EVENT BRIEFING

Event:	Hurricane Eta
Region:	Central America, SE United States

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DesignSafe Project #	PRJ-2954	Release Date:	November 14, 2020

Key Lessons

- ❏ Hurricane Eta again underscores the significant impact of meteorological hazards on communities already contending with the challenges of systemic poverty coupled with frail and unresponsive governance that can do little to create the regulatory or economic climate necessary for more resilient construction; it further reiterates the difficulties in emergency preparedness and response in low- and middle-income countries infrequently impacted by strong hurricanes.
- ❏ The manifestation of socio-economic vulnerability as structural vulnerabilities is well-understood and studied throughout Latin America and the Caribbean, though systemic reform has proven difficult and requires not just incorporation of engineering principles, but strengthening the entire housing delivery system in recognition of the right to dignified and resilient housing.
- ❏ Sufficiently confined masonry and adequately detailed reinforced concrete construction employing slab roofs successfully withstood the Category 4 hurricane and were critical to vertical evacuation during flash flooding in urban areas, though access to such resilient construction is limited to those with economic means.
- ❏ In the absence of expanded access to such construction, roof cover failures should be permitted in informal construction as a beneficial structural fuse to arrest what could be far more disastrous failures of vulnerable wall systems given the high winds.
- ❏ Until societies are able to consistently deliver on the right to dignified and resilient housing, it may be more pragmatic and advisable to encourage such fuses, provided they are coupled with household preparations of interior contents for expected exposure and full evacuation to avoid human injury from flying debris and other sources during the storm.

1.0 Event Description

Hurricane Eta made landfall as a Category 4 hurricane on 3 November 2020 in northeastern Nicaragua, in one of the poorest regions of what is Central America's poorest nation. Eta tied the 2005 record for the most named Atlantic Basin storms in a single season at 28, a record broken when Theta formed in the central Atlantic shortly thereafter on 6 November. Weakening to a tropical depression within 24 hours, Eta moved slowly over Central America dramatically widening the scope of the storm's impacts. The greatest losses have been reported in Honduras (est. 1.8 million persons affected), expected to surpass Hurricane Mitch (1998) with damage reports across 745 communities in 155 municipalities. Guatemala and Nicaragua also have hundreds of thousands of persons affected (est. 311,000 and 130,000, respectively). Already grappling with food insecurity due to the pronounced impacts of COVID-19 in the region and existing high rates of poverty, the millions affected had little capacity to absorb the additional shocks of the hurricane. More gravely, the extensive flooding during a critical planting period in the agricultural cycle surprised farmers unaccustomed to strong November hurricanes, which could mean major losses to staple crops like beans as well as major export crops like coffee (Welsh, 2020).

According to initial media reports, wind damage was concentrated near the point of landfall, with severe to complete damage reported. More notable, however, were the hurricane's heavy rains which caused extensive flooding throughout Central America, from Panama to Guatemala, with thousands of homes in Honduras, Guatemala, Costa Rica and Nicaragua damaged by wind (to a lesser extent) and floodwaters (to a greater extent), with some homes completely washed off their foundations by surging flood waters or buried in mudslides; numerous communities have been isolated due to washed out roads. These issues were especially acute in northern Honduras, in urban areas like La Ceiba, Tegucigalpa, San Pedro Sula, and their surrounding rural communities.

Figure 1.1a illustrates the implications for flood resilience across the rural-urban divide: multistory concrete and masonry structures were inherently more resilient to flood damage and supported vertical evacuation, which was vital to stemming life loss and enabling ongoing high-water rescues. Whereas Figure 1.1b demonstrates the wood-framed homes in rural communities more vulnerable to flood hazards and lacking proper water and sanitation, creating additional flood-induced health risks. Notably such challenges facing Hondouran communities vulnerable to climate-driven hazards have been previously underscored following Hurricane Mitch (McSweeney & Coomes 2011; Guill and Shandera 2001) and are sadly reiterated again during Hurricane Eta.

While exact death tolls in Central America are yet unknown, it is expected to be over 150 persons, with dozens of these deaths attributed to landslides across multiple Central American countries and a number of persons still unaccounted for (AP, 2020). Most notable among these is the village of Queja in the central Guatemalan region of Alta Verapaz where mudslides buried 150 houses and killed approximately 100 persons, with 150 still missing (Decavele and Palencia, 2020). International responses from the US, Canada, EU and UK are currently mobilizing to assist the displaced with basic provisions, as Nicaraguan Red Cross works to provide food and hygiene kits and shelters are at capacity across a number of Central American countries.

(a)

(b)

Figure 1.1. Rising floodwaters in (a) urban residential areas in Honduras, with residents vertically evacuating as waters reach the first story of a concrete building (Source: Twitter - click link for full video) and (b) rural residential areas like Sol de Libertad in Rosita, Nicaragua which lack such evacuation options (Estrada Galo, 2020b).

However, Hurricane Eta's impacts were not confined to Central America, as it restrengthened and spent the next week impacting Florida, with a pair of landfalls, and later the Carolinas. Although only a tropical storm in the US, its impacts were still significant. In Florida, one indirect death was reported due to electrocution in a flooded garage (CBS 4, 2020). Heavy rainfall in North Carolina inundated homes and businesses, washed out roads and bridges, and has resulted in 11 deaths as of 13 November (Vigdor et al. 2020), with other missing persons still unaccounted for, largely the result of surging floodwaters (Brackett and Wesner Childs, 2020).

This event briefing is intended to: (1) summarize the impacts of Hurricane/Tropical Storm Eta across Central and North America with emphasis on structural losses, (2) document the hazard intensity associated with the storm, and (3) identify any lessons learned from this event. While StEER did reach out to contacts in Central America in attempts to collect field observations, this outreach was unsuccessful. Thus all content herein is derived from public reports from news services, mission agencies and social media. It is important to caution that reporting out of Central America is significantly less than for a US-landfall and has focused heavily on the flood-related aspects of the hurricane, which are beyond the scope of StEER's mission.

2.0 Hazard Description

Figure 2.1 shows the evolution of Hurricane Eta through its landfalls in Central America and the United States, with subsections for each region. The lack of reported measurements of storm surge, rainfall and wind speeds in Central America limit the hazard description to largely forecasted values in briefings from the National Hurricane Center (NHC).

2.1 Hazard Characteristics in Central America

Hurricane Eta had reached peak strength as a 150 mph category-4 hurricane on 3 November, after 24 hours of rapid intensification; however, the storm weakened prior to landfall during an eyewall replacement, making landfall in northeastern Nicaragua just south of Puerto Cabezas on 3 November 2020 at 4:00 PM EST with a minimum central pressure of 940 mb and maximum sustained winds of 140 mph. Surface measurements were limited, but sustained winds of 108 mph with gusts to 136 mph were reported (metadata unknown) in Puerto Cabezas through Weather Underground, approximately 15 miles north of Eta's center (Hagen, 2020). Video footage captures the intensity of the winds at landfall in the coastal Nicaraguan community of Miskita. Extent of hurricane force winds was estimated at 25 miles with tropical storm winds extending 115 miles (Guy Carpenter, 2020). NHC predicted a storm surge of 14-21 feet above normal tide levels (NHC, 2020), though the actual observations could not be confirmed in public reports. More notable were the concerns for flash riverine flooding throughout the affected areas given the slow-moving nature of the storm (forward speed of 7 mph), generating torrential rains and inland flooding for days after landfall (Holcombe and Miller, 2020). Though exact rainfall totals could not be secured for this briefing, NHC estimates projected 15-30 inches, with isolated areas receiving up to 40 inches of rain in Honduras, Guatemala and Belize, while portions of Nicaragua, El Salvador and Costa Rica were projected to receive 15-20 inches with some areas seeing 40 inches of rain. Panama and Costa Rica were forecast to receive 10-15 inches inches of rain, with up to 25 inches in some areas. Heavy rainfall was also expected in southeastern Mexico, Jamaica, the Cayman Islands and Cuba.

2.2 Hazard Characteristics in the US

As shown by Figure 2.1, by 6 November Tropical Storm Eta moved back over water headed toward the United States, landfalling first in Cuba, before making its first US landfall on 8 November 2020 as a tropical storm with sustained winds of 65 mph on Florida's Lower Matecumbe Key. Eta produced 18 inches of rain in South Florida from 8-9 November, causing widespread flooding in Miami and Fort Lauderdale. The tropical storm then moved back into the Gulf and as shown in Figure 2.1, briefly regained hurricane force on 11 November, but weakened before making its second US landfall near Cedar Key, FL around 4:00 AM EST on 12 November with maximum sustained winds of 50 mph. A storm surge of 3-4 feet was reported in Tampa Bay, which received between 4 and 8 inches of rain as of the morning of 12 November. Eta's pattern of heavy rainfall continued as it moved across Florida and back over water, inching along the Atlantic Coast of the Carolinas, delivering 3 to 7 inches of rain that resulted in flash flooding conditions.

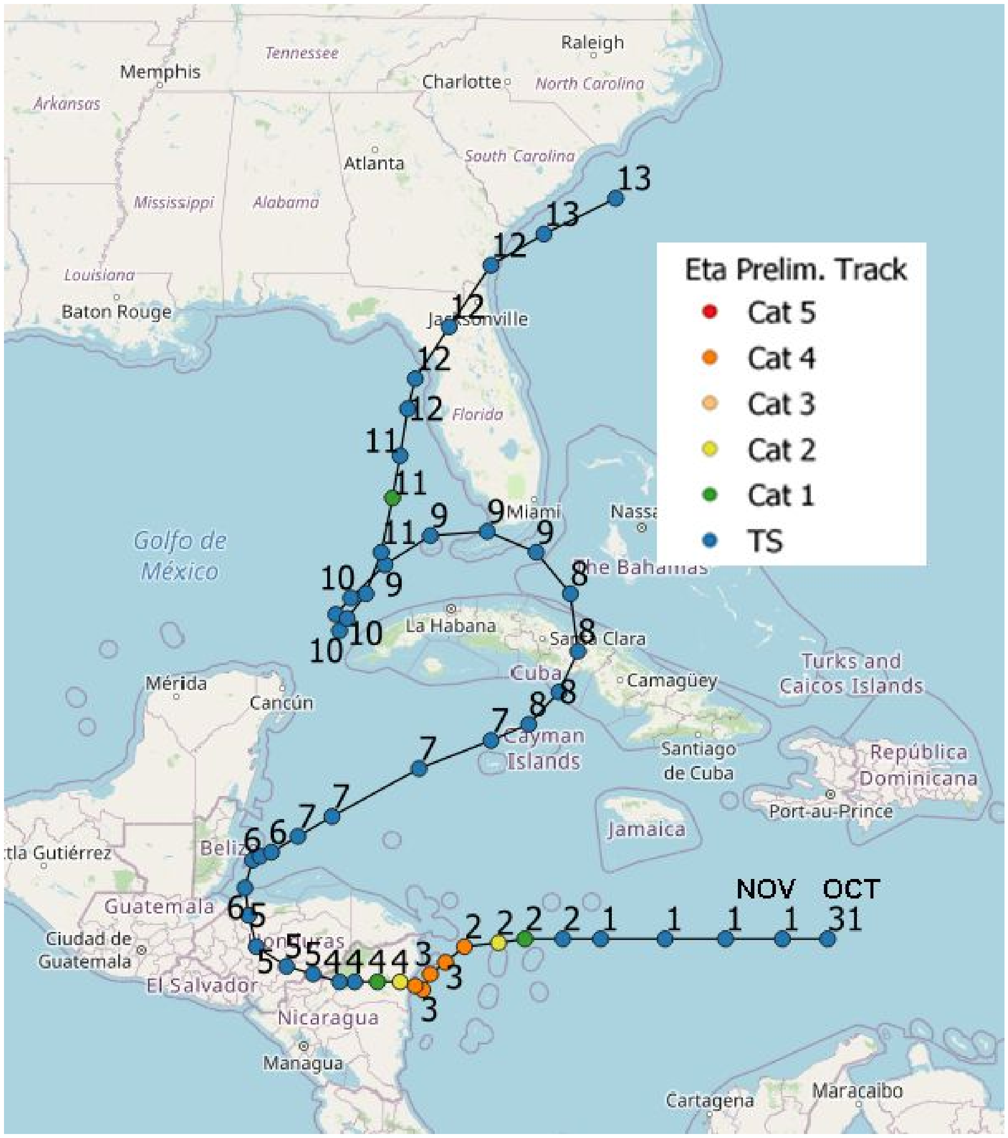

Figure 2.1. Track of Hurricane Eta over multiple landfalls. Numbers on track indicate the date of track location while colored symbols reflect intensity (Data source: NHC).

3.0 Damage to Structures

Given the negligible damage to structures in the US, this section will focus on structural damages to buildings in Central America and specifically Nicaragua, with an emphasis on the potential impacts of wind and storm surge (damage in other Central American countries is confined to flood-related losses). It is important to contextualize these reports within the typologies and construction practices in the region. In more urban and peri-urban areas, residential and commercial construction employs variations of unreinforced masonry and confined masonry. The engagement of reinforced concrete and confined masonry construction in these regions at minimum minimized the potential for structural damage from the expansive flooding in Eta (see Fig. 3.1), though content losses are still significant. Concrete and masonry typologies may employ two possible roof systems: concrete slab roofs or corrugated galvanized iron (CGI) roofs framed by timber, prefabricated open web steel joists or steel-hollow section trusses/purlins (both of which are exemplified later in Fig. 3.2a). The use of timber framing for CGI roofs is more prevalent in lower income/rural areas and that lumber is generally hand-processed and nailed (no use of straps or plates) to lightly frame these roof systems; however, wood species in Nicaragua can provide excellent hardwood for framing. In both settings, CGI attachment is often weak: CGI sheets themselves are commonly corroded or thin gauge and umbrella nails are rarely employed. The styles of construction in this region are consistent with those throughout Latin America and the Caribbean (LAC); the study by Kijewski-Correa et al. (2018) illustrates the vulnerabilities common in these systems as observed in Hurricane Matthew in Haiti.

(a) (b) (c)

Figure 3.1. Floodwaters in Honduras reached the first story of buildings (a-b) as illustrated by examples in Puerto Cortes (Source: La Prensa, 2020a); (c) illustrates the typical multi-story urban residential concrete and masonry typologies in Honduras that are inherently more resilient to flood losses in comparison with wood or other light-framed/clad construction (Source: (https://twitter.com/brianarrubi/status/1325225824182657025/photo/2).

Lower-income urban as well as rural areas often construct timber framed homes or even hybrids of the two systems, with concrete masonry unit (CMU) walls, possibly weakly confined, for the lower elevations prone to flooding, and then framing in wood the upper elevations of the home. Much of this construction would be classified as informal, with confined masonry construction possibly guided by a skilled mason or engineer; most other artisans are informally trained and houses particularly in rural areas may be self-constructed by the owner.

3.1 Building Damage in Nicaragua

The potential for wind-damage was concentrated in Nicaragua over approximately a 100-mile radius, as noted in Section 2.1. Rural areas affected by Hurricane Eta include El Muelle, Nueva Jerusalen and Peter Ferrara neighborhoods of Bilwi, Nicaragua. The 100,000+ people living in Bilwi and the adjacent Caribbean communities are mostly indigenous, and this pair of videos (1 and 2) from the indigenous coastal community Wawa Bar in the municipality of Bilwi provides an indication of impacts to the coastal areas, as well as some of the local residential construction practices. These communities reported damage to residential and school buildings with most losses concentrated in the roof system, and specifically the loss of CGI roof cover. As these roof systems have weak cover attachment, loss of metal roof cover was anticipated, in contrast to concrete slab roofs (Fig. 3.2a), a system accessible to those with higher economic capacity and inherently more resilient to the strong winds and heavy rainfalls associated with hurricanes and tropical storms common in LAC. However, roof cover loss is potentially beneficial as a fuse that avoids propagating uplift forces into more vulnerable wall systems (Kijewski-Correa et al., 2018). Such masonry wall system vulnerability (illustrated in Fig. 3.2b) is generally associated with inadequate confinement, lack of reinforcement or lack of system-level integration of the wall system through ring beams, or a combination thereof, where errors in detailing these critical reinforced concrete confining elements can lead to failure under lateral forces from wind, storm surge or floodwaters. While the loss of roof cover can be a beneficial fuse to avoid propagating more dangerous building-level failures, the resulting content losses due to rainwater infiltration still have significant impacts to building functions and its occupants (Fig. 3.2c). In some cases, roof failures did propagate to building-level collapse of light-framed wood construction in as far inland as the Nicaraguan capital of Managua (Fig. 3.3).

Eastern Nicaraguan coastal communities like Wawa and Miskito were typified by modestly elevated wood-framed homes with losses primarily confined to the roof system, ranging from loss of roof cover to the complete detachment of the roof system (Fig. 3.4a-b), a potentially beneficial structural fuse, as mentioned previously. Some homes were unseated from their elevated foundations and debris evidence suggests this may have resulted from storm surge (Fig. 3.4c). The lack of concrete and masonry construction in some of these coastal communities left residents with few evacuation options.

(a) (b) (c)

Figure 3.2. Eta-related damages in Puerto Cabezas, Nicaragua: (a) representative loss of roof CGI roof cover on single-story building in adjacent to a multi-story building with concrete slab roof (Source: Estrada Galo, 2020b); (b) example of inadequately confined masonry wall failure under lateral loads(Top left, Estrada Galo, 2020b); (c) interior losses due to water-damaged roof (Source: [CNN](#))

Figure 3.3. Structural collapse of residential building in Managua (Davila, 2020)

3.2 Infrastructure Damage in Central America

In addition to widespread power outages due to downed lines and poles in areas like Nueva Jerusalen, Bilwi in Nicaragua (Estrada Galo, 2020a), as well as Honduras, the most notable infrastructure impacts were driven by the widespread flooding. Road closures due to mudslides (Fig. 3.5a), overflowing rivers (Fig. 3.5b) and scouring that undercut roadways left many communities isolated, particularly those in more rural mountainous areas who were cut off from critical aid and recovery support. Failures of steep hillsides also undercut the foundations of entire rows of homes in Honduras (see Twitter video compilation 1 and 2 for failures due to floodwaters). Swelling rivers surpassed the freeboard on a number of vehicular bridges in Honduras (Fig. 3.5c-d) and led to the failure of the Saopin Bridge spanning the Cangrejal River in La Ceiba, Honduras (Fig. 3.5e-f). There is at least one other report of a vehicular bridge being swept away by floodwaters in Guatemala (see Twitter video of collapse).

(d) (e)

Figure 3.4. Damage to elevated wood-frame residential structures in the coastal community of Miskito, Nicaragua due to wind and storm surge impacts: (a-b) displaced boats and debris fields indicative of storm surge; (c-d) typical wind damage to CGI roofs; (e) houses unseated from foundation (Sources: Palmado via Twitter and Paul Cruz via Twitter).

Figure 3.5. Road closures due to (a) mudslides and (b) overflowing rivers in Honduras (Source: LaPrensa, 2020b); (c-d) bridges impacted by the overflowing of the Chamalecon river in western Honduras (Source: Jose Cantarero via LaPrensa, 2020b), (e-f) Bridge collapse in La Ceiba, Honduras (Source: Javier Mendoza via Twitter).

3.3 Infrastructure Damage in North Carolina

The heavy tropical rainfall associated with Eta and an approaching cold front led to severe flash flooding in North Carolina that impacted a number of buildings and other structures. Structural damage appears to be mostly confined to transportation infrastructure. At least four bridges and 50 roadways were breached by the flood waters in Alexander County alone (Vigdor et al., 2020), 2020), as illustrated in Figure 3.6. Rising floodwaters caused evacuation of the Corvian Community Elementary School (WBTV, 2020) located just north of Charlotte, NC (GPS: 35.3228, -80.7565), but no structural damage was reported or expected.

Figure 3.6. Just before and after the collapse of a portion of a bridge on Cheatham Ford Rd in Alexander County, NC (GPS: 35.896155, -81.054812) due to loss of freeboard from rising floodwaters (screen clips from [Fox46 Twitter]() account).

4.0 Recommendations for Further Study

Hurricane Eta again underscores the significant impact of meteorological hazards on communities already contending with the challenges of systemic poverty coupled with frail and unresponsive governance that can do little to create the regulatory or economic climate necessary for more resilient construction. Tragically, the additional shocks of a global pandemic have only amplified this vulnerability. The manifestation of socio-economic vulnerability as structural vulnerabilities is well-understood and the need for incorporation of engineering principles into construction has been documented for decades in Latin America and the Caribbean (e.g., Prevatt 1994), though achieving such change requires systems-level interventions to build technical capacity and strengthen the entire housing delivery system (Burlotos et al. 2020).

From a structural perspective, sufficiently confined masonry and adequately detailed reinforced concrete construction employing slab roofs were more than adequate to withstand the Category 4 hurricane in Nicaragua. Such wind resilience was not a necessity for the majority of the storm's duration over Central America as it had weakened to a tropical storm. Even in regions dominated by Eta's flood hazards, such construction provided life-saving structures for vertical evacuation during flash flooding in urban areas. Thus the challenge is not technical but in expanding the access to such hazard resilient construction (cautioning that masonry and concrete construction can prove vulnerable in earthquakes and thus requires careful multi-hazard engineering in this region).

Moreover, cursory examination of the performance of more vulnerable low-income typologies could errantly direct effort into mitigating CGI roof cover losses through improvements at various points across the roof's load path. However, as demonstrated in past disasters affecting low and middle-income countries (Kijewski et al. 2018), these roofing failures are often a beneficial structural fuse to arrest what could be far more disastrous failures of vulnerable wall systems given that populations lack the economic capacity and technical understanding necessary to strengthen the entirety of the structural load path. Thus until societies are able to consistently deliver on the right to dignified and resilient housing, it may be more pragmatic and advisable to encourage such fuses, provided they are coupled with household preparations of interior contents for expected exposure and full evacuation to avoid human injury during the storm.

Given this pragmatic understanding of likely structural performance, two immediate recommendations are as follows:

1. **Pragmatic Preparation Guidance:** Examine how to align guidance and evacuation protocols to appropriately guide those in high-wind regions on how to prepare (protect) their possessions and appropriately evacuate given anticipated roof failures.
2. **Expand Evacuation Zones:** Reconsider how at-risk populations are defined; Eta underscored such preparation and evacuation is not just required in areas at risk of strong winds and storm surge but also other cascading hazards associated with flash flooding and mud/landslides. This again reiterates the challenges of rating storms and thus the evacuation response based on their wind intensity rather than other factors such as their rainfall potential. Life loss could have been averted in many high-risk areas if pre-emptive evacuations were conducted before the onset of heavy rains; however, this requires appropriate forecasting of inland and riverine flooding as well as identification of geotechnically vulnerable populations. Such emergency management tools must not only be available to low and middle-income countries but coupled with appropriate early warning and evacuation systems to truly be effective.

In light of the above recommendations, StEER does not deem it necessary to form a full Virtual Assessment Structural Team (VAST) or 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 websites (news, mission agencies and social media), and is thus not informed by insights from detailed field investigations. StEER will continue to monitor this event and should the damage to structures warrant the formation of a VAST or FAST, StEER will notify the community through its standard channels.

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This material is based upon work supported by the National Science Foundation under Grant No. CMMI 1841667. Any opinions, findings, and conclusions or recommendations expressed in this material are those of StEER and do not necessarily reflect the views of the National Science Foundation.