StEER STRUCTURAL EXTREME EVENTS RECONNAISSANCE	**EVENT BRIEFING**		
	Event:	Hurricane Zeta	
	Region:	Gulf Coast (Mississippi, Louisiana); Yucatan Peninsula	
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Key Lessons

- ❏ Hurricane Zeta produced less than design-level winds and storm surge and yet the aftermath was still a costly one for the United States, including six confirmed fatalities, over 30,000 damaged houses, up to $5B in onshore insured losses, and at its peak over 2.6 million residents left without power.
- ❏ Residential buildings not designed to current building codes remain a significant vulnerability even in lower intensity hurricanes; their damages/failures will continue to drive the economic losses and societal hardships in future wind events.
- ❏ Power infrastructure failures in inland regions affected millions of consumers despite only moderate wind speeds.
- ❏ Storm impacts to sandy beaches and dune systems were noteworthy and warrant continued investigation by coastal hazards researchers.
- ❏ The fact that Louisiana experienced five storms in a single season is a record, but it is not unprecedented for a state to experience multiple storms in a season. Thus this event re-emphasizes the need to understand the cumulative effects of multiple low-intensity storm events on the built and natural environments, engineered systems and services, societal functions and institutions, and perhaps more importantly, on the citizenry grappling with these recurring evacuation, recovery and repair cycles all within an active pandemic.

1.0 Event Description

Hurricane Zeta began as a tropical disturbance 300 miles southeast of the Yucatan Peninsula, where it made its first landfall on the island of Cozumel as a Category 1 hurricane, before moving onto the peninsula near Tulum on the evening of 26 October 2020. Weaking overland, as the storm

moved back into the Gulf of Mexico, it restrengthened, reaching a peak intensity with a sustained wind speed of 110 mph as it made landfall as a Category 2 hurricane on the Louisiana coast near Cocodrie, a fishing village in Terrebonne Parish, at 4:00 PM CDT on 28 October 2020. It was a fast-moving storm, with a 24 mph translating speed, and it continued to accelerate after landfall, tracking across Mississippi, Alabama, Georgia, North Carolina and Virginia, where it became post-tropical as it merged with a cold front.

Zeta's impacts were widespread, including the Yucatan Peninsula and six US states, resulting in six US fatalities (four occurring due to trees falling on homes, one due to electrocution and one fatality by drowning) and dozens of injuries. Zeta's structural damage, concentrated primarily in Louisiana and Mississippi, was not as severe as that from August 2020's Hurricane Laura, as Zeta's maximum wind speed remained well below design wind speeds for the region and its floodwaters well below the 100-year base flood elevations. Still estimated onshore insured losses could total as high as $5B (Insurance Journal, 2020). Moreover, it must be emphasized that these storms do not act in isolation. In the state of Louisiana, this relatively low-magnitude event only compounds the impacts of previous 2020 hurricanes on the built and natural environment, as well as on the psyche of the citizenry. Notably these cumulative effects are also stressing the resources of associated government agencies, businesses, and aid/recovery organizations in unprecedented ways, as they simultaneously grapple with the constraints and challenges of the COVID-19 pandemic. In fact, Louisiana Gov. John Bel Edwards noted that three sets of hurricane evacuees were sheltering in Louisiana simultaneously, including 3,051 people whose homes were damaged or destroyed by Laura, 172 from Hurricane Delta, and 27 from Zeta (AP, 2020). One particularly essential service, voting access, was also impacted by storm damage in Louisiana, with utility companies prioritizing power restoration and generators to restore power to polling places in Louisiana, Alabama, Georgia and Mississippi by Election Day on 4 November (Deslatte and Chandler, 2020).

Contextualizing Hurricane Zeta with the Historic 2020 Atlantic Hurricane Season

Hurricane Zeta was the:

- 27th named storm of the season
- 11th named landfalling US storm (new record) - previous: 9 storms in 1916
- 5th landfalling storm in Louisiana (see Fig. 1.1)
- latest occurrence of Category 2 hurricane in Gulf of Mexico
- strongest late-forming US landfalling hurricane of 2020 (since 1899)

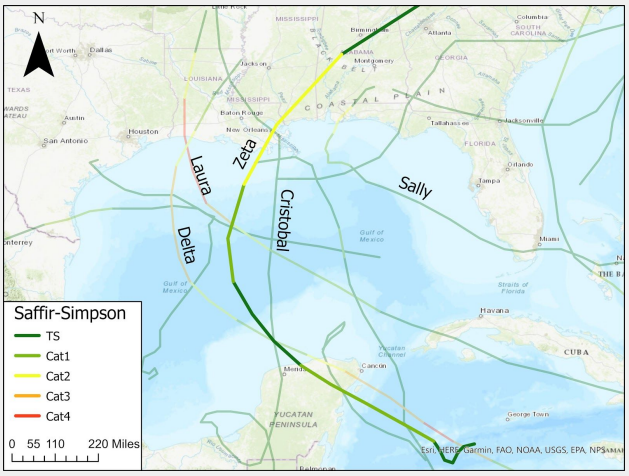


Figure 1.1. Hurricane Zeta preliminary track with best tracks from all 2020 tropical storms (Source: NHC data, map created by D. Roueche).

Also striking was the equally heavy storm activity in the Atlantic Ocean (Fig. 1.2). North Atlantic tropical cyclones threatened communities throughout the Atlantic Basin, from Trinidad and Tobago in the South Caribbean, through several Central American countries, Mexico, the United States and as far north as the Canadian province of Nova Scotia.

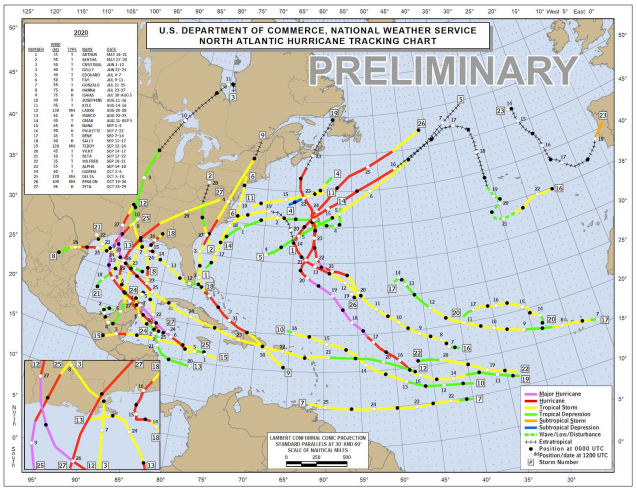


Figure 1.2. Compilation of tracks in the 2020 Atlantic Hurricane season (Source: NHC).

2.0 Hazard Description

2.1 Yucatan Peninsula

Hurricane Zeta first made landfall on the island of Cozumel as a Category 1 hurricane, before moving onto the mainland of the Yucatan peninsula near Tulum on the evening of 26 October 2020, producing more than 10 hours of storm conditions. There were reports of downed power lines, fallen trees and building damage over a large swath of the coast. Prior to its landfall, some municipalities prepared by enforcing evacuations of their residents and removing large road signs. More than 34,000 tourists were also in the area when Zeta hit (Riviera-Maya-News, 2020).

2.2. US Impacts

Hurricane Zeta produced elevated wind and water hazards in both coastal areas and further inland. At landfall, gust wind speeds near the coast peaked around 100 mph (open exposure, 10 m height) based on reported measurements (Fig. 2.1), although higher gusts may have occurred in Waveland, MS, which did not have any reliable weather stations reporting. Wind gust speeds up to 60 mph extended well inland into Alabama, Georgia, and North Carolina as Zeta merged with an approaching cold front and became a post-tropical storm.

Overall, winds remained well below design levels, limiting the structural damage potential. For example, the highest reported gust of 101 mph in Gulfport, MS would be expected to produce wind loads nominally 40% of design levels (based on a design wind speed of 160 mph for typical modern buildings). Storm surge peaked at just over 8 ft (Mean Higher High Water datum) in Waveland, MS, and approximately 5 ft above mean high-water datum in Mobile Bay, AL, approximately 75 miles from the storm's center track (Fig. 2.2). For comparison, the 100-year base flood elevation in affected counties ranges from 18-26 ft MHHW (20-28 ft NAVD88).

However, the storm was still expected to deliver notable impacts to the beaches in Louisiana, Mississippi and Alabama, with significant potentials for dune erosion (Table 2.1) (USGS, 2020).

Table 2.1. Projected impacts of Hurricane Zeta to sandy beaches and dunes (USGS, 2020)

	Sandy Beach Inundation	Sandy Beach Overwash	Dune Erosion
Louisiana	23%	60%	68%
Mississippi	16%	46%	89%
Alabama	Not reported	11%	57%

Figure 2.1. Summary of wind observations (3-second gust) from Hurricane Zeta at 10 m above ground in open exposure (see Appendix A for details of measurements and processing procedures).

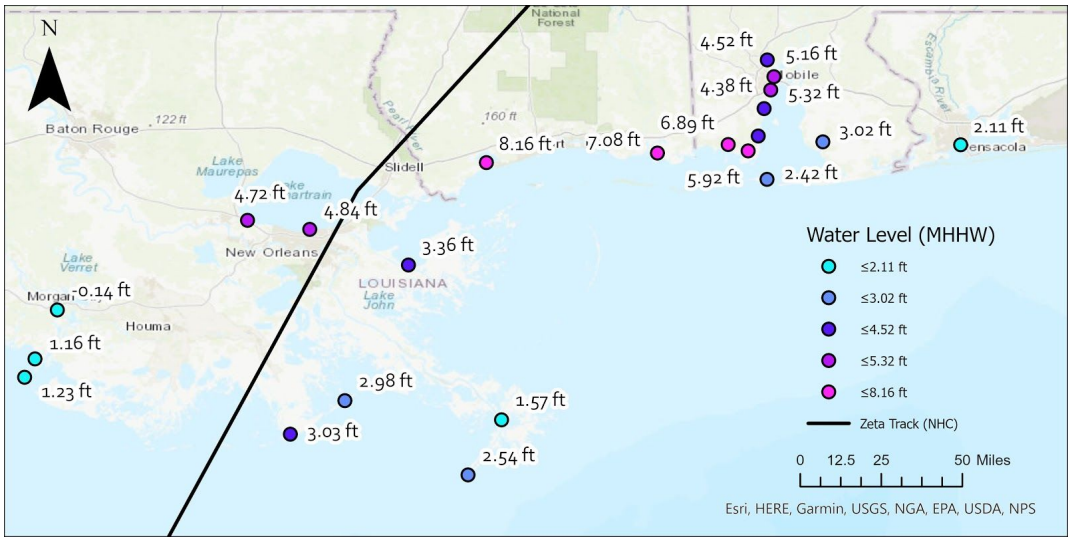


Figure 2.2. Summary of water level observations during Hurricane Zeta sourced from the NOAA CO-OPS data platform (see Appendix B for details of measurements).

3.0 Damage to Structures

While the wind speeds and storm surge levels reported in Section 2 had damage potential, they were well below design levels for most modern structures. As a result, Hurricane Zeta caused structural damage commensurate with a moderately strong, sub-design-level hurricane. Reports indicate light-framed wood single-family residential structures suffered the most damage from wind and storm surge, ranging from loss of roof components and systems, damage to wall cladding systems, and flood losses. Judging by the construction, the majority of reported damaged buildings were older (20+ year old) residential buildings.

3.1 Damage to Buildings in Coastal Regions

Hurricane Zeta-induced building damage is reported herein, organized by location and informed by preliminary reports on social media and by news agencies.

Louisiana: Despite the breach of its levee, elevated construction in Grand Isle appears to have performed adequately, with no reports of major structural damage in the media. In addition to reports of damages to roof cover and sheathing across southeast Louisiana, including homes in Grand Isle (Fig. 3.1.1a) and Chauvin (Fig. 3.1.1b), as well as a school in St. Bernard (Fig. 3.1.2), the propagation of roof failures to unreinforced masonry walls resulted in some of the most significant wind-related damage (Fig. 3.1.3a-c). The failure of brick veneer in an apartment complex in Terrytown (suburb of New Orleans) was also reported (Fig. 3.1.3d). However, reports of such damage, including the complete collapse of a wood-framed restaurant in Chalmette (Fig. 3.1.4), were relatively isolated. While some complete collapses of buildings were also reported in New Orleans, additional investigation suggests these buildings were abandoned and already in a significantly deteriorated state. Additional flood-induced impacts were also reported (Fig. 3.1.5).

(a)

(b)

Figure 3.1.1. Roof damages in Louisiana: (a) loss of metal roof cover on a commercial building (upper left background) and roof sheathing loss and damage to wood roof trusses in elevated homes (foreground) in Grand Isle, LA (Source:BRproud.com); (b) complete detachment of roof section in gable roof home in Chauvin, LA (Source: Chris Granger, AP via USA Today)

Figure 3.1.2. Drone imagery of damage to commercial roofing system and roof deck at St. Bernard Middle School in St. Bernard, LA (Source: Sandy Huffaker, Getty Images via NWF Daily News)

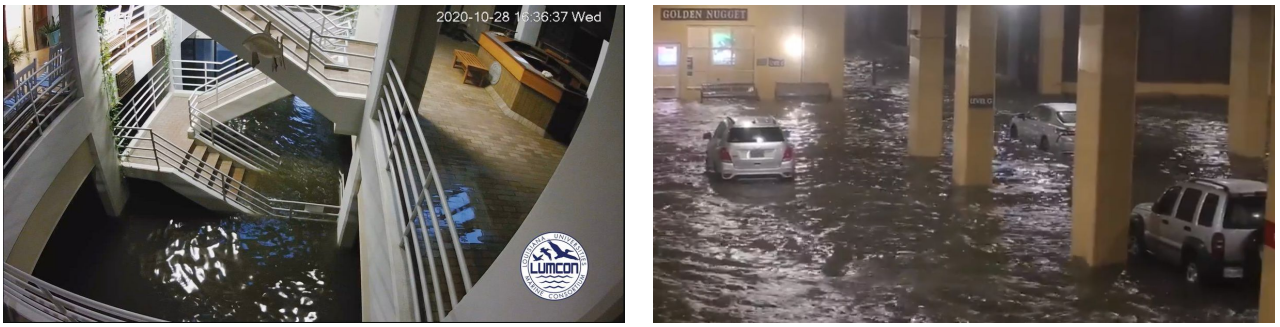
(a)

(b)

(c)

Figure 3.1.3. Masonry failures in Hurricane Zeta: roof failure propagating to the collapse of second-story unreinforced masonry walls (a) of a commercial building in Golden Meadow, LA (Source:Twitter) and (b) in an apartment in New Orleans, LA (Source: NYtimes); (c) loss of brick veneer at apartment building in New Orleans suburb of Terrytown (Image credit: Jefferson Parish).

Figure 3.1.4. Collapsed restaurant in Chalmette, LA (Source: Sandy Huffaker, Getty Images via NWF Daily News)



(a) (b)

Figure 3.1.5. Flood-induced impacts: (a) water accumulating to 5-6 feet in Louisiana Universities Marine Consortium Center in Chauvin, LA (Source: Twitter); (b) flooded parking garage in Golden Nugget, LA (Source: SunHerald)

Mississippi: At the time this briefing was authored, Mississippi counties reported a total of 32,071 homes damaged or otherwise affected by Hurricane Zeta (County breakdowns available at MEMA website), with Harrison County being the most severely impacted with nearly 27,000 damaged homes. While Mississippi Emergency Management Agency (MEMA) does not provide specifics in these damage tallies, social media and news reports documented losses of roof cover and sheathing, as well as treefall damage (Fig. 3.1.6). Similar to the reports in the previous section, failures of brick veneer and unreinforced masonry infill were also reported (Fig. 3.1.7).

(a)

(b)

(c)

(d)

Figure 3.1.6. Examples of roof damage to homes in Waveland, MS, ranging from (a-b) loss of cover and sheathing to (c) additional loss of framing (Source: Twitter); (d) tree falls were also a driver of damage to roofs in areas like Bay St. Louis, MS (Source: Twitter)

Figure 3.1.7. Failure of brick veneer and masonry infill in a residential area in Bay St. Louis, MS (Source: Twitter)

3.2 Damage to Infrastructure

The wind speeds and water levels noted in Section 2 were sufficient to cause widespread disruption to other infrastructure, particularly power distribution networks. Hurricane Zeta-induced damage to other infrastructure and non-building structures is reported herein, organized by structure class and informed by preliminary reports on social media and by news agencies.

Electrical Power Infrastructure: The electrical distribution grid was affected by Hurricane Zeta's winds, resulting in up to 2.6 million people losing electricity distributed across several states (Fig. 3.2.1): 500,000 in Louisiana, 900,000 in Georgia, 190,000 in Mississippi and 530,000 in Alabama (Rojas et al. 2020, PowerOutages). Reports of severely leaning and snapped electrical poles and downed lines associated with three falls or pole failures were widely reported across the Yucatan Peninsula (Fig. 3.2.2a-b) and the southeastern US (Fig. 3.2.2c). The most affected areas were to the east of Hurricane Zeta's track, including Grand Isle, LA (Fig. 3.2.2c); one of the storm's deaths was attributed to electrocution via a downed power line in New Orleans. Notably nearly 1 million Georgians were without power and restoration was ongoing one week after landfall, despite the wind speeds being on the order of 50 mph (11 Alive, 2020). Also note that the power outages shown in upper right of Figure 3.2.1 were caused by the aforementioned cold front producing winter ice storms in Oklahoma and Texas and later interacting with Zeta as it moved inland.

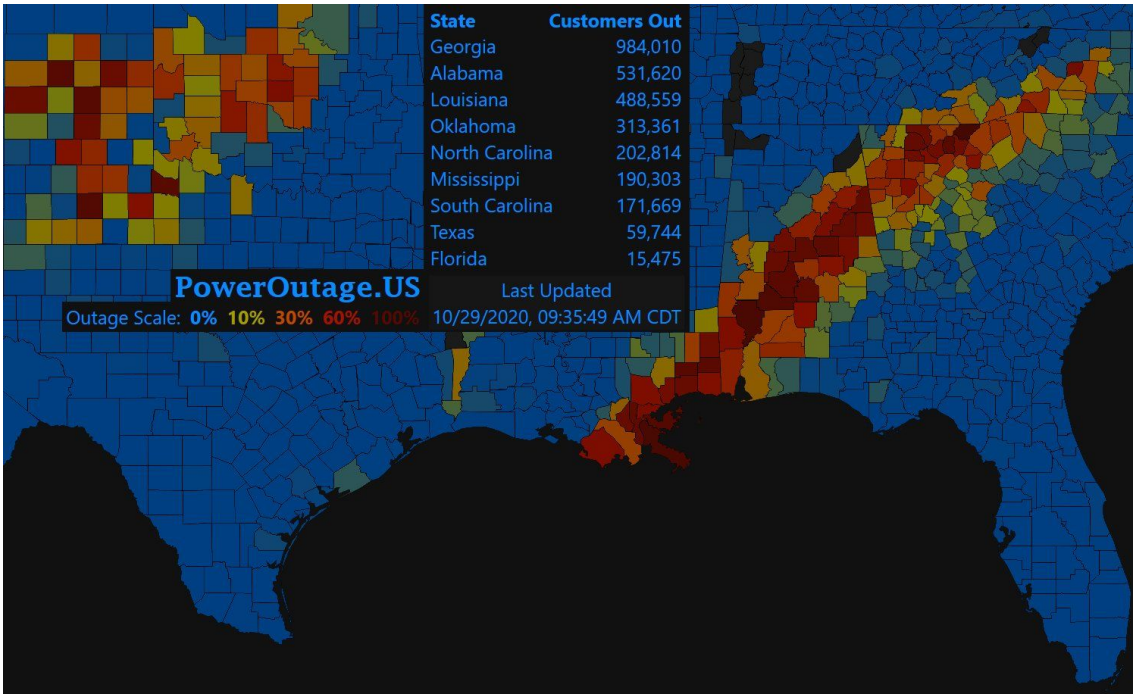


Figure 3.2.1. County-level electric outages on 29 October 2020 at 09:35 am CDT (Source: PowerOutage).

(a)

(b)

(c)

Figure 3.2.2. Power poles leaning or snapped due to Hurricane Zeta in: (a)-(b) Yucatan Peninsula (Source: Riviera-Maya-News) and (b) Grand Isle, LA (Source: CP24)

Gas Station Canopies: As commonly observed in wind events, Zeta damaged a number of gas station canopies in Louisiana and Mississippi, mainly by removal of the canopy metal cladding systems and/or steel framing (Fig. 3.2.3).

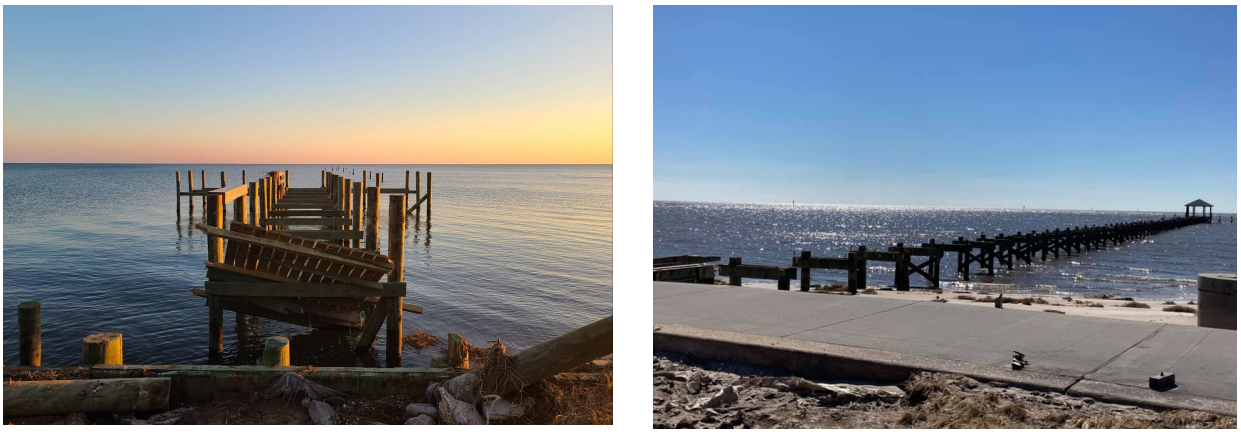
(a)

(b)

(c)

Figure 3.2.3. Damage to gas station canopies: (a-b) in Grand Isle, LA (Source: Facebook 1-2) and (c) Waveland, MS. (Source: Twitter)

Private Docks and Jetties: In Louisiana and Missisppi, several wooden jetties and private boat docks suffered damage due to Zeta's storm surge (Fig. 3.2.4), which had notable impacts to coastal protective systems, as discussed in the following section.



(a) (b)

Figure 3.2.4. Piers damaged by Hurricane Zeta in (a) Coden Beach, LA (Source: Twitter) and (b) Biloxi, MS (Source: Facebook).

4.0 Performance of Coastal Protection

One of the sandy beach residential areas that was heavily impacted was Dauphin Island, AL. Figure 4.1 shows post-storm imagery from NOAA of the island revealing how storm surge cut right through a strip of the island. This image shows the more western end of Dauphin Island; however, the east end, which had a beach restoration project completed in 2016, fared much better. Figure 4.2 shows the beach at the east end just after over 300,000 cubic yards of sand and jetties were added (Sharp, 2016), in contrast to imagery taken following Hurricane Zeta, affirming the benefits of the restoration project in arresting some of the potential erosion from Zeta.

Grand Isle, LA (also shown in Fig. 4.1) was protected by a levee that ran the length of the island (Fig. 4.3, below) and jetties. However, the levee was breached in at least seven locations during Zeta as shown in Figure 4.3. As a result of the waves and storm surge, the geotextile core of the “burrito” levee was exposed and damaged. Water intruded inland as far as the island’s main road (Baurick, 2020). Notably, the levee was repaired after damages in Cristobal in June and received further improvements ahead of Delta's landfall in October (Medina, 2020). This is yet another example of the cumulative effects of relatively lower-intensity hurricanes on coastal infrastructure.

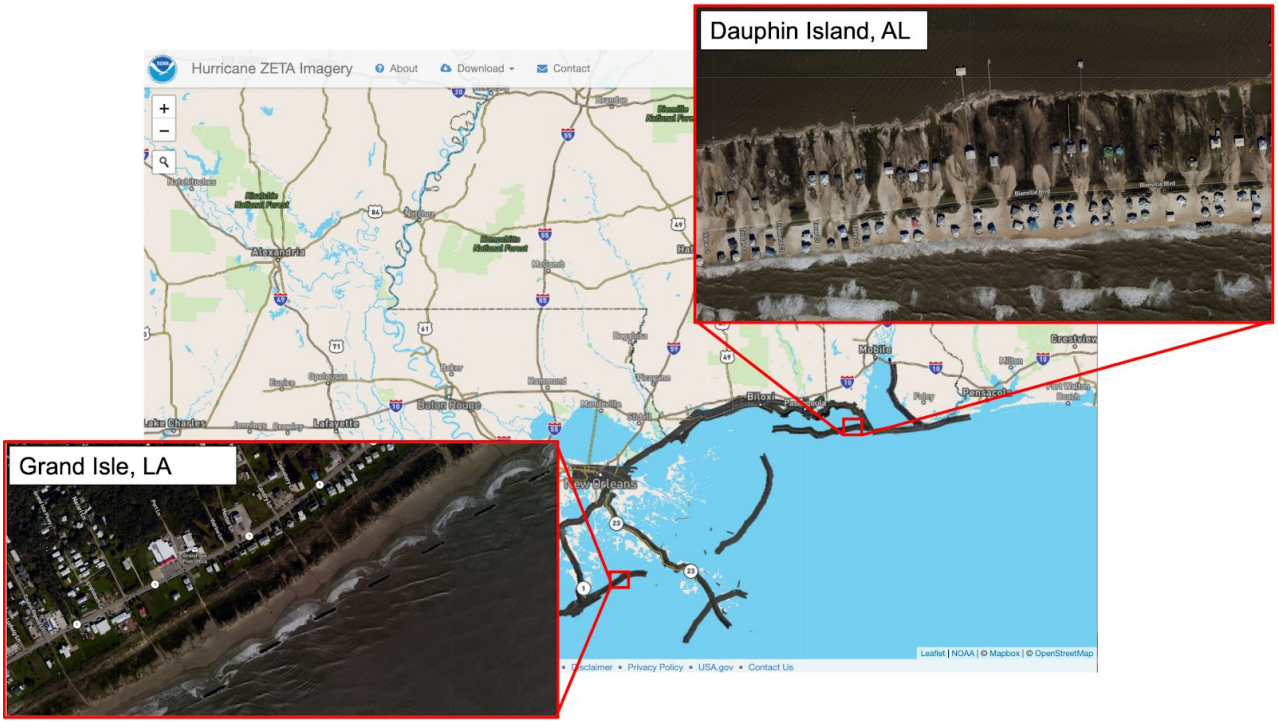


Figure 4.1. Coastal impacts to, residential sandy beaches in Alabama and Louisiana (source: NOAA)

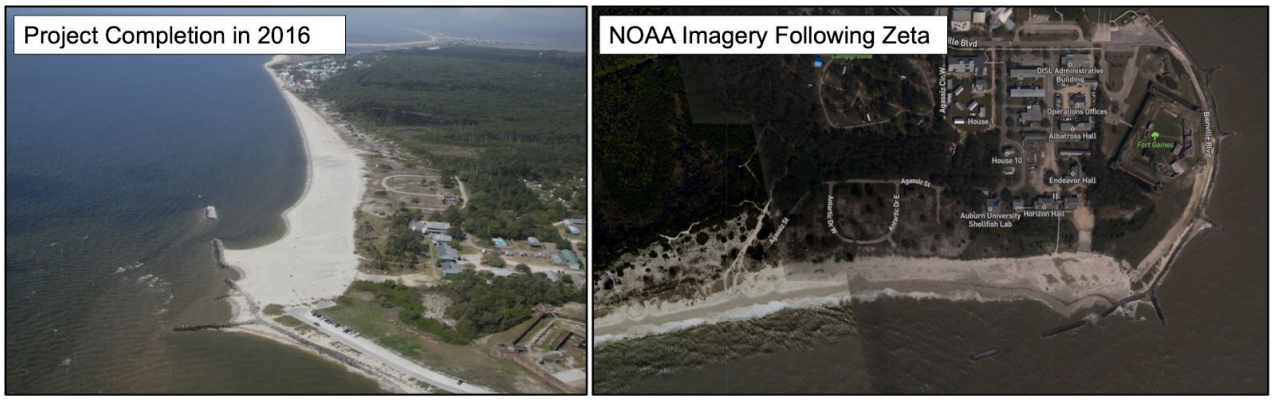


Figure 4.2. East Dauphin Island in Alabama after restoration project completion in 2016 (source: South Coast Engineers) and following Hurricane Zeta (source: NOAA).

Figure 4.3. Grand Isle, LA levee per U.S. Army Corps of Engineers, and one of three breeches due to Zeta (Source: Jefferson Parish Twitter)

5.0 StEER Response & Recommendations

At present, StEER has not deemed it necessary to elevate its Virtual Assessment Structural Team (VAST) to prepare a Preliminary Virtual Reconnaissance Report (PVRR) for Hurricane Zeta, nor does it anticipate activating a Field Assessment Structural Team (FAST) in response to this event. Rather, StEER's present response takes the form of this Event Briefing, which shares with the community StEER's impressions of the event and implications for natural hazard research and practice. Information provided herein was gathered from various news and agency websites, as well as social media. Therefore, this briefing does not include insights from detailed field investigations. StEER will continue to monitor this event and should the damage to structures warrant the further elevation of the present response, StEER will notify the community through its standard channels.

Hurricane Zeta produced less than design-level winds and storm surge, and yet the aftermath was still a costly one in the US, including six confirmed fatalities, over 30,000 damaged houses, as high as $5B in projected onshore insured losses, and at its peak over 2.6 million residents left without power. The damage observed in the houses, jetties, gas station canopies and power infrastructure were not unexpected for a storm of this strength. The majority of damage, as usual, occurred to aged structures, some in poor repair and perhaps built prior to modern model building codes. Hurricane Zeta has again shown that our losses and vulnerability to wind hazards will remain until we address the legacy of existing residential buildings that lack the structural integrity and continuous load paths necessary to resist high winds. Further, the fact that Louisiana experienced five storms in a single season is a record, but it is not unprecedented for a state to experience multiple storms in a season, e.g., in 2004, Florida experienced four hurricanes (Hurricane Charlie, Frances, Jeanne and Ivan). Thus this event re-emphasizes the need to understand the cumulative

effects of multiple low-intensity storm events on the built and natural environments (including beach and dune systems), engineered systems and services, societal functions and institutions, and perhaps most importantly, on the citizenry grappling with these recurring evacuation, recovery and repair cycles all within an active pandemic.

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Appendix A: Wind Speed Observations

ID	Station ID	Peak 1-min Sustained, mph	Date-Time, dd-hh:mm	Direction at Peak 1-min Sustained	Peak 3-sec Gust, mph (Reported)	Peak 3-sec Gust, mph (10 m, z0 = 0.03 m)	Anemometer Height, m	Estimated Roughness Length, m
1	WX FLOW-GULFPORT	74	28-19:57	182	101	101	10.3	0.03
2*	WX FLOW-BAYOU BIENVENUE	70	28-17:52	109	112	94	27.4	0.005
3	KGPT-GULFPORT AIRPORT	63	28-19:49	160	92	92	10	0.03
4	KBIX-BILOXI AIR FORCE BASE	64	28-20:26	160	90	90	10	0.03
5	KNBG-BELLE CHASSE NAVAL AIR STATION	53	28-18:35	210	87	87	10	0.03
6*	WX FLOW-BILOXI	50	28-20:56	180	84	87	15.2	0.1
7	WX FLOW-DULAC	56	28-16:36	336	78	78	10.3	0.03
9	WX FLOW-NEW ORLEANS LAKEFRONT	62	28-19:04	343	77	77	10.3	0.03
10	WX FLOW-WAGGAMAN	51	28-17:34	28	75	75	10.3	0.03
11	KMSY-NEW ORLEANS ARMSTRONG INTL AIRPORT	46	28-18:31	330	71	71	10	0.03
12	KLN1-BOOTHVILLE -VENICE	46	28-17:15	150	68	68	10	0.03
13	KASD-SLIDELL AIRPORT	41	28-18:53	40	68	68	10	0.03
14	KPQL-PASCAGOULA AIRPORT	45	28-19:40	160	61	61	10	0.03
15	WX FLOW-MANDEVILLE	40	28-19:32	287	59	59	10.3	0.03
16	KAPS-RESERVE	40	28-18:15	360	53	53	10	0.03
17	KMCB-MCCOMB AIRPORT	17	28-21:05	310	37	37	10	0.03
18	KBTR-BATON ROUGE AIRPORT	20	28-21:53	270	32	32	10	0.03

Notes: Two observations have been adjusted to reflect standard reporting conditions - 10 m above ground level, 3-second gust averaging time, and open exposure (z0 = 0.03 m) - using Simiu and Scanlan (1996) methodology. The most significant change was to the WX Flow - Bayou Bienvenue observation, which reported a gust wind speed of 112 mph at 27 m AGL in smooth terrain (z0 ~= 0.005 m). The stations that were adjusted are marked with an * next to their ID number. Data and metadata was sourced from the Weatherflow Datascope platform and local NWS office tropical cyclone reports.

Simiu, E., & Scanlan, R. H. (1996). *Wind effects on structures: fundamentals and applications to design.*

Appendix B: Observed Water Levels

Table B.1. Summary of NOAA CO-OP maximum water level observations.

ID	Name	Latitude	Longitude	Max Water Level (ft)	Time at Maximum (CST)
8747437	Bay Waveland Yacht Club	30.325	-89.325	8.159	10/28/2020 19:24
8741533	Pascagoula NOAA Lab	30.3678	-88.5631	7.078	10/28/2020 20:48
8739803	Bayou La Batre Bridge	30.4057	-88.2477	6.886	10/28/2020 22:00
8738043	West Fowl River Bridge	30.3766	-88.1586	5.919	10/28/2020 22:30
8736897	Coast Guard Sector Mobile	30.6483	-88.0583	5.322	10/28/2020 22:06
8737048	Mobile State Docks	30.7083	-88.0433	5.157	10/28/2020 22:00
8761927	New Canal Station	30.0272	-90.1133	4.843	10/28/2020 18:12
8762483	I-10 Bonnet Carre Floodway	30.0679	-90.39	4.721	10/28/2020 17:36
8737138	Chickasaw Creek	30.7819	-88.0736	4.521	10/28/2020 23:24
8735391	Dog River Bridge	30.5652	-88.088	4.38	10/28/2020 23:18
8735523	East Fowl River Bridge	30.4436	-88.1139	3.684	10/28/2020 23:30
8761305	Shell Beach	29.8681	-89.6732	3.36	10/28/2020 22:12
8762075	Port Fourchon, Belle Pass	29.1142	-90.1993	3.031	10/28/2020 16:36
8732828	Weeks Bay, Mobile Bay	30.4169	-87.8254	3.022	10/29/2020 0:24
8761724	Grand Isle	29.2633	-89.9567	2.982	10/28/2020 16:48
8766072	Freshwater Canal Locks	29.5517	-92.3052	2.572	10/28/2020 14:06
8760922	Pilots Station East, S.W. Pass	28.9322	-89.4075	2.539	10/28/2020 16:18
8735180	Dauphin Island	30.25	-88.075	2.418	10/29/2020 0:30
8729840	Pensacola	30.4044	-87.2112	2.106	10/28/2020 23:48
8760721	Pilottown	29.1783	-89.2583	1.568	10/28/2020 17:42
8764314	Eugene Island, North of , Gulf of Mexico	29.3675	-91.3839	1.234	10/28/2020 12:06
8764227	LAWMA, Amerada Pass	29.4496	-91.3381	1.161	10/29/2020 1:18
8764044	Berwick, Atchafalaya River	29.6675	-91.2376	-0.138	10/29/2020 3:06

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