Hurricane Katrina Rapid Response Wind Water Line Report – Mississippi

Task Order 416

June 9, 2006 (Final Report)

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Wind Water Line (WWL) Data Collection – Mississippi
FEMA-1604-DR-MS

Final Report

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Abbreviations and Acronyms

Acronyms	Explanation
CDT	Central Daylight Time (daylight savings time zone)
CHWM	Coastal High Water Mark
DEM	Digital Elevation Model
EDT	Eastern Daylight Time (daylight savings time zone)
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
GPS	Global Positioning System
HMGP	Hazard Mitigation Grant Program
HMTAP	Hazard Mitigation Technical Assistance Program
HWM	High Water Mark
IA	Individual Assistance
kts	Knots
LiDAR	Light Detection and Ranging or Laser Imaging Detection and Ranging
MARIS	Mississippi Automated Research Information System
mb	Millibar
mph	Miles Per Hour
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center
NFIP	National Flood Insurance Program
NGS	National Geodetic Survey
NGVD 29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
PA	Public Assistance
PNP	Private Non-Profit
RHWM	Riverine High Water Mark
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WWL	Wind Water Line

Glossary of Terms

Word	Definition
ArcCatalog®	Software application from ESRI that organizes and manages all Geographic Information System (GIS) information such as maps, globes, data sets, models, metadata, and services.
ArcGIS®	The comprehensive name for the current suite of GIS products produced by ESRI that are used to create, import, edit, query, map, analyze, and publish geographic information.
ArcView®	A software application from ESRI that provides extensive mapping, data use, and analysis, along with simple editing and geoprocessing capabilities.
Base map	A map or chart showing certain fundamental information, used as a base upon which additional data of a specialized nature are compiled or overprinted.
Contour data	All the information required to create lines of equal elevation on a map. These are referred to as contour lines on topographic maps and are used to describe land forms based on elevation above a defined vertical datum.
Contour lines	Lines that connect a series of points of equal ground elevation and are used to illustrate topography, or relief, on a map.
Data point	A point associated with a discrete geographic location where data pertaining to the study were taken.
Debris line	Defines the extent of flooding where debris such as parts of houses, docks, cars, or other non-natural material is generally carried by floodwaters with some velocity and is then dropped as the floodwaters lose velocity and begin to recede.
Disaster declaration	The formal action by the President to make a state eligible for major disaster or emergency assistance under the Stafford Act.
Emergency protective measures	Actions taken by applicants before, during, and after a disaster to save lives, protect public health and safety, and prevent damage to improved public and private property.
Flood recovery map	High-resolution maps that show flood impacts, including high water mark (HWM) flood elevations, flood inundation limits, the inland limit of waterborne debris (trash lines), and storm surge elevation contours based on the HWMs. The maps also show existing FEMA Flood Insurance Rate Map (FIRM) flood elevations for comparison to hurricane data.
Geodatabase	The geodatabase provides the common data access and management framework for ArcGIS. Geodatabases organize geographic data into a hierarchy of data objects. These objects are stored in feature classes, object classes, and feature datasets. An object class is a table in the geodatabase that stores nonspatial data. A feature class is a collection of features with the same type of geometry and the same attributes. A feature dataset is a collection of feature classes sharing the same spatial reference.

Word	Definition
Hazard Mitigation Grant Program	Provides grants to states and local government to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster.
Individual Assistance	Federal assistance provided to families or individuals following a major disaster or emergency declaration. Under a major disaster declaration, assistance to individuals and families is available through grants, loans, and other services offered by various Federal, state, local, and voluntary agencies.
Infrastructure	The basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, water and power lines.
Inundated	Flooded or covered with water.
Inundation polygon	Aerial extent of flooding as shown by polygon feature in ArcGIS.
Knot	A unit of speed, one nautical mile per hour, approximately 1.85 kilometers (1.15 statute miles) per hour.
LiDAR	A technology that determines distance to an object or surface using laser pulses. Like the similar radar technology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.
Millibar	A unit of atmospheric pressure equal to one thousandth of a bar. Standard atmospheric pressure at sea level is about 1,013 millibars.
Mitigation	Any measure that will reduce or eliminate the long-term risk to life and property from a disaster event.
National Flood Insurance Program	The Federal program created by an Act of Congress in 1968 that makes flood insurance available in communities that enact and enforce satisfactory floodplain management regulations.
National Geodetic Vertical Datum of 1929	Vertical control datum that was widely used in the U.S. prior to the establishment of NAVD 88.
North American Datum of 1983	Used as the standard map coordinate system default by the majority of Global Positioning System (GPS) devices.
North American Vertical Datum of 1988	The most widely used vertical control datum in the U.S. today, it was established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-U.S. leveling observations.
Orthorectification	Process by which the effects of relief displacement and imaging geometry are removed from aerial photographs. These adjustments are made to correct for the natural distortions caused by the perspective of the aircraft or spacecraft that took the photographs and recreate the ground geometry in the imagery as it would appear from directly above each point in

Word	Definition
	the photograph. From this process, orthophotos are created, which generally have the same geometric characteristics as topographic maps.
Polygon	In ArcGIS, a shape defined by one or more rings, where a ring is a path that starts and ends at the same point. If a polygon has more than one ring, the rings may be separate from one another or they may nest inside one another, but they may not overlap.
Public Assistance	Federal assistance provided to state and local governments, Native American Tribes, and certain non-profit organizations after a disaster declaration. The assistance is for the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain Private Non-Profit (PNP) organizations. The Federal share of assistance is not less than 75 percent of the eligible cost for emergency measures and permanent restoration. The State determines how the non-Federal share (up to 25 percent) is split with the applicants.
Riverine flooding	Occurs when rivers and streams overflow their banks.
Seed file	Used within software applications and serve as templates in which standard file parameters are set to predetermined standards.
Shapefile	Stores geographic features and their attributes. Geographic features in a shapefile can be represented by points, lines, or polygons (areas).
Storm surge	Onshore rush of water piled higher than normal as a result of high winds on an open water body's surface. It occurs primarily along the open coast, and can destroy houses, wash away protective dunes, and erode soil.
Topographic quadrangle maps	A standard map size and scale used by the United States Geological Survey to show topography, roads, and landmarks.
Water mark	A mark, usually on structures, left by floodwaters.
Wind Water Line	An approximate boundary to delineate the inland extent of the area where structures were damaged as a result of flooding from storm surge from a particular event. Landward of the line, most of the damage is attributable to winds and/or wind-driven rain. Sometimes, the Wind Water Line (WWL) is located along the debris line, but in some cases, inundation and flood damage extend beyond the area where major debris was deposited.
Wrack line	Defines the extent of flooding where organic-type debris such as grass and weeds are carried by floodwaters and then dropped as the floodwaters recede.

Background

Hurricane Katrina began as a tropical depression in the southeastern Bahamas on August 23, 2005. By the next day, the depression had developed into Tropical Storm Katrina. Moving slowly northwestward then westward through the Bahamas, Katrina strengthened over time. Just before landfall in South Florida on August 25, 2005, Tropical Storm Katrina developed into a Category 1 hurricane, with wind speeds of 74 miles per hour (mph)[1] (64 knots [kts]) or greater. Landfall occurred around 6:30 p.m. eastern daylight time (EDT) between Hallandale Beach and North Miami Beach, with wind speeds of approximately 80 mph (70 kts). Gusts of 90 mph (78 kts) were measured as Katrina came ashore. The storm moved southwesterly across the tip of the Florida peninsula with its winds decreasing slightly (see Figure 1). However, having spent only 7 hours on land, Katrina was not significantly diminished, and it regained intensity shortly after moving over the warm waters of the Gulf of Mexico.

Figure 1: Hurricane Katrina Storm Track
Source: http://cimss.ssec.wisc.edu/tropic/archive/2005/storms/katrina/katrina.html

Over the Gulf of Mexico, Hurricane Katrina moved almost due west. A mid-level ridge from Texas weakened and moved westward, causing Katrina to gradually move northwest and then north over the next few days. Katrina attained "major hurricane" status on the

[1] Wind speed and central pressure data are from the National Climatic Data Center (NCDC).

afternoon of August 26, 2005, due to atmospheric and sea level conditions that rapidly intensified the storm.

Over the next 48 hours, Hurricane Katrina continued to intensify, moving in a northerly direction. The storm reached maximum sustained wind speeds of 175 mph (152 kts) with gusts of 215 mph (187 kts) on the morning of August 28, 2005, making it a Category 5 hurricane. Its minimum central pressure dropped that afternoon to 902 millibars (mb), giving it the fourth lowest recorded central pressure for an Atlantic storm at the time and the sixth lowest by the end of the 2005 Hurricane Season.[2] Tropical cyclones rarely stay at Category 5 strength for long; Katrina weakened slightly to a Category 4, and then became a Category 3 at its second landfall near Buras, Louisiana, on August 29, 2005, at approximately 6:10 a.m. central daylight time (CDT) (see Figure 1). Maximum sustained winds at landfall near Buras were approximately 127 mph (110 kts), making Hurricane Katrina a Category 3 storm.

After crossing over Lake Borgne and the Mississippi Sound, Katrina made its third landfall along the Louisiana/Mississippi border with wind speeds of approximately 121 mph (105 kts). Gusts of over 90 mph (78 kts) were recorded in Biloxi, Mississippi, while gusts reached approximately 80 mph (70 kts) in Mobile, Alabama.

[2] Later in the 2005 Hurricane Season, Hurricanes Rita and Wilma developed with minimum pressures of 897 mb and 882 mb, respectively. As a result, Katrina became the sixth most intense Atlantic Basin hurricane on record (Rita is now the fourth and Wilma ranks as the first).

Overview of Impacts in Mississippi

A disaster declaration in response to Hurricane Katrina was authorized by the President for the State of Mississippi on August 29, 2005, with the Federal Emergency Management Agency (FEMA) acting as the Federal Coordinating Agency (FEMA-1604-DR-MS). The declaration provided the necessary assistance to meet immediate needs and to help Mississippi recover as quickly as possible through the following means:

- Public Assistance (PA): includes supplemental Federal disaster grant assistance for the repair, replacement, or restoration of disaster-damaged publicly owned facilities, and the facilities of certain private non-profit (PNP) organizations. There are seven subcategories (A-G) within this designation under two work types: emergency work and permanent work. Unless otherwise noted, PA will include all categories under both work types. However, often only the emergency work categories are designated, which include Category A, debris removal, and Category B, emergency protective measures.

- Individual Assistance (IA): includes cash grants of up to $26,200 per individual or household for housing (reimbursement for hotel or motel expenses, rental assistance, home repair and replacement cash grants, and permanent housing construction assistance in rare circumstances) and other needs (medical, dental, and funeral costs, transportation costs, and other disaster-related needs).

- Hazard Mitigation Grant Program (HMGP): may be used to fund projects that will reduce or eliminate the losses from future disasters by providing a long-term solution to a problem. Eligible applicants include state and local government, Indian tribes or other authorized tribal organizations, and certain non-profit organizations. FEMA can fund up to 75 percent of the eligible costs of each project, and the state or grantee must provide a 25-percent match.

All Mississippi counties were eligible for HMGP funds. Tables 1, 2, and 3 provide the designations for FEMA assistance eligibility by county. In all, 47 counties received IA and PA declarations; 27 counties received PA only; and 8 counties were eligible for PA, Category A and B only. Figure 2 shows this same information graphically.

Table 1: Counties Designated for IA and PA

Adams	Amite	Attala	Choctaw
Claiborne	Clarke	Copiah	Covington
Forrest	Franklin	George	Greene
Hancock	Harrison	Hinds	Jackson
Jasper	Jefferson	Jefferson Davis	Jones
Kemper	Lamar	Lauderdale	Lawrence
Leake	Lincoln	Lowndes	Madison
Marion	Neshoba	Newton	Noxubee
Oktibbeha	Pearl River	Perry	Pike
Rankin	Scott	Simpson	Smith
Stone	Walthall	Warren	Wayne
Wilkinson	Winston	Yazoo	

Table 2: Counties Designated for PA Only

Bolivar	Calhoun	Carroll	Chickasaw
Clay	Grenada	Holmes	Humphreys
Issaquena	Itawamba	Lafayette	Lee
Leflore	Monroe	Montgomery	Panola
Pontotoc	Prentiss	Sharkey	Sunflower
Tallahatchie	Tate	Tippah	Tishomingo
Tunica	Webster	Yalobusha	

Table 3: Counties Designated for PA, Categories A and B Only

Alcorn	Benton	Coahoma	DeSoto
Marshall	Quitman	Union	Washington

The Gulf Coast of Mississippi sustained extreme damage from Katrina. Mississippi's coastline was at the center of the 125-mile stretch devastated by the hurricane, with New Orleans on the western end and coastal Alabama on the eastern end. While the wind was a large contributor to damage and spawned tornadoes across the Southeast, the storm surge was the primary cause of devastation along the Mississippi coastline. Record storm surge levels were reported (see Figure 3). Results of HWM surveying show that Pass Christian had some of the highest surge levels with elevations up to 34.9 feet North American Vertical Datum of 1988 (NAVD 88) for surge elevations including wave height, and 27.2 feet NAVD 88 for surge-only elevations.

A 20 to 30+ foot storm surge flooded coastal cities, leaving large portions of Biloxi, Gulfport, Pass Christian, Bay St. Louis, and several other communities under water. Flooding closed major roads and rose to the second floor of buildings in and around Biloxi. Debris was a major issue (see Figure 4), as storm surge knocked entire buildings off their foundations and destroyed them. Katrina and the subsequent flooding led to power outages for more than 1.7 million people along the Gulf Coast.

Katrina was one of the strongest storms to impact the coast of the U.S. in the last 100 years. Rainfall from its outer bands began affecting the Gulf Coast well before the storm's two landfalls in southeast Louisiana, then on the Louisiana/Mississippi border. When Katrina came ashore on August 29, rainfall rates exceeded 1 inch per hour across a large area of the coast. The National Oceanic and Atmospheric Administration's (NOAA's) Climate Reference Network Station in Newton, Mississippi (60 miles east of Jackson, Mississippi), measured rainfall rates of more than 1 inch per hour for 3 consecutive hours, and rates of more than 0.5 inch per hour for 5 hours on August 29. A precipitation analysis from NOAA's Climate Prediction Center shows that rainfall accumulations exceeded 10 inches along much of the hurricane's path and to the east.[3]

[3] Source: http://www.ncdc.noaa.gov/oa/climate/research/2005/katrina.html

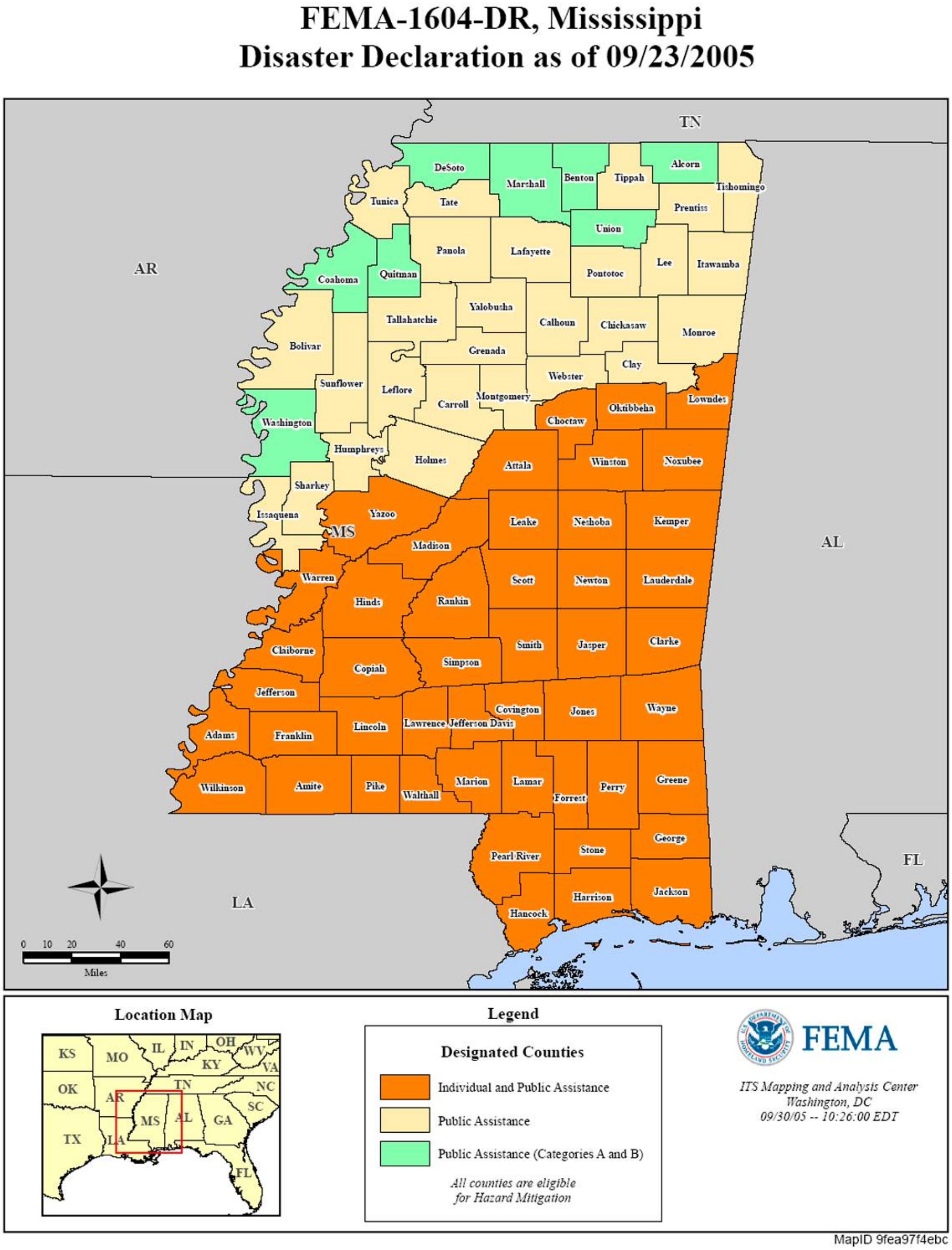

Figure 2: FEMA-1604-DR-MS Disaster Declaration

Figure 3: Mississippi Storm Surge
Source: http://www.katrinadestruction.com/images/v/biloxi_mississippi/?g2_page=4

Figure 4: Mississippi Debris

According to Red Cross damage assessments, approximately 134,000 single-family dwellings in Mississippi sustained major damage or were destroyed as a result of Katrina. An additional 100,000 dwellings sustained minor damage. The coastal counties of Hancock, Harrison, and Jackson suffered the most severe damage by far; approximately 64,000 single-family dwellings were destroyed and approximately 35,000 had major damage. An additional 42,000 dwellings sustained minor damage (see Appendix A).

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Purpose

After a hurricane impacts a coastal area with significant flooding, it is imperative that data be collected to document the event to assist in response, recovery, and mitigation efforts, and to improve disaster preparedness and prevention efforts for future disasters. WWL data collection is an initial step in accurately documenting an event. These data help place the event in historical perspective and improve the ability to estimate current flood risk and future event prediction.

Collection of site-specific flood inundation data along rivers, bays, and coasts has numerous applications. The purpose of this particular data collection effort was to document the extent of flooding caused by storm surge that occurred as a result of Hurricane Katrina in coastal Mississippi. There are several potential uses for these data, including:

- Estimating storm frequency and severity
- Assessing accuracy of Flood Insurance Rate Maps (FIRMs)
- Providing information for use with other studies, including FEMA Building Performance Assessments
- Assisting with the prioritization of mitigation projects and providing data for use in benefit/cost analyses
- Sharing information for calibrating models that simulate the storm (for example, HAZUS and other coastal storm surge models)
- When coupled with sufficient data density and observational information, the data can be used to help create flood recovery maps; building officials can use the maps to update guidance for both reconstruction and future construction by local citizens, developers, and contractors

Specific FEMA programs that directly benefit from post-disaster flood data collection include:

- IA Program – advises individuals on how to use Federal grants to increase their homes' flood resistance
- PA Program – identifies appropriate flood mitigation measures to pursue when providing Federal grants to repair infrastructure
- HMGP – ensures that accurate benefit/cost analysis is performed
- NFIP – provides insurance claim information, floodplain management, repetitive loss classification, and flood hazard identification

The purpose of WWL data collection is to determine the inland extent of damages caused by storm surge-induced flooding, and differentiate this area from those areas farther inland where damages were primarily the result of wind forces. By delineating the WWL, an approximate boundary is created to distinguish areas where both storm surge-induced flooding and wind forces caused damage to structures from those areas where wind forces were the primary cause of damages to structures, and storm surge flooding did not have a significant impact. Sometimes, the WWL is located along the debris line, but in some cases, inundation and flood damages extend beyond the area where major debris was deposited.

Overview of Related Projects

URS Group, Inc. (URS), with support from Government Services Integrated Process Team, LLC, was tasked by FEMA under their existing Hazard Mitigation Technical Assistance Program (HMTAP) contract to assist in disaster recovery efforts for Hurricane Katrina. Assistance provided under this task order included data collection and visual survey of the debris line and the extent of flooding to identify the WWL in Mississippi.

After Hurricane Katrina, FEMA issued several task orders under the HMTAP contract called Rapid Response Task Orders. Generally, the purpose of these task orders was to allow FEMA contractors to move quickly into disaster-stricken areas to collect perishable data for use in defining the parameters of the event that can be used for future studies and flood mitigation activities. In addition to the WWL Task Order, which is summarized in this report, there were several other Rapid Response Task Orders, including Aerial Imagery Data Collection, Coastal High Water Mark (CHWM) Surveys, and Riverine High Water Mark (RHWM) Surveys. HWM survey findings are used to define the extent of flooding and therefore can be used in conjunction with field findings from WWL Task Orders to determine the extent of the WWL. Aerial imagery is also used to estimate the WWL; post-event imagery can be used to identify areas affected by flood damages, as well as the approximate inland extent of storm surge flooding.

In response to Katrina, HMTAP Task Order 416, Rapid Response, Hurricane Katrina Wind Water Line Data Collection– Mississippi, was issued and is the focus of this report. In addition, HMTAP Task Order 411, Rapid Response, Aerial Radar - Louisiana, Mississippi, and Alabama; HMTAP Task Order 413, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Mississippi; and HMTAP Task Order 420, Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – Mississippi, were also issued. An overview of these task orders is provided below.

- Under Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, cartographic analysts were tasked with using post-event aerial imagery to delineate areas affected by flooding along the Mississippi Coast. Uses of post-event aerial imagery for Louisiana and Alabama are discussed in WWL Data Collection Reports prepared under separate HMTAP task orders for those states.

- Under Task Order 413, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Mississippi, field crews collected perishable HWM data at field-observed point locations. The crews looked for evidence of the peak elevation of flooding caused by storm surge, then inventoried and surveyed these elevations. Peak flood elevations in coastal Mississippi were recorded at several locations as part of this task order. These data can be used to help determine the extent of flooding.

- Under Task Order 420, Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – Mississippi, field crews also collected HWM data at field-observed point locations. Field crews for RHWMs focused on areas of overbank flooding where heavy and/or prolonged precipitation resulted in an exceedance of the capacity of rivers and streams to keep floodwaters within their banks. Peak flood elevations for riverine-type flooding were surveyed and recorded as part of this task order.

The entire Katrina WWL study area extended from southwest Alabama west through coastal Mississippi and southeastern Louisiana. This report focuses on the results of data collected in Mississippi to determine the WWL. In Mississippi the entire coastline was studied to identify areas where wind and water damages occurred and inland areas where damages were caused primarily by wind. Figure 5 shows the study area within Mississippi, with the coastal counties highlighted in yellow.

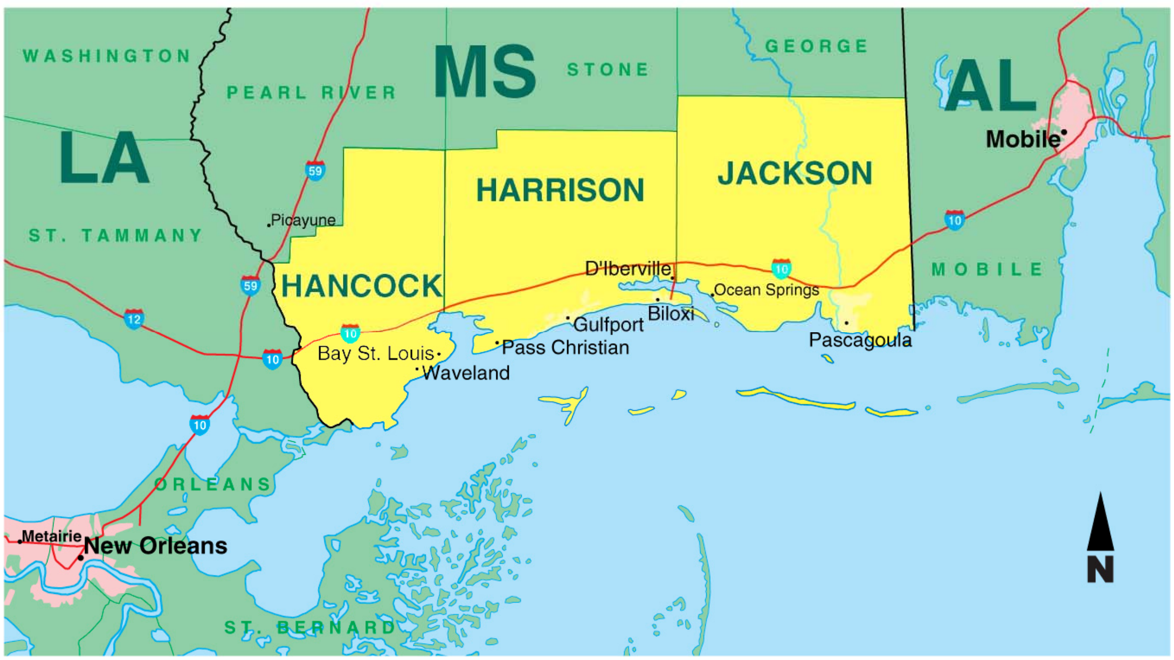

Figure 5: WWL Study Area within Mississippi

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Methodology

There were two basic elements to this project: field data collection and WWL mapping. While field crews worked to collect data in the weeks following Hurricane Katrina, the WWL mapping process occurred after the data had been collected and involved interpretation and analysis of data from several sources.

Data Collection Methodology

URS field crews collected data for Hurricane Katrina in Mississippi. Teams were mobilized within 8 days of the disaster declaration. They met in Tallahassee, Florida, in early September 2005 to be briefed on the project and form field crews. Field data collection efforts began on September 12 and continued through September 23, 2005.

Field crews contacted County Emergency Managers prior to the start of field work to obtain all available information about the location and extent of damage to structures in the county. Areas identified by County Emergency Managers as having been damaged and/or having higher flood levels were given priority.

Data collection for Task Order 416, Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Mississippi, was performed in conjunction with data collection for Task Order 413, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Mississippi, and Task Order 420, Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – Mississippi. Under Task Orders 413 and 420, field crews collected perishable HWM data at field-observed point locations. Under Task Order 413, they looked for evidence of the peak elevation of flooding caused by storm surge, then inventoried and surveyed these elevations. CHWM points are taken where surge directly affects flood levels, including the shoreline of open coasts, bays, and tidally influenced rivers. CHWMs are formed when the water level during a storm rises to a maximum elevation and leaves marks on the interior and/or exterior walls of a structure, or debris or wrack lines along the ground. CHWM field crews are responsible for identifying these marks and recording basic information about the data point. Survey crews then use these initial records to later relocate the points and survey them to determine the peak elevation of flooding.

The WWL points, which are also located by identifying water marks on structures or debris or wrack lines, doubled as HWMs. WWL points are used to define the inland extent of damage to structures caused by surge flooding. Thus, the points generally form a line showing the approximate inland limit of surge flooding. The WWL is so called because landward of the line in coastal areas, damage to structures is usually limited to wind damage, which includes direct rain damage, where the envelope of the structure may have been compromised by wind damage. Seaward of the line, damage to structures is the result of both surge-induced flooding and wind forces (see Figure 6).

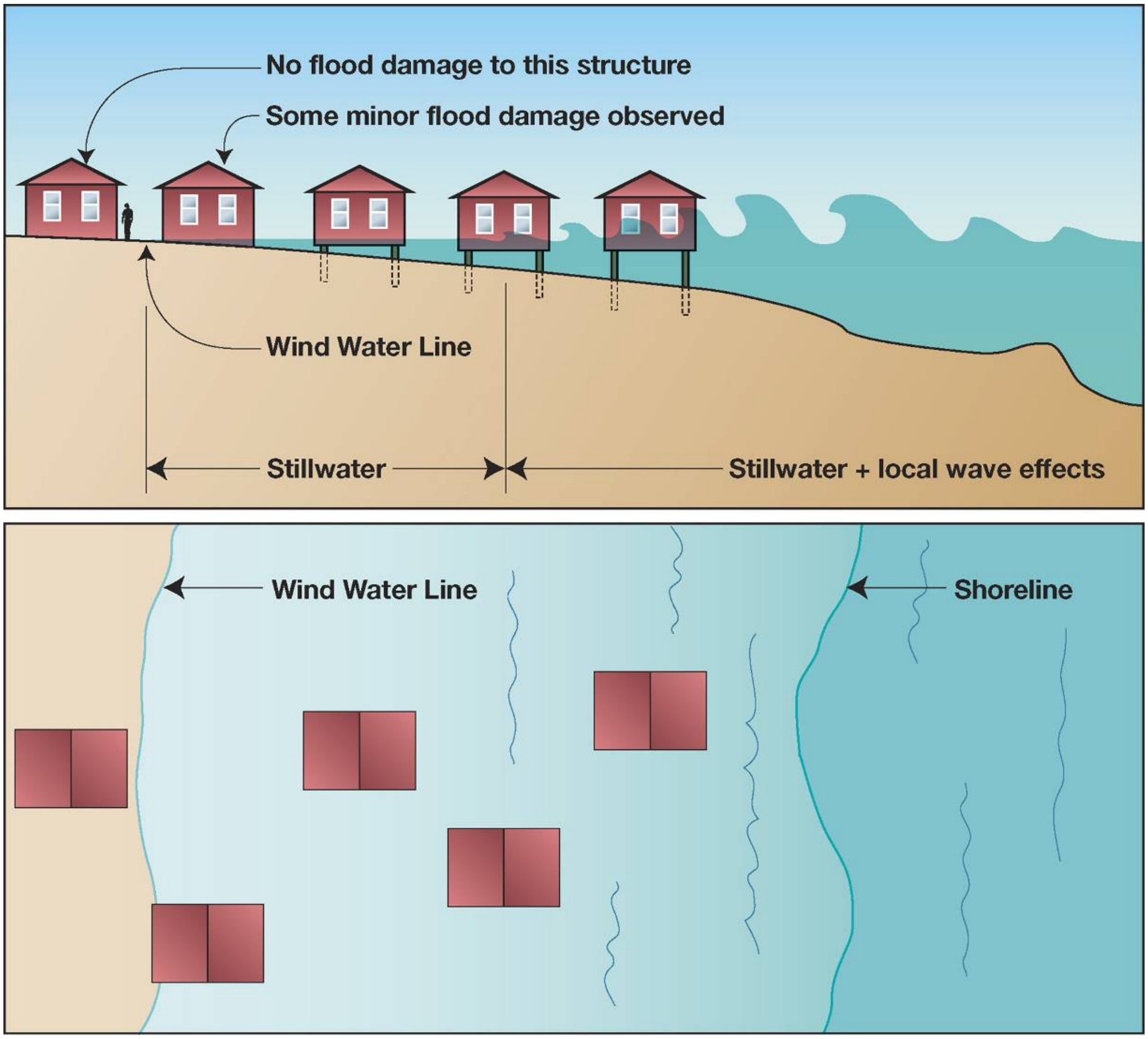

Figure 6: WWL Illustration (Profile View/Plan View)

Each field crew was tasked with identifying the WWL and collecting data points along the coastlines. To define points along the WWL, field crews visited areas of known flood damage. Traveling inland from the coast to the edge of damaged areas, they attempted to locate debris lines (see Figure 7) or water marks (see Figure 8) close to the ground, and trace them along topographic features to determine the extent of flooding and flood damages. Generally, when these features were observed within 1.5 feet of the ground and the field crews could validate through field observations or interviews with local citizens that these features were near the edge of inundation, these points were marked as WWL data points.

Data collection had to be completed quickly given the perishable nature of the data; as community clean-up efforts progressed, valuable debris line and HWM data were being destroyed. The field crews collected raw data for both WWLs and HWMs from September 12 through September 23, 2005. The information for each data point was stored in a database (see Appendix B). In fact, as previously mentioned, the WWL points doubled as

HWM points since a flood elevation could be determined at each of the WWL data points. Therefore, the WWL data points are actually a subset of the HWM data points. WWL data points are assigned a HWM identification number, which is also used as their WWL identifier. It is a three-part alphanumeric label. For example, a point might be labeled KMSC-05-16. The leading 'K' indicates that the HWM/WWL data point is a Hurricane Katrina data point, the middle 'MS' stands for Mississippi, and the last letter can be either a 'C' or an 'R' standing for coastal or riverine flooding. The middle two-digit number identifies the field crew that gathered the data, and the final two-digit number identifies the sequential data points collected by the field crew.

Figure 7: Example of a Debris Line

Figure 8: Example of a HWM

In some areas, both CHWMs and RHWMs were marked as WWL points. This was true along bayous and watercourses situated close to the coast. Although marked as RHWMs, some of these points were very close to the edge of coastal inundation. However, others were determined to be beyond the extent of coastal inundation. Only in four instances were such points used to help define the final WWL. Two of these points were located along Bayou La Salle and Bayou La Terre in Hancock County, and the other two points were located along Mary Walker Bayou and Sioux Bayou in Jackson County.

Usually, WWL data were collected every 2 to 4 miles in developed areas along the coast. However, in areas along the coastline with significant damage to structures from flooding, the density of data points was sometimes higher. Similarly, there are certain stretches of coastline where field crews could not take data points, either because these areas could not be accessed (no roads, thick vegetation, or swampy areas, etc.) or because there was no clear physical evidence to define a WWL point.

At each observed WWL point, the following data were collected:

- Address (if the point was near an addressable structure)
- Latitude/longitude reading, taken in North American Datum 1983 (NAD 83), which is used as the standard map coordinate system default by the majority of Global Positioning System (GPS) devices
- Location description (e.g., neighborhood name or other descriptive name)

- Date data point was taken
- Type of data point including: debris line, water mark, wrack line (indicates the high tide mark)
- Type and severity of observed wind damage
- Flood source
- Approximate flood depth (if water mark data point)
- Digital photographs (named according to the WWL point reference number; see Appendix C)

Mapping Methodology

To create the WWL maps, the project team relied heavily on data supplied from both HMTAP Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, and HMTAP Task Order 413, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Mississippi.

Under Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, cartographic analysts used post-event aerial imagery to delineate areas affected by flooding along the Mississippi Coast. The analysts used natural color orthorectified imagery acquired between September 4 and September 17, 2005, by the firm 3001, Inc. The analysts studied the imagery to locate the extent to which high-velocity floodwaters, including coastal surge, pushed debris inland, and to delineate areas beyond these debris lines where floodwaters had continued to push inland, causing additional flood inundation without leaving behind major debris. Contour data were created using U.S. Geological Survey (USGS) Digital Elevation Models (DEMs) to perform checks as needed of the analysts' interpretations against elevation data. Geographic Information System (GIS) coverage showing the approximate extent of flooding was created as part of this task order. Appendix D includes a summary report prepared by the cartographic analysts summarizing their methodology and product.

Under this task order (Task Order 416, Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Mississippi), field WWL data points were used together with the information about the extent of flooding determined as part of the aerial imagery task order (Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama) to finalize an aerial measure of inundation based on both photointerpretation and field ground-truthed data. The inundation areas defined under Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, served as the base data for determining the WWL, and the field data collected under this task order (Task Order 416, Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Mississippi) were compared to these base data to determine if the two data sets were in agreement.

The URS team compared the locations of the field-collected data points with debris line and inundation extent mapping provided by the cartographic analysts. Where locations varied in excess of 200 feet from the photointerpreted flood area delineation, WWL (and nearby HWM) field data were verified. If the flood elevation data, supporting documentation and topographic information, confirmed that the field-acquired WWL point was correct, the inundation coverage was modified to agree with those data.[4] Notes from these comparisons are included in tabular format in Appendix E.

The extent of flooding was defined not only by the WWL points, but also from data collected as part of Task Order 413, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Mississippi. In some areas, it is difficult to locate WWL points due to access issues, or because there is no clear physical evidence to define a WWL point. This happened particularly in marshy areas where it was not clear how far inland the surge had moved through the marshes. In these cases, the elevation data from the CHWM surveys were used to complement the WWL data points. The CHWM is a measure of the peak flood elevation and, when used with reliable topographic data, can help to determine an approximate WWL boundary. In these cases, CHWM points that appear to be near the edge of inundation (based on interpolation from other WWL points or boundary estimates) were used because surge-induced flood elevations will generally decrease farther inland.

To determine the inland limit of surge along major coastal rivers, HWMs were used. HWMs are grouped into two types, coastal and riverine, and serve as a good tool to help distinguish these two types of flooding. Therefore, the first general indication of the extent of surge was the boundary between CHWMs and RHWMs along a given watercourse. After finding this area, surge elevations for the CHWMs closest to this boundary were identified, and the inland limit of surge was mapped by following the topography along these elevations. Where there was more than one CHWM, the CHWM elevations were averaged if the values were within approximately 1 foot of each other. If CHWM elevations differed by more than 1 foot, generally the CHWM farthest inland along a stream or closest to the stream was used.

Table 4 presents the CHWMs used to determine the inland extent of surge flooding along several waterways in Mississippi. Inundation along smaller streams with a limited inland extent was considered to be entirely a result of surge flooding.

GIS maps of the WWL were produced at a scale of 1:24,000 (see Appendix F). The maps show the location and type of each WWL data point, the debris line, and the approximate coastal inundation extent of storm surge flooding. The GIS maps are based on USGS 7.5-minute topographic quadrangle maps.

It is important to note that the maps in Appendix F use both the debris line and extent of inundation to show the damage caused by flooding. While the debris line helps to show where higher-velocity storm surge pushed debris inland and caused damage, the inundation caused by the surge extends farther inland and shows where less powerful and, in many cases, shallower flooding also caused damage. Together, these illustrate the extent of the WWL along coastal Mississippi.

[4] Five-foot contour data were obtained from the Mississippi Automated Research Information System (MARIS) at http://www.maris.state.ms.us. MARIS digitized the data from USGS topographic maps and validated attribute values via cross-checks with existing data resources including photographs, maps, imagery, and scientific reports.

Table 4. CHWM Points Used to Determine the Inland Extent of Surge Flooding along Watercourses Draining to the Mississippi Sound

County	Stream	Point	Elevation (feet NAVD 88)	Elevation Used (feet NAVD 88)
Jackson	Escatawapa River	KMSC 10-11	7.2	7
	Pascagoula River[a]	KMSC 10-03	12.3	12
Harrison	Biloxi River	KMSC 06-09	11.7	12
	Bernard Bayou	KMSC 10-67	18.7	19
	Wolf River	KMSC 02-29	23.0	23
		KMSC 06-08	23.0	
Hancock	Jordan River	KMSC 06-01	19.5	20[b]
		KMSC 10-56	20.0	
		KMSC 10-58	13.6	
		KMSC 10-59	19.5	
	Pearl River	KMS-USGS-105[c]	14.8	15
	Pearl River	KLAC 06-05[d]	15.2	

[a] This also includes many adjacent watercourses. Several bayous, lakes, and streams make up this drainage system.
[b] Average of 3 of the 4 points. KMSC 10-58 not used since it was 6+ feet lower than the other points.
[c] Some HWM points from USGS field teams were also available.
[d] CHWM taken from data collected under T.O. 413, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Louisiana.

Recommendations

The use of post-event imagery analyzed through photointerpretation, combined with field data and observations, allowed for a balanced interpretation of the WWL along the Mississippi coastline, as shown on the maps in Appendix F. The post-event imagery provided an overview of the extent of flooding within the area and a basis for determining the general flood boundaries. The field data, including field crews' damage observations, pictures, notes about flood depths, etc., provided true ground observations to compare to the WWL developed through the use of the debris line and flood extent created via photointerpretation of the post-event imagery.

One potential area for improvement in the field data collection methodology would be the use of teams with a more specific focus on WWL data collection. While HWM data and field crew observations were helpful in interpreting the WWL locations, field crews with a more narrow focus aimed solely at determining the WWL would probably have allowed for more specific and/or descriptive data about WWL indicators and damages at sites, as well as better visual documentation (photographs) illustrating evidence of the WWL.

Also, a better log or record of field crews' attempts to access areas where no data points were identified would help to create a clearer picture of the efforts made and the ground covered when there are no WWL data points to illustrate the crews' findings. One possible solution would be to make better use of mapping/navigational software to record crews' movements each day. Crews could note directly on a map what hindrances or problems kept them from collecting data in specific areas.

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Findings and Observations

In Mississippi, the WWL was delineated by using both the debris line and the inland limit of surge flooding that extended beyond the debris line in many areas. Flooding along the coastline in many areas extended thousands of feet inland. Along watercourses draining directly to the Mississippi Sound, surge-induced flooding was noted for several miles inland, including along both the Pascagoula River on the eastern side of the state's coastline and along the Pearl River that forms the border with Louisiana. Table 5 presents a summary of inland distances of the WWL with a focus on developed areas, their corresponding flood sources, and the map sheet names and numbers contained in Appendix F.

Table 5. WWL Findings and Map Sheet by Community

County	Location (City or Area)	Major Flood Sources	Inland Extent of WWL (feet)	Map Sheet(s)
Jackson	Far eastern coastal Jackson County	Mississippi Sound	5, 000 to 15,000	Kreole – 19 Grand Bay SW – 29
Jackson	Far eastern Jackson County	Escatawpa River	Up to 4,000 (from main channel)	Big Point – 8 Kreole – 19
Jackson	Pascagoula	Mississippi Sound	1,500	Pascagoula North – 18 Pascagoula South – 28
Jackson	Pascagoula	Pascagoula River	Up to 14,000 (from main channel)	Pascagoula North – 18
Jackson	Eastern Gautier	Gulf of Mexico and Pascagoula River	1,500	Gautier North – 17 Gautier South – 27
Jackson	Western Gautier	Gulf of Mexico	7,000 to 10,000	Gautier North – 17 Gautier South – 27
Jackson	Gulf Park	Mississippi Sound	15,000	Deer Island – 26 Gautier North – 17 Gautier South – 27 Ocean Springs – 16
Jackson	Eastern Ocean Springs	Mississippi Sound	6,000	Deer Island – 26 Ocean Springs – 16
Jackson	Western Ocean Springs	Davis Bayou and Mississippi Sound	15,000	Deer Island – 26 Ocean Springs – 16
Jackson	Between Ocean Springs and D'Iberville	Davis Bayou	4,000	Ocean Springs – 16
Harrison	Eastern Biloxi and D'Iberville	Back Bay of Biloxi, Bayou Poito, Bayou Talia, Big Lake, and Mississippi Sound	500 to 4,000	Biloxi – 15 Ocean Springs – 16 White Plains – 5
Harrison	Western Biloxi	Mississippi Sound	1,500	Biloxi –15
Harrison	Between Biloxi and Gulfport	Mississippi Sound	1,500 to 2,000	Biloxi – 15 Gulfport North – 14
Harrison	Gulfport	Mississippi Sound	1,500 to 2,000	Gulfport North – 14 Gulfport South – 25
Harrison	Long Beach	Mississippi Sound	2,500	Pass Christian – 24
Harrison	Pass Christian	Acadian Bayou, Mississippi Sound, St. Louis Bay, and Wolf River	Up to 15,000 (from St. Louis Bay)	Bay St. Louis – 23 Gulfport NW – 13 Pass Christian – 24 Dedeaux – 12
Hancock	Back bay of St. Louis Bay	St. Louis Bay	3,000 to 6,000	Kiln – 11 Dedeaux – 12

County	Location (City or Area)	Major Flood Sources	Inland Extent of WWL (feet)	Map Sheet(s)
				Waveland – 22
Hancock	Bay St. Louis	Mississippi Sound and St. Louis Bay	15,000 to 30,000	Bay St. Louis – 23 Kiln – 11 Waveland - 22
Hancock	Waveland	Mississippi Sound	15,000 to 30,000	Bay St. Louis – 23 Waveland – 22
Hancock	West of Waveland	Mississippi Sound and Pearl River	4,000 to 20,000	English Lookout –31 Haaswood – 20 Logtown – 21 Nicholson – 9 Rigolets – 30 Saint Joe Pass – 32

Damage caused by coastal storm surge effects was observed all along Mississippi's Gulf Coast. Following is a brief summary of the extent of surge-related flooding in each of the counties included as part of the study. It is suggested that the reader view the maps included in Appendix F while reading these summaries.

Jackson County

In far eastern coastal Jackson County, shown on map sheets 19 and 29, the WWL extends inland from between 5,000 to approximately 15,000 feet (0.9 to 2.8 miles) in some areas, including most of the area between Pascagoula and the border with Alabama. This area is marshy with relatively flat topography; there is little development here.

In Pascagoula, the WWL is located approximately 1,500 feet (0.3 mile), or two to three blocks, inland from the coast in most places as shown on map sheets 18 and 28. Along the Pascagoula River and adjacent bayous and streams, storm surge pushed inland up the watercourses and flooded an area approximately 3 to 5 miles wide (see sheets 2, 3, 6, 7, 17 and 18). Much of this area is not developed because it is flat and marshy but, along its outer edges, development was affected.

Gautier is located on the west side of the Pascagoula River and is shown on sheets 17 and 27. West of the Pascagoula River, eastern Gautier saw storm surge inundation come approximately 1,500 feet (0.3 mile) inland in most places, as evidenced by the WWL. However, along the Pascagoula River, storm surge influenced flooding 20+ miles inland. In the western part of Gautier, the WWL extends approximately 7,000 to 10,000 feet (1.3 to 1.9 miles) inland.

In the Gulf Park area, mapped on sheets 16, 17, 26, and 27, the storm surge came about 15,000 feet (2.8 miles) inland. Ocean Springs is located west of Gulf Park and is shown on sheets 16 and 26. In eastern Ocean Springs, the WWL is located approximately 6,000 feet (1.1 miles) inland, and in western Ocean Springs, it is approximately 1,500 feet (2.8 miles) inland. Davis Bayou also experienced some storm surge flooding in this area. South of Interstate 10, between Ocean Springs and D'Iberville (map sheets 15 and 16), the WWL was found approximately 4,000 feet (0.8 mile) inland.

Harrison County

In Harrison County, Long Beach and Pass Christian suffered heavy damage to structures. In Long Beach, the WWL extends several blocks inland from the coast and Highway 90, up to approximately 2,500 feet (0.5 mile) as shown on map sheet 24. Pass Christian's location at the entrance to St. Louis Bay from the Mississippi Sound makes it particularly vulnerable to storm surge (see sheets 12, 13, 23, and 24). The WWL here extends up to 15,000 feet (2.8 miles) inland. Along the eastern entrance to the bay, storm surge completely washed over the area. Additionally, the storm surge pushed inland and caused flooding along the Wolf River and Acadian Bayou. Pass Christian was flooded from the south (Mississippi Sound), west (St. Louis Bay), and north (bayous and rivers).

Biloxi and Gulfport were similarly devastated. In these communities, surge also destroyed many structures as much as approximately 2,000 feet (0.4 mile) inland. Here, the WWL corresponds directly to the debris line as shown on map sheets 14, 15, and 25.

In eastern Biloxi (map sheets 15 and 16), the storm surge hit straight on from the Mississippi Sound and came up the Back Bay of Biloxi, affecting the coast along the peninsula as well as both the backside of the peninsula and the coast of the mainland where D'Iberville is located. Biloxi Bay and Bayous Poito and Talia also experienced storm surge flooding. In western Biloxi (map sheet 15), the WWL extends approximately 1,500 feet (0.3 miles) inland, as evidenced by the debris line.

Along Highway 90 between Biloxi and Gulfport (map sheets 14 and 15), the WWL (which corresponds to the debris line) was found approximately 1,500 to 2,000 feet (0.3 to 0.4 mile) inland. Similarly, through Gulfport (map sheets 14 and 25) the WWL shows that the storm surge extended 1,500 to 2,000 feet (0.3 to 0.4 mile) inland.

Hancock County

Along the back part of St. Louis Bay in Hancock County, as shown on map sheets 11, 12, and 22, velocity storm surge flooding (debris line) extended approximately 3,000 to 6,000 feet (0.6 to 1.1 miles) inland, with inundation extending much farther, up a system of bayous and rivers that feeds into the bay.

The WWL in Bay St. Louis (map sheets 11, 22, and 23) extends as much as approximately 30,000 feet (5.6 miles) inland. However, a tall bluff on the east side of Bay St. Louis protected some of the downtown area from major flooding damage. There was still flooding, though it was shallower than in many other coastal areas.

In Waveland (map sheets 22 and 23), the debris line was found approximately 4,000 to 5,000 feet (0.8 to 0.9 mile) inland, where many city blocks of residences were destroyed. Beyond the debris line, lower velocity flooding extended inland, covering most of the community. Here, the WWL extended up to 30,000 feet (5.7 miles) inland.

The swampy bayou area west of Waveland is mostly uninhabited. In this area, the WWL extended from approximately 4,000 to 20,000 feet (0.8 to 3.8 miles) inland. Map sheets 9, 20, 21, 30, 31, and 32 include this area.

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Conclusion

Storm surge clearly had a devastating effect along the Mississippi coastline. As the WWL shows, flooding affected structures miles inland in the communities of Pass Christian and Waveland. In the more urban areas of Biloxi and Gulfport, the WWL shows that flood damages extended several city blocks inland, where much of these communities' development is concentrated. All along the coast, including the eastern portion of the state where there is concentrated development in areas like Ocean Springs, Gautier, and Pascagoula, the WWL extends at least 0.25 mile inland.

Field crews were able to identify a total of 72 WWL points in Mississippi. Of these, 33 points were in Harrison County, 30 were in Jackson County, and 9 were in Hancock County. Twenty-one of the points were within a range of approximately 200 feet from either the debris line or inundation polygon developed by photointerpretation of the post-event imagery. Using the data for the remaining 51 points, including the field crews' observations, photographs, post-event imagery, local topography, and base mapping, engineers analyzed the photointerpreted debris line and inundation area and decided that 39 of these points would be used to actually edit the photointerpreted debris line and inundation area.

Post-event imagery, analyst photointerpretation, and field-collected data were all used in the delineation of the WWL and the extent of flooding, as shown on the maps in Appendix F. The post-event imagery provided an overview of the extent of flooding within the area and a basis for determining the general flood boundaries. The field data, including field crews' damage observations, photographs, notes about flood depths, etc., provided true ground observations to compare to the debris line and flood extent developed by photointerpretation of the post-event imagery.

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Appendix A: Mississippi Red Cross Damage Assessments for Single-Family Dwellings

The contents of this appendix, which are referenced in the Overview of Impacts section of the report, quantify building damage of single-family dwellings in Mississippi.

Hurricane Katrina in Mississippi
Red Cross Damage Assessments
for Single-Family Dwellings

County	Destroyed	Major Damage	Minor Damage
Harrison	29,970	15,470	31,905
Jackson	23,250	16,250	8,600
Hancock	10,900	3,600	1,800
Forrest	1,550	7,500	16,000
Pearl River	900	2,000	7,700
Lauderdale	600	10,000	15,000
Wayne	450	4,500	2,000
Jones	270	810	3,250
Stone	220	440	2,600
George	140	700	700
Clarke	80	1,600	3,700
Marion	80	610	937
Lamar	75	525	592
Pike	71	300	1,400
Newton	50	120	400
Walthall	50	165	330
Scott	20	100	200
Lincoln	14	140	1,400
Jefferson	10	34	106
Jasper	7	175	0
Covington	5	26	43
Greene	5	25	250
Warren	3	0	0
Lowndes	2	4	11
Union	2	1	0
Montgomery	1	5	20
Smith	1	2	70
Tallahatchie	1	3	0
Amite	0	0	120
Clay	0	0	1
Copiah	0	50	50
Hinds	0	10	100
Kemper	0	5	100
Lawrence	0	0	300
Leake	0	0	50
Lee	0	1	1
Leflore	0	2	10
Madison	0	0	20

Hurricane Katrina in Mississippi
Red Cross Damage Assessments
for Single-Family Dwellings

County	Destroyed	Major Damage	Minor Damage
Neshoba	0	10	50
Noxubee	0	1	2
Oktibbeha	0	1	2
Perry	0	2	250
Rankin	0	0	50
Simpson	0	50	150
Sunflower	0	1	1
Washington	0	1	10
Winston	0	1	10
Totals	**68,729**	**65,237**	**100,318**

Appendix B: WWL Data Points

Appendix B contains a table with field-collected data for each WWL data point. These data are first referenced in the Data Collection Methodology section of this report and were collected between September 12 and September 23, 2005. As described in the Mapping Methodology section, the data points were used together with information about the debris line and the extent of flooding determined through photointerpretation of post-event imagery to delineate the WWL as presented on the maps in Appendix F. A description of how the data points were used to edit the debris line and limits of inundation defined through photointerpretation of the imagery can be found in Appendix E.

APPENDIX B IS NOT INCLUDED IN THE REPORT VERSION FOR PUBLIC RELEASE DUE TO PRIVACY ISSUES.

Appendix C: WWL Photographs

Appendix C contains an index and thumbnails of the photographs that correspond to each WWL data point presented in Appendix B. The naming convention for photographs uses the data point ID Number (KMSC-XX-XX) and then a sequential number for the photograph(s) associated with that ID Number (KMSC-XX-XX-1, KMSC-XX-XX-2). In most instances, two photographs were taken for each data point.

APPENDIX C IS NOT INCLUDED IN THE REPORT VERSION FOR PUBLIC RELEASE DUE TO PRIVACY ISSUES.

Appendix D: Debris Line and Inundation Mapping Report, HMTAP Task Order 411 Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama

Appendix D contains a summary report of debris line and inundation mapping performed under HMTAP Task Order 411: Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama. Photoanalysts used the post-event aerial imagery to estimate the location of the debris line and the extent of inundation from Hurricane Katrina. As described in the Mapping Methodology section of the report, this information developed by the photoanalysts was used as the initial estimate of the WWL delineation, which was further edited based on the field-collected data presented in Appendices B and C.

Hurricane Katrina Rapid Response: Debris Line and Inundation Mapping 20 January 2006

Background

As part of the Hurricane Katrina Rapid Response disaster relief efforts performed for the Federal Emergency Management Agency (FEMA), EarthData International, LLC (EarthData) supported URS Group, Inc. (URS) in its effort to identify areas of storm damage through mapping procedures. EarthData produced and delivered mapping in ESRI shapefile (SHP) format containing delineation of debris lines caused by ocean surge and polygons surrounding areas inundated by floodwaters from both surge and freshwater flooding from Hurricane Katrina. The areas mapped include the storm-struck areas along the Gulf Coast of Alabama, Mississippi, and Louisiana.

The primary purpose of this mapping effort was to provide a comprehensive, region-wide inventory of areas damaged by Hurricane Katrina with as quick a turnaround as possible. More specifically, the mapping products distinguished between areas damaged by high velocity floodwaters from surge along the coast (debris line), comparably slower moving floodwaters from surge and riverine flooding (inundation polygons), and high winds. FEMA's National Flood Insurance Program (NFIP) requires this type of data to ensure that Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) provide reasonable risk information.

Area of Interest

Mapping coverage extended along the entire Gulf Coast region of Louisiana, Mississippi, and Alabama. The area mapped was approximately 12,000 square miles and included portions of or all of the following counties:

1. **Alabama Counties:** Baldwin and Mobile
2. **Mississippi Counties:** Forrest, George, Greene, Hancock, Harrison, Jackson, Lamar, Marion, Pearl River, Perry, and Stone
3. **Louisiana Parishes:** Jefferson, Livingston, Orleans, Plaquemines, Saint Bernard, Saint Charles, Saint John the Baptist, Saint Tammany, Tangipahoa, and Washington

Imagery Source

EarthData used natural color digital aerial orthophotographs acquired between September 4 and September 17, 2005. The 3001, Inc. source imagery was acquired under an unrelated disaster response contract issued by the U.S. Army Corps of Engineers (USACE) to support their "blue tarp" task. The imagery was made available to URS for use in Hazard Mitigation Technical Assistance Program (HMTAP)-related work. Questions related to the imagery acquisition scope of work and technical specifications should be addressed to the USACE (Kevin Carlock, USACE, Rock Island District, 309-794-5249). The 3001, Inc. imagery provided to EarthData by URS covered approximately 3,600 tiles (4,077 x 4,092 pixels) and was projected in latitude/longitude coordinates.

Accuracy Standards

Digital orthophotography is normally created from aerial photographs combined in an aerotriangulation adjustment with ground and airborne positional control, which is rectified using a digital elevation model

(DEM). In the Hurricane Katrina response, USACE and their contractor, 3001, eliminated some of rigorous photogrammetric processing steps to expedite delivery of the imagery within 24 hours of acquisition. No ground control was acquired. Airborne Global Positioning System (GPS) and inertial measurement unit (IMU) data were used to provide an absolute orientation solution; however, a rigorous aerotriangulation block adjustment was not performed. Due to the flatness of the terrain, it was also decided that planar rectification (using a flat surface) would be performed, rather than rectification to an actual DEM. The resulting orthophotography, therefore, does not meet National Map Accuracy Standards or Federal Geographic Data Committee (FGDC) standards for the final map scale. No rigorous positional accuracy assessment was performed either by the USACE or URS due to 1) lack of extensive ground control check points and 2) turnaround time required for response and recovery products. Based on observations of positional displacements of distinguishable linear features between adjacent flight lines and comparisons of existing geographical information system (GIS) data layers overlaid on the orthophotographs, EarthData estimates the horizontal accuracy of the 3001, Inc. orthophotography to be on the order of ±10 meters. Again, this is not a rigorous accuracy assessment, but rather a subjective estimate of error based on the internal consistency of the image dataset. When using derived mapping products, such as the debris line and inundation mapping described in this report, the end user should be cognizant of the magnitude of the potential spatial errors.

Mapping Products

EarthData used a production staff of eight professional cartographic analysts to produce and deliver mapping products for the above-mentioned areas stricken by Hurricane Katrina. EarthData's project manager and cartographic team leader/supervisor managed all of the day-to-day project functions throughout the life of the project. This mapping effort began on September 9, 2005 and was completed on October 7, 2005.

The final deliverable products consisted of polygon shapefiles in units of meters projected to Universal Transverse Mercator (UTM) Zone 16, North American Datum of 1983 (NAD83). A separate shapefile was produced for each of the mapping features—one for the debris line and one for inundation polygons.

Mapping analysts used 3001, Inc. imagery to interpret areas of storm surge damage along the coast marked by debris lines as well as inland areas that experienced surge and/or riverine flooding. As a secondary source, analysts used 10-foot contours produced from Light Detection and Ranging (LiDAR) and U.S. Geological Survey (USGS) DEM datasets covering the areas of interest. The contours were referenced with the imagery to locate low-lying areas where the potential for flooding was high and debris would likely collect. EarthData's staff used preliminary high water mark points provided by URS as another ancillary reference to locate areas field surveyors identified as flooded.

Using the imagery source provided along with the ancillary sources listed above, EarthData mapped the debris line where visual evidence of the high velocity ocean surge was present. For instance, significant debris from man-made structures, sand, mud, and other biomass would collect along lines where the surge carried it over land.

Additional indications of ocean surge extended along the coast, where trees and vegetation had turned brown due to salt water inundation. Flooding further inland was determined by visual evidence of standing water or deposited debris and mud along bays, rivers, lakes, and other water bodies farther inland; receding floodwaters left the debris behind. In areas where the imagery was either void, corrupt, or covered by clouds, a polygon was digitized around the area and labeled as "obscured."

Software Applications

EarthData used a combination of ESRI ArcCatalog and ArcView software to create the working file templates. These templates, or "seed files," set all of the parameters and applicable attribution that was later populated in the compilation stage, ensuring consistency in the file structure across the entire project. Digitizing of the debris lines and flood polygons was performed using both ESRI ArcView and ArcMap software packages. All final data were merged to create a single file in ESRI shapefile format for each of the two separate featured themes: the debris line and inundation polygons. All shapefiles were reprojected from latitude/longitude to the UTM Zone 16, NAD83 using ArcCatalog.

Interpretation Obstacles

EarthData's analysts used professional interpretation and judgment in identifying areas damaged from ocean surge and inland flooding based on the sources of information provided. Due to the urgency associated with the hurricane response, some scattered areas of the aerial imagery contained cloud cover. Lighting conditions were often less than optimal for interpretation, and it was not physically possible to photograph the entire project area coincident with actual storm surge and peak inundation conditions. Mapping analysts were confronted with the need to make subjective decisions in interpretation.

Figure 1 shows a case of inland flooding along a river, where the high water had partially receded by the time the photograph was taken. In such cases, analysts designated any areas covered with mud, sand, or silt, as well as areas where the color of the ground or vegetation indicated a high level of moisture due to recent inundation, as "flooded."

Figure 1

When flood waters recede quickly before the photographs are taken, analysts are confronted with a more complex interpretation assessment. In these cases, analysts look for signatures in the photographs, such as leaning trees, standing water, deposited debris (mud, silt, vegetation, etc.) and other features, that indicate the presence of inland flood waters. Figure 2 depicts an area which was interpreted to have been entirely inundated with water that receded before the photo was taken. This was determined by the presence of mud, fallen trees and saturated ground indicated by brown coloration throughout the image.

Figure 2

Figure 3 represents an area where the presence of marsh results in a unique situation whereby debris no longer collects as it would typically do on dry land. What is normally a visible debris line on dry land becomes less obvious for photo-interpretation when over marsh and other standing water bodies. In such cases, analysts may use contour lines, the presence of high water marks, deposited mud and silt, and/or any damage to vegetation that has been submerged by flood waters. The marsh in Figure 3 is evident in the lower left and lower right sectors of the image. URS engineers judged final placement of the wind/water line in such areas where photo interpretation alone was not conclusive.

Figure 3

Figure 4 depicts the presence of multiple debris lines. In such cases, the analyst must decide whether all debris was deposited by the ocean surge or some debris was later swept up by inland flooding caused by heavy rain. If tide waters are present along the coast, it can result in multiple debris lines being left behind. Typically, the analyst will place the debris line at the most evident and consistent debris line or along the furthest inland point (high water mark).

Figure 4

Coastal areas containing salt marshes and other low-lying areas such as that represented in Figure 5 can pose a challenge to photo-interpreters delineating flood waters. An analyst must determine whether or not to represent an area as flooded. There are many cases in which land appears to be flooded, but the area is really a marsh and always has saturated characteristics. In these cases analysts often review other sources such as secondary maps, historical data, and field surveyed conditions. Analysts also look for deposited mud and the condition of nearby vegetation to determine whether an area has been flooded or whether it is simply a marsh.

Figure 5

Appendix E: Notes on Comparison of WWL Data Points to Photointerpreted Debris Line and Inundation Area

Appendix E contains a record of the comparison of the photointerpreted data to the field data and the actions taken to resolve any differences between the two. The Mapping Methodology section of this report provides a description of how the field-collected data presented in Appendices B and C were used to edit the photointerpreted debris line and inundation limit that were developed, as explained in Appendix D. This appendix provides detailed descriptions of how each WWL data point was used to either confirm the proper delineation of the WWL based on the photointerpreted data, or to edit this initial delineation of the WWL where the two data sets did not agree.

ID Number	County	Distance to DL (ft)	Distance to Flood Boundary (ft)	Action	Explanation	GIS Comments (optional)	GIS Revisions (optional)
KMSC 02-05	Jackson	---------	within limits	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 02-17	Harrison	---------	341	Used topo to confirm that the inundation limits generally followed the 10- to 15-ft contours on both sides of the Bay. Existing data matched up pretty well with topo through here.	Wrack line taken at road. Imagery and topo match up pretty well for inundation at 10 to 15 ft.	Adjusted DL slightly. Inland flood poly still doesn't match contours well but it does match up with aerials.	
KMSC 02-18	Harrison	---------	within limits	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 02-20	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 02-22	Harrison	657	---------	Made DL follow 15-ft contour closer through here.	Directly east and west of here, line follows 15-ft contour better. Flaggers noted wrack line at this point.	Altered DL so it closely follows 15-ft contour.	
KMSC 02-24	Harrison	---------	3700 (inside flood polygon)	See note for 02-17		Adjusted DL slightly. Inland flood poly still doesn't match contours well but it does match up with aerials.	
KMSC 02-41	Jackson	7922	---------	Used 10-ft and 15-ft contour topo as guide to make an inundation polygon here. Make it generally follow between two lines, but try to include this point in boundary.	Flaggers noted wrack line on the ground at this location. GIS water body coverage shows some water here closer to shore.	Created a new inland flood poly following 10-to 15-ft contours beginning at the DL.	
KMSC 03-07	Harrison	498	498	No action.	Debris line drawn is more conservative. Inland flooding extends beyond debris line. Area is pretty flat.		
KMSC 03-09	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 03-10	Jackson	6311	---------	Left debris line and inundation polygon beyond it as it was.	Appears there is a ridge near the shore where elevation increases; this is where WWL point is. But surge could have easily gotten behind ridge according to topo if it wasn't in fact overtopped. Existing debris line shows debris and flooding went beyond ridge further inland - more conservative.		
KMSC 04-07	Hancock	---------	7200	No action.	With three points (also 06-05) taken along road as edge of surge, good corroboration that surge came ended here. However, there are other routes for the water to get behind the road and topo supports that it is a low area behind the roadway.		
KMSC 04-33	Harrison	357	---------	15-ft contours from state and photointerpreted data match pretty well through here. Made debris line follow these lines better through here and get close to two points taken.	04-33 wrack line on ground 10-53 pictures show clear wrack line adjacent to road (Exit 2 ramp on I-110). Line is not consistent through here with topo. Need to move closer to 15-t contour line through here.	Moved DL north to closely follow 15-ft contour.	
KMSC 05-22	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 05-24	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 05-25	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 05-26	Harrison	501	---------	Moved debris line to follow along road (~25-ft contour). Used imagery to guide.	Points taken at roadway where debris line was found by flaggers. Please take a look to make sure it matches up.	Moved portion of DL to follow road and 25-ft contours.	
KMSC 05-28	Harrison	333	---------	Moved debris line to follow along road (~25-ft contour). Used imagery to guide.	Points taken at roadway where debris line was found by flaggers. Please take a look to make sure it matches up.	Moved portion of DL to follow road and 25-ft contours.	
KMSC 05-29	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 06-01	Hancock	---------	1860	Extended inundation from south up towards 15- to 20-ft contour through here, both west (~7,000 ft) and east (~3,000 ft) of point.	Flooding at higher point from flagger info indicates inundation is probably undermapped through here.	Extended inland flood poly north towards 15-to 20-ft contour.	
KMSC 06-04	Hancock	---------	200	No action.	Very close to edge of inundation polygon.		
KMSC 06-05	Hancock	---------	6450	Extended inundation up through here following outer edge of 10-ft contours.	Evidence from flaggers that water inundated this area.	Extended inland flood poly following 10-ft contours.	
KMSC 06-06	Hancock	---------	3000	No action.	With three points (also 06-05) taken along road as edge of surge, good corroboration that surge ended here. However, there are other routes for the water to get behind the road and topo supports that it is a low area behind the roadway.		
KMSC 06-07	Hancock	---------	2700	Pulled inundation polygons back to better follow these two points and 30-ft contour (from EarthData) through here. .	With two points at similar elevation near each other, good support for trimming this inundation polygon back.	Extended inland flood poly so that it more closely matches contour lines (also compared to aerials).	
KMSC 06-09	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 06-10	Harrison		---------	See note for 02-17		Adjusted DL slightly. Inland flood poly still doesn't match contours well but it does match up with aerials.	

*This point's location data was determined unreliable. KMSC-08-19 and 10-49 are not show on on the maps.
**Riverine flooding at point determined to be beyond WWL.

ID Number	County	Distance to DL (ft)	Distance to Flood Boundary (ft)	Action	Explanation	GIS Comments (optional)	GIS Revisions (optional)
KMSC 06-16	Jackson	2500	---------	No action.	WWL is near coast of peninsula like feature. Don't believe that it was really edge of inundation/flood damage. Flagger noted surge was ~21 through here. This probably shouldn't have been marked as WWL point.		
KMSC 07-21	Harrison	1047	---------	Made DL follow 20-ft contour more closely through here.	Directly east and west of here, line follows 20-ft contour better. Flaggers noted water line with shallow flooding (<1ft).	Altered DL so it closely follows 20-ft contour.	
KMSC 07-28	Jackson		2630	Used HWM data along with contours to draw an appropriate inundation boundary on west side of this inland flood area (Pascagoula River). Majority of points seem to indicate flooding reached elevations of 10-15 ft. Let's see what HWMs say. For east side, seems like boundary follows contours (~10 ft) pretty well, probably in part because it's flatter on that side.	WWL points seem to match similar elevations as shown on contours through here (10- to 15-ft).	Altered inland flood poly to more closely match 10-to 15-ft contours (used aerials also).	
KMSC 08-02	Jackson	402	---------	No action.	Imagery supports existing delineation and it is also more conservative (further inland) than field data points.		
KMSC 08-03	Jackson	339	---------	No action.	Imagery supports existing delineation and it is also more conservative (further inland) than field data points.		
KMSC 08-05	Jackson	---------	within limits	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 08-06	Jackson	---------	931	Used HWM data along with contours to draw an appropriate inundation boundary on west side of this inland flood area (Pascagoula River). Majority of points indicated flooding reached elevations of 10-15 ft. For east side, boundary followed contours (~10 ft) pretty well, probably in part because it's flatter on that side.	WWL points seem to match similar elevations as shown on contours through here (10- to 15-ft).	Altered inland flood poly to more closely match 10-to 15-ft contours (used aerials also).	
KMSC 08-08	Jackson	9638	6995	Add an inland flood polygon here to include this point on Davis Bayou. Used point, 5-ft topo, and imagery to develop inundation polygon. Also, flaggers noted "Mr. John James states that there was 1-2' of water in highway at approximately 12 noon for just a few minutes." This is Hwy 90 where point is located.	Water body (Davis Bayou) is located here and WWL point indicates flooding near upper end of drainage area along Route 90. Witness (see flagger info) corroborated that there was flooding this far inland.	Add new inland flood poly around river using 5-ft contours.	Extended inland flood poly to 15-ft contours to match point elevation.
KMSC 08-15	Harrison	315	---------	Made line follow 20-ft contour more closely through here.	Debris line crosses topo a lot through here. 08-15 witness to flood/debris extent at this point. 15-05 wrack line on ground.	Altered DL so it closely follows 20-ft contour.	
KMSC 08-16	Harrison	1650	---------	Made line follow 15- to 20-ft contour. Move inland significantly.	Two points corroborating that surge/bay flooding came here. Levels were 20 ft on Gulf side. Debris line follows 15-ft contour pretty closely along rest of back bay.	Moved DL south/inland so it closely follows 20-ft contour.	
KMSC 08-17	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 08-18*	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 08-19*	Jackson	6384	---------	See note for 02-41. Point located along same general water body, but closer to coast.	See note for 02-41.		
KMSC 09-14	Harrison	---------	282	Moved debris line to follow along road (between 20- to 25-ft contour).	East and west of here, debris line is at ~22 ft, following the contours. Point taken on gulf side of road/railroad. Flaggers noted debris line.		
KMSC 09-28	Harrison	within limits		No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 10-07	Jackson	---------	130	Used HWM data along with contours to draw an appropriate inundation boundary on west side of this inland flood area (Pascagoula River). Majority of points indicated flooding reached elevations of 10-15 ft. For east side, original inundation boundary followed contours (~10 ft) pretty well, probably in part because it's flatter on that side.	WWL points seem to match similar elevations as shown on contours through here (10- to 15-ft).	Altered inland flood poly to more closely match 10-15 contours (used aerials also)	
KMSC 10-08	Jackson	---------	2061	Used HWM data along with contours to draw an appropriate inundation boundary on west side of this inland flood area (Pascagoula River). Majority of points indicate flooding reached elevations of 10-15 ft. For east side, boundary follows contours (~10 ft) pretty well, probably in part because it's flatter on that side.	WWL points seem to match similar elevations as shown on contours through here (10- to 15-ft).	Altered inland flood poly to more closely match 10-15 contours (used aerials also)	
KMSC 10-23	Jackson	---------	n/a	Sub-drainage area here where inundation polygon was added. Photointerpreted data and state topo don't match very well right around here so really used CHWMs to get some elevation data.	WWL flaggers note water line on garage about 2 ft above garage floor. Topo supports low area here where flooding would have come up.	Used aerials and state contours to extend inland flood poly.	Extended inland flood poly to 10-ft to match point elevation.

*This point's location data was determined unreliable. KMSC-08-19 and 10-49 are not show on on the maps.
**Riverine flooding at point determined to be beyond WWL.

Hurricane Katrina

Mississippi

Notes on Comparison of WWL Data Points to Photointerpreted Data

ID Number	County	Distance to DL (ft)	Distance to Flood Boundary (ft)	Action	Explanation	GIS Comments (optional)	GIS Revisions (optional)
KMSC 10-37	Harrison	---------	2000 (inside flood polygon)	See note for 02-17		Adjusted DL slightly. Inland flood poly still doesn't match contours well but it does match up with aerials.	
KMSC 10-44	Harrison	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 10-46	Jackson	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 10-47	Jackson	within limits	---------	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 10-48	Harrison	451	---------	Added inundation polygon here. Clearly, flooding beyond debris line. Used HWMs and aerial imagery as guide.	Water line 5 ft off the ground noted at this point.	Created new inland flood poly using contours and aerials.	
KMSC 10-49*	Harrison	---------	900	Looked at imagery and did a QC of what photointerpreters drew. Left as it was.	Points fall inside of inundation area. Flagger noted that flood depth at point is ~4 feet. Shouldn't have been marked as edge of WWL.	Majority of inland flood poly looks correct. Expanded slightly southeast of point.	
KMSC 10-50	Harrison	---------	600	No action.	Points fall inside of inundation area. Flagger noted that flood depth at point is ~3 feet. Shouldn't have been marked as edge of WWL.		
KMSC 10-53	Harrison	733	---------	15-ft contours from state and photointerp data match pretty well through here. Made debris line follow these lines better through and get close to two points taken.	04-33 wrack line on ground 10-53 pictures show clear wrack line adjacent to road (Exit 2 ramp on I-110). Line is not consistent through here with topo. Need to move closer to 15-t contour line through here.	Moved DL north to closely follow 15-ft contour.	
KMSC 10-57	Hancock	---------	2661	Extended inundation polygon out to correspond to fan shape of topo. Used 5- to 10-ft contours as outer limits.	Flagger noted high water extended out to here and had witness verification.	Extended inland flood poly west towards 5-to 10-ft contours.	
KMSC 10-64	Harrison	---------	within limits	No action.	Data point agreed with photointerpreted debris line/inundation polygon.		
KMSC 10-73	Harrison	---------	n/a	Point itself is ok. Checked adjacent area and decided to add inundation.	Existing inundation area doesn't match topo. 'Cut out' shape seems wrong.	Altered DL and inland flood poly slightly. Matches well to aerials.	
KMSC 10-74	Hancock	---------	1600	Pulled inundation polygons back to better follow these two points and contours through here. Look at area just west of 06-07 on imagery. Inundation is not following topo well through here, so compared to imagery.	With two points at similar elevation near each other, good support for trimming this inundation polygon back.	Extended inland flood poly so that it more closely matches contour lines (also compared to aerials).	
KMSC 10-75	Hancock	---------	700	Moved inundation limit to better follow 20-to 30-ft contours through this area.	Topo and inundation polygon do not match very well. Wrack line is at about 15-20 from flaggers, but at more than 40 from topo.	Moved inland flood poly so it closely follows 20-to 30-ft contours.	
KMSC 15-02	Harrison	1784	---------	Made line follow 15- to 20-ft contour. Moved inland significantly.	Two points corroborating that surge/bay flooding came here. Levels were 20 ft on Gulf side. Debris line follows 15-ft contour pretty closely along rest of back bay.	Moved DL south/inland so it closely follows 20-ft contour.	
KMSC 15-04	Harrison	within limits	---------	No action.	Originally point had wrong lat/long associated with it. Problem has since been fixed but could not use for mapping.		
KMSC 15-05	Harrison	333	---------	Made line follow 20-ft contour more closely through here.	Debris line crosses topo a lot through here. 08-15 witness to flood/debris extent at this point. 15-05 wrack line on ground.	Altered DL so it closely follows 20-ft contour.	
KMSR 02-01**	Hancock	3049	---------	Extended inundation polygon to include point in this area. Checked imagery to confirm. However, later confirmed that this point was beyond WWL (riverine flooding).	Flaggers noted wrack line 'Looking south, west side of bridge at Canal 3 and Beatline Rd.'	Extended inland flood poly to point following river bank.	
KMSR 10-01	Jackson	---------	900	No action.	Seaward of existing DL. Other nearby points support existing delineation.		
KMSR 10-02	Jackson	---------	979	Used HWM data along with contours to draw an appropriate inundation boundary on west side of this inland flood area (Pascagoula River). Majority of points indicate flooding reached elevations of 10-15 ft. For east side, boundary follows contours (~10 ft) pretty well, probably in part because it's flatter on that side.	WWL points seem to match similar elevations as shown on contours through here (10- to 15-ft).	Altered inland flood poly to more closely match 10-to 15-ft contours (used aerials also).	
KMSR 10-03**	Jackson	---------	n/a	Extended inundation polygon into this area. Used 5-ft contour data and WWL points as guide. Made inundation at 5-7 ft through here. However, later confirmed that this point was beyond WWL (riverine	Clearly there was inundation in this area based on 4 points taken by flaggers.	Extended inland flood poly north using 5-to 7-ft contours.	
KMSR 10-04**	Jackson	---------	n/a	Extended inundation polygon into this area. Used 5-ft contour data and WWL points as guide. Made inundation 5-7 ft through here. However, later confirmed that this point was beyond WWL (riverine flooding).	Clearly there was inundation in this area based on 4 points taken by flaggers.	Extended inland flood poly north using 5-to 7-ft contours.	
KMSR 10-05**	Jackson	---------	n/a	Flaggers noted "Debris line in creek banks below bridge level" inundation stayed close/within stream banks. Used aerials for guidance to map inundation along stream banks. However, later confirmed that this point was beyond WWL (riverine flooding).	Clearly there was inundation in this area based on 4 points taken by flaggers. But MS 5-ft contours don't make sense through here. They go from elevation 10 to 30.	Not enough information to extend inland flood poly to this point. Did not alter.	
KMSR 10-06**	Jackson	---------	n/a	Flaggers noted "Debris line in creek banks below bridge level" inundation stayed close/within stream banks. Used aerials for guidance to map inundation along stream banks. However, later confirmed that this point was beyond WWL (riverine flooding).	Clearly there was inundation in this area based on 4 points taken by flaggers. But MS 5-ft contours don't make sense through here. They go from elevation 10 to 30.	Extended inland flood poly north using stream as guide.	Deleted extension of inland flood poly.

*This point's location data was determined unreliable. KMSC-08-19 and 10-49 are not show on on the maps.

**Riverine flooding at point determined to be beyond WWL.

ID Number	County	Distance to DL (ft)	Distance to Flood Boundary (ft)	Action	Explanation	GIS Comments (optional)	GIS Revisions (optional)
KMSR 10-09**	Harrison	---------	n/a	Extended inundation polygons northward to reach up to this area. Used topo and imagery as guide (30-ft contours). However, later confirmed that this point was beyond WWL (riverine flooding).	Flaggers found debris line up here. Flooding was further north than originally shown on maps. However, later determined it was not surge/coastal flooding.	Extended inland flood poly to point using 20-to 30-ft contours.	
KMSR 10-11**	Jackson	---------	n/a	Extended inundation polygon eastward to include point. Rounded out inundation at 10-15 ft through this area. However, later confirmed that this point was beyond WWL (riverine flooding).	Flaggers noted wrack line on the ground at this location. However, later determined it was not surge/coastal flooding.	Extended inland flood poly to 15-ft contour at point and surrounding areas.	
KMSR 10-15**	Hancock	---------	n/a	Extended inundation up through this drainage area to include point at elevation 35. Confirmed with HWM data that this elevation is in the right ball park. However, later confirmed that this point was beyond WWL (riverine flooding).	Inundation mapping ends downstream/south of here but point indicated flooding went further upstream. However, later determined it was not surge/coastal flooding.	Extended inland flood poly north in the drainage basin using aerials and contours.	
KMSR 10-16	Hancock	---------	600	No action.	Point taken at high point on bridge so wouldn't be 'edge' on inundation.		
KMSR 10-17	Hancock	---------	1300	No action.	Point taken at bridge, could be high point, where inundation continued on. Existing inundation is more conservative.		
KMSR 10-21	Harrison	---------	370	No action.	Point falls inside inundation polygon. Point was taken on bridge, which is a high point in the area, so flooding would have also been occurring at lower points around the bridge.		

*This point's location data was determined unreliable. KMSC-08-19 and 10-49 are not show on on the maps.
**Riverine flooding at point determined to be beyond WWL.

Appendix F: WWL Maps

Appendix F contains the WWL Maps that illustrate the location of the Wind Water Line. Summaries of the WWL by community are found in Table 5 of the main report, which also highlights which of the following map sheets correspond to each community.