6.5.4 Tropical Systems and Hurricanes

6.5.4.1 Hazard Identification

Description of the Tropical System and Hurricane Hazard

Hurricanes, tropical storms, and typhoons, also classified as cyclones, are any closed circulation developing around a low-pressure center in which the winds rotate counter-clockwise in the Northern Hemisphere (or clockwise in the Southern Hemisphere) and whose diameter averages 10 to 30 miles across. A tropical cyclone refers to any such circulation that develops over tropical waters. Tropical cyclones act as a "safety-valve," limiting the continued build-up of heat and energy in tropical regions by maintaining the atmospheric heat and moisture balance between the tropics and the pole-ward latitudes. The pr 6imary damaging forces associated with these storms are high-level sustained winds, heavy precipitation, and tornadoes. Coastal areas are also vulnerable to the additional forces of storm surge, wind-driven waves, and tidal flooding which can be more destructive than cyclone wind.

The key energy source for a tropical cyclone is the release of latent heat from the condensation of warm water. Their formation requires a low-pressure disturbance, warm sea surface temperature, rotational force from the spinning of the earth, and the absence of wind shear in the lowest 50,000 feet of the atmosphere. The majority of hurricanes and tropical storms form in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico during the official Atlantic hurricane season, which encompasses the months of June through November. The peak of the Atlantic hurricane season is in early to mid-September and the average number of storms that reach hurricane intensity per year in this basin is six (6).

Severity of the Tropical System and Hurricane Hazard

As an incipient hurricane develops, barometric pressure (measured in millibars or inches) at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 miles per hour, the system is designated a tropical storm, given a name, and is closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 miles per hour the storm is deemed a hurricane. Hurricane intensity is further classified by the Saffir-Simpson Scale, which rates hurricane intensity on a scale of 1 to 5, with 5 being the most intense. The Saffir-Simpson Scale is shown in Table 6.5.4.1-1.

Table 6.5.4.1-1
Traditional Saffir-Simpson Scale

Category	Maximum Sustained Wind Speed (MPH)	Minimum Surface Pressure (Millibars)	Storm Surge (Feet)
1	74—95	Greater than 980	3—5
2	96—110	979—965	6—8
3	111—130	964—945	9—12
4	131—155	944—920	13—18
5	155+	Less than 920	19+

Source: National Hurricane Center.

The Saffir-Simpson Scale categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential, which are combined to estimate potential damage. Categories 3, 4, and 5 are classified as "major" hurricanes, and while hurricanes within this range comprise only 20 percent of total tropical cyclone landfalls, they account for over 70 percent of the damage in the United States. Table 6.5.4.1-2 describes the damage that could be expected for each category of hurricane.

Table 6.5.4.1-2
Hurricane Damage Classification

Category	Damage Level	Description
1	Minimal	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage.
2	Moderate	Some roofing material, door, and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings may break their moorings.
3	Extensive	Some structural damage to small residences and utility buildings, with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland.
4	Extreme	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.
5	Catastrophic	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required.

Source: National Hurricane Center.

A storm surge is a large dome of water often 50 to 100 miles wide and rising anywhere from four to five feet in a Category 1 hurricane up to 20 feet in a Category 5 storm. The storm surge arrives ahead of the storm's actual landfall and the more intense the hurricane is, the sooner the surge arrives. Water rise can be very rapid, posing a serious threat to those who have not yet evacuated flood-prone areas. A storm surge is a wave that has outrun its generating source and become a long period swell. The surge is always highest in the right-front quadrant of the direction in which the hurricane is moving. As the storm approaches shore, the greatest storm surge will be to the north of the hurricane eye. Such a surge of high water topped by waves driven by hurricane force winds can be devastating to coastal regions, causing severe beach erosion and property damage along the immediate coast.

Storm surge heights, and associated waves, are dependent upon the shape of the continental shelf (narrow or wide) and the depth of the ocean bottom (bathymetry). A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water close to the shoreline, tends to produce a lower surge but higher and more powerful storm waves.

In recent years there has been growing recognition and acknowledgement that the traditional Saffir-Simpson Scale is ineffective at estimating or predicting storm surge heights. Storm surge height is not strictly a function of wind speed and storm strength, but is influenced by a number of geographic variables (discussed above). For example, though Hurricane Ike made landfall in Galveston as a Category 2 storm, with winds averaging 100 MPH, the storm surge experienced in Galveston was that of a Category 4 storm. The category assignment applied to Hurricane Ike, based on sustained wind speed, simply could not account for the severity of the hazards posed by the storm.

The following discussion was obtained from the National Hurricane Center's website:

> The National Weather Service believes that a better approach is to focus directly on conveying the depth of inundation expected at the coast and inland. Because storm surge-induced flooding has killed more people in the United States in hurricanes than all other hurricane-related threats (freshwater flooding, winds, and tornadoes) combined since 1900 the National Oceanic and Atmospheric Administration is working to enhance the analysis and prediction of storm surge. Direct estimates of inundation are being communicated in the NHC's Public Advisories and in the Weather Forecast Office's Hurricane Local Statements. New ways of communicating the threat have also been developed. NHC's probabilistic storm surge product, which provides the likelihood of storm surge values from 2 through 25 feet, became operational in 2009, and the NWS's Meteorological Development Laboratory is providing experimental, probabilistic storm surge exceedance products for 2010. In addition, coastal WFOs will provide experimental Tropical Cyclone Impacts Graphics in 2010; these include a qualitative graphic on the expected storm surge impacts. Finally, the NWS is exploring the possibility of issuing explicit Storm Surge Warnings, and such warnings could be implemented in the next couple of years. In all of these efforts, the NWS is working to provide specific and quantitative information to support decision-making at the local level.

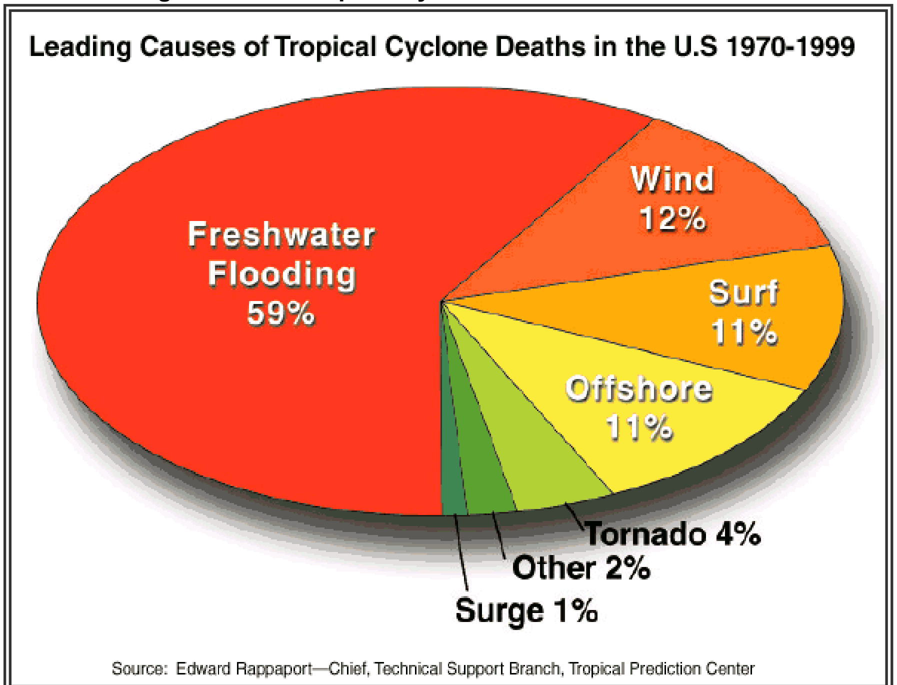
Impact to People and Property from the Tropical System and Hurricane Hazard

Tropical systems and hurricanes present a variety of hazards to both people and property. The threats associated with tropical systems and hurricanes are primarily extreme wind, flooding and storm surge, though other hazards can and do present themselves before, during and after a tropical system or hurricane makes landfall.

Damage during hurricanes may also result from spawned tornadoes and inland flooding associated with heavy rainfall that usually accompanies these storms. Hurricane Floyd, as an example, was at one time a Category 4 hurricane racing towards the North Carolina coast. As far inland as Raleigh, the state capital located more than 100 miles from the coast, communities were preparing for extremely damaging winds exceeding 100 miles per hour. However, Floyd made landfall as a Category 2 hurricane and will be remembered for causing the worst inland flooding disaster in North Carolina's history. Rainfall amounts were as high as 20 inches in certain locales and 67 counties sustained damages.

Texas is affected by a large number of tropical weather systems. Recent research indicates that inland flooding was responsible for the greatest number of fatalities over the last 30 years. Studies also show that 59 percent of the tropical cyclone deaths in the United States resulted from severe inland flooding (Figure 6.5.4.1-1).

Figure 6.5.4.1-1
Leading Causes of Tropical Cyclone Deaths in the United States



Source: Tropical Prediction Center

Occurrences of the Tropical System and Hurricane Hazard

Though not a coastal area, the planning area has experienced a number of tropical systems and hurricanes. This section discusses some of those storms and their impacts. Note that this is not an exhaustive list, but is only a representation to illustrate the types of impacts that these storms have had on the planning area.

09/06/2002 to 09/09/2002 - Atascosa, Bandera, Bexar, Comal, Frio, Gillespie, Guadalupe, Karnes, Medina and Wilson Counties

Isolated showers had occurred over much of South Central Texas in advance of Tropical Storm Fay on Friday, September 6, 2002. Tropical Storm Fay came ashore near Palacios on September 7. Rainfall, at first spotty, became widespread by mid morning. Heavier amounts had fallen from Bandera to San Antonio to Uvalde that averaged between one (1) and two (2) inches, with isolated totals to near six (6) inches. Flash flooding developed over Bandera, Bexar, and Medina counties in the early afternoon, ending in the early evening. Around a dozen rescues occurred in deep water. One mother and daughter drove past a barricade and had to be rescued as their car became submerged. Minor damage was reported to bridges and county roads. By late afternoon, rainfall was widespread across South Central Texas, having spread westward to the Rio Grande. A band of heavy rain stretching from near San Antonio through Floresville to Karnes City produced an additional round of flash flooding from late afternoon into the early evening. Rain amounts averaged from one (1) to two (2) inches with isolated totals to near nine (9) inches in the western part of Wilson County. The planning area experienced $1.3 million in property damage and $250,000 in crop damages; a total of 31 injuries were reported.

10/02/2007 – Medina and Bexar Counties

Tropical Storm Erin heavily impacted Medina and Bexar counties, resulting in more than $5,000,000 in federal disaster assistance to the affected counties.

Because the planning area is located inland of the Texas coastline, hurricanes usually lose strength as they make landfall and move northward without hurricane force winds impacting the area. However, the area has been impacted by hurricanes in the past and it can be expected that they will experience more hurricanes in the future. Table 6.5.4.1-3 includes records of historical hurricanes affecting the AACOG area since 1950. While other hurricanes have undoubtedly impacted the area, the systems had lost their tropical characteristics by the time they reached the planning area, and so were not recorded as either hurricanes or tropical systems.

Table 6.5.4.1-3
Historical Occurrences of Hurricanes

Storm Event	Location	Date	Deaths	Property Damage
Carla	Karnes County and almost entire Texas coast	09/14/1961	0	$400,000,000
Beulah	All AACOG area and Southeast Texas	09/20/1967	15	$100,000,00

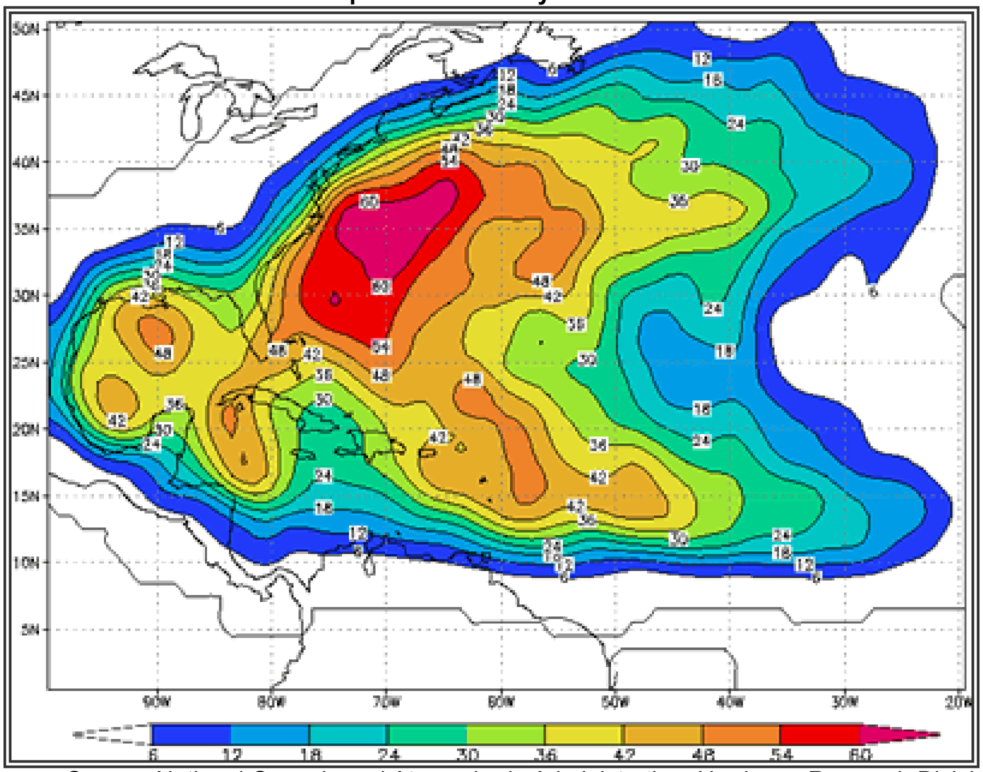
Source: National Climatic Data Center

Map 6.5.4.1-3 shows the tracks of the tropical storms and hurricanes that have passed through the planning area. (This map is found later in this subsection.)

Probability of Future Occurrences of the Tropical System and Hurricane Hazard

Figure 6.5.4.1-2 shows for any particular location what the chance is that a tropical storm or hurricane will affect the area sometime during the entire June to November Atlantic hurricane season. The figure was created by the National Oceanic and Atmospheric Administration's Hurricane Research Division using data from 1944 to 1999 and counting hits when a storm or hurricane was within approximately 100 miles (165 km) of each location.

Figure 6.5.4.1-2
Empirical Probability of a Named Storm



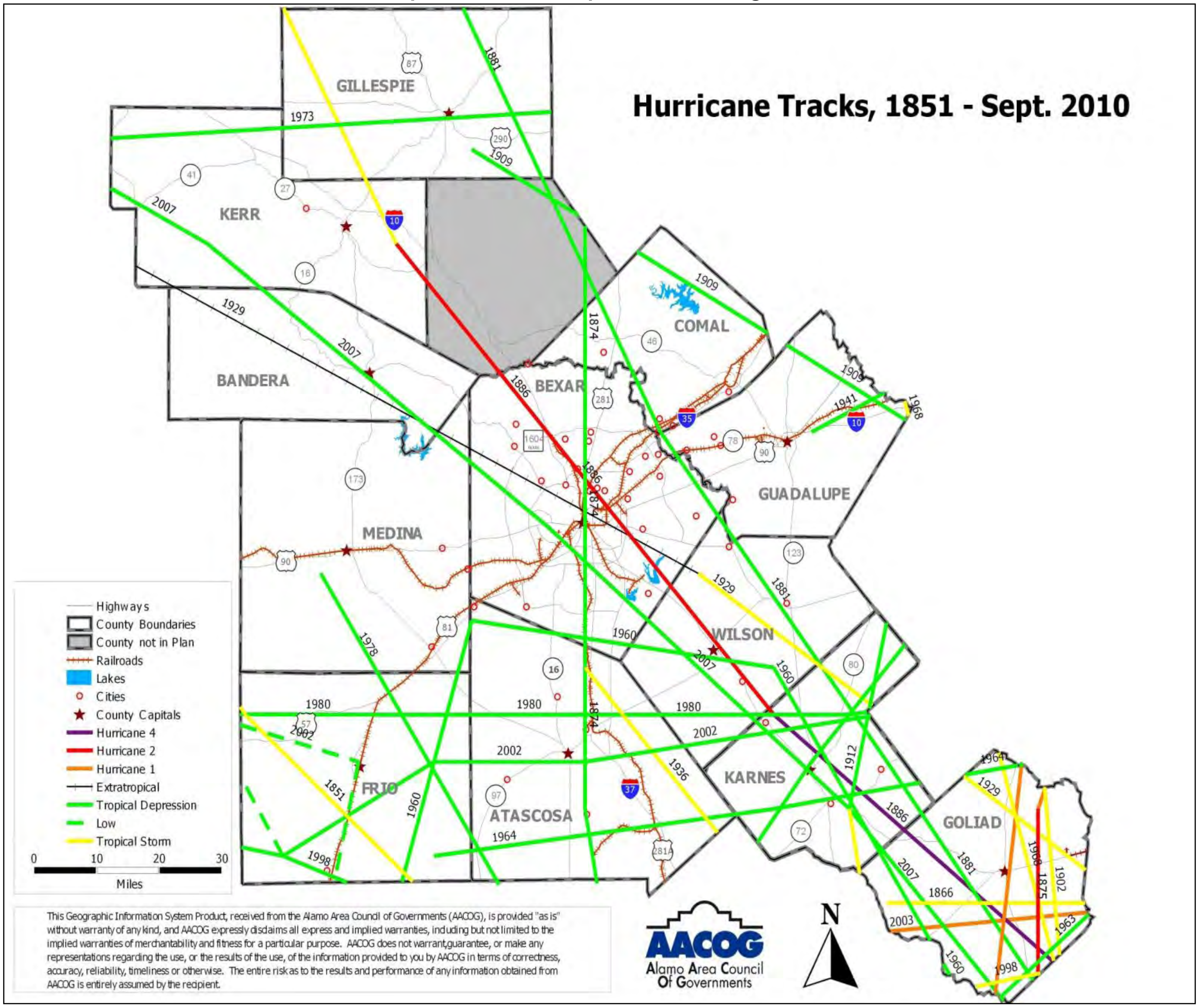
Source: National Oceanic and Atmospheric Administration, Hurricane Research Division.

Based on historical occurrences, the probability of a future occurrence of the hurricane/tropical system hazard is moderate.

Location and Extent of the Tropical System and Hurricane Hazard

Map 6.5.4.1-1 shows the tropical systems and hurricanes that have impacted the entire planning area. This map included all storms recorded between 1851 and September 2010. This map includes those systems that began as tropical systems but had lost their tropical characteristics prior to reaching the planning area.

Map 6.5.4.1-1
Historical Tropical Events to Impact the Planning Area



6.5.4.2 Risk Assessment

This subsection of the Plan Updates provides estimates of future tropical system / hurricane losses, i.e. risk. Each of the loss calculations is based on best available data, but they must be considered estimates because highly detailed engineering was not performed as part of this planning process.

Methodology and Limitations

After discussion and review of the best available data regarding this hazard, and in consideration of the potential impacts of this hazard to the planning area, the EMC determined that the risk assessment should include both qualitative and quantitative analyses, to the extent possible.

Qualitative
Each participating jurisdiction was asked to provide a qualitative risk assessment ranking regarding the tropical system / hurricane hazard. (For definitions of these rankings, please see Table 6.4-1, earlier in this section.) The results of this assessment are presented in the table below.

6.5.4.2-1
Qualitative Risk Assessment Results – Tropical System / Hurricane

Jurisdictions Ranking Hazard as Low	Jurisdictions Ranking Hazard as Moderate		Jurisdictions Ranking Hazard as High	
City of Kirby City of Somerset Gillespie County City of Fredericksburg	Bandera County City of Bandera Bexar County City of Alamo Heights City of Balcones Heights City of Converse City of Helotes City of Leon Valley City of Live Oak City of St. Hedwig City of Terrell Hills City of Universal City	City of Von Ormy City of Windcrest Frio County Guadalupe County City of Schertz Karnes County Medina County City of Castroville City of Devine City of Hondo City of Natalia City of La Vernia San Antonio River Authority	Atascosa County City of Charlotte City of Christine City of Jourdanton City of Lytle City of Pleasanton City of Poteet City of San Antonio Comal County City of Garden Ridge City of Bulverde City of New Braunfels	City of Dilley City of Pearsall City of New Berlin City of Seguin City of Karnes City of Kenedy City of Runge City of Falls City Kerr County City of Ingram City of Kerrville Wilson County City of Stockdale

Quantitative
Each participating jurisdiction provided information regarding the location and type of critical facilities within their planning area. These facilities were mapped in relation to the Wind Risk Zone 3 provided by the Texas Hazard Mitigation Package (THMP). Relative risk areas defined by wind zones are categorized into 5 classes using the “natural breaks” method. This method defines classes based on natural groupings of data values; break points are identified by looking for patterns inherent in the data; then ranges are set where there are relatively big jumps in the data values. Given the lack of building specific data (only location and use type were available), this analysis assumes that all facilities located within the Wind Risk Zone 3 are potentially at risk from the high winds associated with Tropical Storms and Hurricanes. Table 6.5.42.2-2 lists the facilities at risk by jurisdiction

6.5.4.2-2
Quantitative Risk Assessment Results – Tropical System / Hurricane

Jurisdiction	Facilities within Wind Risk Zone 3
Atascosa	1 – Courthouse 6 – Airports 1 – Hospital 9 – Nursing Homes 2 – Police Stations 1 – Power Plant 21 – Schools 14 – Water Supply 10 – Fire Stations
Bandera	1 – City Hall 15 – Airport 7 – Communications 2 – Courthouses 5 – Courts 4 – Day Cares 3 – Emergency Response 9 – Fire Departments 3 – Hospitals 1 – Nursing Home 26 – Other 2 – Police Department 2 – Power Supply 8 – Schools 1 – Transportation 1 – Water Supply
Bexar	23 – Airport 11 – City Halls 46 – Communications 7 – Corrections 3 – Court Houses 41 – Day Cares 2 – Emergency Response 64 – Fire Departments 25 – Fire Stations 68 – Hospitals 6 – Military 168 – Nursing Homes 27 – Other 21 – Police Departments 27 – Police Stations 1 – Power Plant 20 – Power Supply 17 – Public Works 521 – Schools 5 – Stadiums

Jurisdiction	Facilities within Wind Risk Zone 3
	5 – Town Halls 2 – Transportation 74 – Water Supply
Comal	5 – Airport 1 – Communication 1 – Courthouse 5 – Fire Stations 1 – Hospital 11 – Nursing Homes 1 – Power Plant 38 – Schools 12 – Water Supply
Frio	5 – Airport 2 – Communication 1 – Courthouse 3 – Fire Stations 3 – Hospitals 3 – Nursing Homes 3 – Police Stations 1 – Power Plant 7 – Schools 4 – Water Supply
Gillespie	11 – Airport 1 – Courthouse 1 – Day Care 1 – Fire Department 5 – Fire Stations 1 – Hospital 8 – Nursing Homes 10 – Other 1 – Police Department 1 – Power Supply 1 – Public Works 15 – Schools 2 – Water Supply
Guadalupe	14 – Airport 3 – Communications 1 – Courthouse 1 – Hospital 13 – Fire Stations 11 – Nursing Homes 2 – Police Stations 4 – Power Plants 34 – Schools 12 – Water Supply
Karnes	6 – Airport 3 – City Halls

Jurisdiction	Facilities within Wind Risk Zone 3
	1 – Courthouse 5 – Day Cares 2 – Emergency Response 1 – Fire Department 5 – Fires stations 3 – Hospitals 12 – Nursing Homes 11 – Other 3 – Police Departments 1 – Police Station 15 – Schools 5 – Water Supply 6 – Un-categorized
Kerr	10 – Airport 1 – City Hall 6 – Communications 1 – Courthouse 9 – Day Cares 5 – Fire Departments 8 – Fire Stations 2 – Fuel Supply 11 – Nursing Homes 4 – Other 3 – Police Departments 1 – Police Station 3 – Power Supply 29 – Schools 4 – Transportation 3 – Water Supply
Medina	7 – Airports 1 – Communication 1 – Courthouse 6 – Fire Stations 1 – Hospital 6 – Nursing Homes 3 – Police Stations 22 – Schools 5 – Water Supply
Wilson	8 – Airport 4 – City Halls 10 – Communications 1 – Courthouse 20 – Day Cares 3 – Fire Departments 8 – Fire Stations 5 – Fuel Distributors 2 – Hospitals 5 – Nursing Homes

Jurisdiction	Facilities within Wind Risk Zone 3
	7 – Other 32 – Schools 26 – Water Supply

Data to collect in order to improve this methodology prior to the Plan Update includes:

- Data regarding building construction (materials, protection systems, etc.)

Risk Assessment Conclusions

A significant number of critical facilities within each jurisdiction fall within the Wind Risk Zone 3. Jurisdictions should consider assessing the wind ratings of these facilities to determine if mitigation actions are needed.