4.0 Overview of the Risk Assessment Process

Requirement CFR §201.6(2) 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.

Risk assessment requires the collection and analysis of hazard-related data in order to enable the participating jurisdictions to identify and prioritize appropriate mitigation actions that will reduce/eliminate losses from potential hazards. The eight following risk assessment steps have been integrated where applicable for each hazard identified as a threat to the City of Biloxi served under this planning effort:

- Identifying hazards
- Profiling hazards
- Assessing Vulnerability:Overview
- Assessing Vulnerability: Identifying Structures
- Assessing Vulnerability: Addressing Repetitive Loss Properties
- Assessing Vulnerability: Estimating Potential Losses
- Assessing Vulnerability: Analyzing Development Trends

4.1 Risk Assessment

Section 4.2 incorporates all the related steps of the risk assessment for the City of Biloxi. The section is organized by CFR regulations. The Hazard Mitigation Planning Committee conducted an exercise to review 36 natural and human-caused hazards. The Committee separated the hazards by Critical Natural Hazards, Non-critical Natural Hazards, and Man-made/Health-Related Hazards. For the purposes of this Plan Update, the basic components and products of thunderstorms (thunderstorm, high wind, and lightning) are combined into a single hazard. The Planning Committee identified 6 critical hazards, and a risk assessment was conducted for each of these hazards:

- Coastal Storms (Hurricanes/Tropical Storms)
- Floods
- Severe Thunderstorms (Lightning and High Wind)
- Storm Surge
- Tornadoes
- Wildfires

This assessment will be updated in the future to incorporate changes in zoning laws, land uses, or hazard conditions as applicable. The vulnerability assessment incorporatesthe best available new and existing critical facility, infrastructure, and building information available at this time. For this update, information, including estimates of potential dollar losses for each hazard, are incorporated into the Plan Update. There is reasonable expectation that some data was not recoverable post-Katrina.

The methodology used to develop the rankings for probability of future occurrences of hazards is provided in Table 4.1.

Table 4.1
Hazard Probability of Occurrence Ranking

Rank	Probability based on % chance of occurrence annually
Very Low	Less than 10% chance occurrence annually
Low	10%-25% chance of occurrence annually
Medium	25%-50% chance of occurrence annually
High	50% or greater chance of occurrence annually

4.2 Identifying and Profiling Hazards

Requirement CFR §201.6(2)(i) [The risk assessment shall include a] description of the type, location, and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.

Hazard identification is the process of recognizing risk-related events that threaten a community. Events are described as natural or human-caused hazards that inflict harm on people or property, or interfere with commerce or human activities. Such events would include, but are not limited to hurricanes, floods, tornadoes, and other incidents that can affect populated or built areas.

Hazard profiling involves describing the physical characteristics of the hazards through analysis of past occurrences, location, extent and probability. This process was accomplished by creating base maps of the City of Biloxi facilities, and then collecting, documenting, and analyzing hazard data obtained from various sources. The degree to which hazards are profiled is dependent on the availability of data. Data limitations are addressed per hazard. The level of risk for each hazard was also estimated and assigned a rank of high, medium, or low by the Planning Committee and was based upon factors unique to that hazard.

The City of Biloxi Hazard Mitigation Planning Committee reviewed all of the potential hazards that can affect the City of Biloxi and ranked the hazards by natural hazard and man-made/health-related hazard. For the identified natural hazards, the Planning Committee determined if the hazard was to be considered critical or non-critical, based on severity and frequency of occurrence. Table 4.2 lists the identified natural hazards and the level of criticality and probability of occurrence identified by the Planning Committee.

Table 4.2
Hazard Criticality and Probability Identification

Natural Hazards	Critical	Non-Critical	Probability of Occurrence
Coastal/Riverine Erosion		X	Low
Coastal Storms (Hurricanes, Tropical Storms)	X		High
Drought		X	Low
Earthquakes		X	Low
Exotic Species (Nutria, Cogon Grass, Formosain Termites)		X	Low
Fog		X	Low
Floods	X		Medium
Hail		X	Low
Heat Wave		X	Low
Landslides/Sinkholes		X	Low
Pandemic (Bird Flu, West Nile)		X	Low
Salt Water Intrusion		X	Low
Sea Level Rise		X	Low
Severe Thunderstorms (Including Strong Winds andLightning)	X		High
Storm Surge	X		High
Tornadoes	X		High
Tsunamis		X	Low
Wildfires	X		High
Winter Storm/Freezes		X	Low

Critical Hazards

4.2.1 Coastal Storms (Hurricanes, Tropical Storms)

Description of the Hazard

Hurricanes and tropical storms are naturally occurring events that produce damaging high winds, generate dangerous storm surge flooding, cause pounding storm surf, spawn tornadoes, and produce torrential rainfall that can cause inland flooding. Due to the City of Biloxi's geographic location on the northern coast of the Gulf of Mexico, hurricanes and tropical storms are recognized as the most dangerous natural hazardthreat to the City.

Hurricanes are the strongest natural hazard threat to human life and property on a recurrent basis. Tropical storms and hurricanes threaten the City with high winds, rain, and storm surge. The City of Biloxi's Office of Emergency Management participates with local media in educating the public regarding the dangers of hurricanes. Due to the size of hurricanes and coastal storms, the entire City of Biloxi can be impacted by these storms.

Hazard Profile

The Atlantic hurricane season begins June 1 and ends on November 30, but hurricanes have developed outside of the designated season.

Hurricane wind intensity is measured with the Saffir-Simpson Hurricane Scale. The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's intensity at the time of measurement. This is used to give an estimate of the potential property damage expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale. All winds are described using the U.S. 1-minute average. Previously, storm surge was described by the Saffir-Simpson Scale, but is no longer included.

The following excerpt from the National Hurricane Center explains revised definition of the Saffir-Simpson Hurricane Scale and the separation of storm surge from storm category:

> *Earlier versions of the Saffir-Simpson Hurricane Scale incorporated central pressure and storm surge as components of the categories. The central pressure was used during the 1970s and 1980s as a proxy for the winds as accurate wind speed intensity measurements from aircraft reconnaissance were not routinely available for hurricanes until 1990. Storm surge was also quantified by category in the earliest published versions of the scale dating back to 1972. However, hurricane size (extent of hurricane-force winds), local bathymetry (depth of near-shore waters), topography, the hurricane's forward speed and angle to the coast also affect the surge that is produced. For example, the very large Hurricane Ike (with hurricane force winds extending as much as 125 mi from the center) in 2008 made landfall in Texas as a Category 2 hurricane and had peak storm surge values of about 20 ft. In contrast, tiny Hurricane Charley (with hurricane force winds extending at most 25 mi from the center) struck Florida in 2004 as a Category 4 hurricane and produced a peak storm surge of only about 7 ft. These storm surge values were substantially outside of the ranges suggested in the original scale. Thus to help reduce public confusion about the impacts associated with the various hurricane categories as well as to provide a more*

scientifically defensible scale, the storm surge ranges, flooding impact and central pressure statements are removed from the Saffir-Simpson Hurricane Scale and only peak winds are employed in this revised version.

The Saffir-Simpson Hurricane Scale no longer predicts storm surge on a grand scale. Storm surge is predicted by the NOAA Weather Field Office (WFO) for each storm and is updated as the storm approaches landfall. (See Storm Surge, Section 4.2.4).

Table 4.3 depicts the Saffir-Simpson Scale by category, associated wind speeds and expected damages from a particular event.

Table 4.3
Saffir-Simpson Hurricane Scale

Category	Winds	Effects on Land
One	74-95 mph	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees.
Two	96-110 mph	Some roofing material, door, and window damage to buildings. Considerable damage to vegetation, mobile homes, and piers.
Three	111-130 mph	Some structural damage to small residences and utility buildings with a minor amount of curtain wall failures Mobile homes are destroyed.
Four	131-155 mph	More extensive curtain wall failures with some complete roof structure failure on small residences. Major erosion of beach. Major damage to structures near the shore.
Five	Greater than 155 mph	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Major damage to all structures located within 500 yards of the shoreline.
(Source: National Hurricane Center)		

The following terms are used to describe tropical storms / hurricanes:

Tropical Wave: A tropical wave is a trough or cyclonic curvature maximum in the trade-wind easterlies.The wave may reach maximum amplitude in the lower middle troposphere.

Tropical Depression: A tropical depression is a tropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) is 33 kt (38 mph or 62 km/hr) or less.

Tropical Storm: A tropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) ranges from 34 kt (39 mph or 63 km/hr) to 63 kt (73 mph or 118 km/hr).

Hurricane: A tropical cyclone in which the maximum sustained surface wind (using the U.S. 1-minute average) is 64 kt (74 mph or 119 km/hr) or more.

Assessing Vulnerabilities

The entire City of Biloxi is vulnerable to the threat of hurricanes and tropical storms. A direct or indirect impact from these systems can produce damage from surge (See Section 4.2.4) and flooding along the coastal areas, and can inflict high wind and isolated tornadoes across all of Biloxi.

The information presented in this Plan Update reflects a significant part of the recovery costs from strong winds and storm surge. However, there are also very significant costs associated with interrupted business, lost wages, and utility disruption that are very difficult to quantify but are nevertheless important metrics for determining the impact.

Previous Occurrences

The Mississippi Gulf Coast, including the City of Biloxi, has experienced numerous hurricanes over the past century. Each year there is a 10% chance that a hurricane or a tropical storm will impact the Mississippi Gulf Coast, and a 3% that a major hurricane will impact the area[1].

Hurricanes that have made landfall along the Mississippi Coast over the past 40 years include:

- Hurricane of 1901 - Category 4
- Hurricane of 1906 - Category 3
- Hurricane of 1916 - Category 3
- Hurricane of 1926 - Category 4
- Hurricane Camille (1969) – Category 5
- Hurricane Frederick (1979) – Category 3
- Hurricane Elena (1985) – Category 3
- Hurricane Katrina (2005) – Category 3

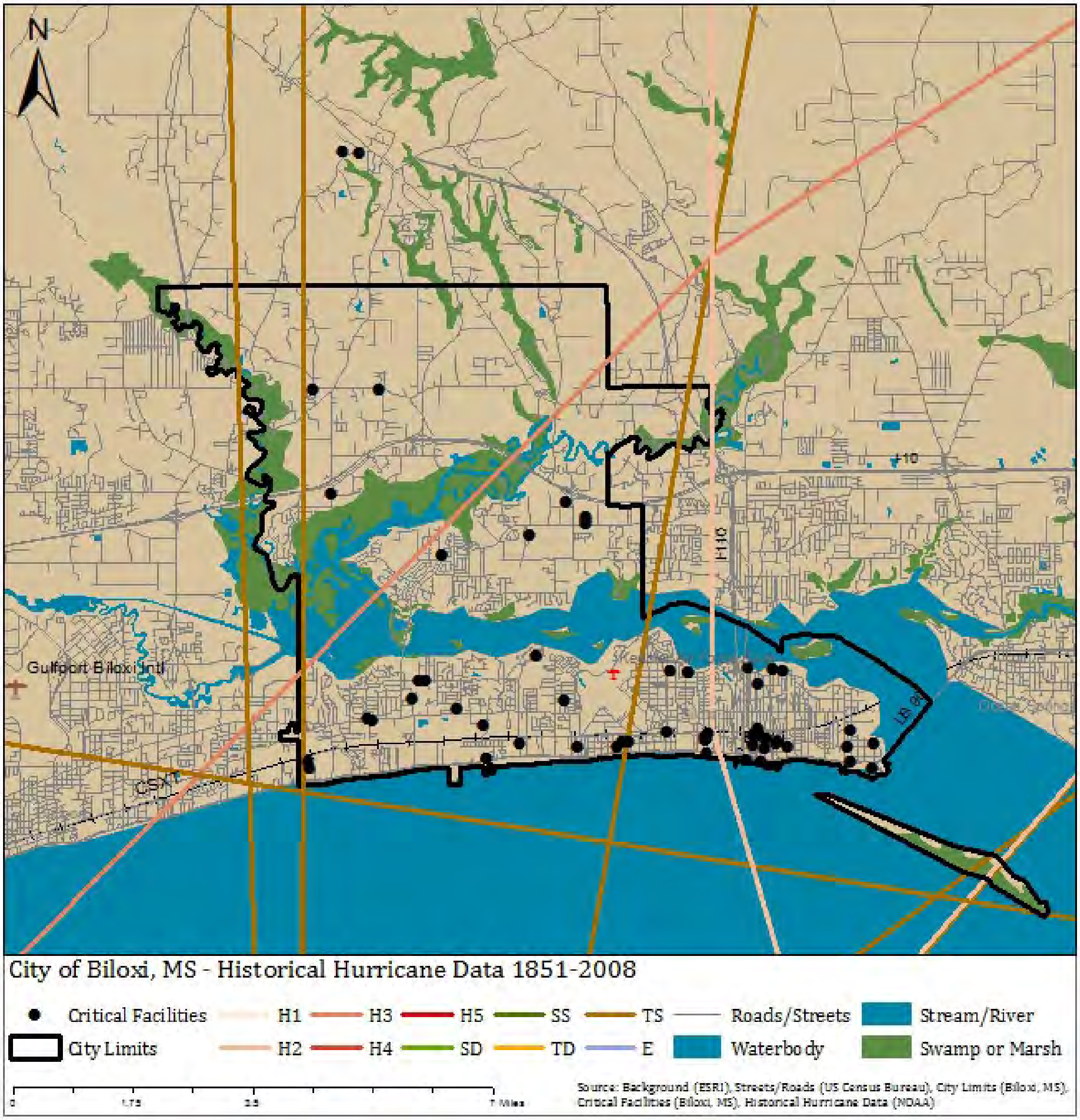
In addition to the above major storms, the following tropical systems also impacted the City of Biloxi to some degree. Hurricane/tropical storm events are listed by storm name and year.

- Erin - 1995
- Opal - 1995
- Danny - 1997
- Georges – 1998
- Hermine – 1998
- Allison – 2001
- Bertha – 2002
- Hanna – 2002
- Isidore – 2002
- Bill - 2003
- Ivan –2004
- Arlene - 2005
- Cindy- 2005
- Dennis – 2005
- Fay – 2008
- Gustav – 2008
- Lee – 2011
- Isaac - 2012

Map 4.1 on the following page illustrates the historic tracks of hurricanes and tropical storms that have crossed over or near the City of Biloxi.

[1]Hurricane Watch - Forecasting the Deadliest Storms on Earth; Jack Williams and Bob Sheets; 2001.

Map 4.1
City of Biloxi Hurricane Tracks
(Source: ESRI, City of Biloxi, NOAA)



Notable hurricane events over the past ten years are summarized below:

September 2002-Tropical Storm Isidore: Tropical Storm Isidore made landfall near Grand Isle, LA during the early morning of September 26, 2002. The tropical storm moved north across southeast Louisiana and by the evening was located in central Mississippi, where it was downgraded to a tropical depression. Tropical Storm Isidore had a large circulation with tropical storm force winds extending several hundred miles from its center. Tide levels were generally 4 to 7 feet above normal, with locally higher levels, across much of coastal Mississippi. Significant beach erosion occurred along the coast and on the barrier islands. The maximum storm surge reading on the Mississippi Coast was 7.61 feet NGVD at the Corps of Engineers tide gage at Gulfport Harbor, and 6.86 feet NGVD in Biloxi Bay at Point Cadet. There were two fatalities on the Mississippi Coast related to the tropical storm; one direct and another indirect. Rainfall amounts associated with Isidore were generally 5 to 8 inches and resulted in some river flooding and flash flooding. Approximately 2,500 homes in Hancock County, 1,400 homes in Harrison County and 50 homes and businesses in the City of Biloxi were flooded, primarily as the result of storm surge, with river flooding and flash flooding causing some of the flood damage.

August 28, 2005-Hurricane Katrina: Hurricane Katrina was one of the most destructive hurricanes on record to impact the coast of the United States. It was one the worst natural disasters in the history of the U.S. to date, resulting in catastrophic damage and numerous casualties along the Mississippi coast. Damage and casualties resulting from Hurricane Katrina extended as far east as Alabama and the panhandle of Florida. Post-event analysis by the National Hurricane Center indicates that Katrina weakened slightly before making landfall as a strong Category 3 storm in initial landfall in lower Plaquemines Parish. The storm continued on a north northeast track with the center passing about 40 miles southeast of New Orleans with a second landfall occurring near the Louisiana and Mississippi border as a Category 3 storm with maximum sustained winds estimated at121 mph. Katrina continued to weaken as it moved north-northeast across Mississippi during the day, but remained at hurricane strength 100 miles inland.

Damage across coastal Mississippi was catastrophic. The storm surge associated with Hurricane Katrina approached or exceeded the surge associated with Hurricane Camille (1969) and impacted a much more extensive area. Almost total destruction was observed along the immediate coast in Hancock and Harrison Counties with storm surge damage extending north along bays and bayous to Interstate 10. Thousands of homes and businesses were destroyed by the storm surge. Hurricane-force winds also caused damage to roofs, power lines, signage, downed trees, and some windows were broken by wind and wind-driven debris in areas away from storm surge flooding, wind damage was widespread with fallen trees taking a heavy toll on houses and power lines. Excluding losses covered by the National Flood Insurance Program (NFIP), insured property losses in Mississippi were estimated at $9.8 billion dollars. Uninsured and insured losses combined were estimated to exceed $100 billion dollars across the Gulf Coast. An estimated storm surge of approximately 23 feet occurred at the Hancock County EOC operations area in Waveland, and the high water mark measured in the City of Biloxi was 34.1

feet. Storm total rainfall amounts generally ranged from 10 to 16 inches across coastal and south Mississippi with much lower amounts observed over southwest Mississippi.

September 1, 2008–Hurricane Gustav: Hurricane Gustav made landfall as a Category 2 hurricane near Cocodrie, LA during the morning of September 1st.Gustav continued to move northwest and weakened to a Category 1 storm over south central Louisiana later that day.The highest wind gust recorded in south Mississippi was 74 mph at the Gulfport-Biloxi Regional Airport while the highest sustained wind of 54 mph was recorded at the Waveland Yacht Club.No official wind observations were available in far southwest Mississippi; however wind gusts to hurricane force may have occurred.Rainfall varied considerably ranging from around 4 to 10 inches.Gustav produced mainly light wind damage across coastal Mississippi, although more significant and concentrated damage occurred in southwest Mississippi closer to the track of center of the storm.Widespread power outages occurred in southern Mississippi.

August 28, 2012–Hurricane Isaac: Hurricane Isaac impacted the City of Biloxi with significant flooding associated with storm surge. Official storm surge statistics and damage figures were not available through the Nation Hurricane Center at the time of this Plan Update, but will be incorporated into the next Plan Update.

Probability

Numerous hurricanes and coastal storms have impacted southern Mississippi including City of Biloxi. Since 1993, 19 hurricanes/tropical storms have impacted the City of Biloxi, yielding a 100% probability of annual occurrence; therefore, the probability of a future occurrence in high.

4.2.2 Flood

Description of the Flooding Hazard

A flood is a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties from:

- Overflow of inland or tidal waters; or
- Unusual and rapid accumulation or runoff of surface waters from any source, or a mudflow.

Flooding occurs not only with coastal storms, but also with seasonal rainfall. The majority of properties having repetitive flood insurance claims over the past two decades made at least one of those claims due to rainfall not associated with a hurricane. The flooding of structures occurred because of localized drainage problems, which Biloxi has been addressing over the past years.

The flood prone areas located in Biloxi are identified on the maps within the subsection of this chapter. With the vast amount of waterfront property within the city, portions of many properties are within the floodplain. The flooding of homes has generally been because of obstructed drainage channels causing water to backup onto property.

The City of Biloxi Zoning Ordinance regulates the development of those areas that are subject to periodic or occasional inundation from stream overflows and tide conditions. All lands lying within this district are subject to inundation by the base (or 100 year) flood as defined on the Flood Insurance Rate Maps (FIRMs) of City of Biloxi, Mississippi. The FEMA Flood Insurance Rate Maps estimate the amount of risk associated with flood hazard areas within the mapped area. Flood insurance zones and zone numbers are assigned based on the type of flood hazard and the Flood Hazard Factor (FHF), respectively. A unique zone number is associated with each possible FHF and varies from a 1 for a FHF of 005 to a maximum of 30 for a FHF of 200 or greater.

Zone A (1% annual chance flooding). Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these areas.

Zone AE (1% annual chance flooding). Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. In most instances, base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

Zone AH (1% annual chance flooding). Areas with a 1% annual chance of flooding where shallow flooding (usually areas of ponding) can occur with average depths between one and three feet.

Zone AO (1% annual chance flooding). Areas with a 1% annual chance of flooding, where shallow flooding average depths are between one and three feet.

X500 (0.2% annual chance flooding). Represents areas between the limits of the 1% annual chance flooding and 0.2% chance flooding.

Zone V(1% annual chance flooding). Areas subject to inundation by the 1% annual chance flood event with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone VE(1% annual chance flooding). Areas subject to inundation by the 1% annual chance flood event with additional hazards due to storm-induced velocity wave action. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone X. Areas outside of the 1% annual chance floodplain and 0.2% annual chance floodplain, areas of 1% annual chance sheet flow flooding where average depths are less than one (1) foot, areas of 1% annual chance stream flooding where the contributing drainage area is less than one (1) square mile, or areas protected from the 1% annual chance flood by levees. No Base Flood Elevation or depths are shown within this zone.

The areas that pose the greatest probability of flooding are located within the A and V zones. Areas within the X500 are less likely to flood but still pose a 0.2% possibility of flooding in any given year.

Hazard Profile

Historical documentation of flooding indicates that flooding may occur during any season of the year. For the planning area, the most damaging floods have occurred in April, June, and July. Based on historical analysis, floods are most likely to occur between March and September. Floods are least likely to occur in autumn and winter months, but two floods have been recorded in December 1994 and January 1993.

Flooding is a relatively frequent hazard in the planning area. Severity ranges from localized to city-wide and regional events. Flood events can last from a few hours to a few days, leaving roads and bridges rendered impassible. The primary flooding sources for the planning area are flash flooding from torrential rains. The most costly floodevents were reported on June 11, 2001 and March 28, 2009, with recorded property damages for each event of $750,000. Another event of note occurred on April 1, 2005 flood event was caused by torrential rains that started on the evening of March 31 and resulted in the flooding of numerous roadways and homes in sections of coastal and south Mississippi. The hardest hit area was the City of Biloxi where 8 to 12 inches of rain fell during the night and morning hours. The heavy rain also resulted in significant flooding in lower portions of several rivers and streams in south Mississippi, particularly along major rivers in Harrison and Jackson Counties, such as the Escatawpa, Biloxi and Tchoutacabouffa Rivers. Overall, 250 homes and numerous roadways were flooded across City of Biloxi.

Beyond using standardized DFIRM zones, it is difficult to predict the extent of flood depth without performing detailed land surveys because depth is variable based on topography and the amount of water entering the floodplains and planning area. The DFIRMs are provided as Maps 4.2 through 4.3 (following pages) for the planning area and show the Special Hazard Flood Areas, their expected extent of flooding beyond the river basins, and their relation to the City of Biloxi critical facilities. Table 4.4 provides an estimate of flood levels, based on the City of Biloxi 2007 FIS.

Table 4.4
Flood Depth Estimates

Jurisdiction	FIS Effective Date	Est. Lower End of 1% Flood Depth Range	Est. Higher End of 1% Flood Depth Range
City of Biloxi	November 15, 2007	1 foot	1 foot+

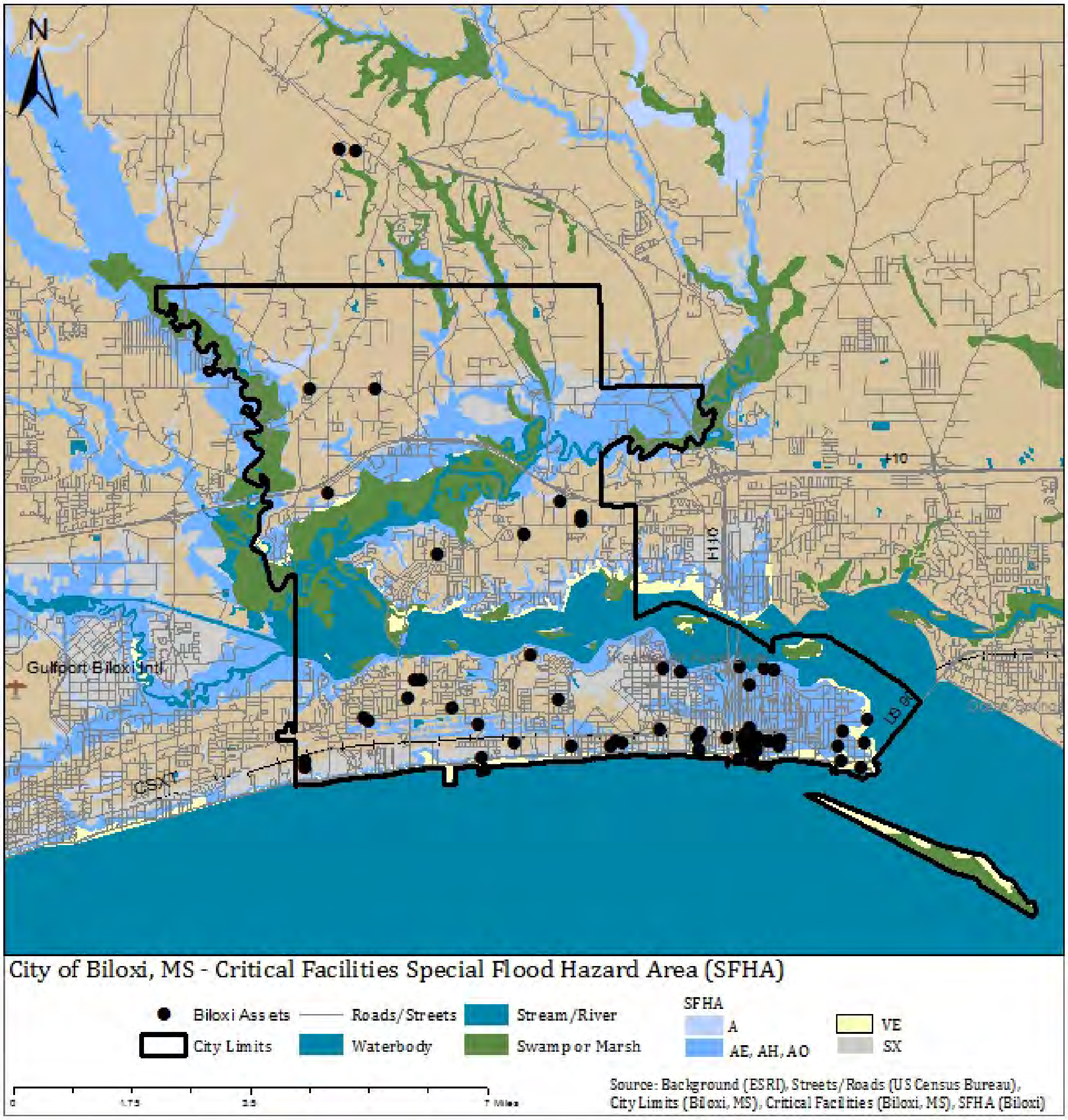
Assessing Vulnerabilities

The City of Biloxi has a total of 18 identified critical facilities within the 0.1% annual chance flood zone. Sixteen of the City of Biloxi critical facilities are located in the .02% annual chance flood zone. It is important to consider that floods, especially flash floods, can and do occur outside the floodplain. It is important to consider that floods, especially flash floods, can occur outside the floodplain. Maps 4.2 through 4.3 identify the critical facilities located within the SFHA.

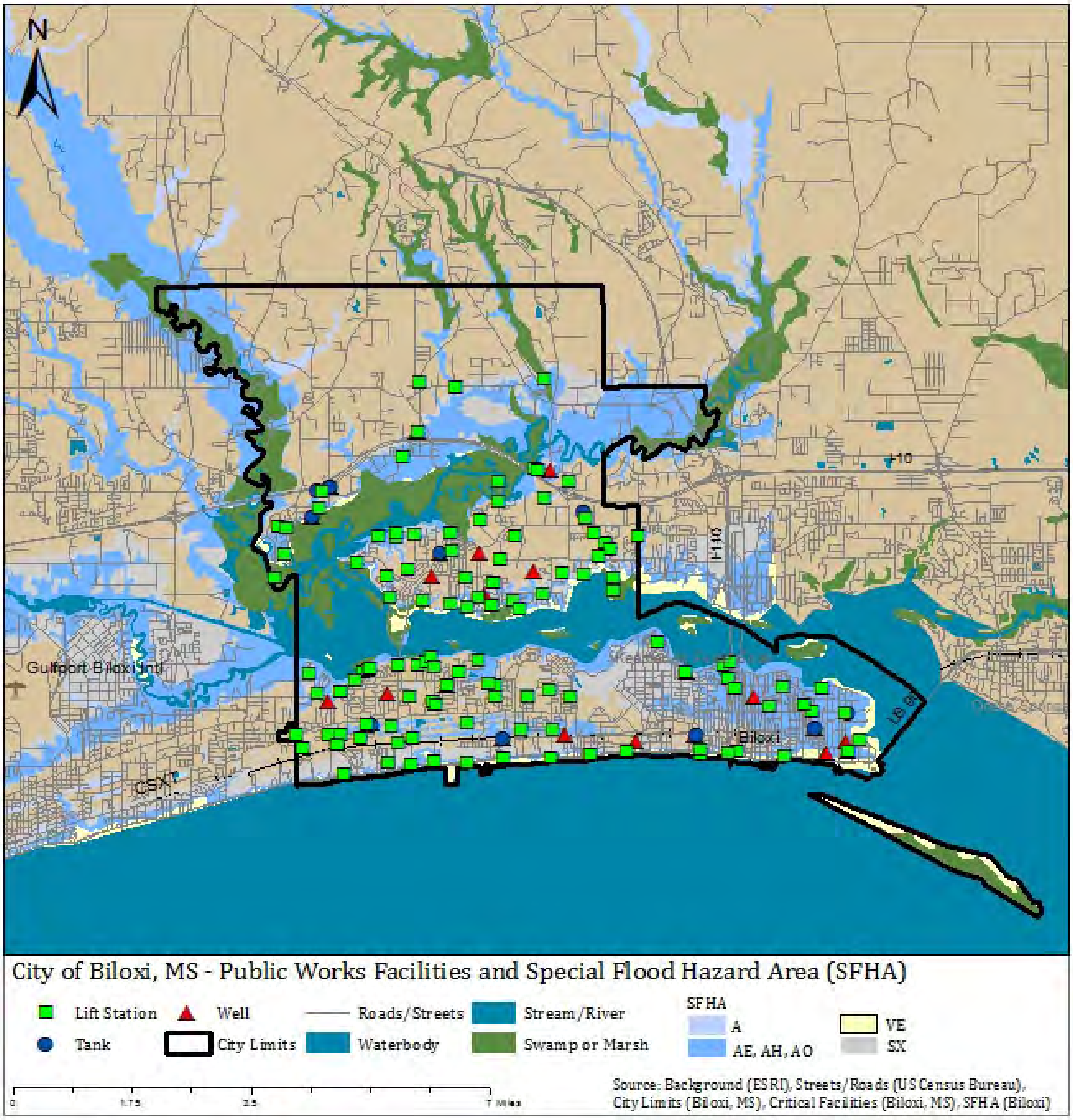
Map 4.2

City of Biloxi Critical Facilities in the Special Hazard Flood Area

(Source: ESRI, City of Biloxi)



Map 4.3
City of Biloxi Public Works Facilities in theSpecial Hazard Flood Area
(Source: ESRI, City of Biloxi)

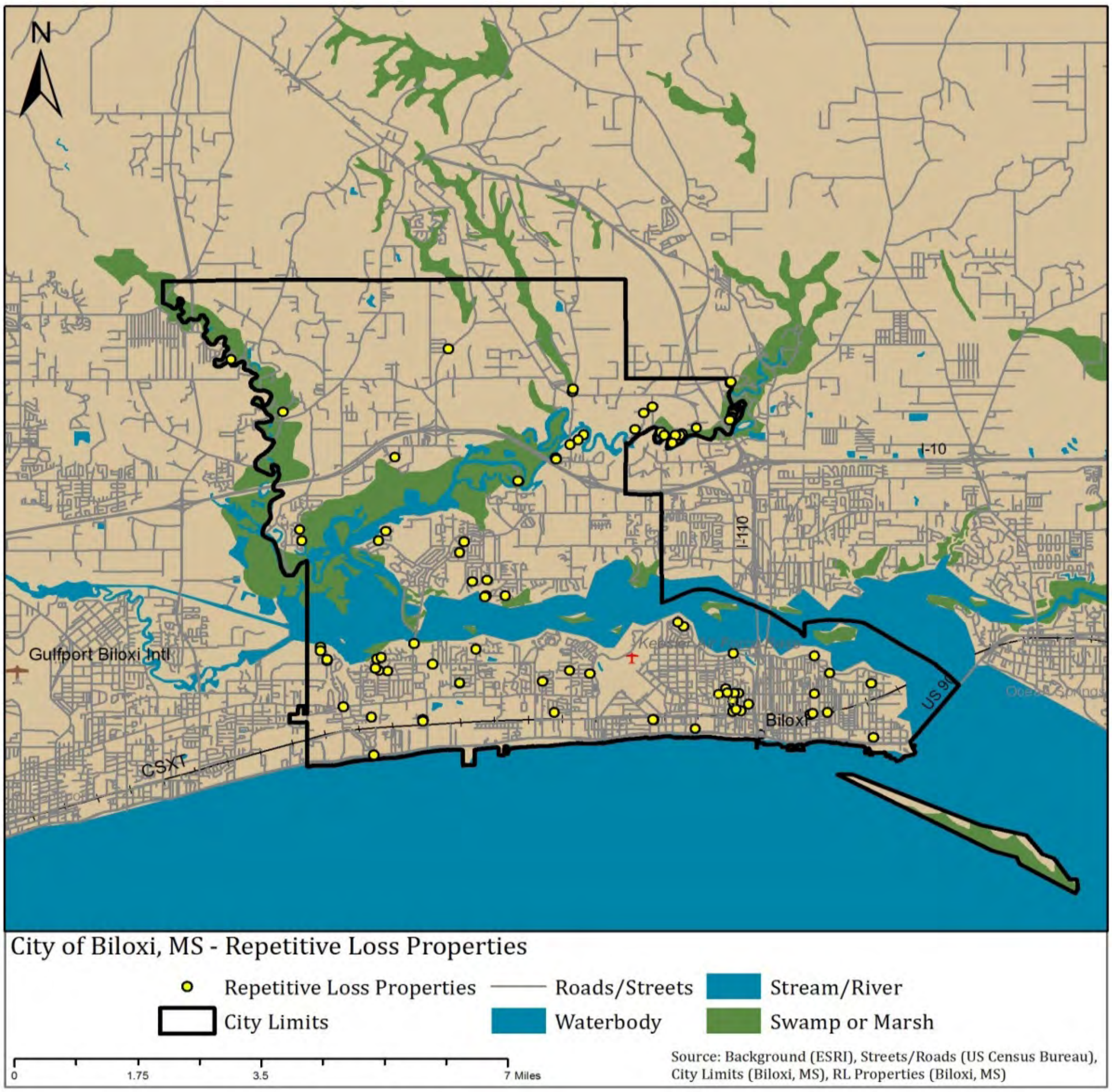


Repetitive Loss Areas

By definition, a Repetitive Loss property is an area containing one or more properties for which two or more National Flood Insurance Program (NFIP) losses of at least $1,000 each have been paid within any ten year period since 1978.

The list of Repetitive Loss properties included in this Plan Update was furnished by FEMA. The City of Biloxi Planning Committee reviewed the list of FEMA Repetitive Loss properties and determined that of the109 Repetitive Loss properties on record with the NFIP, 85 fell within the identified SFHA while 24 of the properties were located outside the identified SFHA. Repetitive Loss properties for the City of Biloxi are identified in Map 4.4.

Map 4.4
City of Biloxi Repetitive Loss Properties
(Source: ESRI, City of Biloxi)



Previous Occurrences

All of the identified flooding events are entered into the National Climatic Data Center (NCDC) at the county level, with no distinction of separate jurisdiction or municipalities. For the purposes of this Plan Update, the data provided in the Table 4.5 below is considered to be the best available data. The following is a list of flooding events gathered from the NCDC U.S. Storm Events Database.

Table 4.5
Previous Occurrences of Flooding in City of Biloxi

Date	Event Type	State	County	Injuries	Fatalities	Property Damage
6/11/2001	Flooding	MS	Harrison	0	0	$750,000.00
3/28/2009	Flooding	MS	Harrison	0	1	$750,000.00
1/20/1993	Flooding	MS	Harrison	0	0	$500,000.00
7/1/2003	Flooding	MS	Harrison	0	0	$250,000.00
4/1/2005	Flooding	MS	Harrison	0	0	$108,333.33
7/8/1996	Flooding	MS	Harrison	0	0	$100,000.00
12/3/1994	Flooding	MS	Harrison	0	0	$50,000.00
4/1/2005	Flooding	MS	Harrison	0	0	$50,000.00
5/9/1995	Flooding	MS	Harrison	0	1	$0.00
Total				0	2	$2,558,333.33
Source: NCDC, City of Biloxi						

Probability

The planning area is subject to flash, coastal, and riverine flooding. With 9 events occurring in the City of Biloxi since 1993, an annualized average of 47% chance of occurrence can be expected with varying degrees of impact in Biloxi. Based on historical data, the probability of a future occurrence of the flooding hazard in City of Biloxi is medium.

4.2.3 Severe Thunderstorm/High Wind/Lightning

Description of the Hazard

Thunderstorms are defined by the National Weather Service (NWS) as “a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder”. The storms alone don’t cause losses to life or property, but the components of a thunderstorm can be devastating. Thunderstorms can include high winds, lightning, tornadoes, heavy rain (flash flood) and hail. The NWS further defines a thunderstorm that produces a tornado, winds of at least 58 mph (50 knots), and/or hail at least ¾" in diameter as a “severe thunderstorm”. Structural wind damage may imply the occurrence of a severe thunderstorm. This hazard section focuses on the high wind and lightning hazards associated with thunderstorms. Flood and tornadoes are discussed as separate hazards in Sub-sections 4.2.2 (Flood) and 4.2.5 (Tornado).

High winds are a general term associated with sustained or gusting winds of significant strength to cause risk or damage to crops, vegetation, buildings, infrastructure, or transportation. High winds are typically associated with weather frontal systems that often bring other severe weather products such as hail and lightning.

Lightning is a visible electrical discharge produced by a thunderstorm. The discharge may occur within or between clouds, between the cloud and air, between a cloud and the ground or between the ground and a cloud. Lightning is created by static electrical energy and can generate enough electricity to set buildings on fire, and electrocute people.

For the purposes of this Plan Update, high wind and lightning were analyzed together as products of thunderstorms.

Hazard Profile

After review of the identified hazards for the 2012 Biloxi Hazard Mitigation Plan Update, the Hazard Mitigation Planning Committee determined Severe Thunderstorms (including Lightning and Strong Winds) to be a critical hazard of concern for the City of Biloxi. (Note: The Hazard Mitigation Planning Committee determined that the hail hazard should be addressed separately; for planning purposes it is not considered to be a critical hazard.)

High wind and lightning have the potential to cause significant impacts in the City of Biloxi. High winds can damage property by carrying projectile debris or by breaking building envelopes as wind buffets weak points around doors, windows, and roof structures.Winds can increase speed as they pass between closely situated buildings through a venturi effect that may increase the potential for damage. Metal buildings and tall structures, open fields, and swimming pools are at greater risk of lightning strikes.

The National Weather Service recognizes and defines three levels of wind events:

- *Wind Advisory* – Sustained winds of 30mph or more or gusts of 45mph or greater for a duration for one hour or longer.
- *High Winds* – Sustained winds of 40mph or greater for at least one hour, or frequent gusts of wind to 58mph or greater.
- *Extreme Wind Warnings* – Sustained winds of 115mph or greater during a land-falling hurricane.

Winds and related damages can also be defined through the Beaufort Wind Scale as shown in Table 4.6:

Table 4.6
Beaufort Wind Scale

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects	
			On the Water	On Land
0	Less than 1	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1-3	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Small waves 1-4 ft.becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Moderate waves 4-8 ft taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger waves 8-13 ft, whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Sea heaps up, waves 13-20 ft, white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	34-40	Gale	Moderately high (13-20 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Whole trees in motion, resistance felt walking against wind
9	41-47	Strong Gale	High waves (20 ft), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs, slate blows off roofs
10	48-55	Storm	Very high waves (20-30 ft) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
11	56-63	Violent Storm	Exceptionally high (30-45 ft) waves, foam patches cover sea, visibility more reduced	
12	64+	Hurricane	Air filled with foam, waves over 45 ft, sea completely white with driving spray, visibility greatly reduced	
Source: NOAA Storm Prediction Center				

Based on historic information provided by NCDC, the City of Biloxi has experienced high winds associated with severe thunderstorms up to 74 mph.

Lightning can strike anywhere and anytime thunderstorms are in the area. Almost all lightning occurs within 10 miles of the parent thunderstorm, but in rare cases it can strike as much as 50 miles away.There are two major categories of lightning:

- *Cloud Flashes* – Cloud flashes sometimes have visible channels that extend out into the air around the storm but do not strike the ground. This is often further defined as cloud-to-air, cloud-to-cloud, or intra-cloud lightning.
- *Ground Flashes* – Lightning channels that travel from cloud-to-ground or ground-to-cloud.There are two categories of ground flashes: natural and artificially initiated/triggered. Artificially initiated lightning includes strikes to tall structures, airplanes, rockets, and towers on mountains.Artificially initiated lightning goes from ground to cloud while natural lightning goes from cloud to ground.

Assessing Vulnerabilities

High wind and lightning are not location-specific hazards; all areas within the planning area are vulnerable to these hazards. People, buildings, and property are at risk from the effects of high wind and lightning.Buildings, automobiles, and infrastructural components (such as electrical feed lines) can suffer damage from high wind and lightning; outdoor populations are vulnerable to injury of death from lightning. High winds can cause debris to strike people, buildings and property, which in turn can cause significant injuries, fatalities, and property damage.

Previous Occurrences

According to data obtained from the City of Biloxi Emergency Management Director and the National Climatic Data Center (NCDC), at least 29 severe thunderstorms have impacted Biloxi since 1994. According to NCDC data records, 66 severe thunderstorm events have impacted Harrison County over the same timeframe; however due to limited reporting of City-specific information only the afore-mentioned 29 events could be confirmed as directly impacting the City of Biloxi.

Based on historic information, the entire City of Biloxi can experience severe thunderstorms/strong winds/lightning. Table 4.7 provides details of those thunderstorms that have produced strong winds or lightning.

Table 4.7
Thunderstorms in Biloxi - September 1994 – July 2011

Location	Date	Event	Property Damage
Biloxi	7/9/1995	Thunder Storm and Wind	$5,000
Biloxi	1/24/1996	Thunder Storm and Wind	$7,000
Biloxi	5/28/1996	Lightning	N/A
Keesler/Biloxi	8/2/1996	Thunder Storm and Wind	$1,000
Biloxi	8/3/1996	Lightning	$0
Biloxi	9/21/1996	Thunder Storm and Wind	$15,000
Biloxi	4/11/1997	Thunder Storm Wind	$0
Biloxi	6/23/1997	Hail	$0
Biloxi	6/23/1997	Thunderstorm Wind	$8,000
Biloxi	1/7/1998	Thunderstorm Wind	$100,0000
Biloxi	9/5/2000	Thunderstorm Wind	$5,000
Woolmarket/Biloxi	6/11/2001	Thunderstorm Wind	$1,000
Biloxi	6/6/2005	Lightning	$0
Biloxi	11/15/2006	Thunderstorm Wind	$50,000
Biloxi	06/19/2007	Thunderstorm Wind	$30,000
Biloxi	09/03/2007	Thunderstorm Wind	$0
Biloxi	03/07/2008	Thunderstorm and Wind	$80,000
Biloxi	05/15/2008	Thunderstorm Wind, andLightning	$33,000
Biloxi	07/14/2008	Thunderstorm and Wind	$3,000
Biloxi	08/03/2008	Thunderstorm and Wind	$1,000
Biloxi	08/12/2008	Thunderstorm Wind	$1,000
Keesler/Biloxi	07/04/2009	ThunderstormWind	$1,000
Keesler/Biloxi	12/12/2009	Thunderstorm Wind	$0
Biloxi	12/24/2009	Thunderstorm Wind	$3,000
Biloxi	03/01/2010	Thunderstorm Wind	$3,000
Biloxi	04/08/2010	Thunderstorm Wind	$15,000
Biloxi	05/18/2010	Thunderstorm Wind	$500
Biloxi	05/25/2010	Thunderstorm Wind	$2,000
Woolmarket/Biloxi	10/27/2010	Thunderstorm Wind	$5,000
Source: NOAA National Climatic Data Center Extreme Events			

Since August of 2010, the Biloxi Police Department has reported 11 lightning strikes that have impacted the City of Biloxi's warning sirens, causing approximately $23,000 in damages.

Potential impacts to life are low, as high wind and lightning are primarily a threat to property. Vulnerable populations, such as those who congregate outdoors for activities and sporting events may be at risk. Early warning systems that are in place and activated prior to a hazard event may reduce this risk.Impacts to property are designated as low and are equal across the planning area.

Probability

The City of Biloxi has experienced 29 severe thunderstorm events in the past 18 years yielding a reoccurrence rate of more than one event per year. This equates to a 100% probability of occurrence, making the probability of future occurrence high.

With the combination of NCDC records and the Biloxi Police Department accounts of lightning strikes. The total number of recorded strikes over the past 18 years was 12, equating to a 67% annual probability of occurrence, making the probability high.

4.2.4 Storm Surge

Description of the Hazard

The National Hurricane Center defines storm surge as an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge should not be confused with storm tide, which is defined as the water level rise due to the combination of storm surge and the astronomical tide. This rise in water level can cause extreme flooding in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides reaching up to 20 feet or more in some cases.

Hazard Profile

The storm surge is potentially the most devastating factor associated with hurricanes.Within the boundaries of the City of Biloxithose properties adjacent to areas affected by tides are the most susceptible to damage from storm surge with heavy flooding as the most common result.In extreme cases such as Hurricanes Camille and Katrina, the incoming wall of water and wind could destroy well-built buildings along the immediate coastline.

Assessing Vulnerabilities

Storm surges are caused primarily by high winds pushing on the ocean's surface. The wind causes the water to pile up higher than ordinary tidal levels. Historically, storm surge from hurricanes causes significant damages. The City of Biloxi is subject to the threat of storm surge, particularly in areas south of U.S. Highway 90.

Previous Occurrences

The NCDC database indicates that the City of Biloxi has experienced five storm surge events since 2002. Included in these events were Hurricanes Katrina, Gustav, Ike, and Isaac as well as Tropical Storm Lee. All of these events produced storm surge within the planning area of the City of Biloxi, with the most significant event being Hurricane Katrina. A storm surge of more than 27 feet was reported in Pass Christian, while the severe damage and high water marks indicate that the surge reached from six to 12 miles inland in some areas, especially along bays and rivers. Data provided by NOAA suggests that the storm surge in Biloxi reached a high water mark of 34.1 feet above mean sea level (measured by the exterior trim line of the Beau Rivage Lighthouse in Biloxi, MS).

As with the hurricane hazard, this information reflects a significant part of the recovery costs from strong winds and storm surge. However, there are also very significant costs associated with interrupted business, lost wages, and utility disruption that are very difficult to quantify but are nevertheless important metrics for determining the impact.

In 2010, the National Hurricane Center separated storm surge from storm categories for the purposes of public advisories. For planning purposes they currently have not released separate storm surge modeling.

Probability

There have been eight recorded storm surge events impacting the City of Biloxi coast since 1998. Based on that data, the planning area experiences storm surge at a 57% chance of annual occurrence, making the probability of future storm surge impact high.

4.2.5 Tornado

Description of the Hazard

Tornadoes are defined as a violently rotating column of air in contact with the ground and extending from the base of a thunderstorm. A debris cloud beneath a thunderstorm is all that is needed to confirm the presence of a tornado, even in the total absence of a condensation funnel. Most of the time, vortices remain suspended in the atmosphere. When the lower tip of a vortex touches earth, the tornado becomes a force of destruction. They are created during severe weather events such as thunderstorms and hurricanes, when cold air overrides a layer of warm air, causing the warm air to rise rapidly. The instability created results in the rotation of air and formation of the tornado.

Hazard Profile

Prior to February 1, 2007, the Fujita Scale was used to measure tornado severity. On February 1, 2007, the Fujita scale was decommissioned in favor of the more accurate Enhanced Fujita Scale. Table 4.8 shows the Fujita Scale.

Table 4.8
Pre-2007 Fujita Scale

F-Scale Number	Intensity Phrase	Wind Speed	Type of Damage
F0	Gale tornado	40-72 mph	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	73-112 mph	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	Significant tornado	113-157 mph	Considerable damage.Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	158-206 mph	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted
F4	Devastating tornado	207-260 mph	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	261-318 mph	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.
F6	Inconceivable tornado	319-379 mph	These winds are very unlikely.The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds.Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage.If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies
Source: NOAA			

The Enhanced Fujita Scale, or EF Scale (Table 4.9), is the current scale for rating the strength of tornadoes in the United States; magnitude is estimated via the damage left behind by the tornado. Implemented in February 2007, it replaced the Fujita Scale. The scale has the same basic design as the original Fujita Scale, six categories from zero to five, representing increasing degrees of damage. The new scale takes into account how most structures are designed, and is thought to be a much more accurate representation of the surface wind speeds in the most violent tornadoes.

Table 4.9
Enhanced Fujita Scale

Enhanced Fujita Category	Wind Speed (mph)	Potential Damage
EF0	65-85	Light damage. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.
EF1	86-110	Moderate damage. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	111-135	Considerable damage. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
EF3	136-165	Severe damage. Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance.
EF4	166-200	Devastating damage. Well-constructed houses and whole frame houses completely leveled; cars thrown and small missiles generated.
EF5	>200	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (109 yd); high-rise buildings have significant structural deformation; incredible phenomena will occur.

Source: NOAA

Figure 4.1 shows wind zones across the United States; note that the planning area falls in Zone 3 (200MPH). Figure 4.2 (following) shows tornado activity nationwide.

Figure 4.1
Wind Zones in the United States
(Source: FEMA)

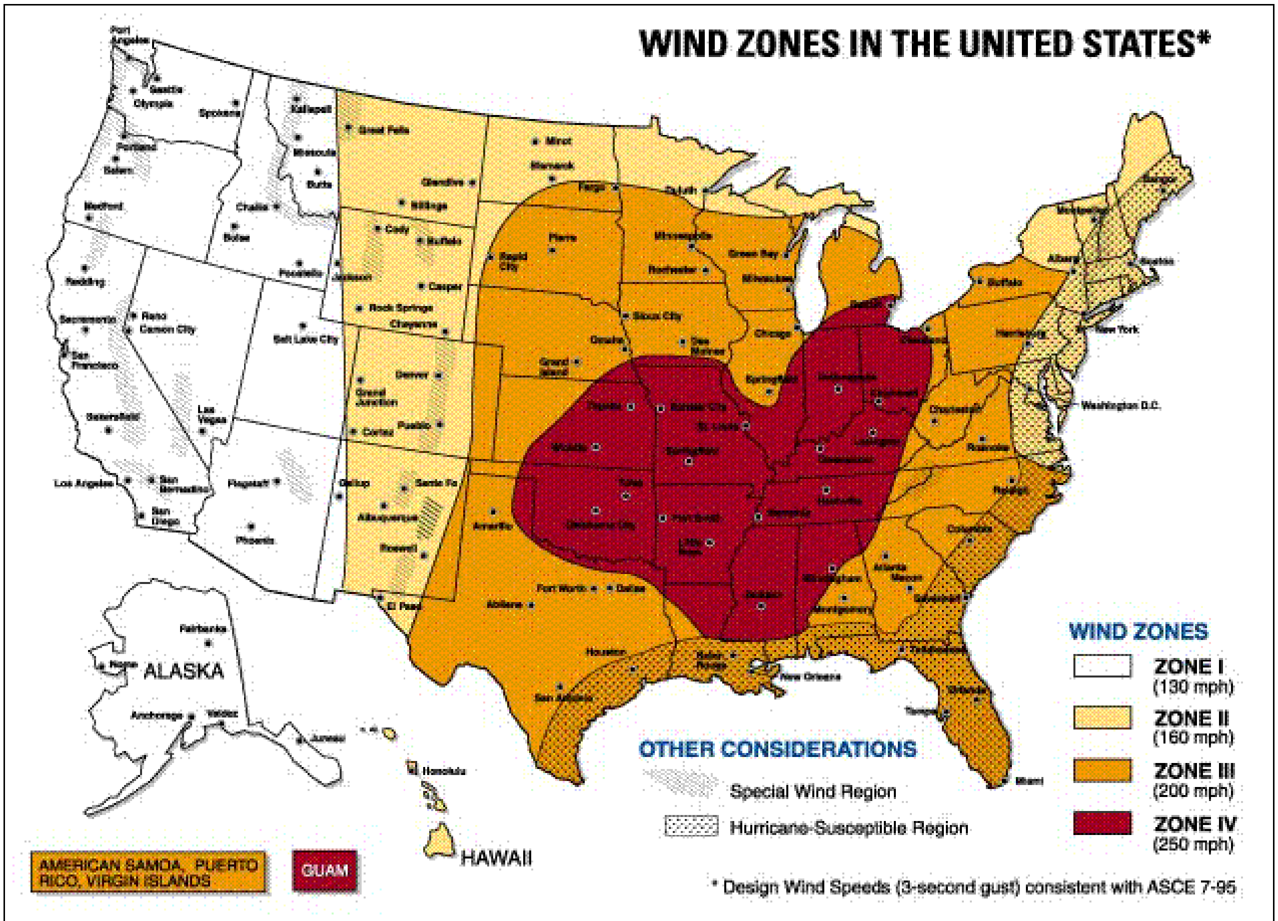
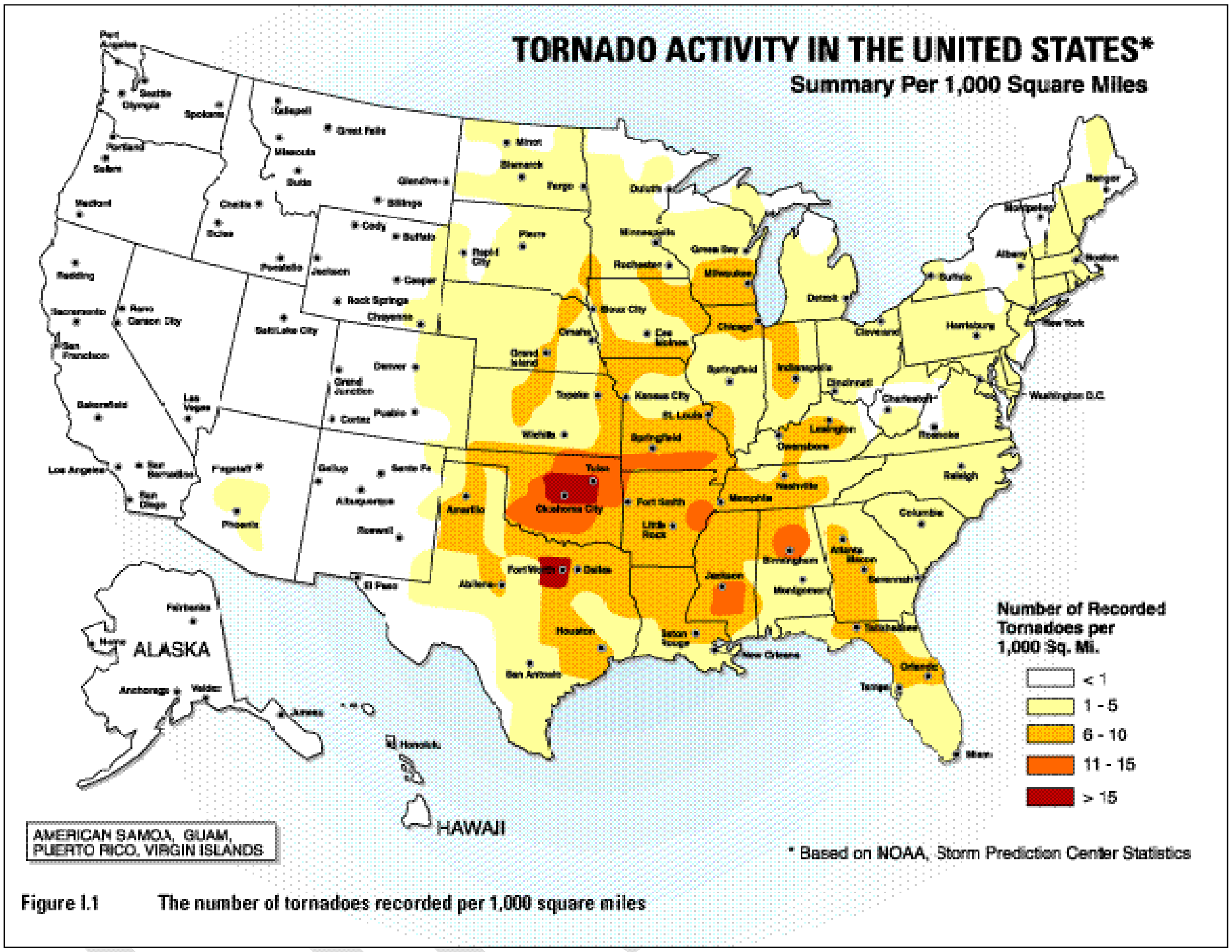


Figure I.2 Wind zones in the United States

Figure 4.2
Tornado Activity in the United States
(Source: FEMA)



Assessing Vulnerabilities

All locations within the planning area are subject to tornadoes. Map 4.5 shows the tracks of recorded, confirmed tornadoes in the City of Biloxi.

Previous Occurrences

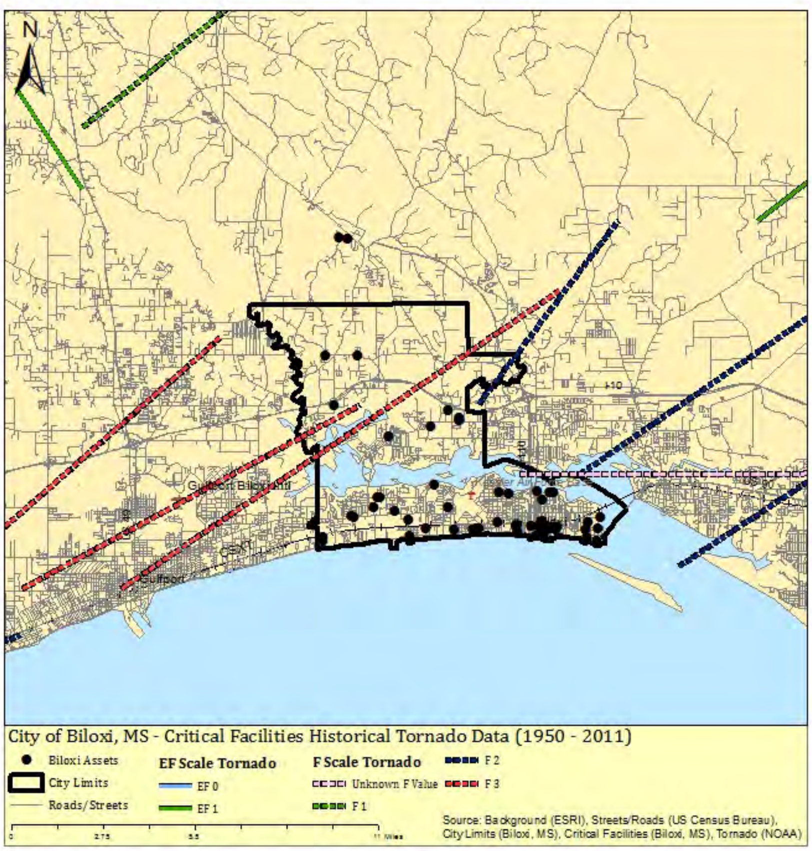
According to the National Climatic Data Center, 25 tornadoes have touched down in Harrison County since 1980. Eight of those tornadoes have been recorded within the City of Biloxi, causing loss of life and extreme property damage. Table 4.10 indicates the date, magnitude, total number of fatalities, injuries and the property damage attributed to the Biloxi tornadoes. Based on NCDC records, the City of Biloxi has experienced tornadoes ranging from EF0 to EF3 in terms of severity, but due to the unpredictable nature of tornadoes the City could experience a tornado of greater magnitude.

Table 4.10
Tornado History in City of Biloxi

Location or County	Date	Type	Magnitude	Fatalities	Injuries	Property Damage
Biloxi	4/13/1980	Tornado	F3	0	25	$5,000,000
Biloxi	5/16/1980	Tornado	F3	0	0	$525,000
Biloxi	5/19/1980	Tornado	F3	0	4	$350,000
Biloxi	4/20/1982	Tornado	F2	0	0	$25,000
Biloxi	4/12/1994	Tornado	F2	2	15	$5,000,000
Biloxi	7/22/2000	Tornado	F0	0	0	0$0
Biloxi	10/3/2002	Tornado	F0	0	0	$15,000
Keesler AFB	03/09/2011	Tornado	EF1	0	0	$100,000

Source: NCDC, City of Biloxi

Map 4.5
Location of Tornado TouchdownsNear the City of Biloxi
(Source: ESRI, NOAA, City of Biloxi)



The unpredictable nature of tornadoes, combined with their active history throughout the county and their likelihood of developing during a hurricane or thunderstorm, make tornadoes a serious threat to the City.

The strongest and most damaging confirmed tornado in the City of Biloxi was an F-3 tornado on April 13, 1980, injuring 25 people causing an estimated $5,000,000 in property damages.

The tornado reports to the NCDC for the planning area ranged in severity from F-0 to F3 tornadoes on three occasions. Since 1980,NCDC report eight tornadoes within the City of Biloxi.

The unpredictable nature of tornadoes results in minimal, if any, warning time which can result in higher injury and fatality rates. People are less able to protect themselves when they have little or no warning time to prepare for the arrival of tornadoes.

Probability

According to NOAA, the State of Mississippi is ranked 12th in the nation for tornado occurrences, with an average of 23.6 tornadoes per year. The City of Biloxi has experienced eight confirmed tornadoes since 1980, which equates to an annual occurrence rate of 25% producing a low probability of occurrence. Although the probability of occurrence is low the Planning Committee determined the hazard to be critical due to the unpredictable and violent nature of tornadoes.

4.2.6 Wildfire

Description of the Hazard

Fire is a natural process of forests, including the pine savannahs located in the City of Biloxi. Fire clears the underbrush and allows new growth to occur. As the City becomes more populated, the impact of wildfire increases. Homes can become threatened by the fire itself (from both flames and ash) and people are affected by the smoke that invades neighborhoods and obstructs vision on the roadways. An effort to control the outbreak of wildfire has been undertaken throughout the City by the use of prescribed burns. By allowing fire on a scheduled basis, the forest managers hope to minimize the impact on the human population compared to out-of-control blazes. The presence of natural barriers such as bayous and drainage basins further limit the city's vulnerability to wildfires. Even with periodic controlled burns, and the area's natural barriers, wildfires continue to strike.

Hazard Profile

Table 4.11 demonstrates the Fire Danger Rating System, from the U.S. Forest Service's Wildland Fire Assessment System.

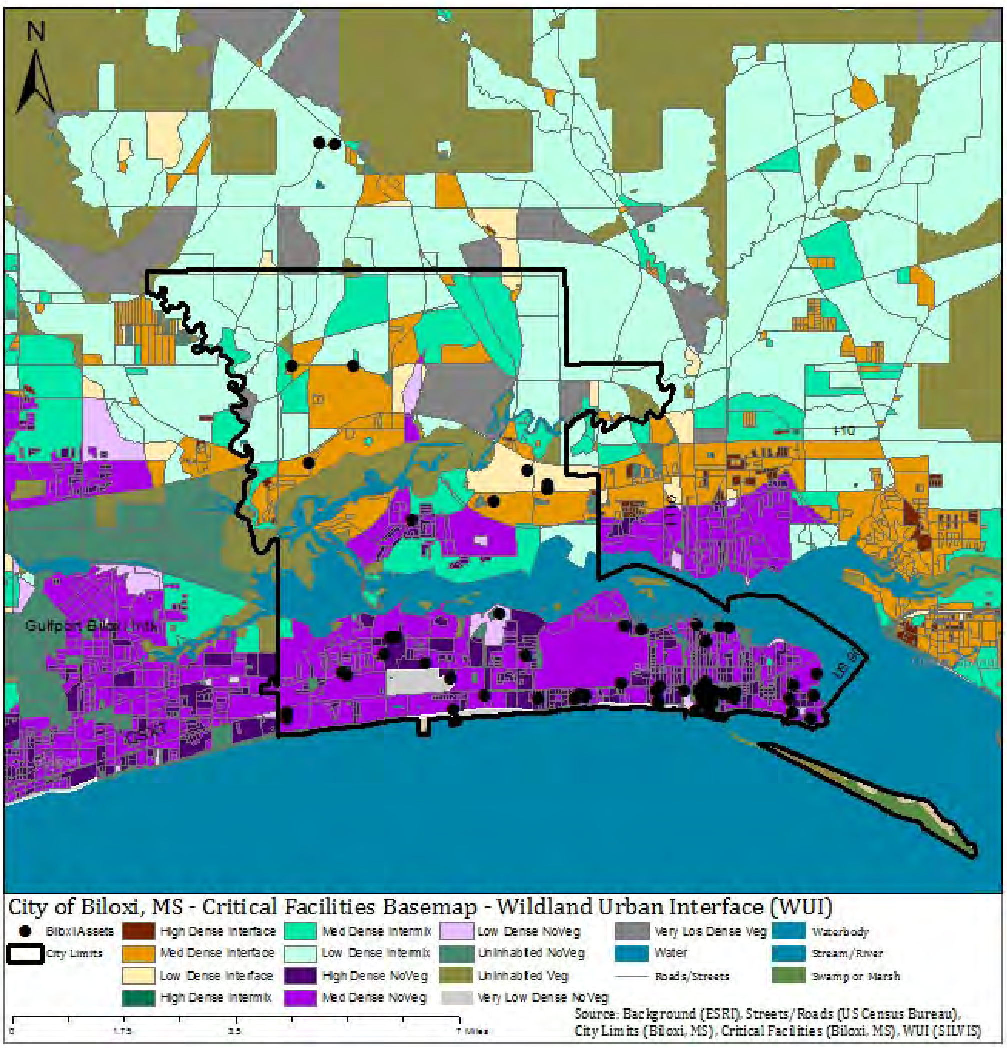
Table 4.11
Fire Danger Rating System

Rating	Basic Description	Detailed Description
CLASS 1: Low Danger (L) Color Code: Green	Fires not easily started	Fuels do not ignite readily from small firebrands. Fires in open or cured grassland may burn freely a few hours after rain, but wood fires spread slowly by creeping or smoldering and burn in irregular fingers. There is little danger of spotting.
CLASS 2: Moderate Danger (M) Color Code: Blue	Fires start easily and spread at a moderate rate	Fires can start from most accidental causes. Fires in open cured grassland will burn briskly and spread rapidly on windy days. Woods fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel - especially draped fuel - may burn hot. Short-distance spotting may occur, but is not persistent. Fires are not likely to become serious and control is relatively easy.
CLASS 3: High Danger (H) Color Code: Yellow	Fires start easily and spread at a rapid rate	All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High intensity burning may develop on slopes or in concentrations of fine fuel. Fires may become serious and their control difficult, unless they are hit hard and fast while small.
CLASS 4: Very High Danger (VH) Color Code:Orange	Fires start very easily and spread at a very fast rate	Fires start easily from all causes and immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high-intensity characteristics - such as long-distance spotting - and fire whirlwinds, when they burn into heavier fuels. Direct attack at the head of such fires is rarely possible after they have been burning more than a few minutes.
CLASS 5: Extreme (E) Color Code: Red	Fire situation is explosive and can result in extensive property damage	Fires under extreme conditions start quickly, spread furiously and burn intensely. All fires are potentially serious. Development into high-intensity burning will usually be faster and occur from smaller fires than in the Very High Danger class (4). Direct attack is rarely possible and may be dangerous, except immediately after ignition. Fires that develop headway in heavy slash or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions, the only effective and safe control action is on the flanks, until the weather changes or the fuel supply lessens.
Source: USFS via http://www.wfas.net/content/view/34/51/		

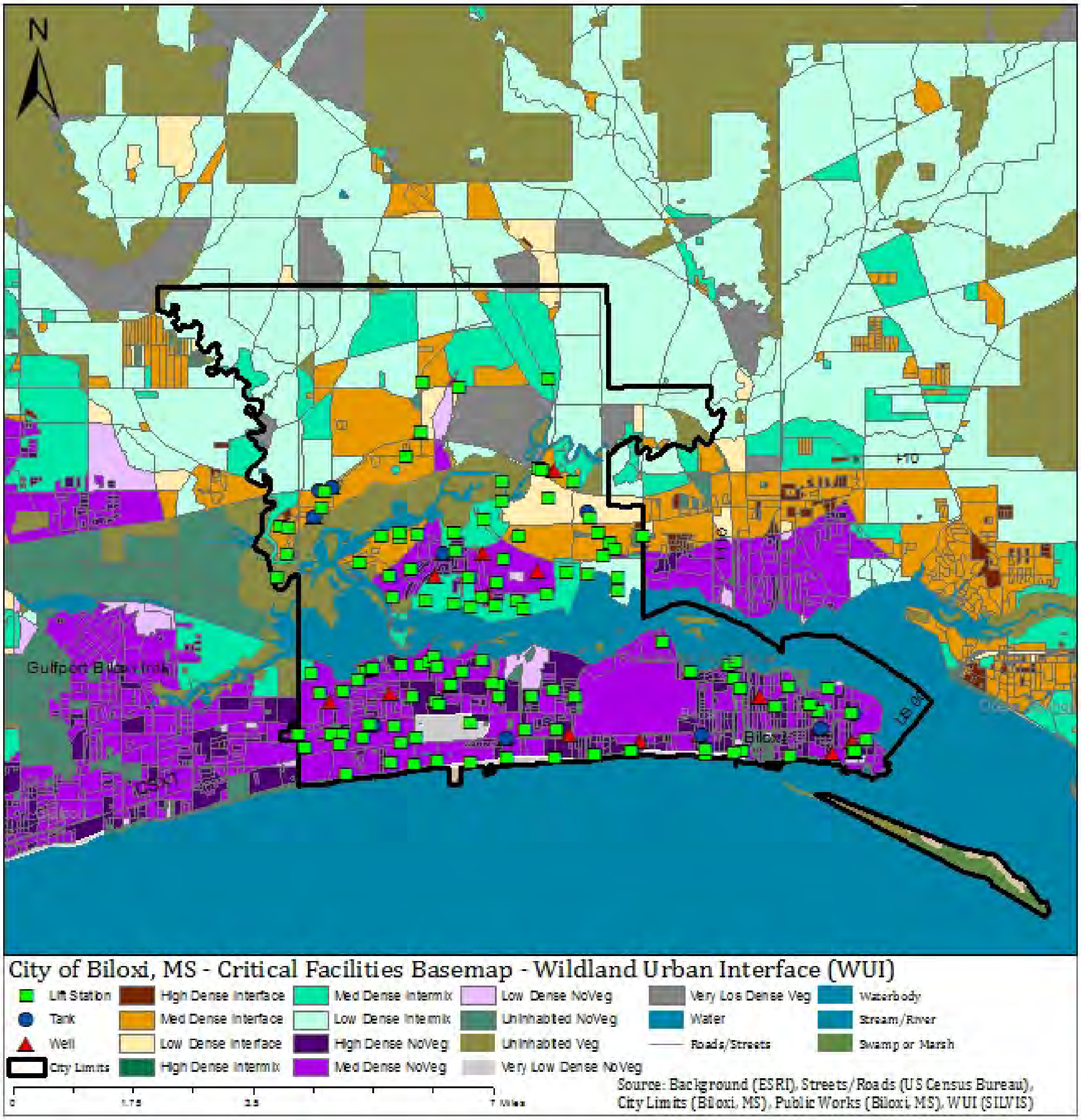
Assessing Vulnerabilities

Parts of the City of Biloxi have a high wildfire risk due to years of fire suppression in the native open pine savannah. Wildland Urban Interface (WUI) studies make a best case judgment on a list of factors including forestation and vegetative growth as they relate to distance from developed areas.Interface maps in the City of Biloxi shows moderate risk. A portion of the City of Biloxi has buildings that are located in Medium Density Wildland Interface areas. Interface communities are areas with housing in the vicinity of contiguous vegetation. Interface areas have more than one house (or building) per 40 acres, have less than 50% vegetation, and are within 1.5 mile of an area over 1,325 acres that is more than 75% vegetated. The minimum size limit ensures that areas surrounding small urban parks are not classified as interface WUI. Map 4.6 and Map 4.7 show the Wildland Urban Interface for City of Biloxi.

Map 4.6
Wildland Urban Interface in the City of Biloxi and Critical Facilities
(Source: ESRI, SILVIS)



Map 4.7
Wildland Urban Interface in the City of Biloxi and Public Works Facilities
(Source: ESRI, SILVIS)



Previous Occurrences

Since 2007, the Biloxi Fire Department has documented 327 wildfires within the City. While the Biloxi Fire Department is well equipped to handle a wildfire outbreak occurring in the City, depending upon the location and the magnitude of the fire, the Fire Department will coordinate response efforts with forestry personnel and neighboring public safety agencies.

Given the number of recent incidents and the multitude of areas within the City vulnerable for potential wildfires, the Biloxi Fire Department and the Hazard Mitigation Planning Committee consider wildfires a critical hazard.

Probability

Based on the data provided by the City of Biloxi Fire Department, there have been 327 wildfire occurrences in the past 5 years. The numbers provided by the City of Biloxi Fire Department average out to 65 wildfires per year making the probability of annual occurrence 100%; therefore the probability of occurrence is high.

Non-Critical Hazards

4.2.7 Coastal Erosion

Description of the Hazard

NOAA defines coastal erosion as a phenomenon of land loss precipitated by large storms, flooding, strong wave action, sea level rise, and human activities, which wears away the beaches and bluffs along the coast. Contributing human activities include alterations to the land (such as groundwater pumping) and shore protection structures. Coastal erosion can damage or destroy homes, businesses, and public infrastructure with long-term economic and social consequences.

Hazard Profile

Coastal erosion is a concern in Biloxi and along the Mississippi Gulf Coast.Storm surge has resulted in erosion of the beach. The Sand Beach Authority has the responsibility for protecting and maintaining the sand beach in Harrison County and the City of Biloxi and actively works to prevent erosion caused by wave action and wind.Sand dunes have been constructed generating vegetation along the shoreline thus minimizing erosion.

Assessing Vulnerabilities

Development can destroy wetlands that serve as important buffers again storm surge and other types of flooding. While nothing can be done to prevent coastal hazard events, their adverse impacts can be reduced through proper planning. Channel management and stewardship can reduce and, in some cases, reverse coastal erosion. Harbor and channel widening and/or deepening removes natural sediment that settles around the mouths of rivers. When this sediment is allowed to build-up along the shorelines, coastal land loss is reduced. However, sediment can also negatively impact navigable waterways and dredging activity is required to maintain the channels. Dredge spoils may be pumped beyond the gulf shelf or dumped inland in landfills. If used properly, dredge spoils can reduce or reverse coastal erosion through beach nourishment or land reclamation.

Previous Occurrences

The Sand Beach Authority has undertaken three sand beach replenishment projects to replenish the sand beach after erosion was caused by major storms. The projects took place in 1972, 1987, 2001 and 2007. The beach erosion caused no direct impact on residential or commercial structures.

No additional erosion issues were noted by the Hazard Mitigation Planning Committee since the 2007 Plan Update; therefore the Biloxi Hazard Mitigation Planning Committee considers this hazard to be non-critical at this time. It is recommended that this hazard and potential impacts be reviewed periodically due to the proximity of beachfront in and around the City of Biloxi.

Probability

Given the historical data provided of four projects in a 40 year period dating back to 1972. The annual probability of occurrence is 10% providing a probability of low occurrence.

4.2.8 Drought

Description of the Drought Hazard

According to NOAA, a drought is defined as a period of unusually persistent dry weather that persists long enough to cause serious problems, such as crop damage and/or water supply shortages. The severity of the drought depends upon the degree of moisture deficiency and the duration of the drought.

Drought occurs under differing conditions, based on the reference points:

- **Meteorological** drought is defined by a period of substantially diminished precipitation duration and/or intensity. The commonly used definition of meteorological drought is an interval of time, generally on the order of months or years, during which the actual moisture supply at a given place consistently falls below the average moisture supply.
- **Agricultural** drought occurs when there is inadequate soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought usually occurs after or during meteorological drought, but before hydrological drought and can affect livestock and other dry-land agricultural operations.
- **Hydrological** drought refers to deficiencies in surface and subsurface water supplies from deficiencies in precipitation. It is measured as stream flow, snow pack, and as lake, reservoir, and groundwater levels. There is usually a delay between lacks of rain or snow and less measurable water in streams, lakes, and reservoirs. Therefore hydrological measurements tend to lag behind other drought indicators.
- **Socio-economic** drought occurs when physical water shortages start to affect the health, well-being, and quality of life of the people, or when the drought starts to affect the supply and demand of an economic product.

Hazard Profile

A drought's severity depends on numerous factors, including duration, intensity, and geographic extent as well as regional water demands by humans, livestock, crops, and vegetation. The severity of drought can be aggravated by other climatic factors such as prolonged high winds and low relative humidity. Due to its multi-dimensional nature, drought is difficult to define in exact terms and also poses difficulties in terms of comprehensive risk assessments.

In 1965, Wayne Palmer developed an index to "measure the departure of the moisture supply." This index was based on the supply-and-demand concept of the water balance equation, taking into account more than merely the precipitation deficit at specific locations. The objective of the Palmer Drought Severity Index (PDSI) was to provide a measurement of moisture conditions that were "standardized" so that comparisons using the index could be made between locations and between time periods. While Palmer's indices are water balance indices that consider water supply (precipitation), demand (evapotranspiration) and loss (runoff), another commonly used drought index, the Standardized Precipitation Index (SPI), is a probability index that considers only precipitation. Therefore and for the purposes of this plan, drought will be analyzed using the PDSI.

The PDSI varies roughly between -4.0 and +4.0. Weekly Palmer Index values are calculated for the Climate Divisions during every growing season and are available from the Climate Prediction Center. Biloxi could expect to experience the entire range of drought severity and classification. Table 4.12 lists the Palmer Drought Severity Index.

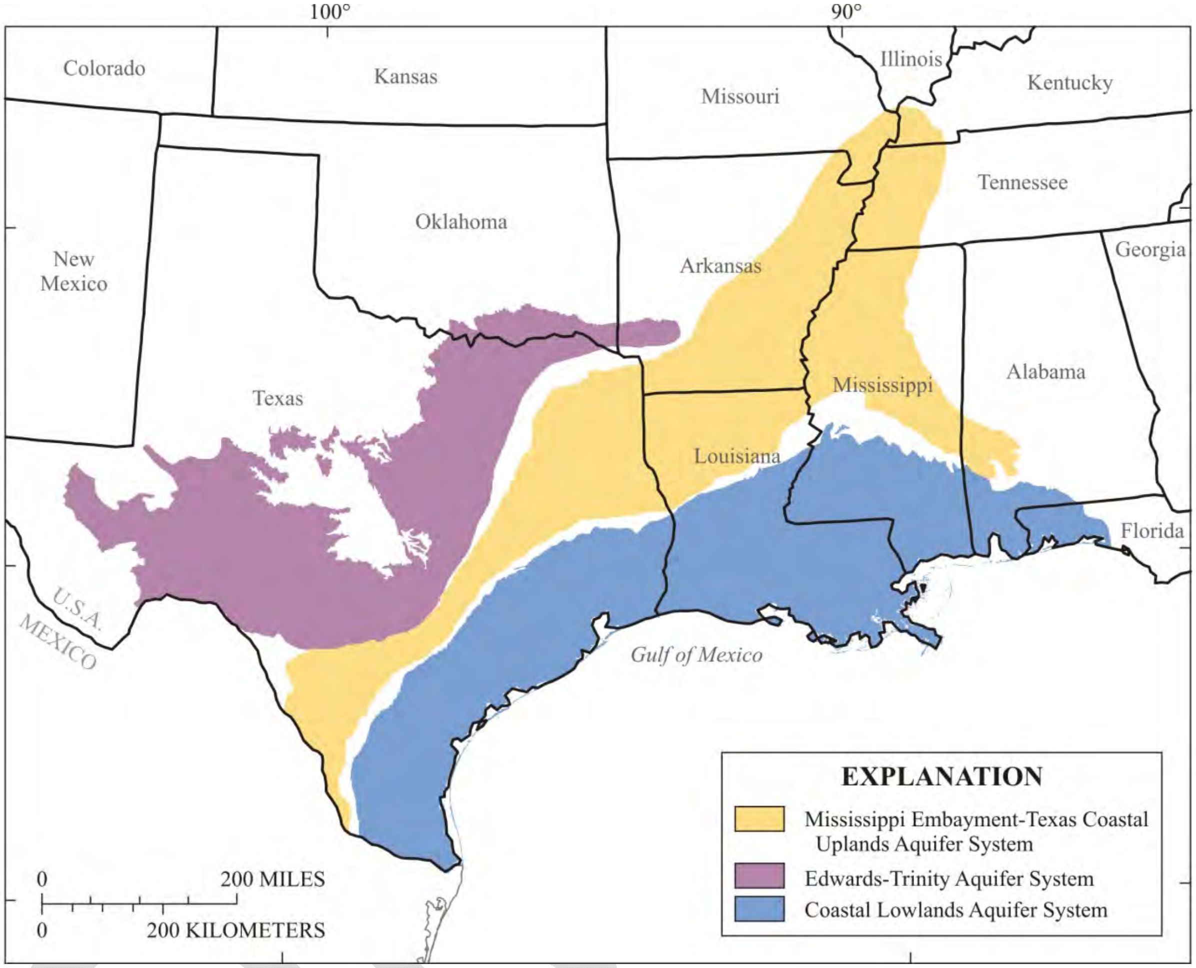
Table 4.12
Palmer Drought Severity Index

Index Value	Classification	Index Value	Classification
4.00 or more	Extremely wet	-0.50 to -0.99	Incipient dry spell
3.00 to 3.99	Very wet	-1.00 to -1.99	Mild drought
2.00 to 2.99	Moderately wet	-2.00 to -2.99	Moderate drought
1.00 to 1.99	Slightly wet	-3.00 to -3.99	Severe drought
0.50 to 0.99	Incipient wet spell	-4.00 or less	Extreme drought
0.49 to -0.49	Near normal		
Source: http://drought.unl.edu/whatis/indices.htm			

Assessing Vulnerabilities

Drought is not a location-specific hazard. All areas of the City of Biloxi are equally vulnerable to drought. Map 4.8 shows the location of the Coastal Lowlands Aquifer System which provides drinking water tothe City of Biloxi.

Map 4.8
Southern Coastal Aquifer System
(Source: USGS)



A severe, prolonged drought could have negative and lasting impacts on residents, agriculture, industry and infrastructurein the City of Biloxi. When available water tables decline and potable water becomes harder to obtain, the residents, commuting population, and visitors are exposed to greater health risks. Any water-dependent functions in the City of Biloxi are exposed to potential loss of or failure to function.

Previous Occurrences

The current conditions across southern Mississippi show Biloxi outside any drought condition zone. Historically, Mississippi is the third wettest state in the nation (behind Hawaii and Louisiana), receiving an average of 59.23' of rain per year. Since the forecast period is a snapshot of current or foreseeable conditions over a reasonably long planning period, seasonal weather trends and use of the U.S. Drought Monitor can provide indicators of oncoming drought conditions.

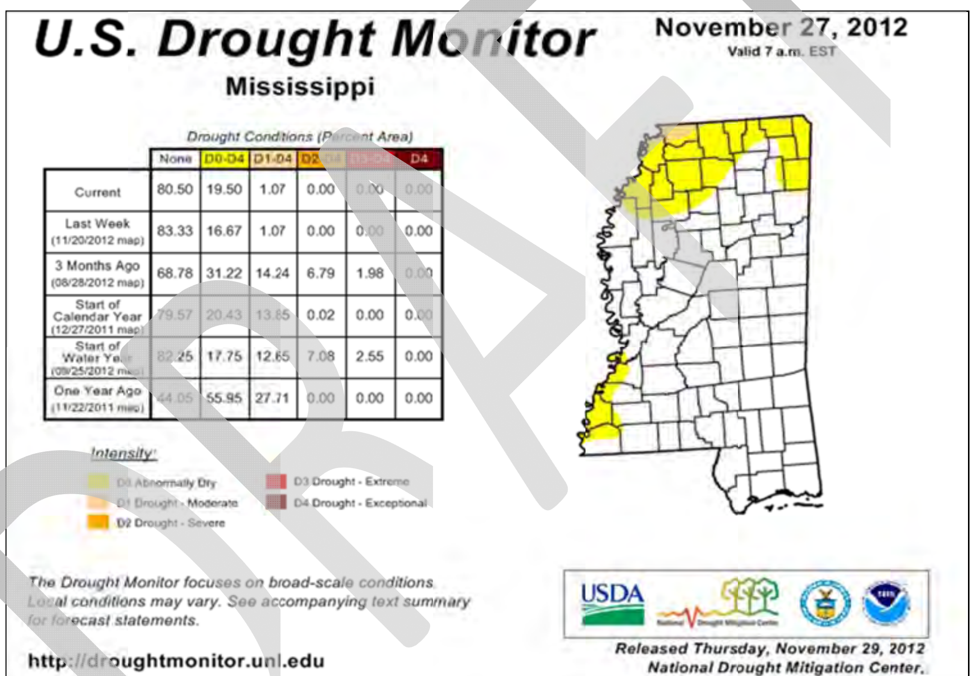
There have been no recorded droughts for the City of Biloxi.

Probability

A lack of recorded historical drought data and forecasting limitations makes estimating probability of drought unrealistic within the context of this plan. Given statewide drought indices, the probability of future drought conditions is considered to be low as determined by the U.S. seasonal drought outlook. However, it is important to note that the seasonal drought outlook is a forecast through February 2013, and is a much shorter timeframe than the five year planning horizon of this plan. Continuous monitoring of drought indices and forecasts are recommended.

Figure 4.3 shows current drought data for Mississippi (the smallest unit of data available); Figure 4.4 shows current national drought data; Figure 4.5 shows the U.S. Seasonal Drought Outlook.

Figure 4.3
Drought Monitor Data for Mississippi
(Source: USDA)



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	80.50	19.50	1.07	0.00	0.00	0.00
Last Week (11/20/2012 map)	83.33	16.67	1.07	0.00	0.00	0.00
3 Months Ago (08/28/2012 map)	68.78	31.22	14.24	6.79	1.98	0.00
Start of Calendar Year (12/27/2011 map)	79.57	20.43	13.85	0.02	0.00	0.00
Start of Water Year (09/25/2012 map)	82.25	17.75	12.65	7.08	2.55	0.00
One Year Ago (11/22/2011 map)	44.05	55.95	27.71	0.00	0.00	0.00

Figure 4.4
Drought Monitor Data for theUnited States
(Source: USDA)

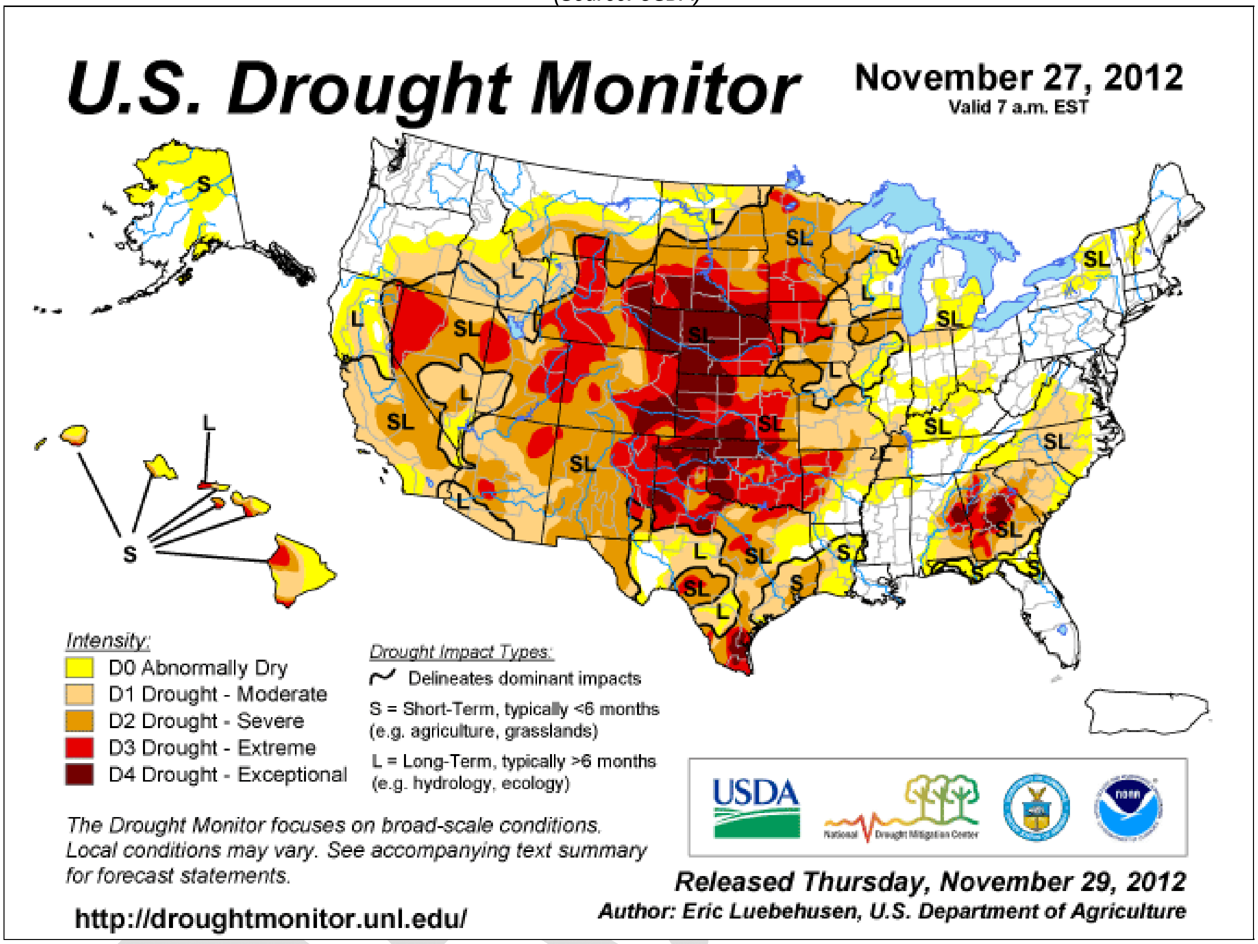
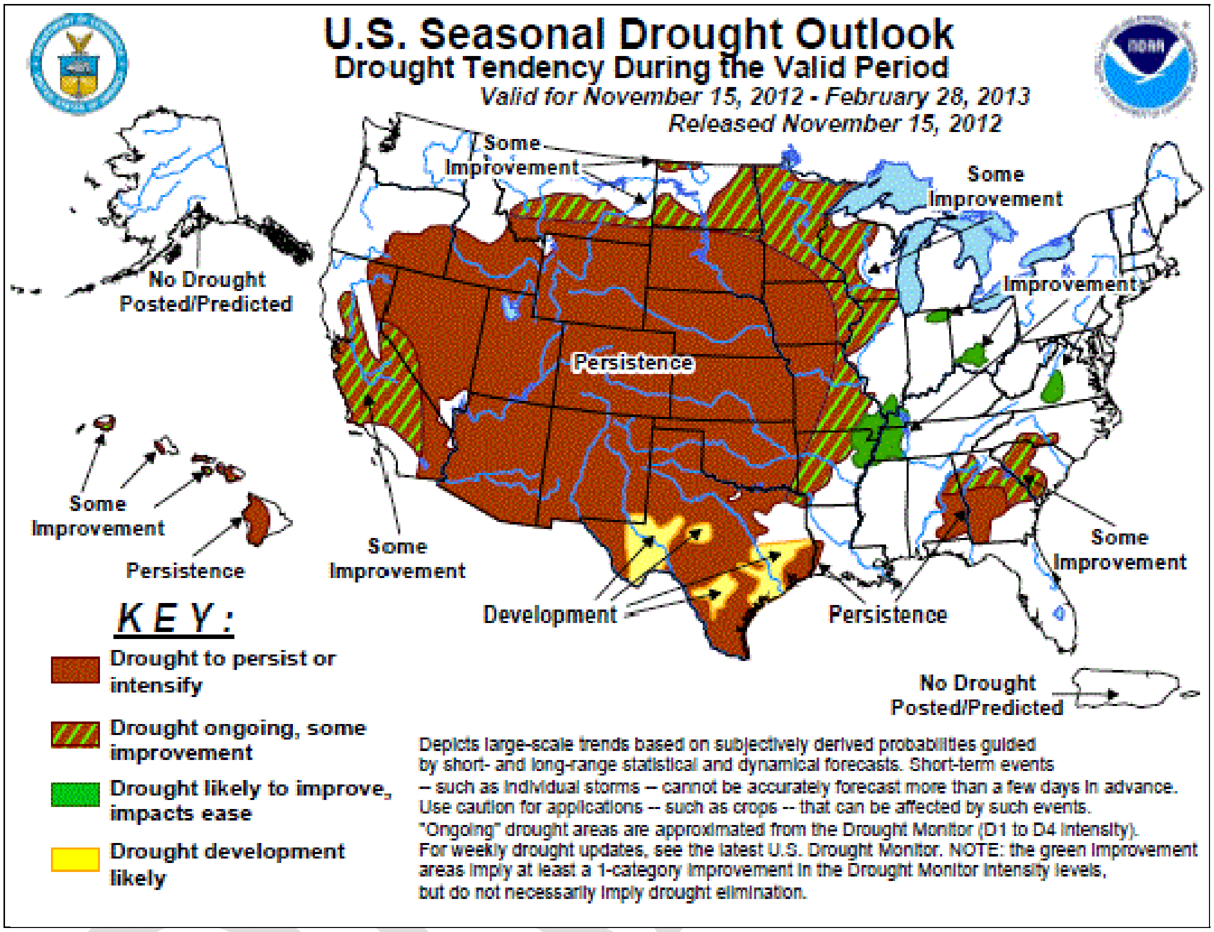


Figure 4.5
U.S.Seasonal Drought Outlook
(Source: USDA)



4.2.9 Earthquakes

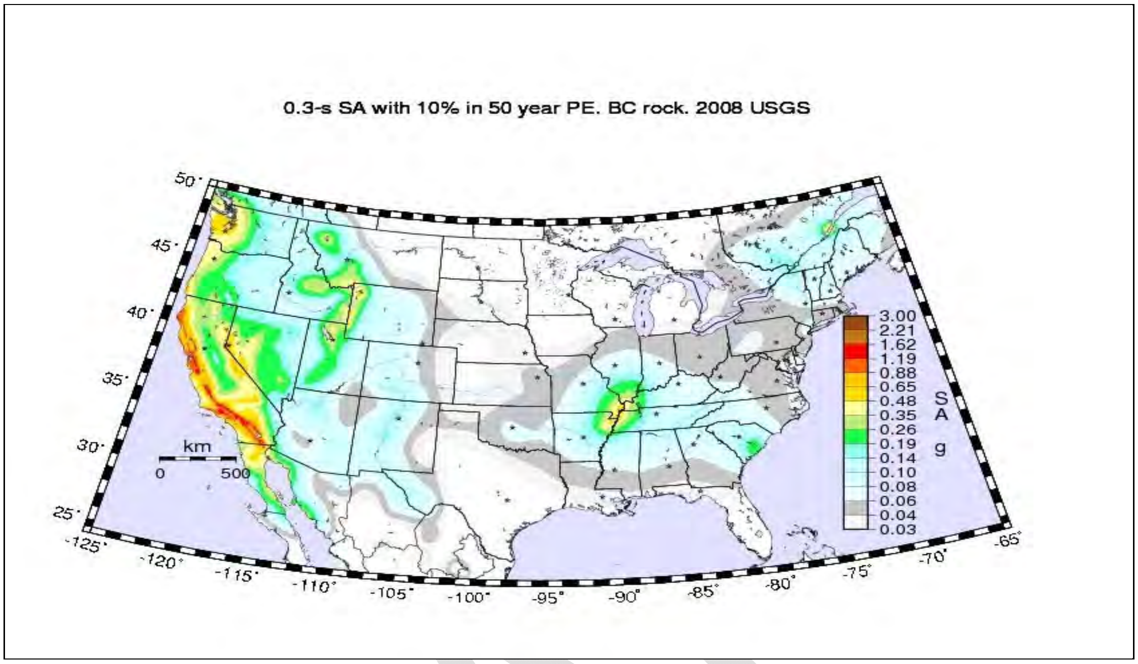
Description of Hazard

The United States Geologic Survey (USGS) defines an earthquake as a sudden motion or trembling of the earth caused by an abrupt release of stored energy beneath the earth's surface.

Hazard Profile

The USGS rates areas of the U. S. for their susceptibility to earthquakes based on a 10% probability of a given peak being exceeded in a 50 year period. The City of Biloxi lies in an area of low seismic risk, with a peak acceleration of 1%,which according to the USGS is equivalent to the potential for light shaking with no damage. Figure 4.6 provides an overview of the entire United States and peak ground acceleration. As FEMA guidelines suggest, areas located within a region of 2% peak acceleration or less are at nominal risk, therefore, the Biloxi Hazard Mitigation Planning Committee considered earthquakes a non-critical hazard.

Figure 4.6
Areas with 10% PE in 50 Years
(Source: USGS 2008)



The USGS is responsible for providing information about earthquakes to other government agencies and to the public. Information about earthquakes is used in many ways, including the response to felt earthquakes by the public, by federal, state, and local government agencies, and by private organizations.

In 1935, Charles Richter developed the local magnitude, ML scale for moderate-size (3 < ML < 7) earthquakes in southern California. The ML scale is often called the “Richter scale” by the press and the public. All current methodologies for measuring earthquake magnitude (ML, duration magnitude mD, surface-wave magnitude MS, teleseismic body-wave magnitude mb, moment magnitude M, etc.) yield results that are consistent with ML. In fact, most modern methods for measuring magnitude were designed to be consistent with the Richter scale.The Richter scale is presented in Table 4.13 (following).

Table 4.13
Richter Scale

Magnitude	Earthquake Effects
Less than 3.5	Generally not felt, but recorded.
3.5-5.4	Often felt, but rarely causes damage.
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0-7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred kilometers across.
Source: United States Geological Survey (USGS)	

Previous Occurrences

While earthquakes are not believed to pose a great threat to Biloxi, there is some history involving earthquakes within the Gulf Coast area. Although the number of earthquakes known to have been centered within Mississippi's boundaries is small, the state has been affected by numerous events located in neighboring states. Specific events of record includethe 1811 and 1812 series of great earthquakes near the New Madrid, MO area; the earthquakes were felt as far south as Biloxi. The New Madrid earthquakes caused the banks of the Mississippi River to cave in as far south as Vicksburg, more than 300 miles from the epicentral region.

On February 1, 1955, an earthquake was felt by people along a 30-mile strip of the Mississippi Gulf Coast. In Gulfport, houses shook, windows and dishes rattled and deep rumbling sounds were heard by many. In Biloxi, several persons were alarmed by the rumbling noise heard.

There have been no reported earthquakes in Biloxi since 1955.

Probability

With the limited history of occurrences of two earthquake events felt in Biloxi over a two hundred year period, the occurrence rate is <1%, making the probability low.

<u>4.2.10 Fog</u>

Description of Hazard

According to the National Weather Service, fog occurs when the air near the ground is saturated with moisture and condenses on tiny particles suspended in the air. These particles are called cloud condensation nuclei and actually attract water vapor molecules to their surfaces. Once condensation occurs on these tiny surfaces, the resulting liquid drops can remain suspended in the air because their weight causes them to descend slowly to the ground or be carried around by wind. The dew-point temperature, or saturation vapor pressure, can be reached by either adding more water vapor to the air or cooling the air down to the dew-point temperature. Fog is classified by the dominant formation process and exists as long as processes continue to maintain saturated conditions.

Based on information provided by the National Weather Service, fog becomes hazardous once visibility is reduced to less than ¼ of a mile.

Assessing Vulnerabilities

Major transportation corridors are most vulnerable to the fog hazard due to the number of vehicles traversing the roadways. The areas along U.S. Highway 90, Interstate 10 and the recently completed U.S. Highway 67 are the areas of most concern for the City of Biloxi. The major concern in the highly traveled area is that of vehicle accidents related to fog conditions.

Previous Occurrences

There have been no recorded fog events through the NCDC database for the City of Biloxi.

Probability

Fog is a hazard that occurs sporadically with limited reporting. Due to a lack of reporting of events it is virtually impossible to determine the frequency of occurrence for the fog hazard. Due to a lack of recorded history and limited severity, the Planning Committee determined the fog hazard to be a non-critical hazard at the time of the plan update.

4.2.11 Hail

Description of Hazard

Hail is defined by the National Weather Service (NWS) as a showery precipitation in the form of irregular pellets or balls of ice more than 5 mm in diameter, falling from a cumulonimbus cloud. Studies of thunderstorms provided through the NWS indicate that two conditions are required for hail to develop: sufficiently strong and persistent up-draft velocities and an accumulation of liquid water in a super-cooled state in the upper parts of the storm. Hailstones are formed as water vapor in the warm surface layer rises quickly into the cold upper atmosphere. The water vapor is frozen and begins to fall; as the water falls, it accumulates more water vapor. This cycle continues until there is too much weight for the updraft to support and the frozen water falls too quickly to the ground to melt along the way.

Hazard Profile

Previously, the NWS issued severe thunderstorm warnings whenever a thunderstorm is forecast to produce wind gusts to 58 miles per hour (50 knots) or greater and/or hail size 3/4 inch (penny-size) diameter or larger. Hail storms are associated with thunderstorms and due to the widespread and unpredictable nature the entire City of Biloxi can experience hail events.

Assessing Vulnerabilities

Hail is a non-location specific hazard and may cause damage anywhere in the City of Biloxi. Critical infrastructure associated with power transmission, telecommunications and road signage are vulnerable to hail. Manufactured homes are particularly susceptible to hail events due to construction types (vinyl siding, lesser gauge metal roofs).

Previous Occurrences

Since 1994 the NCDC has recorded six hail events in the City of Biloxi. Of the reported events no property damage losses have been reported. The following table provides dates and location of the hail events from the NCDC database.

Table 4.14
Hail Events in Biloxi
September 1994 – July 31, 2012

Location	Date	Event	Property Damage
Biloxi	3/1/1994	Hail	0K
Biloxi	1/24/1997	Hail	0K
Woolmarket/Biloxi	7/21/2000	Hail	0K
Biloxi	7/21/2000	Hail	0K
Biloxi	4/26/2005	Hail	0K
Biloxi	06/12/2007	Hail	0K
Source: NOAA National Climatic Data Center Extreme Events			

Probability

With six hail events recorded in the past 18 years, the annual occurrence rate is 33% making the probability medium. Despite the frequency of occurrence of the hail hazard, the Biloxi Hazard Mitigation Planning Committee determined that the lack of severity associated with the events lead to the determination to consider hail as a non-critical hazard with limited impacts. Based on this determination, hail will not be profiled in further detail.

4.2.12 Heat Wave

Hazard Profile

A heat wave as defined by the American Meteorological Society is aperiod of at least 48 hours during which neither the overnight low nor the daytime high heat index falls below the NWS heat stress thresholds (80° and 105°F, respectively).

Description of Hazard

Heat Wave is a not location-specific hazard; all areas within the planning area are vulnerable to this hazard.

Previous Occurrences

According to the NCDC only three reported heat related events have occurred in Harrison County including the City of Biloxi since 1950. Based on historic data provided by the National Weather Service the City of Biloxi experienced a record high temperature of 104 degrees, recorded on August 29, 2010**.**

Probability

Based on available data, three recorded events in 62 years equated to an annual occurrence rate of 5%, yielding a very low probability of occurrence. The Planning Committee determined the hazard to be non-critical and no additional profiling will be completed for this Plan Update.

4.2.13 Landslide/Sinkholes

Description of Hazard

According to the USGS, alandslide is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments.

Sinkholes are defined by the USGS as natural and common geologic feature in areas with underlying limestone and other rock types that are soluble in natural water. Most limestone is porous, allowing the acidic water of rain to percolate through their strata, dissolving some limestone and carrying it away in solution. Over time, this persistent erosional process can create extensive underground voids and drainage systems in much of the carbonate rocks. Collapse of overlying sediments into the underground cavities produces sinkholes.

Previous Occurrences

There have been no reported occurrences of landslides/sinkholes in the City of Biloxi.

Probability

Due to the lack of historic occurrences of the hazard, the Hazard Mitigation Planning Committee determined that the hazard has a low probability of occurrence and was not considered for further discussion in the plan update. The Planning Committee discussed the possibility of removing the hazard from future plan updates.

4.2.14 Salt Water Intrusion

Description of Hazard

Salt Water Intrusion is defined by the USGS as the mixing of saltwater with freshwater. It can occur in either surface- water or groundwater bodies.

Hazard Profile

According to the USGS, salt water intrusion occurs in coastal freshwater aquifers when the different densities of both the saltwater and freshwater allow the ocean water to intrude into the freshwater aquifer. These areas are usually supporting large populations where the demanding groundwater withdrawal from these aquifers is exceeding the recharge rate. This can cause lateral and vertical intrusion of the surrounding saltwater. The encroaching seawater will encounter an area known as the zone of dispersion, where the freshwater and saltwater mix and form an interface. This interface moves back and forth naturally because of fluctuations in the recharge rate of freshwater back into these coastal aquifers. Due to the proximity of the City of Biloxi to the Gulf of Mexico, the entire City is at risk to saltwater intrusion.

Assessing Vulnerabilities

According to the USGS the most vulnerable structures and systems related to Salt Water Intrusion are water wells. Due to Salt Water Intrusion causing changes in water tables, wells have to be re-drilled thus making the extraction of fresh water more difficult and expensive. The entire City of Biloxi can be impacted by the hazard due to the proximity to the Gulf of Mexico and potential salt water intrusion in to ground water sources.

Previous Occurrences

According to the Hazard Mitigation Planning Committee there have been no recorded occurrences of salt water intrusion in the City of Biloxi.

Probability

Based on a lack of recorded occurrences the probability of occurrence for this plan update was considered to be very low. The Planning Committee determined the salt water intrusion hazard to be non-critical at the time of this plan update.

4.2.15 Sea Level Rise

Description Hazard

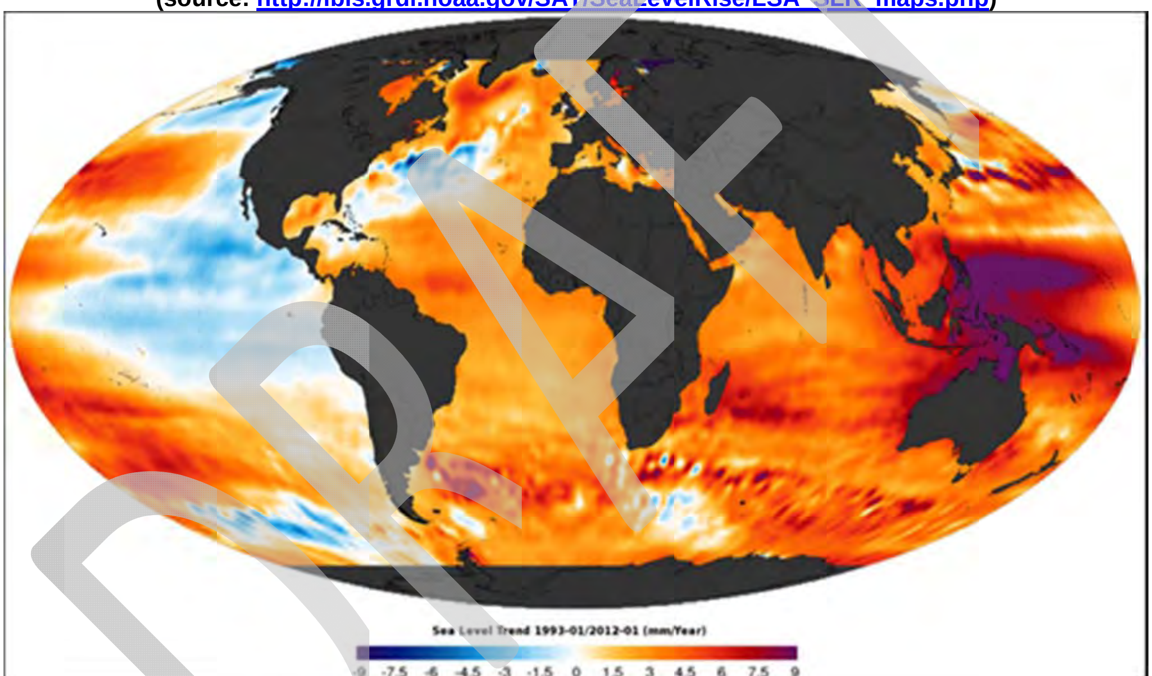
Sea-level rise is a phenomenon that affects coastal and tidal areas, and land areas with elevations close to sea level. Land subsidence, caused by the compaction of loose soils such as that found in river delta areas, will affect land elevation. Relative sea-level rise in these areas will be greater.

Hazard Profile

The City of Biloxi areas adjacent to the shoreline are at risk to impact from sea level rise. A specific local study is currently being conducted. The Hazard Mitigation Committee recognizes that climate change is affecting the mean sea level along the Gulf Coast and will eventually impact low elevation areas of the City of Biloxi. Once the study is complete, the Planning Committee will be able to reference the study in the next mitigation plan update.

Figure 4.7 provides estimates of sea level rise based on measurements from satellite radar altimeters. The local trends were estimated using data from TOPEX/Poseidon (T/P), Jason-1, and Jason-2, which have monitored the same ground track since 1992, and were published by NOAA.

Figure 4.7
Sea Level Change, in millimeters per year, 1993-2010
(source: http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_maps.php)



As indicated by the color coding on the above map, the Mississippi Coast has experienced sea level changes of 1.5-4.5 millimeters since 1993.

Assessing Vulnerabilities

Land use and urban planning in coastal areas must take into account the phenomenon of sea level rise. Sea levels are currently rising along the Gulf Coast as a result of climate change. Rising sea levels inundate low areas, erode beaches and wetlands, increase flooding from storm surges and rainstorms, and enable saltwater to advance upstream.

As coastal population densities increase, greater numbers of people and assets are at risk. For example, increased storm surges due to rising sea levels could impact low-lying roadways, inland marshes along the areas south of U.S. Highway 90.

Rising sea level affects both the natural and the human-made environment. Future sea level rise could result in the disappearance of a large percentage of coastal wetlands which are already stressed by development and other activities. Saltwater advancing upstream can alter the point at which flocculation leads to sedimentation and the creation of shoals. Storm surges from hurricanes can reach further inland as mean sea levels rise.

As sea level rises, drainage systems become less effective. Rainstorms will have the potential to cause greater flooding. As the sea level rises, these areas may experience increased flooding and slowed recovery from flood waters.

Port facilities on the water's edge are particularly susceptible to sea level rise. Docks, jetties, and other facilities are deliberately set at an optimal elevation relative to the water level, and therefore a rise in sea level leaves them at a suboptimal elevation. However, these facilities tend to be rebuilt relatively frequently compared with the time it takes for a substantial rise in sea level.

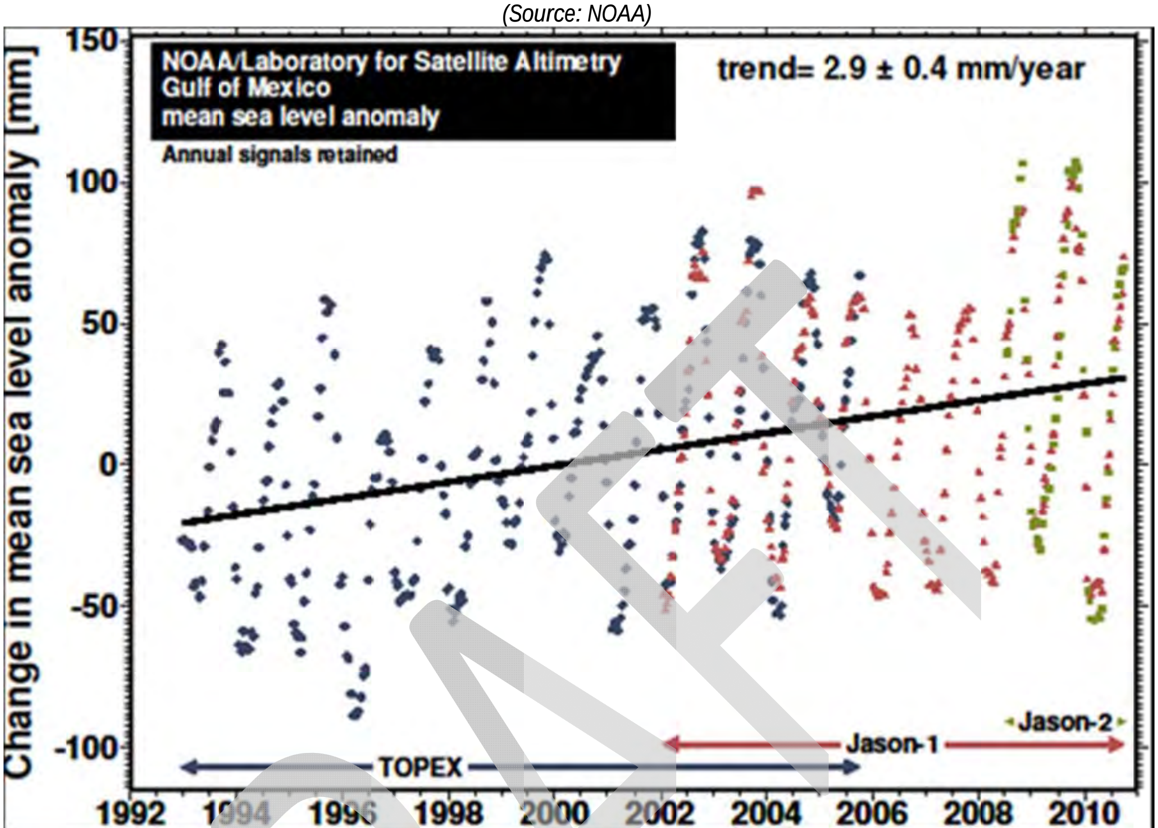
Commercial, industrial, and residential properties along the coastline that are currently at risk to flooding and storm surge are also vulnerable to sea level rise.

Previous Occurrences

The Intergovernmental Panel on Climate Change (IPCC) concludes that there has been a global mean rise in sea level between 10 and 25 cm (approximately 4 to 10 inches) over the last 100 years

NOAA tracks changes in sea level by body of water, such as the Caribbean Sea or the Gulf of Mexico. Therefore, all occurrence data that is available for this hazard as it relates to the City of Biloxi is at the level of the Gulf of Mexico. Figure 4.8 indicates the change in sea level rise in the Gulf of Mexico from 1992 through 2010, which is the most recent data available from NOAA. This data indicates an increase in sea level in the Gulf of Mexico of 2.9 mm per year (+/- 4 mm per year).

Figure 4.8
Mean Sea Level – Gulf of Mexico
(Source: NOAA)



Probability

The IPCC estimates that global sea level will rise 9 to 88 centimeters during the 21st century. For the purposes of this plan update, the Hazard Mitigation Planning Committee determined the sea level rise hazard to be a non-critical hazard pending the results of the completed local study.

4.2.16 Tsunamis

Description of Hazard

Tsunamis are large water waves, generated by seismic activity, that have historically caused significant damage to coastal communities throughout the world. According to a publication of the National Geophysical Data Center entitled *Tsunamis and Tsunami-Like Waves of the Eastern United States*, the threat of tsunamis and tsunami-like waves hitting the United States is very real, despite a general impression to the contrary. Tsunamis can be generated from earthquakes, sub-marine landslides, explosive decompression of underwater methane deposits, or oceanic meteor splashdowns.

Areas along and south of U.S. Highway 90 in Biloxi are most susceptible to experiencing a tsunami event based on proximity to the Gulf of Mexico.

Previous Occurrences

There are recorded occurrences of tsunamis in the Gulf of Mexico. According to the "Regional Assessment of Tsunami Potential in the Gulf of Mexico: U.S. Geological Survey Administrative Report" three recorded tsunami events have occurred in the Gulf of Mexico in the past century. Of the recorded events, the highest wave action recorded was near Galveston, TX at .64 meters or just over 2 feet.

Probability

With no recorded occurrence of tsunamis in the City of Biloxi, the probability of occurrence is very low. The Planning Committee determined the tsunami hazard to be a non-critical hazard at the time of this plan update; therefore no further profiling of the hazard was done.

4.2.17 Winter Storms/Freezes

Description of Hazard

According to NOAA, winter storms can be defined in several ways depending on the various portions of the country. Winter storms in the South (including the City of Biloxi) typically consist of light snow (snow flurries with little to no accumulation), freezing rain (rain that falls when ground temperatures are below freezing), or sleet (transparently frozen or partially frozen raindrops).

The National Weather Service defines freezes as when the surface air temperature is expected to be 32°F or below over a widespread area for a climatologically significant period of time. Use of the term is usually restricted to advective situations or to occasions when wind or other conditions prevent frost.

Hazard Profile

According to the National Weather Service the City of Biloxi has experienced a wide range of annual low temperatures since 1960 with the record low temperature of 10 degrees (F) recorded in 1962 to the low temperature of 41 degrees (F) recorded in 1989. Figure 4.9 below provides information related to temperatures and wind chills provided by the National Weather Service.

Figure 4.9
National Weather Service Wind Chill Chart
(Source: NWS)

NWS Windchill Chart

Temperature (°F)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph) *Effective 11/01/01*

Assessing Vulnerabilities

According to the Centers for Disease Control and Prevention, populations most at risk to extreme cold and heat events include the following: 1) the elderly, who are less able to withstand temperatures extremes due to their age, health conditions and limited mobility to access shelters; 2) infants and children under 4 years of age; 3) individuals who are physically ill (e.g., heart disease or high blood pressure), 4) low-income persons that cannot afford proper heating and cooling; and 5) the general public who may overexert during work or exercise during extreme heat events or experience hypothermia during extreme cold events.

Previous Occurrences

According to the NCDC there have been a total of two winter weather events in Harrison County since 1990, with the latest such event occurring in 2004. On December 25, 2004, a mixture of sleet and snow fell off and on during much of Christmas Day, resulting in a dusting to one-half inch of accumulation across much of the coast. A few traffic accidents were reported along roads and bridges that were icy, but the winter weather was short lived. Due to the widespread nature of winter storm events, in the rare case of such occurrences of winter storms the entire City of Biloxi can be impacted by the hazard. Both of the recorded events combined for a total damage estimate of approximately $12,500.

Probability

This phenomenon is considered a moderate risk to life and infrastructure; however, due to the low frequency of occurrences (9% annual occurrence rate, based on 2 recorded events in 22 years) the Hazard Mitigation Planning Committee determined Winter Storm/Freezes to be a non-critical hazard with no further profiling for this Plan Update

Man-Made/Health-Related Hazards

4.2.18 Hazardous Materials (Transportation)

Description of Hazard

The location of the transportation hazard can be best described as proximity to transportation corridors, be it railways or highways. For the purposes of this Plan Update, the proximity used for analysis purposes was a .5 mile buffer zone around major transportation corridors (based on available data at the time of the Plan Update the recently completed U.S. Highway 67 loop was not included). An analysis of all modes of transportation revealed that rail and roadway transportation modes pose risks to the health, safety and welfare of citizens as well as visitors or those traveling through the City. The level of risk and the impact of the hazards vary depending on conditions such as, the location, time and size of the incident, direction of wind and other factors. Hazardous Materials related hazards seem to be more of a human life issue than a property damage issue although some incidents could result in significant property damage.

Hazard Profile

Due to the large number and wide variety of Hazardous Material transportation corridors in the community, it is difficult to identify areas and populations vulnerable to the hazard. There are simply too many factors determinant of vulnerability.

An east/west rail line running the entire length of the Biloxi corporate limits is owned by the CSX Railroad. CSX carries, among other things, large volumes of toxic chemicals and hazardous materials from Texas to points in Louisiana, Mississippi, Alabama, and Florida. The rail line bisects all but one municipality in Harrison County. By virtue of the fact that over 10,000 rail cars annually carry toxic chemicals or hazardous materials on the CSX Railroad, the track is designated a “key route” by Federal railroad authorities. This designation requires daily track inspection and the highest level of regulation. The CSX Railroad runs 20 to 30 trains per day through Biloxi ranging from a mile to a mile and a half in length at speeds not exceeding 45 mph. The greatest risk of an incident is a derailment or damage to rail cars caused at a crossing accident involving motor vehicles.

Assessing Vulnerabilities

Location, magnitude, type of problem, wind velocity and direction and weather conditions vary with each incident, thus making assessment of vulnerability difficult at best. Populations and areas vulnerable to the two most significant technological hazards identified in this plan can be addressed in the following general terms.

In the case of an accident on the CSX Railroad, population and areas within.5 miles on either side of the railroad are most vulnerable to hazardous materials. The number of cars involved in the accident, volume and type of materials carried, wind direction and velocity and atmospheric conditions will dictate with more specificity areas that are vulnerable and the resultant need for evacuation or other actions.

Heavy trucks carrying hazardous chemicals on U.S. Highway 90, I-10 or I-110 pose the greatest risk to areas and populations within .5 miles of the highway system. Variables such as atmospheric conditions, wind direction and velocity, and type of chemical will dictate with more specificity, vulnerable areas and populations

Previous Occurrences

According to the National Transportation Safety Board there have been no reported hazardous materials incidents in the City of Biloxi along transportation corridors.

Probability

Based upon the lack of previous occurrences of hazardous materials incidents along major transportation corridors within Biloxi, the likely hood of future occurrence is low. Although the probability of occurrence is low, due to the unpredictable nature of the hazard, the Planning Committee considers this a critical man-made hazard. A full risk assessment is presented later in the chapter.

4.2.19 Pandemic

Description of Hazard

The Center for Disease Control and Prevention (CDC) defines a pandemic as an epidemic occurring worldwide or over a very wide area, crossing international boundaries, and usually affecting a large number of people. According to the CDC, an epidemic is a widespread occurrence of an infectious disease in a community at a particular time.

Hazard Profile

Locations within the City of Biloxi with high population concentrations such as schools, casinos and retail locations are at the greatest risk of the pandemic hazard.

Pandemic issues noted by the Hazard Mitigation Planning Committee including Pandemic Influenza and the West Nile Virus. Pandemic Influenza particularly “Bird Flu” was mentioned by the Planning Committee however due to a lack of reported cases in the U.S. no further discussion of "Bird Flu" occurred in this Plan Update. The West Nile Virus is transmitted to humans through mosquito bites. Mosquitoes become infected when they feed on infected birds that have high levels of WNV in their blood. Infected mosquitoes can then transmit WNV when they feed on humans or other animals.

Areas are at greatest risk for the spread of the West Nile Virus during the summer months, particularly, July and August. Infection by the West Nile Virus usually causes mild, flu-like symptoms; however, in some cases, encephalitis can result in serious illness and death. Table 4.15 provides information on reported cases of West Nile Virus for the State of Mississippi and Harrison County for 2004 through 2012. For planning purposes, city specific reports were not available; therefore state and county level data was used.

Table 4.15
Reported Cases of West Nile Virus 2006-2012

Year	Number of Reported Cases MS	Number of Reported Cases Harrison County	Number of Fatalities State of MS	Number of Fatalities Harrison County
2002	N/A	4	N/A	N/A
2003	N/A	17	N/A	N/A
2004	N/A	2	N/A	N/A
2005	N/A	N/A	N/A	N/A
2006	183	12	12	0
2007	136	6	4	0
2008	65	0	3	0
2009	53	7	5	0
2010	8	0	0	0
2011	52	0	0	0
2012	234	2	1	1

Note: N/A represents data not available for the identified year and location
Source: Centers for Disease Control and Prevention

Probability

With the data available for occurrences of the West Nile Virus 50 cases have been reported since 2002 making the probability of occurrence five cases per year on average; thus yielding a 100% probability of occurrence. Although the probability of occurrence was noted as high, for the purposes of this plan update the Planning Committee determined the hazard to be non-critical.

4.2.20 Terrorism

Description of Hazard

Terrorism is defined by the Federal Bureau of Investigation as the unlawful use offorce against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in the furtherance of political or social objectives. Table 4.16 provides examples of the terrorism hazard identified by the Biloxi Hazard Mitigation Planning Committee.

Table 4.16
Terrorism Hazard Examples

Arson	Civil Disturbance	Kidnapping
Armed Assaults, Assassination	Cyber Terrorism	Nuclear Release-Weapons
Biological Agent Release	Environmental Destruction	Product Tampering – Sabotage
Bombing	Hijacking, Building Seizure, Raids and Attacks on facilities	Robbery – Attempted Robbery
Bomb Threat	Hostage Taking	

Hazard Profile

Providing a specific location of terrorism is difficult due to the fact there is no defined geographic boundary for terrorism. It is assumed by the Planning Committee that the areas of higher risk for terrorism are those areas/facilities within the City with large numbers of people or facilities listed in the Homeland Security Information Protection (HSIP) data list. Due to the sensitive nature of this hazard no further profile information will be included in this Plan Update.

Assessing Vulnerabilities

The risks associated with terrorism hazards and related issues are set out in the Harrison County Emergency Management Terrorism Counteraction Operating Procedures Manual. Due to the unpredictable nature and sensitive information associated with Terrorism Hazard it is impossible to provide a detailed vulnerability assessment within the framework of this Plan Update.

Previous Occurrences

There have been no recorded occurrences of terrorism in the City of Biloxi.

Probability

Due to no recorded terrorism event in the City of Biloxi the probability of occurrence was considered low by the Planning Committee.

4.2.21 Exotic Species

Description of Hazard

As defined by the United States Environmental Protection Agency. An exotic or invasive species is a species that has been introduced and become a pest in its new location, spreading (invading) by natural means.

Hazard Profile

The information associated with Exotic Species remained the same as the 2007 Hazard Mitigation Plan. No further information was available at the time of the Plan Update.

The Harrison County Hazard Mitigation/Flood Protection Plan recognizes a number of non-native exotic species as potential hazards and worthy of mention in the hazard mitigation planning process. According to the County Plan, without methods of control or eradication, exotic species in the area could evolve into property damaging problems. Exotic species in the area include Formosan termites, Cogon grass and nutria. While at present these species are not major risks, their presence in the area is reason for concern and reason for education of the public relative to the risks posed by these species.

Assessing Vulnerabilities

The warm, moist climate of Biloxi and the Mississippi Gulf Coast makes the area vulnerable to subterranean termite infestation and termite treatment is required by building code administrators and lenders. Formosan termites were introduced to New Orleans through cargo entering the Port of New Orleans. The Formosan termites are causing widespread damage to buildings and trees in New Orleans and some isolated cases have been reported along the Mississippi Coast. Formosan termites offer new challenges since they are airborne (unlike subterranean termites) and can enter the upper portions of structures and are not readily detectable. The major challenge of the Formosan is his resistance to conventional chemicals used to protect against subterranean species. Current treatment for the Formosan termites is extremely expensive and does not necessarily prevent infestation. Current treatment methods for the Formosan are ineffective in trees because chemicals used to eradicate the termites can kill the trees.

Cogon grass is known to be spreading through Harrison County and is likely found in some of the areas annexed by Biloxi in 1999 and 2003. According to agricultural and soil conservation officials, cogon grass, a species native to Southeast Asia, is spreading in Harrison County. Cogon grass was originally introduced as packaging material in products imported from Asia. Extremely intrusive, cogon grass is unappetizing to livestock and wildlife and crowds out native species that provide fodder for animals.It is also resistant to conventional herbicides. The only effective method of control, at present, involves repetitive deep plowing, burning and application of herbicide.

According to the Harrison County Plan, Nutria are also found in Harrison County and are most likely to be more prevalent in areas annexed in 1999 and 2003. The rodents, which are native to South America, were introduced into the Louisiana marshes in the last century to supplement the fur trapping industry. Unfortunately, nutria are hostile to native species and are voracious eaters. Some areas have become overpopulated with nutria, completely crowding out native species. Their eating habits have denuded stream banks, especially along coastal bayous, causing erosion from rising and falling tides. Additionally, with the current distaste for fur garments, their value to the fur trade is greatly diminished. Prolific breeders with few natural enemies, nutria are a prime example of human intervention in nature running amuck.

Probability

Due to a lack of recorded occurrences of Exotic Species it is difficult to determine the probability of future occurrences with limited data available. At the time of the plan update the Planning Committee determined Exotic Species to be a non-critical hazard with no further profiling at this time.

4.3 Vulnerability Assessment

4.3.1 Overview of Vulnerability Assessment

Requirement CFR §201.6(2)(ii) [the risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described and shall include an overall summary of each hazard and its impact on the community.

Vulnerability is susceptibility to physical injury, harm, damage or economic loss and is dependent on location, construction, contents, and function of a facility. Understanding vulnerability is essential in mitigation planning for the City of Biloxi as it leads to an understanding of the types and costs of injury and damages that may result from a future hazard event.

For each hazard addressed in the plan, the Planning Committee was asked to provide qualitative damage/loss estimates, using low/medium/high designations and based upon their knowledge of the city and facilities. Committee members looked at potential risk to people/life safety (loss of life or injury), risk to buildings and critical facilities (primarily damage to the physical structure), and risk to infrastructure (utilities and roads). Table 4.17 shows the methodology used to determine the qualitative assessment results.

Table 4.17
Qualitative Hazard Ranking Assessment Methodology

Impacts to People	
Low	Some injury possible but unlikely
Moderate	Injury expected some deaths possible
High	Several deaths expected
Impacts to Business	
Low	Cosmetic damages to structures, < 1 day LOF
Moderate	Some structural damages, 1-2 days LOF
High	Some structures irreparably damaged, > 2 days LOF
Impacts to Infrastructure	
Low	Loss of Function up to 6 hours of temporary blockage or power loss
Moderate	Loss of Function for 6 – 12 hours of temporary blockage or power loss
High	Loss of Function for greater than 12 hours of blockage or power loss

The overall impacts to the City of Biloxi were determined by the Hazard Mitigation Planning Committee and are shown in the Qualitative Risk Assessment Summary and Analysis. To help determine which hazards would receive a full risk assessment, the qualitative analysis was used by giving each hazard ranking a value. One point was given for each "low" ranking, two points for "moderate", and three points for "high". Those hazards scoring six points or more were considered significant enough for a quantitative risk assessment, provided data was available to support one. The result of the risk analysis follows in Tables4.18 and 4.19.

Table 4.18
Summary and Analysis of Qualitative Risk Assessment

People	Buildings	Infrastructure	Score
Coastal Erosion			
Low	Low	Low	3
Drought			
Low	Low	Low	3
Flood			
High	High	High	9
Hurricane/Coastal Storm			
High	High	High	9
Sea Level Rise			
Low	Low	Low	3
Storm Surge			
High	High	High	9
Thunderstorm/High Wind/Lightning			
High	High	High	9

People	Buildings	Infrastructure	Score
Tornado			
High	High	High	9
Wildfire			
Moderate	Moderate	Moderate/Low	5/6
Earthquake			
Low	Low	Low	3
Extreme Heat			
Moderate	Moderate/Low	Moderate/Low	4/6
Salt Water Intrusion			
Moderate	Moderate/Low	Moderate/Low	4/6
Technological Hazards			
High	High	High	9
Terrorism			
Moderate	Moderate/Low	Moderate/Low	4/6

Table 4.19
List of Hazards by Priority

Hazard	Priority	Hazard	Priority
Hurricane/Coastal Storm	High	Wildfire	Moderate
Storm Surge	High	Sea Level Rise	Low
Flood	High	Earthquake	Low
Thunderstorm/High Wind/Lightning	High	Extreme Heat	Moderate/Low
Tornado	High	Salt Water Intrusion	Moderate/Low
Coastal Erosion	Low	Technological Hazards	High
Drought	Low	Terrorism	Moderate/Low

4.3.2 Identifying Structures

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

In order to assess the vulnerability of the City of Biloxi to the identified critical hazards, the Hazard Mitigation Committee utilized HAZUS-MH (FEMA's Methodology for Estimating Potential Losses from Disasters), GIS technology, historical data and personal knowledge to develop an extensive inventory of critical facilities located within the City. Critical facility examples provided by FEMA include all manmade structures or other improvements that; because of their function, size, service area, or uniqueness; have the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if they are destroyed, damaged, or if their functionality is impaired.

- Hospitals, nursing homes and housing likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a flood or other emergency.
- Public safety facilities such as fire stations, vehicle and equipment storage facilities and emergency operations centers needed for disaster response activities before, during and after a flood or other disaster.
- Public and private utilities that is vital to maintaining or restoring normal services to areas before, during and after a flood or other disaster.
- Structures or facilities that produce, use or store highly volatile, flammable, explosive toxic and/or water-reactive materials.

The identification of critical facilities is crucial in the hazard mitigation planning process. Exhaustive meetings were conducted in a collaborative effort to identify each and every critical facility subject to damage from the various hazards that exist in the City of Biloxi.Many critical facilities can also present hazards.

Critical Facilities

Based upon the above definition and information reviewed from the previous Plan, the Biloxi Hazard Mitigation Committee developed the list of critical facilities that appears in Table 4.20 below. Detailed information on these facilities is also provided in Appendix 4.1-A.

Table 4.20
List of City-Designated Critical Facilities

Back Bay-Fire Station #3	Dr. Frank Gruich, Sr. Community Center	Mississippi Marine Patrol Dispatch
Bay Vista-Fire Station #5	East Biloxi Library and Civic Center	North Bay Elementary
Beau Rivage	East End-Fire Station #2	North Woolmarket Elementary
Beauvoir Elementary	Grand Casino	Oaklawn Rd-Fire Station #9
Biloxi Communications Center	Gray-Slay House	Old Brick House
Biloxi Community Living Center	Gulf Coast Medical Center	Old Public Library
Biloxi Emergency Operations	Gulf Oak Hospital	Palace Casino
Biloxi Jr High School	Gulf Shore Villas	Police Station-Lopez/Quave
Biloxi Regional Medical Center	Hard Rock Casino	Popps Ferry Elementary
Bond House	Harrison County Courthouse	Popps Ferry-Fire Station #6
Boomtown Casino	Imperial Palace Casino	Public Safety Garage
Cadet Point	Isle of Capri Casino	Public Works
Cedar Lake Medical Center	Jeff Davis Elementary	Saenger Theatre
Cedar Lake/Popps Ferry-Fire Station #7	Juvenile Detention Center	Seashore Personal Care
Central-Fire Station #1	Keesler Air Force Base	Swetman House
City Hall	Keesler Medical Center	Treasure Bay Casino
Coast Transit Authority	Lighthouse	Veterans Administration Hospital
Communications Tower	Lighthouse Visitor's Center	Veterans-Fire Station #4
Community Development	Loyalton of Biloxi	West End Hose Co #3
Creole Cottage	Magnolia Hotel	Woolmarket Civic Center
Donal Snyder Community Center	Margaritaville Casino	Woolmarket Elementary
Dr Eldon Bolton State Office Bldg	Michel 7th Grade School	
Source: City of Biloxi		

Information for water tanks, water wells and lift stations was provided by the Biloxi Department of Public Works. Ten water tanks, 24 water wells and 114 lift stations were identified and used to develop maps displaying vulnerable facilities by hazard type. The information associated with the water wells in Table 4.21 includes water well names and locations. Damage figures are located under each of the identified critical hazards as part of the quantitative risk assessment.

Table 4.21
List of Water Wells

67 &Oaklawn Well	Kuhn St Well	Park Dr Well
BradfordStWell	Lakeview Well	Pine St Well
Cedar Lake Well	Mapel St Well	Porter Ave Well
Debuys Well	New Bay Vista Well	Rustwood Well
Father Ryan Well	North Biloxi #1 well	South Hill Well
Greater Ave Well	North Rivervue Well	Sports Complex Well
Hospital Well	Oaklawn Well	Tullis Manor Well
Iberville Well	Old Bay Vista Well	Vee St Well
Source: City of Biloxi Public Works		

The Hazard Mitigation Planning Committee looked at each building and prioritized them for mitigation actions based on a series of criteria from Level 1 to Level 5, with Level 1 being the most critical buildings (The asset lists are provided in Table 4.20 List of Identified Critical Facilities). Table 4.22 lists the methodology and results for building ranking. For the purposes of this plan update, the Planning Committee noted the ten city owned "level 5" facilities as 9 piers and 1 pavilion (yet to be completed), these ten facilities were notedin the asset inventory; however no further analysis was conducted utilizing these facilities due to their low level of criticality

Table 4.22
Building Ranking Methodology

Criticality Level	Description	Number of Biloxi Critical Facilities
Level 1	Public safety buildings (Police, Fire, EMS, EMA/EOC), shelters, hospitals, urgent care centers, public works facilities and other buildings that MUST remain operational during a disaster event.	33
Level 2	Buildings that provide essential government services and must be operational within 12 to 24 hours of a disaster. These facilities include pharmacies, and buildings used for response/recovery operations (schools, airports, etc).	6
Level 3	Buildings that must be functional during recovery operations such as government administrative buildings, courthouses and service stations.	4
Level 4	Buildings that support normal living, commerce, and tourism such as museums, vacation cabins, and casinos.	23
Level 5	Support buildings and facilities that do not meet any of the other criteria such as pole barns, pavilions, piers, and storage sheds.	10

Quantitative Risk Assessments were conducted based on the best data available at the time of the plan update. Based on available data and for this planning horizon, the thunderstorm/high wind/lightning hazard will be excluded from further risk assessment. Due to insufficient location data and the widespread nature of the hazard there was not enough data available to perform a reasonable quantitative analysis. The remaining assessments are summarized in Table 4.22.

Table 4.22
Summary of the City of Biloxi Quantitative Risk Assessment

Hazard Type	ExposedFacilities	Level 1	Level 2	Level 3	Level 4	Level 5
Hurricane/Coastal Storm	66	33	6	4	23	10
Storm Surge	57	24	6	4	0	10
Flood	18	3	1	1	13	0
Tornado	66	33	6	4	23	0
Wildfire	4	0	0	0	0	0

4.4 Estimating Potential Losses

Requirement CFR §201.6(2)(ii)(B) [the plan should describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified and a description of the methodology used to prepare the estimate.

Utilizing the list of critical hazards identified in Tables 4.20 and 4.21, the Biloxi Hazard Mitigation Committee compiled thorough vulnerability assessments utilizing GIS mapping tools as well as HAZUS-MH software. The results of each analysis are provided in conjunction with the corresponding critical hazard identified by the Committee.

The following hazards identified for the risk assessment discuss the methodology and results for the given hazard. Each of the loss calculations is based on the best available data, but they must be considered estimates only, as highly detailed engineering study was not performed as part of the planning process.

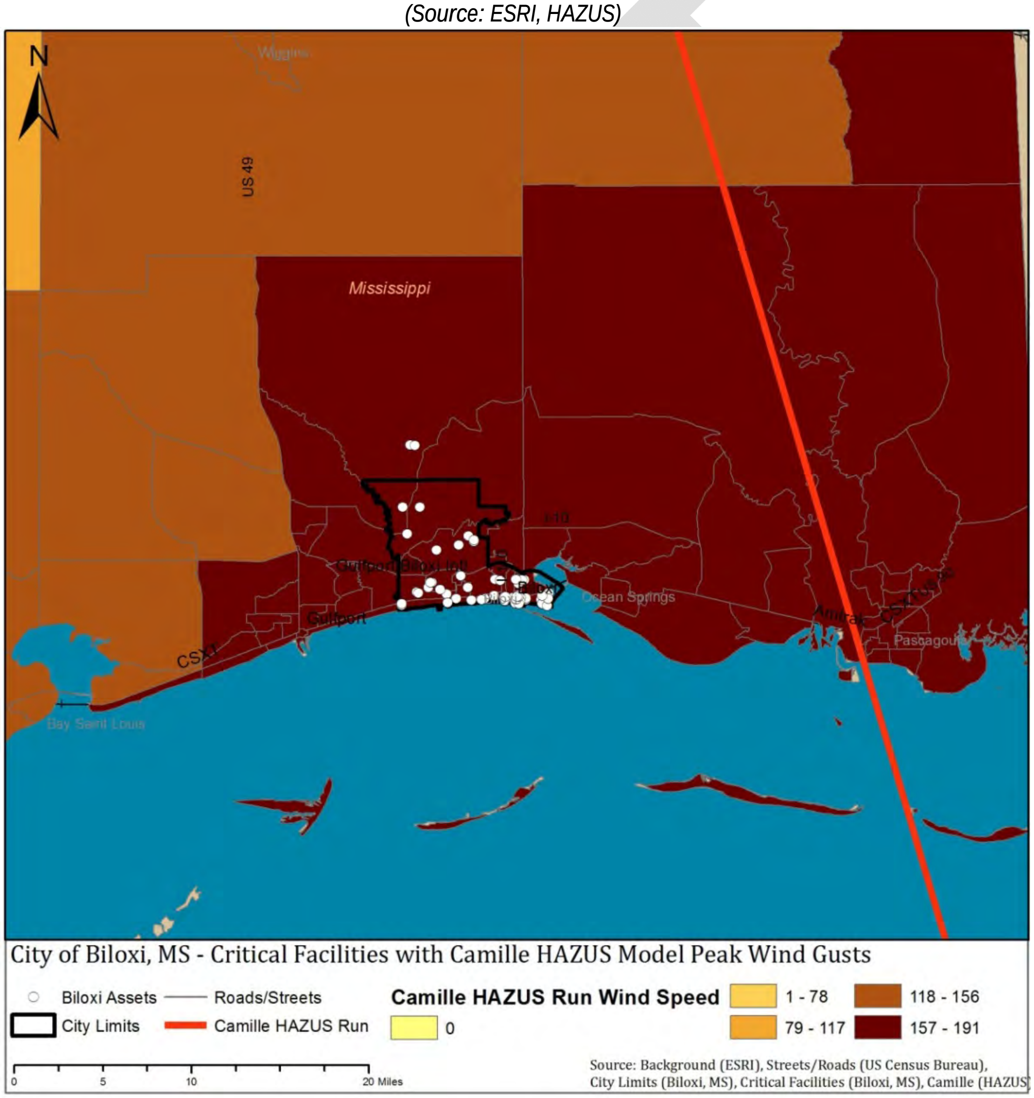
4.4.1 Coastal Storm (Hurricane/Tropical Storm)

In order to better understand the risks and vulnerability of the participating jurisdictions to hurricanes, HAZUS-MH was used to estimate the wind fields created by a Hurricane Camille, Category 5 event making landfall directly in the City of Biloxi. Because this is a modeled hazard event, there may be significant differences between the modeled results contained in this plan and the actual social and economic losses following a specific hurricane. These results can be improved by using enhanced inventory data.

Using this scenario, damage estimates were attained by assuming a 60% damage function to building stock in the buffer zone. Since population estimates are variable and not known for the buildings impacted by the scenario, impacts to human lives cannot be accurately defined.

This scenario shows one possibility, and is not all-inclusive of the risk to the City of Biloxi. City facilities are mapped with model wind field data that depicts the potential wind speed impacts across Biloxi during a Category 5 storm. The wind fields are shown in Maps 4.9 through 4.10.

Map 4.9
City of Biloxi, Hurricane Camille HAZUS Model
Peak Wind Gusts and Critical Facilities
(Source: ESRI, HAZUS)



Map 4.10
City of Biloxi, Hurricane Camille HAZUS Model
Peak Wind Gusts and Public Works Facilities
(Source: ESRI, HAZUS)

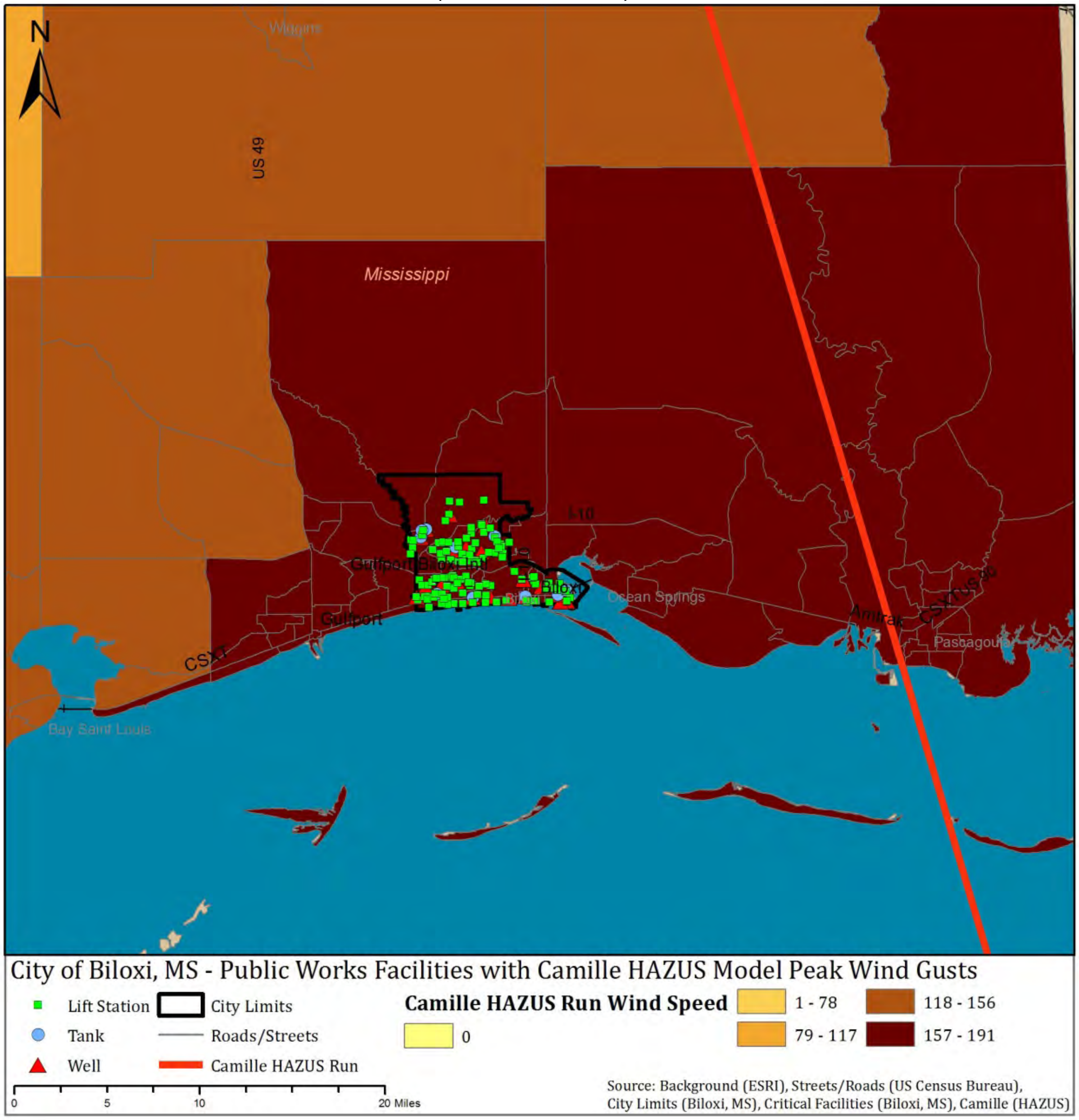


Table 4.23
Hurricane Wind Damages to City of Biloxi Facilities and Building Stock from a Category 5 Hurricane

Building Type	Number of Buildings Impacted	60% Estimated Loss
Level 1	33	$12,944,002.20
Level 2	6	$0
Level 3	4	$0
Level 4	23	$21,940,149.60
Note: For fields with $0, replacement figures were not available at the time of thePlan Update for the identified facilities		

Based on the HAZUS-MH model of Hurricane Camille and public works facilities, 10 water tanks, 24 water wells and 114 lift stations fell within the identified hazard area. The damage figures associated with water tanks, wells and lift stations was $13,425,000.

4.4.2 Storm Surge

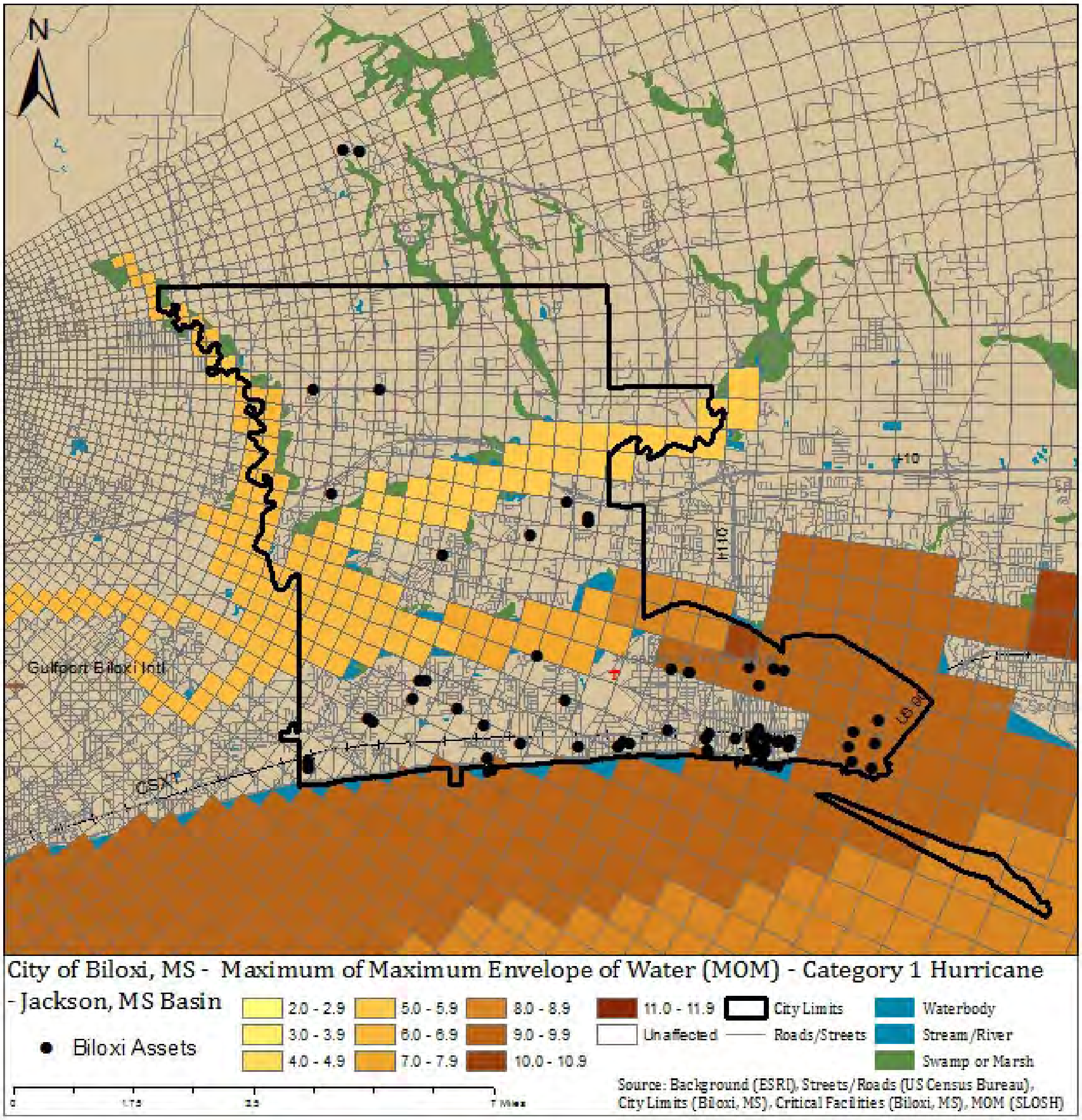
Storm Surge risk assessment models were developed using the National Hurricane Center's SLOSH data based on maximum modeled surge inundation for future hurricane events. Maps 4.11 through 4.16 show the storm surge inundation models for City of Biloxi.

The storm surge scenarios were developed using "maximum of maximums" (MOMs) models for the worst case scenario of storm surge for each cell noted in the basin and for Category 1, 3, and 5 storm surges in the City of Biloxi. Data and loss analysis focused on the Category 5 storm surge using the assumption that a Category 5 is the worst possible damage scenario. Property loss was estimated with a 50% damage function to building stock in the buffer zone. Since population estimates are variable and not known for the buildings impacted by the scenario, impacts to human lives cannot be accurately defined.

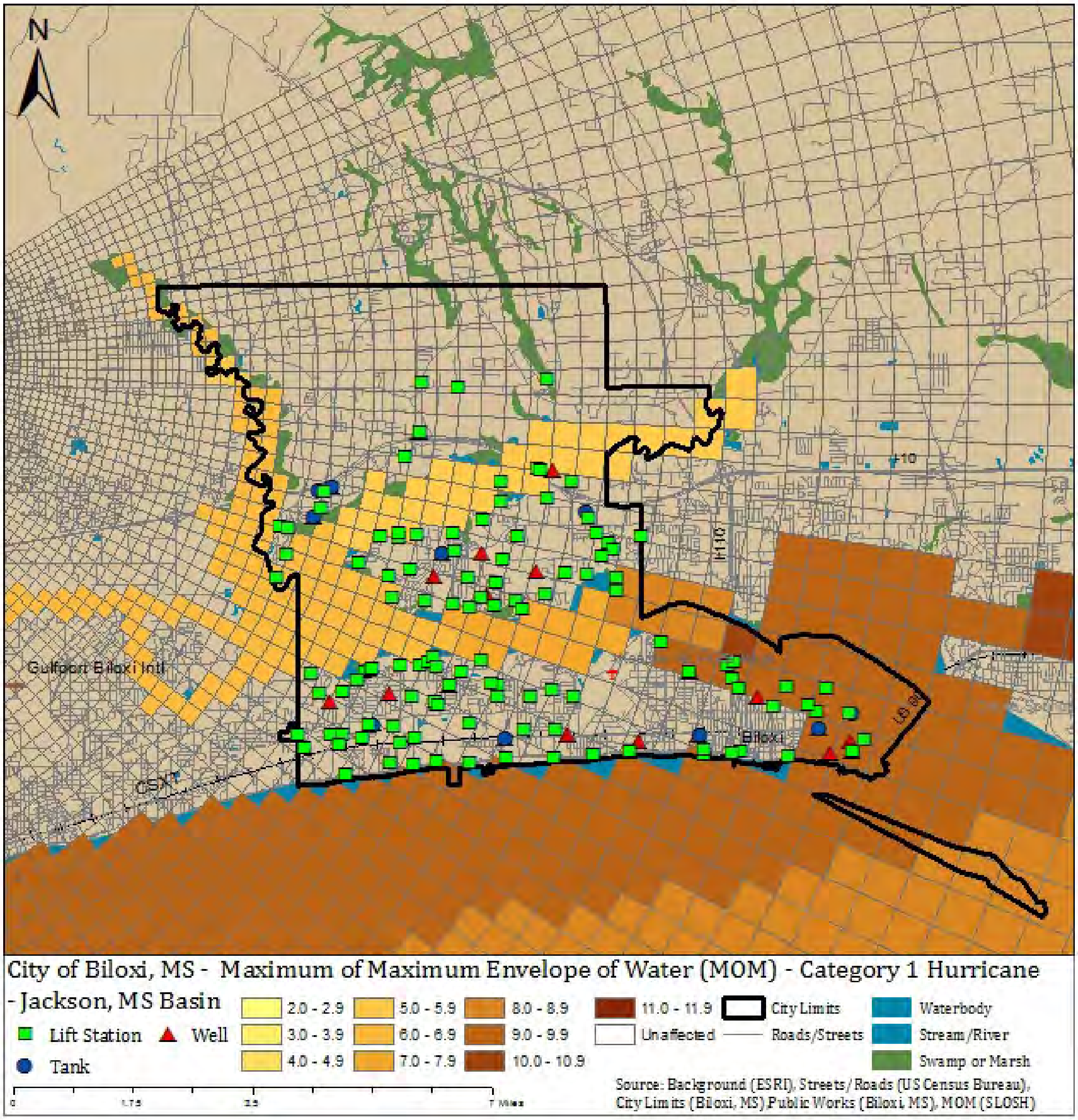
In 2010, the National Hurricane Center separated storm surge from storm categories, but to date the NHC has not released separate storm surge modeling.

This scenario shows one possibility, and is not all-inclusive of the risk to City of Biloxi.

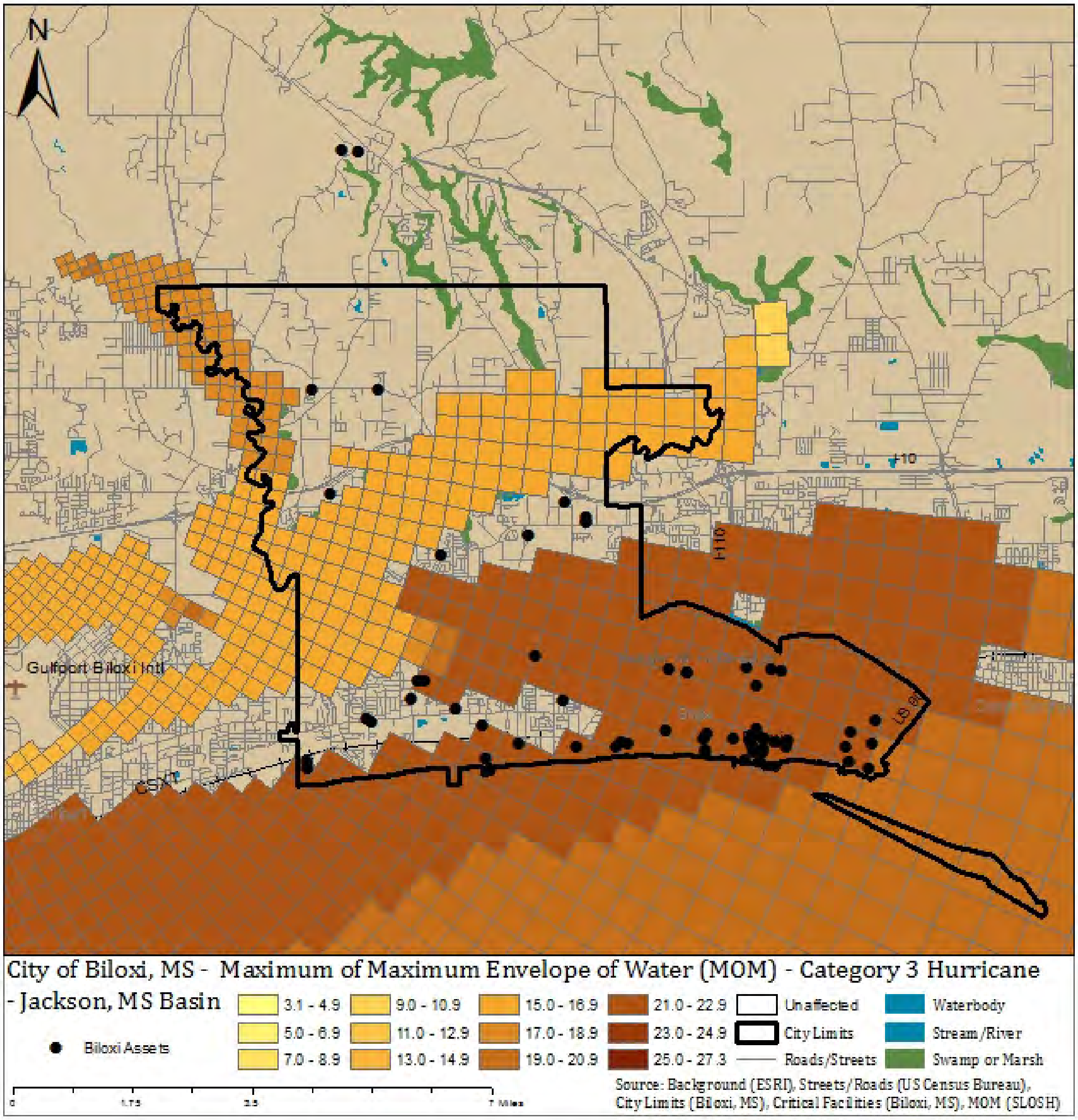
Map 4.11
Category 1 Storm Surge Exposure and Critical Facilities
(Source: ESRI and NOAA)



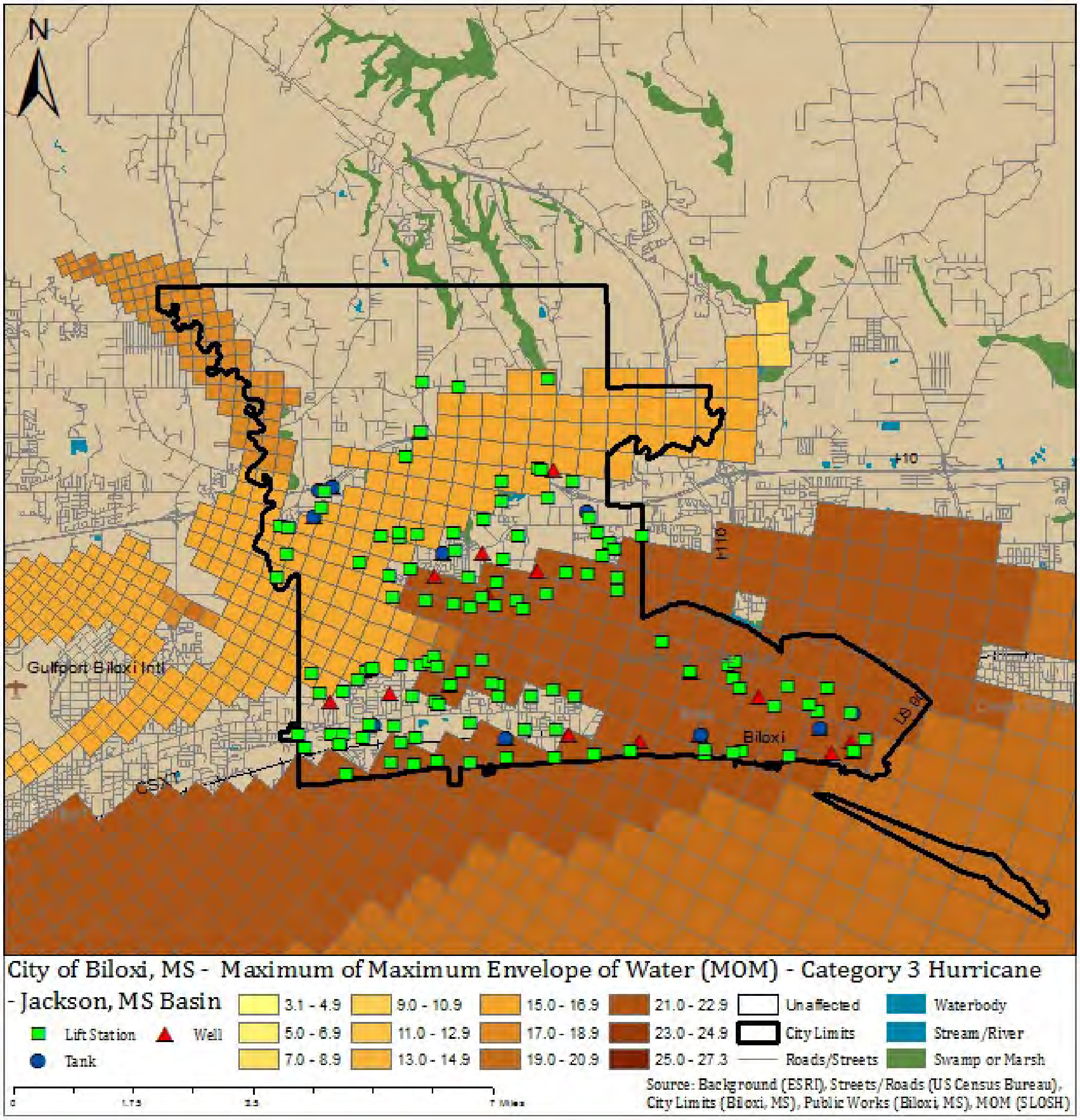
Map 4.12
Category 1 Storm Surge Exposure and Public Works Facilities
(Source: ESRI and NOAA)



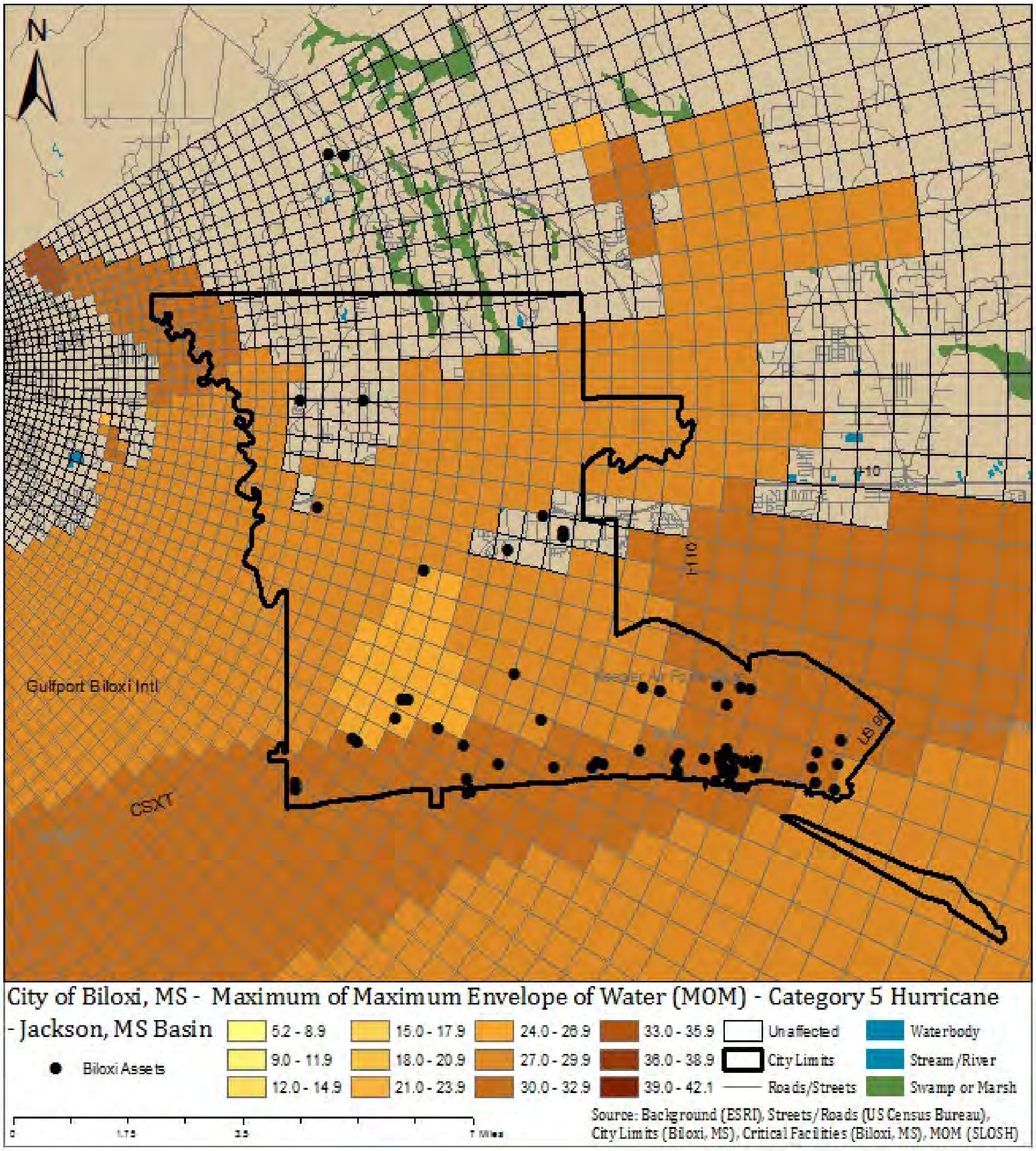
Map 4.13
Category 3 Storm Surge Exposure and Critical Facilities
(Source: ESRI and NOAA)



Map 4.14
Category 3 Storm Surge Exposure and Public Works Facilities
(Source: ESRI and NOAA)



Map 4.15
Category 5 Storm Surge Exposure and Critical Facilities
(Source: ESRI and NOAA



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Map 4.16
Category 5 Storm Surge Exposure and Public Works Facilities
(Source: ESRI and NOAA)

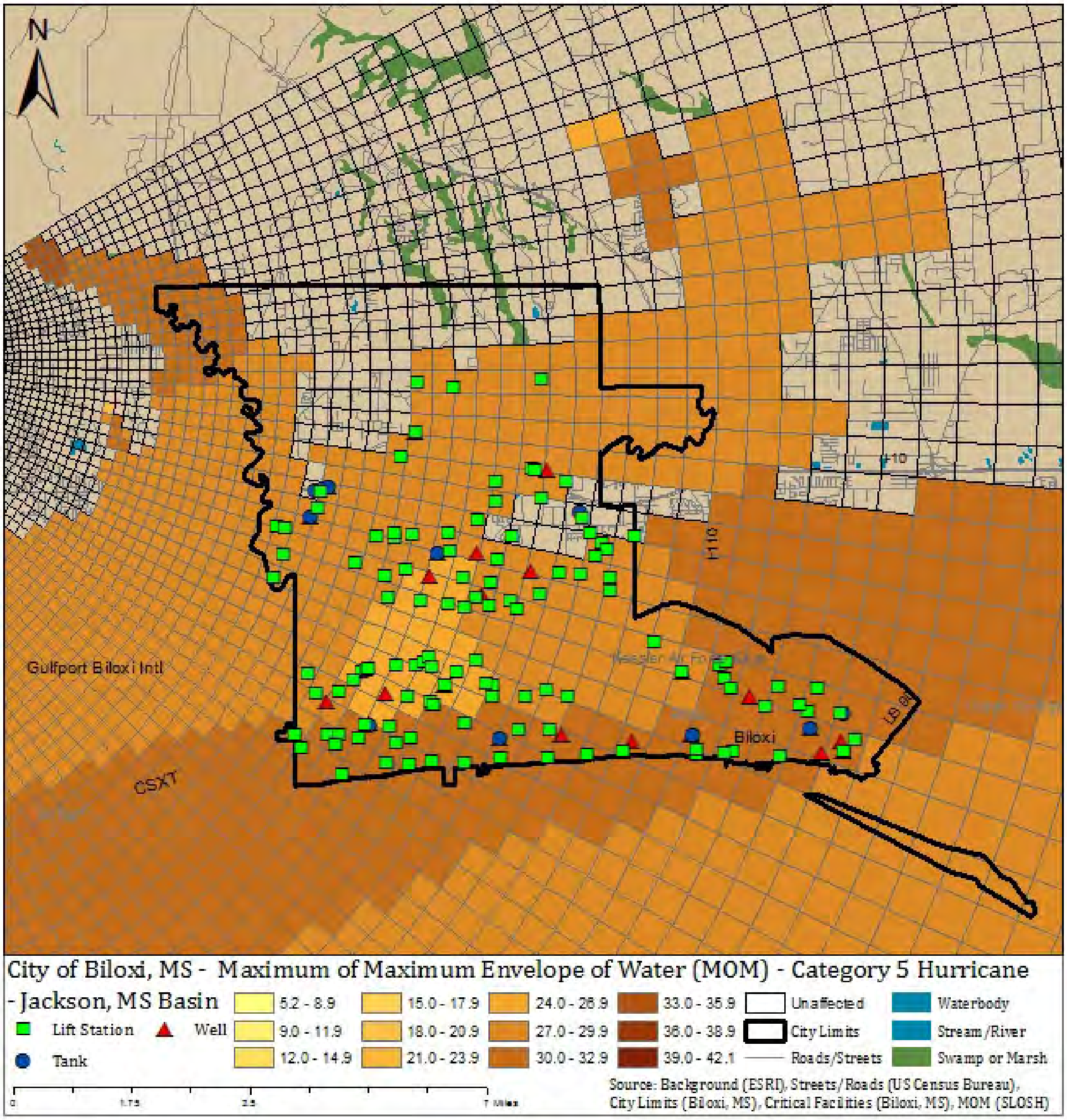


Table 4.24
Storm Surge Damages to City of Biloxi Facilities and Building Stock from a Category 5 Surge

Building Type	Number of Buildings Impacted	50% Estimated Loss
Level 1	24	$9,956,945.50
Level 2	5	$0
Level 3	4	$2,473,923
Level 4	22	$15,653,485
Note: For fields with $0, replacement figures were not available at the time of the plan update		

Based on the Category 5 Storm Surge Exposure scenario, 8 water tanks; 24 water wells and 110 lift stations fell within the storm surge exposure area with varying inundation depths. The damage figures associated with water tanks, wells and lift stations was $9,625,000.

4.4.3 Flood

The floodrisk assessment for the City of Biloxi was developed through the incorporation of the SFHA 1% flood zones. The flood zones were intersected with existing critical facilities to determine the areas at risk from this hazard. The SFHA is depicted on Map 4.17 and 4.18 (following pages). Flood depth range is estimated in Table 4.25.

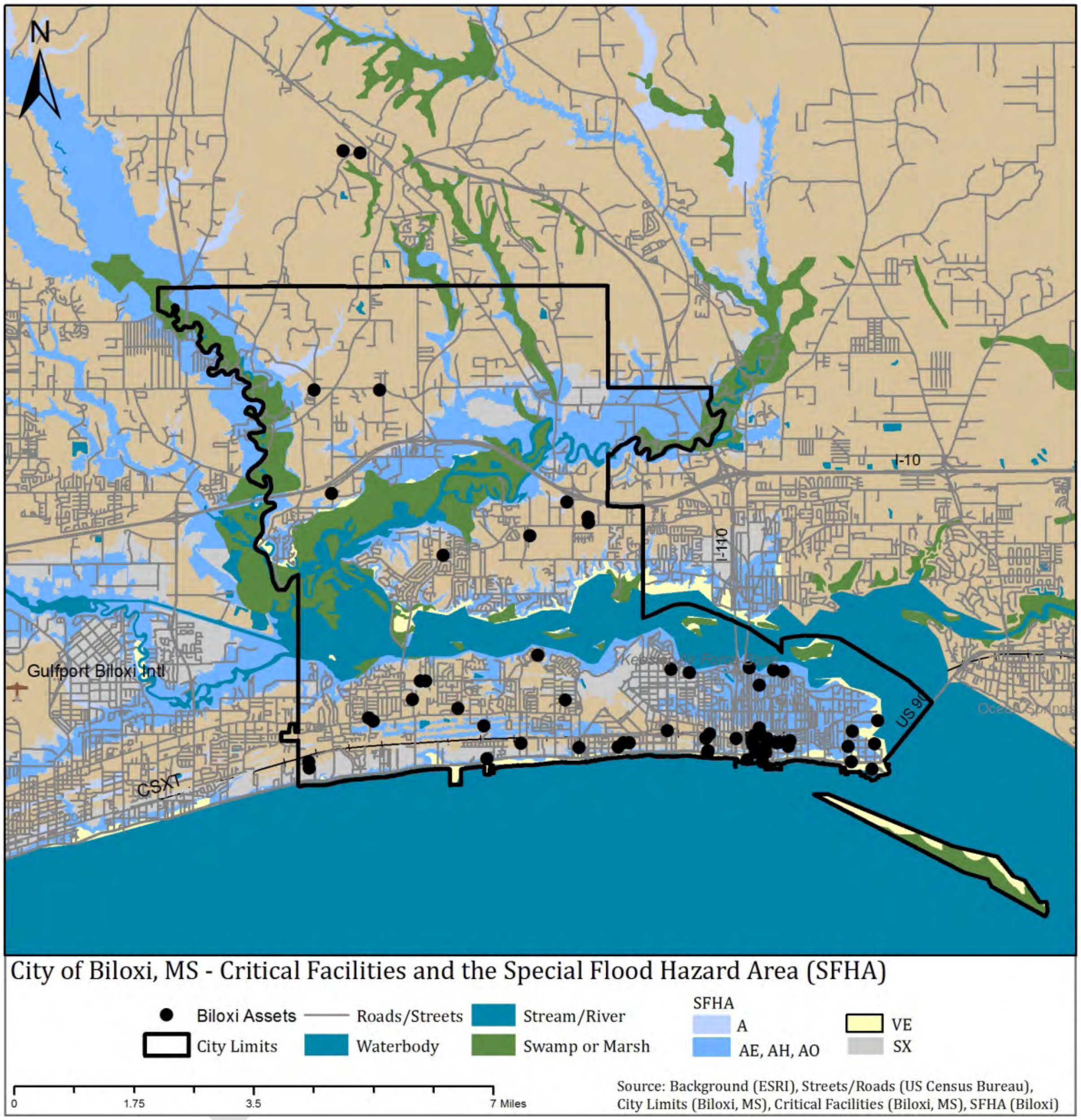
FIS Effective Date	Est. Lower End of 1% Flood Depth Range	Est. Higher End of 1% Flood Depth Range	Notes
November 16, 2007	1 foot	1 foot+	A significant portion of the SFHA within the area is designated as Zone A or X, indicating that no base flood elevations or flood depths have been determined.

Using the SHFA and depth estimates, damage was assumed at 20% to building stock in the flood zone.

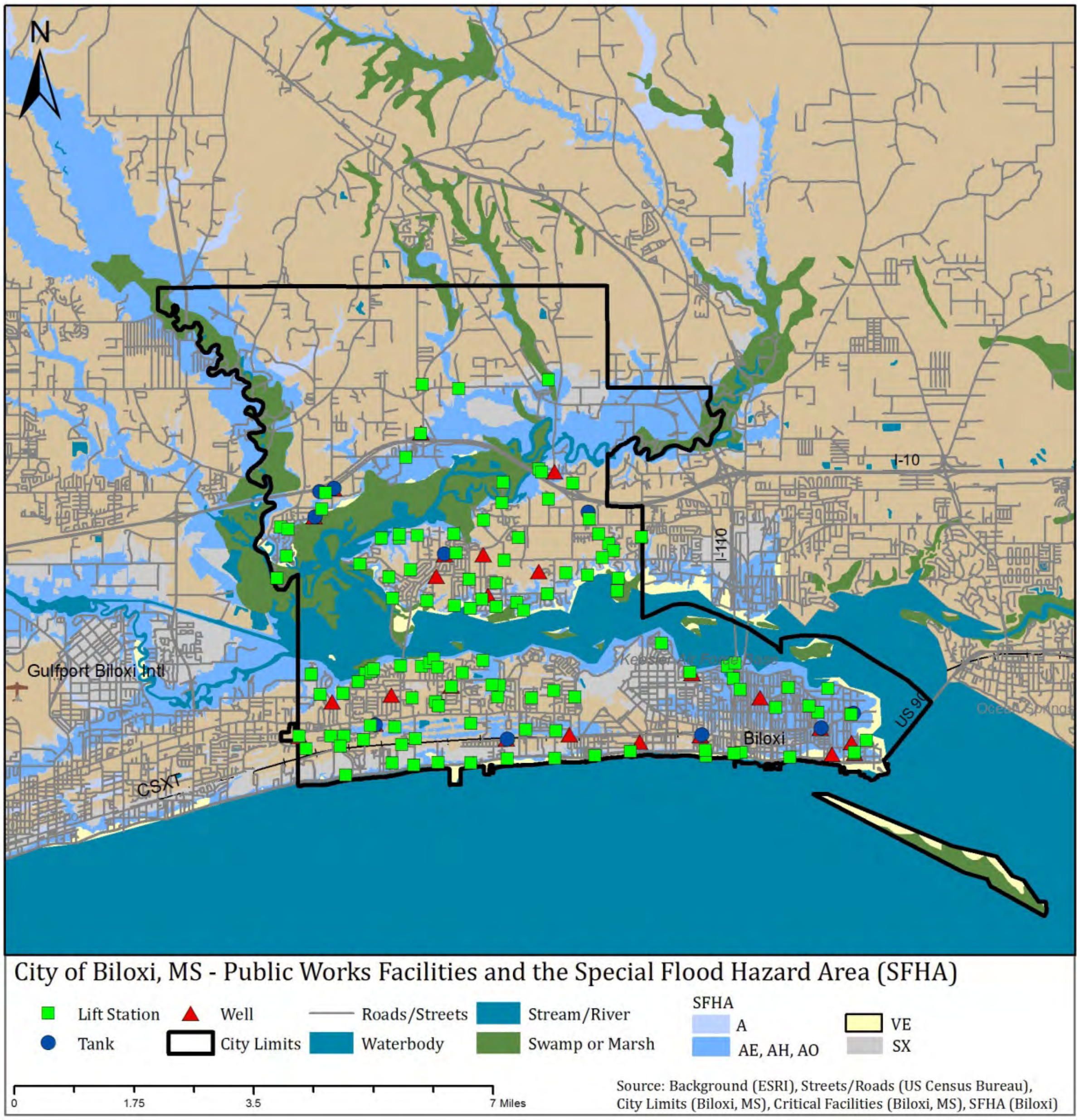
Table 4.26
Flood Damages to the City of Biloxi Facilities and Building Stock

Building Type	Number of Buildings Impacted	20% Estimated Loss
Level 1	3	$288,08
Level 2	1	$0
Level 3	1	$0
Level 4	13	$1,651,039
Note: For fields with $0, replacement figures were not available at the time of the plan update for the identified facilities.		

Map 4.17
City of Biloxi Critical Facilities and FEMA (SFHA)
(Source: City of Biloxi, FEMA (DFIRM) and ESRII)



Map 4.18
City of Biloxi Public Works Facilities and SFHA
(Source: City of Biloxi, FEMA (DFIRM) and ESRI)



Based on the SFHA and public works facilities, 4 water tanks and 13 water wells fell within the identified SFHA. The damage figures associated with water tanks and wells was $1,395,000.

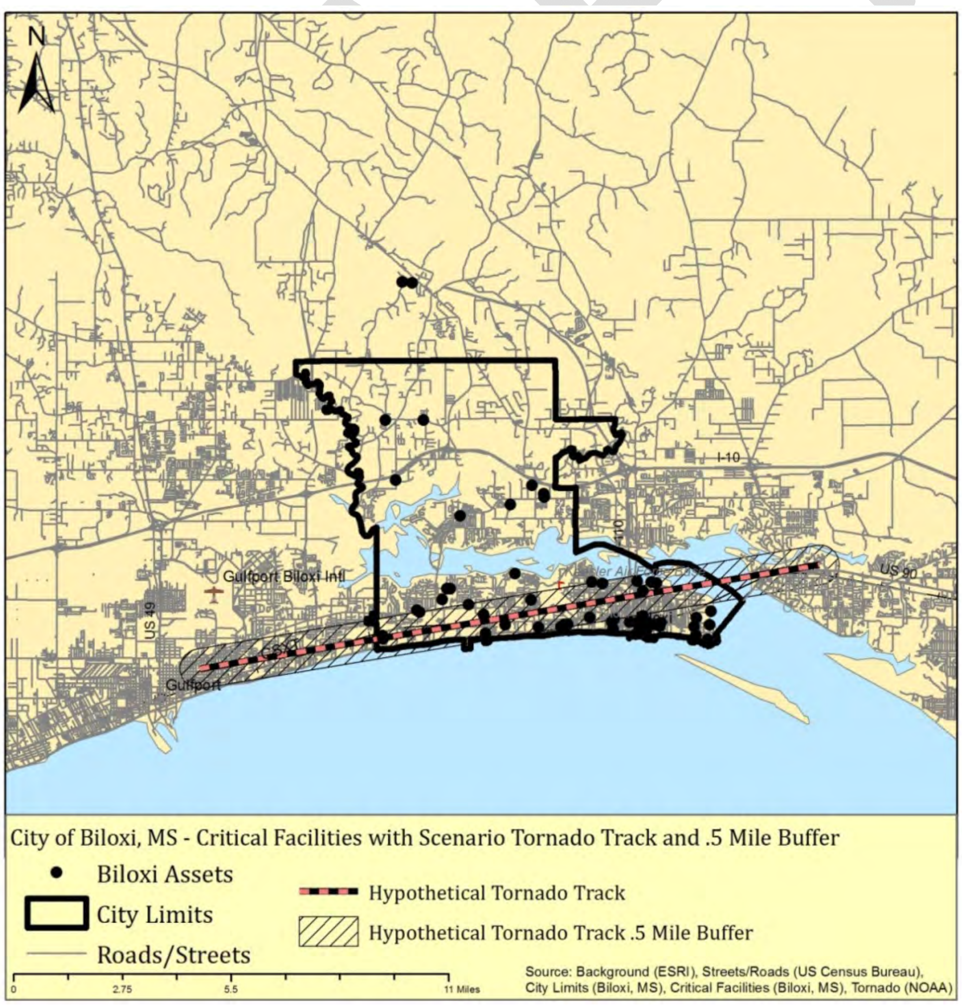
4.4.4 Tornado

To estimate vulnerability in the City of Biloxi, a tornado scenario was developed using historic tornado tracks with a .5 mile damage swath. In the Biloxi scenario, an F3 tornado touched down and moved across the city. Using this scenario, damage estimates were attained by assuming a 50% damage function to building stock in the buffer zone. Since population estimates are variable and not known for the buildings impacted by the scenario, impacts to human lives cannot be accurately defined.

This scenario shows one possibility, and is not all-inclusive of the risk to the City of Biloxi. The entire planning area is at an equal risk from the potentially devastating effects of tornadoes.

Map 4.19 depicts the EF-3 tornado scenario, with city facilities noted and public works facilities on Map 4.20.

Map 19
City of Biloxi Tornado Scenario and Critical Facilities
(Source: ESRI, City of Biloxi)



Map 4.20
City of Biloxi Tornado Scenario and Public Works Facilities
(Source: ESRI, City of Biloxi)

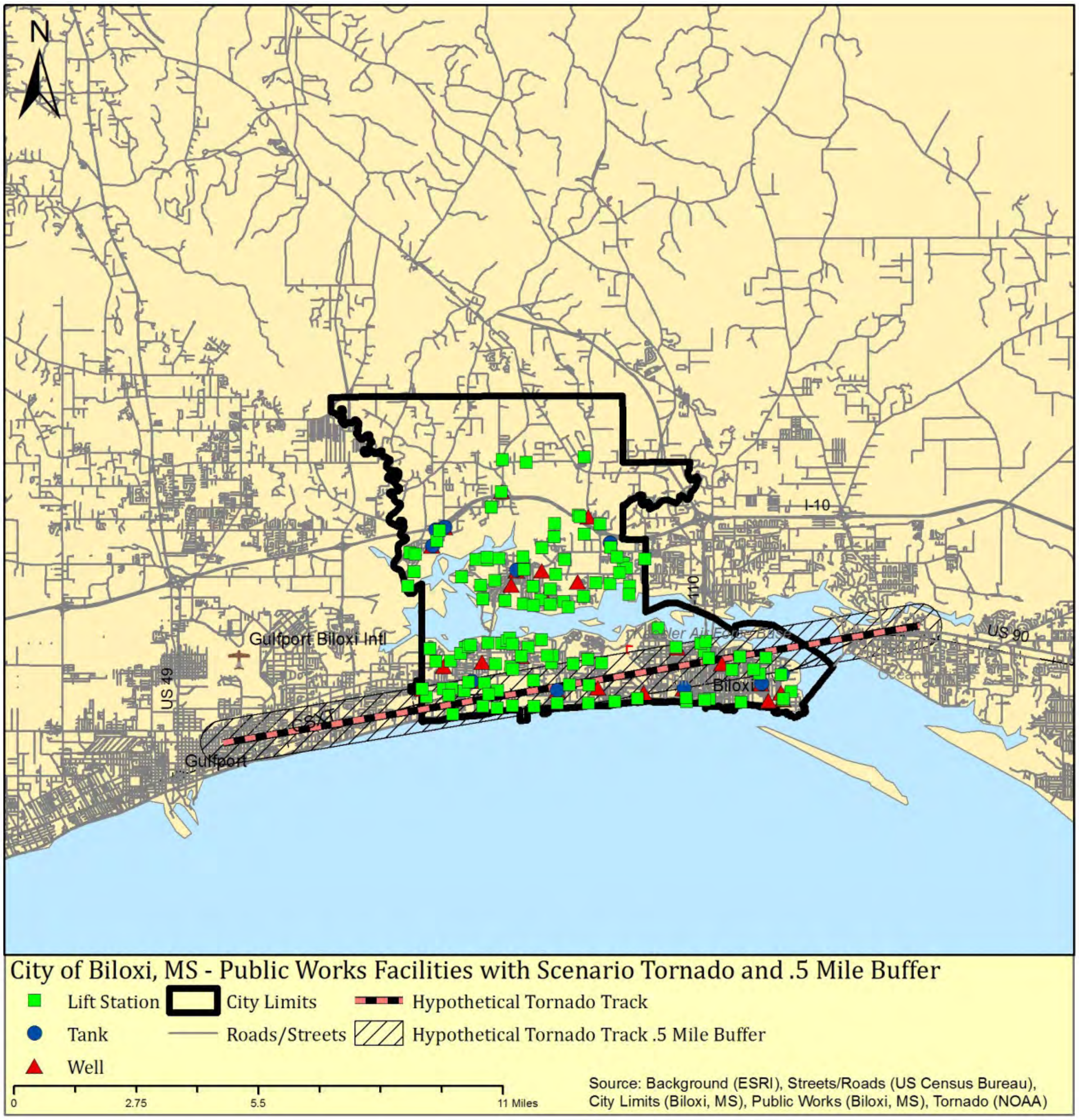


Table 4.27
Tornado Scenario Damages to City of Biloxi Facilities and Building Stock from an F-3 Touchdown

Building Type	Number of Buildings Impacted	50% Estimated Loss
Level 1	11	$823,382
Level 2	2	$0
Level 3	1	$0
Level 4	5	$509,415
Note: For fields with $0, replacement figures were not available at the time of the plan update for the identified facilities.		

Based on the Tornado Scenario and public works facilities, 2 water tanks, 7 water wells and 14 lift stations fell within the identified SFHA. The damage figures associated with water tanks, wells and lift stations was $1,812,500.

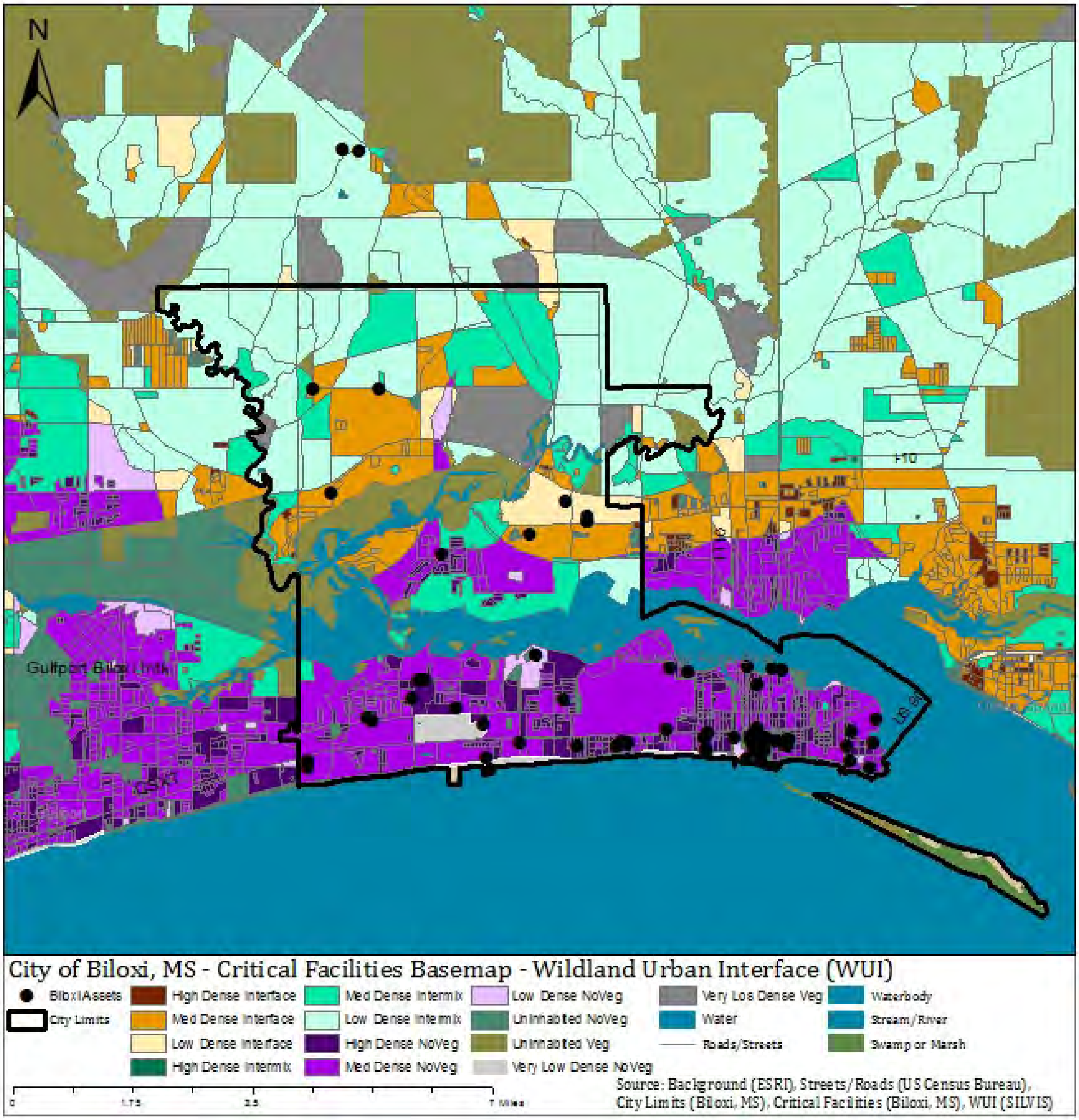
4.4.4 Wildfire

Wildland Urban Interface (WUI) studies make a best case judgment on a list of factors including forestation and vegetative growth as they relate to distance from developed areas.

Interface maps in the City of Biloxi show moderate risk.Portions of the City have buildings that are located in Medium Density Wildland Interface areas, specifically the Oaklawn Rd – Station 9, North Bay and Woolmarket Elementary Schools and the Woolmarket Civic Center. Interface communities are areas with housing in the vicinity of contiguous vegetation. Interface areas have more than one house (or building) per 40 acres, have less than 50% vegetation, and are within 1.5 mi of an area over 1,325 acres that is more than 75% vegetated. The minimum size limit ensures that areas surrounding small urban parks are not classified as interface WUI. Map 4.21 and Map 4.22 show the Wildland Urban Interface for the City of Biloxi.

Map 4.21 illustrates that wildfires could have an impact on one fire station, two schools and one civic center. Based on the results of Map 4.22, five water wells, three Water Tanks and 18 lift stations located in the rural, wooded portion of the City, and may be at risk from wildfire.

Map 4.21
Wildland Urban Interface in the City of Biloxi
Including Critical Facilities
(Source: ESRI, SILVIS, City of Biloxi)



Map 4.22
Wildland Urban Interface in the City of Biloxi
Including Public Works Facilities
(Source: ESRI, SILVIS, City of Biloxi)

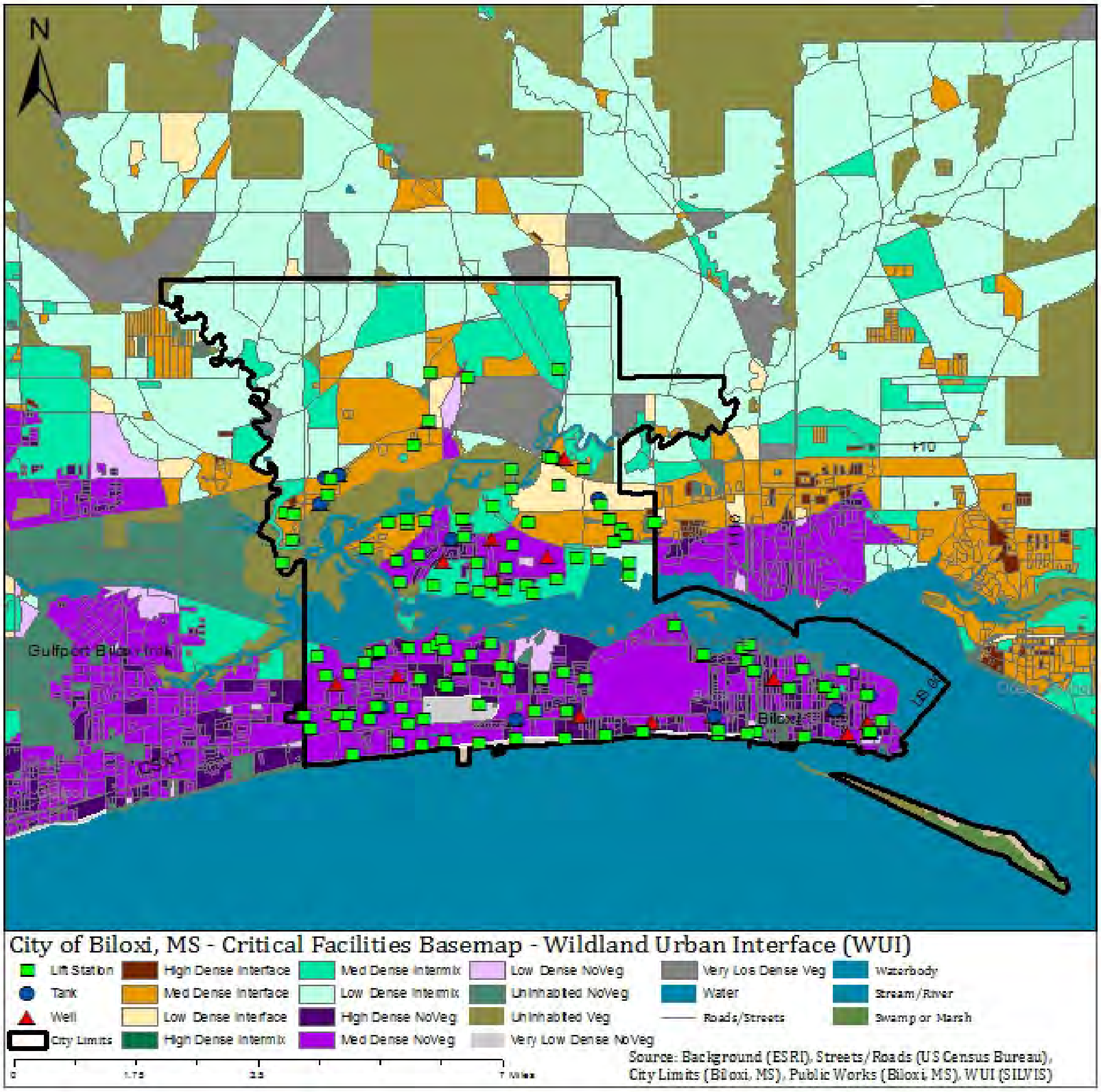


Table 4.28
Wildland Urban Interface (WUI)and City of Biloxi Facilities
With Building Stock

Building Type	Number of Buildings Impacted	100% Estimated Loss
Level 1	4	$873,947

Based on the Wildland Urban Interface and public works facilities, three water tanks, five water wells and 18 lift stations fell within the identified Interface Areas. The damage figures associated with water tanks, wells and lift stations was $5,300,000.

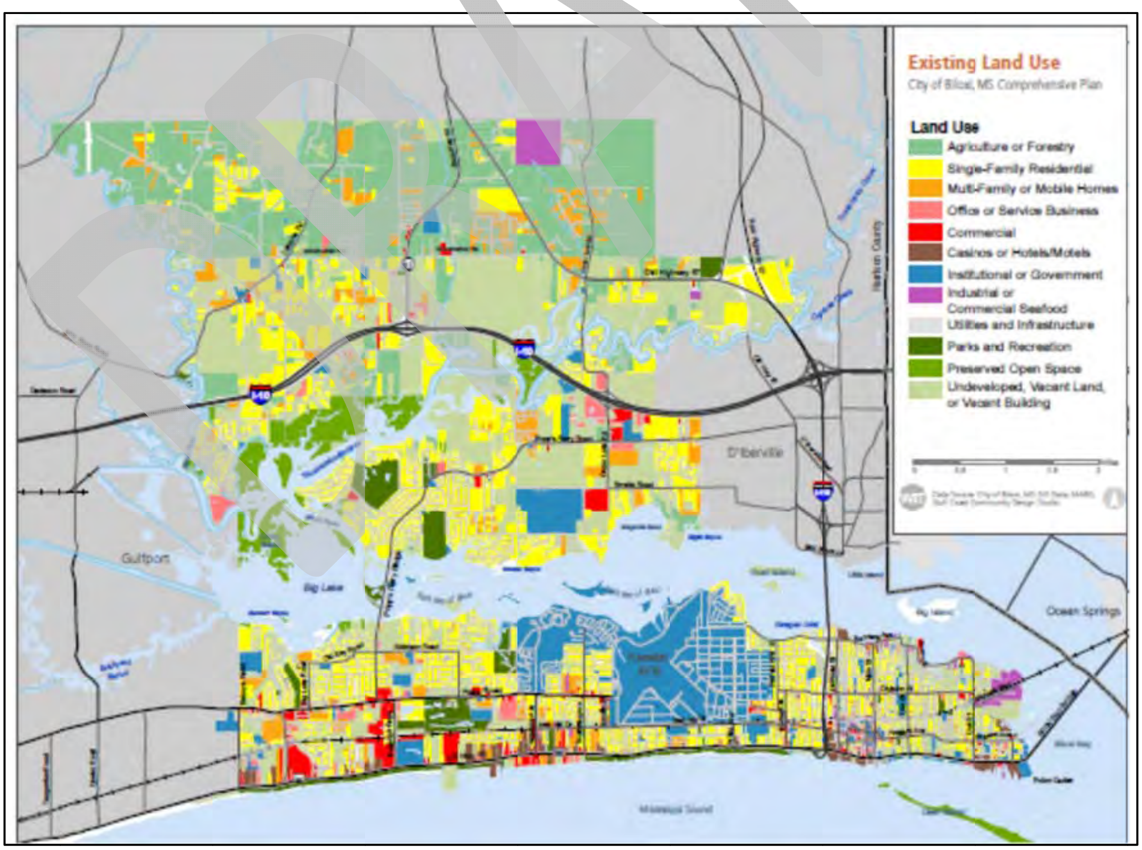
4.5 Analyzing Development Trends

Requirement CFR §201.6(2)(ii)(C) [the plan should describe vulnerability in terms of] providing general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.

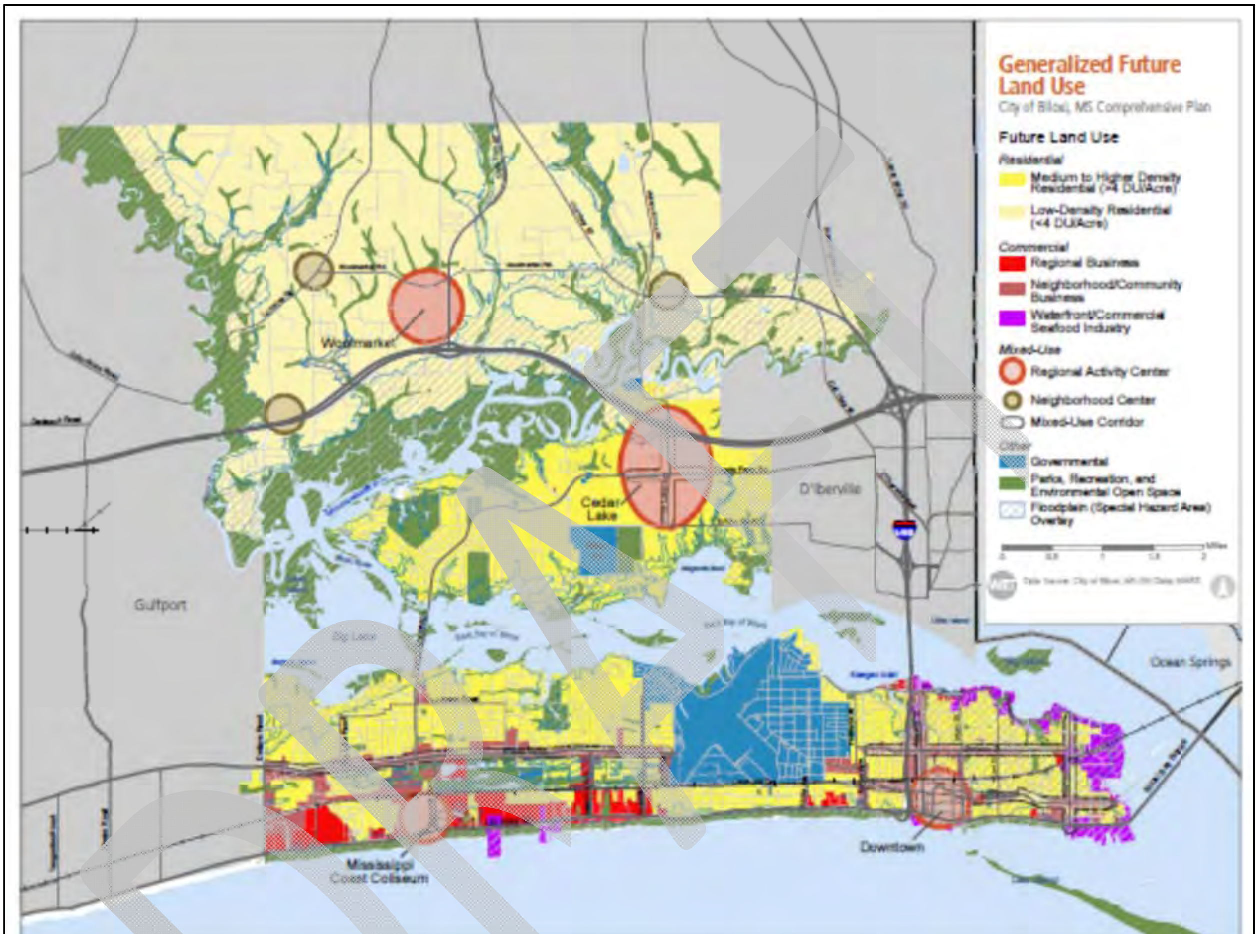
Requirement 201.6(d)(3): A local jurisdiction must review and revise its plan to reflect changes in development, progress in local mitigation efforts, and changes in priorities, and resubmit it for approval within five years in order to continue to be eligible for mitigation project grant funding.

4.5.1 General Development Trends

Biloxi originally developed on the eastern part of the peninsula and slowly grew west and north across the Back Bay. It is expected Biloxi's land use pattern will continue to change considerably in the future. New construction of single- and multi-family residential land uses will continue to move northward although condominium, commercial, casino and hospitality related uses will continue to dominate the areas along Highway 90. Availability of land in previously undeveloped areas, as well as cost of wind pool coverage and flood insurance, will greatly affect the residential development pattern. The Existing Land Use map prepared for the 2009 Comprehensive Plan is shown below.



The type and location of future development will be guided by development regulations such as zoning, environmental constrains, availability of infrastructure and land costs. The Future Land Use Plan for the City is shown below and will help guide development regulations.



4.5.2 Land Available for Development

Approximately 12,196 acres, or about 50% of the total land area in the City of Biloxi, is classified as vacant buildings, lots, or undeveloped land (including land used for agriculture or woodlands). The percentage of vacant land use overall increased significantly after Hurricane Katrina. While this may seem like a large area, nearly half of this land contains sensitive environmental features, such as the revised 100-year and coastal floodzones, wetlands, steep slopes, and the Biloxi River Marshes Coastal Preserve.

Vacant land was categorized for preparation of the 2009 Comprehensive Plan using the 2007 Assessor's parcel and land use database, with adjustments based on GIS data provided by the Gulf Coast Community Design Studio (GCCDS) where appropriate. In addition to vacant landresulting from Hurricane Katrina, undeveloped land, including woodlands and agriculture land as classified by the Harrison County Assessor's Office, is included in this analysis. Another source used in the vacant land analysis was the Harrison County suitability model developed in 2001. The model is intended as a growth management tool to help communities accommodate sustainable development and reduce development pressure on natural resources. Vacant land characteristics, as it pertains to development constraints, can be found in Table 4.29.

Table 4.29
Vacant and Undeveloped Land
Development Constraints

Description	Acres	Percent
Total vacant and undeveloped land*	12,196	100
- Subject to the 100-year flood	5,100	42%
- Subject to the coastal flood (Velocity Zone)	680	6%
- Subject to steep slopes	940	8%
- Subject to other development constraints (Harrison County Suitability Analysis)	4,338	36%
- Located with the coastal preserve	770	6%
Total Environmentally Constrained Vacant Land**	5,786	47%
Total without Environmental Constraints	6,410	53%
- East Biloxi (Unconstrained)	35	0.5%
- West Biloxi (Unconstrained)	573	9%
- North Biloxi (Unconstrained)	919	14%
- Woolmarket (Unconstrained)	4,884	76%

** Total vacant land includes undeveloped agricultural land.*
*** Environmental features overlap and therefore do not add up to the total constrained vacant land area.*

East Biloxi

Proportionally to its planning area size, East Biloxi has the largest concentration of environmentally constrained, vacant land. Not surprisingly, the major issue in this area is the 100-year and velocity floodplain boundary. Larger tracts of vacant land remain in areas not rebuilt since Hurricane Katrina.

Changes in the floodplain regulations present challenges for rebuilding in East Biloxi and other areas of the City. To comply with regulations and obtain flood insurance, buildings must be built above the base flood elevation or, if non-residential, beflood proofed.Rebuilding in a designated flood hazard area introduces issues related to cost, required building heights, safety, and impacts on natural resources.

Hurricane Katrina dramatically altered the land use pattern in East Biloxi, especially along the coast and on Point Cadet. Today there is a mix of land uses developing along the coastline, including casinos, hotels, and condominiums.

West Biloxi

West Biloxi has both environmentally constrained and unconstrained vacant land. Vacant land within the 100-year floodplain, south of Pass Road, and the velocity zone along Highway 90 is constrained. North of Pass Road, there are larger vacant parcels without environmental constraints.

Major retail offerings and restaurants are found in West Biloxi, particularly at the Edgewater Mall. The mall continues to expand and recently added a branch of the University College at Tulane, which offers associate and bachelor degrees.

West Biloxi has the highest concentration of non-casino, retail, office, and service businesses. Grocery and convenience type stores are located along Pass Road. Other areas of the City have limited grocery and convenience options.

North Biloxi and Woolmarket

In North Biloxi, there are large parcels near Popp's Ferry and Cedar Lake Road that do not seem to be environmentally constrained. There are also areas of vacant/undeveloped land with environmental constraints, such as steep slopes (above 8%) or floodplains along the north side of the Back Bay. Other major constraints include the floodplain along the Tchoutacabouffa River which forms the Planning Area's northern boundary.

North Biloxi and Woolmarket experienced a lesser degree of storm damage than East Biloxi. In the Woolmarket area, land is higher in elevation and generally located outside of the floodplain.The largest area of undeveloped land without environmental constraints is located in the Woolmarket Planning Area. Of the total vacant/undeveloped land without environmental constraints in Biloxi, about 76% is located in Woolmarket.

New residential development primarily occurs in this northern portion of the City. This previously undeveloped land offers developers the opportunity of using current site design and building housing products preferred by today's buyers. As new residential rooftops appear, commercial and institutions such as schools and medical facilities are being built to provide services to residents. New commercial projects are planned near and around Interstate 10, Highway 67 and Lorraine Road. As water and sewer services continue to expand further into the northern tier of the City, planners expect significant growth, particularly residential, to continue in this area.

4.5.3 Population Growth

Population growth is an indicator of development trends. Biloxi's 13% population loss between 2000 and 2010 is significant; however, as the housing stock increases, it is expected a slow but steady growth will continue in the immediate future. The Census Bureau's annual estimate of population indicates the City experienced a 2% increase in population from 2010 to 2011. Table 4.30 shows population estimates from 2005 through 2011.

Table 4.30
Population Estimates Post Katrina Period

Year	Population	Percentage change
2005	50579	
2006	46166	-10%
2007	46246	0%
2008	45828	-1%
2009	44766	-2%
2010	44054	-2%
2011	44940	2%

4.5.4 Housing

As indicated in Chapter 3, housing units in Biloxi decreased 3.9% between the Census counts of 2000 and 2010, or 837 units from the 2000 Census count of 22,115. Most of the loss can be attributed to storm damage from Hurricane Katrina. An estimated 80% of the East Biloxi housing stock was either destroyed or made uninhabitable. Many of these structures were demolished and not rebuilt.

Building Permit Information from the Census Bureau indicates a total of 795 "New Privately-Owned Residential" Building Permits were issued from January 2007 through November 2012. It should be noted issuance of a building permit does not indicate actual construction.

Table 4.31
Building Permits January 2007 through November 2012
New Privately-Owned Residential Units

Type	Buildings	Units	Construction cost
Single Family	719	719	$122,279,064
Two Family	14	26	$1,560,000
Three and Four Family	12	45	$5,274,862
Five or More Family	50	820	$61,899,000
Total	795	1610	$191,012,926

4.5.5 Development Priorities

Recent planning initiatives in Biloxi reflect an effort to respect the environmental aspect of land development in controlling storm water runoff, flooding and other types of natural hazards. Updates to the FEMA flood elevation maps and subsequent regulations will help with future flooding issues, while land development regulations require strict oversight of construction projects and land disturbance. These and other efforts should decrease the vulnerability of the City as it pertains to hazard mitigation.

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