Valley Study Area Hurricane Evacuation Study Evacuation Zone Development Report

Prepared by

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And
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The Texas A&M University System

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Valley Study Area Hurricane Evacuation Study
Transportation Analysis Report

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Background

A critical element in conducting the Valley Study Area's Hurricane Evacuation Study was working with the local communities to develop new evacuation zones based primarily on the most recent hurricane surge risk modeling data. These new zones set the framework for subsequent vulnerability analysis and transportation analysis, but most importantly result in the development of hurricane evacuation zones that would 1) enable local households and individuals to readily understand their residential location relative to potential hurricane storm surge risk; and 2) enhance the ability of local emergency management to both plan for and mobilize their local populations to evacuate when facing future hurricane threats, a critical component of evacuation planning for any community. In other words, the development these zones is critical for addressing life safety issues related to hurricane surge risk but also for facilitating effective communication to diverse populations, hoping to motivate individuals and households within these zones to respond to evacuation orders and those outside these zones to remain in safe locations**.**

This report documents the processes undertaken to develop new evacuation zones for Willacy and Cameron Counties, the information and data utilized in the development of these zones, and the final zones created.

Evacuation Zone Development

There are no recognized or established guidelines for the development of evacuation zones although there are many examples from the host of hurricane studies that have been performed that can provide some guidance (i.e., Wilmot and Meduri 2005). Fundamentally, the establishment of evacuation zones must be based on the best scientific modeling evidence for likely surge inundation, because it has been well established that hurricane surge is the greatest risk to life safety. There are other factors that might be considered as well. Some of these include local features of the natural and built environment, transportation road networks, bridges, population concentrations, additional hazard data, etc. While these and other factors can be important, an additional set of critical factors, next to the inundation data, are directly related to effective emergency communication. Specifically evacuation zones must be readily identifiable by both the public and authorities. The public must be able to easily identify their location, particularly residential and work locations, with respect to evacuation zones and emergency management should be able to utilize these zones to effectively plan and call for public evacuation. Hence, both with respect to local conditions and developing effective emergency management communications, it is critical that evacuation zone development be undertaken with local community involvement.

Meetings and Consultation with Stakeholders: As part of the overall Hurricane Evacuation Study there were eleven meetings held with various stakeholder groups. These meetings include a phone conference kick-off meeting, a web-ex meeting addressing evacuation scenario development, and nine workshops. All of the workshops were held down in the Valley. In total, there were 115 attendees at these meetings, not including the TTI/HRRC team nor the FEMA and USACE leads, representing over 44 local county and city governments and local, state, and federal agencies.

The kick-off meeting and five workshops addressed issues related to the development of the evacuation zones. Specifically, the initial kickoff meeting and two workshops were held in Brownsville (February 6, 2015 and April 1, 2015) to address the data that would be utilized, identify criteria for zone development, and discuss preliminary zone boundaries. These more general meetings were followed by a series of three workshops held in Raymondville (Willacy County), San

Benito (northern Cameron County) and Brownsville (southern Cameron County) on May 18th and 19th, 2015. These more focused workshops enabled the team to work with local officials and agencies in particular to make final decisions on specific boundary locations within each county and with respect to local communities and places. When just considering the meeting and workshops that focused on evacuation zone development, there were a total of 80 attendees – 57 of which were unique attendees that attend at least one of the meetings. The attendees represented 37 local governments or local, state, or federal agencies.

Data and web-based GIS platform:

A variety of data were gathered and integrated into an interactive web-based GIS platform to assist and facilitate the development of the evacuation zones. The following provides a listing and brief description of the data gathered, along with examples of how these data were used.

United States Army Corps of Engineers Slosh Based Storm Surge Inundation Risk Area Data: The United States Army Corps of Engineers (USACE) has developed slosh-based storm surge data for use in Hurricane Evacuation Studies (USACE 2014). More specifically, the USACE has collaborated with the National Oceanic and Atmospheric Administration (NOAA) to develop a process of combining NOAA's SLOSH (Sea, Lake, and Overland Surges from Hurricanes) data with other data sources to generated GIS-based storm surge inundation risk area maps. Essentially, the USACE process SLOSH modeled output for maximum of maximums (MOMs) for each storm category at high tide, digital elevation data (DEMs) from a variety of sources, 12 digit hydrological unit (HUCs) data and coastal water feature data to produce a surge risk inundation mapping layer. The processing emphasizes the hydrology of the coastal area modeled and then various smoothing and elimination processes are undertaken, yielding the final result. The modeling for the Valley Study Area (VSA) was completed during the summer of 2013. Figure 1 displays an example of these data layers for the VSA as it appears in the HES website developed for this project.

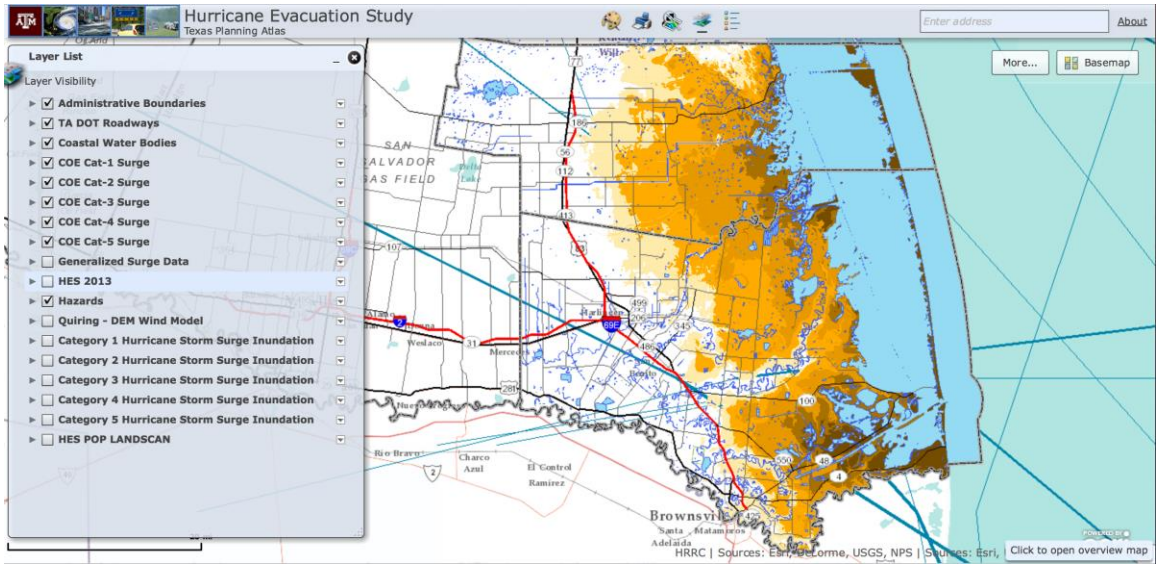

Figure 1. USACE's Slosh Based Storm Surge Inundation Risk Area Data

HES-COE generalized surge inundation risk data: As we began to work with the surge inundation data provided by the Corps of Engineers (COE), it became evident that it can be difficult to make a determination of where a potential evacuation zone boundary might be placed due to the

somewhat ragged edges of the inundation areas and the fact that there are many "orphaned" or "lost" pockets of inundation. Figure 2, for example, displays the inundation areas (golden in color) for a category 3 storm in and around San Perlita, in northern Willacy County. Figure 3, displays the same area, but now overlaid on image data for the same area. Both of these figures are again from the web-based GIS platform created as part of the HES project. In both of these figures one can clearly see a Resaca (an old bend in a river) just to the east of San Perlita as well as many orphaned inundation areas throughout the area to the north and south east of the city. Furthermore, there are a number of very small cannels, streams and waterways throughout the area that are subject to surge, but are difficult to see when using the mapped data.

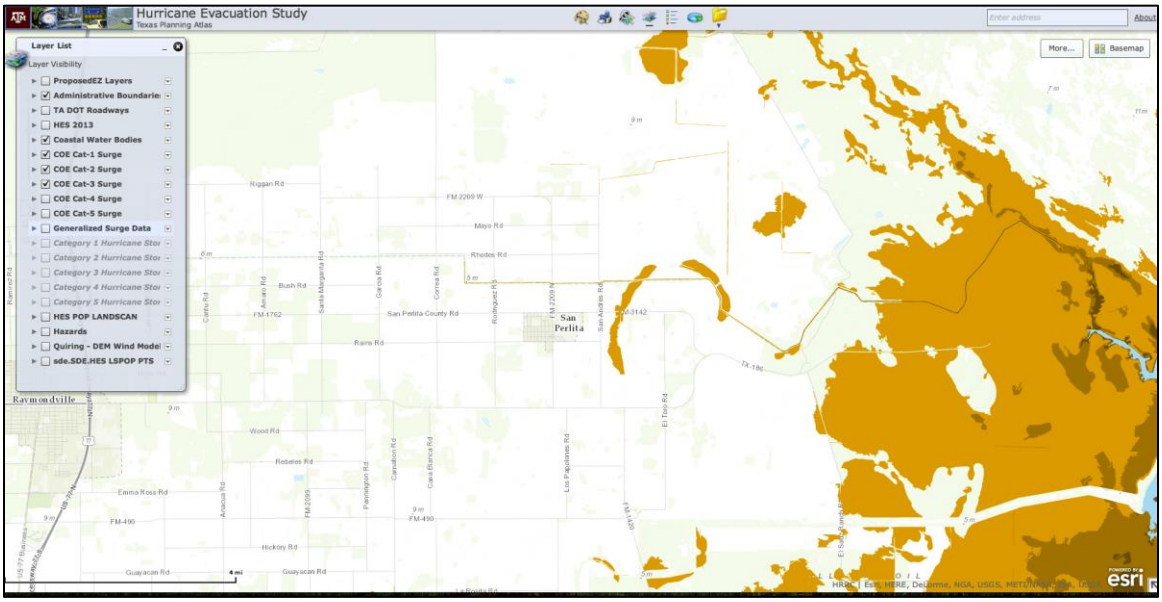

Figure 2. Cat 3 USACE inundation data near San Perlita in Willacy County

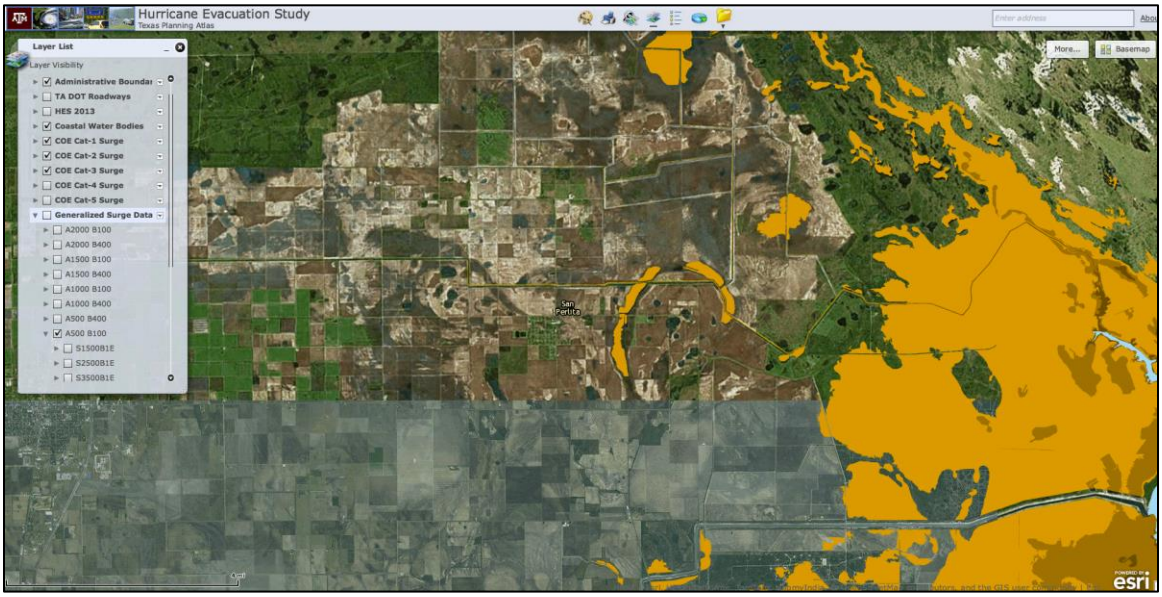

Figure 3. Cat 3 USACE inundation data near San Perlita in Willacy County Over an Image of the Area.

It is important to note that the ragged nature of these inundation data as well as the orphaned or lost inundation areas that are separated from main inundation areas are not necessarily errors. They are simply a function of taking the rather coarse SLOSH output, combined with higher resolution digital terrain data. In an attempt to make interpretation of the USACE inundation data somewhat easier, as part of the HES study, a "generalized" version of these data was created. Essentially the generalized version of these data aggregates or clusters inundation areas that were relatively close to each other and then adds a buffer around these aggregated areas so that they would be more easily recognizable. Specifically this process aggregated inundation areas that are within 500-meters and then generates a 100-meter buffer around them. The buffer also makes more visible waterways and channels that maybe subject to surge according to the USACE inundation data.

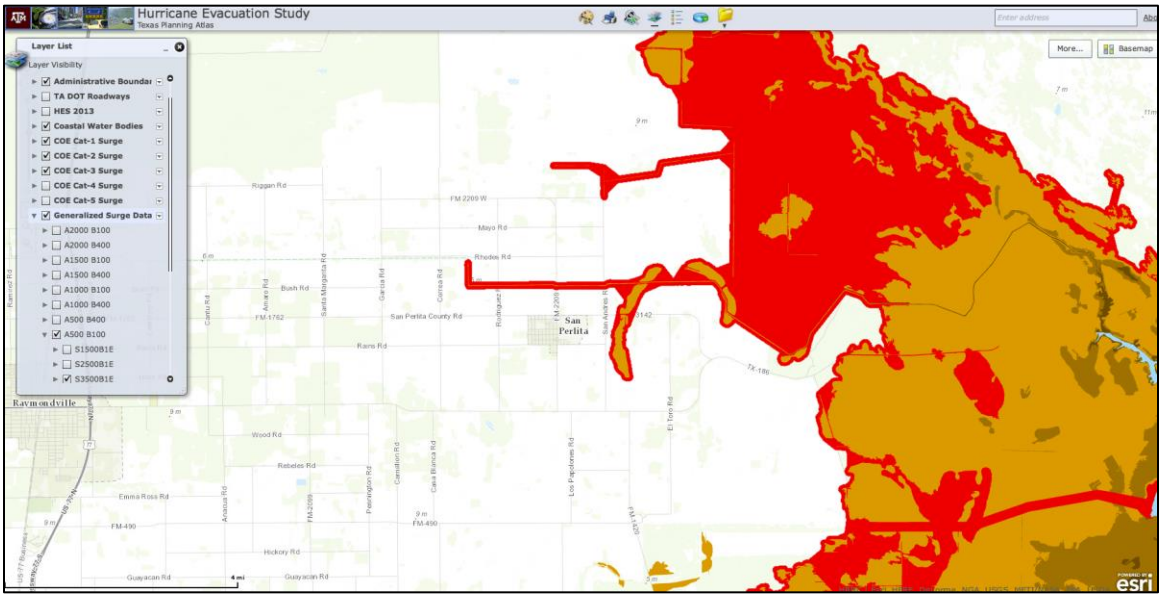

Figure 4. Generalized Cat 3 USACE inundation data near San Perlita in Willacy County.

Figure 4 displays the same area around San Perlita with the new generalized version of the USACE inundation data. It is important to realize that these generalized data layers aggregate areas that may not be subject to surge with those that are (based on the SLOSH and digital elevation data), but they have the advantage of forming smoother boundaries and making more visible streams and channels that may be subject to surge. In a very real sense, these data layers are perhaps even more conservative representations of risk, which may make sense given the importance of life safety issues.

Additional Hazard Data: In addition to the surge inundation data, the HES team, in part as a response to local stakeholders, also gathered wind and flood hazard data and incorporated them into the integrated GIS platform. Specifically, FEMA flood zone data for the area along with two wind hazard data layers were also incorporated into the HES GIS website. The wind risk data are from the ASCE-7 wind fields maps and newer wind risk modeling data created by Dr. Steven Quiring from the Department of Geography at Texas A&M for the Texas Department of Emergency Management. Dr. Quiring's model is based on historical storms that have actually crossed coastal Texas, including the study area. Both sets of wind risk data are only approximate risk data and do not necessarily reflect the precise wind hazard risk for an area. However, they do provide some indication of the potential wind risks for areas within the VSA. Figure 4 and 5 show examples of the respective wind hazard data based on the ASCE-7 and Dr. Quiring's TEM wind hazard estimates.

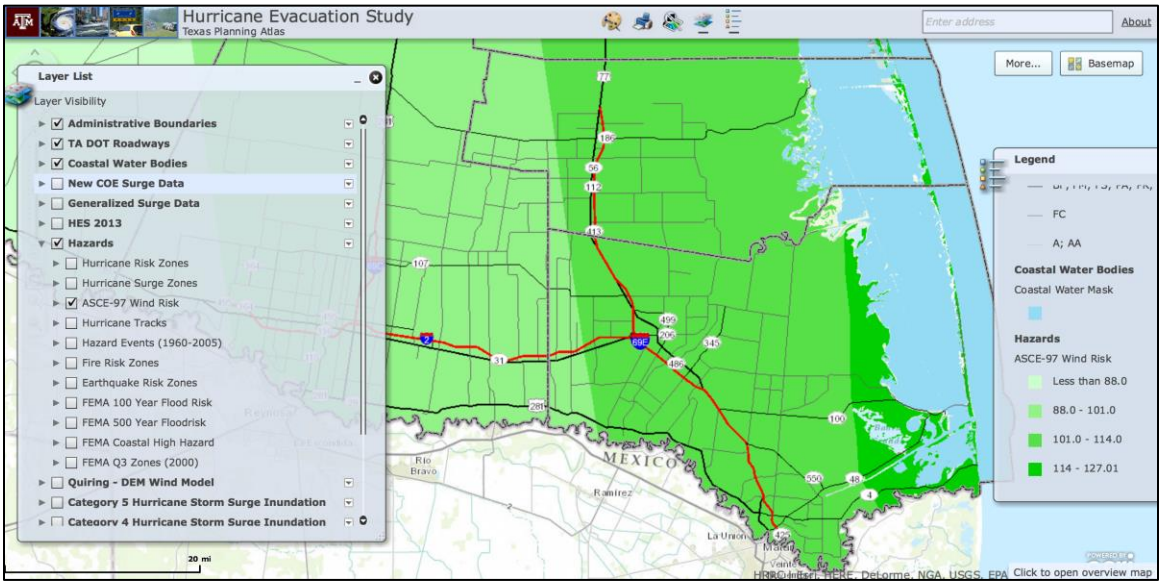

Figure 5. ASCE-7 Wind Fields for the Valley Study Area

The wind data generated by Dr. Quiring clearly reflects historical storms, many of which emerge in the western portion of the Gulf of Mexico, gathering strength and then hitting the lower Rio Grande Valley area of Texas. The lower Rio Grande Valley is historically susceptible to hurricanes developing in this area of the Gulf, which results in a particularly threat because these storms are often quick to develop and can threaten this area shortly after forming (Ismal, Merrell, Seitz and Harris 2009).

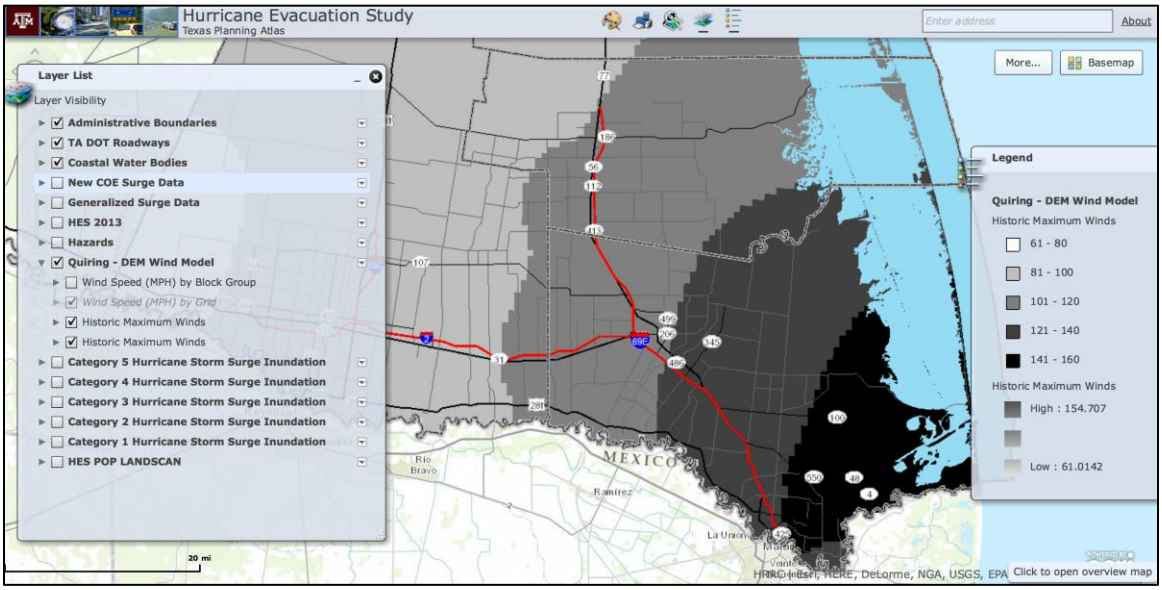

Figure 6. Dr. Quiring's TDEM Wind Fields for the Valley Study Area

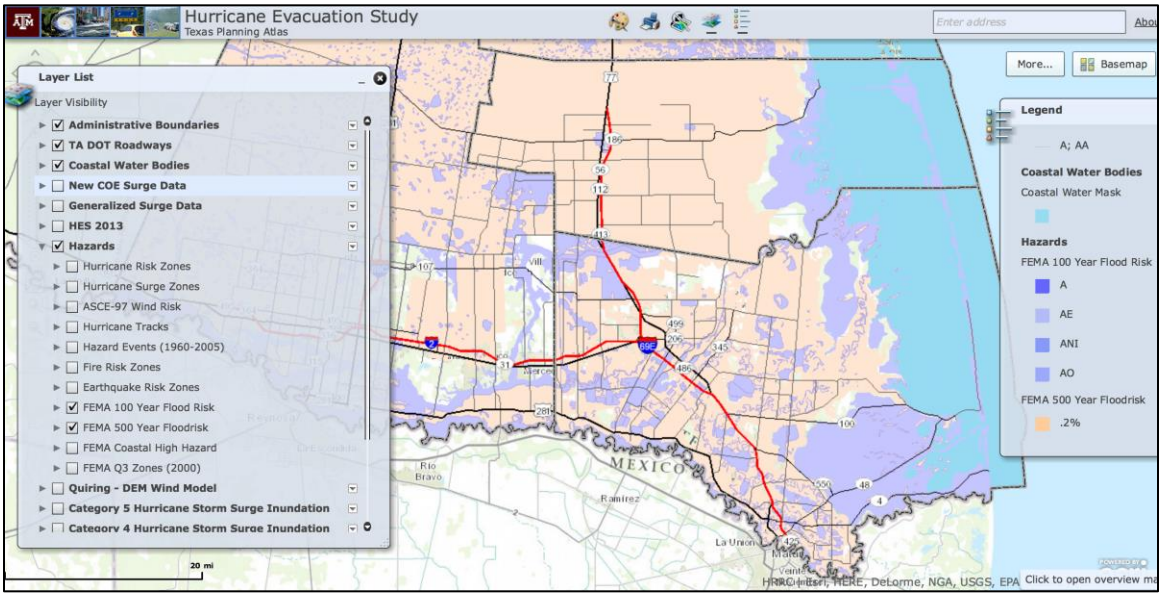

Figure 7. FEMA Flood Zones for the Valley Study Area

Figure 7 displays the FEMA flood data for the Valley Study Area. As can be readily seen, almost the entire area is included in either the 100-year or 500 year flood zones. Flood risk, weather from inland flooding or surge is a major problem for the area, particularly for the Willacy and Cameron counties.

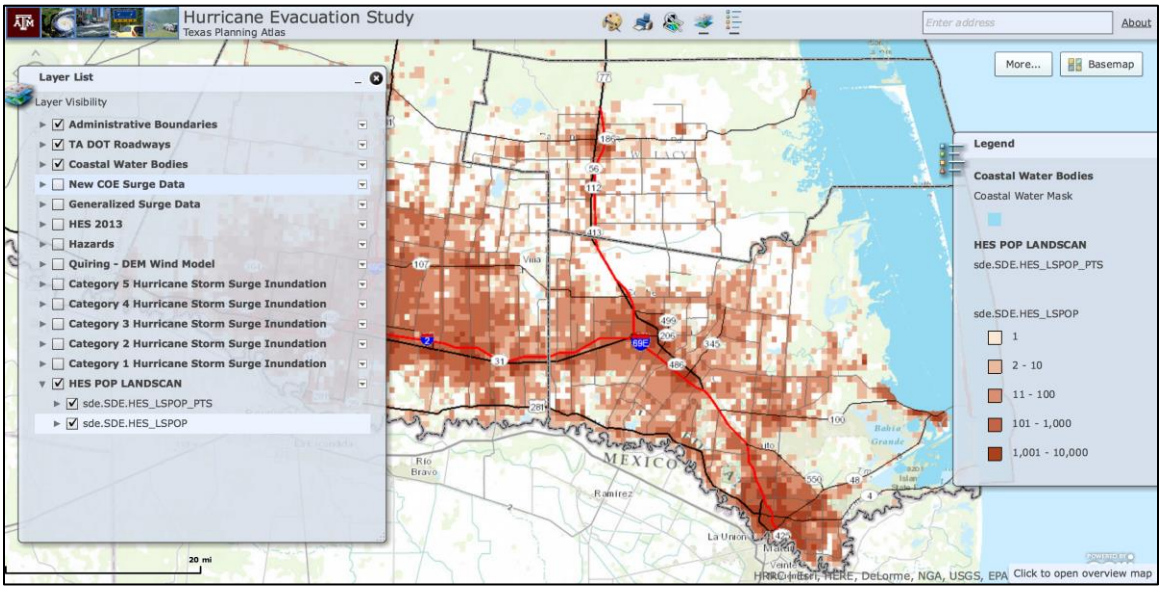

Figure 8. *Landscan* Population Density Data for the VSA

<u>Population Density Data</u>: The final data set utilized for developing the new evacuation zones captured population density. There are a variety of data that might be utilized to capture population density, such as U. S. Census data at the census block level. Unfortunately these data are only available from the decennial census and, most unfortunately, the census block can be rather large, particularly in more rural areas such as the eastern reaches of both Willacy and Cameron County. Fortunately there are population density data that have been produced by Oak Ridge National

Laboratory that capture an estimated number of people per square kilometer. Figure 8 displays the population density data for the VSA.

In addition to these layers, other data were employed periodically during the development of the evacuation zones. Most of these layers were available via *Esri* default background layers that were incorporated into the interactive web-based GIS platform created to facilitate evacuation zone development. These background layers included OpenStreetMap, Imagery layers, National Geographic, USGS National Topo Map, and USA Topo Map. Finally, we also made available older Hurricane Risk (Evacuation) Zone, Hurricane Surge Zone layers.

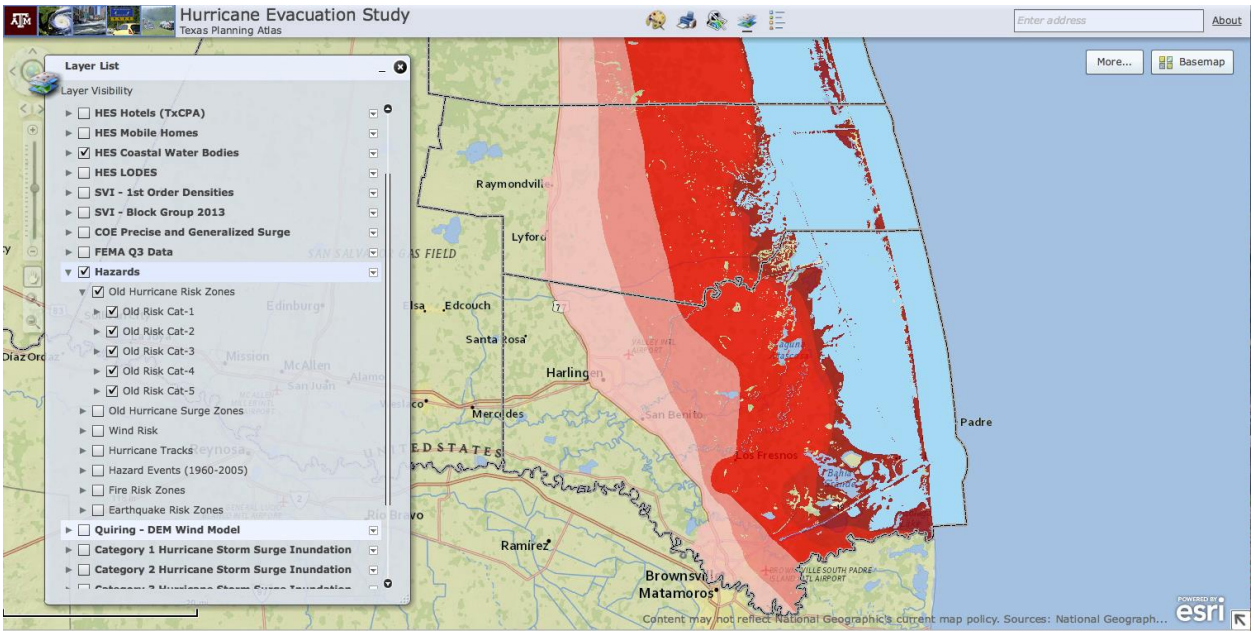

Figure 9. Old (current 2015 season) Hurricane Evacuation/Risk Zones for the VSA

Figure 9 displays the current, and soon to be old, hurricane evacuation/risk zones. There were five zones, although it may be difficult to see on this map. If you look closely, there is a slightly darker red zone (Category 2) just behind the darkest red zone (Category 1) that includes the barrier island and the immediate mainland shore. With the exception of the final evacuation zone, which had Highway 77 as its western boundary, the other boundaries are simply contours on the map, there are no clearly and readily identifiable features demarcating the boundaries between Zones. Often roadways, zip-codes, or other easily identifiable boundaries are utilized to demarcate evacuation zone boundaries. However, in this case, three are very few roadways right along the coast that might be used to identify boundaries and zip-codes in this area tend to run east and west, making them impossible to use consistently throughout the area.

General Guidelines and Principles for Zone Development

As part of the workshops with local stakeholders a set of guidelines and principles for establishing the new evacuation zones was developed after reviewing potential data inputs and general discussion. The guidelines were as follows:

1. Life safety will be of paramount concern when developing new evacuation zones.

2. Storm surge will be the key hazard risk driving evacuation zone development. Other hazards should be considered such as the generally high flooding potential for the area, and wind issues, particularly for mobile home residents.
3. Evacuation zone development should facilitate risk/warning communication such that the zones and their boundaries are easily communicable and interpretable by the public.
4. Evacuation zones should make sense for Emergency Management decision-making when calling for evacuations.
5. Storm categories should not be used as they were in the past to define 5 evacuation zones; rather, there should be three zones – A, B, & C – similar to those developed in the hurricane evacuation study carried out locally in 2013.

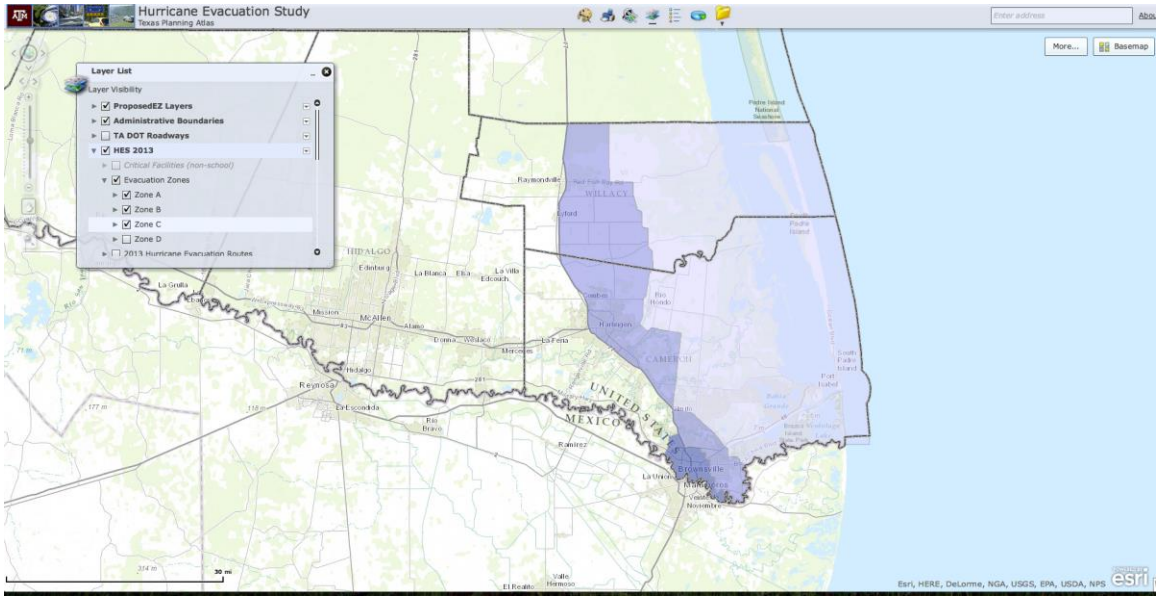

Figure 10. Old Hurricane Evacuation Zones Developed as Part of the Local 2013 Hurricane Evacuation Study.

In many respects the development of the new evacuation zones was made much easier by the fact that in 2013 Willacy and Cameron Counties had already worked on the development of three evacuations zones – A, B, & C. These zones are presented in Figure 10, where Zone A appears in light blue, Zone B in a darker shade of blue, and Zone C is the darkest area found over the western section of Brownsville. Furthermore, by going with three zones, it was much easier to employ highways and road to distinguish boundaries between each of the zones. Hence, based on the 2013 work, roads, highways, and other distinguishing geographic features became the default boundaries for the new evacuation zones.

The critical task therefore became incorporating the new surge modeling data and other data as necessary, analyzing how the 2013 zones might be modified to better capture potential surge risks. The TTI/HRRC team accomplished this by creating detailed maps of problematic areas where the 2013 boundaries should be modified given the most recent surge data. In almost all cases both the standard and generalized USACE data were employed, supplemented by image data, topographic data/maps, population data, road/highway network data and other data as necessary. Alternative boundary configurations were generated and these became the focus of discussions at the three workshops conducted with local communities in Willacy and Cameron Counties. Figure 11 presents

an example of some of the boundary alternatives consider for evacuation zone A, in Willacy and Cameron Counties. Much more detailed maps were generated for workshop discussion; this map is just an overview of areas to be discussed. The goal in all cases was to reach consensus of boundary decisions in each workshop. In all cases consensus was reached and new boundaries were generated.

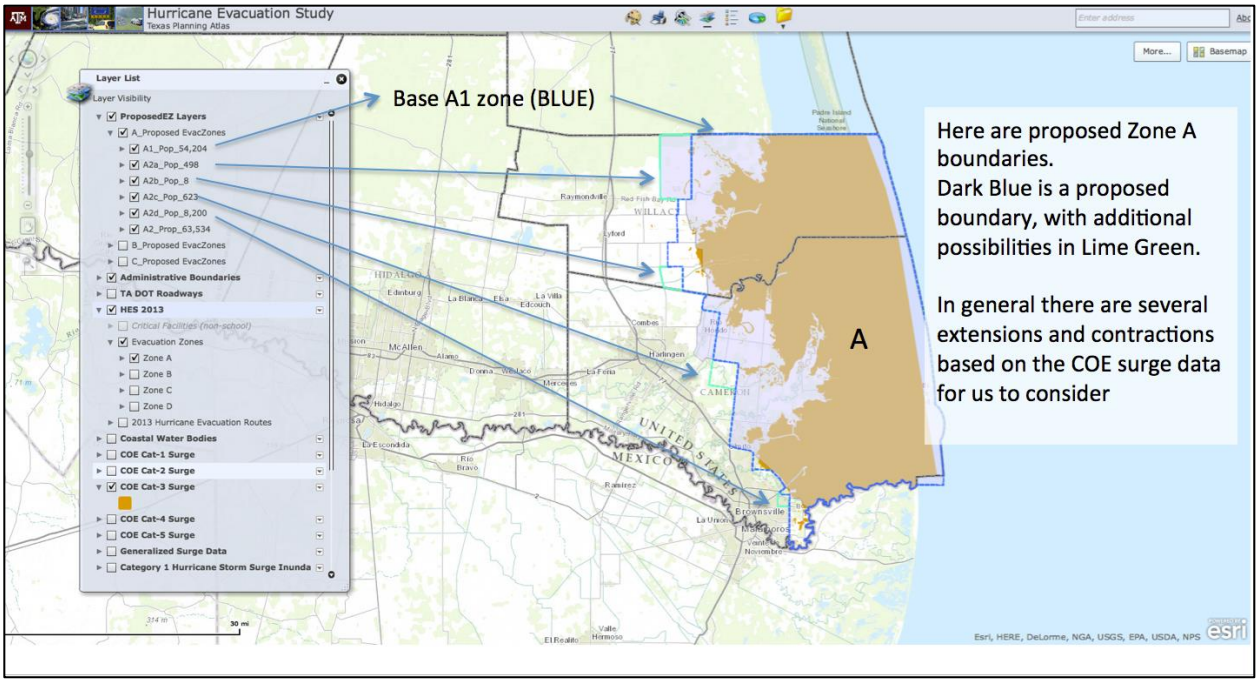

Figure 11. Potential Zones Boundaries Based on 2013 Hurricane Evacuation Study Boundaries.

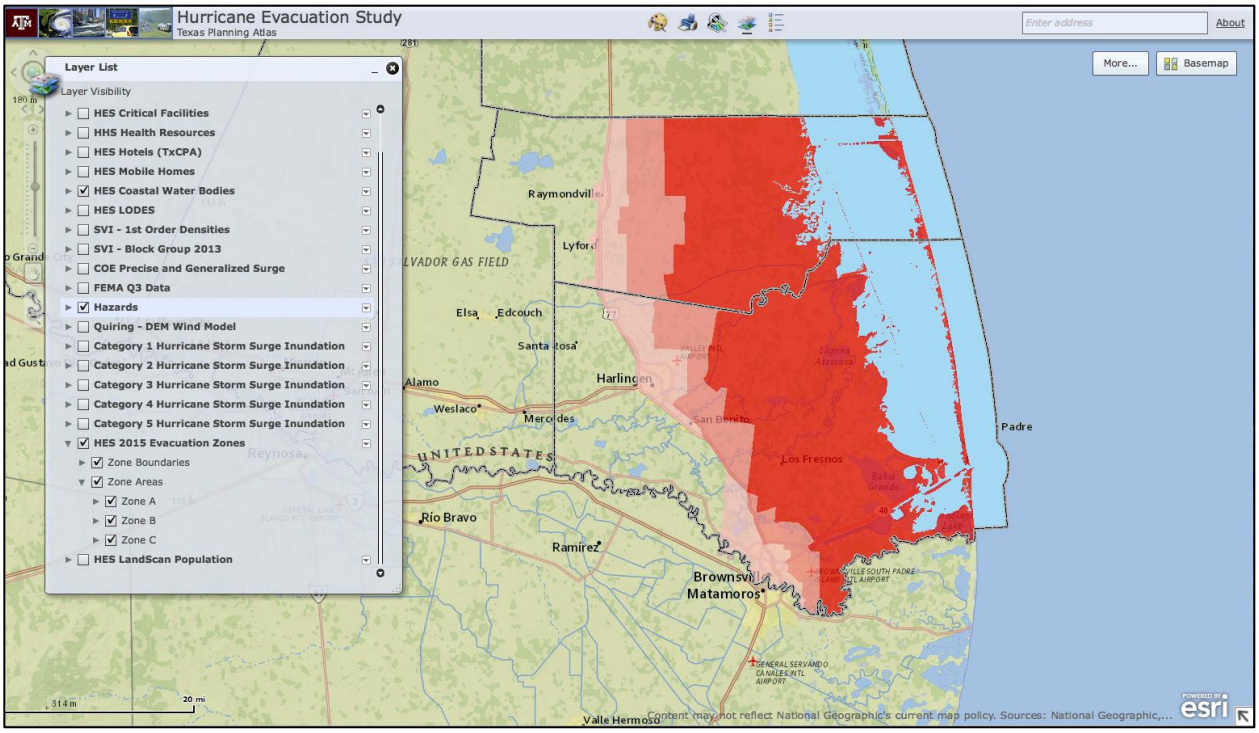

Figure 12. New Evacuation Zones for the VSA.

New Evacuation Zones

Figure 12 displays the new evacuation zones for Willacy and Cameron Counties. The dark red area is Zone A, the highest risk zone, followed by Zone B in in light red, and Zone C in pink. Areas not shaded in both Willacy and Cameron County should not be subject to hurricane surge. The following provides a brief description of the evacuation zones for each county.

Willacy County Evacuation Zones

Figure 13 displays the three evacuation zones for Willacy County. Zone A includes all of the barrier island, and much of the eastern third of the county including Port Mansfield, the Willamar Oil Field, extending just west of San Perlita in northern Willacy to the intersection with FM 507 and County Line Road (FM2629) in the South. Zone B is a fairly narrow strip extending west from Zone A. The boundary between Zones B and C begins in the north at a hypothetical line extending north from Cantu County Road to the boarder between Willacy and Kenedy Counties and ends in the south where Iris meets County Line Road (FM 2629). The final evacuation zone, Zone C, includes the cities of Raymondville, Lyford, and Sebastian in the south. The western boundary for Zone C is formed in the north by Expressway 77, but branches as one travels south to Business 77 and the western most boundaries for Raymondville, Lyford and Sebastian.

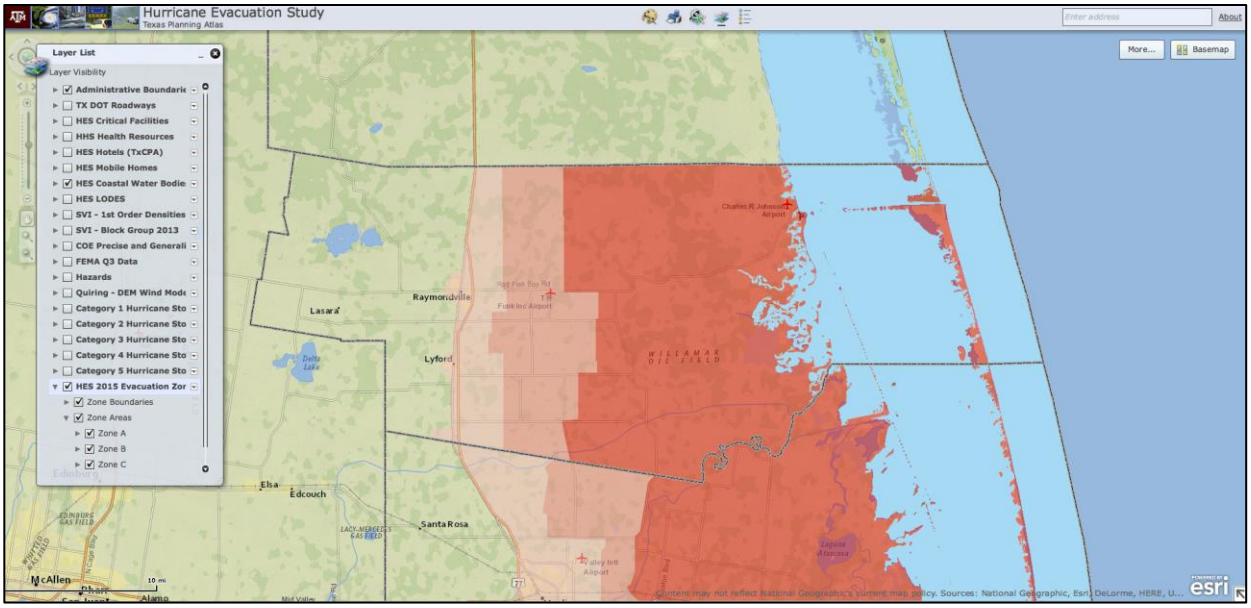

Figure 13. New Evacuation Zones for the VSA

Figure 14 zooms in to the northern section of Willacy County, capturing in more detail the road networks that define the boundaries for each of the zones. Figure 15 does the same for the southern sections of Willacy County.

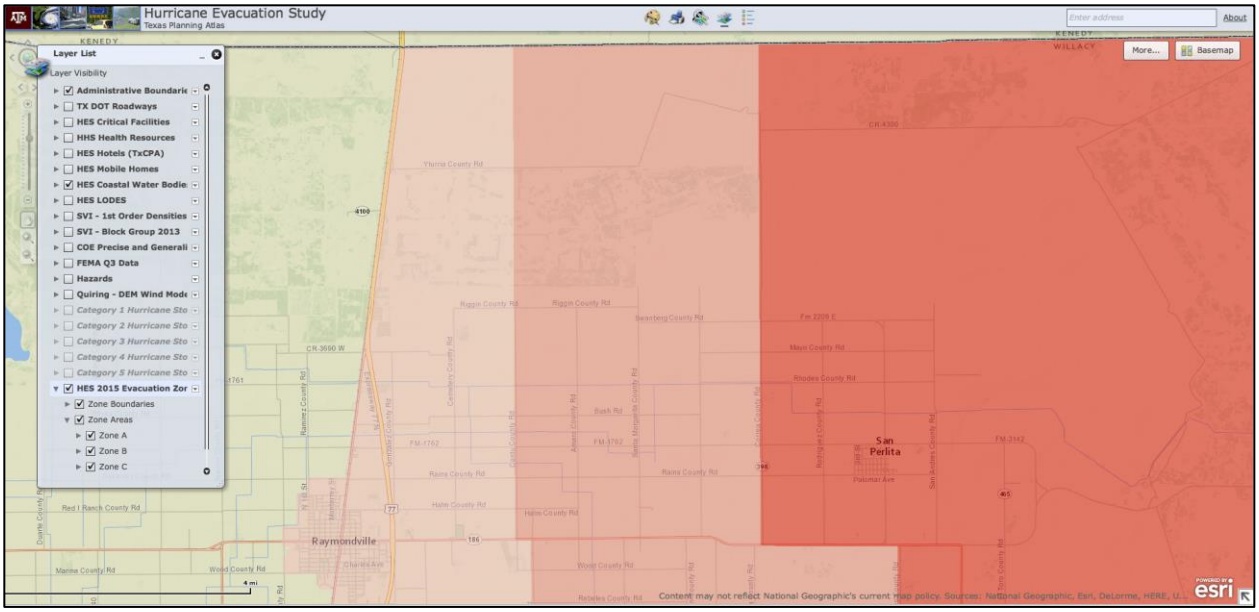

Figure 14. Evacuation Zone Boundaries for Northern Willacy County.

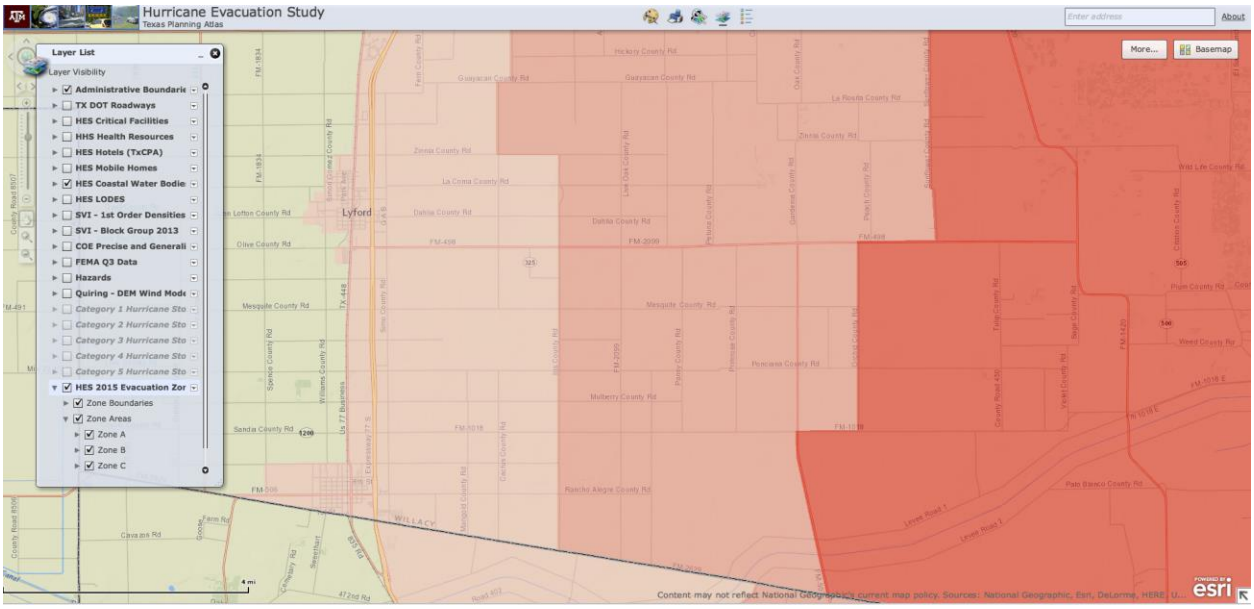

Figure 15. Evacuation Zone Boundaries for Southern Willacy County.

Cameron County Evacuation Zones

Figure 16 displays the evacuation zones for Cameron County. Zone A includes all of South Padre island including the cities of South Padre Island and Port Isabel on the mainland. It include just over a third of the county extending west of, and therefore including Rio Hondo in the north, Indian Lake, Bayview and Los Fresnos as one moves south, and the extending into the eastern boundaries of Brownsville, just east of the Brownsville-South Padre Island International Airport. Zone B begins

at the intersection of Road 402 and County Line Road (FM 2629) in the north, running south on Briggs Coleman Road, skirting east of Harlingen and the Valley International Airport, following FM

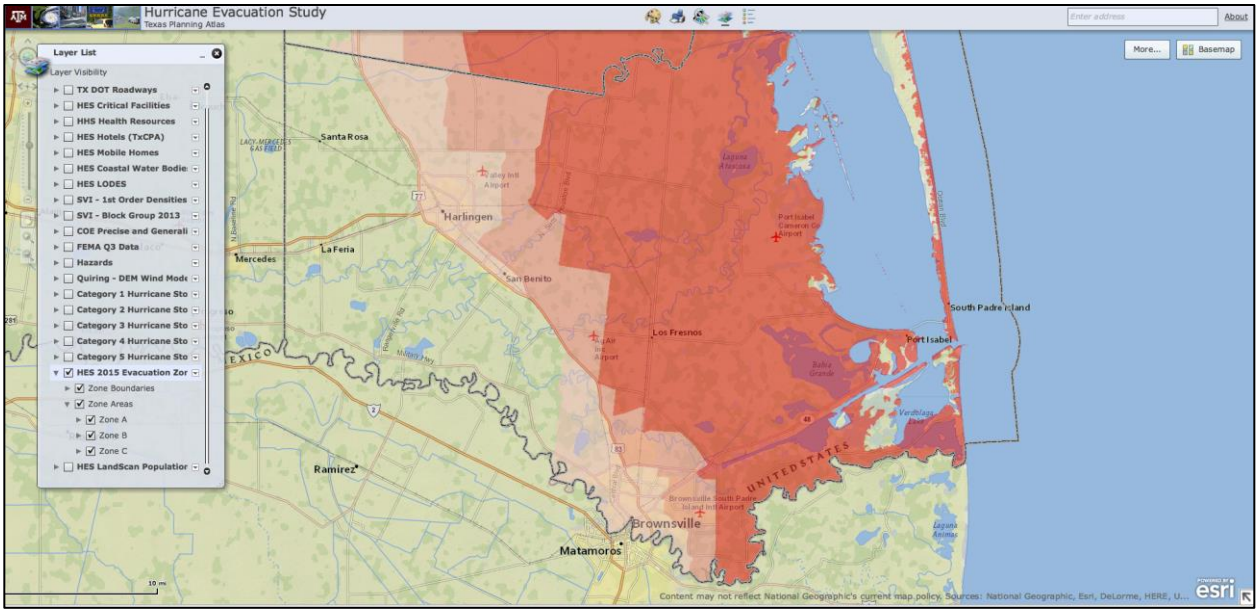

Figure 16. Evacuation Zones for Cameron County

509 and ultimately meeting up with Business 77, cutting through the northeastern part of San Benito and merging into Expressway 77. The southern section of Zone B includes a large swath arching through north and northeastern Brownsville and includes much of the most populous parts of east Brownsville, including areas around and to the south of the airport. Zone C is split into two parts, one of which includes the most populous urban areas in the county. In the north, Zone C includes all remaining areas east of US 77, including Harlingen and San Benito. In the southern parts of Cameron County, Zone C includes the remaining areas of Brownsville east of US 77 and all of the city west of US 77, and extends northwest to include all areas east of Carmen Boulevard, New Carmen Avenue, and Willow Drive. These latter areas include Olmito and Ranch Viejo.

Figures 17 through 22 provide more detailed views of the boundaries between Zones A, B, and C for Cameron County. These more detailed figures begin with the boundary area north of Harlingen in Figure 17, where the northern boundaries for each zone branch off of County Line road (FM 2629). Figure 18 is for the Harlingen area proper, followed by Figure 19 for San Benito, Figure 20 for the Olmito and Ranch Viejo area, Figure 21 for north and west Brownsville, and finally, Figure 22 for eastern and southern sections of Brownsville.

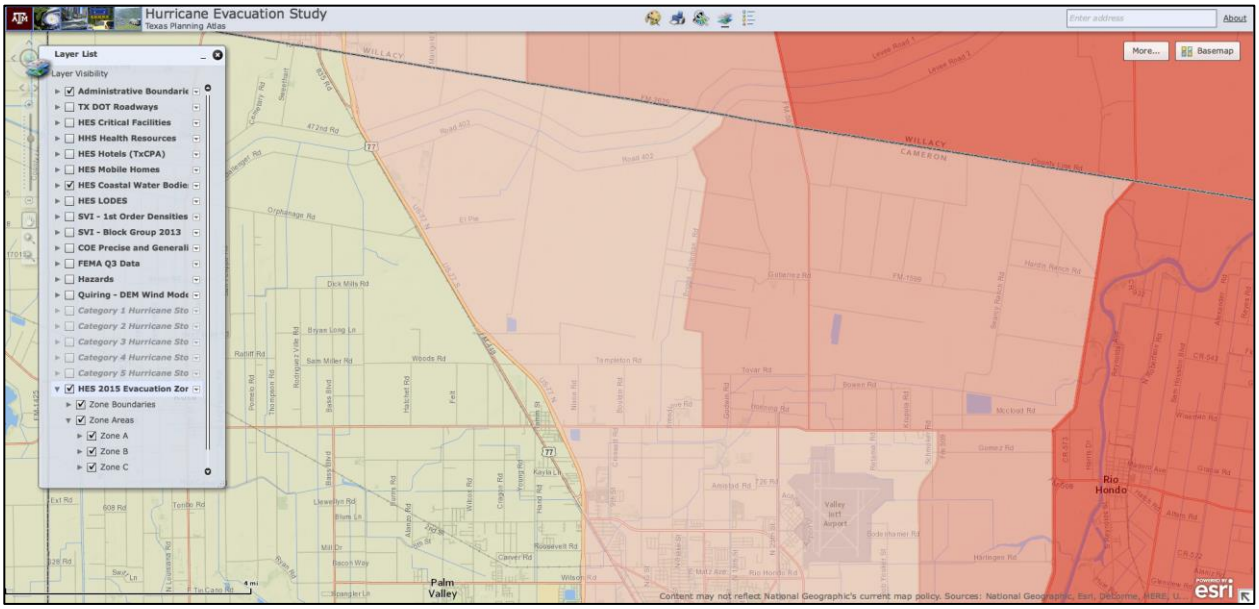

Figure 17. Evacuation Zone Boundaries: North of Harlingen

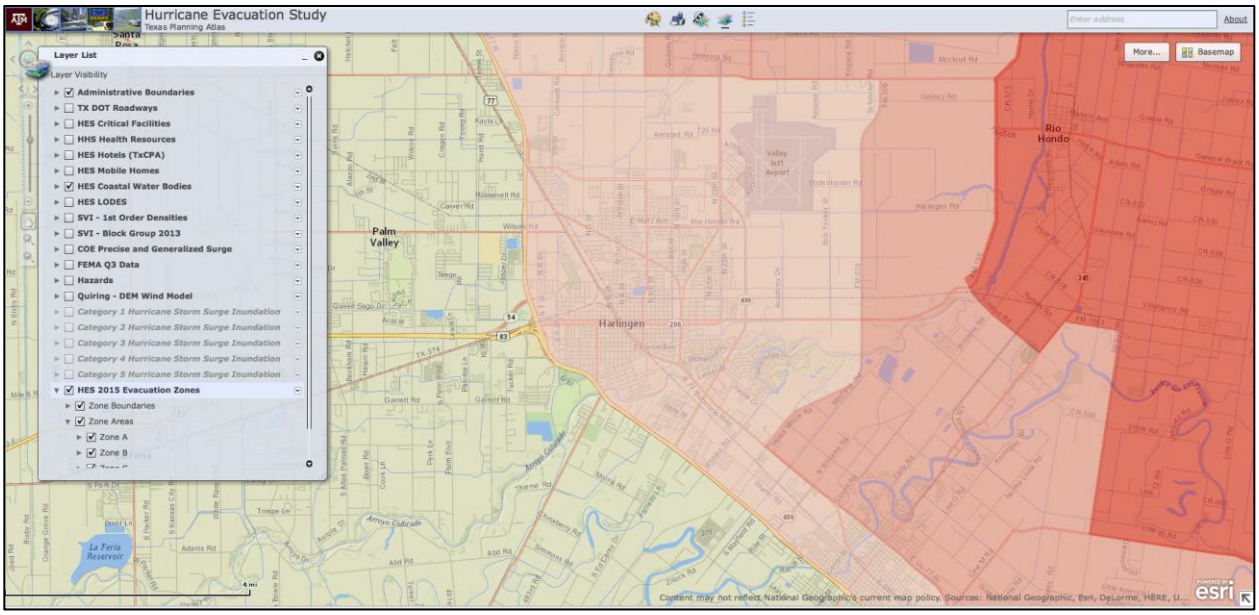

Figure 18. Evacuation Zone Boundaries: Harlingen

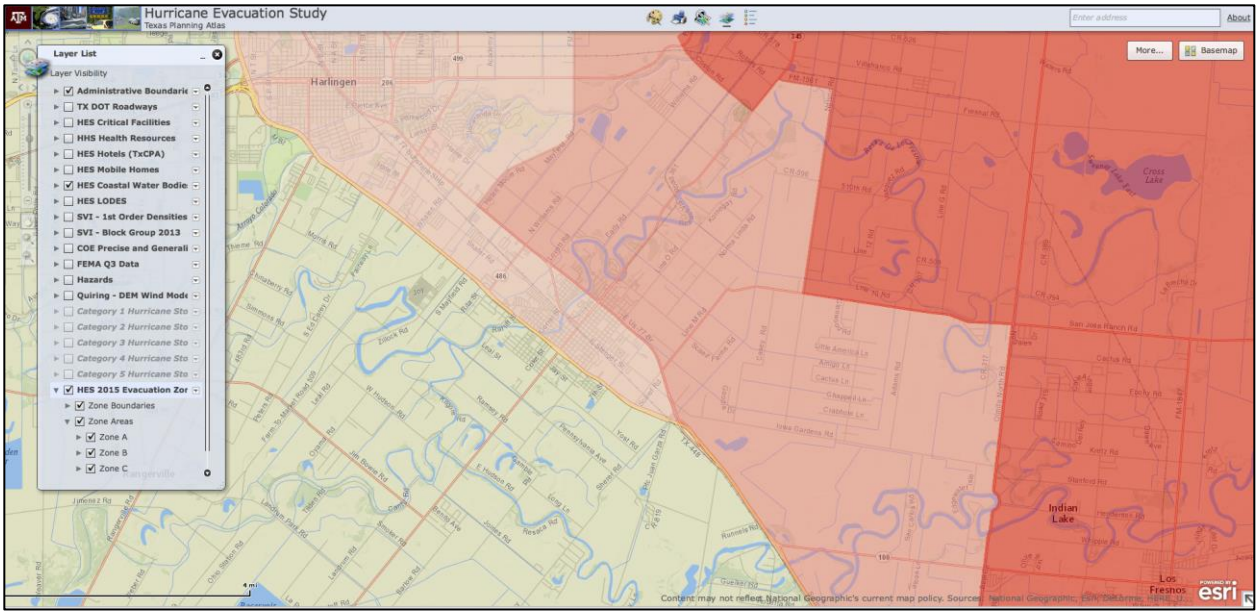

Figure 19. Evacuation Zone Boundaries: San Benito and Vicinities

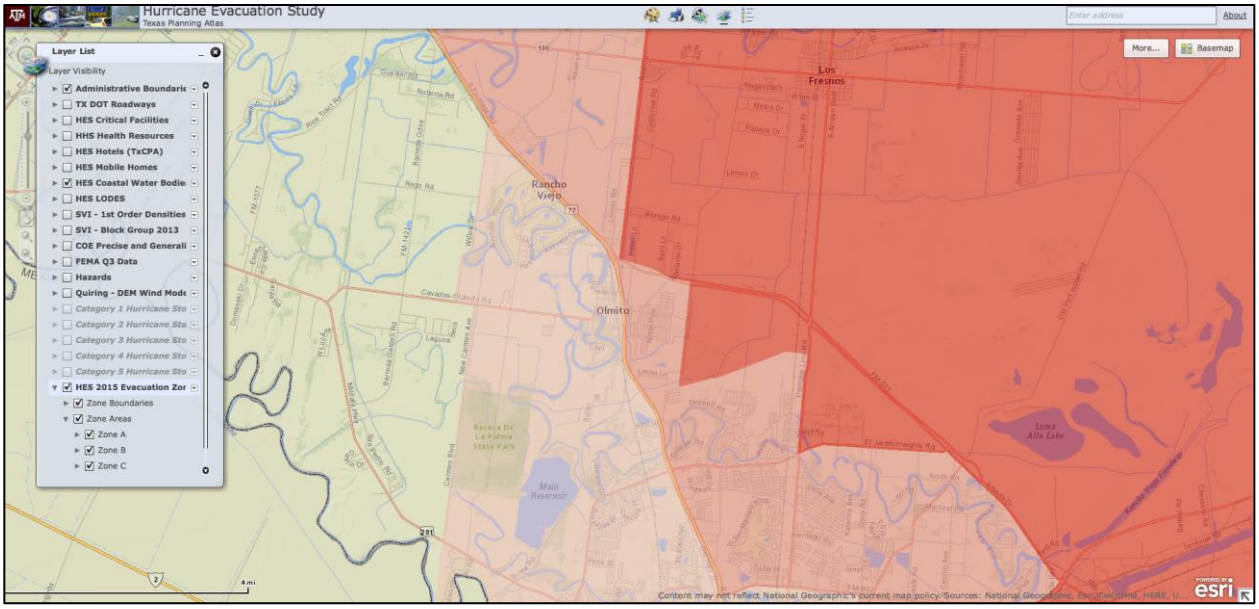

Figure 20. Evacuation Zone Boundaries: Ranch Viejo, Olmito, and Northwest Brownsville

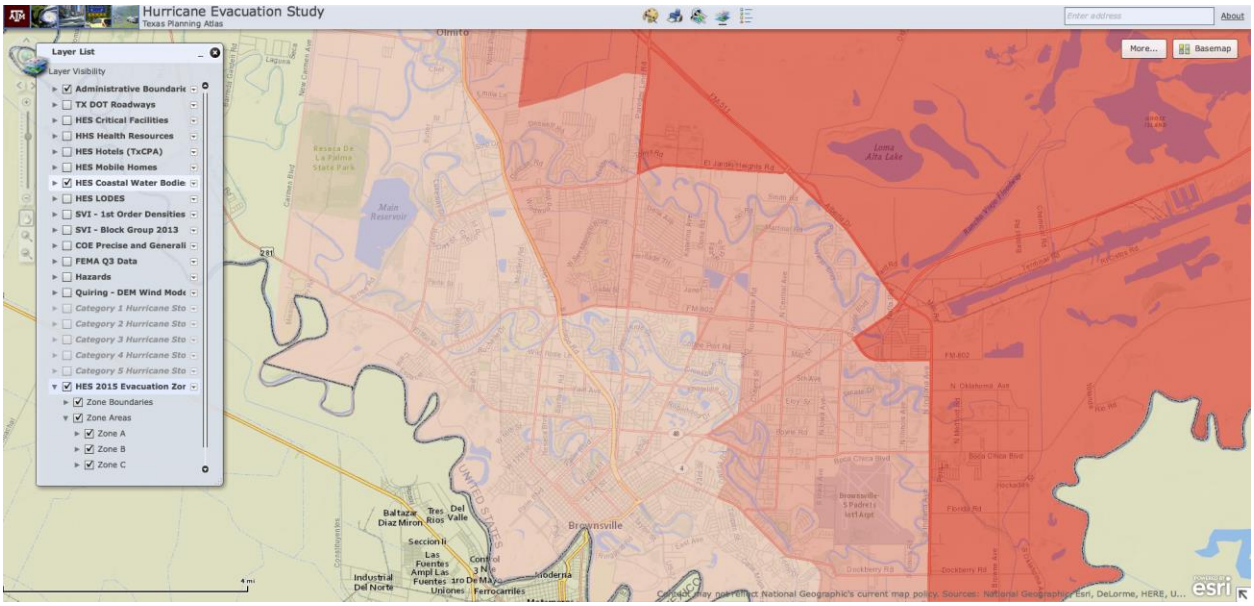

Figure 21. Evacuation Zone Boundaries: North and West Brownsville

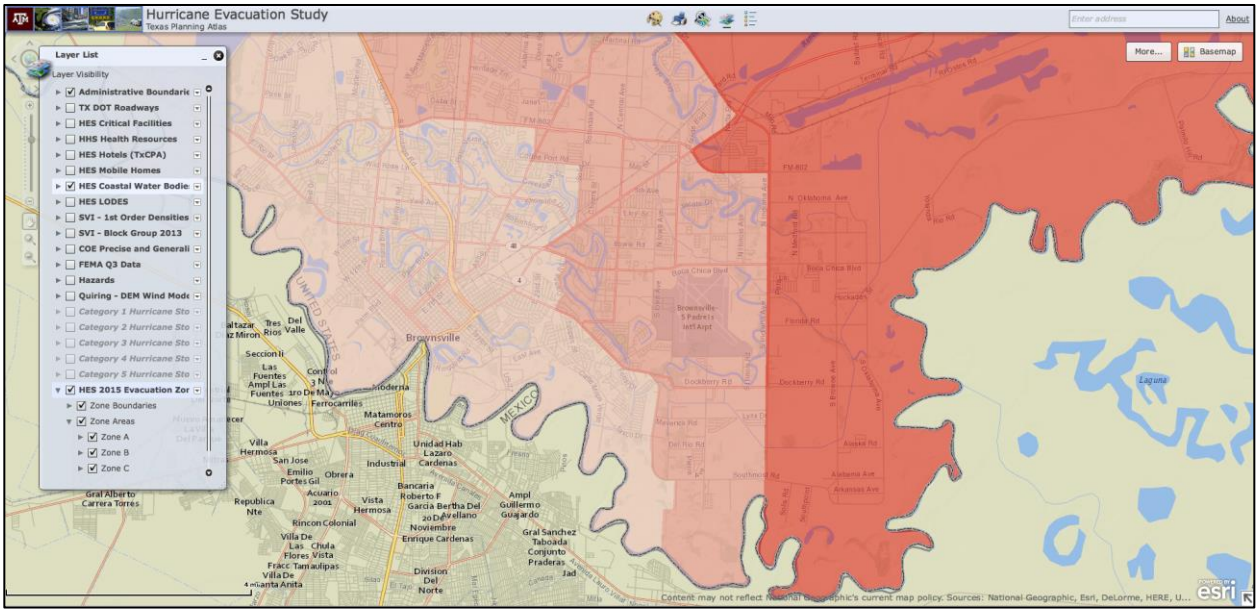

Figure 22. Evacuation Zone Boundaries: South and East Brownsville

Conclusions

While there are no recognized or established guidelines for the development of evacuation zones there are many examples previous studies (i.e., Wilmot and Meduri 2005). In this report, we draw on these previous studies, as well as the most current data sources, to develop an approach to creating evacuation zones for Cameron and Willacy Counties in South Texas. Evacuation zones must accomplish two purposes. First, they must be based on accurate data of where storm surge and wind damage are likely to occur. Second, zones must be drawn in a way that is readily understood by both the public and local authorities. It is critical that the local population be able to easily and readily identify their residential location relative to evacuation zones.

Researchers assembled data from a variety of official sources, processed it to be more comprehensible and interpretable, and using a Web-GIS interface, worked with over 100 stakeholders and officials representing over 40 local, state, and federal organizations, governments, and agencies to visualize threatened areas to identify three evacuation zones that were understandable to both residents and local authorities. These zones also form the basis for modeling different storm scenarios and clearance times in the subsequent traffic study and vulnerability analysis undertaken by the TTI/HRRC team.

REFERENCES

Islam, T., W. Merrell, W. Seitz, and R. Harriss. (2009) Origin, Distribution, and Timing of Texas Hurricanes: 1851-2006. *Natural Hazards Review*. DOI: 10.1061/(ASCE)1527-6988(2009)10:4(136).

Michael K. Lindell, Yue Ge, Shih-Kai Huang, Carla S. Prater, Hao-Che Wu, HungLung Wei. *Behavioral Study, Valley Hurricane Evacuation Study, Willacy, Cameron, and Hidalgo Counties, Texas.* Texas A&M University Hazard Reduction & Recovery Center, September 2013.

Wilmot, C.G. and N. Meduri. (2005) Methodology to Establish Hurricane Evacuation Zones. Transportation Research Record: Journal of the Transportation Research Board, No. 1922, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 29–137.