

Section 7 Risk Assessment

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7.1 Interim Final Rule Requirement for Risk Assessment

Requirement §201.6(c)(2): *The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.*

Requirement §201.6(c)(2)(ii): *[The risk assessment shall include a] description of the jurisdiction’s vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.*

Requirement §201.6(c)(2)(ii): *[The risk assessment] **must** also address National Flood Insurance Program (NFIP) insured structures that have been repetitively damaged floods.*

Requirement §201.6(c)(2)(ii)(A): *The plan **should** describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard area . .*

Requirement §201.6(c)(2)(ii)(B): *[The plan **should** describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(ii)(A) of this section and a description of the methodology used to prepare the estimate . .*

Requirement §201.6(c)(2)(ii)(C): *[The plan **should** describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation*

options can be considered in future land use decisions.

Requirement §201.6(c)(2)(iii): *For multi-jurisdictional plans, the risk assessment **must** assess each jurisdiction's risks where they vary from the risks facing the entire planning area.*

In 2005, the National Hurricane Center compiled a list of the five places in the United States most vulnerable to hurricanes. Galveston was one of the five areas names. Low elevation and limited evacuation routes off of the island were the primary reasons to Galveston's inclusion on the list.

As discussed in Section 6 of this Plan (Hazard Identification, Profiling and Ranking), the City of Galveston has at least some exposure to as many as 28 hazards, but most of them have such low probability of occurrence that there is little or no serious risk to the City. Section 6 described the process by which the City reduced the list of 28 possible hazards to the 14 that create the greatest risk to the City of Galveston's residents, assets, and operations:

- Biological Event
- Coastal Erosion
- Coastal Retreat
- Coastal Subsidence
- Drought
- Environmental Disaster
- Extreme Wind
- Flooding
- Hazardous Materials Incident (Fixed Site and Transport)
- Lightning
- Sea Level Change
- Terrorism
- Tsunami
- Wildfire / Urban Fire

This list of 14 hazards was then further analyzed to determine past occurrences and the likelihood of future occurrence. A qualitative risk assessment was discussed and performed for all hazards profiled (the results of which can be found earlier in this section.) The following hazards were deemed a significant enough risk, with sufficient data available, to the City to merit a quantitative risk assessment:

- Coastal Erosion
- Extreme Wind
- Flooding
- Hazardous Materials Incident (Fixed Site and Transport)
- Wildfire / Urban Fire

7.2 2010 Galveston County Plan Update Risk Assessment Data Summation

The following tables provide a summation of the risk assessment findings from the 2010 Galveston County Hazard Mitigation Plan Update, as it relates to the City of Galveston.

Table 7.2-1
Summary of 2010 County Plan Update Risk Assessment Data
(Source: Galveston County Mitigation Plan Update)

Hazard Risk Ranking from 2010 Galveston County Hazard Mitigation Plan Update		
Hazard	Ranking	Methodology/Basis for Ranking
Coastal Flood	High	GIS Analysis, Exposure of Assets
Inland Flood	NA	GIS Analysis, Exposure of Assets
Hurricane Wind	High	GIS Analysis, Loss Estimates
Tornado	Medium	Statistical Assessment, Loss Estimates
Drought	Very Low	Statistical Assessment, Exposure of Assets
Earthquake	Low	GIS Analysis, Loss Estimates
Hail	Low	Statistical Assessment, Loss Estimates
HazMat Incident	Medium	GIS Analysis, Potential Impact
Pipeline Failure	Medium	GIS Analysis, Potential Impact
Wildfire	Very Low	GIS Analysis, Historical Data/Knowledge, Potential Impact
Winter Storm	Very Low	Historical Data/Knowledge, Potential Impact
Tsunami	Very Low	Historical Data/Knowledge

Table 7.2-2
Summary of Risk Assessment Methodologies Used in 2010 Galveston County Plan Update

Summary Description of Methodologies Used in County Update	
Methodology	Summary Description
GIS Analysis	This methodology was used to determine the estimated vulnerability of people, buildings and critical facilities to the identified hazards, using the best available geospatial data. GIS data included the use of HAZUS-MH, FEMA's standardized loss estimation software, which allows for analysis at a regional level (rather than a structure-by-structure basis). Using HAZUS-MH requires some data normalization to account for recognized differences between actual values and estimated values.
Statistical Assessment	This methodology uses a statistical approach and mathematical modeling of risk to predict a hazard's frequency of occurrence and estimated impacts based on recoded or historic damage information. This methodology uses the best available data and records to identify patterns in frequency, intensity, vulnerability and loss, and to extrapolate probabilities from those patterns.
Loss Estimates	This methodology produces economic loss predictions using two interrelated risk indicators – the Annualized Loss (AL) and the Annualized Loss Ratio (ALR). Annualized Loss is the estimated long-term weighted average value of losses to property in any single year in a specified geographic area. Annualized Loss Ratio is the estimated annualized loss normalized by property replacement value. $ALR = \text{Annualized Losses} / \text{Total Exposure}$

7.3 Risk Assessment Methodology

The risk assessment describes and analyzes the risks and vulnerabilities to the City of Galveston from the hazards profiled in Section 6 Hazard Identification, Profiling and Ranking. The assessment includes a vulnerability description and information as to the identified risk to public and private assets (where applicable).

The City of Galveston Hazard Mitigation Planning Stakeholder Committee (HMPSC) conducted a risk assessment exercise to determine the vulnerabilities to assets within the planning area. The exercise was conducted at an HMPSC meeting. The updated hazard profiles were used as the basis to determine the vulnerability of and risk to assets within the City. A variety of data sources were used to complete this risk assessment, including:

- Local knowledge and experience of HMPSC Members and City Staff
- Reports and studies commissioned by the City
- Plans produced and maintained by the City
- Reports and studies provided by other agencies, both State and Federal

In all instances, the best available data was utilized. Where possible, post-Ike data was used, as there are few (if any) sectors of the City of Galveston that were not impacted by Hurricane Ike. It is hoped that the 5 year update of this Plan will be able to incorporate all post-Ike data.

Prioritizing the potential impacts of hazards on City assets was based on both a quantitative and a qualitative analysis of the identified hazards. This allowed the HMPSC to focus planning effort on the hazards most likely to cause future impacts to the community. The HMPSC used historical data, local knowledge and experience to rate the exposure, probability and impact of each of these hazards. Each hazard identified and profiled received a qualitative risk assessment. The anticipated impact of the hazards was then assigned a value of Low, Moderate or High. Table 7.3-1 describes the definitions assigned to these terms.

**Table 7.3-1
Definitions of Risk Assessment Impact Terminology for Qualitative Risk Assessment**

Definitions of Risk Assessment Impact Terminology for Qualitative Risk Assessment			
Term	Potential Impact to People (Life Safety/Livelihood)	Potential Impact to Buildings/Critical Facilities	Potential Impact to Infrastructure
Low	Some injuries possible but unlikely	Cosmetic damages to structures Loss of Function for less than 1 day	Some roads/bridges temporarily blocked Temporary power loss
Moderate	Injuries expected, some deaths	Some structural	Road/bridge closures

Definitions of Risk Assessment Impact Terminology for Qualitative Risk Assessment			
Term	Potential Impact to People (Life Safety/Livelihood)	Potential Impact to Buildings/Critical Facilities	Potential Impact to Infrastructure
	possible	damages Loss of Function for 1-2 days	Power and utility loss
High	Several deaths expected	Some structures irreparably damaged Loss of Function for 3-5 days	Long-term road/bridge closures Long-term power and utility loss

These ratings were then used to determine the qualitative ranking of the hazards, the City's risk of exposure to the hazard, the probability of the hazard occurring and the potential impact of that hazard to the City of Galveston. This data is shown in Table 7.3-2. Table 7.3-3 shows this data ranked by risk.

Table 7.3-2
Qualitative Risk Assessment Ranking, by Hazard – City of Galveston

Qualitative Risk Assessment Ranking, by Hazard			
Hazard	Impact to People (Life Safety /Livelihood)	Impact to Buildings /Critical Facilities	Impact to Infrastructure
Biological Event	Low	Low	Low
Coastal Erosion	Low	Moderate	Moderate
Coastal Retreat	Low	Low/Moderate	Moderate
Coastal Subsidence	Low	Low	Low
Drought	Low	Low	Low
Environmental Disaster	Moderate/High	Low	Low
Extreme Wind	High	High	High

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Qualitative Risk Assessment Ranking, by Hazard			
Hazard	Impact to People (Life Safety /Livelihood)	Impact to Buildings /Critical Facilities	Impact to Infrastructure
Flooding	Moderate	High	High
Hazardous Materials Incident (Fixed Site and Transport)	Low/Moderate	Low/Moderate	Low/Moderate
Lightning	Low	Low	Low
Sea Level Rise	Low	Moderate	Moderate
Terrorism	Moderate/High	Moderate/High	Moderate/High
Tsunami	Low	Low	Low
Wildfire / Urban Fire	Moderate	High	Low

Table 7.3-3
Qualitative Risk Assessment Ranking, by Risk Determination – City of Galveston

Qualitative Risk Assessment Ranking, by Risk Determination			
Hazard	Impact to People (Life Safety /Livelihood)	Impact to Buildings /Critical Facilities	Impact to Infrastructure
Extreme Wind	High	High	High
Flooding	Moderate	High	High
Terrorism	Moderate/High	Moderate/High	Moderate/High
Sea Level Rise	Low	Moderate	Moderate
Environmental Disaster	Moderate/High	Low	Low
Coastal Erosion	Low	Moderate	Moderate
Wildfire / Urban Fire	Moderate	High	Low

Qualitative Risk Assessment Ranking, by Risk Determination			
Hazard	Impact to People (Life Safety /Livelihood)	Impact to Buildings /Critical Facilities	Impact to Infrastructure
Coastal Retreat	Low	Low/Moderate	Moderate
Hazardous Materials Incident (Fixed Site and Transport)	Low/Moderate	Low/Moderate	Low/Moderate
Biological Event	Low	Low	Low
Coastal Subsidence	Low	Low	Low
Drought	Low	Low	Low
Lightning	Low	Low	Low
Tsunami	Low	Low	Low

Some hazards were determined to have varying degrees of impact, based on the particular circumstances surrounding the occurrence. Through discussion and consideration of all aspects of the profiled hazards, the committee determined that some hazards would have the potential to cause more of less of an impact, based on the particulars of the incident. Those hazards and the rationale are discussed below:

- **Coastal Retreat** – Impact to Buildings and Critical Facilities determined to be Low/Moderate. The moderate impact determination was due to the proximity of various buildings and critical facilities to areas of the island that are known to be experiencing Coastal Retreat, including areas of the Port of Galveston. For those buildings and critical facilities not in proximity to these known hazard areas, the impact was determined to be low.
- **Environmental Disaster** – Impact to People determined to be Moderate/High. This determination was based on discussion of the wide range of potential causes of environmental contamination, and the variance in potential impacts to people.
- **Hazardous Materials Incident (Fixed Site and Transport)** – All impacts determined to be Low/Moderate. This determination was based on the variances in the types of hazardous materials incidents that can occur in the City, and the variances in population, built environment, and infrastructure.
- **Terrorism** - All impacts determined to be Moderate/High. This determination was based on the variances in the types of terrorism incidents that can occur in the City, and the variances in population, built environment, and infrastructure. Also considered was the human element required for terrorism, which is unpredictable, and the typical reason for committing terrorism, which is the intent to instill fear and/or damage.

7.4 Areas of Particular Concern for the City of Galveston

As a barrier island community, the City of Galveston has particular concern and vulnerabilities that must be addressed as part of any mitigation planning effort. Prior to the commencement of the planning effort, the City identified three areas of particular concern. The HMPSC determined that these areas should receive particular consideration (where applicable) during the planning process. These areas are discussed below.

Data from a variety of sources was consulted to determine these specific concerns, including:

- Local knowledge and experience of HMPSC Members and City Staff
- Reports and studies commissioned by the City
- Plans produced and maintained by the City
- Reports and studies provided by other agencies, both State and Federal

7.4.1 Critical Facilities

The HMPSC determined that a focus of the Plan would be risks and vulnerabilities of critical facilities. The Committee considered the definition of critical facilities found in FEMA 386. After discussion and consideration, they determined that the definition could be used if it was expanded. The following is the definition of critical facilities for the City of Galveston's Hazard Mitigation Plan:

“Facilities that are critical to the health and welfare of the population and that are especially important following hazard events. Critical facilities include, but are not limited to, shelters, police and fire stations, hospitals, and other facilities necessary for continuity of government.”

The HMPSC analyzed facilities throughout the City in conjunction with the hazard identification. Over the course of several discussions, the HMPSC identified a broad range of critical facilities. Further analysis produced assessments of the value of the facilities, the contents, and the cost to replace those facilities, all of which was included in the risk assessment, where applicable and available.

The HMPSC opted to include the risk assessments for critical facilities with the City's overall risk assessments, rather than the separate them. This was done to present a complete and overall picture of the City's actual risks and vulnerabilities to the hazards deems to present the greatest risk to the City.

It is intended that future updates of this Plan will include more quantitative data than was available during the development of this Plan.

An inventory of the identified critical facilities can be found in Appendix H. *(Note: This Appendix is not available in drafts of this plan available for public viewing, due to security concerns).*

7.4.2 Historic Assets

The HMPSC determined that an additional focus of the Plan would be risks and vulnerabilities of historic structures, neighborhoods and assets. After discussion with the City's Historic Preservation Staff, the Committee opted to use the definition of historic asset found in FEMA 386:

"As defined by 36 CFR Part 800, means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term includes properties of traditional religions and cultural importance to an Indian Tribe or Native Hawaiian organization and that meet the National Register."

The HMPSC analyzed historic assets throughout the City in conjunction with the hazard identification. Further analysis produced assessments of the value of the assets, the contents, and the cost to replace those facilities, all of which was included in the risk assessment, where applicable.

The HMPSC opted to include the risk assessments for historic assets with the City's overall risk assessments, rather than the separate them. This was done to present a complete and overall picture of the City's actual risks and vulnerabilities to the hazards deems to present the greatest risk to the City.

It is intended that future updates of this Plan will include more quantitative data than was available during the development of this Plan.

An inventory of the identified historic structures and neighborhoods can be found in Appendix I. *(Note: This Appendix is not available in drafts of this plan available for public viewing, due to privacy concerns.)*

7.4.3 Beaches and Shorelines

The HMPSC determined that a final focus of the Plan would be risks and vulnerabilities of beaches and shorelines, both Gulf-facing and Bay-facing. A discussion was held during a Committee meeting, in which the Committee talked through various concerns regarding the beaches and shorelines in Galveston. Among these concerns are

- Wetland health along the Bay
- Threats to endangered species and critical habitat (Bay and Gulf)
- Loss of dune systems and vegetation, specifically as a result of Hurricane Ike, which has increased the island's vulnerability to coastal flooding, storms and erosion
- Maintenance of beach front roads and walkovers
- Maintenance of privately-owned septic systems

The HMPSC analyzed risks and vulnerabilities from beach-issues throughout the City in conjunction with the hazard identification. Further analysis produced assessments of the value of the assets, the contents, and the cost to replace those facilities, all of which was included in the risk assessment, where applicable.

The HMPSC opted to include the risk assessments developed in relation to beach-issues with the City's overall risk assessments, rather than the separate them. This was done to present a complete

and overall picture of the City's actual risks and vulnerabilities to the hazards deems to present the greatest risk to the City.

7.5 Overview and Analysis of the City of Galveston's Vulnerability to Hazards

In 2005, the National Hurricane Center compiled a list of the five places in the United States most vulnerable to hurricanes. Galveston was one of the five areas names. Low elevation and limited evacuation routes off of the island were the primary reasons to Galveston's inclusion on the list.

As discussed in Section 6 of this Plan (Hazard Identification, Profiling and Ranking), the City of Galveston has at least some exposure to as many as 28 hazards, but most of them have such low probability of occurrence that there is little or no serious risk to the City. Section 6 described the process by which the City reduced the list of 28 possible hazards to the 14 that create the greatest risk to the City of Galveston's residents, assets, and operations:

- Biological Event
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- Sea Level Change
- Terrorism
- Tsunami
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This list of 14 hazards was then further analyzed to determine past occurrences and the likelihood of future occurrence. A qualitative risk assessment was discussed and performed for all hazards profiled (the results of which can be found earlier in this section.) The following hazards were deemed a significant enough risk to the City to merit a quantitative risk assessment:

- Coastal Erosion
- Extreme Wind
- Flooding
- Hazardous Materials Incident (Fixed Site and Transport)
- Wildfire / Urban Fire

This section addresses risks related to these 5 predominant hazards, including estimates of potential future losses, in accordance with the Federal Emergency Management Agency's (FEMA) requirements. The most significant hazard to which the City is exposed to is flooding. Other significant hazards to the City include extreme wind and wildfire / urban fire.

7.5.1 Social Vulnerability Index (SOVI™)

For emergency response and hazard mitigation planning, populations can be assessed by their vulnerability to various hazards (fire, flood, etc). Physical vulnerability refers to a population's exposure to specific potential hazards, such as living in a designated flood hazard area. There are various methods for calculating the potential or real geographic extents for various types of hazards.

As previously discussed in Section 3, social vulnerability refers to sensitivity to this exposure due to population and housing characteristics: age, income, disability, home value and other factors. The social vulnerability score presented in this section is determined by a web service offered by the University of South Carolina, Department of Geography, Hazards and Vulnerability Research Institute, and is based upon a 2000 article from the *Annals of the Association of American Geographers* which sums the values of 8 variables as a surrogate for "social vulnerability". For example, low-income seniors may not have access to a car to simply drive away from an ongoing hazard such as a flood. A map of the flood's extent can be overlaid on the social vulnerability layer to allow planners and responders to better understand the demographics of the people affected by the hazard.

The following population characteristics are considered to determine a population's social vulnerability:

- **Socio-economic Status** (Income, Political Power, Prestige): Socio-economic status affects the ability of a community to absorb losses and be resilient to hazard impacts. Wealth enables communities to absorb and recover from losses more quickly using insurance, social safety nets, and entitlement programs.
- **Gender**: Women often have a more difficult time during recovery than men because of sector-specific employment (e.g., personal services), lower wages, and family care responsibilities.
- **Race and ethnicity**: These factors impose language and cultural barriers and affect access to post-disaster funding and occupation of high-hazard areas.
- **Age**: Extremes of age affect the movement out of harm's way. Parents lose time and money caring for children when day care facilities are affected; the elderly may have mobility constraints or concerns that increase the burden of care and lack of resilience.
- **Commercial and industrial development**: The value, quality, and density of commercial and industrial buildings provide indicators of the state of economic health of a community, potential losses in the business community, and longer-term issues with recovery after an event.
- **Employment loss**: The potential loss of additional employment following a disaster increases the possible number of unemployed workers in a community. Such losses contribute to a slower recovery from the disaster.
- **Rural/Urban**: Rural residents may be more vulnerable because of lower incomes and more dependence on a locally based resource economy (e.g., farming or fishing). High-density areas (urban) complicate evacuation out of harm's way.
- **Residential property**: The value, quality, and density of residential construction affect potential losses and recovery. Expensive homes on the coast are costly to replace, mobile homes are easily destroyed and less resilient to hazards.
- **Infrastructure and lifelines**: The loss of sewer, bridges, water, communications, and transportation infrastructure compounds potential disaster losses. The loss of

infrastructure may place an insurmountable financial burden on smaller communities that lack the financial resources to rebuild.

- **Renters:** People rent because they are transients, do not have the financial resources for home ownership, or do not want the responsibility of home ownership. They often lack access to information about financial aid during recovery. In extreme cases, renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.
- **Occupation:** Some occupations, especially those involving resource extractions, may be severely affected by a hazard event. Self-employed fishermen suffer when their means of production is lost, and they may not have the requisite capital to resume work in a timely fashion; therefore, they may seek alternative employment. Migrant workers engaged in agriculture and low-skilled service jobs (housekeeping, child care, and gardening) may suffer similarly as disposable income fades and the need for services declines. Immigration status also affects occupational recovery.
- **Family structure:** Families with large numbers of dependents and single-parent households often have limited wherewithal to outsource care for dependents and thus must juggle work responsibilities and care for family members. All these factors affect resilience to and recovery from hazards.
- **Education:** Education is linked to socioeconomic status in that higher educational attainment affects lifetime earnings, and limited education constrains the ability to understand warning information and access recovery information.
- **Population growth:** Counties experiencing rapid growth lack available high quality housing, and the social services network may not have had time to adjust to increased populations. New migrants may not be able to speak the language and may not be familiar with how to deal with bureaucracies in obtaining relief or recovery information. All these factors increase vulnerability.
- **Health status:** The public health literature shows that people with preexisting illnesses may be at risk for death/illness/injury in disaster settings. People with preexisting cardiovascular and respiratory conditions who are exposed to smoke and haze from forest fires may be more at risk for adverse health outcomes; they also may be vulnerable to heart attacks during seismic activity.
- **Medical Services:** Health care providers, including physicians, nursing homes, and hospitals, are important post-event sources of relief. The lack of proximate medical services lengthens the time needed to obtain short-term relief and achieve longer-term recovery from disasters.
- **Social dependence:** People who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period.
- **Special-needs population:** Special-needs populations (infirm, institutionalized, transient, the homeless) are difficult to identify, let alone measure and monitor. Yet it is this segment of society that invariably is left out of recovery efforts, largely because of this invisibility in communities.

This thematic map provides a simple summary of the social vulnerability of populations in each state or county in the United States. It answers the question “Where are the areas of relatively greater potential impact from disaster events within this state or county?” from the perspective of social vulnerability to hazards.

County-level socioeconomic and demographic data were used to construct an index of social vulnerability to environmental hazards, called the Social Vulnerability Index (SOVI™) for the United

States based on 1990 data. After obtaining the relevant data, a factor analysis was used to reduce the data into set of components. Slight adjustments were made to the components to ensure that the sign of the component loadings coincided with the individual population characteristics influence on vulnerability. All components were added together to determine a numerical value that represents the social vulnerability for each county. The SOVI™ was created as a comparative index at a county-level for the entire United States.

Map 7.5.1-1 depicts social vulnerability at the block group level for residents of the City of Galveston. The lower the value, the more vulnerable the population in that geographic area has been determined to be. The vulnerability scale depicted in this map was refined from county-level data for Galveston County. Galveston County ranks in the 71st percentile nationally for social vulnerability.

Map 7.5.1-1
Social Vulnerability Index for Galveston
(Source: ESRI, Hazards and Vulnerability Research Institute)



It should be noted that the opposite side of social vulnerability is social resiliency. The indicators for SOVI™ focus on the more negative indicators that reveal vulnerability, and does not seek to capture

the more positive indicators that can indicate resiliency or social strength of a community. While resiliency is not the stated purpose of SOVI™, it is a limitation of the model.

This information provides a backdrop to consider the City's risks and vulnerabilities, and provides a window into the post-Ike capability of the City to mitigate these risks and vulnerabilities.

7.6 Estimate of Potential Losses

This section describes the risk to the City of Galveston, including its residents and critical, government and historical assets from the list of hazards profiled in Section 6 – Hazard Identification, Profiling and Ranking. As noted above, risk is an expression of expected future losses resulting from the impacts of the identified hazards.

7.6.1 Coastal Erosion Risk to the City of Galveston

While usually a slow-evolving hazard, coastal erosion presents a serious threat to the City of Galveston. As a densely-populated barrier island, any loss of land equates to an increase in the City's vulnerability to hurricanes, coastal storms and above-average tidal events. When the land lost is beach that provides valuable protections from these coastal storm events, that loss results in greater vulnerability.

Background of Coastal Erosion Vulnerability

Galveston frequently experiences coastal erosion. According to the Texas General Land Office (GLO), the natural coastal environment of Texas is the product of climate, tides, relative sea-level change, tropical storm frequency, the amount of sediment delivered to the Gulf of Mexico by rivers and the rate of dispersal of that sediment by waves and currents. Some of these processes contribute to long-term (chronic) coastal erosion, and others cause short-term (storm-induced) erosion. Daily winds and tides have only a moderate effect on the shoreline. Hurricanes and tropical storms have a significant impact where winds drive currents and large volumes of beach shoreface sand (to the west and southwest) along the Texas coast. Chronic erosion is generally more difficult to address than storm-induced erosion.

Coastal shoreline recession and erosion is caused by a relative rise in sea level, and the fact that the amount of sediment removed by wave energy exceeds that supplied to the beach by longshore currents. According to a study done by Texas A&M University Galveston (TAMUG), the relative rise in sea level in Galveston was measured at 0.24" per year. This is significant because Texas beaches are relatively flat and any rise in sea level can result in substantial shoreline recession. Climate change (from wetter to drier) during the past 18,000 years has decreased the volume of sediments carried to the Texas coast by rivers. Droughts can cause stabilizing vegetation to die and increase erosion of bay shorelines and coastal sand dunes.

Human modifications or actions can contribute to or accelerate localized coastal erosion. Jetties, groins, and breakwaters hinder sediments that would normally collect along the shoreline. Seawalls, revetments and bulkheads also contribute to the hindrance of sediments normal patterns of distribution – and all of these exist in Galveston. Waves generated by boats and ships can erode

unprotected shorelines or accelerate erosion in areas already affected by natural processes. An increase in the number of ships with large wakes could prove detrimental to coastal properties.

The GLO has defined "eroding areas" as "a portion of the shoreline which is experiencing a historical erosion rate of greater than two feet per year based on published data of the University of Texas at Austin, Bureau of Economic Geology." An eroding area is considered critical when the rate of erosion exceeds two feet per year and poses a threat to:

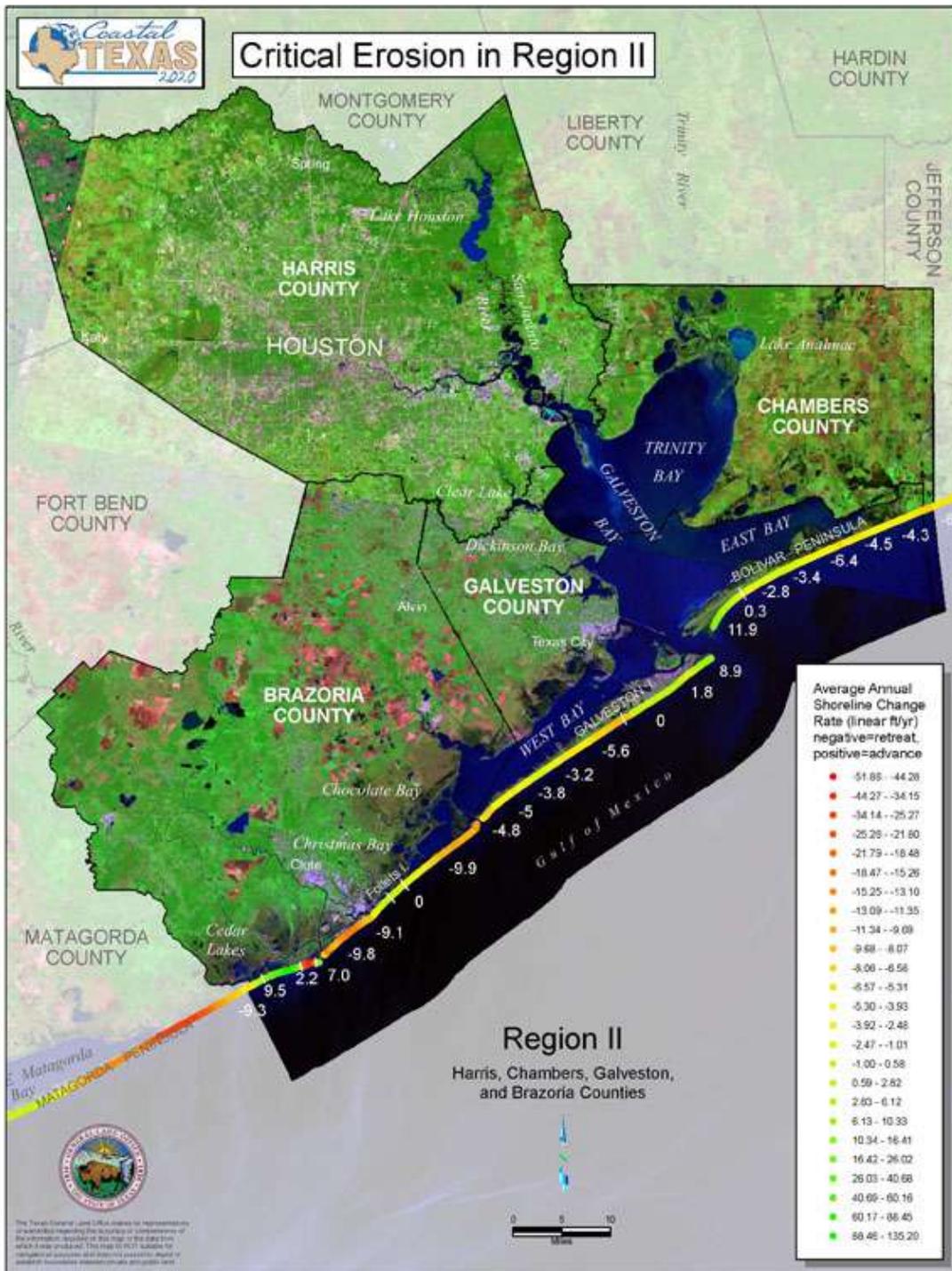
- public infrastructure or areas of national importance,
- public beach access and recreation,
- traffic safety,
- private property, or
- fish or wildlife habitat.

Galveston is experiencing coastal erosion on both sides – both its Gulf-Facing beaches and its Bay-facing wetlands and other sensitive areas. It is believed that the Bay side of the Island is experiencing much more significant and dramatic erosion.

The GLO has designated two Critical Erosion Areas in Galveston County. The first is Caplen Beach, Bolivar Peninsula. The second Critical Erosion Area in Galveston County is Galveston Island State Park Bay Shoreline. In this area, the marshes are being converted to open water. This is severely increasing due to the loss of protective emergent shoals. Wave erosion due to recreational vessel wakes has lowered the elevation of protective shoals towards the shoreline.

Map 7.6.1-1 shows the location of the Coastal Erosion hazard in the City of Galveston. Based on the map below, the Gulf-facing coast of Galveston is eroding at an average rate of between 1 and 9 linear feet per year.

Map 7.6.1-1
Shoreline Change Rates along Upper Texas Gulf Coast
 (Source: Texas General Land Office)



While this calculation does include the effects of coastal storms, it does not account for the erosion that occurred as a result of Hurricane Ike. After Hurricane Ike, the Texas GLO funded a technical

study which studied the effects of Hurricane Ike along the Upper Texas Coast, including the City of Galveston. The results of that study showed that Galveston experienced significant coastal erosion and retreat as a result of Hurricane Ike. The estimated rate of erosion is presented in Table 7.6.1-1 below.

Table 7.6.1-1
Estimated Coastal Erosion in Galveston as a Result of Hurricane Ike
(Source: GLO, HDR Engineering)

Estimated Coastal Erosion in Galveston as a Result of Hurricane Ike	
Location	Estimated Erosion (in linear feet)
Galveston East Beach	315
Galveston Seawall	Shoreline eroded to Seawall and limited by Seawall
Galveston West End	195
Galveston Far West End (San Luis Pass)	200

Figure 7.6.1-1 shows pre- and post-storm aerial imagery from the Galveston Each Beach area. In these photographs, it is clear that several hundred linear feet of coastline were lost to Hurricane Ike.

Figure 7.6.1-1
Evidence of Coastal Erosion in Galveston as a Result of Hurricane Ike
(Source: USGS)



Valuation Methodology for Coastal Erosion Vulnerability

The risks and vulnerabilities to humans and to the built environmental from coastal erosion are difficult to assess using traditional valuation methodologies. Coastal erosion is not just a threat to people and the things they build; it also poses a risk to the surrounding ecosystems. Some would

argue that the environmental risks of coastal erosion are more significant than the risks to people and their construction.

There are a variety of generally accepted methods to quantify the risks of coastal erosion. One is to use a market value-based methodology. In other words, to determine how the erosion affects various economic activities or interests, such as tourism or private property values. This involves the calculation of direct damages to people and property from coastal erosion. The market price method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques for measuring the economic benefits from marketed goods, based on the quantity people purchase at different prices, and the quantity supplied at different prices. The idea of property value is based on the notion that the property can be utilized for human purposes. If that property no longer exists, such as if it is inundated by seawater, the value of that property evaporates. Typically, coastal property that is eroding or is inundated has diminished value when compared to land that is not eroding and is not inundated.

Another methodology involves the calculation or estimation of damages avoided. This method estimates the value of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services. This method does not provide strict measures of economic values, which are based on peoples' willingness to pay for a product or service. Instead, it assumes that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services. This is based on the assumption that, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them. Thus, the methods are most appropriately applied in cases where damage avoidance or replacement expenditures have actually been, or will actually be, made.

Some examples of cases where this method might be applied include:

- Valuing improved water quality by measuring the cost of controlling effluent emissions.
- Valuing erosion protection services of a forest or wetland by measuring the cost of removing eroded sediment from downstream areas.
- Valuing the water purification services of a wetland by measuring the cost of filtering and chemically treating water.
- Valuing storm protection services of coastal wetlands by measuring the cost of building retaining walls.
- Valuing fish habitat and nursery services by measuring the cost of fish breeding and stocking programs.

While the second methodology would likely result in a more complete and holistic assessment of the risks of coastal erosion to the City of Galveston, the data required to calculate those values is currently unavailable or incomplete. This methodology may be employed in future updates of this Plan.

Therefore, this plan will evaluate the risks of coastal erosion in terms of the threat it poses to people and the built environment, the risks to Galveston's tourism industry, and the costs associated with restoring eroded areas.

Coastal Erosion Risks to Galveston Residential Assets

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Table 7.6.1-1, located earlier in this section, provided details of the estimated coastal erosion on the West End of Galveston Island as a result of Hurricane Ike. The loss of so much beach, so quickly left many residential structures vulnerable to further coastal erosion, as their protective dunes and vegetation were destroyed by the storm surge. At least 350 residential structures were placed at risk as a result of Ike-related erosion.

Shortly after Hurricane Ike, in May 2009, aerial images of the West End of Galveston Island were developed. These images document the coastline of the Island after Ike, and were used to establish the new boundary between private land and the public beach. These images are also useful for demonstrating the effects of coastal erosion on the at-risk residential structures. While there are far too many images to include all of them in this Plan, a sampling has been included to demonstrate the risk of erosion to beachfront residential assets.

In the images that follow, the black line indicates the point at which the estimated elevation of the land reaches 4.5 feet. The red line indicates 200 feet from mean high water.

In Figure 7.6.1-2, there are at least 25 structures (or former locations of structures) that are at risk from coastal erosion and other coastal hazards.

To protect residential structures from the risks associated with coastal erosion, the City is considering the adoption and enforcement of at least a 75' beach setback for all new construction. This means that all structures would be at least 75' from the north toe of the dune, or 350' from mean high water (whichever is greater), which would place them out of the area most at risk for erosion during most coastal storm events. This ordinance is still under consideration.

Coastal Erosion Risks to Galveston Critical Facilities

Galveston does have critical facilities that are potentially at risk from coastal erosion. While there are no known structures at risk, there are inter-dependent lines that are potentially at risk, as well as roadways that provide access to property owners, emergency responders, and beach visitors. Some of these lines and roads were damaged or destroyed by Hurricane Ike, and remain vulnerable as a result of the coastal erosion experienced during that storm.

Map 7.6.1-2 illustrates the location of Galveston's sewer lines; map 7.6.1-3 shows the location of Galveston's water lines. Roadways are also indicated on both maps. Note the proximity of utility lines and roads on the West End in relation to the Gulf-facing beaches. These lines are constantly at risk of suffering a failure to function from coastal erosion.

Map 7.6.1-4 identifies the locations of roads and bridges designated as critical to the City of Galveston. Note the proximity of these critical access routes and points to potential sources of erosion, both from the Gulf and from the Bay.

Map 7.6.1-2
Location of Galveston Sewer Lines and Roads
(Source: ESRI, GLO, City of Galveston)



Map 7.6.1-3
Location of Galveston Water Lines and Roads
(Source: ESRI, GLO, City of Galveston)



Map 7.6.1-4
Location of Galveston Critical Roads and Bridges
(Source: ESRI, GLO, City of Galveston)

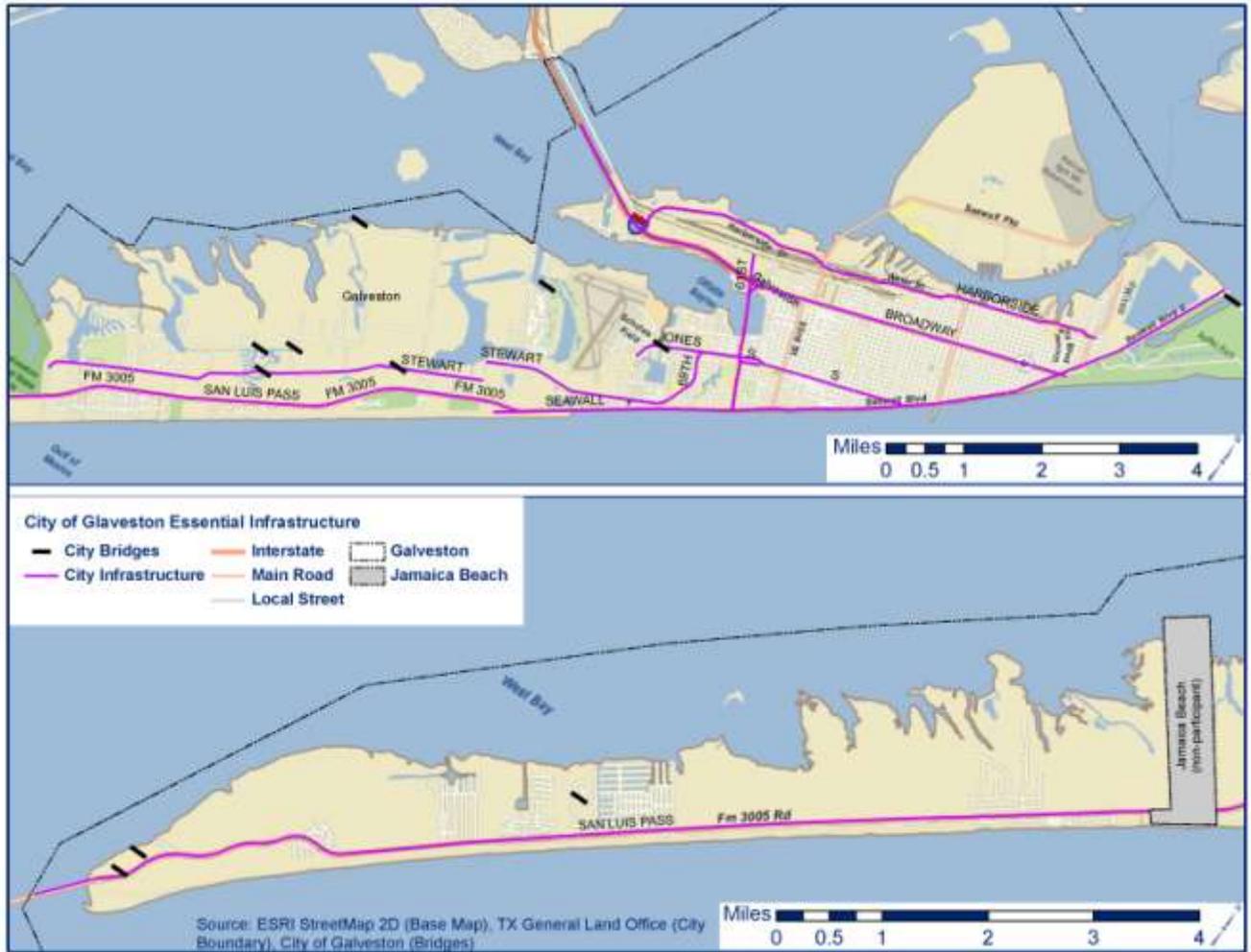


Table 7.6.1-2 provides valuation for water and wastewater facilities and lines in the City of Galveston. Two different valuations are calculated. The first is the valuation of the actual facility, equipment or line. This is based on the service capacity of the facility, equipment or line, and is the industry-standard calculation method. The second value is based on the service provided by the utility. This value was calculated based on the methodologies provided in FEMA's *What is a Benefit?* handbook.

All associated water and sewer lines are included in plant estimates.

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**Table 7.6.1-2
Critical Water and Wastewater Facility Inventory
(Source: City of Galveston Municipal Utilities Department)**

Galveston Critical Facilities at Risk from Coastal Erosion				
Facility Name	Facility Location	Facility, Equipment and/or Line Value	Service Value	Total Value at Risk Per Day of Service
59 th Street Pump Station	59 th Street and RR Tracks	\$4,924,000 (Existing Pump Station) \$16,500,000 (New Pump Station)	\$1,494,736 per day (30% of population)	\$6,418,736 - \$17,994,736
30 th Street Pump Station	30 th Street and Ball Avenue	\$7,387,200 (Existing Pump Station) \$16,416,000 (New Pump Station)	\$1,494,736 per day (30% of population)	\$8,881,936 - \$17,910,736
Airport Pump Station	7915 Airport Boulevard	\$7,387,200	\$996,525 per day (20% of population)	\$8,383,725
Jamaica Beach Pump Station	16510 Captain Kidd Lane	\$410,400	\$996,525 per day (10% of population)	\$1,406,925
Pirate's Beach Pump Station	13805 Stewart Road	\$1,231,200	\$996,525 per day (10% of population)	\$2,227,725
All associated potable water lines	Various locations throughout Island	Included in estimates for pump stations	Included in Pump Station Service Estimates	Included in Total Value at Risk Estimates
Potable water main	Railroad Causeway	\$4,250,000 (Does not included costs for causeway itself)	\$4,982,420 per day (100% of population)	\$9,232,420
Wastewater Treatment System – Main Plant	5200 Port Industrial Boulevard	\$60,000,000	\$1,101,949 per day (68% of population)	\$61,101,949
Airport Treatment Plant	7618 Mustang	\$21,000,000	\$388,935 per day (24% of population)	\$21,388,935

Galveston Critical Facilities at Risk from Coastal Erosion				
Facility Name	Facility Location	Facility, Equipment and/or Line Value	Service Value	Total Value at Risk Per Day of Service
Terra Mar Beach Treatment Plant	3715 ½ Laguna	\$3,000,000	\$48,609 per day (3% of population)	\$3,048,609
Pelican Island Treatment Plant	Seawolf Parkway	\$30,000	\$503 per day (.3% of population)	\$30,503
Pirate's Beach Treatment Plant	13614 Moyenne Place	\$3,738,000	\$64,823 per day (4% of population)	\$3,802,823
Grand Totals:		\$113,358,000 - \$133,878,800	\$12,566,286	\$125,924,286 - \$146,445,086

In addition to municipal utility infrastructure, roadways are also at risk from coastal erosion. As a result of Hurricane Ike-caused erosion, the City lost several thousand feet of roadway to erosion, leaving neighborhoods and homes inaccessible. The roadways identified as critical in Map 7.6.1-4 are as follows:

- 61st Street
- Harborside Drive
- Broadway (Avenue J)
- Seawall Boulevard / FM 2005 / San Luis Pass Road
- Stewart Road (Avenue S)

To quantify the estimated replacement costs for at-risk roadways, estimates for replacement were obtained from the City's Public Works Director. An average replacement cost per 1000' and per mile was established for both asphalt and concrete roadways. While actual replacement costs will vary based on the degree of damage and the circumstances, these figures are useful for estimating potential losses in a quantifiable way.

For each of these critical asphalt roadways that are damaged or destroyed by coastal erosion, the average replacement costs are \$152,000 per 1,000', or more than \$800,000 per mile. For each of these critical concrete roadways that are damaged or destroyed by coastal erosions, the average replacement costs are \$179,000 per 1,000', or more than \$947,000 per mile.

Coastal Erosion Risks to Galveston Historic Assets

Currently, there are no historical structures in Galveston that are known to be at risk from coastal erosion. However, the Galveston Seawall is constantly exposed to erosion.

Hurricane Ike pounded the Seawall with waves and debris for at least 12 hours, damaging pavement, causing sinkholes along the sidewalk on top of the wall and swallowing up the protective

beach in front of it. The beach along a 51-block stretch of the Seawall required replenishment with more than 400,000 yards³ of sand from nearby land. The storm eroded most of the sand at the base of the Seawall, leaving it vulnerable to corrosion or further erosion, which could have undermined the structural integrity of the Seawall. The Seawall maintained its structural integrity but required the first major repair project in its 105-year history, according to the U.S. Army Corps of Engineers' Galveston office. This repair project was estimated to cost \$10 MM.

Using the above project as a baseline, the estimated potential loss to the 10.2 mile Seawall from coastal erosion is estimated at approximately \$1 M per mile.

Coastal Erosion Risks to Galveston Beaches

Beaches create recreational and storm damage reduction benefits. Tax revenues are generated as a result of the dollars that visitors spend while at the beach and the increases in local property values. Increases in spending that result from beach tourists purchasing meals, for example, contributes to incremental spending and incremental taxes. Spending on meals by local residents visiting the beach is not incremental spending and does not contribute to incremental taxes, because this spending is assumed to occur in the region whether the local residents visit the beach or engage in some other local activity.

Galveston's beaches are the major tourist attraction in the City. Prior to Hurricane Ike, the City's annual revenue from tourism averaged almost \$20M. Total tourism spending on the island averaged \$560M in 2007 (the most recent figures available). Any hazard or risk to the beaches in Galveston represents a threat to the City's very livelihood.

For the purposes of quantifying the risks of coastal erosion to the City, tourism estimates from May 27-31, 2010 (Memorial Day Weekend) were used. These estimates are based on traffic counts of the number of cars going eastbound on the I-45 Causeway. The estimated number of cars, and estimated number of passengers, is presented in Table 7.6.1-3.

Table 7.6.1-3
Estimated Memorial Day Weekend Visitors to Galveston
(Source: City of Galveston Public Works Department)

Estimated Memorial Day Weekend Visitors to Galveston		
Day	Estimated Number of Cars	Estimated Number of Passengers (2 per car)
Thursday, May 27, 2010	33,493	66,986
Friday, May 28, 2010	40,049	80,098
Saturday, May 29, 2010	45,861	91,722
Sunday, May 30, 2010	54,471	108,942
Monday, May 31, 2010	45,361	90,722

As indicated by the table above, for this one holiday weekend there were at least 18,000 visitors to the Island, and potentially upwards of 60,000. This temporary increase in population was evident on Galveston's beaches, which were busier and more populated than at any time since Hurricane Ike. It can be assumed that Galveston's beaches and shorelines were a primary attraction for so many visitors to the City and the Island.

Beach nourishment is the process of placing sand on an eroding beach to provide a protective buffer against storm and wave damage, and/or to enhance the recreational value of a beach. However, beach nourishment is a controversial shore protection measure because it has the potential to adversely impact a variety of natural resources. Consequently, a relatively complex series of federal, state, and local laws and regulations has evolved over the last century for the management and permitting of beach nourishment projects. Today, beach nourishment projects must comply with a wide range of complex laws and regulations, as well as associated funding constraints.

As previously discussed, Galveston's beaches experience annual erosion at a rate of between 1 and 9 linear feet per year, with rates much, much higher during coastal storms. If the beaches continue to experience unmitigated erosion, or if they are not renourished after significant erosion events, the livelihood of the City of Galveston could be at risk.

Maintaining and renourishing Galveston's beaches has a cost, though this cost is somewhat difficult to quantify. Various agencies have various responsibilities for the beaches and shores in Galveston, making it difficult to determine with any finality the annual costs attributable to the coastal erosion hazard. Therefore, this Plan will present one example of these costs, and will seek to provide additional quantifiable data in future updates.

There are a variety of dune restoration and beach renourishment projects that have been implemented, planned or suggested as a result of the erosion caused by Hurricane Ike. One such project would focus on 6 miles on the West End, west of the Seawall. The cost for this project, which will restore less than 1/3 of the West End of Galveston, is estimated at \$6.6 MM per mile, or approximately \$40 MM.

7.6.2 Extreme Wind Risk to the City of Galveston

This assessment considered the effects of all extreme winds that impact the City of Galveston, its residents, and assets. Winds from the following sources were considered:

- Severe Thunderstorms
- Straight Line Winds
- Tropical Systems/Hurricanes
- Tornadoes

Background of Extreme Wind Vulnerability

The City of Galveston has a long and well-documented history of exposure to and damages from extreme winds. As a barrier island, winds from tropical systems reach the City before the mainland, leaving the City to absorb the brunt of the winds. Galveston also receives winds from storms that move from the mainland into the Gulf of Mexico.

Table 7.6.2-1 provides information regarding Presidential Disaster Declarations involving extreme wind that have included the City of Galveston. Note that this list is representative, and does not include all declared extreme wind events known to have occurred in Galveston. For a more complete listing of occurrences, please see Section 6.3.7.

Table 7.6.2-1
Presidentially-Declared Extreme Wind Disasters in the City of Galveston Since 1961
(Source: FEMA)

Declared Extreme Wind Disasters in the City of Galveston, 1961-2009		
Disaster Type	Year of Declaration	Disaster or Emergency Declaration Number
Hurricane	2008	DR-1791 - Hurricane Ike
Hurricane	2008	EM-3294 - Hurricane Ike
Hurricane	2008	EM-3290 - Hurricane Gustav
Hurricane	2005	DR-1606 - Hurricane Rita
Hurricane	2005	EM-3261 - Hurricane Rita
Hurricane	2003	DR-1479 - Hurricane Claudette
Hurricane	2002	DR-1434 - Tropical Storm Fay
Hurricane	2001	DR-1379 - Tropical Storm Allison
Severe Storms	1998	DR-1257
Hurricane	1998	DR-1245 - Tropical Storm Frances
Hurricane	1983	DR-689 - Hurricane Alicia
Hurricane	1961	DR-118 - Hurricane Carla

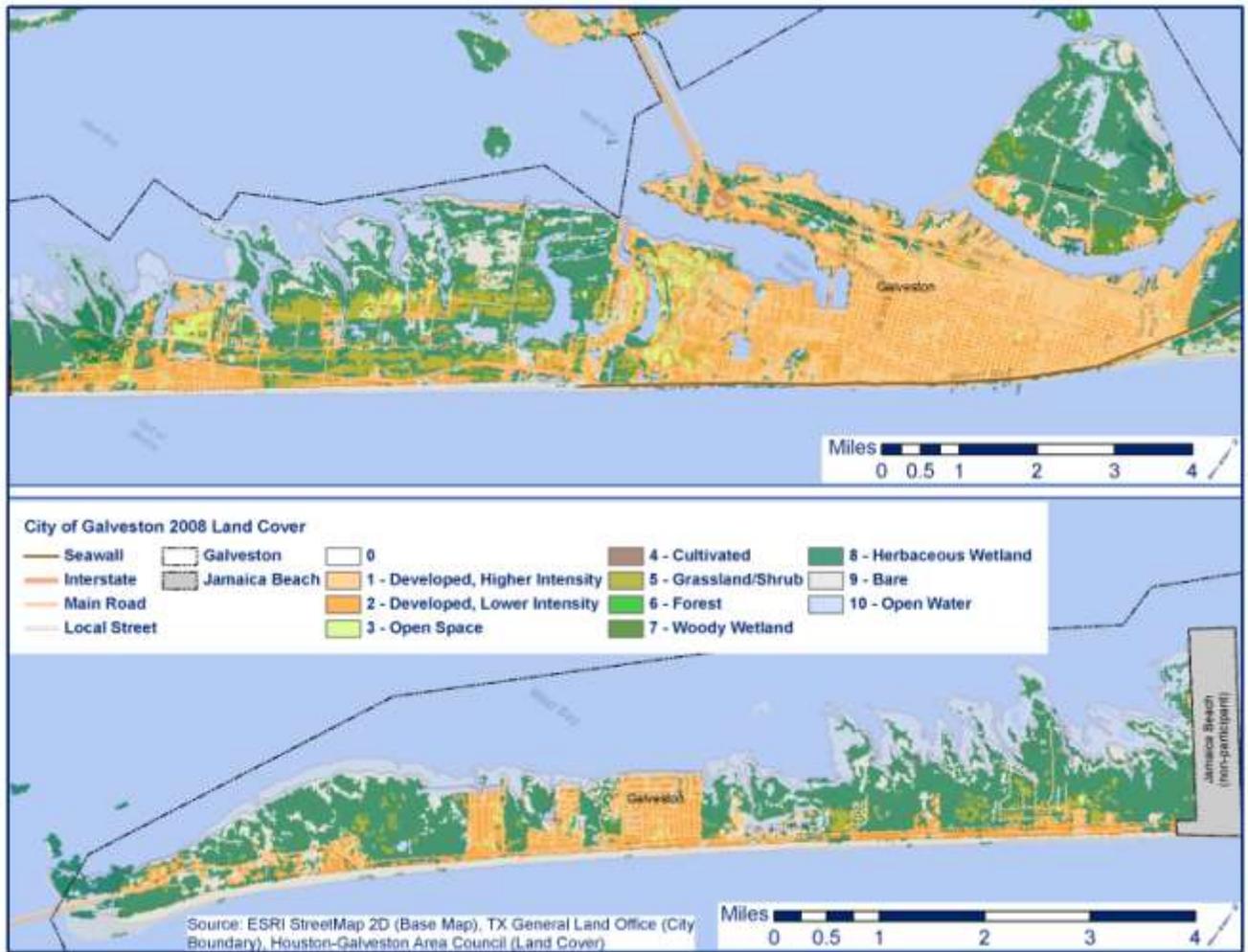
Table 7.6.2-2 details the anticipated wind speeds based on extreme wind events. This information was obtained from HAZUS in July 2010.

Table 7.6.2-2
Extreme Wind Recurrence Intervals
 (Source: HAZUS, July 2010)

Anticipated Wind Speeds Based on Recurrence Intervals							
In MPH:	10 Year Event	20 Year Event	50 Year Event	100 Year Event	200 Year Event	500 Year Event	1000 Year Event
Average	67	86	111	124	133	144	151
Minimum	64	82	107	123	131	137	149
Maximum	74	97	116	125	134	149	155
Maximum Variation	10	15	9	2	3	12	6

Map 7.6.2-1 shows the land cover in the City of Galveston. Note the density of development on the eastern side of the City, behind the Seawall.

Map 7.6.2-1
Land Cover in Galveston, TX
 (Source: HGAC)



Map 7.6.2-2 shows the locations of historic tornado touchdowns in the City, based on NCDC data. Map 7.6.2-3 shows the probabilistic paths of hurricanes; this map was developed using data obtained from HAZUS.

Map 7.6.2-2
Historic Tornado Touchdowns in Galveston
(Source: ESRI, NCDC)



Map 7.6.2-3
Probabilistic Hurricane Storm Tracks in Galveston
(Source: ESRI, GLO, HAZUS)



Note the number of probable paths in the above map which place the City of Galveston in the northeast quadrant, known to contain the most damaging winds associated with hurricanes and tropical storms. Of the seven probable paths, four are estimated to place Galveston in the path of the most dangerous and damaging winds.

Methodology for Determining Extreme Wind Vulnerability

As discussed throughout this document, this Plan was developed using the best available data from a variety of sources. Where possible, existing qualitative data regarding risks and vulnerabilities in Galveston was used, such as data from previous mitigation plans and other planning efforts. As such, the data presented in this section is a hybrid of existing data and newly developed / refined data, often extracted from State or County-level sources. Where applicable, the limitations of data on such a small scale, such as a municipality, have been noted. Where planning assumptions were made, those assumptions have been noted and detailed. Every effort has been made to create an assessment that successfully details and quantifies the City's current risks and vulnerabilities, as

they exist in the post-Ike environment. In some instances, pre-storm data was used, as it was considered to be the best available data.

Extreme Wind Risk to Galveston Assets

This section incorporates data obtained from the 2010 Galveston County Mitigation Plan Update. This data was, by and large, created using scenarios in HAZUS-MH, and uses 2000 Census data.

Based on data from the 2010 Galveston County Mitigation Plan Update, which was obtained using HAZUS, the City’s total exposure to extreme wind is estimated at \$3,920,377,102. This figure accounts for all improved property in the City, as estimated by HAZUS. The Galveston County Plan Update then annualized this exposure for residential and commercial properties, and determined both the total expected property losses and the annual percent loss ratio. These figures include historic assets in the City of Galveston, which were not separated in the calculations. This information is presented in Table 7.6.2-3 below.

**Table 7.6.2-3
Annualized Property Losses from Extreme Wind
(Source: 2010 Galveston County Plan Update, HAZUS)**

Annualized Property Losses from Extreme Wind Events				
Total Exposure	Residential Structure Risk	Commercial Structure Risk	Total Expected Property Losses	Percent Loss Ratio
\$3,920,377,102	\$20,439,331	\$12,010,466	\$32,449,797	.83%

In short, the City and its residents can expect to incur property losses of almost 1% per year, or more than \$32 M, from extreme wind events.

Extreme Wind Risk to Galveston Critical Facilities

In the 2010 Galveston County Plan Update, the risk to critical facilities from extreme wind was calculated using data from HAZUS. HAZUS estimated information on 71 critical facilities within the City, though no details were available to compare these identified facilities with the City’s identified critical facilities. A scenario was created using a 100-year hurricane wind event and a 500-year hurricane wind event. The results of those scenarios are presented below.

The 100-year scenario determined that, during a 100-year hurricane wind event with winds averaging 124 MPH, 3 critical facilities would experience a total loss of function, and the remaining 68 would experience a partial loss of function. No critical facility in the City would retain the ability to fully function during or after a 100-year hurricane wind event.

During a 500-year hurricane wind event, with winds averaging 144 MPH, all 71 identified critical facilities would experience a total loss of function. No facility would retain partial function, and none would be able to fully function.

As part of the plan development process, the Stakeholder Committee and Galveston City Staff identified specific critical facilities for the City of Galveston. The complete list of these facilities, their estimated replacement values, and their service values (where applicable) can be found in Appendix I.

The Stakeholder Committee discussed the use of the data from the 2010 Galveston County Plan Update, and determined that the identification of specific facilities would not result in a significant change to the level of exposed risk to those facilities, and agreed to retain the critical facility risk assessment for extreme wind found in Galveston County's Plan Update.

It is anticipated that specific data regarding critical facilities will be developed prior to the update of this Plan, and that that data will be available for use in the update of this Plan.

Extreme Wind Risk to Galveston Beaches

The primary extreme wind risk to Galveston's beaches manifests in the hazard of coastal erosion. Erosion can and does result from extreme wind events. For more information on the risks to Galveston's beaches, please see section 7.6.1.

7.6.3 Flooding Risk to the City of Galveston

This assessment considered the effects of all flooding that can impact the City of Galveston, its residents, and assets. This includes coastal, flash and urban flooding, as well as storm surge. No differentiation was made in the type of flooding for this assessment.

The City of Galveston, as a matter of established policy, mandates evacuations for residents and non-essential personnel for any storm anticipated to cause hurricane conditions higher than a Category 1. Evacuations are mandated beginning with residents of the unprotected West End, and move east. Tourists and other visitors to the Island are encouraged to evacuate when there is any threat of tropical or coastal storm, particularly those who are unfamiliar with such storms. The City does not maintain any official shelter for those residents who choose not to evacuate, though they have previously offered “shelters-of-last-resort” to those residents who seek shelter but did not evacuate when ordered.

Background of Flooding Vulnerability

The City of Galveston has a long and well-documented history of exposure to and damages from flooding. As a barrier island, flooding from coastal storms is often more severe than on the mainland.

Galveston has been devastated by flooding twice in the past 110 years – once in 1900, and again in 2008. Despite the protection afforded by the Seawall, Galveston remains vulnerable to flooding, particularly from the Bay.

Table 7.6.3-1 provides information regarding Presidential Disaster Declarations involving flooding that have included the City of Galveston. Note that this list is representative, and does not include all declared flood event known to have occurred in Galveston. For a more complete listing of occurrences, please see 6.3.8.

Table 7.6.3-1
Presidentially-Declared Flooding Disasters in the City of Galveston Since 1961
(Source: FEMA)

Declared Flooding Disasters in the City of Galveston, 1961-2009		
Disaster Type	Year of Declaration	Disaster or Emergency Declaration Number
Hurricane	2008	DR-1791 - Hurricane Ike
Hurricane	2008	EM-3294 – Hurricane Ike
Hurricane	2008	EM-3290 – Hurricane Gustav
Hurricane	2005	DR-1606 – Hurricane Rita
Hurricane	2005	EM-3261 – Hurricane Rita
Hurricane	2003	DR-1479 – Hurricane Claudette
Hurricane	2002	DR-1434 – Tropical Storm Fay
Hurricane	2001	DR-1379 – Tropical Storm Allison
Severe Storms	1998	DR-1257
Hurricane	1998	DR-1245 – Tropical Storm Frances
Hurricane	1983	DR-689 – Hurricane Alicia

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Declared Flooding Disasters in the City of Galveston, 1961-2009		
Disaster Type	Year of Declaration	Disaster or Emergency Declaration Number
Hurricane	1961	DR-118 – Hurricane Carla

Table 7.6.3-2 provides the estimated land use by type for Galveston, TX. This data was obtained from the Houston-Galveston Area Council in 2010. Note that Galveston’s total acreage is 569,984.6 acres.

**Table 7.6.3-2
Land Use in Galveston
(Source: HGAC)**

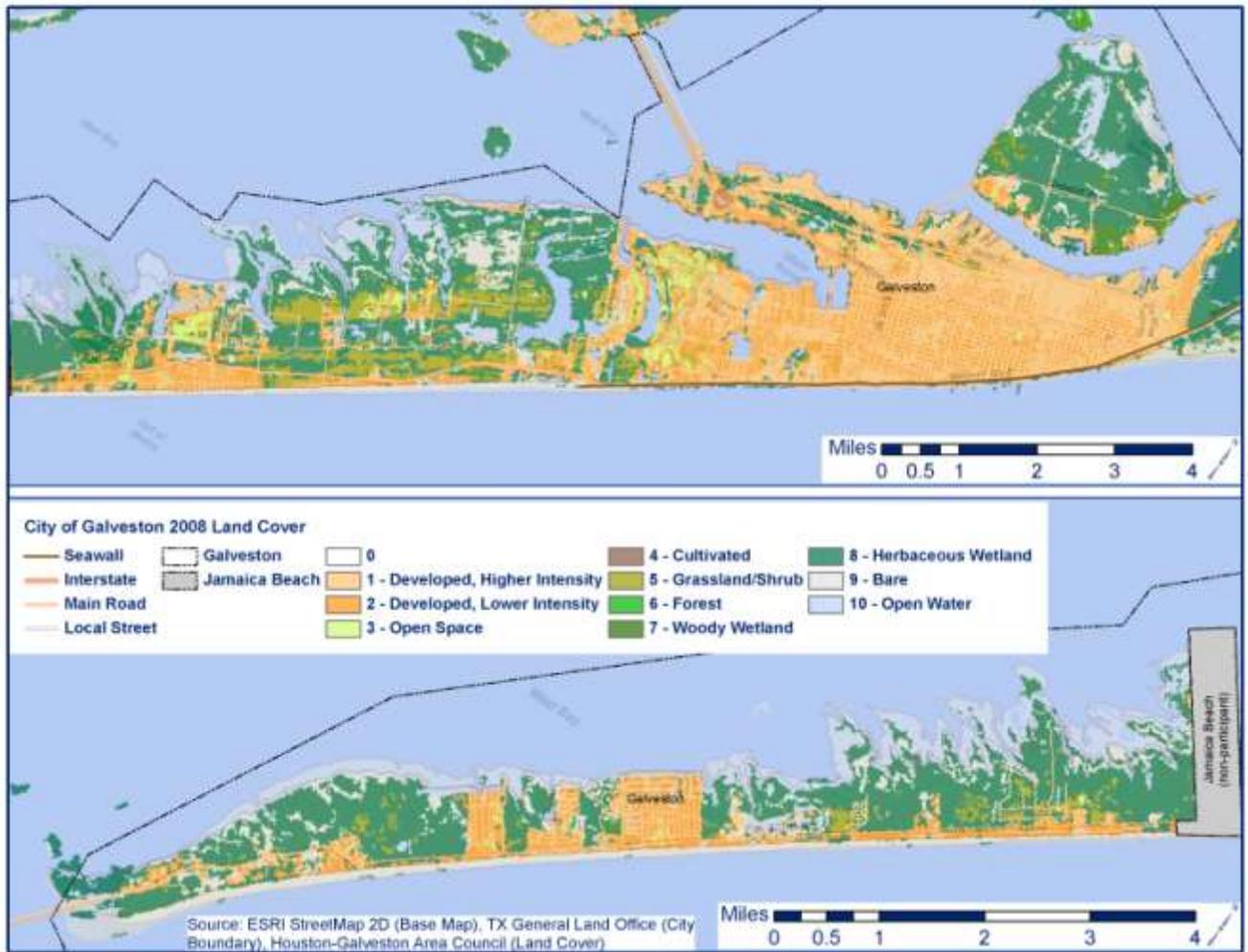
Galveston Land Use, By Acres		
Land Use Description	Land Use Category	Acres
Commercial	Commercial	13870.45
Commercial Vacant	Commercial	29.00
Schools (unknown type)	Other	19.90
Colleges/Universities Public	Other	1239.20
Secondary Schools (HS) Public	Other	348.88
Primary Schools (K-8) Public	Other	698.19
Farm/Ranch Land (in use)	Farm Ranch	93446.47
Farm/Ranch Land (not in use)	Farm Ranch	26281.91
Farm/Ranch Property (homestead & other)	Farm Ranch	13400.85
Farm/Ranch Property (homestead only)	Farm Ranch	767.10
Farm/Ranch Property (other)	Farm Ranch	0.90
Industrial	Industrial	3416.05
Landfill (Active/Inactive)	Industrial	1026.95
Solid Waste Processing Facility	Industrial	7.36
Airport	Other	1021.96
Public Transportation Facilities	Other	10.58
Railways	Undevelopable	2.24
Cemeteries	Undevelopable	278.97
Unusable land (land under water)	Undevelopable	313541.61
Special Purpose Public Facility	Other	2.91
Public Roads	Undevelopable	17422.37
Hospitals	Other	86.20
Government Owned	Other	378.561
Small Parks (<5 acres)	Parks	83.697
Large Parks (>= 5 acres)	Parks	5387.63
Recreational Sports Facility	Parks	600.27
Golf Courses	Parks	1425.56
Sports Fields	Parks	252.79
Small Open Spaces (Circles/Spaceways/Triangles)	Parks	2.74
Residential Available Inventory	Residential	46.10
Residential Available Inventory (vacant)	Vacant	1132.18
Residential Available Inventory (single-family)	Residential	0.93
Residential Condo	Residential	196.57
Residential Multi-Family	Residential	1259.46
Residential Single-Family	Residential	36228.87601

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Galveston Land Use, By Acres		
Land Use Description	Land Use Category	Acres
Residential Mobile Home	Residential	2496.22
Residential Other	Residential	187.46
Utility Right of Way	Industrial	967.23
Other Right of Way/Easement	Industrial	9478.62
Flood Control/Retention	Industrial	276.28
Waste Water Treatment Plant	Industrial	489.13
Vacant Residential Lots/Tracts	Vacant	53.90
Vacant Nature Conservancy/Reserves	Parks	151.87
Vacant	Vacant	19444.71
Undetermined Land Use	Undetermined	2523.52

Map 7.6.3-1 shows the land cover in the City of Galveston. Note the high level of development on the eastern side of the City.

Map 7.6.3-1
Land Cover in Galveston, TX
(Source: ESRI, HGAC)



Methodology for Determining Flooding Vulnerability

As discussed throughout this document, this Plan was developed using the best available data from a variety of sources. Where possible, existing qualitative data regarding risks and vulnerabilities in Galveston was used, such as data from previous mitigation plans and other planning efforts. As such, the data presented in this section is a hybrid of existing data and newly developed / refined data, often extracted from State or County-level sources. Where applicable, the limitations of data on such a small scale, such as a municipality, have been noted. Where planning assumptions were made, those assumptions have been noted and detailed. Every effort has been made to create an assessment that successfully details and quantifies the City's current risks and vulnerabilities, as they exist in the post-Ike environment. In some instances, pre-storm data was used, as it was considered to be the best available data.

Flooding Risk to Galveston Assets

The 2010 Galveston County Mitigation Plan Update utilized HAZUS-MH to determine the flooding risk and exposure to assets in the City of Galveston. This Plan incorporates those findings where applicable.

No area of Galveston is truly immune from the risk of flooding. Despite the protection of the Seawall, almost 90% of the residential structures in Galveston were damaged by storm surge inundation during Hurricane Ike.

Map 7.6.3-2 shows the identified Special Flood Hazard Areas (SFHA) in the City of Galveston, and also notes the location of the City's primary flood protection, the Seawall. This information is based on the 2002 FIRMs, as the revised FIRMs were not available at the time of plan development. The City hopes to include those revised maps in their five year update, as they believe these revised maps will depict a more current assessment of the flood risk in Galveston.

As shown in the map below, the only portion of Galveston Island that is considered to be "outside" of the SFHA is along the Seawall. Note that this area does not extend the entire length of the Seawall, but is concentrated in the center.

Map 7.6.3-2
Galveston Special Flood Hazard Areas
(Source: ESRI, GLO, City)



Map 7.6.3-3 shows the identified Special Flood Hazard Areas (SFHA) in the City of Galveston, and notes the identified historic neighborhoods and structures within those hazard areas. Based on information from the City's Historic Preservation Officer, and from the Texas Historical Commission, all structures east of 61st Street may be eligible for inclusion in a registry of historic assets. This map notes those structures where a determination has been made. Note that this map does not include the West End of Galveston, as no historic structures have been identified on property within the City of Galveston.

A complete listing of these structures can be found in Appendix I. *(Note: This Appendix contains information protected by the Privacy Act of 1974, and is redacted from public versions of this Plan.)*

Map 7.6.3-3
Galveston Special Flood Hazard Areas with Historic Assets and Neighborhoods Noted
 (Source: ESRI, GLO, City)

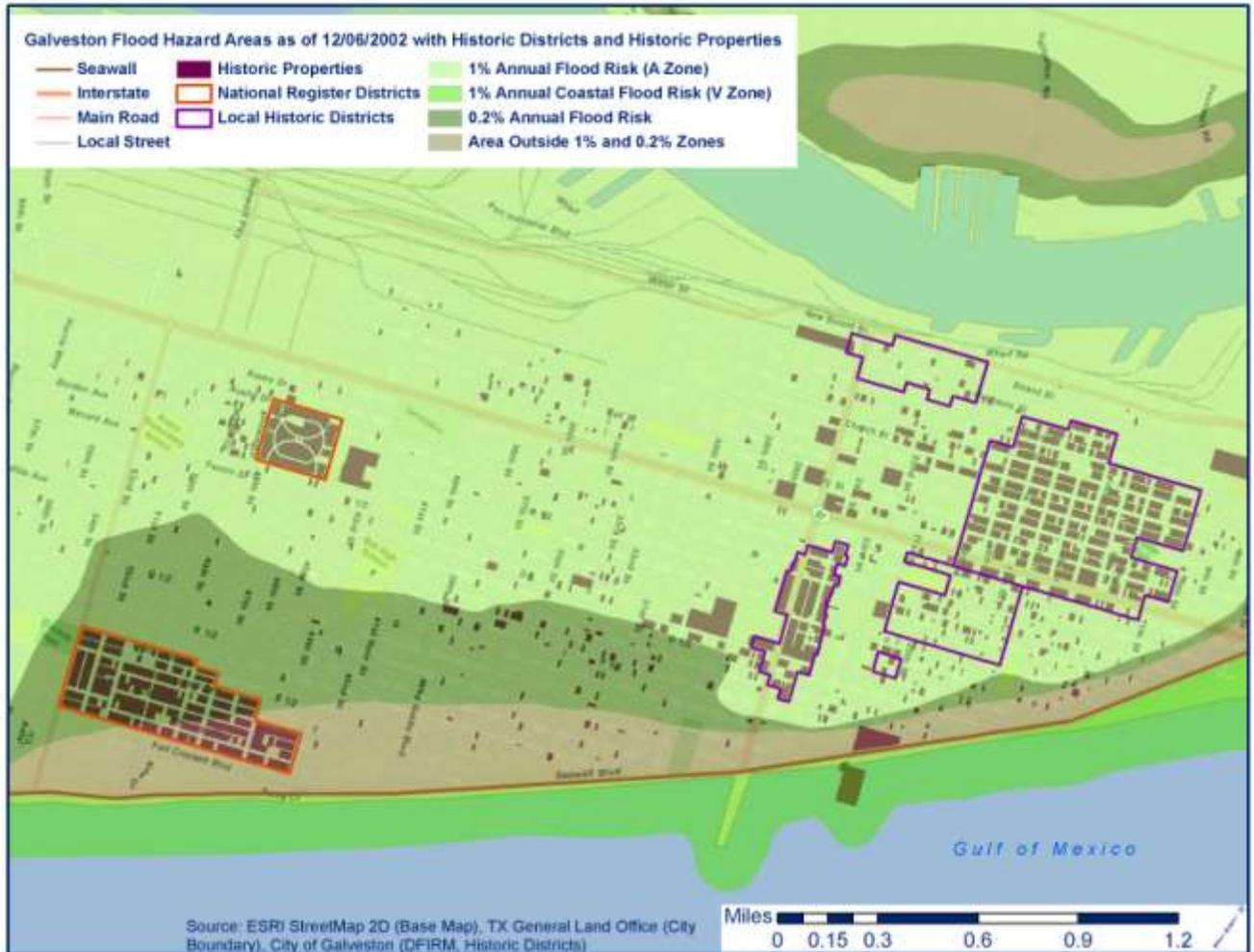


Table 7.6.3-3 shows the estimated exposure of people and parcels in the city of Galveston, by storm surge height. Note that this data refers to structures in existence before Hurricane Ike, includes historic structures and HAZUS-identified critical facilities, and uses the 2000 Census population figures. More current information regarding structures was not available at the time of the development this plan, but will be included in future updates.

As evident in the table below, surge inundation of more than approximately 6 feet would place the majority of the City under water. More than 9 feet would place the entire City under water, for all practical purposes. This table illustrates Galveston’s very real vulnerability to storm surge inundation.

Table 7.6.3-3
Estimated Exposure of People and Parcels to Storm Surge Inundation
(Source: 2010 Galveston County Plan Update, HAZUS-MH)

Estimated Exposure of People and Parcels to Storm Surge Inundation					
Surge Height (in feet)	# Residents at Risk	% of Residents at Risk	# Parcels at Risk	% of Parcels at Risk	Value of Parcels at Risk
4 – 5	22,466	39%	10,708	38%	\$2,110,212,564
6 - 8	33,666	58%	18,853	67%	\$2,940,856,447
9 – 12	57,113	98%	27,083	96%	\$3,806,731,803
13 – 18	58,067	100%	27,876	99%	\$3,809,001,952
>18	58,067	100%	27,876	99%	\$3,809,001,952

Table 7.6.3-4 illustrates the exposure of people and parcels to flood hazards by flood zone designation. Note that this data refers to structures in existence prior to the landfall of Hurricane Ike, includes historic structures and HAZUS-identified critical facilities, and uses the 2000 Census population estimates. This data is based on the 2002 FIRMs. It is anticipated that the revised FIRMs – expected to be available sometime in 2011 – will present a more current analysis of flooding risk in Galveston.

Table 7.6.3-4
Estimated Exposure of People and Parcels to Flood Hazard, by Flood Zone
(Source: 2010 Galveston County Plan Update, HAZUS-MH)

Estimated Exposure of People and Parcels to Flood Hazard, By Flood Zone					
Flood Zone	# Residents at Risk	% of Residents at Risk	# Parcels at Risk	% of Parcels at Risk	Value of Parcels at Risk
V or VE	8,370	14%	6,029	21%	\$522,766,454
A or AE	46,599	80%	18,447	66%	\$2,958,365,858
X (shaded)	11,961	21%	3,187	11%	\$837,708,961

Flooding Risk to Galveston Repetitive Loss Structures

Based on information obtained from FEMA in February 2010, there are 443 structures in the City of Galveston identified as Repetitive Loss. A discussion of Repetitive Loss and complete listing of these structures can be found in Appendix F. (*Note: Appendix F is not available in public versions of this Plan, as this information is protected by the Privacy Act.*)

Map 7.6.3-4 shows the general location of identified Repetitive Loss structures within the City of Galveston.

Map 7.6.3-4
SFHA and Repetitive Loss Structures
(Source: ESRI, GLO, City of Galveston, FEMA)



Flooding Risk to Galveston Critical Facilities

Galveston experienced a high damage rate to its critical facilities as a result of Hurricane Ike. Virtually the entirety of the water and wastewater systems were either damaged or destroyed. Many damaged elements have yet to be fully repaired, pending negotiations with FEMA and availability of funding, materials, equipment and contractors for work. City Hall was damaged, and portions were rendered unusable for months until repairs could be made. In addition, two fire stations were completely destroyed, and one continues to operate out of a temporary facility.

As part of the plan development process, the Stakeholder Committee and Galveston City Staff identified specific critical facilities for the City of Galveston. The complete list of these facilities, their estimated replacement values, and their service values (where applicable) can be found in Appendix H.

The Stakeholder Committee determined that the identification of specific facilities would not result in a significant change to the level of exposed risk to those facilities, and agreed to retain the risk

assessment for flooding found in Galveston County’s Plan Update and presented earlier in this section. To illustrate the real-world damages to critical facilities from flooding events, however, the following table is included. This table lists the actual damages incurred to critical facilities by the storm surge associated with Hurricane Ike in September 2008, with damages grouped by facility function (i.e., water, wastewater, etc). This table also includes damages related to debris removal, including saltwater killed trees and storm drain cleaning. Debris from Hurricane Ike had a significant impact upon all critical operations in the City of Galveston. These estimates are from Project Worksheets written by FEMA.

For the complete list of damages incurred at each individual facility, please see Appendix H.

Table 7.6.3-5
Estimated Damages to City-Identified Critical Facilities and Equipment from Hurricane Ike Flooding, Based on FEMA PWs
(Source: FEMA, City of Galveston)

Estimated Damages to City-Identified Critical Facilities and Equipment from Hurricane Ike Flooding, Based on FEMA Project Worksheets	
Facility Type	Flooding Damages
City Government	\$ 2,171,754.45
Municipal Airport	\$2,131,717.15
Central Garage / Central Fleet	\$1,750,541.33
Fire Department	\$2,646,644.86
Island Transit	\$1,352,876.74
Police Department	\$4,511,379.81
Transfer Station	\$287,032.35
Wastewater Treatment	\$10,350,677.57
Water (potable)	\$3,522,114.27
Debris	\$69,567,245.58
Total Flooding Damages:	\$ 127,016,722.64

Flooding Risk to Galveston Beaches

The most significant flooding risk to Galveston’s beaches comes in the form of coastal erosion. Powerful storm surges buffer the coastline, causing sand and soil to be worn away under the force of so much wind and water. This risk is discussed in detail in 7.6.1.

Figure 7.6.3-1 below provides pre- and post-Ike aerial imagery of the East Beach area of Galveston. Note the significant loss of beach in the photographs. This loss of beach means there is less of a flooding buffer between the next coastal storm and the built environment, which increases the risk for this beach front structure.

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Figure 7.6.3-1
Beach Erosion Post-Ike
(Source: USGS)



7.6.4 Hazardous Materials Incident Risk to the City of Galveston

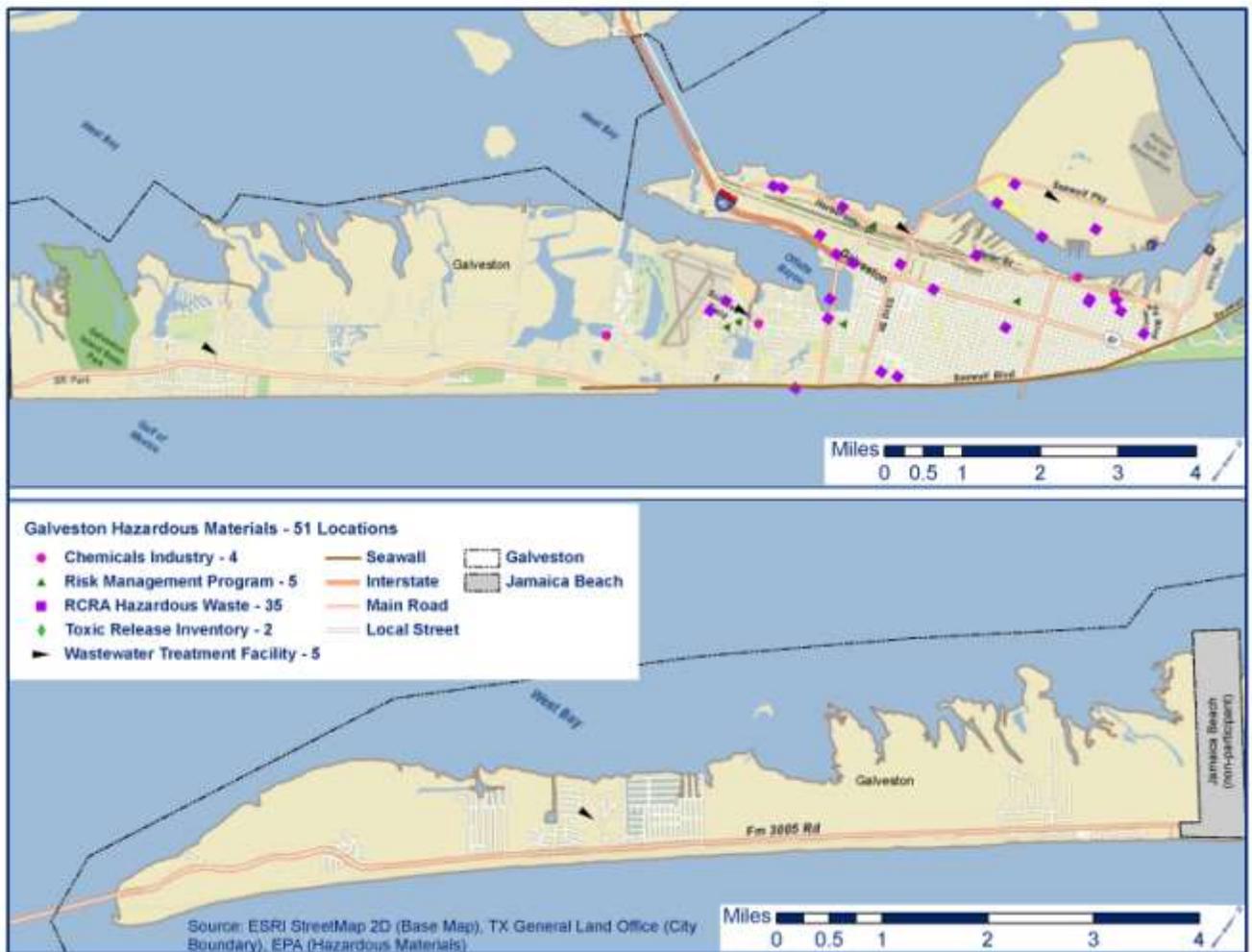
This assessment considered the effects of hazardous materials incidents (fixed site and transport) that can impact the City of Galveston, its residents, and assets. This assessment looked at these incidents in general terms, and did not specifically consider or identify exact risks or damages associated with specific hazardous materials, other than those used for scenarios.

Some material and data in this section is considered sensitive by the City of Galveston, or is proprietary to service providers to the City, and will be redacted from public versions of the Plan.

Background of Vulnerability to Hazardous Materials Incidents

Galveston has a high level of risk from hazardous materials incidents. There are at least 51 fixed site hazardous materials facilities, as illustrated in the map below. This translates to at least one fixed site hazardous materials facility per 11,000 acres on Galveston Island. This map also shows the major transportation routes in, out and around Galveston.

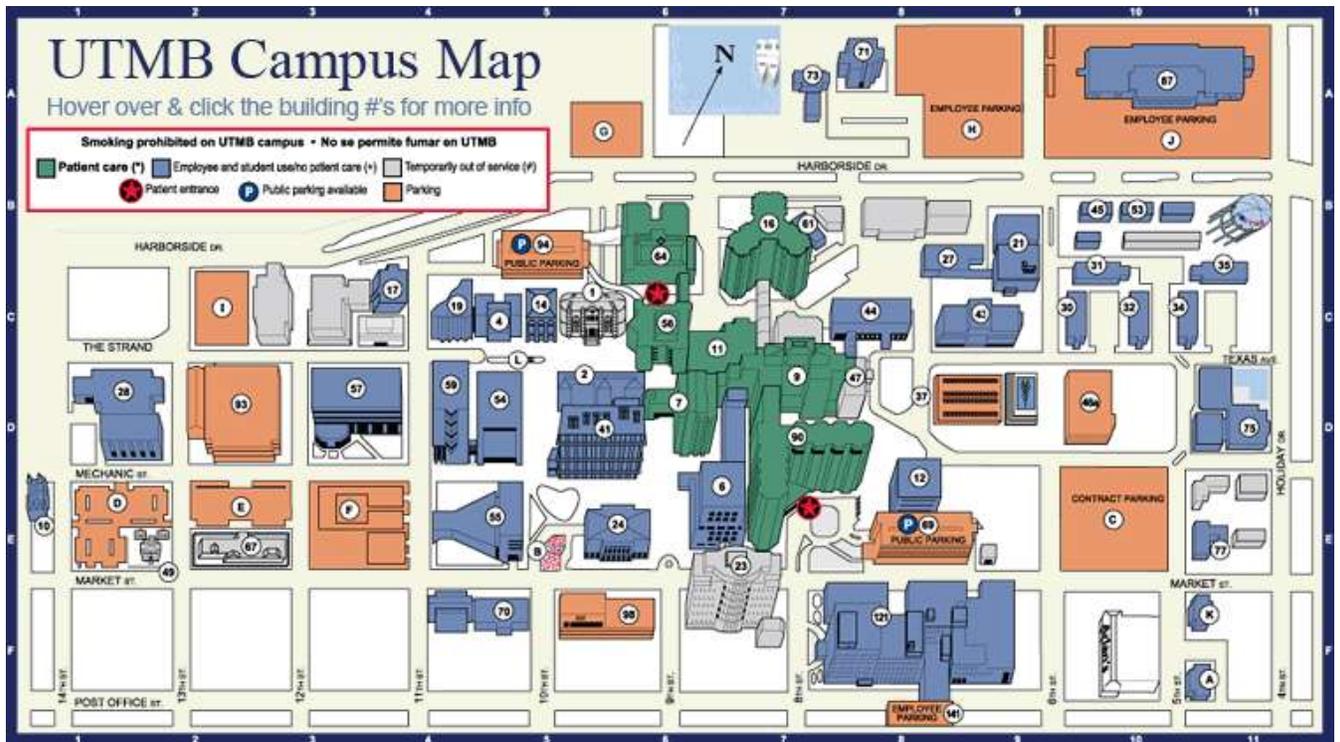
Map 7.6.4-1
Location of Fixed Site Hazardous Materials Facilities in Galveston
(Source: ESRI, EPA, City of Galveston)



Map 7.6.4-2 shows the location of hazardous materials lines and pipelines in the City of Galveston. **Please note that this information is sensitive, and this image is redacted from public versions of the Plan.**

In addition to the identified facilities, lines and pipelines, an area of concentration of hazardous materials in the City of Galveston is on the campus of the University of Texas Medical Branch. UTMB is a full-service medical provider, medical research university, and medical college, and is also home to the Galveston National Lab. Map 7.6.4-3 shows the campus of UTMB. Note that green designates those facilities that provide patient care, and that are likely to contain hazardous materials.

**Map 7.6.4-3
Campus of UTMB
(Source: UTMB)**



For ease of reference, Map 7.6.4-4 shows the location of the UTMB Campus within the City of Galveston.

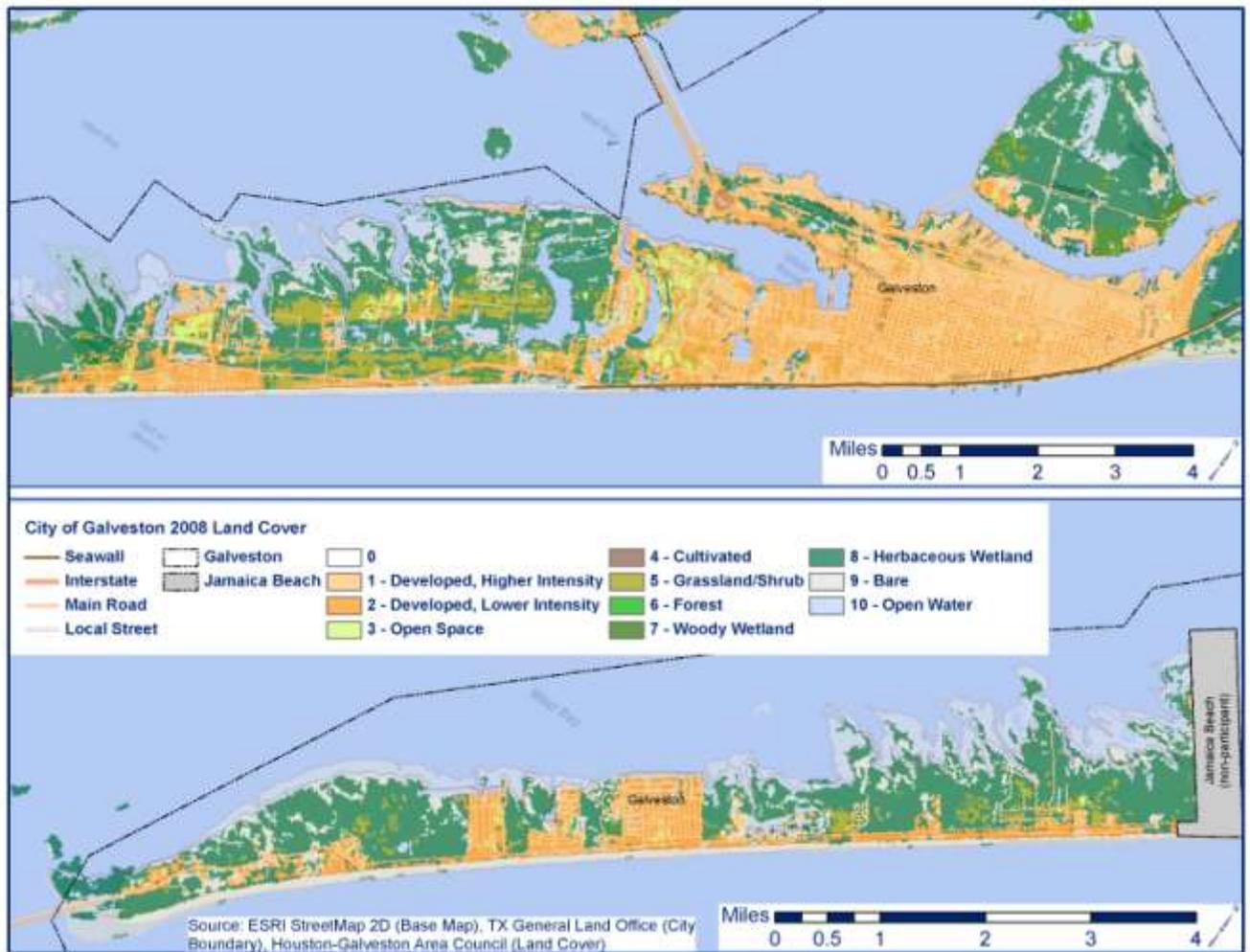
Map 7.6.4-4
Campus of UTMB in Galveston
(Source: ESRI, GLO, City of Galveston, UTMB)



There have been no federal disaster declarations related to hazardous materials incidents in Galveston. This does not mean that there have been no incidents, however. For a listing of previous hazardous materials incidents, please see section 6.3.9.

Map 7.6.4-5 shows the land cover in the City of Galveston. Note the high density development on the eastern side of the City. This development coincides with the major transportation routes on the island.

Map 7.6.4-5
Land Cover in Galveston, TX
(Source: HGAC)



Methodology for Determining Hazardous Materials Incident Vulnerability

As discussed throughout this document, this Plan was developed using the best available data from a variety of sources. Where possible, existing qualitative data regarding risks and vulnerabilities in Galveston was used, such as data from previous mitigation plans and other planning efforts. As such, the data presented in this section is a hybrid of existing data and newly developed / refined data, often extracted from State or County-level sources. Where applicable, the limitations of data on such a small scale, such as a municipality, have been noted. Where planning assumptions were made, those assumptions have been noted and detailed. Every effort has been made to create an assessment that successfully details and quantifies the City's current risks and vulnerabilities, as they exist in the post-Ike environment. In some instances, pre-storm data was used, as it was considered to be the best available data.

Hazardous Materials Incident Risk to Galveston Assets

GIS analysis results provided in the 2010 Galveston County Plan Update defines the risk to Galveston assets from a variety of hazardous materials incident (fixed site and transport) scenarios. The following tables show the estimated exposure of people and parcels to hazardous materials incidents of various points of origin. Note that these tables use the best available data population data from the 2000 Census, and use parcel and structure data from pre-Ike. Critical facilities and historic structures were included in the parcel counts, and were not separated out for individual analysis.

For Tables 7.6.4-1 through 7.6.4-3, buffer zones of .31 miles and 1.5 miles were used in the scenarios. For Tables 7.6.4-4 and 7.6.4-5, buffer zones of one-half mile and 1 mile were used.

Table 7.6.4-1
Estimated Exposure of People and Assets to Hazardous Materials Incidents – Fixed Site
(Source: 2010 Galveston County Plan Update)

Estimated Exposure of People and Assets to Hazardous Materials Incidents – Fixed Site								
			Immediate Impact Area (.31 Miles)			Secondary Impact Area (1.5 Miles)		
Estimated Population (2000 Census)	Estimated Number of Parcels (Pre-Ike)	Estimated Value of Improved Parcels	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk
58,067	28,111	\$3,920,377,102	5,953	1,393	\$285,733,477	46,633	18,515	\$2,965,038,817

Table 7.6.4-2
Estimated Exposure of People and Assets to Hazardous Materials Incidents – Highway and Rail
(Source: 2010 Galveston County Plan Update)

Estimated Exposure of People and Assets to Hazardous Materials Incidents – Highway and Rail								
			Immediate Impact Area (.31 Miles)			Secondary Impact Area (1.5 Miles)		
Estimated Population (2000 Census)	Estimated Number of Parcels (Pre-Ike)	Estimated Value of Improved Parcels	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk
58,067	28,111	\$3,920,377,102	19,977	6,789	\$815,748,242	49,623	16,802	\$2,874,336,022

Table 7.6.4-3
Estimated Exposure of People and Assets to Hazardous Materials Incidents – Gulf Intracoastal Waterway
(Source: 2010 Galveston County Plan Update)

Estimated Exposure of People and Assets to Hazardous Materials Incidents – Gulf Intracoastal Waterway								
			Immediate Impact Area (.31 Miles)			Secondary Impact Area (1.5 Miles)		
Estimated Population (2000 Census)	Estimated Number of Parcels (Pre-Ike)	Estimated Value of Improved Parcels	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk
58,067	28,111	\$3,920,377,102	2,650	740	\$232,756,902	37,118	12,939	\$2,391,323,790

Table 7.6.4-4
Estimated Exposure of People and Assets to Hazardous Materials Incidents – Natural Gas Pipelines
(Source: 2010 Galveston County Plan Update, Texas Railroad Commission)

Estimated Exposure of People and Assets to Hazardous Materials Incidents – Natural Gas Pipelines								
Immediate Impact Area (.5 Miles)						Secondary Impact Area (1 Mile)		
Estimated Population (2000 Census)	Estimated Number of Parcels (Pre-Ike)	Estimated Value of Improved Parcels	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk
58,067	28,111	\$3,920,377,102	10,216	6,144	\$79,699,934	24,215	11,967	\$1,294,256,738

Table 7.6.4-5
Estimated Exposure of People and Assets to Hazardous Materials Incidents – Oil Pipelines
(Source: 2010 Galveston County Plan Update, Texas Railroad Commission)

Estimated Exposure of People and Assets to Hazardous Materials Incidents – Oil Pipelines								
Immediate Impact Area (.5 Miles)						Secondary Impact Area (1 Mile)		
Estimated Population (2000 Census)	Estimated Number of Parcels (Pre-Ike)	Estimated Value of Improved Parcels	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk	Estimated Number of People at Risk	Estimated Number of Parcels at Risk	Estimated Value of Parcels at Risk
58,067	28,111	\$3,920,377,102	1,097	617	\$13,980,770	1,669	1,439	\$89,372,473

In addition to the above quantitative data, it is often useful to use scenarios to visualize the effects of hypothetical incidents involving hazardous materials. While these scenarios are just that – scenarios – they can often illustrate risk and vulnerability in ways that quantitative data cannot.

For this risk assessment, three scenarios were designed, using ALOHA® (Areal Locations of Hazardous Atmospheres), an atmospheric dispersion model used for evaluating releases of hazardous chemical vapors. These scenarios were based on the types of hazardous materials incidents that are most likely to occur in Galveston, based on historical data, rather than the most catastrophic type of incidents that could occur. The purpose of these scenarios was to illustrate the risk and vulnerability of this barrier island community, in the event of a hazardous materials incident, and not to show the worst case scenarios.

Scenario #1 was based on a transportation incident, involving a 7,500 gallon tanker truck carrying liquid ammonia that developed a leak in the tank. An estimated 26,460 pounds were released over 2 minutes in this scenario. Finally, typical August afternoon climate for Galveston was used - 96° F, 80% relative humidity, and a SW breeze at 5.6 MPH.

Figure 7.6.4-1 shows the path of dispersion for the above described scenario. Note that a transportation incident in this location would have the potential to render the I-45 Causeway impassable, and would inhibit traffic to and from the Island. An incident in this location would also have the potential to render both the police department and the closest fire station unable to respond to the incident, requiring response from other emergency responders from outside of the impacted area.

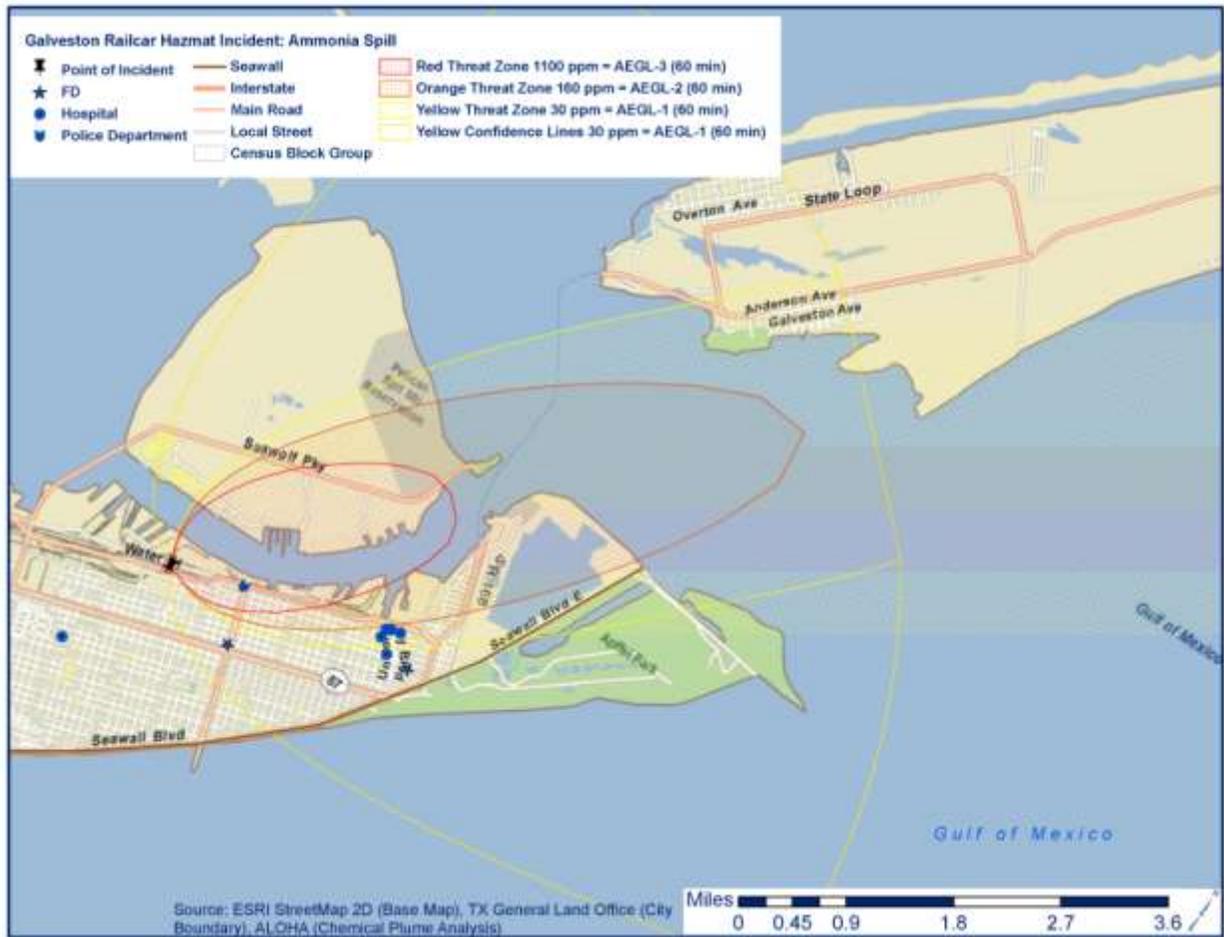
Figure 7.6.4-1
Scenario #1 – Potential Dispersion Path – Tanker Incident
(Source: ESRI, GLO, ALOHA, City of Galveston)



Scenario #2 uses the same perimeters as Scenario #1, except that this scenario is based on a rail yard incident involving rail cars, rather than a tanker truck. Figure 7.6.4-1 shows the path of dispersion for this incident, with the rail yard as the point of origin.

Scenario #2 would have the potential to heavily impact the UTMB area, which is highly populated during the day. This could lead to a compromised ability to access medical care for those people affected by such an incident.

Figure 7.6.4-2
Scenario #2 – Potential Dispersion Path – Rail Yard Incident
(Source: ESRI, GLO, ALOHA, City of Galveston)



The final scenario, #3, involves a hazardous materials incident at the Airport Water Treatment Plant, which is located roughly in the center of the Island. While there are more hazardous materials that are routinely used in water treatment plants, discussions with City staff revealed that the most likely incident would involve a leak in a liquid ammonia storage tank. On average, more than 200 gallons of liquid ammonia are housed at water treatment plants in Galveston. This scenario, which uses the same atmospheric conditions as the previous scenarios, begins with a leak in one of the storage tanks. For scenario purposes, a release of 428 pounds occurred.

Figure 7.6.4-3 shows the probable path of dispersion for the scenario described above, assuming the atmospheric conditions established in the scenario.

Figure 7.6.4-3
Scenario #3 - Dispersion Path - Water Treatment Plant Incident
(Source: ESRI, GLO, ALOHA, City of Galveston)



Note that while this scenario does not show any emergency response facilities impacted, it does reveal a higher risk of impacted residents.

A final GIS application was used in this risk assessment, to illustrate the potential vulnerability of Galveston to hazardous materials incidents. Map 7.6.4-5 illustrates a one-half mile buffer zone surrounding external utilities, including pipelines. **Please note that this information is sensitive and proprietary, and this image is redacted from public versions of the Plan.**

Hazardous Materials Incident Risk to Galveston Critical Facilities

As part of the plan development process, the Stakeholder Committee and Galveston City Staff identified specific critical facilities for the City of Galveston. The complete list of these facilities, their estimated replacement values, and their service values (where applicable) can be found in Appendix H.

The Stakeholder Committee determined that the identification of specific facilities would not result in a significant change to the level of exposed risk to those facilities, and agreed to retain the risk assessment for hazardous materials incidents (fixed site and transport) found in Galveston County's Plan Update and presented earlier in this section. It is anticipated that more detailed critical facility data will be developed in the coming years, and will be available for use in the next mitigation plan update.

Note that critical facilities were accounted for in the scenario figures in the preceding subsection.

Hazardous Materials Incident Risk to Galveston Beaches

Any hazardous materials incident that occurs in the Bay, the Gulf or the shipping channel has the potential to impact Galveston's beaches. Estimated risks would vary, based on a variety of factors, including:

- Chemical or substance released
- Quantity released
- Amount/rate of dissipation
- Current and tide

For these same reasons, costs would also vary, as the environmental containment and clean-up required would vary greatly from substance to substance. Some substances could be allowed to dissipate naturally; other substances may require the closing of the beach and the immediate remediation of the substance.

Regardless of the chemical or substance involved, a hazardous materials incident could have serious risks to both the beaches and to those who use the beach. For a discussion of the importance of the beaches to Galveston's economy, please see 7.3.1.

7.6.5 Wildfire / Urban Fire Risk to the City of Galveston

This assessment considered the effects of wildfires and urban fires that can impact the City of Galveston, its residents, and assets. This assessment looked at these hazards in terms of the City's capability post-Ike.

Background of Vulnerability to Wildfire / Urban Fire

There have been at least 4 federal emergency or fire assistance declarations related to wildfire / urban fire that included the City of Galveston. Table 7.6.5-1 lists these declared events. In addition, the City may have been included in one or more Fire Assistance Declarations. That information was not available from FEMA as this plan was being developed.

Table 7.6.5-1
Presidential Wildfire / Urban Fire Emergency Declarations including the City of Galveston Since 1993
(Source: FEMA)

Wildfire / Urban Fire Declarations Including the City of Galveston, 1993-2009		
Disaster Type	Year of Declaration	Emergency Declaration Number
Extreme Fire Hazard	1999	3142-EM
Severe Wildfire Potential	1998	3137-EM
Fire Emergency	1996	3117-EM
Extreme Fire Hazard	1993	3113-EM

Table 7.6.5-2 provides the estimated land use by type for Galveston, TX. This data was obtained from the Houston-Galveston Area Council in 2010. Note that Galveston's total acreage is 569,984.6 acres.

Table 7.6.5-2
Land Use in Galveston
(Source: HGAC)

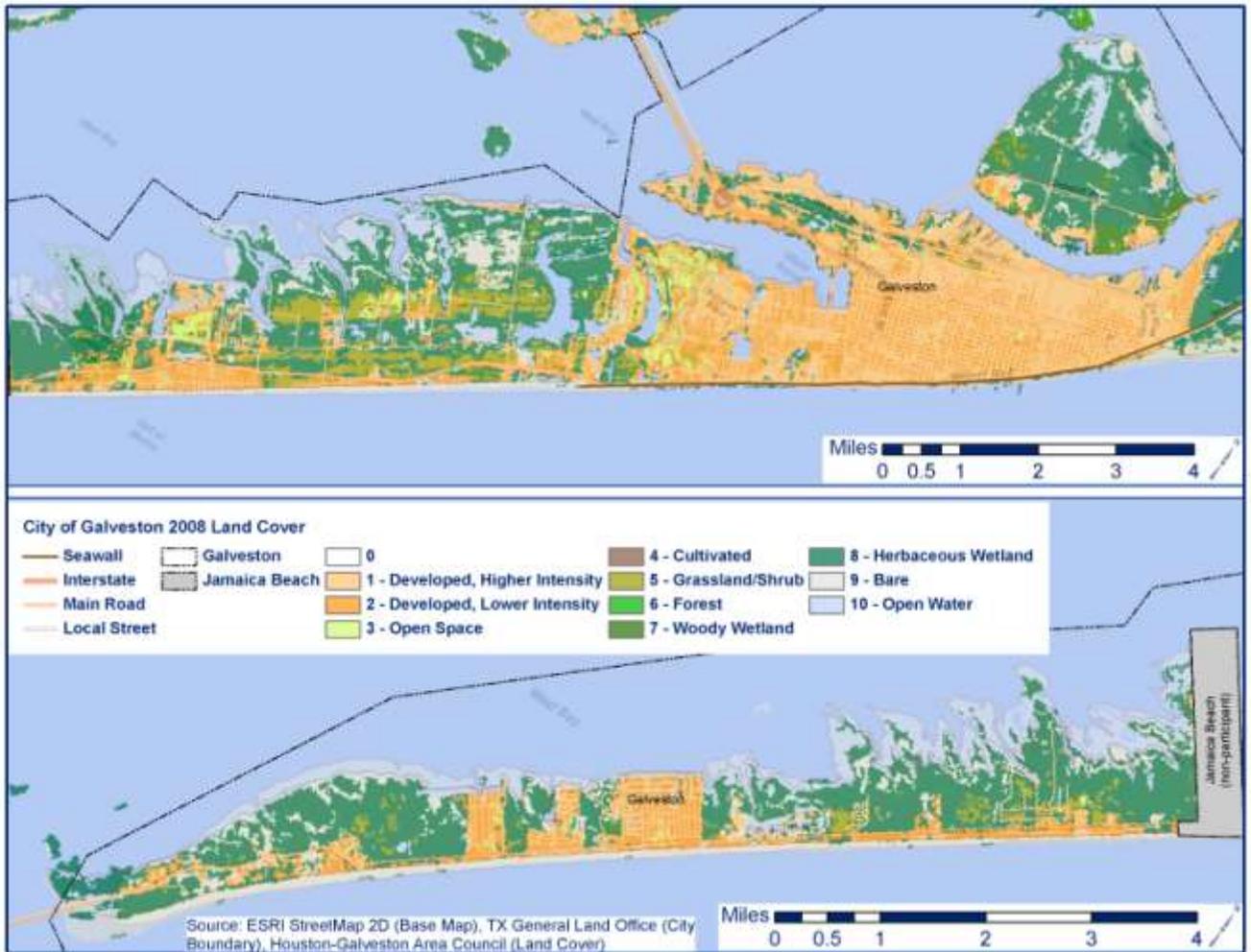
Galveston Land Use, By Acres		
Land Use Description	Land Use Category	Acres
Commercial	Commercial	13870.45
Commercial Vacant	Commercial	29.00
Schools (unknown type)	Other	19.90
Colleges/Universities Public	Other	1239.20
Secondary Schools (HS) Public	Other	348.88
Primary Schools (K-8) Public	Other	698.19
Farm/Ranch Land (in use)	Farm Ranch	93446.47
Farm/Ranch Land (not in use)	Farm Ranch	26281.91
Farm/Ranch Property (homestead & other)	Farm Ranch	13400.85
Farm/Ranch Property (homestead only)	Farm Ranch	767.10
Farm/Ranch Property (other)	Farm Ranch	0.90
Industrial	Industrial	3416.05
Landfill (Active/Inactive)	Industrial	1026.95
Solid Waste Processing Facility	Industrial	7.36
Airport	Other	1021.96

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Galveston Land Use, By Acres		
Land Use Description	Land Use Category	Acres
Public Transportation Facilities	Other	10.58
Railways	Undevelopable	2.24
Cemeteries	Undevelopable	278.97
Unusable land (land under water)	Undevelopable	313541.61
Special Purpose Public Facility	Other	2.91
Public Roads	Undevelopable	17422.37
Hospitals	Other	86.20
Government Owned	Other	378.561
Small Parks (<5 acres)	Parks	83.697
Large Parks (>= 5 acres)	Parks	5387.63
Recreational Sports Facility	Parks	600.27
Golf Courses	Parks	1425.56
Sports Fields	Parks	252.79
Small Open Spaces (Circles/Spaceways/Triangles)	Parks	2.74
Residential Available Inventory	Residential	46.10
Residential Available Inventory (vacant)	Vacant	1132.18
Residential Available Inventory (single-family)	Residential	0.93
Residential Condo	Residential	196.57
Residential Multi-Family	Residential	1259.46
Residential Single-Family	Residential	36228.876
Residential Mobile Home	Residential	2496.22
Residential Other	Residential	187.46
Utility Right of Way	Industrial	967.23
Other Right of Way/Easement	Industrial	9478.62
Flood Control/Retention	Industrial	276.28
Waste Water Treatment Plant	Industrial	489.13
Vacant Residential Lots/Tracts	Vacant	53.90
Vacant Nature Conservancy/Reserves	Parks	151.87
Vacant	Vacant	19444.71
Undetermined Land Use	Undetermined	2523.52

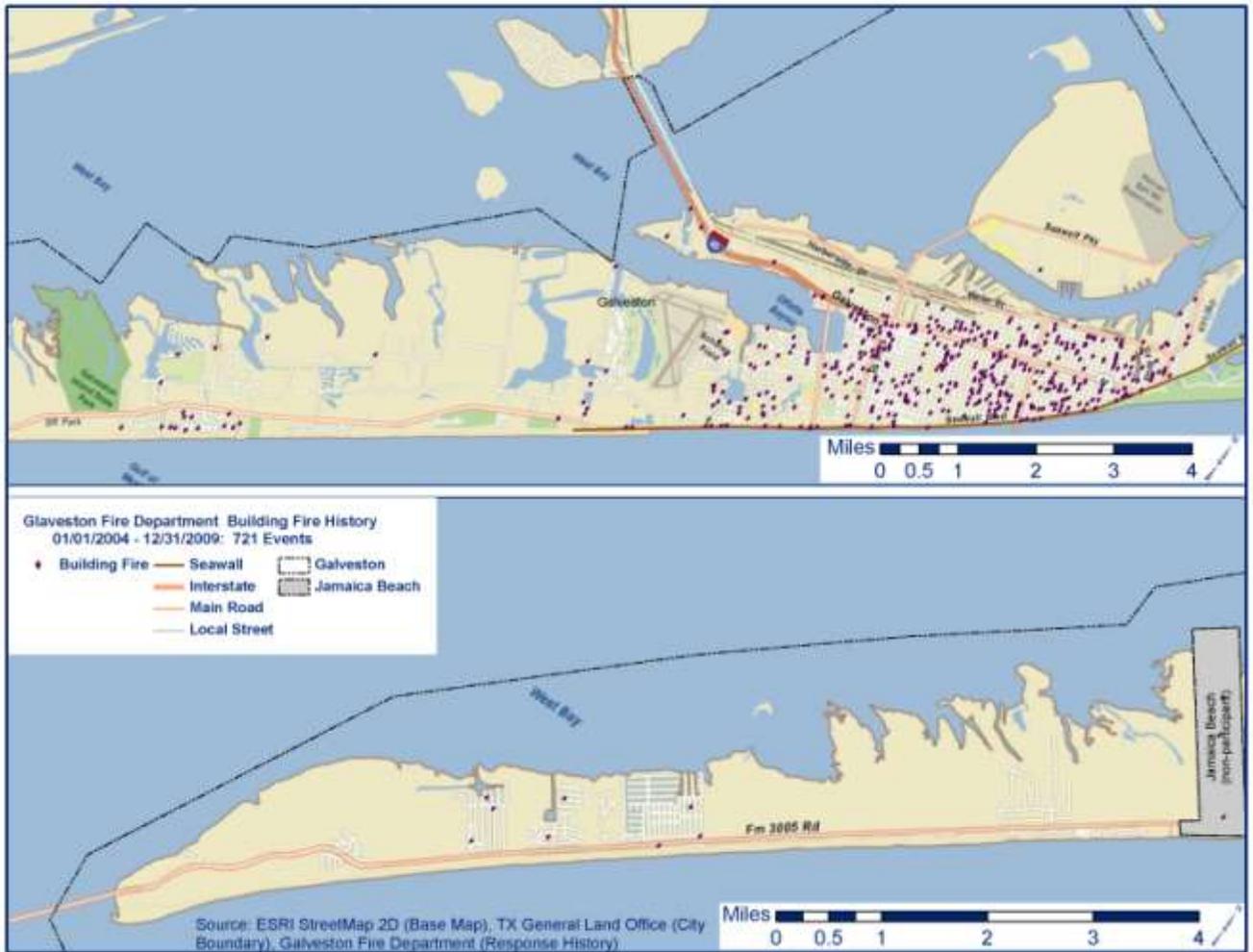
Map 7.6.5-1 shows the land cover in the City of Galveston. Note the density of development on the eastern side of the City.

Map 7.6.5-1
Land Cover in Galveston, TX
(Source: ESRI, HGAC)



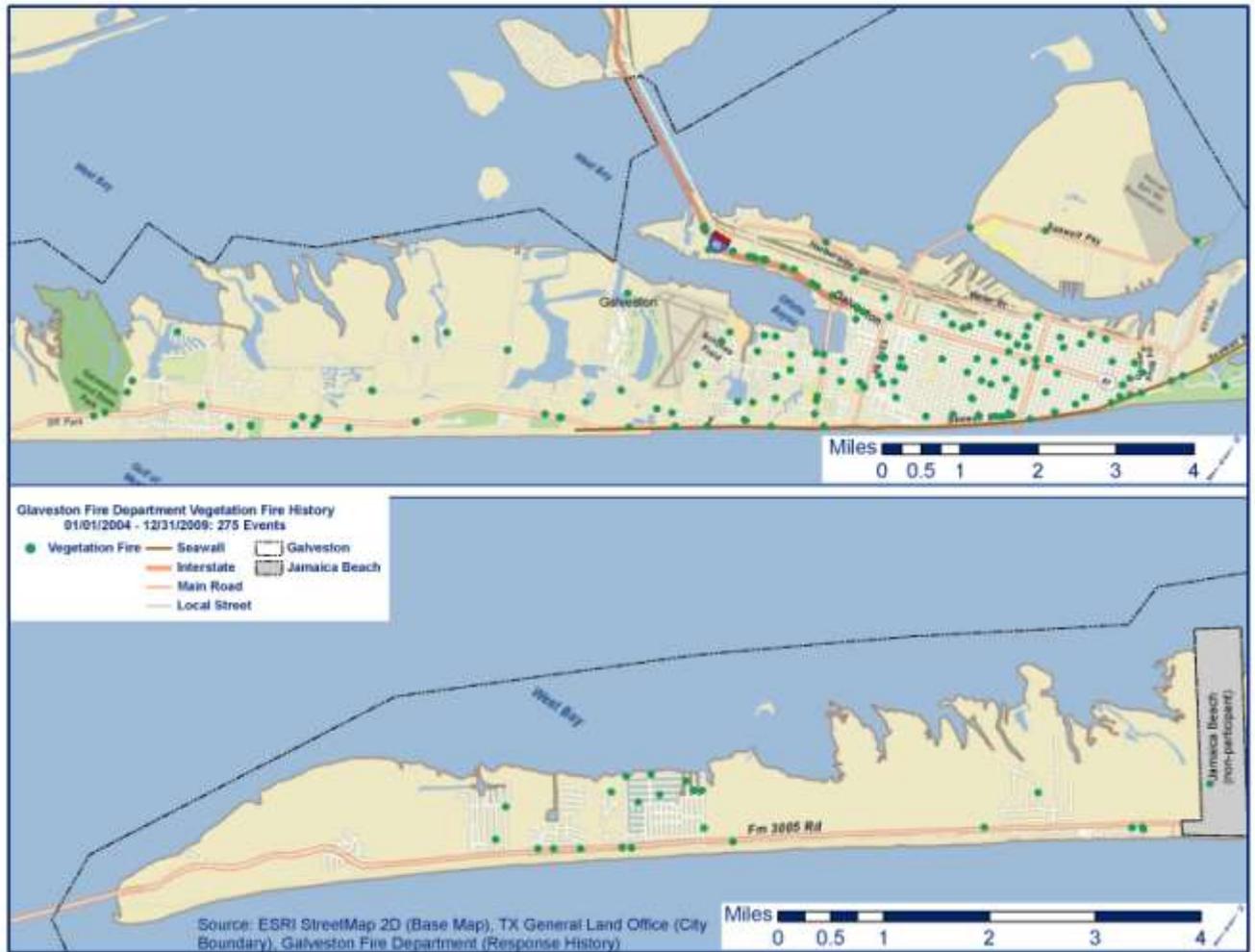
Map 7.6.5-2 shows the location of the 721 structure fires in the City of Galveston between January 2004 and December 2009. Note that the locations of these fires have a strong correlation to the density of development depicted in Map 7.6.5-1.

Map 7.6.5-2
Location of Structure Fires in Galveston, 2004 - 2009
(Source: ESRI, GLO, Galveston Fire Department)



Map 7.6.5-3 shows the location of the 275 brush, vegetative and wildland fires in the City of Galveston between January 2004 and December 2009. Note that the locations of these fires do not necessarily correlate to the grassland, forest and woodland areas depicted in Map 7.6.5-1. This is indicative of vegetative, brush and wildland fires with non-natural or human origins.

Map 7.6.5-3
Location of Vegetation, Brush and Wildland Fires in Galveston, 2004 - 2009
(Source: ESRI, GLO, Galveston Fire Department)



Methodology for Determining Wildfire / Urban Fire Vulnerability

As discussed throughout this document, this Plan was developed using the best available data from a variety of sources. Where possible, existing qualitative data regarding risks and vulnerabilities in Galveston was used, such as data from previous mitigation plans and other planning efforts. As such, the data presented in this section is a hybrid of existing data and newly developed / refined data, often extracted from State or County-level sources. Where applicable, the limitations of data on such a small scale, such as a municipality, have been noted. Where planning assumptions were made, those assumptions have been noted and detailed. Every effort has been made to create an assessment that successfully details and quantifies the City's current risks and vulnerabilities, as they exist in the post-like environment. In some instances, pre-storm data was used, as it was considered to be the best available data.

Wildfire / Urban Fire Incident Risk to Galveston Assets

Analysis data provided in the 2010 Galveston County Plan Update illustrates the risk to Galveston assets from the wildfire portion of this identified hazard. The following table shows the estimated exposure of people and parcels to this portion of the hazard. Note that this table uses the best available data population data from the 2000 Census, and uses parcel and structure data from pre-Ike. Critical facilities and historic structures were included in the parcel counts, and were not separated out for individual analysis.

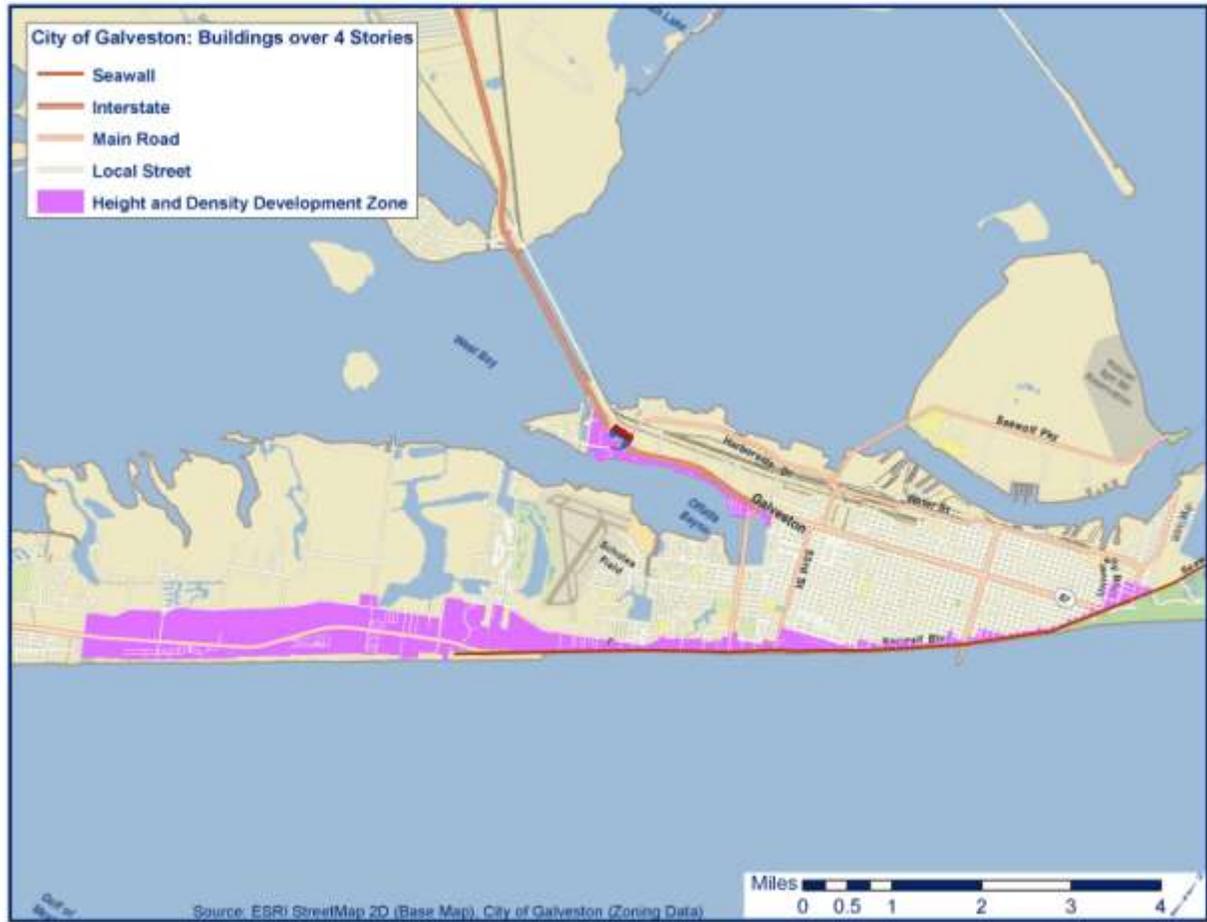
Table 7.6.5-3
Estimated Exposure of People and Assets to Wildfire / Urban Fire
 (Source: 2010 Galveston County Plan Update)

Estimated Exposure of People and Assets to Wildfire / Urban Fire					
Total Estimated Population	Total Estimated Number of Improved Parcels with Values	Total Value of Improved Parcels	Number of People at Risk	Number of Parcels at Risk	Value of Parcels at Risk
58,057	20,507	\$3,920,377,102	25,272	9,244	\$1,523,551,186

Of particular concern for the City of Galveston are high rise structures. The City’s Fire Department lacks the equipment necessary to efficiently and safely attack any fire above the third story of a building. By the Fire Department’s estimates, there are approximately 50 such structures on the Island – the majority of them being condominiums, hotels and apartment buildings. In other words, those buildings that the Fire Department would have the hardest time responding to are the buildings which typically house the greatest numbers of people.

Map 7.6.5-4 shows the areas of the City zoned to allow these high rise buildings. As of the development of this Plan, GIS information on the 50 high rise buildings was not readily available. This information will be included in future updates of this Plan.

Map 7.6.5-4
Location of Height and Density Zones in Galveston
(Source: ESRI, Galveston Planning and Community Development Department)



Wildfire / Urban Fire Risk to Galveston Historic Assets

Fire is a hazard of particular concern to historic structures. Most of the historic structures in Galveston, and almost all of the residential historic structures, are wood frame construction, or are constructed almost entirely of wood and other materials that catch and burn easily. This increases their vulnerability to fire dramatically over residential structures construction of more fire-resistant materials.

In addition to the vulnerability of the structures themselves, the threat of fire spreading through historic neighborhoods is also a concern. This is what happened during the Great Galveston Fire of 1885, described in Section 6. In that fire, 568 structures were lost, with damages incurred over 42 City blocks. Map 7.6.5-4 illustrates the path of the 1885 Fire in relation to the currently-designated historic neighborhoods and residences in the City of Galveston. While a fire of such magnitude may be unlikely, given modern fire fighting techniques, knowledge and equipment, the post-Ike capability and capacity of the City's fire department (discussed in Sections 3 and 8) must be considered in any scenario.

Map 7.6.5-4
Location of Historic Structures and Neighborhoods in Galveston and the Path of the 1885 Fire
(Source: ESRI, GLO, Galveston Planning and Community Development Department)



Based on the historic accounts of the fire, and using the most current median home price in Galveston, it is possible to estimate the potential loss if such an event were to occur today. If the 1885 fire were to happen today, and the structures in the same locations were to burn, this would mean an estimated property loss of at least \$4,240,000.

Wildfire / Urban Fire Risk to Galveston Critical Facilities

As part of the plan development process, the Stakeholder Committee and Galveston City Staff identified specific critical facilities for the City of Galveston. The complete list of these facilities, their estimated replacement values, and their service values (where applicable) can be found in Appendix H.

The Stakeholder Committee determined that the identification of specific facilities would not result in a significant change to the level of exposed risk to those facilities, and agreed to retain the risk assessment for wildfire / urban fire found in Galveston County's Plan Update and presented earlier in this section.

Wildfire / Urban Fire Risk to Galveston Beaches

Beaches and shorelines were determined to have no direct vulnerability to wildfire / urban fire. The hazard was determined to present to no direct threat to beaches and shorelines in Galveston.

7.7 The City of Galveston's Future Development Trends

Any discussion of future development must be done in the context of the City's current struggle to recover from the devastation of Hurricane Ike. Ike left no aspect of the City untouched; every facet of the City was affected, from population to housing stock to land use to infrastructure. This section will discuss future development of the City in the context of its recovery from Hurricane Ike.

As a barrier island, Galveston has a finite potential for growth and future development. All unincorporated areas of the island have been incorporated by the City, or are within the City limits of the Village of Jamaica Beach or are within the area owned by the State of Texas and managed as the Galveston Island State Park. No unincorporated areas remain on the island.

Prior to Hurricane Ike, the City's population was approximately 58,000, with an annual growth rate of less than one-half percent. Hurricane Ike, and the resulting displacement of the population, has reduced the population of the City by almost 20%. It will be a year before the official Census population count is available, but the City currently estimates the population to be approximately 48,000.

As of February 2010, there were 24,210 Galveston residents employed. However, the labor force has increased faster than employment resulting in an increasing unemployment rate which currently stands at 8.1%. The unemployment rate had been steadily increasing in the months preceding Hurricane Ike, due to broader economic conditions, and spiked to 9.7% immediately following the storm. The damage forced many businesses to close and some employers have not returned to pre-storm capacity. A recent estimate places 35,000 jobs in Galveston, indicating that a significant number of jobs are being filled by people who do not live in the City.

Galveston is home to a high number of renters and rental properties, as is common in beach communities. In 1990 and 2000, rental market conditions in the City were soft, with vacancy rates at 14.8% and 15.9% respectively. Subsequently, however, the market showed signs of improvement; at the end of February 2008 (prior to Hurricane Ike), the vacancy rate had decreased to 8.3%. Nevertheless, impact from the storm and the economic slowdown has severely dampened demand for rental units once again. As of February 2010, the vacancy rate had reached 20.7%. There are indications that many units have been renovated and many rental properties are fully operational, this implies that the high vacancy rate is likely due to economic conditions rather than to units being off-line from sustained damage.

According to Census estimates there are 12,704 renter-occupied units in the City. Approximately 5,856 of the renter-occupied households paid more than 30% of their income towards rent. This means that 50% of all renters were burdened by housing costs. Although average rents might be expected to decrease as vacancy rates increase –due to traditional supply and demand economics – the opposite has been observed in the last 2 years. From February 2008 to February 2010, average rents have increased from \$714 to \$804 per month or nearly 13%. This could be due in part to recently renovated units entering the market that command higher premiums.

In the aftermath of the 1900 Storm, the City's leaders recognized the importance of mitigation in their reconstruction of the City. The same can be said of the City's current leaders and staff.

With so much of the City damaged by Hurricane Ike, concerted efforts have been made to reconstruct the City to be safer and more resilient to future disasters. The City's Planning and Community Development Department has made the following suggested ordinance revisions, which will serve to provide better mitigation for future development:

- Adoption of a beach setback ordinance, requiring that new construction be located at least 75' from the north toe of the dune;
- Adoption and enforcement of the 2009 edition of the International Building Code; and
- Consideration of significant revisions to the City's Flood Damage Prevention Ordinance, including
 - Adoption of a freeboard requirement
 - Adoption of a cumulative substantial improvement/substantial damage provision.

The City leaders and staff recognize that Galveston is a high hazard area, subject to impacts from a variety of hazards, and that all future development and construction must be done in such a way that the best possible protection is afforded to all future development.

In addition, the City's recent housing market study makes a series of recommendations to aid in the revitalization of the City in the aftermath of Hurricane Ike. These recommendations are intended to aid the City in both recovery from the storm and in future development. These recommendations were grouped into five categories:

1. The City should build upon its assets as a springboard: the momentum of the recovery environment, existing housing- and recovery-related programs, and ongoing planning efforts — all of which can supply the impetus for progress in the desired direction.
2. Focus development on the City's urban core, particularly north of Broadway Boulevard between 25th and 46th Streets. Several key considerations — including the level of damage resulting from Ike — justify strategic approaches to rehabilitating and encouraging new development in this area.
3. Future development must be done in an environmentally sensitive manner that adequately accounts for human safety and ecological preservation when considering the design, placement and building practices of development on the island. By containing the Island's developed footprint and encouraging more environmentally friendly and risk-averse development within that footprint, the City can move towards this goal.
4. Approach the City's recovery as part of a broader, comprehensive effort to improve the built environment. Short-term recovery and development should be approached within the context of existing efforts to ensure a coordinated approach and to provide additional impetus for implementing them.
5. Utilize and guide market forces to encourage innovative changes in development on and perception of the island. The City of Galveston has two primary challenges to successfully harness market: the underlying issues that have led to perceptions of the Island as an unsuitable place to reside must be addressed, and the vision of living on Galveston Island must be reframed and marketed. By following logical market responses to their current situation and encouraging those market forces in appropriate manners, the city can ultimately shape not only its recovery, but its urban future.

7.8 Summary of Risk Assessment

Mitigation planning is intended to provide a rational method for communities to decide what actions to take to reduce their risks from natural hazards. Aside from actually determining and implementing specific actions, perhaps the most important part of a mitigation plan is the risk assessment, which establishes an objective basis for prioritizing mitigation efforts. The risk assessment in this plan has been used to identify the most significant risks to the City of Galveston; to identify the hazards that present the most potential damage to the City and its assets; to ascertain where additional study may be warranted; and to begin identification and prioritization of mitigation actions.

As noted earlier, the purpose of risk assessment is to identify and quantify future losses from hazards, with the goal of using this information to determine what actions should be taken to reduce damages. Although the City as a whole has more risk from flooding and extreme wind than it does from coastal erosion and hazardous materials incidents, there are several factors that must be considered and understood in order to put this into context. First, because Galveston is a barrier island, what would be a minor risk for a mainland community becomes a more significant risk to this community, who has significant potential for isolation. Infected cruise ship passengers, disembarking from a cruise at the Port of Galveston, have the potential to cause a biologic incident in this tourist community. Cascading events in particular are a planning consideration for the City. A routine hazard, such as a traffic accident on the I-45 Causeway, has the potential to become a serious risk to the community, should the event be prolonged and require closure of the Causeway.

Second, there are no large-scale mitigation measures that would reduce risks to all properties simultaneously, so facility or site-specific risks are a more significant consideration than City-wide ones in most cases. It is necessary to calculate risks on a facility or site-specific basis as a first step in developing meaningful mitigation actions. The paragraphs below describe initial steps that the City and its partners can take to begin a more detailed risk assessment process that will inform the process of developing mitigation actions.

Section 9 of this Plan outlines a series of general recommendations that can be implemented on a City-wide basis as well as a wide range of specific, prioritized actions have been identified for specific facilities as part of the planning process. The HMPSC used the present risk assessment section as the basis for these actions and priorities. However, it has been generally acknowledged that additional information would be helpful in refining and updating this Plan in the years to come. Section 9 also includes actions to aid in this process that include the following general steps:

- Continue to identify and prioritize critical facilities, facilities with high occupancies, or operations with high value
- Study hazard vulnerabilities based on specific conditions and hazards at sites for the highest priority sites and facilities
- Undertake detailed risk assessments for critical facilities in hazard areas, and with known vulnerabilities
- Develop appropriate, cost-effective mitigation measures for the facilities.