaking 2020 Atlantic hurricane season. Early on August 27, Laura made landfall near peak intensity on Cameron, Louisiana. Hurricane Laura's storm surge of more than 19 feet was among highest recorded in Louisiana. A tremendous wall of seawater more than 17 feet high moved ashore with Hurricane Laura, sweeping many Cameron Parish homes off their foundations. Fortunately, the storm made landfall in a relatively unpopulated portion of the Louisiana coast, but still caused the deaths of at least 42 people in the U.S. and inflicted an estimated $16 billion in damages on southwestern Louisiana and southeastern Texas. Rainfall in many areas of the coast was predicted to exceed 8 inches with highs of 13 inches (Figure 2).

Post-storm assessments indicated extensive damage to Louisiana's industrial facilities, with one-third showing some type of damage and nine out of the 138 facilities showing critical damage, causing environmental concerns. Some of the most critically damaged facilities were the BioLab facility and the Equistar Chemicals facility in Westlake, and the Chemical Waste Management facility and the Lotte Chemical plant in Lake Charles.[6]

Many of the repairs in Louisiana were undone six weeks later by Hurricane Delta, which made landfall just 12 miles (19 km) east of where Hurricane Laura did, with many areas in and around hard-hit Lake Charles being damaged again. If Hurricane Laura had made landfall further to the east, towards the Atchafalaya River or even Grande Isle, the impacts to the LNG site would have been far worse and the site may have experienced surges of 12 to 20 feet.

Hurricane Delta was the record-tying fourth named storm of 2020 to strike Louisiana, as well as the record-breaking tenth named storm to strike the United States in that year. The twenty-sixth tropical cyclone, twenty-fifth named storm, ninth hurricane, and third major hurricane of the record-breaking 2020 Atlantic hurricane season. Delta made landfall near Creole, Louisiana with winds of 100 mph (Cat 2) and a pressure of 970 mb (28.64 inHg). Like with Hurricane Laura, Louisiana and Southeast Texas were again hit by heavy rain, high winds, and storm surge, and 14 weak tornadoes were confirmed in Mississippi, Alabama, Georgia, and the Carolinas. Total insured losses resulting from the storm amounted to $4 billion in the US. The impacts of Delta were widespread. Street flooding was reported in Baton Rouge on October 8.

The Baton Rouge Metropolitan Airport reported 8 inches of rain, which prompted a flash flood warning issued by the NWS. At least 25 motorists were stuck in high water in Baton Rouge. The next day, Lake Charles Regional Airport reported a wind gust of 60 mph as the storm

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[4] https://en.wikipedia.org/wiki/Gulf_Coast_of_the_United_States. Lasted visited Feb 7, 2021.
[5] Tropical Cyclone Naming https://en.wikipedia.org/wiki/Tropical_cyclone_naming. Last viewed Feb 4, 2021
[6] Hurricane Laura https://en.wikipedia.org/wiki/Hurricane_Laura. Last viewed Feb 4, 2021.

approached, while another station in Lake Charles recorded a peak gust of 88 mph. In the following hours, a WeatherFlow observing site near Cameron reported a wind gust of 51 mph and a National Ocean Service station at Calcasieu Pass reported sustained winds of 53 mph, a wind gust of 64 mph, and a pressure of 983.8 mb (29.05 inHg).[7] Around the time of landfall, a Florida Coastal Monitoring Tower near Lake Arthur reported a sustained wind of 77 mph and a gusts to 96 mph while a NOAA National Weather Service water level gauge at Freshwater Canal Locks reported 8 feet (2.4 m) of storm surge. Shortly after that, the Lake Charles Regional Airport reported sustained winds of 64 mph with gusts to 95 mph.

Delta made landfall just 12 miles east of where Hurricane Laura did six weeks earlier. Many areas in hard-hit Lake Charles were damaged again and some homes were flooded in Moss Bluff. Additional damage occurred in Jennings and widespread power outages were reported. In Calcasieu Parish, several vehicles were overturned on I-10. Due to multiple car accidents on the Calcasieu River Bridge, both directions of the bridge, carrying I-10 and US 90, were closed to traffic.[8]

Although Hurricane Delta was only a Category 2 storm its impacts were severe and widespread, exacerbating the impacts of Hurricane Laura just a few weeks previous. Again, if this storm would have tracked further east into more heavily industrialized parts of Louisiana the impacts would have been far more severe, with surges at the LNG site in the 5 to 15 feet range NGVD88 and about 8 inches of rain.

Hurricane Zeta was the record-tying sixth hurricane to make landfall in the United States and the record fifth-named storm to strike Louisiana in 2020. The system was also the first tropical cyclone since Hurricane Sandy in 2012 to produce accumulating snow and one of only four tropical cyclones since 1804 to do so. It continued to strengthen until it reached its peak intensity of 110 mph and a minimum pressure of 970 mbar (28.64 inHg) as it made landfall in Cocodrie, Louisiana as a Category 2 storm. A sustained wind of 45 mph was reported at Caillou Bay. Just after a landfall, a personal weather station at Golden Meadow reported winds of 83 mph with a gust to 105 mph while another unofficial weather station nearby reported sustained winds of 94 mph and gusts to 110 mph. Additionally, a wind gust to 52 mph was reported at Houma and a wind gust to 53 mph was reported at New Orleans Lakefront Airport. A WeatherFlow station in Harahan reported sustained winds of 56 mph and a gust to 75 mph while an elevated station at Bayou Bienvenue south-southeast of New Orleans reported sustained winds of 88 mph and a gust to 112 mph. Shell Beach reported sustained winds of 81 mph with a gust to 101 mph.[9] This was only a Category 2 storm.

Predicted storm surge was between 4 and 8 feet along the Louisiana and Mississippi coats (Figure 3). Zeta deposited up to 5 inches of rainfall in Louisiana. Zeta caused $3.75 billion in damage in the United States.

[7] Hurricane Delta https://en.wikipedia.org/wiki/Hurricane_Delta. Last viewed Feb 4, 2021
[8] Hurricane delta. https://en.wikipedia.org/wiki/Hurricane_Delta. Last viewed Feb 4, 2021.
[9] Hurricane Zeta. https://en.wikipedia.org/wiki/Hurricane_Zeta. Last viewed Feb 4, 2021.

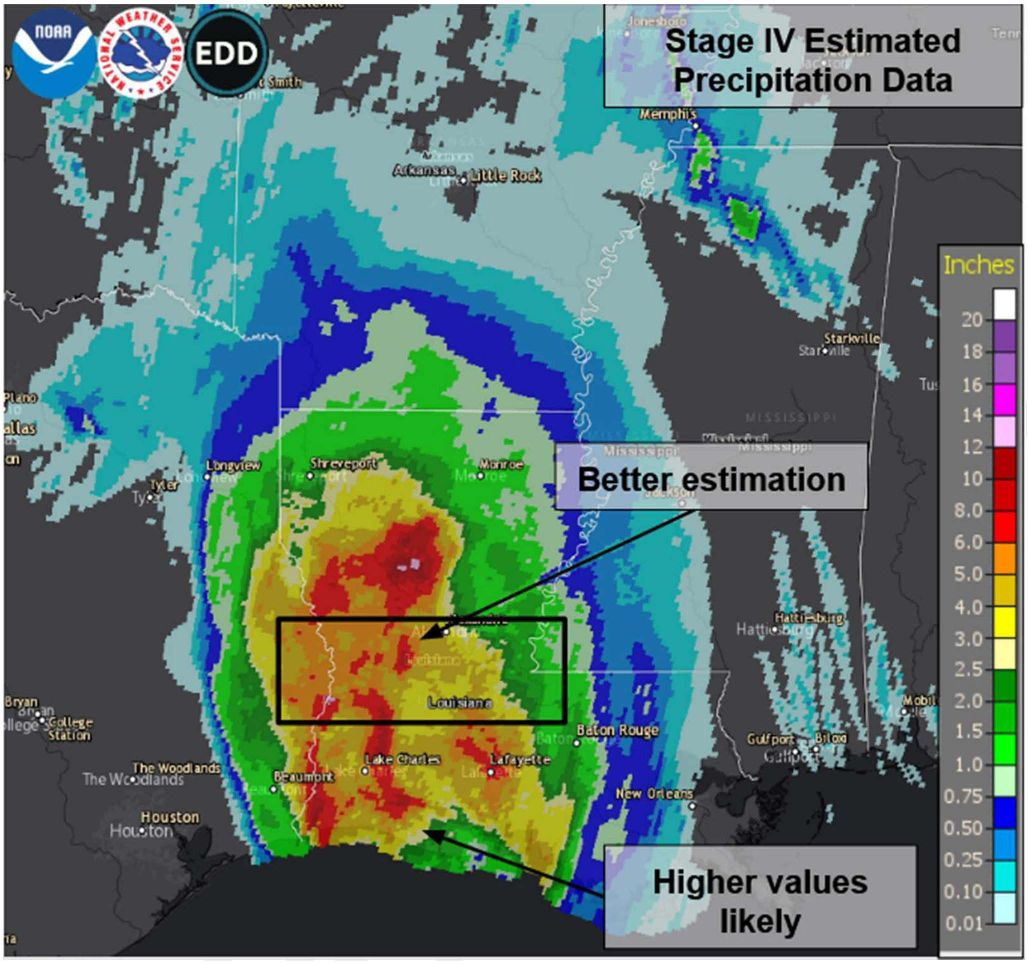

Figure 2. Estimates of Hurricane Laura Rainfall.

Figure 3. Predicted storm surge, Hurricane Zeta, 2020.

b. The 2021 Storm and Hurricane Season

A frenetic start to the 2021 Atlantic hurricane season generated a number of destructive landfalls and major inland flooding before ending strangely quiet. But the 2021 season generated 21 named storms, the third most for any Atlantic hurricane season, behind only 2020's record 30 storms and 2005's 28 storms. The entire hurricane names list for the season was used up for the second year in a row. Only this year, a new supplemental names list developed to replace Greek alphabet names wasn't needed, as Wanda was the season's last storm. Despite the high number of storms, 2021's hurricane tally (7) was right in line with the average over the past 30 years, being half of the nearly-record-breaking 2020 total of 14 hurricanes.

i. Storms and Rainfall

On May 17 and 18, 2021, deadly flash floods ravaged parts of southern Louisiana after torrential rains fell across a water-logged region still recovering from the impacts of two hurricanes during the 2020 Atlantic Hurricane season. In particular, Lake Charles, southwest of Baton Rouge, was hard hit, as a foot of rain fell in only 24 hours (Figure 4).

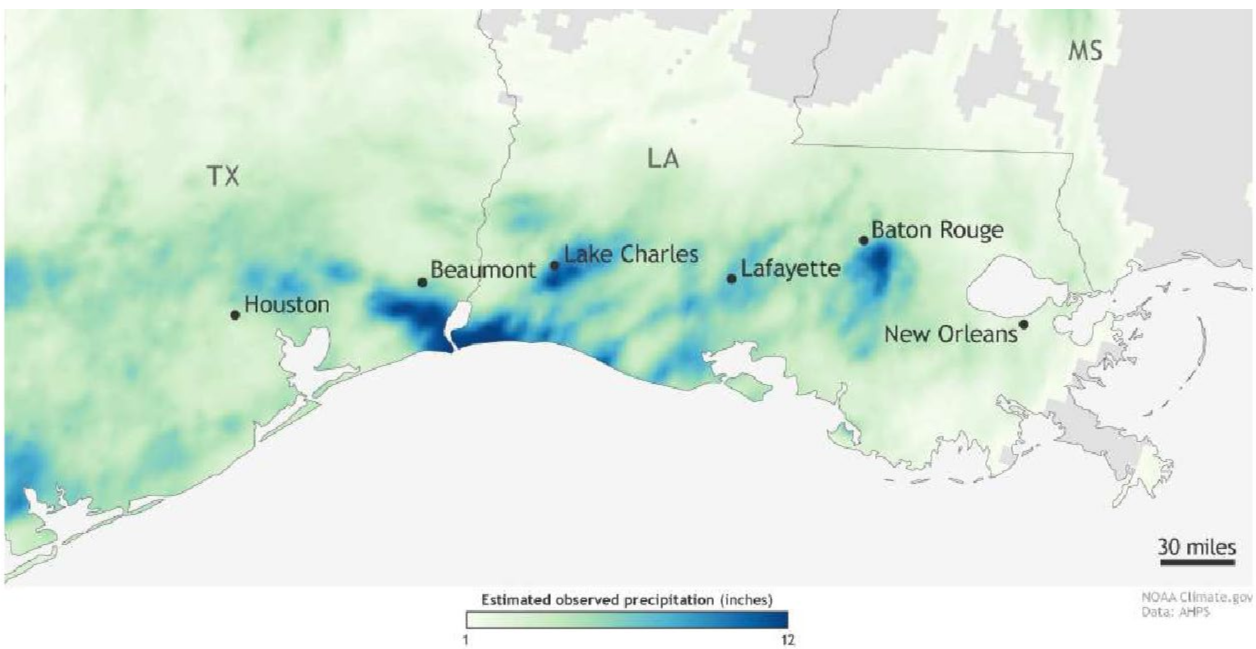

Figure 4. Cumulative precipitation over May 17-18, 2021, across Texas and Louisiana. Several areas received more than a foot of rain. Map by NOAA Climate.gov, based on AHPS data from the National Weather Service.[10]

According to news reports, the resulting flash flooding turned roads into rivers, submerged cars and inundated homes and businesses across southwestern Louisiana. In Lake Charles, over

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[10] http://www.climate.gov/news-features/foot-rain-causes-flash- flood-emergency-louisiana-during-mid-may-2021

1000 calls for rescues were made as nearly half the roads in the parish were under some water. The governor of Louisiana had to declare a state of emergency.

By July 1, 2021, Baton Rouge had received just over 48 inches of rain. Normally its 12-month total is 61.94 inches, so 78 % of the annual rain fell in the first months of 2021.[11]

In July 2021, Ascension Parish limited any new construction for nine months due to uncertainty around extreme rainfall and the impact on new infrastructure; Iberville Parish passed a similar hold in areas around St. Gabriel. Emad Habib, a professor of civil engineering who directs the Louisiana Watershed Flood Center, said "with higher populations and more development, 5 inches of rain falling in a short period of time likely has different impacts than, say, 20 years ago. We expect that if you include the most recent data which has seen more extreme rainfall then your intuition would say we'd have to design our infrastructure for more of these extreme events — higher levees, bigger retention ponds (and) bigger pipes," he said.

On August 13, 2021, local news outlets in Louisiana reported that, following 1.56 inches of rain over several days, New Orleans had already topped the average annual rainfall of 63.35 inches by more than an inch. Baton Rouge had similarly topped its average rainfall by over an inch. The increased number of more intense rains in 2021 fits a pattern that climatologists have linked to global warming, caused in part by higher temperatures helping the atmosphere hold onto more moisture. The addition moisture can be triggered into thunderstorms by spring and summer temperatures and low pressure, according to LSU professor Barry Keim, the Louisiana state climatologist.

The state will also soon revise estimates for rainfall amounts. If higher, it could shift infrastructure standards for new bridges, canals and other projects, potentially leading to higher bills for taxpayers and homeowners. Determining rain estimates will likely take Louisiana two years to complete and won't begin until this spring.[12]

ii. Hurricane Ida

Hurricane Ida slammed Louisiana as a Category 4 and its remnants went on to trigger disastrous rainfall flooding in the Northeast. Ida began as Tropical Depression Nine on Aug. 26 while south of the Cayman Islands. Just over six hours later, an Air Force Reserve Hurricane Hunter mission found its winds were strong enough to upgrade to Tropical Storm Ida. The storm then took advantage of very warm Gulf water, weak winds aloft with little shear, and plenty of moist air to rapidly intensify from Cat. 1 to Cat. 4 status in the 24 hours ending the morning of Aug. 29.

Ida's center crossed the coast near Port Fourchon, Louisiana, at 11:55 a.m. CDT on Aug. 29. Maximum sustained winds were 150 mph, making Ida a high-end Category 4 hurricane (Figure 5). Storm surge predictions showed that vast areas of the coast would be flooded by more than 9 feet above land, including the proposed Venture Capital LNG site (Figure 6).

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[11] https://www.theadvocate.com/baton_rouge/news/article_d64b16a2-d5d5-11eb-aabb-0b036faa676a.html

[12] U.S. National Oceanic and Atmospheric Administration officials said. https://www.theadvocate.com/baton_rouge/news/article_d64b16a2-d5d5-11eb-aabb-0b036faa676a.html

Figure 5. Hurricane Ida's track across the Gulf of Mexico and the US mainland, a direct hit for Louisiana.

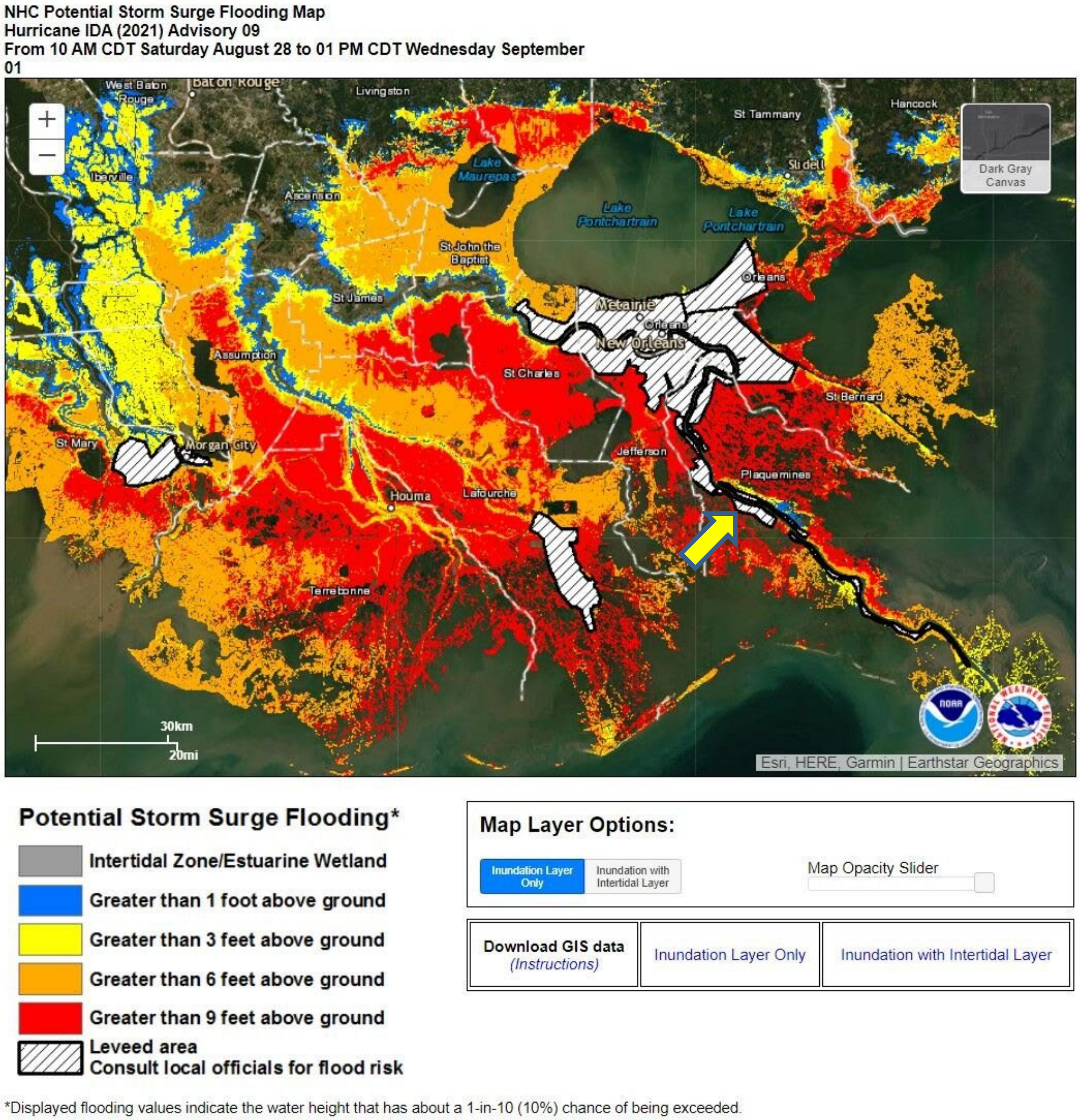

Figure 6. Potential storm surge as predicted by the National Hurricane Center (NHC).

The combination of storm surge and torrential rain prompted the NWS to issue rare flash flood emergencies for the lakeshore area of metro New Orleans, and also for St. John the Baptist and St. Charles Parishes, including LaPlace late on Aug. 29. The NWS issued several extreme wind warnings for parts of southeast Louisiana on Aug. 29, a rarely-issued warning for tornado-like winds of 115 mph or greater in the eyewall of Ida. According to NOAA's Best Track database, no Category 3 or stronger hurricane had taken a northward path just west of New Orleans similar to Ida in almost 106 years.

Numerous wind gusts over 100 mph were clocked in far southeast Louisiana near the coast, including in Galliano and Dulac. A gust to 172 mph was measured aboard a ship in Port

Fourchon as Ida made landfall, one of the strongest hurricane gusts on record in the U.S. Damage was reported in many areas of southeast Louisiana. In the New Orleans metro area, wind gusts up to 99 mph not only downed trees and power lines, but also damaged or destroyed some older buildings. Damage was captured on video in the French Quarter, and in other parts of the city. The winds knocked out power to all of Orleans Parish due to what Entergy referred to as “catastrophic transmission damage”. Over 1 million customers lost power in Louisiana from Ida. Ten to 14 inches of rain was measured in New Orleans before rain ended early on Aug. 29. Rigolets-Slidell, Louisiana, reported 15.73 inches of rainfall from Ida. So, the LNG site most likely had winds of 100 mph and possibly 15 inches of rain.

Despite years of preparations, New Orleans Mayor Latoya Cantrell said there was no time to issue a mandatory evacuation order as Ida rapidly intensified into a powerful Category 4 hurricane. She urged city residents to “hunker down.” Mass evacuations require coordination among multiple parishes and states, and there was not enough time. In several surrounding parishes, people were told to evacuate, but in low-lying and flood-prone areas, many residents could not afford to leave – such as in Port Sulphur and further down the Mississippi River.

The damage outside the New Orleans levee system—which was strengthened in the wake of Hurricane Katrina—was devastating. In St. John the Baptist Parish, about 30 miles northwest of New Orleans, Ida’s storm surge flooded the largest town, LaPlace. Most LaPlace residents couldn’t afford to evacuate. When the storm hit, people pleaded for boat rescues. Two months later, residents were still waiting for repairs, and some were contemplating leaving permanently.

Native communities living in the bayous of coastal Louisiana are also facing the risk of permanent displacement. One example is the Houma people, who saw many of their homes damaged or destroyed. The Houma have been recognized by the state as a tribe since 1972 but are not recognized by the federal government and thus are not eligible for federal community assistance. Instead, members apply for assistance as private citizens. Many were left without housing, and their displacement erodes the Houma’s sense of “community” and connection to their land.

The NWS New Orleans/Baton Rouge Hurricane Ida Post Tropical Cyclone Report for Plaquemines Parish stated:

> The parish suffered extreme impacts from storm surge and damaging winds. Storm surge flooding overtopped the white ditch levee causing significant flooding along Hwy 39 from White Ditch to Braithwaite. The surge also overtopped the back levees along the West bank, flooding areas along Hwy 23 from West Point a la Hache through Myrtle Grove, Ironton and Alliance.

Many homes in the area are elevated, but unelevated homes were pushed off of their foundations and others were flooded with several feet of water. Elevated homes suffered some wind damage as well as flooding of garages and other under-home storage areas. Numerous cattle and horses were killed when they were trapped by the flood waters. Wind damage was also common throughout the upper portions of the parish, with numerous trees downed and many homes suffering minor to moderate roof damage. Power lines and power poles were damaged or downed parish-wide and nearly the entire parish was left without electricity following the storm."[13]

The proposed LNG site was flooded, and data indicates the site would have needed at least a 27-foot storm wall to prevent overtopping during Hurricane Ida, as discussed below in Section III.a.

Shell's refinery in Norco spewed black smoke from its stacks for days after Ida passed through the area (Figure 7). A reporter for the Guardian on September 4, 2021, 6 days after landfall, reported that the smell of rotten eggs, the signature scent of sulfur emissions, lingered in the air. In an effort to burn off toxic chemicals before and after Hurricane Ida, many industrial facilities sent the gases through smokestacks topped with flares. But the hurricane blew out some of those flares like candles, allowing harmful pollution into the air.

Health concerns linked to potential toxic exposure underscore the array of long-term impacts brought by the category-4 Hurricane Ida that struck southeast Louisiana. As of early September 2021, nearly a million homes and businesses were without power and hundreds of thousands more without access to clean water. And with hundreds of chemical facilities located within the path of the hurricane, numerous air quality tracking systems were left out of commission. Louisiana State Police, which has deployed its hazardous materials unit to handle toxic emissions from industrial facilities in the past, was out of commission for an extended period.

Figure 7. Black smoke rises from Shell's petrochemical plant in Norco, Louisiana, after Hurricane Ida knocked out the facility's power. Photograph: Julie Dermansky/The Guardian

The US Coast Guard received at least 17 calls about air releases to the National Response Center, including multiple reports of ammonia released into the air because flares were blown out by the storm (https://www.theguardian.com/us-news/2021/sep/04/louisiana-shell-refinery-toxic-chemicals-hurricane-ida). Figures 8a and 8b reveal damage done to one of many coastal facilities during Ida. Other examples are available at Desmog.com (search for Hurricane Ida).

[13] https://www.weather.gov/lix/pshhurricaneida.

Figures 8 a and b. photos of damage to an oil and gas facility baywards of the LNG site during the passage of Hurricane Ida.

c. NOAA’s 2022 Sea Level Rise Report

The Gulf Coast of the USA includes 48 contiguous coastal counties in four States, running from Houston/Galveston, TX, to Mobile, AL. This region is home to almost 10 million people living in a range of urban and rural settings and contains critical transportation infrastructure, industrial facilities, oil and gas infrastructure and an extensive built environment.

Global warming is adversely impacting this area, especially the Louisiana coast where Relative Sea Level Rise (RSLR) is one of the highest in the world. Coupled with the loss of its protective apron of coastal wetlands, hurricanes storm surges, for a given storm, are increasing in places fairly dramatically with increased pressure on the built environment.

The coastal geography of the region is highly dynamic due to a unique combination of geomorphic, tectonic, marine, and atmospheric forcings that shape both the shoreline and interior land forms. Due largely to its sedimentary history, the region is low lying, and much of the central Gulf Coast region is prone to flooding during heavy rainfall events, hurricanes, and lesser tropical storms. Land subsidence is a major factor in the region, as sediments naturally compact over time. Specific rates of subsidence vary across the region, influenced by both the geomorphology of specific locations as well as by human activities (e.g., due to compaction of subsurface sediments, extraction of subsurface hydrocarbons or water, collision of tectonic plates, isostatic response, sediment loading, and subsurface faulting).

Most of the coastline also is highly vulnerable to erosion and wetland loss, particularly in association with tropical storms and frontal passages. It is estimated that 56,000 ha (217 mi^2) of land were lost in Louisiana alone during Hurricane Katrina. Further, many Gulf Coast barrier islands are retreating and diminishing in size. The Chandeleur Islands, which serve as a first line of defense for the New Orleans region, lost roughly 85 percent of their surface area during Hurricane Katrina. As barrier islands and mainland shorelines erode and submerge, onshore facilities in low-lying coastal areas become more susceptible to inundation and destruction.

The unique natural environment and geology of the Gulf Coast region brings its own set of considerations and challenges in designing the built environment. Some of these physical characteristics, such as low topography, high rates of subsidence, and predilection for coastal erosion, significantly increase the vulnerability of the area to climate change impacts. The propensity for flooding is higher in areas that are experiencing subsidence (i.e., the gradual lowering of the land surface relative to a fixed elevation). Near the coastline, the net result of land subsidence is an apparent increase in sea level. Parts of Alabama, Texas, and Louisiana are experiencing subsidence rates that are much higher than the 20th –century rate of global sea level rise of 1-2 mm/year (IPCC, 2001). For example, in the New Orleans area the average rate of subsidence between 1950 and 1995 was about 5 mm/year (Burkett et al., 2003), with some levees, roads, and artificial-fill areas sinking at rates that exceed 25 mm/year (Dixon et al., 2006). As a result of subsidence, which was accelerated by the forced drainage of highly organic soils and other human development activity, most of the city of New Orleans and other forced drainage areas are below sea level (van Heerden and Bryan, 2006).

Sea level rise (SLR) and subsidence are significant issues in the design of flood protection for southeast Louisiana. Flood walls, in particular, cannot be easily raised after construction, so future SLR must be considered in their initial design (van Heerden and Bryan 2006, van Heerden etal 2006). There is high confidence that the rate of observed sea level rise was greater in the 20th century compared to the 19th century (IPCC, 2007 and IPCC 2022). The rate of sea level rise in the world ocean basins varied significantly during the 20th century. Sea level rise during the 21st century is projected to have substantial geographical variability as well. The historical rate of sea level rise calculated from tide gauge records, and satellite altimetry is much higher in the Gulf of Mexico than in many other ocean basins.

Locally, sea level may also rise relative to the land level due to subsidence. This is termed relative sea level rise (RSLR). The relative sea level and its rise over time alter the extent and degree that surge, and wave heights generated by hurricanes impact coastal areas. In the past, RSLR was included in coastal protection design by raising design water levels an amount equivalent to the RSLR. But surge generation and propagation are nonlinear processes and linear addition of RSLR to design water levels underestimates the impact in many areas. In addition to the surge elevation, wave heights also increase with water level in coastal areas where the wave height is limited by water depth. RSLR impacts not only the storm response, but also landscape type in southeast Louisiana. Higher water levels in wetlands impact vegetation type, where a wetland may change from freshwater marsh to brackish marsh to open water with increasing water level. RSLR may also lead to wetland loss, shoreline erosion, erosion of protective barrier islands (through overwash and breaching), and an overall change in the local morphology (islands transforming to submerged shoals and wetlands becoming open lakes or bays).[14]

The 2022 Sea Level Rise Technical Report (NOAA, 2022) provides the most up-to-date sea level rise projections available for all U.S. states and territories; decision-makers will look to it for information. This multi-agency effort, representing the first update since 2017, offers projections out to the year 2100 and information to help communities assess potential changes

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[14] Van Heerden and Bryan, 2006; van Heerden etal, 2006, and Wamsley et al. (2009a,b) discuss the potential impact of wetland loss on hurricane surges.

in average tide heights and height-specific threshold frequencies as they strive to adapt to sea level rise.

Water levels along Louisiana's coast are expected to rise between 1½ (0.46 m) and 2 feet (0.61 m) by 2050, and could rise over 4 feet (1.21 meters) by 2100, according to new estimates of the effects of global warming on sea level rise (NOAA, 2022).

The 2100 estimates for the state have increased since the 2017 version of the report, which expected Louisiana to see about 3.87 feet of rise by the end of the 21st century. The report, authored by the National Oceanic and Atmospheric Administration and NASA, also lays bare the havoc global warming will wreak along the nation's coastlines in the next few decades, predicting an average sea rise of 1 foot by 2050 and 2 feet by 2100 (2022 Sea Level Rise Technical Report (noaa.gov)).

III. Plaquemines LNG Will Cause Direct and Significant Impacts to Coastal Waters and Damage to the Levees, Wetlands, and the Community.

The above short review of the 2020 and 2021 hurricane season and latest sea level rise data reveals just how vulnerable coastal Louisiana is to multiple tropical cyclones impacting the state each year. If Hurricane Laura followed by Hurricane Delta had made landfalls further east—east of the the Atchafalaya River, for example—the consequences and impacts would have been much more severe for Louisiana (possibly catastrophic) and the proposed LNG site would have experienced substantial flooding, resulting in potential chemical spills/leaks, if not worse. The potential chemical impacts from such a hurricane could have been catastrophic.[15]

It is my opinion after years of studying hurricanes and flooding that this LNG site will be flooded, in the not-too-distant future and perhaps even the next hurricane season, by the surge associated with a major hurricane. There would, therefore, be a high probability of runoff of landfill (during construction) and chemicals (during operation) being carried off the site and into homes, businesses, farmland, and fragile coastal wetlands.

In my opinion, the construction of the proposed project will cause irreparable harm to coastal wetlands and their ecosystems as well as the integrity of the levees and properties within the same flood area, as described below.

Thus, it is my opinion that the Plaquemines LNG project will cause direct and significant impacts to coastal waters. It is my view that the Corps and LNDR failed to conduct the necessary analysis of the environmental consequences before approving permits for this facility in this location and should do so before considering reinstating any permit for the LNG facility.

a. Risks from storm surge and flooding at the project site are significant.

Venture Global Plaquemines LNG, LLC and Venture Global Gator Express LLC, Minneapolis, Minnesota have applied for a permit to construct a New Marine and Terminal Site and Pipeline System within and along the Mississippi River, Plaquemines Parish. The project site is located

[15] https://southerlymag.org/2020/12/07/louisiana-chemical-facilities-are-ticking-time-bombs-during-hurricanes-residents-are-left-in-the-dark-about-the-risks/. Last viewed Feb 7, 2021

within and along the right descending bank of the Mississippi River, at about miles 55-54, above Head of Passes, off Louisiana State Highway 23, in Port Sulphur, Plaquemines Parish (Figure 9).

According to the 2013 Louisiana Coastal Wetland Vegetation Type map, the site is referenced as other but fronted by a saline marsh (Figure 10). It is bounded on its southwest (back side) by a non-federal (parish) levee and on the front by the Mississippi River flood levee. Highway 23 crosses the front of the property. The site appears to be drained farmland at this time.

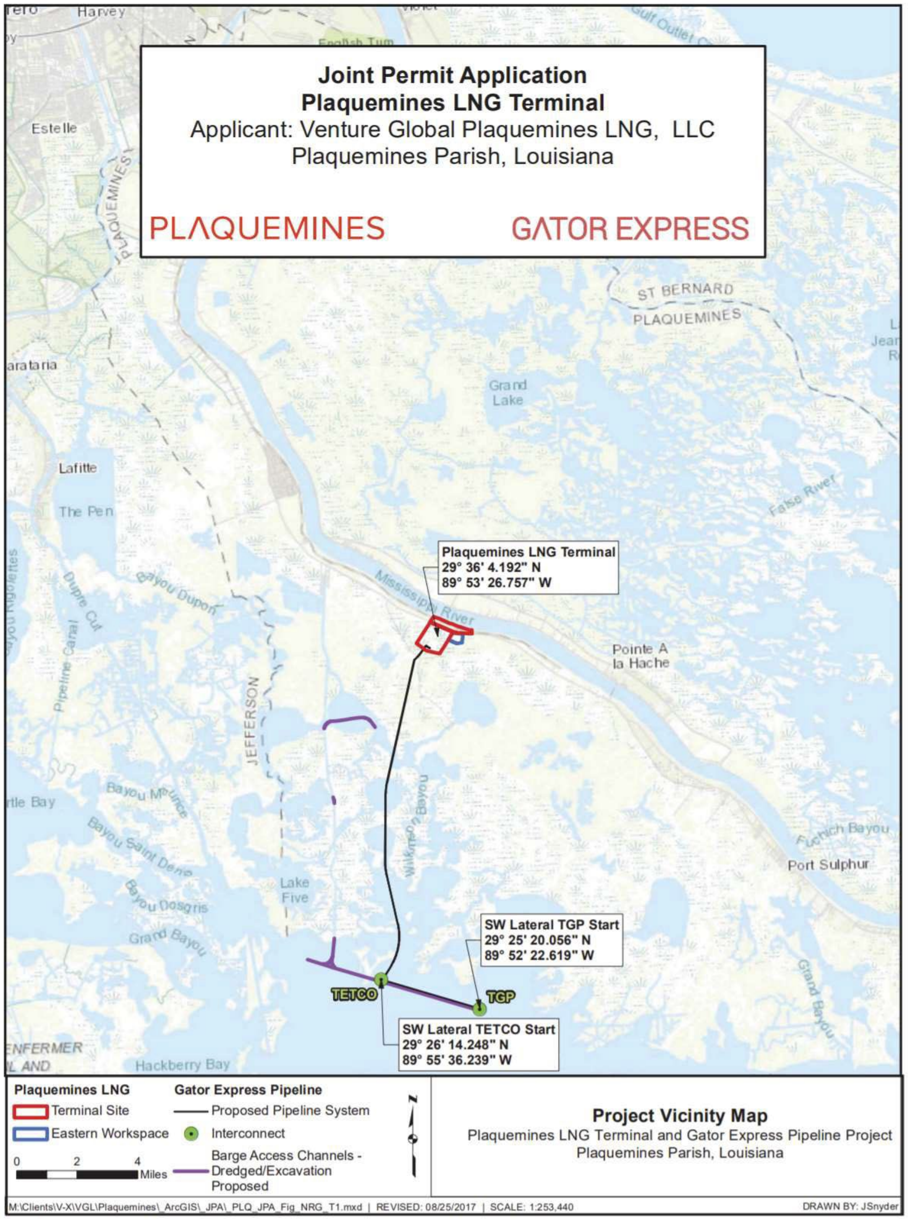

Figure 9. Location of proposed Venture Capital LNG Facility (USACOE 2018).

Figure 10. Google Earth image of the proposed LNG site on drained farm lands known as Deer Range Lake and at least -4.0 feet NAVD 88. Arrow points North.

The proposed site design is shown in Figure 11.

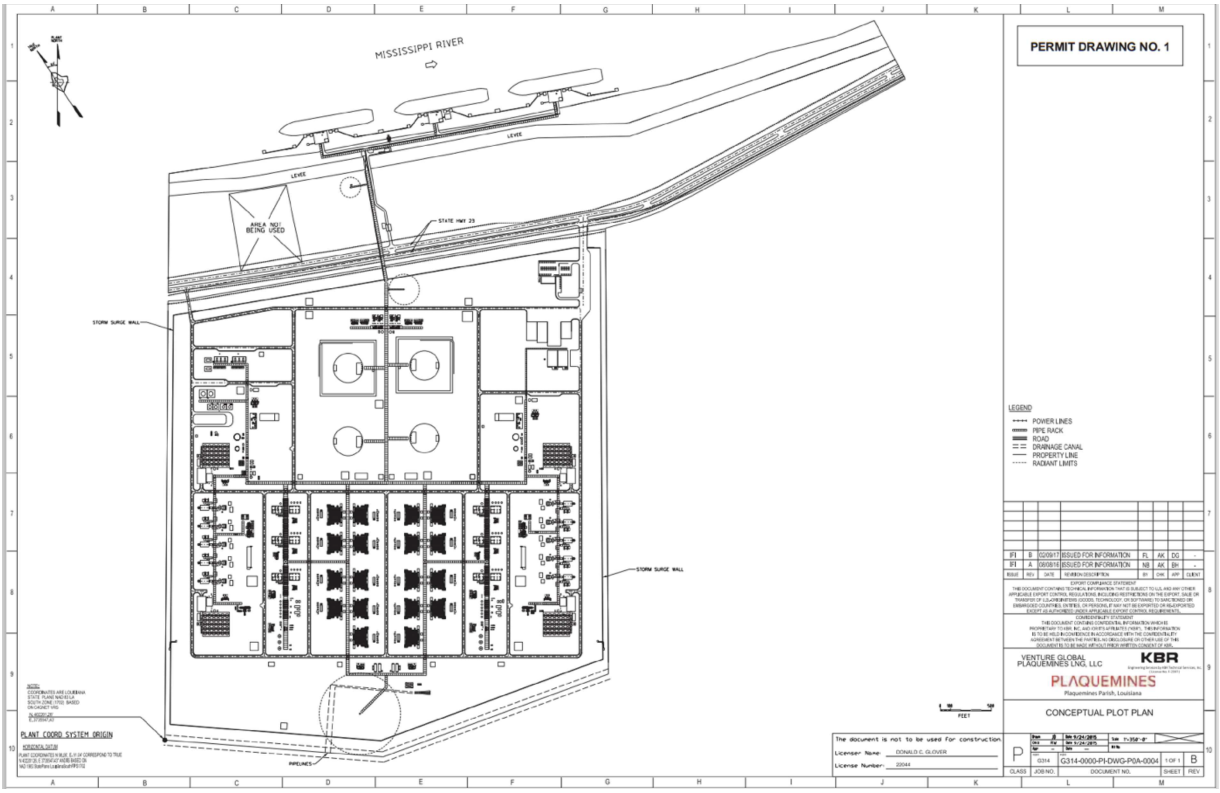

Figure 11. Plan of the proposed Venture Capital LNG facility.

In order to fully understand the implications of this site it is necessary to know the true (latest) elevations of the site and then to assess its potential vulnerability to hurricanes and severe storms, commonly now referred to in Louisiana as "storms on steroids."

i. Flooding baseline at the site

FEMA (2021) allows one to find the Flood Map data for locations in Plaquemines Parish, data that became effective January 15, 2021. This data reveals that the elevation of Highway 23 along the site is +0.6 feet NAVD88 (North American Vertical Datum of 1988, used to measure and compare height above sea level). While the center of the site has an elevation of -4.8 to -5.1 feet NAVD88. Locals know the site as Deer Range Lake (Figure 12 and 13). The site does not flood on normal tides because of an agricultural levee along it back side facing Barateria Bay (Figure 10). In other words, the site is a drained polder and as such is subject to much higher subsidence rates than if still virgin marsh (van Heerden and Bryan, 2006 pg 160). Data on the elevation of this levee is not readily available but as the area flooded in Hurricane Ida, must be just a few feet above 0.0 feet NAVD 88—not very secure.

FEMA (2021) reports the Base Flood Elevation (BFE) for the site is 13 feet. FEMA defines the BFE as the computed elevation to which the flood water is anticipated to rise during the base flood. The base flood is also referred to as the 1-percent annual chance flood or 100-year flood. The Base Flood Elevation is a baseline pulled together from historic weather data, local topography, and the best science available at the time. FEMA states that it is a reasonable standard to insure against, although many scientists would disagree.

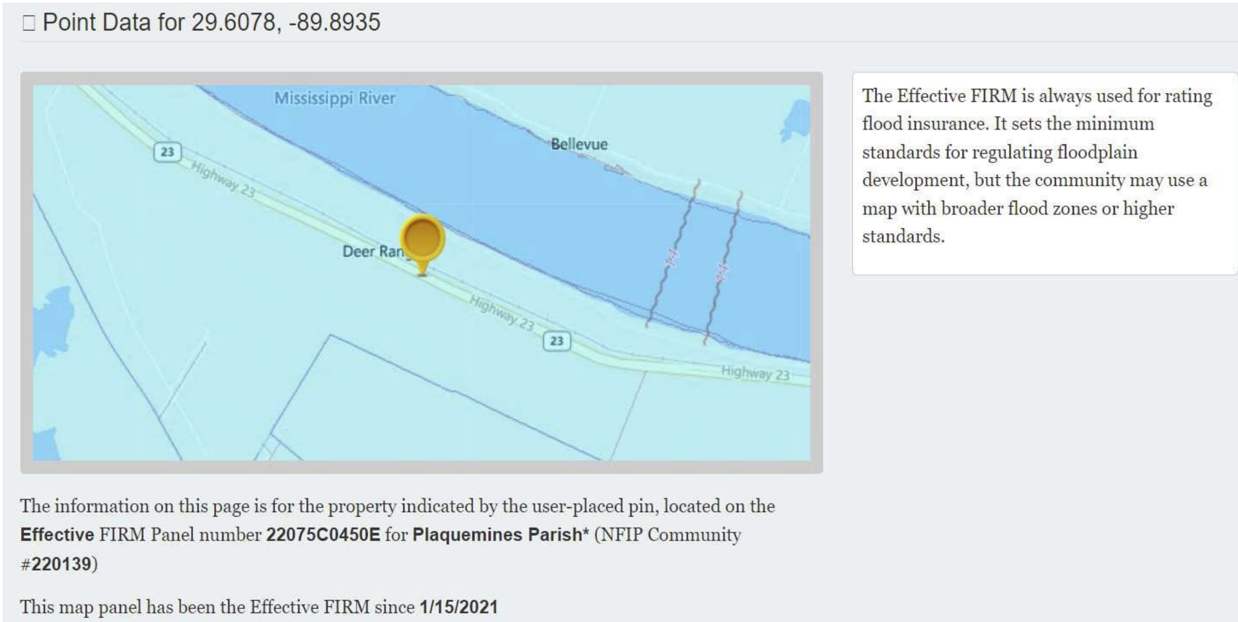

Figure 12. FEMA Flood Map for site showing particulars of Highway 23, elevation 0.6 feet NAVD88 some 5 feet or more higher than the LNG project site. BFE is 13 feet NAVD88.

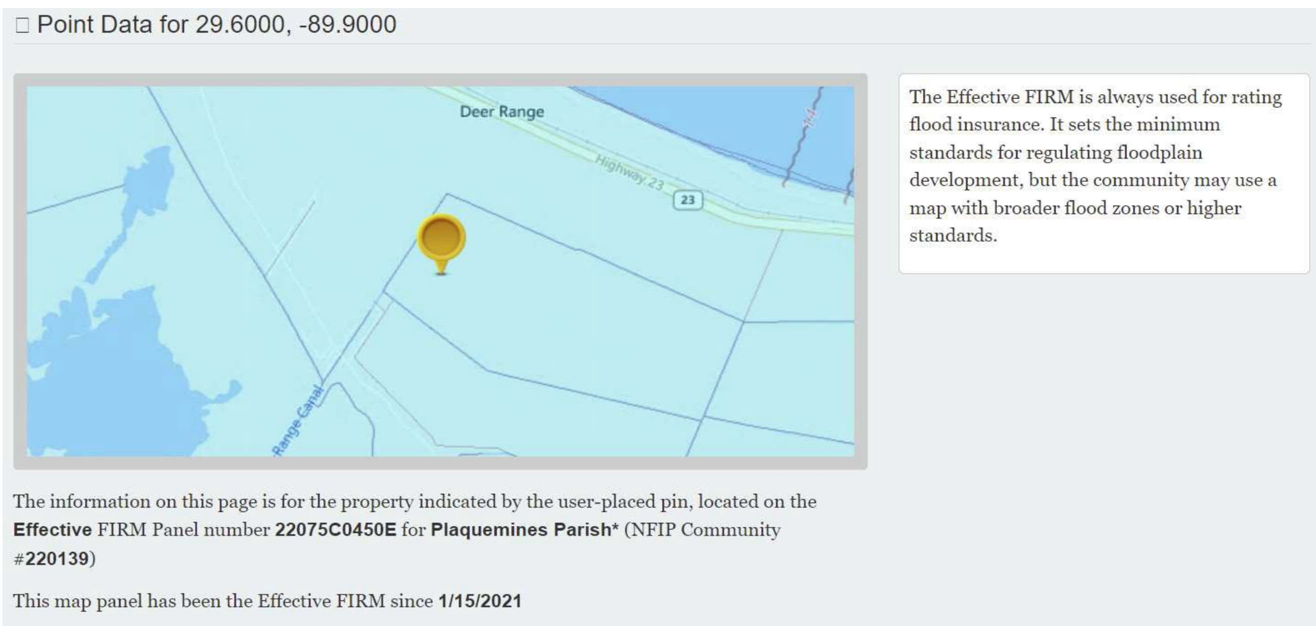

Figure 13. FEMA Flood Map for site showing particulars of drained polder, elevation -4.8 to -5.1 feet NAVD88 some 5 feet or more lower than Highway 23.

For Plaquemines Parish, FEMA seemingly used 2005's Hurricane Katrina and Rita as the storms of reference. Rita made landfall in western Texas, just west of the Louisiana Border and had very little surge impact in Plaquemines Parish. During Hurricane Katrina, on the other hand, the eye passed close to the site, maximum surges were in in the range of 16 to 20 feet as the Mississippi River levee formed a dam against which the surge water coming from the Gulf backed up, hence these high flood levels (Figure 14). The US Army Corps of Engineers have claimed that Katrina was a one in 300-year flood, although the National Hurricane Center and the former Louisiana State University (LSU) Hurricane Center scientists disagreed (van Heerden et al, 2007), providing evidence that Hurricane Katrina was a one in 30-year storm. In subsequent litigation, a federal court agreed with the LSU scientists. Thus, one could strongly question the use of these two storms by FEMA to determine a BFE when there are other, more relevant storms such as Hurricanes Laura (2020) and Ida (2021) to choose from.

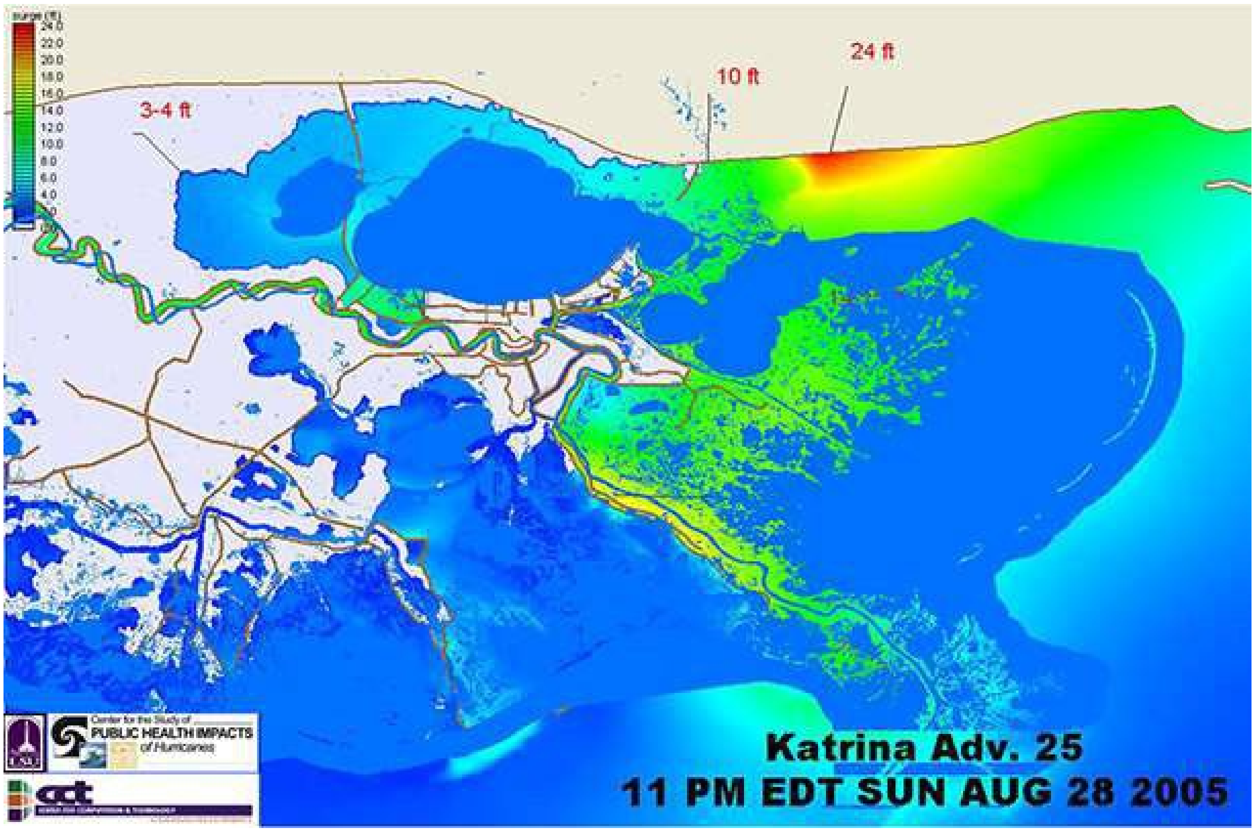

Figure 14. Storm surge prediction performed by van Heerden, etal, just prior to Hurricane Katrina landfall. Note surge at LNG site 16 to 19 feet above sea level (0.0 NAVD88)

It is important to recognize that at least 50% of the proposed LNG Facility is presently below minus 5 feet NAVD88. The only reason it is not wet most of the time is an agricultural back levee (non-federal) that separates this low-lying drained farmland or polder from Barataria Bay. The property, typical of all of coastal Louisiana, has experienced subsidence in the past and is still subsiding relative to sea level. Subsidence rates in this area exceed 3 feet per 100 years (GSATG337GW.pdf (geosociety.org)). Subsidence will result in significant adverse effects on the proposed project site. There is ample research and data such as NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model outputs that reveal that the LNG Facility site would experience surges of at least 18 feet (NAVD88) and some model runs indicate higher surges as much as 24 feet above sea level (NAVD 88). In other words, the site would be surge flooded. Moreover, the SLOSH model does not account for additional subsidence at the site that would exacerbate flooding risk.

As noted, if Hurricane Laura had made landfall further to the east, towards the Atchafalaya River or even Grande Isle, the site may have experienced surges of 12 to 20 feet (see Figures 15a and 15b). As also noted, the proposed LNG site flooded during Hurricane Ida in 2021. Major storms such as Hurricane Katrina have about a one in 30-year return period — the frequency at which a hurricane can be expected to pass within 50 nautical miles of a specific location.[16]

Flooding would pose environmental risks and operational safety problems, and once the surge starts to retreat there is a real risk that contaminants would be carried seawards into Louisiana's precious coastal wetlands and the Mississippi River in addition to local communities. For example, in 2017, when Hurricane Harvey landed on the Texas Coast many petrochemical plants shut down; one flooded plastic plant exploded; and contaminants from industrial wastewater from a variety of plants released benzene, vinyl chloride, and other carcinogens into surrounding neighborhoods and water bodies.[17]

ii. Potential surge and wave conditions at site.

In order to assess the implications of this facility for Mississippi River levee safety and the validity of the ring levee design it is important to understand what sort of surge and wind-wave conditions could occur at the site. For this quantification, I relied on the NOAA SLOSH model, which is the official federal surge data source. The NOAA SLOSH models are extensively used by the NHC in determining the storm surge vulnerability.

Figures 15a and b, 16a and b, and 17a and b, below, depict NOAA SLOSH model outputs. This computerized numerical model was developed by the National Weather Service (NWS) to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes by taking into account the atmospheric pressure, size, forward speed, and track data. These parameters are used to create a model of the wind field which drives the storm surge. The figures presented are so-called Composite Approach model outputs. The Composite Approach predicts surge by running SLOSH several thousand times with hypothetical hurricanes under different storm conditions. The products generated from this approach are the Maximum Envelopes of Water (MEOWs)[18] and the Maximum of MEOWs (MOMs)[19] which are regarded by National Hurricane Center as the best approach for determining storm surge vulnerability for an area since they consider forecast uncertainty. The MEOWs and MOMs play an integral role in emergency management as they form the basis for the development of the nation's

[16] van Heerden, Ivor L. and M. Bryan, The Storm – What Went Wrong and Why during Hurricane Katrina – the Inside Story from One Louisiana Scientist, Publ. Penguin/Viking, New York, New York, 308pp (2006) (van Heerden and Bryan 2006); van Heerden et al. 2007.

[17] See, e.g. Frank Bajak & Lise Olsen, Hurricane Harvey's Toxic Impact Deeper Than Public Told, A.P. and HOUSTON CHRONICLE, Mar. 23, 2018), https://apnews.com/e0ceae76d5894734b0041210a902218d/Hurricane-Harvey's-toxic-impact-deeper-than-public-told#:~:text=Benzene%2C%20vinyl%20chloride%2C%20butadiene%20and,waterways%20following%2 0Harvey's%20torrential%20rains (last visited Feb, 4 2021).

[18] Maximum Envelopes of Water (MEOWs), https://www.nhc.noaa.gov/surge/meowOverview.php.

[19] Maximum of MEOWs (MOMs), https://www.nhc.noaa.gov/surge/momOverview.php.

evacuation zones.[20] Figure 6 below represents the outputs for (Figure 15a) Category 3 storms (on the Saffir-Simpson Hurricane Wind Scale) and (Figure 15b) Category 5 storms approaching from the southeast. Figure 16 shows the same outputs for storms from the south, and Figure 17 from the southwest. The location of the proposed LNG site is depicted by an arrow on each figure.

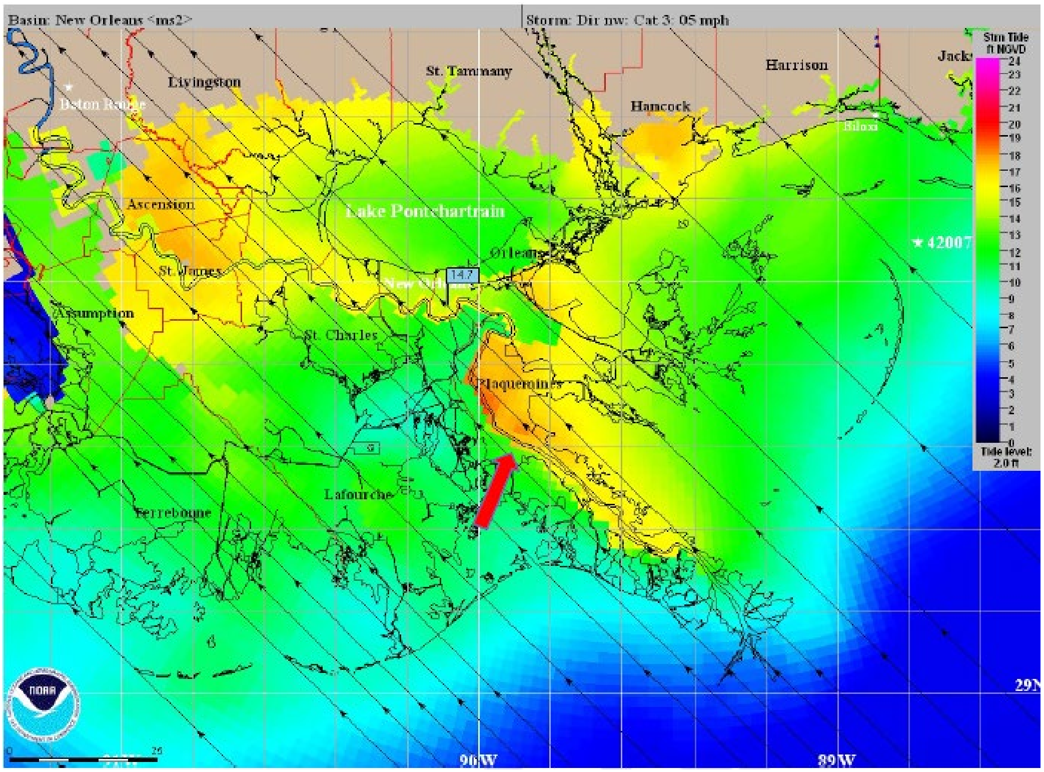

Figure 15a. SLOSH MOM output for a Cat 3 hurricane from Southeast.

[20] National Hurricane Center and Central Pacific Hurricane Center, Sea, Lake, and Overland Surges from Hurricanes (SLOSH), https://www.nhc.noaa.gov/surge/slosh.php (last visited Jun. 19, 2020).

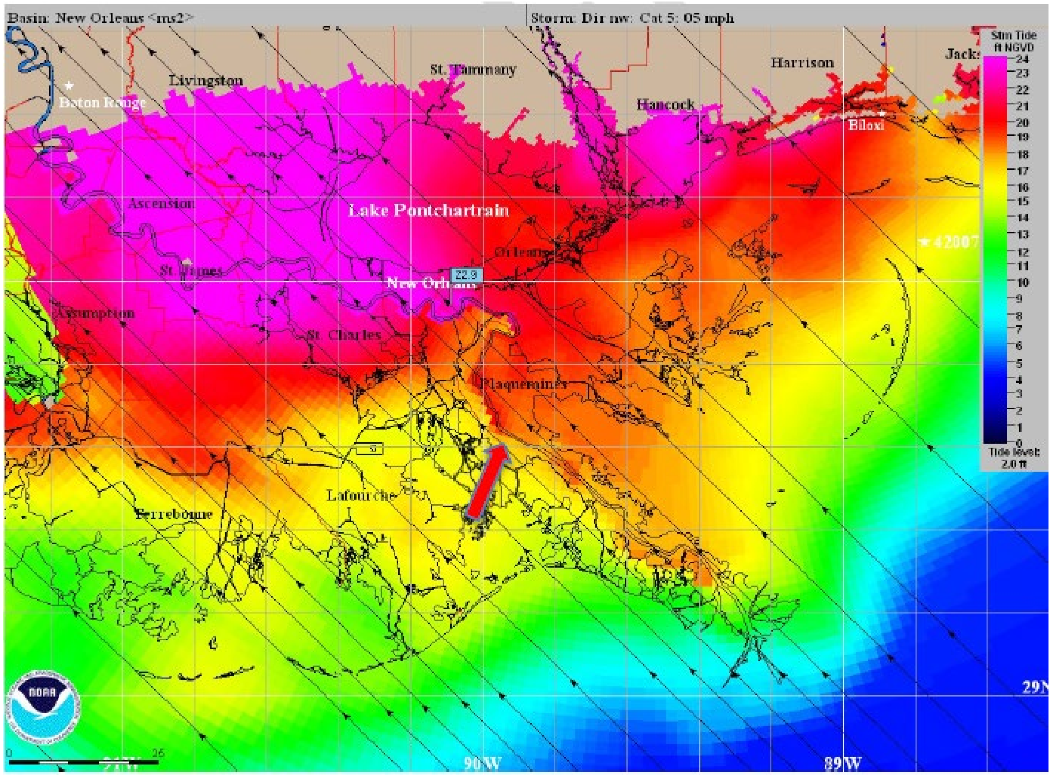

Figure 15b. SLOSH MOM output for a Cat 5 hurricane from Southeast.

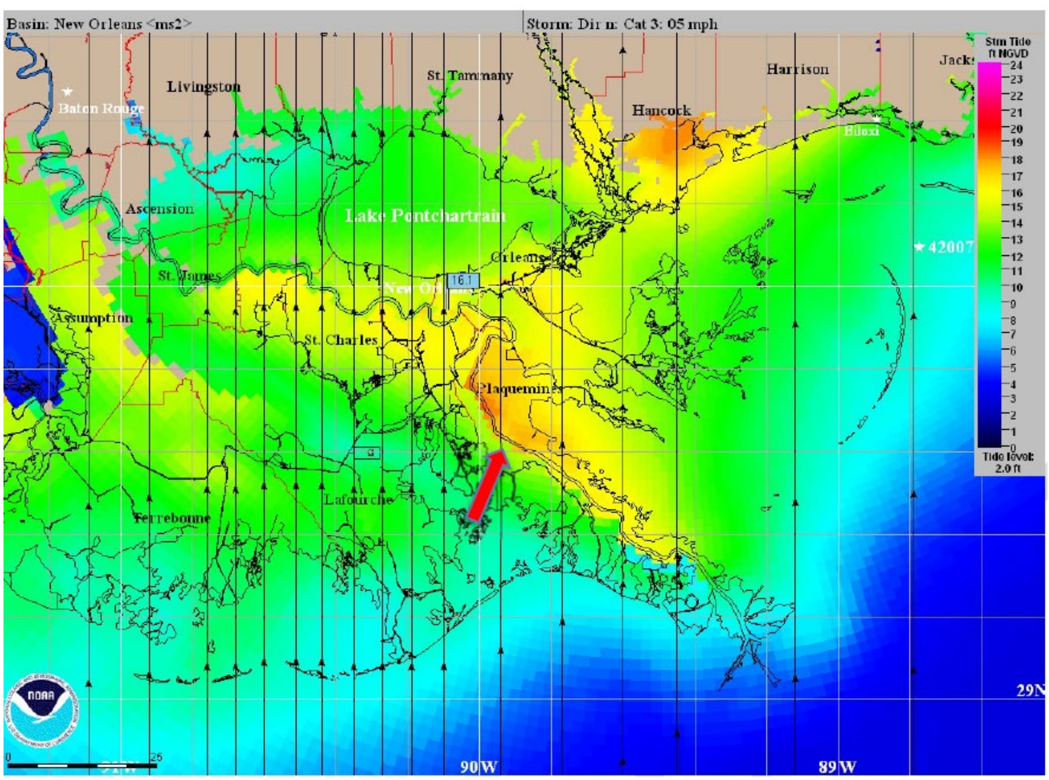

Figure 16a. SLOSH MOM output for a Cat 3 hurricane from South.

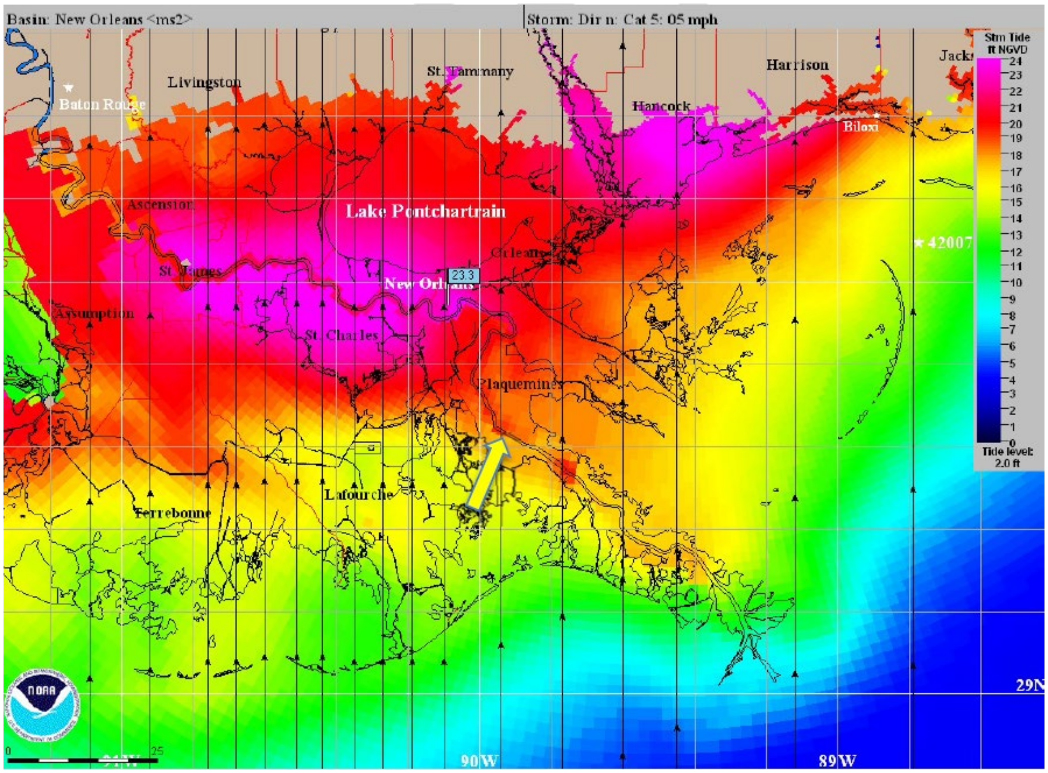

Figure 16b. SLOSH MOM output for a Cat 5 hurricane from South.

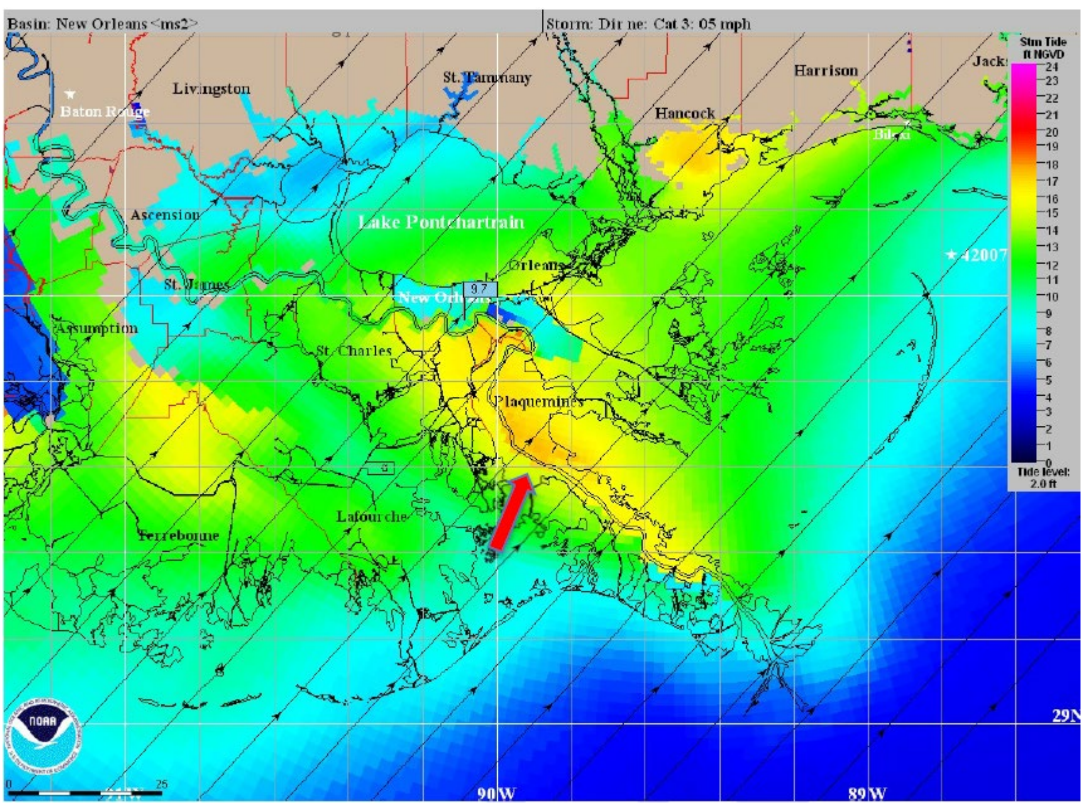

Figure 17a. SLOSH MOM output for a Cat 3 hurricane from Southwest.

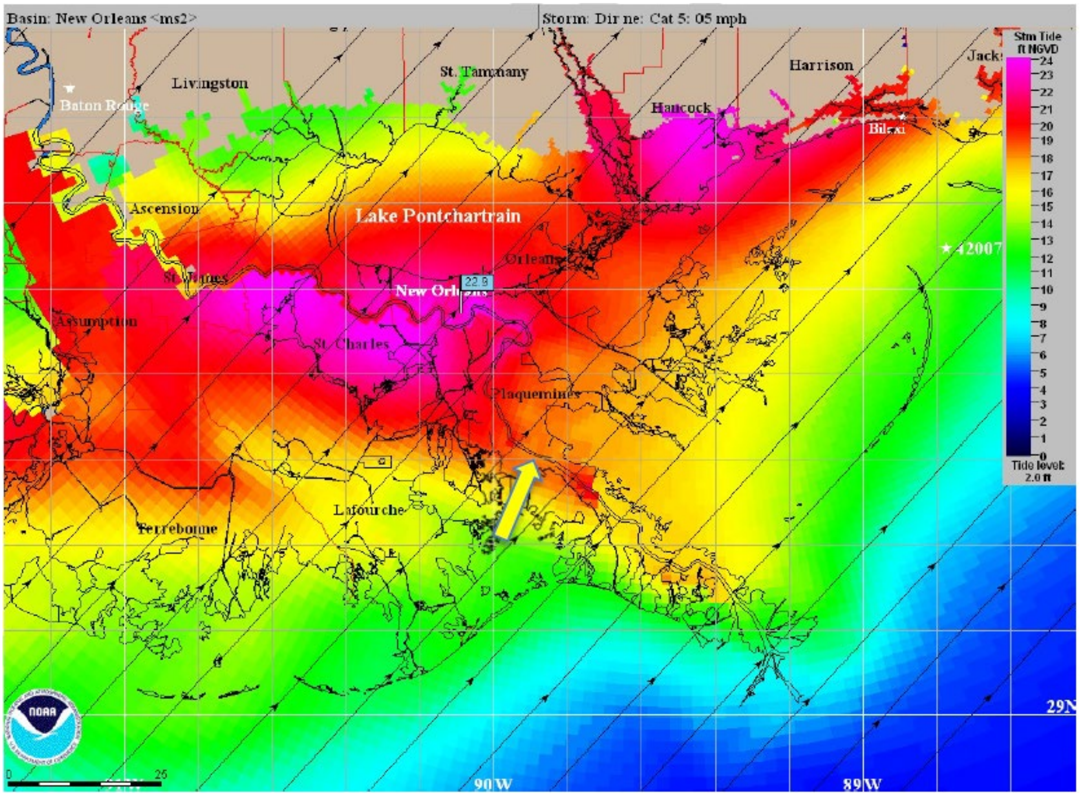

Figure 17b. SLOSH MOM output for a Cat 5 hurricane from Southwest.

The SLOSH model outputs are based on the NAVD29 datum which is different to that of the NAVD88 Datum. **NAVD 88 is generally higher than NGVD 29**, so the conversion factor will be a positive number. The elevation converted to NAVD 88 will be a higher number than the elevation in NAVD 29. Van Heerden et al (2007) found in Greater New Orleans that two feet need to be added to the NAVD29 elevations to correct to NAVD88 (partly due to subsidence). As the proposed LNG site is in much younger sediments the difference is most likely more than 2.0 feet, so the assumption made is a conservative one.

The SLOSH model outputs demonstrate that Category 3 storms generate surges from 18 to 20 feet (corrected to NAVD88) at the project site, and surges generated by Category 5 storms range from 23 to 26 feet above the NAVD88 datum. Storm surge inundation is the term used when referencing storm surge heights as height above the datum, not ground elevation. In this case assuming an average ground elevation of -5.0 feet NAVD88 for the LNG Facility site means that the whole site would be flooded with Category 3 storms with up to 25 feet of surge, and Category 5 storms would have flooding of up to 31 feet above ground level. The SLOSH model does not take into account rainfall nor waves on top of the surge. With surge water depths of up to 31 feet deep and winds in the 80 to 110 miles per hour, a vicious wave field would be developed with a lot of destructive energy and wave sets, up to 12 feet high. The agricultural back levee—which is owned, operated and maintained by the Plaquemines levee district—is believed to have a top elevation of 4.8 to 5.8 feet NAVD 88, so it would be totally overwhelmed. There is no elevation data recorded in the National Levee database for this back levee. (https://levees.sec.usace.army.mil/#/levees/system/4405000511/segments). The federal levee fronting the property along highway 23 has a minimum height of 13.3 feet but the datum is not specified in the National Levee Database (https://levees.sec.usace.army.mil/#/levees/system/4405000511/segments) so for now is assumed to be NAVD88. The LNG plant design apparently used a 500-year BFE of 19.1 feet NAVD88 – an estimation that in my opinion is not viable as a true expression of tropical storm conditions that can develop at this location.

The Joint Public Notice (USACOE, 2018) for this site does show a ring levee of sheet piles around the facility with a top elevation of 26 feet NAVD 88, but there are design issues that will be discussed in Section III.c; it would at least be overtopped by wave wash with surges as low as 15 feet NAVD88. Based on this analysis, there is a high probability that Venture Capital's proposed LNG Facility would be flooded during a major storm, even assuming the ring dike held.

The SLOSH model does not account for rainfall nor waves on top of the surge. With surge water depths of up to 31 feet deep and winds in the 80 to 110 miles per hour, a vicious wave field would be developed with a lot of destructive energy and waves up to 12 feet above the storm surge level.

As noted, during Hurricane Ida, the proposed LNG site flooded. Hindcast surge data (Figure 18) reveal that the surge elevation was in the range of about 8.8 feet to 12 feet NAVD88, so in some places water depths would have been at least 15 feet. Winds at landfall were horrific (up to 150 mph) so a vicious and very destructive wave field would have covered its surface, and waves would have been up to 12 feet high. Thus, the concerns about overtopping during a storm is not merely hypothetical: the ring levee at the LNG facility would have to have been 27 feet high NAVD88 to avoid overtopping during Hurricane Ida, assuming it held. However, if the hurricane had arrived on a different track with more surge (see Figures 15b, or 16b, or 17b), the combined surge and wave height maximum water level could have been 37 feet over NAVD88, using shallow water wave equations. This is more than 10 feet above the proposed 26-foot storm wall.

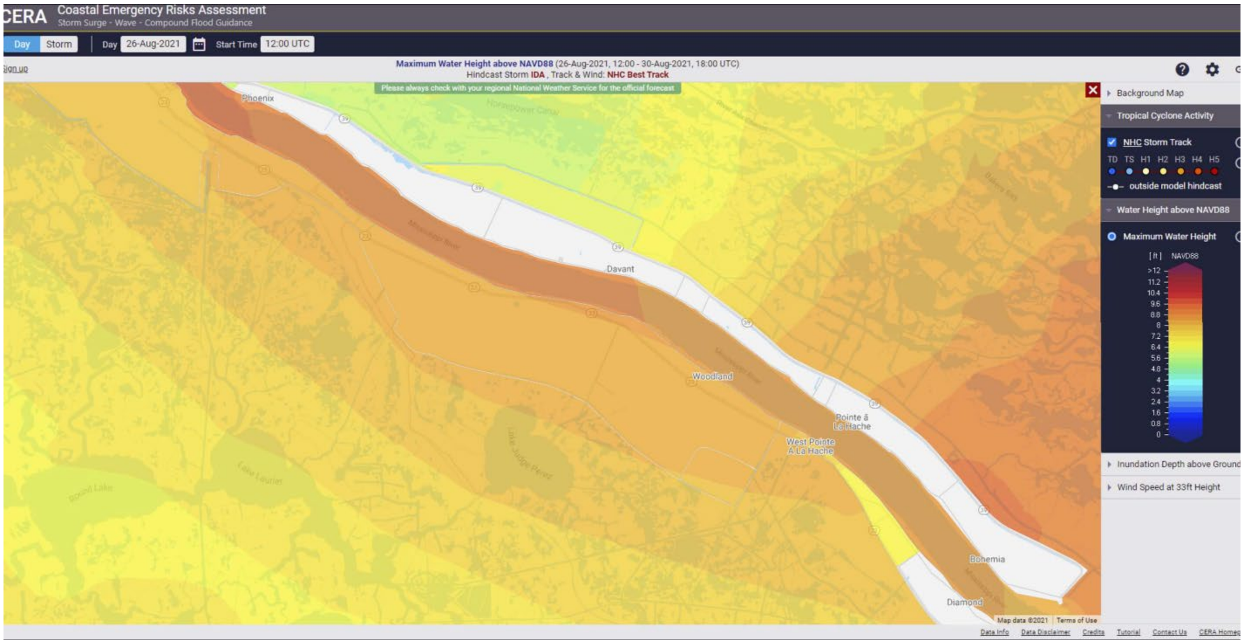

Figure 18. Hindcast of Hurricane Ida storm surge elevation at the proposed LNG site.

iii. Sea Level Rise Exacerbates Flooding Risk at the Project Site

Most structures and levees and other protection for industrial facilities and the built environment utilized the FEMA 100–year Base Flood Elevation (BFE). For the LNG site, the BFE is 13.0 feet.

While the Plaquemines LNG facility relies on this FEMA data to determine the Base Flood Elevation, no account is taken of the expected sea level rise in designs as well as the impact this sea level rise will have on surge elevations in the future, which will be higher. I present here two approaches to examine the impact of sea level rise at the project site. First, I conducted a simple empirical approach. Second, I used computer model data, consistent with recently published scientific literature.

<u>Simplistic approach; what does a 1 foot (0.30 m) rise in sea level mean for the LNG site?</u>

This simplistic approve requires two steps: (1) determining the increase in water volume resulting from higher sea level, and then (2) calculating the storm surge level.

First, examining the water volume requires considering the characteristics of Barateria Bay, which is the large water body seawards of the site, is about 33 miles wide and 25 miles long (Figure 2). The Bay has the ability to carry a storm surge from the coastline, a broken low lying and porous barrier island chain, as well as to potentially enhance that surge depending on local topography. Below is a first order attempt to determine what a 1-foot rise in sea level in the Bay would mean for potential surge at the LNG site.

The area of the bay is approximately 33 x 25 = 825 square miles, or about 23,000,000,000 square feet. If you raise the water level by 1 foot throughout you will increase the volume of Barateria Bay by 23,000,000,000 cubic feet. The additional water volume will serve as extra potential supply to the surge. Additionally, the Bay is now 1 foot deeper, so when the winds blow across the Bay the bottom friction (Manning's n) on the waves and water being moved by the wind will be less, causing the surface elevation of the water driven by the wind to be more than just the 1 foot (0.3 m) rise in sea level.

Second, there is a potential increase in storm surge height given the increased water volume. Barateria Bay is basically an artificial polder that is open to the sea. That is, it has artificial levees backing the bay along its west, north and east edges (Figure 19). The line of artificial levee resembles an upside down "C." These levees are in essence the most landward that the storm surge can penetrate to the east, or the west, or the north. When hurricane storm surges are present, a levee—while offering protection to those inside the system—forms a 'dam wall' to stop and backup the surge and the surging waters can thus pile up against this wall. Failure or overtopping of this wall is a possibility that we will ignore.

From measurements off a state map, one can determine the average width of the protective wetlands between the artificial levee and the open water of the Bay. This is about 7 miles (Figure 19).

Figure 19. Barateria Bay. Orange represents land lost from 1937. Red wavy line approximate location of levees.

Total length of the Bay/wetland shoreline is approximately 70 miles. So, the area of wetlands to reduce the surge in front of the levees (the "marsh apron"), is 7 x 70 = 490 square miles, or 13,600,000,000 square feet. Assuming a Cat 3 or Cat 5 Hurricane from the south (Figures 16a and 16b), it is possible to calculate the surge increase due the deeper water in the Bay. A very simple calculation allows a first order determination of the surge increase with these storms (Figures 16a and 16b). The surge increase would be the volume of water that can be blown up against the levees from the Bay divided by the surface area of the wetland apron. In the first example we assume that the surge is equally spread on the east, north and west sides of the Bay, which is somewhat unrealistic.

Example 1. Volume of water in Bay due to 1 foot (0.3.m) of sea level rise divided by area of whole upside down "C" wetland apron = 23,000,000,000/16,600,000,000 = 1.38 feet or 0.42 m. So, all around the Bay, there would be a 1.38-foot increase in the surge height above what is presented in Figure 3a and 3b. But as revealed in Figures 3a and 3b, the surge is concentrated up against about 1/2 to 1/3 of the levee system mostly along the east and north sides. So, example 2 only considers half the length of the levee system acting as a dam and example 3 considers the surge backing up against 1/3 of the levee.

Example 2. A one foot rise in sea level over one-half of the levee system = 23,000,000,000/8,300,000,000 = 2.28 feet (0.7 m) increase in surge height.

Example 3. One foot rise in sea level over one-third of levee system = 23,000,000,000/5,533,333,333 = 4.16 feet (1.23 m) increase in surge height. In other words, a 1-foot rise in sea level could effectively increase storm surge height by four times that.

While this is a simplistic approach, it indicates that raising sea level by one foot (0.3 m) has a significant potential to raise storm surges, an add-on effect, of between 3.28 feet (1.0 m) and 5.16 feet (1.6 m).

Computer model data from the scientific Literature.

McKee Smith etal (2010) published various computer model outputs assuming two different seas rise scenarios. Potential impacts of 0.5 m (1.64 feet) and 1.0 m (3.28 feet) RSLR on hurricane surge and waves in southeast Louisiana are investigated using the numerical storm surge model ADCIRC and the nearshore spectral wave model STWAVE. The models were applied for six hypothetic hurricanes that produce approximately 100 yr water levels in southeastern Louisiana. An example of a ADCIRC surge output is presented in Figure 20.

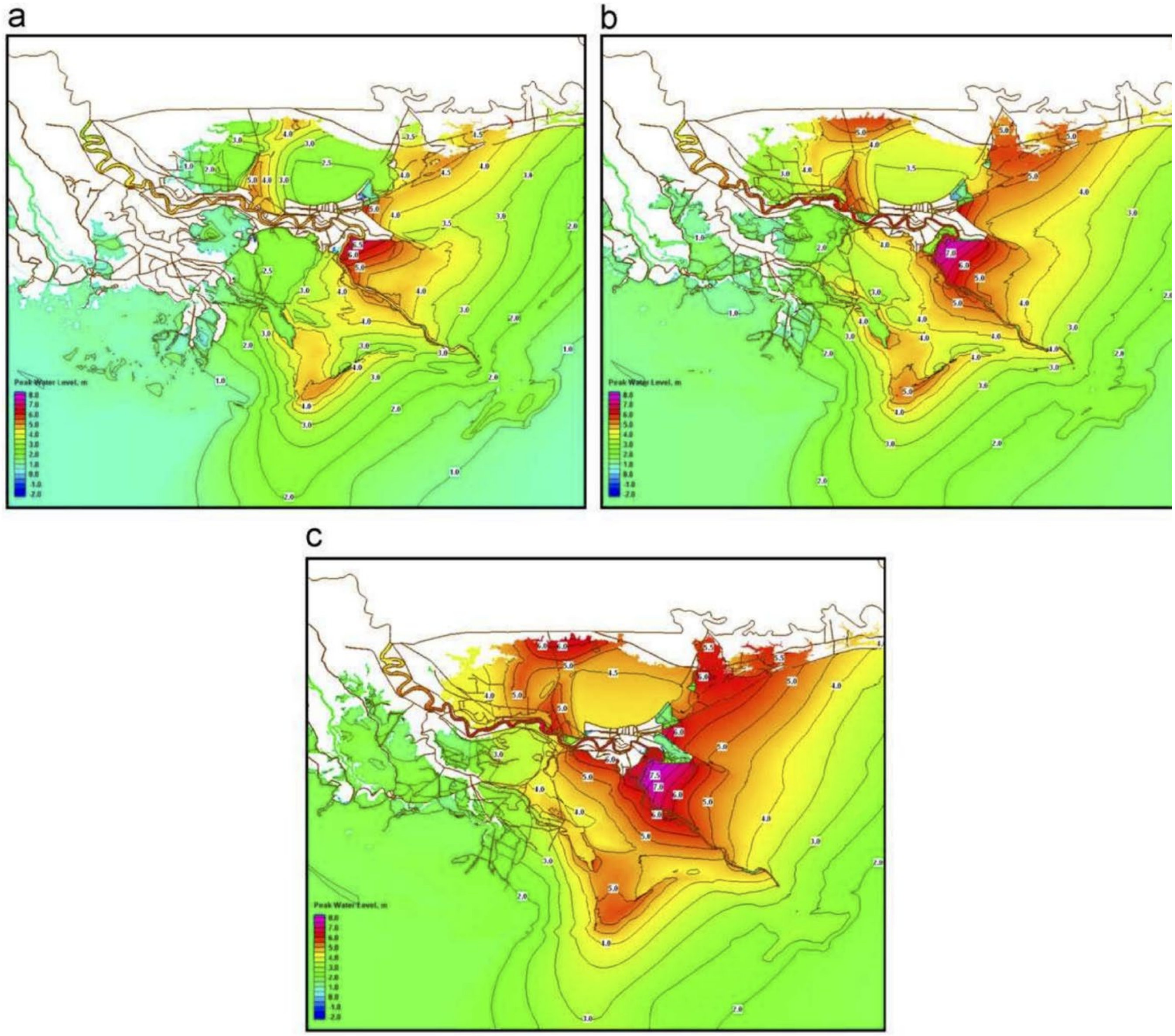

Figure 20. (a) Maximum surge for Storm 017 base case (0 m RSLR) (b) Maximum surge for Storm 017 for 0.5 m RSLR, (c) Maximum surge for Storm 017 for 1,0 m RSLR.

As shown, a RSLR of 0.5 m raises the surge elevation over a relatively large area and a RSLR of 1.0 m significantly raises the surge elevation over most of the area impacted by the surge. The same trends were visible in the other model runs done by McKee Smith etal (2010).

RSLR in the region in the next 50–100 yr is expected to be greater than 0.5–1m (NOAA, 2022). The RSLR will strongly impact wetland vegetation in this micro-tidal environment. In setting up the computer models, the bottom friction (the Manning n roughness values) were modified to reflect the evolution of marsh type with RSLR, as wetlands evolve from freshwater marsh to brackish marsh to open water with increasing water level. The bathymetry was not modified to reflect possible erosion or accretion of sediments, but erosion is more likely in this sediment starved region. The computer models were used to simulate the hurricanes under the base case (no RSLR) and 0.5 m (1.64 feet) and 1 m (3.28 feet) of RSLR. The trends shown in the simulations were similar (McKee Smith et al, 2010). In the peak-surge areas, the maximum surge generated under the RSLR scenarios increased relatively linearly with RSLR, although, the surge values increased by as much as 0.5–1.0 m (up to 3.28 feet) in some simulations. The reason for the relatively linear response is likely due to the large surge values in these areas (5–7.5 m; up to 24.6 feet), so the RSLR was a smaller portion of the total surge in these areas. Thus, the surge propagation and the interaction with the bottom were not so significantly changed by RSLR. But certainly the additional 0.5–1.0 m (up to 3.3 feet) of surge, in addition to an RSLR (of up to 3.3 feet), is significant in the design and construction of sea walls and levees. In some areas the maximum surge is also limited by the surrounding topography and levee heights (McKee Smith et al, 2010).

In wetland or wetland-fronted areas of moderate peak surges (2–3 m), the surge levels were increased by as much as 1–3 m (above the RSLR). The water level increases are as much as double and triple the RSLR over broad areas and as much as five times the RSLR in isolated areas (McKee Smith et al, 2010). The areas most impacted are the West Bank and Lake Maurepas. The deeper water depths (due to RSLR) and the degradation of the wetlands (reduced Manning n values) appear to increase the surge propagation speed and allow greater inundation. Similar amplification of surge occurred in other wetland areas, e.g., Lake Borgne and Lower Plaquemines Parish, but the amplification factors were not as high. The loss of the cypress canopy in the Lake Maurepas area also contributed to large local variations in surge associated with RSLR. The surge amplification patterns were very similar for 0.5 and 1 m of RSLR, but the relative impact of RSLR (surge increase divided by RSLR) was greater for the 0.5 m RSLR.

Waves increase significantly in shallow areas due to the combined increases in water depth resulting from RSLR and surge increases. Maximum increases for the storm suite were 1–1.5 m. The main mechanism for increased wave energy is reduction of depth-limited wave breaking but reduced frictional dissipation and increased wave growth also contribute. In areas of depth-limited wave breaking, increased wave height is approximately linear with the change in total depth (RSLR plus surge).

The major conclusion is that surge does not increase linearly with RSLR. Linear addition of RSLR to design water levels is not appropriate in this region. Although it appears that the peak surge may increase modestly (0.5–1 m above the 0.5–1 m of RSLR), regions of more modest surge (2–3 m) may see very significant increases in surge from sea level rise (1–3 m above the 0.5–1 m RSLR).

Surge propagation over broad, shallow, wetland areas is highly sensitive to RSLR. Waves also generally increased for all RSLR cases. These increases were significant (0.5–1.5 m for 1 m RSLR), but less dramatic than the surge increases. Smith et al. (2008), in a similar study where Manning n values were not changed with RSLR, found similar surge amplification results, indicating the sensitivity to RSLR. As wetlands deteriorate, it is likely that water depths will increase further and RSLR will impact surge levels to an even greater extent, compared to the base case estimates.

In another study, Irish et al (2013) undertook simulations of Hurricane Katrina (2005) under sea level and climate conditions for 1900. Here, observed climate and sea level trends over the last century (c. 1900s to 2000s) are used to provide insight regarding future coastal inundation trends. The actual impacts of Hurricane Katrina (2005) in New Orleans are compared with the impacts of a similar hypothetical hurricane occurring c. 1900. Estimated regional sea level rise since 1900 of 0.75 m, which contains a dominant land subsidence contribution (0.57 m), serves as a "prototype" for future climate-change induced sea level rise in other regions. Landform conditions c. 1900 were estimated by changing frictional resistance based on expected additional wetlands at lower sea levels.

To assess the relative influence of climate change along with local anthropogenic influences on SLR, scenarios were constructed to represent a storm like Hurricane Katrina should it have occurred at the turn of the last century, c. 1900. In selecting these scenarios, the following assumptions were made:

1. Mean Sea Surface Temperature (SST) rise in the Gulf of Mexico region since the late 1800's is approximately 0.45 °C, based on a linear trend of 0.34 °C/100 yr in annual SSTs in the region over the period 1873–2005.

2. Mean Eustatic Sea Level Rise (ESLR) over the last century is approximately 0.18 m, using the global mean sea level change as the adjustment.

3. Mean local SLR effects, in addition to the global, ESLR signal, in the study area over the last century give a RSLR of approximately 0.57 m. Thus, the regional sea level was 0.75 m lower than present.

4. Tropical cyclones a century ago were relatively less intense, due to the absence of 20th century greenhouse-gas-induced climate warming.

Tropical cyclone intensity as a function of tropical regional SST may be approximated as an 8 %/°C increase and 3.7 %/°C increase, respectively for barometric pressure and wind speed. By applying assumption 1, about one century ago, hurricane central pressure differential was 3.6 % less and wind speeds were 1.7 % weaker. The de-intensified meteorological event is hereafter called 'De-intensified Hurricane Katrina.' Additionally, the size of the storm also changes in the same sense for the hurricane. For the c. 1900 case, for example, the tangentially averaged surface wind speeds of our wind field (with 1.7 % reduction of intensity) have a radius of hurricane force winds that decreases from 0.1 % to 1.2 % depending on the time period examined. As noted in a previous idealized study with the GFDL (Geophysical Fluid Dynamics Laboratory) hurricane model (Knutson and Tuleya,1999), the radius of hurricane force winds in that model's climate warming experiments tends to increase along with the storm intensity. They noted an increase of about 2.5 % in radius of hurricane force winds corresponding to an overall storm intensity increase of 8 %. Using this same scaling implies an 0.5 % decrease in radius of hurricane force winds for a 1.7 % decrease in storm intensity, which generally supports the reduction in size used in the c. 1900 hurricane wind field. Based on the above assumptions, six scenarios were identified to evaluate flooding characteristics: the 2005 event plus five modifications to the 2005 event that consider sea level trends and hurricane de-intensification (Figures 21 and 22):

1. 2005 event: Historical Hurricane Katrina (central pressure=920 mb and maximum wind speed=57 m s–1) with present-day sea level (sea level=0.00 m, MSL2000s).

2. Historical Hurricane Katrina with lower sea level, eustatic only (sea level=−0.18 m, MSL2000s).

3. Historical Hurricane Katrina with lower sea level, eustatic and local (sea level=−0.75 m, MSL2000s).

4. De-intensified Hurricane Katrina (central pressure= 924 mb and maximum wind speed=56 m s−1) with present-day sea level (sea level=0.00 m, MSL2000s).

5. De-intensified Hurricane Katrina with lower sea level, eustatic only (sea level=−0.18 m, MSL2000s).

6. De-intensified Hurricane Katrina with lower sea level, eustatic and local (sea level=−0.75 m, MSL2000s). Hereafter, these scenarios will be referred to using the above numeric identifiers. This is the most representative modification of the c 1900 conditions.

The relevant processes contributing to flood levels and inundation extent during a hurricane are: surge generated by wind and by the inverse barometer effect (surge), setup induced by depth- induced wave breaking (wave setup), astronomical tides, and flooding from river discharge and precipitation. In the Irish 2014 study, the analysis is simplified by considering flooding by surge and wave setup only. An integrated numerical simulation approach was employed, which dynamically couples the hydrodynamic model ADCIRC (Luettich and Westerink 2004) with the full-plane spectral wave model STWAVE-FP (e.g., Smith 2007). For more information on the modeling, see Irish et al (2014).

Looking back in time allows an estimation that demonstrates the historical changes have had a significant impact on coastal flood potential in greater New Orleans. In the simulations, the flood elevations during Hurricane Katrina in 2005 were estimated to be 15% to 60% higher in coastal areas because of SLR (with associated wetlands loss) and hurricane intensification estimated for the past century. Consequently, one can infer that the amount and extent of damage would have been less severe had Hurricane Katrina taken place under c. 1900 climate and sea level conditions. Additionally, the data also demonstrate that in terms of surge generation, the influence of SLR (including wetlands loss) is much more significant than climate-change induced hurricane intensification. The end result is that slight changes in hurricane intensity along with substantial (0.75 m) SLR give rise to large changes in surges in some locations. Several simplifying assumptions were made including no changes in bathymetry or topography with SLR, and a simplified model for evaluating land cover change was adopted.

Looking forward, it is critically important that we understand future coastal flooding vulnerability and risk. The Hurricane Katrina example shown here provides some insight regarding the increases in coastal storm flood risk facing other coastal cities around the globe in the coming century and beyond. ESLR projections for 2100 are in the range of the relative rates realized in New Orleans over the last century, 0.75 m. SLR increases the risk of coastal flooding from storm surges, and that depending on the setting, the increases in flood elevation for a given storm may greatly exceed the SLR for that region. Future flood level increases would presumably lead to wider spread destruction, which in turn may lead to more pronounced global economic and community impacts.

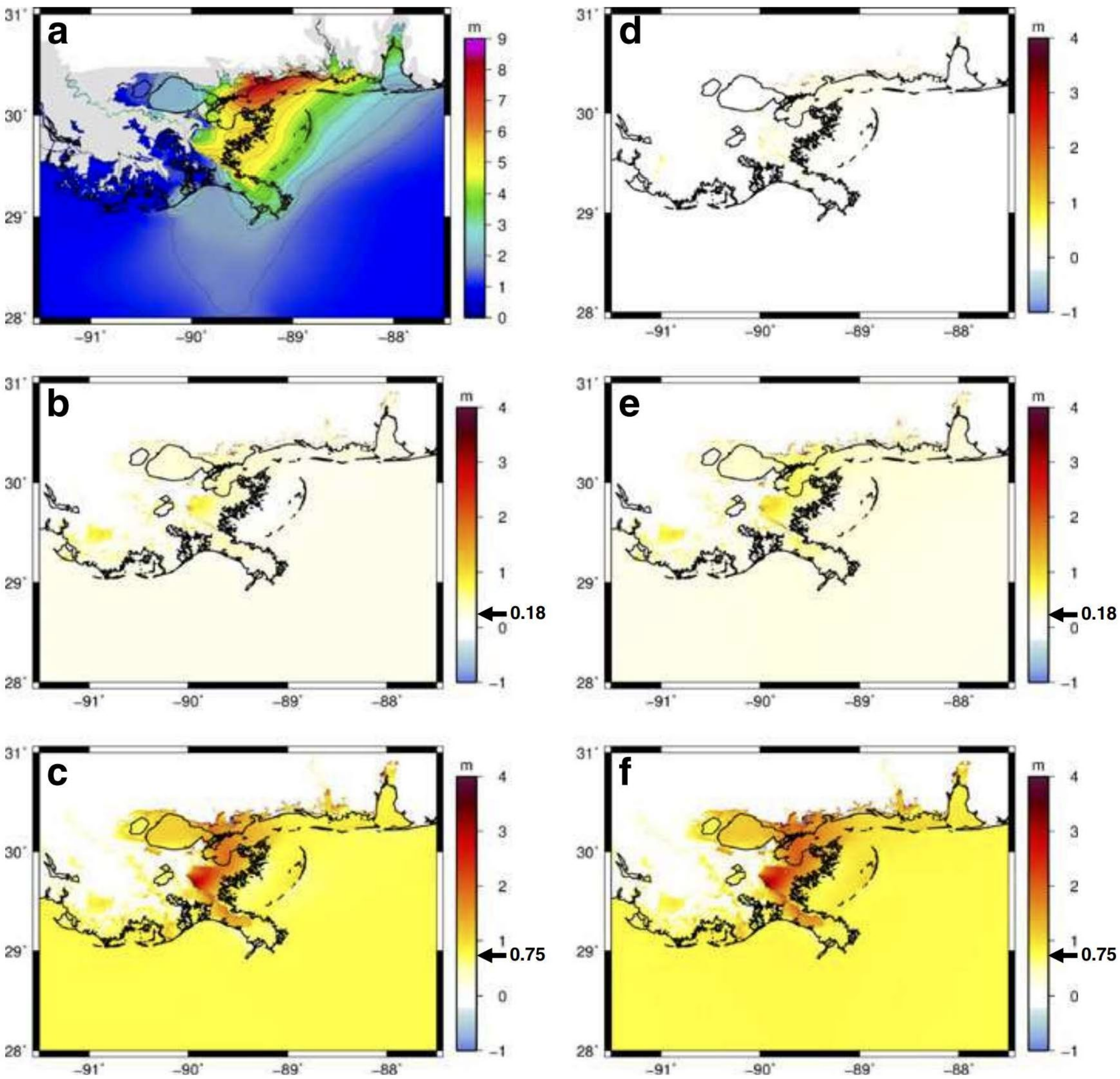

Figure 21 Simulated differences in flood elevations, with respect to flood elevations for the 2005 event, namely Historical Hurricane Katrina and current sea level (MSL2000s) (Scenario 1) (a). Differences are computed as the 2005 event simulation (Scenario 1) minus the alternate simulation; (b) Historical Hurricane Katrina but sea level that is 0.18 m lower than MSL2000s (Scenario 1 minus Scenario 2); (c) Historical Hurricane Katrina but sea level that is 0.75 m lower than MSL2000s (Scenario 1 minus Scenario 3); (d) De-intensified Hurricane Katrina and current sea level (MSL2000s) (Scenario 1 minus Scenario 4); (e) De-intensified Hurricane Katrina andsea level that is 0.18 m lower than MSL2000s (Scenario 1 minus Scenario 5); (f) De-intensified Hurricane Katrina and sea level that is 0.75 m lower than MSL2000s (Scenario

1 minus Scenario 6). Flood elevations are shown in m, relative to MSL2000s. Arrows next to the color bars indicate the alternate sea level value for that simulation.

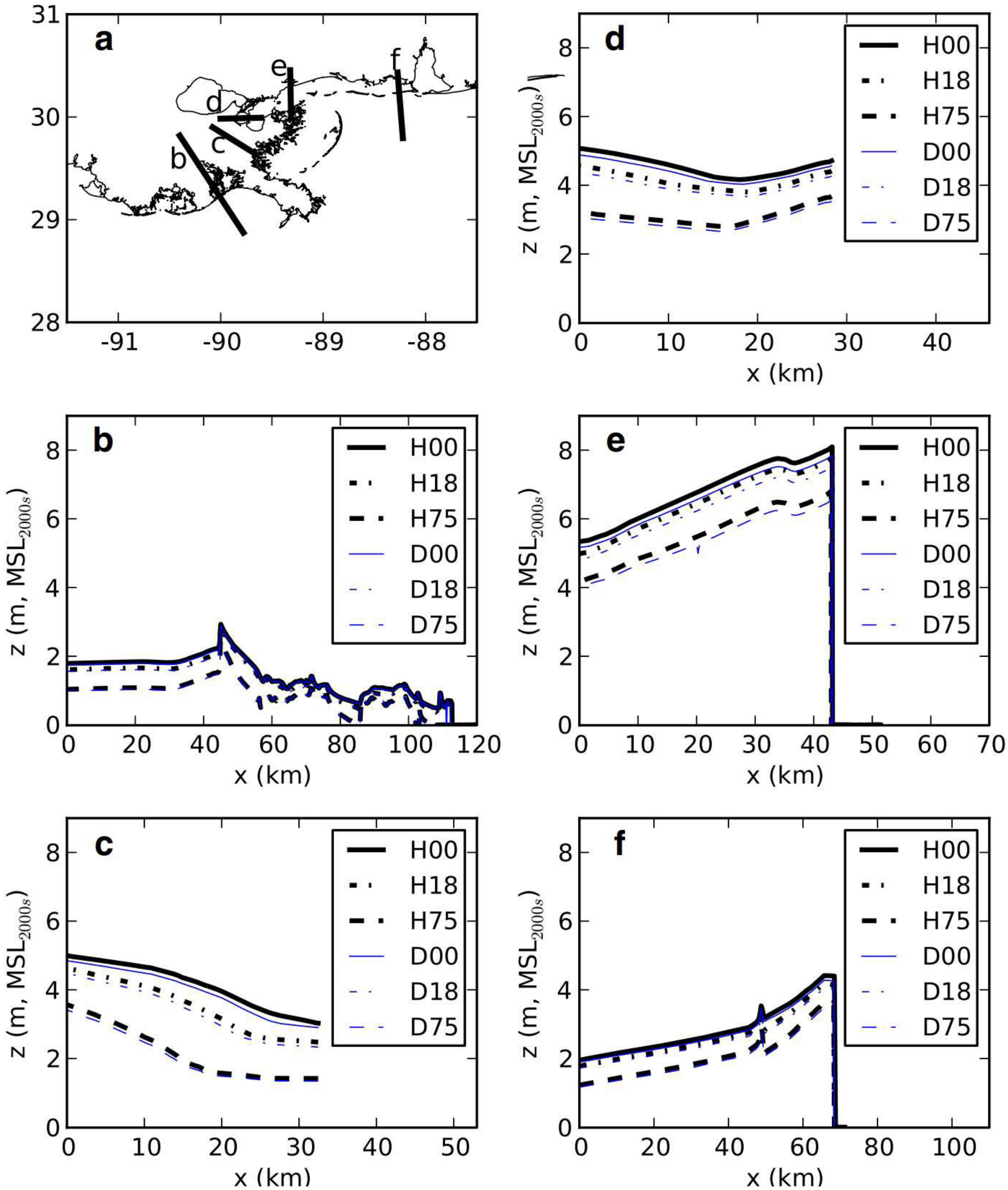

Figure 22. Transects of simulated flood elevations at selected locations shown in (a). Legends are specified as H00 = Historical Hurricane Katrina with current sea level (MSL2000s) (Scenario 1), H18 = Historical Hurricane Katrina but sea level that is 0.18 m lower than MSL2000s (Scenario 2), H75 = Historical Hurricane Katrina but sea level that is 0.75 m lower than MSL2000s (Scenario 3), D00 = De-intensified Hurricane Katrina and current sea level (MSL2000s) (Scenario 4), D18 = De-intensified Hurricane Katrina and sea level that is 0.18 m lower than MSL2000s (Scenario 5), D75 = De-intensified Hurricane Katrina and sea level

that is 0.75 m lower than MSL2000s (Scenario 6). Transects directions are oriented from offshore to onshore.

Overall, the potential gain of four hurricanes over the next century from a 20 percent increase in storm intensities nearly doubles the strike probability of the historical record. Not only will hurricane incidence increase under these assumptions, but individual storms will be stronger such that more catastrophic storms are likely to develop regardless of landfall location. Sea level rise (SLR) and subsidence are significant issues in the design of flood protection for southeast Louisiana. Flood walls, in particular, cannot be easily raised after construction, so future SLR must be considered in their initial design (van Heerden and Bryan 2006, van Heerden etal 2006). Key takeaways are:

1. RSLR is accelerating based on NOAA (2022) data. Estimates for coastal Louisiana areup to 2.0 feet by 2050 and 4.0 feet by 2100.

2. Sea level rise leads to a diminishing wetlands apron as well as reductions in bottom friction (Manning's n). Thus, RSLR means the surge waters can more easily move landwards towards the levee and the LNG facility.

3. A simplistic linear model suggests for a 1.0 foot increase in RSL, the surge is in Barateria Bay at the site could be between 3.28 feet, and 5.16 feet higher.

4. A study by McKee Smith etal in 2010 shows that at the LNG site a rather week storm (Figure 20) and a 0.5 m RSLR would raise the surge by about 3.5 m (11.5 feet) and a RSLR of 1.0 m would raise the surge by about 7.0 m (23.0 feet).

5. Another study by Irish et al (2014), doing a comparison of Hurricane Katrina, which made landfall October 2005, should it have made landfall in 1900 with adjusted sea level and wetlands apron and wind speed would have surges from 3.0 m (9.8 feet) to 5.0 m (16.4 feet) lower for areas close to the site (Figures 22 b and c).

In the past, relative sea level rise (RSLR) was included in coastal protection design by raising design water levels an amount equivalent to the RSLR. But surge generation and propagation are nonlinear processes and linear addition of RSLR to design water levels underestimates the impact in many areas.

The expected sea level rise of 2 feet by 2050 and 4 feet by 2100 will greatly raise the surge elevations at the LNG site as pointed out by van Heerden (2022). The Joint Public Notice (USACOE, 2018) for this site shows a ring levee of sheet piles around the facility with a top elevation of 26 feet NAVD 88, but it would at least be overtopped by wave wash with surges as low as 15 feet NAVD88 (van Heerden, 2022). Based on this analysis, there is a high probability that Venture Capitals proposed LNG Facility would be flooded during a major storm, even assuming the ring dike held. With a RSLR of 2.0 feet by 2050 the surge could well be between 11.5 feet and 23 feet higher, and this a relatively weak storm. A Cat 5 Slosh model shows surge elevations up to 20 feet at the site, which would be totally inundated even without any wave overtopping.

Thus, the proposed design does not ensure protection from flooding over the project life.

Flooding would pose environmental risks and operational safety problems, and once the surge starts to retreat there is a real risk that contaminants would be carried seawards into Louisiana's precious coastal wetlands and the Mississippi River in addition to local communities.

The central Gulf Coast is also one of warmest, wettest regions in the United States, where annual rainfall averages over 150 cm (60 inches) per year (Christopherson, 2000). Since there is very little topographic relief, changes in precipitation and runoff could have a dramatic impact on fragile Gulf Coast ecosystems and coastal communities by changing the hydroclimatology of the region.

b. Flooding of the LNG facility during a storm surge could cause catastrophic damage to the coastal zone

It is my opinion after years of studying hurricanes and flooding that this LNG site will be flooded, in the not-too-distant future and perhaps even this year's hurricane season, by the surge associated with a major hurricane. There would, therefore, be a high probability of runoff of landfill (during construction) and chemicals (during operation) being carried off the site and into homes, businesses, farmland, and fragile coastal wetlands. Moreover, the risk of an LNG leak during a major hurricane is significant, and the potential impacts from such an event could be catastrophic. Therefore, it is my opinion that the Plaquemines LNG facility will cause direct and significant impacts to coastal waters.

The density of LNG falls between 430 kg/m3 and 470 kg/m3 (3.5 to 4 lb./US gal). LNG is less than half the density of water; therefore, as a liquid, LNG will float if spilled on water. I could not find any data on the design of the plant especially the four large storage tanks. Will these be kept in place with exterior mooring pilings (that will allow them to float)?, Will they be on a large concrete footing that is anchored into the ground with very deep concrete or metal footings? There has to be a recognition that if this site floods with 15 to 30 feet of water, the storage tanks will be very buoyant and will want to float if they are not properly anchored.

An example of such an event was the Murphy Oil USA refinery oil spill that resulted from the failure of a storage tank at the refinery into the residential areas of Chalmette[21] and Meraux[22] as a consequence of Hurricane Katrina's surge in August 2005. The refinery was flooded with six to 18 feet of water and a 250,000-barrel above-ground storage tank floated off its moorings and was punctured. Approximately 25,110 barrels (1,055,000 US gal) of oil was released and the contaminated water impacted approximately 1,700 homes in adjacent residential neighborhoods of Chalmette, over an area of about one square mile. Additionally, several canals were also impacted.[23] The tanks floated as they were had a combined fluid/tank density less than water, were therefore buoyant; the tanks floated off their moorings, attached piping broke, and moorings pierced the tank. More than 640 acres were contaminated as the oil covered surge

[21] Chalmette Louisiana. https://en.wikipedia.org/wiki/Chalmette,_Louisiana. Last viewed fb 3 2021
[22] Mereaux, Louisiana. https://en.wikipedia.org/wiki/Meraux,_Louisiana. Last viewed Feb 4, 2021.
[23] WIKIPEDIA, *Murphy Oil USA refinery spill*, https://en.wikipedia.org/wiki/Murphy_Oil_USA_refinery_spill (last visited Feb 4, 2021).

water spread out over the built environment.

i. Proposed LNG Facility Design

Liquified natural gas (LNG) is the liquid form of natural gas at cryogenic temperature of −265°F (−160°C). When natural gas is turned into LNG, its volume shrinks by a factor of approximately 600. This reduction in volume enables the gas to be transported more easily over long distances.

An example LNG plant overall flow diagram and the main process units are shown in Figure 23. Typically, the feed gas is delivered at high pressure (for example, up to 1,300 psi) from upstream gas fields via trunklines and any associated condensate is removed. The gas is metered and pressure-controlled. The gas is first pretreated to remove any impurities that interfere with processing or are undesirable in the final products (Figure 24). Heavier hydrocarbons are also removed from the dry sweet natural gas using high level refrigerant to provide the cooling needed to condense the liquids, and the residual gas is then liquefied using high-level and low-level refrigerant. The remaining gas is made up mainly of methane and contains less than 0.1 mol% of pentane and heavier hydrocarbons. It is further cooled in the cryogenic section to approximately –160°C and is completely liquefied. Mildly pressurized LNG is further subcooled in one or more stages to facilitate storage at pressures slightly above atmospheric. Flashed vapors and boil off gas are recycled within the process (Qualls et al., 2005).

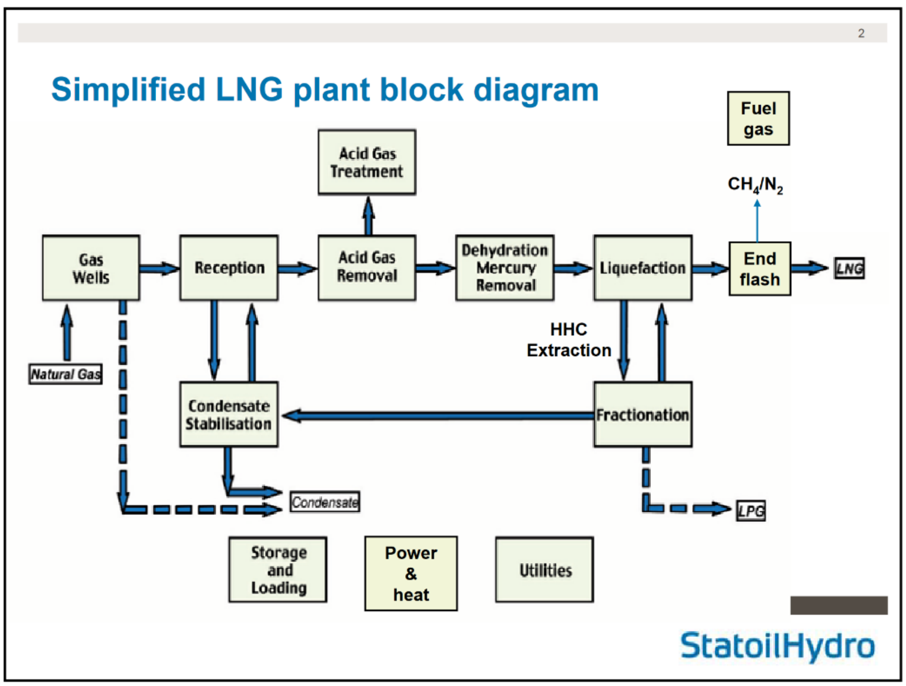

Figure 23. Simplified LNG plant block diagram.

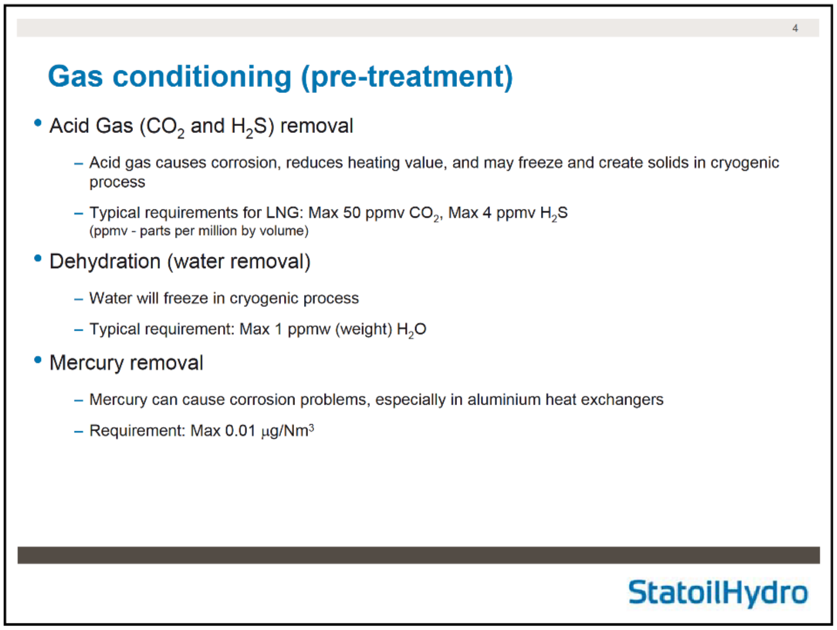

Figure 24. Aspects of Gas conditioning. Notice mercury is a byproduct.

The liquefaction process is the key element of the LNG plant. Liquefaction is based on a refrigeration cycle, where a refrigerant by means of successive expansion and compression, transports heat from the process side to where the natural gas is stored. LNG plants often consist of a number of parallel units, called trains, which treat and liquefy natural gas and then send the LNG to several storage tanks. The capacity of a liquefaction train is primarily determined by the liquefaction process, the refrigerant used, the largest available size of the compressor/driver combination that drives the cycle, and the heat exchangers that cool the natural gas (Smaal, 2003).

Venture Capital is proposing to install and maintain a liquefied natural gas (LNG) export terminal which will include: six pretreatment facilities (three in each phase); a liquefaction plant with 18 integrated single-mixed refrigerant blocks and support facilities (otherwise referred to as liquefaction blocks or blocks) to be constructed in two phases (nine blocks in each phase); four 200,000-cubic-meter (m^3) aboveground LNG storage tanks; three LNG loading docks within a common LNG berthing area; air-cooled electric power generation facilities; as well as a floodwall, jetty substation, and water intake platform. The pipeline system will consist of two parallel 42-inch-diameter natural gas lateral pipelines and associated above ground facilities which includes: two platform-based meter stations, six mainline valves, a pipe bridge, and 50-foot long permanent road. At times as many as three marine vessels for transporting LNG could be docked at the facility, each holding about 125,000 to 150,000 m^3 of LNG (Figures 25 and 26). In total, there may be in excess of 1,200,000 m^3 of LNG at the site. This is a very large volume of LNG potentially available for release during a hurricane passage.

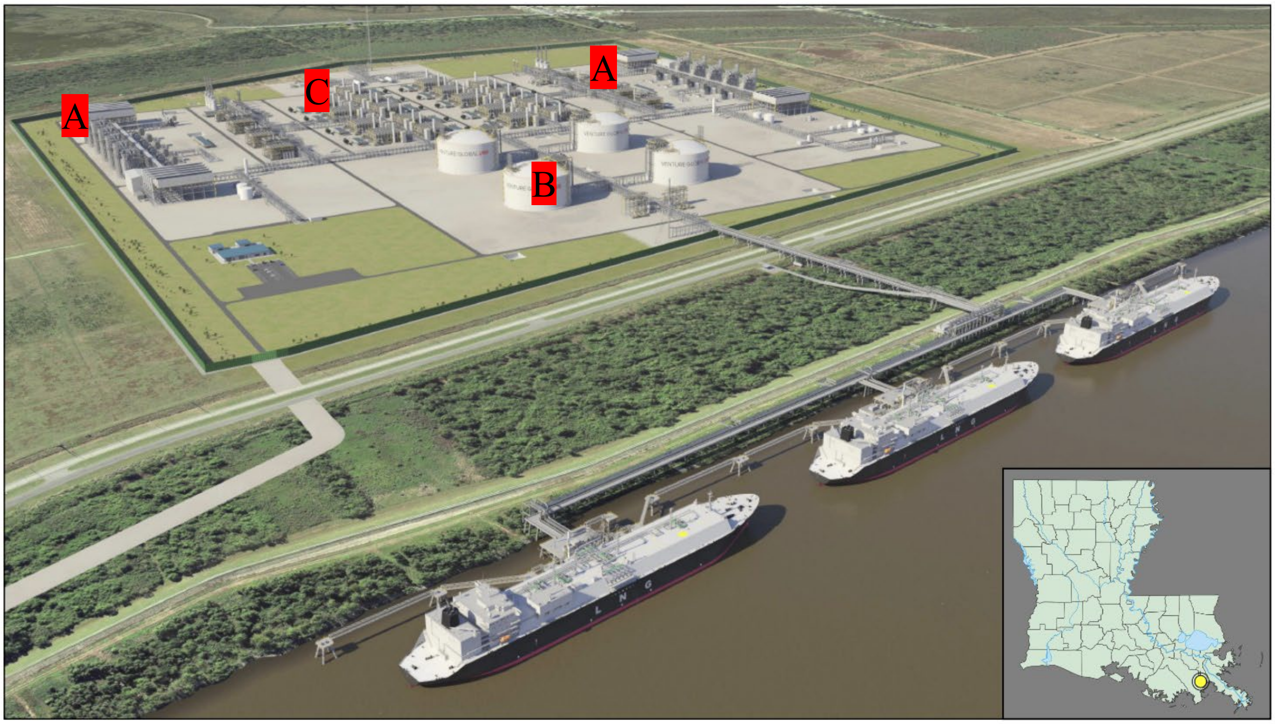

Figure 25. Conceptual rendition of the Venture Capital LNG facility with three vessels docked. A = Pretreatment blocks, B = 4 very large storage tanks, C = liquefaction blocks

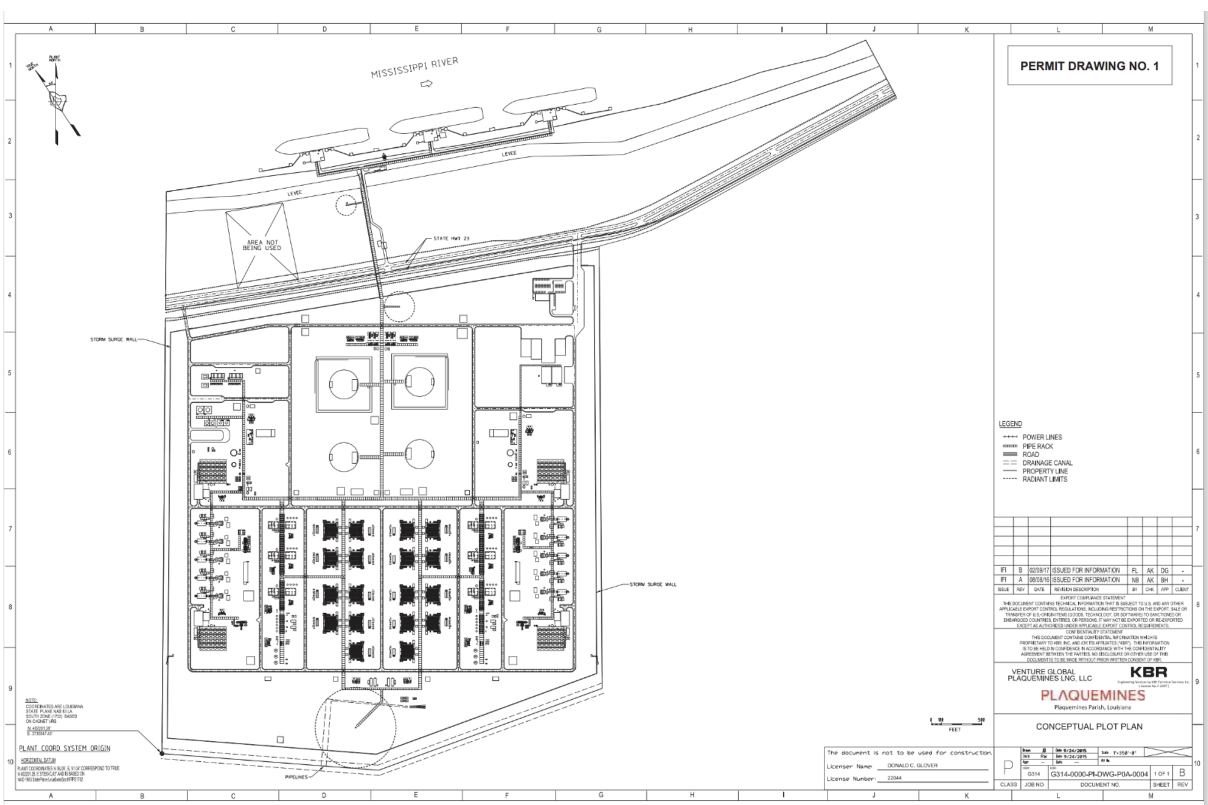

Figure 26. Conceptual Plot Plan.

ii. **Risk of Contamination from Runoff of Landfill (During Construction) and Chemicals (During Operation)**

As noted, in my opinion, there is a high probability that the surge from a major hurricane will result in runoff of landfill (during construction) and chemicals (during operation) being carried off the site and into homes, businesses, farmland, and fragile coastal wetlands. For example, cranes, pump trucks, flatbed trucks, dump trucks, excavators, front end loaders—all of which will be purchased as permanent equipment[24]—could each leak oil, grease, heavy metals, and other toxic chemicals[25] if they are submerged in even a few feet of water. Similarly, the two on-site combined-cycle gas plants will contain motors, generators, flares, and other industrial equipment, and there will be a substation and transformer yard nearby. [26] Any of these components would cause extensive contamination with oil, grease, heavy metals, and other chemicals if submerged.[27] The warehouse and maintenance shop and oily water treatment unit will also likely contain contaminants that, if submerged, could enter floodwaters and rapidly pollute the surrounding environment.

While Venture Global has proposed a Spill Prevention, Control, and Countermeasure Plan (SPCC) and Stormwater Pollution Prevention Plan (SWPPP), there is no indication that the measures outlined in those plans would provide any use in eliminating risk of contamination resulting from flooding during a major hurricane or other flooding event. For instance, the SPCC—which only applies to construction, not ongoing operations—indicates that "spill kits" will include things like absorbent pads, containment barriers, and skimmer pumps. Any of these items would be worthless to prevent spills from spreading if the entire site is submerged. Similarly, the stormwater collection and treatment system will be entirely overrun if the site is submerged. During such an event, stormwater and receding flood waters will spill into many adjacent waterbodies without passing through any stormwater collection system.

iii. **Factors Influencing an LNG Spill from a Ship at a Dock**

Figure 27 provides an artist's rendering of the various factors or events that can occur during an LNG spill over water from a vessel, including one docked that might be docked at the proposed LNG site. A spill would occur if an LNG cargo tank is breached, either from an accidental event such as a collision or grounding or possibly from a malevolent or intentional event. Quantifying the likelihood and results of such events are very important because they influence the size and location of a possible breach, the potential volume of a spill, and the associated hazards. Many site-specific, and system-specific variables must be considered including; the LNG vessel size and design type, cargo tank geometry and construction materials, potential ignition sources, site-specific environmental factors such as waves, wind, and terrain, safety and security measures and operations, and emergency response plans and initiatives (Highwater, 2004, 2006).

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[24] *FEIS at 4-129*

[25] https://www.epa.gov/sites/default/files/2015-10/documents/sector_p_transportationfacilities.pdf; https://www.epa.gov/sites/default/files/2015-10/documents/sector_o_steamelectricpower.pdf

[26] *JPA Narrative at 11*

[27] https://www.epa.gov/sites/default/files/2015-10/documents/sector_p_transportationfacilities.pdf; https://www.epa.gov/sites/default/files/2015-10/documents/sector_o_steamelectricpower.pdf

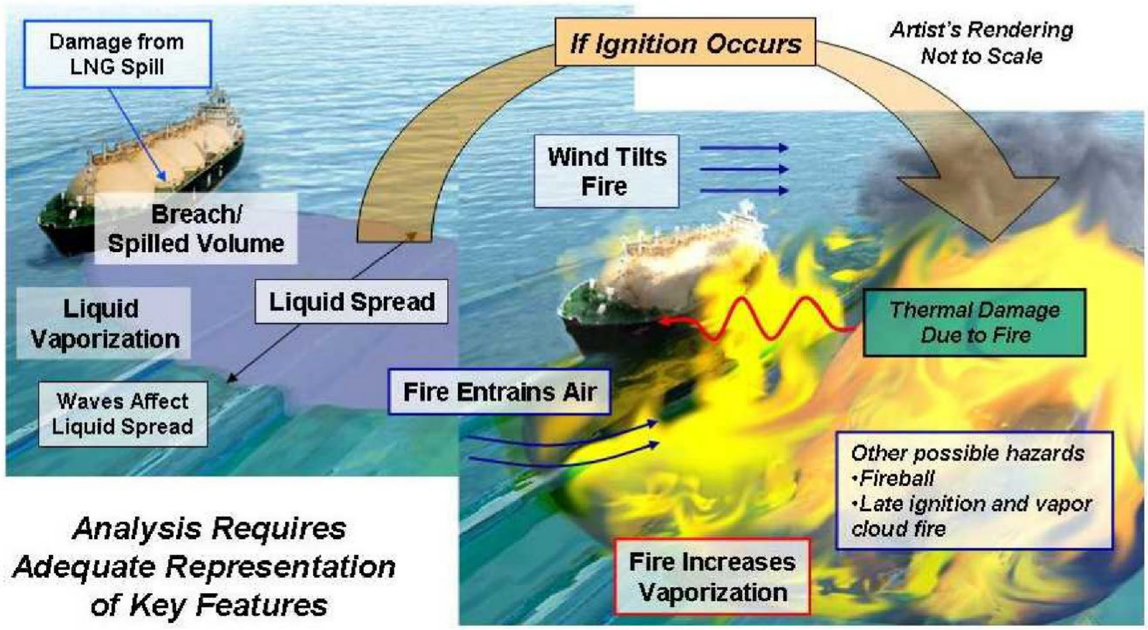

Figure 27. Key factors that Influence an LNG vessel spill over water (Highwater, 2006)

Depending on the size and location of an LNG cargo tank breach, LNG could spill onto or into the LNG ship, flow from the breach onto the water surface, or both. Depending on whether there is early or late ignition, LNG dispersion will occur through volatilization of the LNG from contact with water and be transported as a vapor cloud in the air or as a liquid on the water surface. The timing of a potential ignition will determine whether the LNG will disperse without a fire, burn as a pool fire, or burn as a vapor fire.

These factors can each significantly influence the estimates of the hazard distances and hazard levels for an LNG spill and each should be carefully assessed for each site. For example, an evaluation of several recent LNG spill studies showed significant differences in thermal hazard estimates due to differences in assumptions and modeling approaches used in each analysis (Lehr and Simecek-Beatty 2003; Fay 2003; Quest 2003; Vallejo 2003; Pitblado 2004).

Unfortunately, there is no data concerning large LNG spills over highly turbulent water in hurricane-force winds.

iv. Potential Hazards from Large LNG Spills Over Water

To provide the general scale of the potential hazards of a large LNG spill over water, existing experimental data were evaluated and analysis and modeling were used by Highwater (2006) to assess several potential spill hazards including; asphyxiation, cryogenic burns and cryogenic damage to the ship from the very cold LNG, dispersion, fires, and explosions. Highwater (2006) used available accidental and intentional threat information to identify possible breaching scenarios.

Based on this review, the most likely hazards to people and property from an LNG spill are thermal hazards from an LNG fire. Cryogenic and fire damage to an LNG ship were also identified as concerns that could cause additional damage to LNG cargo tanks following an initial cargo tank breach.

To help the public get a feel of the expected scale and range of the hazards from a large LNG spill over water, the hazard distances for several possible accidental and intentional breach scenarios of a standard LNG vessel, holding between 125,000 and 140,000 m^3 of LNG, for generally stable atmospheric conditions—not hurricane-force winds or other extreme weather—were evaluated by Sandia and are presented in the guidance report.

The results consider spill volumes of one-half the contents of a standard LNG cargo tank, approximately 12,500 m^3, for each LNG cargo tank breached. The range of the results for thermal fire hazards, based on different assumptions and various spill parameters, are presented in Table 1. Most intentional events are expected to provide an ignition source such that a pool fire occurs and a large unignited release of LNG is therefore unlikely. Table 2 though, provides information on possible hazard distances for a spill with a significant delay in ignition of the LNG. The 37.5 kW/m^2 and 5 kW/m^2 values shown in Table 1 are thermal flux values commonly recognized for defining hazard distances for LNG (NFPA 2001). The 37.5 kW/m^2 is a level suggesting severe structural damage and major injuries if experienced for over 10 minutes.

Table 1: Potential Thermal Hazard Distances for Possible Breaching Events of a Standard LNG Vessel

HOLE SIZE (m^2)	TANKS BREACHED	DISCHARGE COEFFICIENT	BURN RATE (m/s)	SURFACE EMISSIVE POWER (kW/m^2)	POOL DIAMETER (m)	BURN TIME (min)	DISTANCE TO 37.5 kW/m^2 (m)	DISTANCE TO 5 kW/m^2 (m
ACCIDENTAL EVENTS								
1	1	.6	$3X10^{-4}$	220	148	40	177	554
2	1	.6	$3X10^{-4}$	220	209	20	250	784
INTENTIONAL EVENTS								
5	3	.6	3×10^{-4}	220	572	8.1	630	2118
5*	1	.6	3×10^{-4}	220	330	8.1	391	1305
5	1	.9	3×10^{-4}	220	405	5.4	478	1579
5	1	.6	8×10^{-4}	220	202	8.1	253	810
12	1	.6	3×10^{-4}	220	512	3.4	602	1920

* nominal case considered

Table 2: Potential Lower Flammability Limit (LFL) Distances for Possible Vapor Dispersions

HOLE SIZE (m^2)	TANKS BREACHED	POOL DIAMETER (m)	SPILL DURATION (min)	DISTANCE TO LFL (m)
Accidental Events				
1	1	181	40	1536
2	1	256	20	1710
Intentional Events				
5	1	405	8.1	2450
5	3	701	8.1	3614

The 5 kW/m^2 level represents second-degree skin burns on exposed skin if expected for periods of over 20 seconds, and this value is the suggested protection standard for people in open spaces. The distances shown in Table 2 are to the lower flammability limit (LFL), which is the lowest level at which LNG will burn. The LFL value is commonly used as the maximum hazard distance for a vapor dispersion fire.

The results suggest that thermal hazards will occur predominantly within 1600 m (just under one mile) of an LNG spill for this common size LNG vessel, with the highest hazards generally in the near field (approximately 250-500 m of a spill). These results provide information on the general scale of the hazard distances for a large spill from current LNG vessels. Actual distances will vary based on site-specific environmental conditions, fire dynamics, terrain, ship sizes, and safety and emergency response measures in place. It is very important to note that these data are only for generally stable atmosphere conditions and do not apply to an LNG spill during a hurricane with flooding surges and winds of 100 mph. In the latter case, the area of contamination would be much, much greater.

LNG spilled onto water sometimes undergoes a rapid phase transition (RPT) or physical explosion creating localized overpressure. Such physical explosions are also observed when water contacts molten metal or hot lava (steam explosions).

v. Underwater Releases

Little is known about behavior of LNG following its release underwater, and current models are not sufficient to quantify the potential hazards from such a spill (Ikeaalumba and Wu, 2014). However, at least one study indicates there could be significant harm to the environment resulting from an underwater release.

Using a concrete pit filled with water, Qi et al. (2011) carried out tests at the Brayton Fire Training Field to understand the phenomena that occur from an underwater LNG release, including the behavior of the emanating vapor. LNG was released from a 2.5 cm (9.84 in.) nozzle at a depth of 0.71 m (2.33 ft) below the water surface. There was no notable LNG pool formation on the water surface, most likely because of the high rates of evaporation and gas release. It is also possible that all of the LNG was not vaporized underwater but, instead, was thrown up with the rest of the vaporized liquid. The vapor cloud that emanated from the water surface was at a temperature below the dew point of air, and as a result, the vapor cloud was visible. The lowest temperature recorded for the vapor cloud was −1 °C, which would freeze and kill all wetland plants that come into contact. Depending on the depth of freezing water a lot of aquatic species could also be wiped out.

vi. Human Impacts

The recent studies regarding human safety focus on thermal hazards from LNG fires rather than the cryogenic effects of a LNG pool/vapor cloud or the asphyxiation from a LNG vapor cloud. Current regulations, such as the U.S. DOT Regulations, 49 CFR, part 193, and the NFPA 59A standard, Bartzis (1991) require that a safety distance is set at a radiant heat flux of 5 kW/m^2. Unfortunately, there has been no significant research to determine whether this criterion is correct.

On the basis of this regulation, Raj (2008) conducted some studies on the effectiveness of ordinary civilian clothing to withstand a 30-second exposure of 5 kW/m^2. It was found that ordinary civilian clothing provides a reduction of radiant heat flux by a factor of 2 and any object that intervenes (even a newspaper held in front of the person) can lead to a reduction by a factor of 4. A person with ordinary civilian clothing can withstand a heat flux of 5 kW/m^2 for 25-30 seconds and 4 kW/m^2 for 60-120 seconds without severe pain or suffering injuries. However, repeated exposure without cooling will reduce this tolerance. Raj (2008) concluded that the public should be safe with the current “hazard” definition, which opposes the idea posed by Havens and Spicer (2007) that a heat flux of 5 kW/m^2 will lead to second-degree burns within 30 seconds. It is important to note that the weather, number of clothing layers, age, sex, and health of people can all play a role in determining the radiant heat flux that can be withstood.

People can easily run from an LNG pool fire, but in the case of a jet fire, flash, or vapor cloud explosion (VCE), the possibility of humans protecting themselves decreases dramatically.

vii. Lack of recent studies on LNG spill impacts

The existing reviews related to LNG production and the events following a LNG spill were all done *prior to 2006* (Ikealumba and Wu, 2014). In the literature, most of the experiments concerning LNG spreading on water were conducted prior to 2007. Those experiments were on small scales, and application of such experiments results to large-scale applications are known to have the main technical uncertainties in terms of the dynamics of the front of the spreading pool and the heat-transfer rate (Luketa- Hamlin etal, 2007). While efforts were made to deploy models for simulating bubble formation at large scales based on small-scale experimental data, the effect of waves and ice formation can introduce some more uncertainties in such predictions (Cleaver etal, 2007).

There is therefore a very large data gap and significant unknowns about the impacts of large releases of LNG. Thus, large-scale experiments are certainly still in need (Ikealumba and Wu, 2014).

Based on public safety issues and risk mitigation and prevention considerations, Highwater (2006) developed guidance to assist risk management professionals, emergency management and public safety officials, port security officials and other appropriate stakeholders in developing and implementing appropriate safety and risk management strategies and processes for marine LNG operations. In summary, the guidance recommends for accidental and intentional spills:

- Use effective security and protection operations that include enhanced interdiction, detection, delay procedures, risk management procedures, and coordinated emergency response measures, to reduce the risks from a possible breaching event;
- Implement risk management strategies based on site-specific conditions and the expected impact of a spill on public safety and property. Less intensive strategies could often be sufficient in areas where the impacts of a spill are low.
- Where analysis reveals that potential impacts on public safety and property could be high, such as a hurricane impacted the area, and where a spill could interact with terrain or structures, modern, validated Computational Fluid Dynamics models can be used to improve analysis of site-specific hazards.

Despite the lack of more comprehensive studies, it is my opinion that the impacts to surrounding communities and wetland and aquatic habitats could well be catastrophic, including gassing and asphyxiation, and/or release and freezing, and/or fires and explosions.

c. Risks of Instability in the Levee Structure

A site visit was made the morning of 28th December 2021. The levee front of the property was walked to try to discern is there was any piping or similar leakage. None was found, reflecting mostly that the river water not high enough. It was noted that the Batture is well vegetated, and that the concrete outer embankment of the levee was cracked with noticeable grass and other growth in the cracks (Figures 35a and b).

Figure 35a. Crest of river levee fronting LNG site and 27b. river side shown crack concrete capping.

If this levee fails, we will not see a whole lot of damage at the site as it stands in December 2021. However, a huge channel, basically a crevasse, will form that will initially wash away Highway 23 at the breach (crevasse) site and then extend towards Barateria Bay. This crevasse may open to such an extent that it may not be able to seal it without the expenditure of many millions of dollars.

IV. Conclusions

The report gives an indication of how dynamic the Louisiana Coastal Zone is, whether it be hurricanes, sea level rise, river floods, storms on steroids, subsidence and the resultant loss of the apron of wetlands that have protected Louisiana for so many years. Climate change is here and happening fast, meaning any weather-related events are going to become more severe in the future with greater impacts. This reality must be front and center to any permitting of any feature to be constructed or placed in the coastal wetlands.

Given that the site flooded during Hurricane Ida and data indicates the proposed I-wall would not have protected the Plaquemines LNG site even if it held, the reviewing agencies have underestimated the flooding risk at the proposed LNG site. Moreover, there is evidence that climate-driven extreme weather, hurricanes, and rainfall will all continue to exacerbate the flooding risk over the life of the proposed LNG facility. Failure of any levee, and especially the I-wall ring dike, will result in catastrophic release of chemical contaminants towards Barataria Bay impacting wetlands as well as the waters of the Bay. The impact to wetland fauna and flora would be immense. For these reasons, it is my opinion that the Plaquemines LNG facility will cause direct and significant impacts to coastal waters.