Hurricane Rita Rapid Response Wind Water Line Report – Louisiana

Task Order 447

February 28, 2006 (Final)

FEMA

Hazard Mitigation Technical Assistance Program
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Hurricane Rita Rapid Response
Wind Water Line (WWL) Data Collection – Louisiana
FEMA-1607-DR-LA

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
DNU	Do not use
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
mb	Millibar
mph	Miles Per Hour
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NGVD 29	National Geodetic Vertical Datum of 1929
NHC	National Hurricane Center
NUAR	Not Used After Review
NWI	National Wetlands Inventory
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 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	Ground elevation data displayed as continuous lines for given elevations.
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 collected.
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.
Flagger	Member of field team tasked with locating HWMs and WWL data points, marking them, and performing general data collection. Flaggers were out in the field within a week of the event.
Flood recovery map	High-resolution maps that show flood impacts, including high water mark flood elevations, flood inundation limits, the inland limit of waterborne debris (trash lines), and storm surge elevation contours based on the high water marks. 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

Word	Definition
	geometry and the same attributes. A feature dataset is a collection of feature classes sharing the same spatial reference.
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
High Water Mark	Indicators of high water levels found on the ground or on structures. Examples are debris lines, wrack lines, and mud lines.
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	LiDAR (Light Detection and Ranging or Laser Imaging Detection and Ranging) is a technology that determines distance to an object or surface using laser pulses. Similar to 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.
Mud line	Type of high water mark found on structures. Occurs when suspended solids carried by floodwaters are deposited along the walls, doors, etc. of structures leaving an indicator of the peak flood level.
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 widely used in the U.S. prior to the establishment of NAVD 88.
North American Datum of 1983	Horizontal datum used as the standard map coordinate system default by the majority of GPS devices.
North American Vertical Datum of 1988	The most widely used vertical control datum in the U.S. today; it was officially established in 1991 by the minimum-constraint adjustment

Word	Definition
	of the Canadian-Mexican-U.S. leveling observations.
Orthorectified	Orthorectification removes the effects of relief displacement and imaging geometry from aerial photographs.
Polygon	A polygon, in ArcGIS, is 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 States 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 among the applicants.
Riverine flooding	Occurs when rivers and streams overflow their banks.
Seed file	Seed files are used within software applications and serve as templates in which standard file parameters are set to predetermined standards.
Shapefile	Shapefiles store 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 is located along the debris line, but in some cases, inundation and flood damage extends 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

The 18th tropical depression of the 2005 Hurricane Season formed on September 17 to the east of the Turks and Caicos Islands. It then became the 17th tropical storm of the season on September 18 less than a day after forming and was named Rita. On September 18, a mandatory evacuation was ordered for the entire Florida Keys.

As Rita moved westward over the next couple days, it was slow to become a hurricane. National Hurricane Center (NHC) discussions issued early on September 20 indicated that while some wind measurements suggested Rita might have surface level wind speeds of 74 miles per hour (mph), or 144 knots, the lack of a complete eyewall did not support the hurricane designation. Therefore, the NHC continued to designate Rita as a tropical storm with 70 mph (136 knots). However, Rita did gain strength and by 11:00 a.m. EDT on September 20, it was designated a Category 2 strength hurricane with 100 mph (194 knots) maximum sustained winds. Rita stayed a Category 2 for the rest of the day on September 20, but began increasing in intensity rapidly on September 21. By 5:00 p.m. EDT on September 21, Hurricane Rita was a Category 5 storm with maximum wind speeds of 165 mph (321 knots). Rita continued to strenghten and by the night of September 21, its maximum sustained winds had increased to 175 mph (340 knots) with an estimated minimum pressure of 897 millibars (mb).

After peaking with steady winds of 175 mph (340 knots), Rita made landfall on September 24, between Sabine Pass, TX, and Johnson’s Bayou, LA, as a Category 3 hurricane with windspeeds of 120 mph (233 knots) and a storm surge of 10 feet, or 3 meters (m). Figure 1 shows Rita’s path beginning on September 18, 2005 and ending on September 25 a day after making landfall.

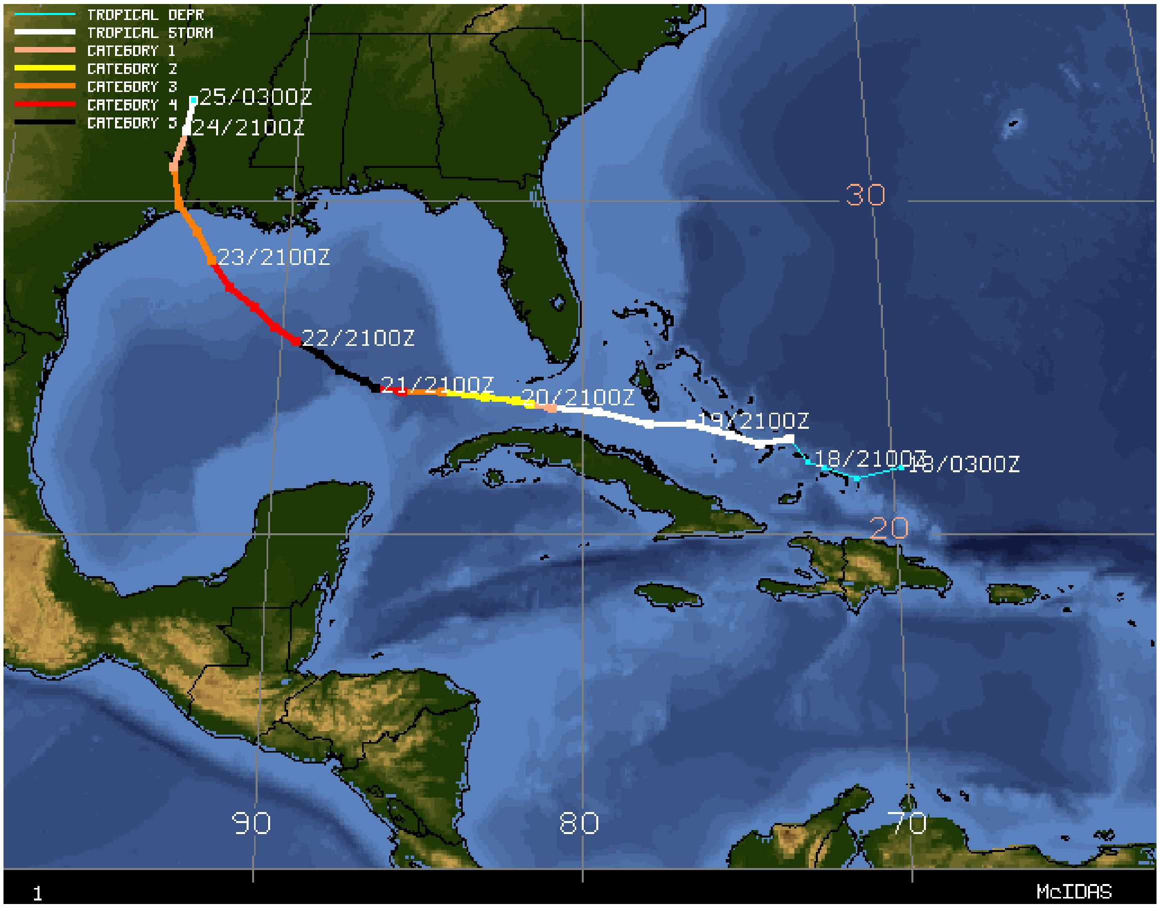

Figure 1: Hurricane Rita Storm Track
Source: http://cimss.ssec.wisc.edu/tropic/archive/2005/storms/rita/rita.html

Overview of Impacts in Louisiana

On September 24, 2005, the President authorized a disaster declaration for several Louisiana parishes (FEMA-1607-DR-LA). Through subsequent amendments, all 64 of Louisiana's parishes were eventually included in the declaration, which provided the necessary assistance to meet immediate needs and to help Louisiana 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, Public Assistance 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 (hotel or motel expenses reimbursement, 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): funds projects that will reduce or eliminate losses from future disasters by providing a long-term solution to a problem. Eligible applicants include State and local governments, Indian tribes or other 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 Louisiana Parishes are eligible for HMGP funds. Tables 1 through 4 provide listings of which designation(s) each parish received for IA and PA. Figure 2 shows these designations graphically.

Table 1: Parishes Designated Only for Public Assistance, Categories A and B Only

Assumption	Avoyelles	Bienville	Bossier
Caddo	Caldwell	Catahoula	Claiborne
Concordia	East Baton Rouge	East Carroll	East Feliciana
Franklin	Grant	Iberville	Jackson
La Salle	Lincoln	Madison	Morehouse
Orleans	Ouachita	Point Coupee	Red River
Richland	St. Bernard	St. Charles	St. Helena
St. James	St. John the Baptist	Tangipahoa	Tensas
Union	Washington	Webster	West Carroll
West Feliciana	Winn		

Table 2: Parishes Designated Only for Public Assistance, All Categories

De Soto	Natchitoches	Rapides

Table 3: Parishes Designated for Both Individual Assistance and Public Assistance, Categories A and B Only

Ascension	Jefferson	Lafourche	Livingston
Plaquemines	St. Martin	St. Tammany	West Baton Rouge

Table 4: Parishes Designated for Both Individual Assistance and Public Assistance. All Categories

Acadia	Allen	Beauregard	Calcasieu
Cameron	Evangeline	Iberia	Jefferson Davis
Lafayette	Sabine	St. Landry	St. Mary
Terrebonne	Vermillion	Vernon	

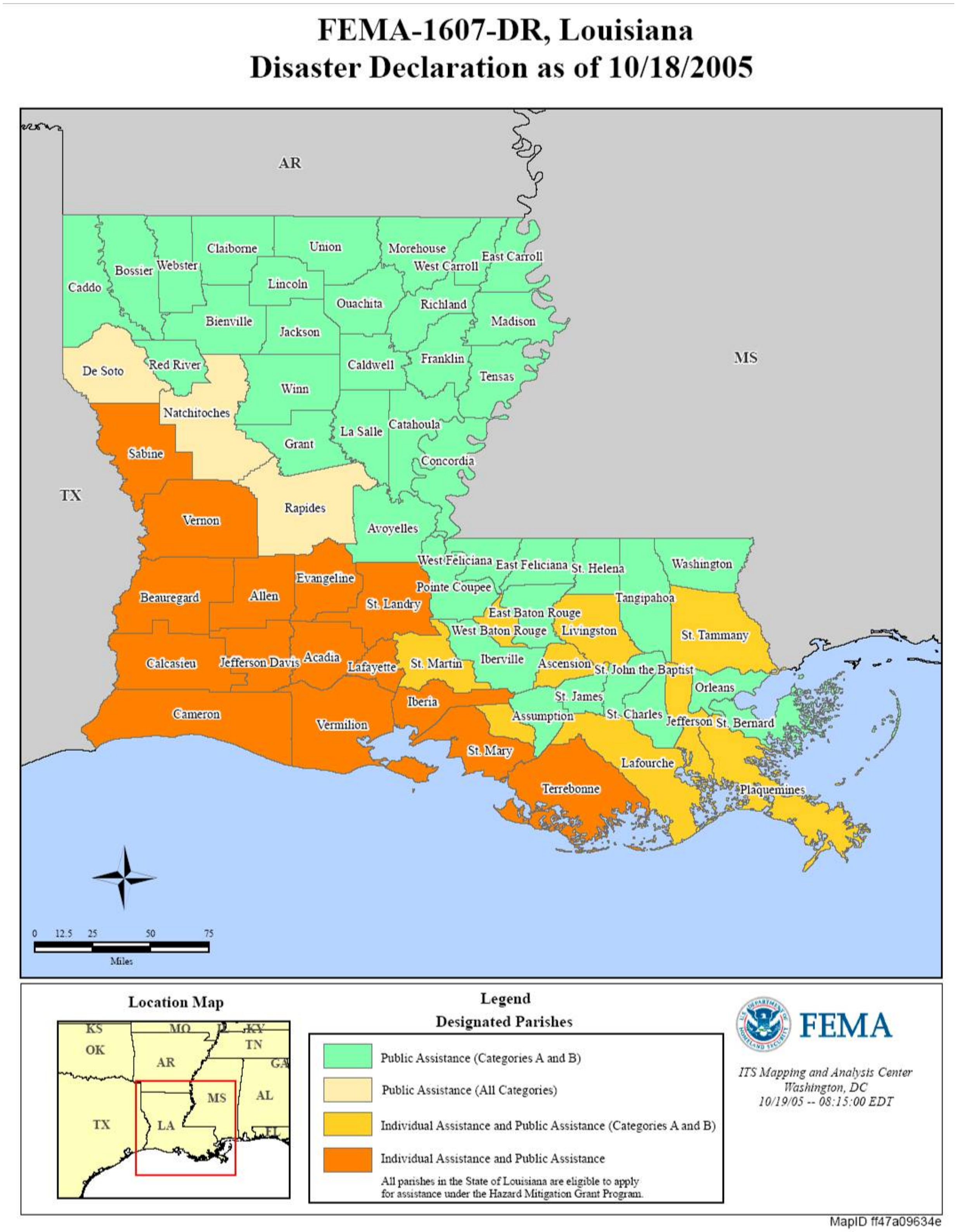

Figure 2: FEMA-1607-DR-LA Disaster Declaration

According to reports on the website for Wikipedia (http://en.wikipedia.org) which cite several established news sources including CNN, in southwestern Louisiana, severe damage was reported. In Cameron Parish, communities including Hackberry, Cameron, Creole, Grand Chenier, and Holly Beach either suffered heavy damages, or destruction. In Calcasieu County, a casino boat and several barges, floated unmoored in Lake Charles and damaged a bridge spanning Interstate 10 across the Calcasieu River. In the Lake Charles area, floodwaters reportedly rose to 6 to 8 feet.

According to FEMA's Public Information Officer (PIO) for Louisiana, Cameron, Calcasieu, and Vermilion Parishes sustained heavy damage to infrastructure. Widespread flooding was reported along other coastal parishes further east, including Terrebonne Parish where virtually every levee was breached.

The levee system in New Orleans was already heavily damaged from Hurricane Katrina before heavy rains from Rita began to fall on the city. Along the damaged Industrial Canal levee, rising water was already pushing through two of the levees' patched breaches by approximately 9:00 a.m. CDT on September 23, and into the already devastated Ninth Ward. By 11:00 a.m. CDT, water was reportedly waist-deep. By late afternoon, water was pouring through another patched breach in the London Avenue Canal and into the Gentilly neighborhood. By the night of September 24, water from a 150-foot wide breach in the Industrial Canal levee resulted in flooding of up to 8 feet in some areas of the Ninth Ward.

In New Orleans, there was also extensive damage to the Louis Armstrong New Orleans International Airport and to the city's electrical system. In Baton Rouge, approximately 30 bridges were damaged as a result of Rita.

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. Wind Water Line (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 Federal Emergency Management Agency's (FEMA's) National Flood Insurance Program (NFIP) requires data to identify flood damages to provide a valid basis for establishing eligibility of flood insurance benefits. Information for insurance purposes is time-critical because the flood insurance and homeowner insurance claims cannot be concluded until the cause of damage is established. The WWL data provide a basis for delineating areas subject to flooding and help to identify approximate boundaries between areas where damages are due to flooding and wind versus areas of wind-only damages. FEMA uses these data to provide inundation boundaries and information on the flooding extent along the affected shoreline areas.

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

- Human Services: provides advice to individuals on how to use Federal grants to increase their homes' flood resistance;
- Public Assistance (PA): identifies appropriate flood mitigation measures to pursue when providing Federal grants to repair publicly owned infrastructure; and
- Hazard Mitigation Grant Program (HMGP): ensures that accurate benefit/cost analysis is performed.

The purpose of the Wind Water Line (WWL) Study is to determine the inland extent of damages caused by storm surge-induced flooding, and to differentiate this area from those farther inland where damages were primarily the result of wind forces. By delineating the WWL, an approximate boundary is created between 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 surge flooding did not have a significant impact. Sometimes, the Wind Water Line is located along the debris line, but in some cases, inundation and flood damages extend beyond the area where major debris was deposited.

The WWL study extended from the northern portion of the Gulf Coast of Texas eastward through southwestern Louisiana. This report focuses on the determinations based on data collected in Louisiana, where the entire coastline was studied. Figure 3 shows the WWL Study Area within Louisiana.

Figure 3: Study Area

Overview of Related Projects

URS Corporation, with support from Government Services Integrated Process Team, LLC (GSIPT), was tasked by FEMA under their existing Hazard Mitigation Technical

Assistance Program (HMTAP) contract to assist in disaster recovery efforts for Hurricane Rita. Assistance provided by this Task Order included data collection and visual survey of the debris line and the extent of flooding to identify the WWL.

After Hurricane Rita, FEMA issued several task orders under the HMTAP contract called Rapid Response Task Orders. Generally, the purpose of these task orders is 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 then can be used for future studies and flood mitigation activities. In addition to the Wind Water Line Task Order, there are several other types of Rapid Response Task Orders, including Aerial Imagery Data Collection, Coastal High Water Mark (CHWM) Surveys, and Riverine High Water Mark (RHWM) Surveys. High Water Mark Survey findings are used to define the extent of flooding and therefore can be used in conjunction with field findings from Wind Water Line 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 Rita, HMTAP Task Order 447, *Rapid Response, Hurricane Rita Wind Water Line – LA* was issued and is the focus of this report. In addition, HMTAP Task Order 443, *Rapid Response, Aerial Radar – Texas and Louisiana;* HMTAP Task Order 445, *Rapid Response, Hurricane Rita Coastal High Water Mark Survey – LA;* and HMTAP Task Order 450, *Rapid Response, Hurricane Rita Riverine High Water Mark Survey – LA* were also issued. An overview of these task orders is provided below:

- Under Task Order 443, *Rapid Response, Aerial Radar – Texas and Louisiana*, cartographic analysts were tasked with using post-event aerial imagery to delineate areas affected by flooding along the western edge of Louisiana's Gulf Coast and the northeast portion of Texas' coastline.

- Through Task Order 445, *Rapid Response, Hurricane Rita Coastal High Water Mark Survey - LA*, field crews collected perishable HWM data at field observation 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 Louisiana were recorded at several locations as part of this task order. This data can be used to help determine the extent of flooding.

- For Task Order 450, *Rapid Response, Hurricane Rita Riverine High Water Mark Survey – LA*, field crews also collected high water mark data at field observation point locations. Field crews for the RHWM survey 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. Riverine HWMs can be used to help delineate the extent of surge flooding by showing where riverine flooding predominates.

In addition, comparison of WWL data with the impacts projected by modeled storm events provides insight into how well numerical models simulate a specific event (e.g., coastal storm surge, riverine flooding). When coupled with sufficient data density and observational information, it is possible to create flood recovery maps, which are high-resolution maps that show flood impacts, including HWM flood elevations, flood inundation limits, the inland limit of waterborne debris (trash lines), and storm surge elevation contours based on the HWMs. These event-related data can be used in conjunction with or, in some cases, instead of, effective Flood Insurance Rate Map (FIRM) data to establish recommended coastal flood elevations for redevelopment and rebuilding purposes.

In Louisiana, data collected through several HMTAP rapid response Task Orders are being used in Task Order 436 *Flood Data Analysis - Louisiana*, to develop the Hurricane Rita Surge Inundation and Advisory Base Flood Elevation Maps, commonly referred to as “Rita Recovery Maps.” Specifically, the Rita Recovery Maps were created from data from this WWL Task Order, *Rapid Response, Hurricane Rita Coastal High Water Mark Survey – Louisiana* and Task Order 450, *Rapid Response, Hurricane Rita Riverine High Water Mark Survey – LA*. The data are being used to develop event-related themes that document the storm’s impacts along the Louisiana coast where HWMs showed that Rita's surge flooding was greater than that of Katrina. Superimposed on the event themes will be Advisory Base Flood Elevations (ABFEs), determined from a flood-frequency analysis of several hurricanes that have affected the area. The Rita Recovery Maps will help to guide decisions about reconstruction in the areas affected by surge flooding from Hurricane Rita (where this surge flooding was greater than caused by Hurricane Katrina) along Louisiana’s coastal floodplain.

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 Rita, 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 were mobilized within seven days of the disaster declaration. Field teams tasked with locating HWMs, marking them, and performing general data collection were called ‘flaggers’ and they began field work on October 1, 2005 continuing through October 19. Surveying teams followed the flaggers surveying the already identified points from October 27 through December 5. Data collection for Task Order 447, *Rapid Response, Hurricane Rita Wind Water Line – LA* was performed in tandem with data collection for Task Order 445, *Rapid Response, Hurricane Rita Coastal High Water Mark Survey – LA* and Task Order 450, *Rapid Response, Hurricane Rita Riverine High Water Mark Survey – LA*. 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 extent inland of where there is damage to structures caused by surge flooding. Thus the points generally form a line showing the approximate inland limit of surge flooding. The Wind Water Line 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 high wind damage. Seaward of the line, damage is the result of surge-induced flooding with wind forces contributing as well (see Figure 4).

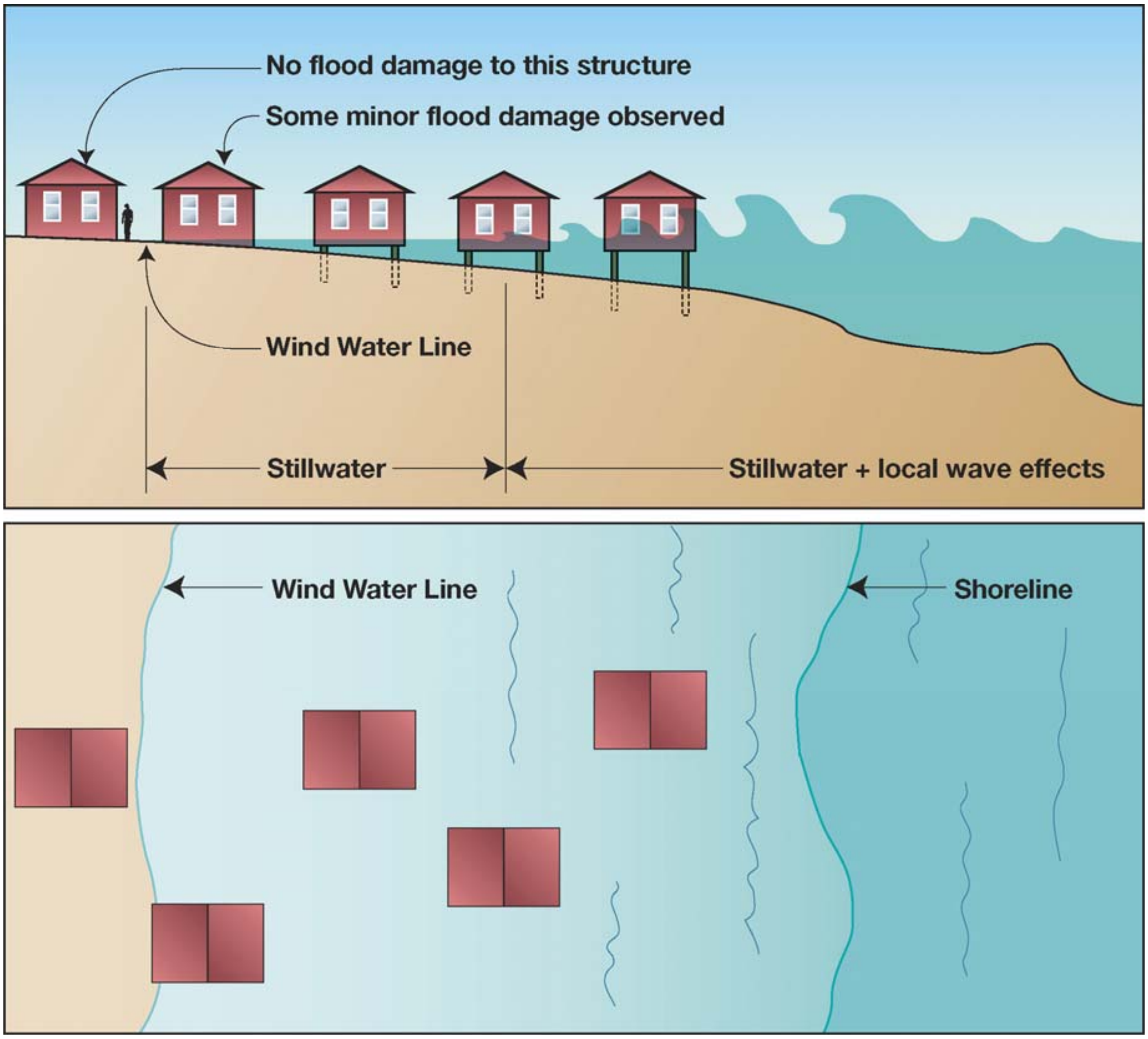

Figure 4: Wind Water Line Illustration (Profile View/Plan View)

Each field crew was tasked with identifying and documenting the WWL and collecting pertinent data points along the coastlines. The WWL were documented using a standardized flagger form to collect detailed information about the point. To define points along the WWL, field crews visited areas of known flood damage. Traveling away from the coast to the edge of damage, they attempted to locate debris fields (see Figure 5) or water marks close to the ground, and to trace them along topographic features to determine the extent of flooding (see Figure 6) and flood damages.

Figure 5: Example Debris Field

Figure 6: Example Water Marks[1]

[1] This HWM illustrates the concept of a water mark on a structure, but would be too high to be considered a WWL data point.

Field crews notified County Emergency Managers prior to the start of fieldwork in order 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 greater attention.

Generally, WWL data were collected every two to four miles in developed areas inland. However, in areas with significant damage to structures from flooding along the coastlines, the density of data points was sometimes higher. Similarly, there were certain stretches of coastline where field crews could not take data points 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.

The following data were collected at each observed WWL point:

- Address (if the point was near an addressable structure);
- Latitude/longitude reading, taken in North American Datum (NAD) 1983, which is used as the standard map coordinate system default by the majority of Global Positioning System (GPS) devices;
- Location description (e.g., neighborhood 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), etc.;
- Type and severity of observed wind damage;
- Flood source;
- Approximate flood depth (if water mark data point); and
- Digital photographs (named according to the WWL point identification number; see Appendix B[2]).

The data points were labeled with HWM IDs. These alphanumeric labels consist of four letters: the first letter indicates the storm name, the second and third letters are the state abbreviation, and the fourth letter is either a ‘C’ for coastal or an ‘R’ for riverine type flooding. These 4 letters are followed by a two-digit code indicating the team number, and another two-digit code indicating the point number for that particular team. Therefore, a coastal flooding type data point in Louisiana for Rita that was the third point taken by Team 2 would be labeled RLAC-02-03. However, some points labeled ‘C’ were actually later determined to be riverine and likewise some points labeled ‘R’ were later determined to be coastal type flooding. Therefore, whenever there is an ‘R’ point followed by (coastal) or a ‘C’ point followed by (riverine), the flood type listed in parentheses is the correct reference.

Data had to be collected quickly; as community clean-up efforts progressed, valuable debris line and water mark data were being destroyed. WWL data were entered into a database (Appendix A). Each photograph was named according to the WWL point reference number (Appendix B).

[2] The SD memory cards containing some of the images became corrupt, and as such, the images on them were unrecoverable. For this reason, images for 25 of the WWL points are not available.

After the WWL data points were compiled and checked for accuracy, they were surveyed for elevation. Geographic information systems (GIS) analysts worked with the data to make geodatabases and create associated shapefiles.

Mapping Methodology

To create the Wind Water Line maps, the project team relied heavily on data supplied from HMTAP Task Orders 443, *Rapid Response*, *Aerial Radar – Texas and Louisiana*; *444*, *Rapid Response, Hurricane Rita Coastal High Water Mark Survey – LA*; and 450 *Rapid Response, Hurricane Rita Riverine High Water Mark Survey – LA.*

Under Task Order 443, *Rapid Response*, *Aerial Radar – Texas and Louisiana*, cartographic analysts used post-event aerial imagery to delineate areas affected by flooding along the Louisiana Coast. The analysts used natural color orthorectified 3001, Inc. imagery acquired between September 30, 2005 and October 9, 2005 for southwestern Louisiana including Calcasieu, Cameron, and Jefferson Davis Parishes. They 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 and causing additional flood inundation without major debris. The analysts also delineated riverine flooding that occurred near the coast in their analysis. A GIS coverage showing the approximate extent of flooding was created as part of this task order. A summary report for this effort is provided as Appendix C.

Through Task Order 445, *Rapid Response, Hurricane Rita Coastal High Water Mark Survey- LA*, field crews collected perishable high water mark data at field-observed, point locations. They looked for evidence of the peak elevation of flooding caused by storm surge, then inventoried and surveyed these elevations. HWM points were taken where surge directly affected flood levels, including the shoreline of open coasts, bays, and tidally influenced rivers. HWMs 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. HWM field crews are responsible for identifying these marks, and recording some basic information about the data point. Survey crews then used these initial records to later relocate the points and survey them to determine the peak elevation of flooding.

Under this task order, field WWL data points were used together with the information about the extent of flooding determined as part of the aerial imagery task order to determine the aerial measure of inundation based on both photointerpretation and field ground-truthed data. The inundation areas defined under Task Order 443, *Rapid Response, Aerial Radar – Texas and Louisiana* served as the 'base data' for determining the WWL, and the field data collected under this task order were compared to this base data to determine if the two data sets were in agreement. However, this base data was only available where post-event imagery was captured; the imagery was taken in southwestern Louisiana in Calcasieu, Cameron, and Jefferson Davis Parishes. In these areas, where WWL field data points did not agree with the photointerpreted flood area delineation, analyses using information about the depth of flooding and flood elevation for the WWL (and potentially for nearby HWM points) were conducted. If the flood elevation data and supporting documentation, including comments and photographs from the field crews, confirmed that the WWL point was correct, the inundation coverage was modified to agree with the field collected data and topography was used to delineate the boundaries for these modifications. Notes from these comparisons are included in tabular format in Appendix D and summarized by parish below.

Where the aerial imagery, and subsequently the photointerpreted debris line and inundation area, were not available, the WWL data from the flaggers were used in conjunction with local topography to delineate the WWL. This methodology was used in all areas west of Calcasieu, Cameron, and Jefferson Davis Parishes. The local topography was obtained from the Louisiana State University website at http://atlas.lsu.edu/. It is 2-foot contour data provided to the university by the Louisiana Oil Spill Coordinator's Office and was generated from LiDAR processed by 3001, Inc.

Additionally, the extent of flooding was defined not only by the WWL points, but also from data collected as part of the HWM surveys (Task Orders 445 and 450). In some areas, it was difficult to locate WWL points due to access issues, or because there was no clear physical evidence to define a WWL point. This happened particularly in swampy areas where it was not clear how far inland the surge had moved through the swamps. In these cases, the elevation data from the HWM surveys was used to complement the WWL data. The CHWM is a measure of the peak flood elevation from surge and, when used along with reliable topography 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) should be used since surge induced flood elevations generally increase towards the coastline. Additionally, in these swampy areas, a general coastal wetland coverage based on National Wetlands Inventory (NWI) data was developed to illustrate why WWL data points could not be located along portions of the southern coast of Louisiana.

Assumption

The WWL was created to follow the six-foot contour and include one of the two WWL points identified in Assumption Parish (RLAR-15-11). The lack of post-event imagery in this area prevented the photointerpreters from creating an inundation polygon. However, a review of the flagger forms, photos, and topography supported the delineation of the WWL to include the southern portion of Assumption Parish up to the six-foot contour.

The second point (RLAR-15-09) was located in the northern portion of Assumption Parish. Topography, location, and online imagery did not provide evidence that this area was affected by coastal surge. A review of flagger forms did not conclusively support coastal flooding at this point.

Calcasieu

Calcasieu Parish had 24 identified WWL points. Five of the identified WWL points in the parish were located within 200 feet of the photointerpreted inundation polygon, indicating the data sets were in agreement and that no further comparison between the five points and the photointerpreted data was necessary. Table 5 summarizes the WWL points in Calcasieu Parish and the changes required to the inundation polygon. See Appendices D and E for more information.

After a review of the flagger forms and photos, inundation polygon, imagery, and topography for the remaining 19 points, 5 WWL points located inside the inundation polygon were found not to represent the WWL. At these five points, the imagery and topography supported that flooding occurred further inland.

Table 5: WWL Data Points in Calcasieu Parish

WWL Points	Action	Explanation
RLAC-08-03 RLAC-08-04 RLAC-09-27 RLAC-12-06	Leave as is	Within 200' of the WWL and inundation polygon.
RLAC-03-03 RLAC-07-02 RLAC-08-02 RLAC-09-14 RLAR-02-05	No Action	WWL points located inside the inundation polygon. Flooding extended further inland.
RLAC-08-01 RLAC-09-15 RLAC-09-16 RLAC-09-18 RLAC-09-41 RLAC-10-02	Modify inundation polygon	Imagery and survey documentation supports extending the inundation polygon.
DNU-RLAC-02-11[1] DNU-RLAC-02-14[1] DNU-RLAC-08-07[1] RLAC-04-01 RLAC-09-42 RLAC-09-43 RLAC-09-44 RLAC-09-45 RLAR-09-19	After review, WWL points not used	WWL points located outside the inundation polygon.

1. DNU = Do Not Use. Designation given to HWM points after a QC check determined that the data point was unreliable.

A review of the flagger forms and photos, inundation polygon, imagery, and topography found that the inundation polygon at six points should be modified. At two points (RLAC-08-01 an RLAC-09-41), it was recommended to extend the inundation polygon to follow the 14-ft contour to include these points. At another point (RLAC-09-15), it was recommended that the inundation polygon be updated to follow the 10-foot contour. The recommendation for updating the inundation polygon at WWL point RLAC-09-16 was to extend the polygon northward along the tributary. The recommendation for the WWL point RLAC-09-18 was to extend the polygon west using the imagery as a guide to include the point. The recommendation for the sixth point (RLAC-10-02) was to remove an area from the inundation polygon to account for an area of higher elevation that was above flood levels.

A review of the inundation polygon, imagery, and topography, found that eight WWL points outside of the inundation polygon did not represent WWL points. Flagger forms and pictures could not support that the flooding at these eight points was due to coastal surge.

In general, the WWL follows the inundation polygon; however, tributaries can be affected by flooding not related to surge. The WWL along the Sabine River, in the western portion of Calcasieu Parish, was determined to reach an elevation of 6 feet as indicated by HWM point RLAC-09-16, as well as three points in Texas: RTXC-03-07, RTXC-03-06, and RTXR-05-14 (coastal). The average elevation at these points was 6 ft NAVD 88. Along the Calcasieu Ship Channel, the WWL extended to an elevation of 8 ft NAVD 88 with HWM point RLAC-08-04 (elevation 8.4 ft NAVD 88) used as a reference.

Cameron

Two of the three WWL points identified in the parish (RLAC-09-12 and RLAC-10-16) were located within 200 feet of the inundation polygon and WWL. According to the flagger forms, photos, and topography, the third point (RLAC-03-02) was located along a road within the inundation polygon and WWL with lower elevations surrounding it, supporting the fact that the general area was flooded by coastal surge. The data points supported the existing debris line and inundation polygon delineation, so no changes were recommended.

Iberia

The WWL was delineated to follow the 8-foot contour and include the single WWL point identified in Iberia Parish (RLAC-03-05). The lack of post-event imagery in this area prevented the photointerpreters from creating an inundation polygon. However, a review of the flagger forms, photos, and topography supported the extension of the WWL to include the southern portion of Iberia Parish up to the 8-foot contour.

Jefferson

The area to the south of Lake Pontchartrain, including Jefferson Parish, proved difficult for flaggers to differentiate between flooding from Hurricane Rita and Hurricane Katrina. No WWL points were identified in the parish.

Jefferson Davis

No changes were recommended for Jefferson Davis. The one WWL point identified (RLAR-02-03) was located in the northern portion of the parish. Aerial imagery and topography provided evidence that this area was not flooded by coastal surge during the event. A review of the flagger forms and photos supported the fact that this point did not truly represent evidence of flooding due to coastal surge. Therefore, no changes were made to photointerpreted GIS coverages.

Lafourche

The general coastal wetland coverage included the four WWL points identified in Lafourche Parish (RLAC-15-14, RLAC-15-15, RLAC-15-16, and RLAC-15-17). Flagger forms, photos, topography, and pre-event imagery supported including this area as coastal wetlands.

Lafourche Parish is extremely rural with only one road running through to the coastal area. The four WWL points identified in Lafourche Parish were located along this road.

Livingston

An inundation area was delineated along Lake Pontchartrain to include three of the four WWL points in Livingston Parish (RLAR-15-02, RLAR-15-04, and RLR1-15-06). Flagger forms, topography, and online imagery supported the addition of an inundation area following the 6-foot contours in the southeastern portion of Livingston Parish. However, after further analysis of riverine versus coastal flooding in the area, the limit of coastal surge was determined to be east of Livingston Parish and so the WWL did not extend into the parish.

Orleans

In Orleans Parish, one possible WWL point was identified (RLAC-14-23). This area was greatly affected by Hurricane Katrina, which made it difficult to differentiate whether the flooding was caused by Hurricane Katrina or Rita. The flaggers noted that the observed HWMs may have been left by Hurricane Katrina. Therefore, no inundation or WWL is shown for Orleans Parish.

Plaquemines

An inundation area and WWL were delineated for Plaquemines Parish to include two WWL points identified in the parish (RLAC-17-14 and RLAC-17-17). The inundation area and WWL covered the area to the south and west of the Mississippi River levees. The levees to the south of the Mississippi River, some of which were breached, and State Highway 23 were suspected of preventing floodwaters from moving to the north. Flagger forms, photos, topography, and pre-event imagery supported the mapping of an inundation area following State Highway 23.

St. Bernard

The area to the south of Lake Pontchartrain, including St. Bernard Parish, proved difficult for flaggers to differentiate between flooding from Hurricane Rita and Hurricane Katrina. Flaggers were not able to identify WWL points in St. Bernard parish.

St. Charles

In St. Charles Parish, the one WWL point identified (RLAR-15-12) was isolated from the other points and flagger notes and photos indicate that flooding did not overtop the bulkhead along Petit Lac Des Allemands.

In the area to the south of Lake Pontchartrain, including St. Charles Parish, flaggers had difficultly differentiating between flooding from Hurricane Rita and Hurricane Katrina. Therefore, no inundation or WWL is shown for St. Charles Parish.

St. John the Baptist

The WWL was extended from Tangipahoa Parish into the northeastern portion of St. John the Baptist Parish following HWMs RLAC-13-18 and the Anderson Canal, between Lake

Pontchartrain and Lake Maurepas. The WWL continued south to Interstate I-10 and veered eastward to Lake Pontchartrain. The inundation polygon continued from St. James Parish into St. John the Baptist Parish following Interstate I-10 to Lake Pontchartrain.

St. Martin

The one WWL point identified (RLAR-15-10) was located in the northeastern portion of the parish. Topography, location, and online imagery did not provide evidence that this area was affected by coastal surge. A review of flagger forms did not conclusively support coastal flooding at this point. Therefore, no inundation or WWL is shown for St. Martin Parish.

St. Mary

The inundation polygon and WWL were extended from Iberia Parish to follow the 8-foot contour and include the northwestern most point of the six WWL points identified in St. Mary Parish (RLAC-03-06). The inundation polygon transitioned from the 8-foot contour to the 6-foot contour to follow Bayou Teche and included four additional WWL points near Morgan City (RLAC-01-04, RLAC-01-05, RLAR-15-06 (coastal), and RLAR-15-08). The WWL followed the inundation polygon and was cutoff along the Lower Atchafalaya River at an elevation of 6 ft. based on RLAC-01-04. No post-event imagery was taken in St. Mary Parish, so no inundation polygon or debris line was created for this area as part of Task Order 443, *Rapid Response, Aerial Radar – Texas and Louisiana*. However, a review of the flagger forms, photos, and topography supported the extension of the inundation polygon and WWL to include St. Mary Parish.

According to the flagger forms, photos, and topography, the remaining point in St. Mary Parish (RLAC-18-09) was located along a road surrounded by wetlands at a lower elevation. The location and surrounding wetlands supported the fact that this point should not be included in the inundation polygon.

Inaccessibility and the lack of information to the east of St. Mary Parish prevented the photoanalysts from extending the inundation polygon any further east along the coast.

St. Tammany

A WWL was added to the Lake Pontchartrain area of St. Tammany Parish to include seven of the eight WWL points identified in the parish (RLAC-13-03, RLAC-13-04, RLAC-13-05, RLAC-13-06, RLAC-13-07, RLAC-13-08, and RLAC-13-15). Flagger forms, photos, topography, and pre-event imagery supported the addition of a WWL following the 6-foot contours in the southern portion of St. Tammany Parish. These data sources also indicated that from RLAC-13-03 east to RLAC-13-06, this line was a debris line.

The eighth point in St. Tammany Parish (RLAR-20-11), located approximately 12 miles upstream on the West Pearl River, was isolated from the other points in St. Tammany Parish that are closer to the shoreline of Lake Pontchartrain. Flagger forms indicate that the source of flooding at this point was the West Pearl River and that the flooding type was riverine.

Tangipahoa Parish

The WWL was extended from St. Tammany Parish into the southeastern portion of Tangipahoa Parish following the 6-foot contour. The WWL extend from north to south along the west coast of Lake Pontchartrain to include CHWMs RLAC-13-17 and RLAC-03-18. The inundation polygon continued west along the 6-foot contour into Livingston Parish, but all HWMs in this area were riverine.

Terrebonne

The general coastal swamp coverage included the WWL point identified in Terrebonne Parish that was surrounded by wetlands (RLAC-03-07). Flagger forms, topography, and pre-event imagery supported including this area as coastal wetlands.

Information was difficult to collect in Terrebonne Parish due to the lack of road access in the western section of the parish.

Vermilion

CHWMs were used in Vermilion Parish to delineate the WWL and inundation. To the south of White Lake in Vermilion Parish, no WWL points were identified. As post-event imagery ended approximately 17,000 feet to the east of the border between Cameron and Vermilion Parishes, no photointerpreted inundation boundaries were delineated. As the photointerpreted debris line generally followed State Highway 82, the debris line was extended to follow six CHWMs along the highway (RLAC-11-21, RLAC-11-22, RLAC-11-23, RLAC-11-27, and RLAC-11-33) and the 6- and 8-foot contours through the area. This extensionended near the CHWM point RLAC-11-25. Flagger notes and photos indicated wrack and mud lines were located along Highway 82. The land between the coast and Highway 82 is swampy and undeveloped without access.

The lack of imagery in this area prevented the photointerpreters from creating an inundation polygon. However, a review of the flagger forms, photos, topography, and online imagery supported the extension of the inundation polygon to include Vermilion Parish.

The inundation polygon was extended to follow the 4-foot contour and include HWM RLAR-12-06 in Vermilion Parish; however, subsequent analysis showed that this area was actually subject to riverine flooding and beyond the limits of the WWL. The inundation polygon and WWL transitioned to follow the 6-foot contour interval to include three of the eight WWL points identified in Vermilion Parish (RLAC-01-01, RLAC-01-02, and RLAC-03-01). The inundation polygon and WWL transitioned from the 6-foot contour to the 8-foot contour to include two additional WWL points (RLAC-11-24 and RLAC-01-03). The inundation polygon transitioned from the 8-foot contour to the 10-foot contour to follow a nearby tributary and include WWL point RLAR-12-09. The inundation polygon and WWL continued to follow the 8-foot contour into Iberia Parish to include RLAC-03-04.

After a review of the flagger forms and photos, inundation polygon, imagery, and topography, one WWL point (RLAC-14-13) located inside the extended inundation polygon was found not to represent the WWL. At this point, the topography supported that flooding reached further inland along the inundation polygon.

Map Details

GIS maps of the WWL were produced at a scale of 1:24,000 (Appendix E). 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 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, causing damage, the inundation caused by surge extends further 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 Louisiana.

Findings and Observations

The WWL, shown as the boundary of the surge inundation areas on the maps in Appendix E and as the debris line in portions of Vermillion and St. Tammany Parishes, is focused on the western and central coast of Louisiana, the southwest portion of Plaquemines Parish, and the areas around Lake Pontchartrain. Table 6 presents a summary of the flooding conditions and the location of the surge inundation for the sections of each parish included in the study.

Table 6: Wind Water Line Findings

PARISH[1]	LOCATION (City or Area)	DISTANCE INLAND TO DEBRIS LINE (ft)	DISTANCE INLAND OF SURGE INUNDATION (ft)	MAJOR FLOOD SOURCES	MAP PANEL NAMES AND NUMBERS
Acadia	Southwest along the border with Jefferson Davis and Vermilion Parishes	None	15,100	Lake Arthur and Mermentau River	Gueydan – 32 Mermentau – 19
Assumption	Amelia	None	300 – 1,200 [2]	Bayou Boeuf	Amelia – 88
Calcasieu	West along Texas border	None	700 – 15,800 [2]	Sabine River	Echo – 11 Orange – 23
Calcasieu	North and east of Moss Lake, including Lake Charles	None	0 – 8,000 [2]	Calcasieu River	Lake Charles – 15 Moss Lake – 26 West Lake – 14
Calcasieu	South along the border of Cameron Parish	None	103,000 – 142,000	Calcasieu Lake, Calcasieu Ship Channel, Intracoastal Waterway	Black Lake – 25 Cameron Farms – 24 Echo – 11 Lake Charles SE – 28 Lake Charles SW – 27 Moss Lake – 26 Orange – 23 Sulphur – 13 Vinton – 12

PARISH[1]	LOCATION (City or Area)	DISTANCE INLAND TO DEBRIS LINE (ft)	DISTANCE INLAND OF SURGE INUNDATION (ft)	MAJOR FLOOD SOURCES	MAP PANEL NAMES AND NUMBERS
Calcasieu	East near Jefferson Davis Parish	None	900 – 12,500 [2]	Bayou Lacassine	Lacassine – 16 Lake Charles SE – 28 Hayes – 29
Cameron	Parish-wide	0 – 40,000	47,000 – 114,000 [3]	Gulf of Mexico	Big Constance Lake - 92 Black Lake – 25 Boudreaux Lake – 40 Browns Lake – 37 Cameron – 57 Cameron Farms – 24 Catfish Lake – 61 Collicon Lake – 62 Cow Island – 77 Creole – 59 Creoleoes – 75 Deep Lake – 78 Five Lakes – 35 Floating Turf Bayou – 79 Grand Bayou – 58 Grand Cheniere – 60 Greens Bayou – 35 Gueydan – 32 Hackberry – 38 Hayes – 29 Hog Bayou – 76 Holly Beach – 55 Johnsons Bayou – 54 Lake Arthur – 31 Lake Charles SE – 28 Lake Charles SW – 27 Lake LeBleu – 63 Lake Misere – 41 Latania Lake – 42 Latanier Bayou – 44 Mallard Bay – 43 Moss Lake – 26 Orange – 23 Orangefield – 22 Peveto Beach – 55 Port Arthur South – 52 Rollover Lake – 93 Sabine Pass – 73 Sweet Lake – 39 Texas Point – 74 Thornwell – 30 West of Greens Bayou – 34 West of Johnsons Bayou – 53
Iberia	Lake Peigneur southeast to Jeanerette and south to Weeks	None	30,000 – 50,000	Gulf of Mexico	Delcambre – 49 Hamock Lake – 84 Jeanerette – 51 Kemper – 70 New Iberia South – 50 Tigre Lagoon – 68

PARISH[1]	LOCATION (City or Area)	DISTANCE INLAND TO DEBRIS LINE (ft)	DISTANCE INLAND OF SURGE INUNDATION (ft)	MAJOR FLOOD SOURCES	MAP PANEL NAMES AND NUMBERS
					Weeks – 69
Jefferson	Southeast border with Plaquemines Parish	None	0-9,200	Gulf of Mexico	Lake Laurier – 99 Three Bayou Bay – 98
Jefferson Davis	Southwest near Calcasieu and Cameron Parishes	None	720 – 26,000 [2]	Bayou Lacassine	Hayes – 29 Lacassine – 16 Thornwell – 30 Welsh South – 17
Jefferson Davis	Southeast near Cameron, Vermilion, and Acadia Parishes	None	70 – 27,500 [2]	Lake Arthur and Mermentau River	Jennings – 18 Lake Arthur – 31
Plaquemines	Venice to Phoenix	None	258,000	Gulf of Mexico	Bastian Bay – 106 Bay Batiste – 102 Bay Coquette – 110 Bay Ronquille – 105 Buras – 107 Empire – 104 Happy Jack – 101 Lake Laurier – 99 Pass Tante Phine – 111 Phoenix – 91 Pilottown – 112 Pointe a la Hache – 100 Port Sulphur – 103 Three Bayou Bay – 98 Triumph – 108 Venice – 109
St. John the Baptist	Western portion	None	3,200 – 24, 000	Lake Pontchartrain	Laplace – 33 Manchac – 6 Ponchatoula SE – 7 Ruddock – 20
St. Mary	Sorrel east to the border of Assumption Parish	None	48,000 – 91,000	Gulf of Mexico	Amelia – 90 Centerville – 72 Ellerslie – 86 Franklin – 71 Hammock Lane – 84 Jeanerette – 51 Kemper – 70 Marone Point – 85 Morgan City – 89 North Bend – 87 Patterson – 88 Weeks – 69
St. Tammany	Madisonville to northern portion of Mandeville	None	100 – 13,000	Lake Pontchartrain	Covington – 5 Madisonville – 4
St. Tammany	City of Mandeville	400 – 8,000	None beyond debris line	Lake Pontchartrain	Mandeville – 8
St. Tammany	West of Mandeville to Lacombe to	None	7,000 – 20,000	Lake Pontchartrain	Lacombe – 9 North Shore – 21

PARISH[1]	LOCATION (City or Area)	DISTANCE INLAND TO DEBRIS LINE (ft)	DISTANCE INLAND OF SURGE INUNDATION (ft)	MAJOR FLOOD SOURCES	MAP PANEL NAMES AND NUMBERS
	south of Slidell				Slidell – 10
Tangipahoa	Southern portion	None	25,000 – 60,000	Lake Pontchartrain	Manchac – 6 Ponchatoula – 2 Ponchatoula NE – 3 Ponchatoula SE – 7
Vermilion	Northwest along border with Jefferson Davis Parish	None	330 – 8,300 [2]	Lake Arthur and Mermentau River	Gueydan – 32 Lake Arthur – 31
Vermilion	West of Forked Island	32,000 –50,000	37,000 – 116,000 [3]	Gulf of Mexico	Fearman Lake – 81 Floating Turf Bayou – 79 Forked Island – 65 Forked Island NW – 45 Jacks Point Island – 64 Kaplan South – 46 Lake Le Bleu – 63 Latanier Bayou – 44 Mulberry Island West – 94 Mulberry Island East – 95 Pecan Island – 80 Rollover Lake – 93
Vermilion	East of Forked Island	None	30,000 – 77,000	Gulf of Mexico	Abbeville East – 48 Abbeville West – 47 Cheniere au Tigre – 96 Delcambre – 49 Fearman Lake – 81 Forked Island – 65 Hebert Lake – 67 Hell Hole Bayou – 97 Intracoastal City – 66 Kaplan South – 46 Mulberry Island East – 95 Pumpkin Islands – 82 Redfish Point – 83 Tigre Lagoon – 68

[1] The point in St. Martin parish was found to not represent an accurate WWL point. Points in Lafourche, St. Charles, and Terrebonne Parishes were located in the middle of wetlands where the extent of inundation was difficult to determine due to inaccessibility. Flood levels south of Lake Pontchartrain, including Orleans Parish, were difficult to identify as most of the area had been heavily impacted by Hurricane Katrina.
[2] Distance inland from channel bank of flooding source.
[3] Distance inland from delineated Debris Line.

Damage caused by coastal storm surge was observed all along the gulf coast of Louisiana. The landfall of Hurricane Rita between Sabine Pass in Texas and Johnson's Bayou in Louisiana placed the central and western portion of the coast within the right front quadrant of the storm. In this section of the counterclockwise wind circulation, the forward speed of the storm added to the magnitude of the wind speeds and storm surge. The wetlands that line the Louisiana coastline was able to absorb some of the impacts from the storm surge; however, it was not enough to prevent the surge from reaching inland. Due to a low elevation and very gentle slope of this coastal area, the storm surge reached

20 to 30 miles further inland along the coastline of Cameron Parish and Vermilion Parish with maximum surge elevations between 12 and 16 feet measured near the shoreline.

In Cameron Parish, the debris line along the western side of the parish was found to be very close to the coastline. In the eastern side of Cameron Parish, the debris line extended further inland, up to 7.5 miles from the coastline. Except for some minor areas with higher elevations, the remaining portion of Cameron Parish north of the debris line was inundated by storm surge from the Gulf of Mexico. Calcasieu Lake, which is about 30 miles east of the landfall location, had maximum surge heights of 9.5- to 10-feet along its northern shoreline.

The storm surge from the Gulf of Mexico experienced in Cameron Parish also crossed the border of the parish and stretched five miles further north into Calcasieu Parish. Storm surge also inundated areas an additional three miles inland along the Sabine River, Calcasieu River, and Bayou Lacassine in Calcasieu Parish.

The southern potion of Jefferson Davis Parish experienced a storm surge up to 5 miles from the banks of Bayou Lacassine and the Mermentau River.

From the eastern border with Cameron Parish, the debris line continued into Vermilion Parish along State Highway 82 for an additional 22 miles. The debris line extends inland from the coastline of Vermilion Parish up to 9.5 miles. Vermilion Parish was inundated by surge up to 30 miles inland from the coast.

The surge inundation continued into Iberia Parish and extended up to 9.5 miles from the coastline. Storm surge also affected St. Mary Parish and extended up to 17 miles inland from the coast. To the north of St. Mary Parish, Assumption Parish was also inundated by storm surge, which continued up to 1,200 ft. from the border with St. Mary Parish.

Plaquemines Parish, on the eastern side of the Louisiana coast, experienced surge inland along the Mississippi River channel for over 45 miles from the coast. The inundation did not extend beyond 1.2 miles from the banks of the channel because of levees and roadways that acted as a barrier.

Flooding on the northern side of Lake Pontchartrain created a 19.5-mile WWL in St. Tammany Parish. The WWL extended up to 4.5 miles inland from Lake Pontchartrain. The area to the west of Lake Pontchartrain, including Lake Maurepas and portions of Tangipahoa Parish, Livingston Parish, Ascension Parish, and St. John the Baptist Parish, experienced storm surge flooding up to 22 miles inland.

Conclusions

The majority of the coastal surge and damage occurred in Cameron and Vermillion Parishes. The southern portions of Calcasieu and Jefferson Davis Parishes and the coastal regions of Iberia, Saint Mary, and Plaquemines Parishes were also affected by coastal surge.

Although field crews attempted to visit coastal areas along the Gulf of Mexico in Terrebonne, Lafourche, Jefferson, Plaquemines and St. Bernard's Parishes, the swampy characteristics of the Louisiana Coast prevented access to and clear identification of WWL points in many of these areas. NWI information is shown on the WWL Maps to illustrate the extent of wetlands in southeastern Louisiana. Effects from surge in these areas were partially absorbed by the wetlands, but the wetlands did not provide full 'buffering' from the effects of the storm.

Similarly, low lying wetland areas west of Lake Pontchartrain were difficult to access, and thus estimates of the WWL in these areas are based on CHWMs and topography. Field crews noted that there is not significant development for much of this area due to the land cover. North of Lake Pontchartrain, St. Tammany Parish experienced damage as result of flooding from surge along Lake Pontchartrain.

A total of 67 WWL points were identified by field crews in southeast Louisiana. Calcasieu Parish had the greatest number of identified WWL points with twenty-four points. Eight WWL points were identified in both St. Tammany and Vermillion Parishes, six were in St. Mary Parish, four were in both Lafourche and Livingston Parishes, three were in Cameron Parish, two were in both Assumption and Plaquemines Parishes, and one WWL point was in each of the following parishes: Iberia, Jefferson Davis, Orleans, St. Charles, St. Martin, and Terrebonne.

Of these 67 points, seven were within a range of approximately 200 feet from either the inundation polygon or the debris line developed by photointerpretation of the post-event imagery. Using the remaining 60 points, including the field crews' observations, photos, post-event imagery, local topography, and base mapping, engineers analyzed the photointerpreted debris line and inundation area to extend these boundaries beyond the post-event imagery. These engineers decided that 32 of these points would be used to actually edit and extend the inundation polygon and debris line. Therefore, the field data presented a good complement to the information developed solely from analyzing the post-event imagery.

Appendix A: Wind Water Line Data Points

Appendix A contains a data table for the WWL data points.

DUE TO PRIVACY ISSUES (ADDRESSES ARE INCLUDED TO IDENTIFY POINT LOCATIONS), THIS APPENDIX IS NOT AVAILABLE IN THE VERSION OF THE REPORT POSTED ON THE FEMA WEBSITE.

Appendix B: Photographs

Appendix B contains an index and thumbnails of the photographs. The naming convention for the photographs uses the data point ID Number (RLAC-XX-XX) and then a sequential number for the photographs(s) associated with that ID Number (RLAC-XX-XX-1, RLAC-XX-XX-2). In most instances, two photographs were taken for each data point; however, when additional information was needed, three photographs were taken.

NOTE: The SD memory cards containing some of the images became corrupt and the images on them were unrecoverable. For this reason, images for 25 of the WWL data points are not available.

DUE TO PRIVACY ISSUES, THIS APPENDIX IS NOT AVAILABLE IN THE VERSION OF THE REPORT POSTED ON THE FEMA WEBSITE.

Appendix C: Debris Line and Inundation Mapping Summary (HMTAP Task Order 443)

Appendix C contains a summary report from HMTAP Task Order 443: *Rapid Response, Aerial Radar – Texas and Louisiana*. The aerial imagery collected under this task order was used to delineate a debris line and flood boundaries that served as base data for HMTAP Task Order 447, *Rapid Response, Hurricane Rita Wind Water Line – Louisiana*. WWL data points were used in conjunction with these data to delineate the WWL.

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

Background

As part of the Hurricane Rita 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 Rita. The areas mapped include the storm-struck areas along the Gulf Coast of Louisiana and Texas.

The primary purpose of this mapping effort was to provide a comprehensive, region-wide inventory of areas damaged by Hurricane Rita 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 help identify areas that experienced flood damage in order to provide a valid basis for establishing flood insurance benefits.

Area of Interest

Mapping coverage extended along the entire Gulf Coast region of Louisiana and Texas. The area mapped was approximately 8,000 square miles and included portions of or all of the following counties:

1. **Texas Counties:** Chambers, Galveston, Jefferson, Jasper, Hardin, Liberty, Newton, Orange, Tyler
2. **Louisiana Parishes:** Calcasieu, Cameron, Jefferson Davis

Imagery Source

EarthData used natural color digital aerial orthophotographs acquired between September 30 and October 9, 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. The 3001, Inc. imagery provided to EarthData by URS covered approximately 2,800 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 Rita 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 Rita. 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 15, 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."

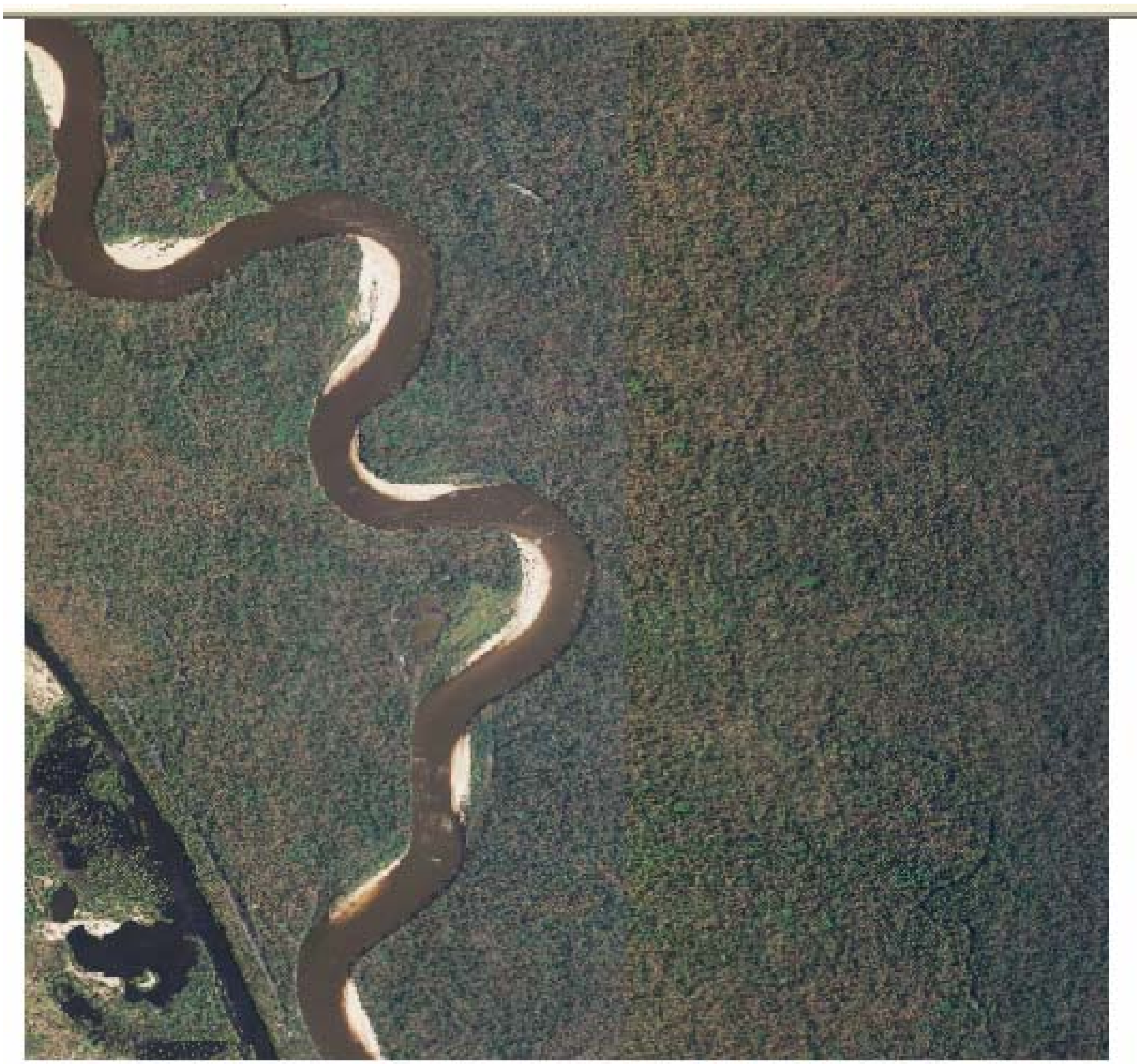

Figure 1

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 D: Notes on Analysis of Wind Water Line Data Points

Appendix D 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. Where photointerpreted data were not available, notes on how the WWL data points were used are included.

Hurricane Rita
Louisiana
Notes on Analysis of Wind Water Line Data Points

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAC-01-01	Vermilion	4.2	4	N/A			Extended inland flood polygon to meet point using 4 and 6 ft contours.	No inundation polygon was shown in this area from aerial imagery photointerpretation. Flagger form and photos indicate there was flooding here ("never flooded before Rita").
RLAC-01-02	Vermilion	7.4	6	N/A			Extended inland flood polygon to meet point using 4 and 6 ft contours.	No inundation polygon was shown in this area from aerial imagery photointerpretation. Flagger observations and photos indicate there was flooding here ("never flooded before Rita").
RLAC-01-03	Vermilion	7.8	8	N/A			Extended inland flood polygon from RLAC 11-24 using 6 and 8ft contours.	No inundation polygon was shown in this area from aerial imagery photointerpretation. Flagger observations indicate flooding occurred here (waterline- 1' HWM to ground).
RLAC-01-04	St. Mary	5.0	6	N/A			Extended marsh polygon to this point using coast and HWY 317 as boundaries.	Area has low elevations and includes undeveloped marshland and should be included in the marsh polygon.
RLAC-01-05	St. Mary	4.5	6	N/A			Extended marsh polygon to this point using coast and HWY 317 as boundaries.	Point was taken on shoulder of road which is a high point in the area. Marshland surrounds the road and development. Flooding could have affected surrounding areas.
RLAC-02-11 [1,2]	Calcasieu	3.7	4	6	120	------	No action.	Point is within 200 ft of the inundation polygon.
RLAC-02-14 [1,2]	Calcasieu	10.9	24	10	33000	------	Designated as a WWL Data Point NUAR.	Point falls outside of the inundation polygon at an elevation that is greater than the flooding elevation. Ponding due to poor drainage is suspected as the cause of the observed HWM. Point should not have been designated as a WWL point.
RLAC-03-01	Vermilion	6.8	6	N/A			Extended inland flood polygon to meet point using 4 and 6 ft contours.	No inundation polygon was show in this area from aerial imagery photointerpretation. Flagger observations and eyewitness account indicates flooding occurred here.
RLAC-03-02	Cameron	4.6	4	4	2300	------	No action.	Point falls inside of inundation polygon. Point was taken on shoulder of the road which is a high point in the area so flooding could have reached further north.
RLAC-03-03	Calcasieu	6.1	8	8	730	------	No action.	Point lies within the inundation polygon.
RLAC-03-04	Vermilion	8.0	8	N/A			Extended inland flood polygon from RLAR 12-09 using 8ft contours.	No inundation polygon was shown in this area from aerial imagery photointerpretation. Flagger observations indicate flooding occurred here.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

Hurricane Rita
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Notes on Analysis of Wind Water Line Data Points

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAC-03-05	Iberia	6.9	8	N/A			Extended inland flood polygon from RLAC 3-05 using 8-ft contours.	Point falls outside of the inundation polygon. Point was taken on the road shoulder, which is a high point in the area, so flooding could have reached surrounding areas.
RLAC-03-06	St. Mary	9.6	10	N/A			Extended inland flood polygon from RLAC 3-06 using 8ft contours.	Point falls outside of the inundation polygon. Point was taken on the road shoulder, which is a high point in the area, so flooding could have reached surrounding areas.
RLAC-03-07 [3]	Terrebonne	2.0	2	N/A			Extended mash areas polygon to point using pre-event imagery and contours.	Point is surrounded by undeveloped, swampy area. This is an isolated WWL point and nearby HWMs are concentrated in area along highways/roadways since surrounding land is inaccessible.
RLAC-04-01 [2]	Calcasieu	14.6	20	10	1240	------	Designated as a WWL Data Point NUAR.	Point falls outside of the inundation polygon at an elevation that is greater than the flooding elevation. It is suspected that flooding in the area was due to the lack of drainage. The point should not have been designated as a WWL point.
RLAC-07-02 [2]	Calcasieu	6.7	7	6	450	------	No action.	Point lies within the inundation polygon.
RLAC-08-01	Calcasieu	8.2	6	10-14	280	------	Extend the inundation polygon by using 12- and 14-ft contours and aerial imagery.	Point falls within the inundation polygon. Flaggers observations and imagery supports that flooding occurred further inland from the riverbank.
RLAC-08-02	Calcasieu	7.8	8	8	390	------	No action.	Point lies within the inundation polygon. Topography, flagger observations, and aerial imagery support that flooding went further inland.
RLAC-08-03	Calcasieu	7.8	8	6	57	------	No action.	Point is within 200 ft of the inundation polygon.
RLAC-08-04	Calcasieu	8.4	9	10	100	------	No action.	Point is within 200 ft of the inundation polygon.
RLAC-08-07 [1,2]	Calcasieu	7.0	6	6	10550	------	Designated as a WWL Data Point NUAR.	No inundation polygon was shown in this area from aerial imagery photointerpretation. No photos of site were available and the surveyed elevation was not consistent with points in surrounding area.
RLAC-09-12	Cameron	4.9	2	2	140	------	No action.	Point is within 200 ft of the inundation polygon.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

Hurricane Rita
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Notes on Analysis of Wind Water Line Data Points

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAC-09-14	Calcasieu	5.3	4	4	6000	------	No action.	Point falls within the inundation polygon. Flagger observations, photos, and imagery support that flooding went further inland.
RLAC-09-15	Calcasieu	8.2	10	10	720	------	Flood polygon was extended to this point by following the 8- and 10-ft contours.	Flagger observations and imagery support that flooding went further inland from the tributary.
RLAC-09-16	Calcasieu	8.5	6	6-8	6200	------	Extended the inundation polygon northward along the tributary to reach the point.	Flaggers noted a wrack line here. This area is flat and the imagery supports that the flooding went further inland from the tributary.
RLAC-09-18	Calcasieu	9.2	10	10~12	3200	------	Extended the inundation polygon northwestward to reach up this point using imagery as guide.	Flaggers noted a wrack line here. This area is very flat and the imagery supports that flooding occurred further inland.
RLAC-09-27	Calcasieu	9.9	9	9	4	------	No action.	Point falls within 200 ft of inundation area. Flagger notes that point was taken on the roadway, which is a high point in the area, so flooding would have also occurred at lower points north of the road.
RLAC-09-41 2	Calcasieu	14.2	16	14	12,470	------	Extended inland flood polygon north around stream channel by following the 14-ft contour.	No inundation polygon was shown in this area from aerial imagery photointerpretation. Flagger forms and photos indicate there was flooding here.
RLAC-09-42 2	Calcasieu	23.5	28	18	9,650	------	Designated as a WWL Data Point NUAR.	Point falls outside of the inundation polygon at an elevation that is greater than the flooding elevation. Ponding due to poor drainage is suspected as cause for the observed HWM. Point should not have been designated as a WWL point.
RLAC-09-43 2	Calcasieu	21.7	22	24	72	------	Designated as a WWL Data Point NUAR.	Point falls outside of the inundation polygon, which is not in close proximity to a coastal drainage area. Ponding due to poor drainage is suspected as cause for the observed HWM. Point should not have been designated as a WWL point.
RLAC-09-44 2	Calcasieu	35.3	38	32	10,800	------	Designated as a WWL Data Point NUAR.	Point falls outside of the inundation polygon, which is not in close proximity to a coastal drainage area. Ponding due to poor drainage is suspected as cause for the observed HWM. Point should not have been designated as a WWL point.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAC-09-45 2	Calcasieu	32.8	33	10	60,000	------	Designated as a WWL Data Point NUAR.	Point falls outside of the inundation polygon at an elevation that is greater than the flooding elevation. Ponding due to poor drainage is suspected as cause for the observed HWM. Point should not have been designated as a WWL point.
RLAC-10-02	Calcasieu	8.2	10	6	0	------	Created a "dry" area on island using aerial photos.	Point falls within inundation polygons. The wrack line was located on an island inside the river channel. The higher ground of this island beyond this point was not flooded.
RLAC-10-16	Cameron	4.7	4	4	64	------	No action.	Point is within 200 ft of the inundation polygon.
RLAC-11-24	Vermilion	8.0	no contours available	N/A			Extended inland flood polygon from RLAC 3-01 using 6 and 8ft contours.	No inundation polygon was shown in this area from aerial imagery photointerpretation. Flagger form and photos indicate there was flooding: "water stopped in area; some homes flooded."
RLAC-12-06 2	Calcasieu	9.0	7	8	30	------	No action.	Point is within 200ft from the inundation polygon.
RLAC-13-03	St. Tammany	8.2	8	N/A			See note for RLAC-13-15. Added debris line between RLAC 13-03 and RLAC 13-06 using 6-ft contour.	WWL points from RLAC-13-03 to RLAC-13-08 form a good inundation boundary for flooding caused by Lake Pontchartrain.
RLAC-13-04	St. Tammany	6.6	6	N/A			See note for RLAC-13-03.	see note for RLAC-13-03.
RLAC-13-05	St. Tammany	6.0	4	N/A			See note for RLAC-13-03.	see note for RLAC-13-03.
RLAC-13-06	St. Tammany	5.0	2	N/A			See note for RLAC-13-03. From RLAC-13-06 to RLAC-13-07, added WWL using 4-ft and 6-ft contours.	see note for RLAC-13-03.
RLAC-13-07	St. Tammany	5.3	2	N/A			Added WWL between RLAC-13-06 and RLAC13-08 using 4-ft and 6-ft contours.	see note for RLAC-13-03.
RLAC-13-08	St. Tammany	6.1	6	N/A			See note for RLAC-13-07.	see note for RLAC-13-03.
RLAC-13-15	St. Tammany	7.2	8	N/A			Added WWL between RLAC-13-03 and RLAC-13-15 using 6 and 8 ft contours.	No existing inundation polygon in this area. A series of HWMs and WWLs which were surveyed around Lake Pontchartrain form a good wind water line.
RLAC-14-13	Vermilion	10.9	10	N/A			No action.	Point falls inside of the inundation polygon that has RLAC-03-04 on the boundary.
RLAC-14-23 3	Orleans	5.6	2	N/A			No action.	There are no other WWL points south of Lake Pontchartrain since this whole area was heavily flooded by Hurricane Katrina. Flaggers noted a broken levee, which was possibly from Hurricane Katrina.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

Hurricane Rita
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Notes on Analysis of Wind Water Line Data Points

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAC-15-14 [3]	Lafourche	6.3	2	N/A			Designated as a WWL Data Point NUAR.	Point located in undeveloped, swampy area. Nearby HWM points are concentrated in areas along highways/roadways. Point is a wrack line caught on fence (6' depth) and should not have been designated as a WWL.
RLAC-15-15 [3]	Lafourche	5.8	no contour available	N/A			Designated as a WWL Data Point NUAR.	Point located along highway surrounded by undeveloped, swampy area. Point is a wrack line caught on fence (2' 7" to grade)- and should not have been designated as a WWL.
RLAC-15-16 [3]	Lafourche	6.4	no contour available	N/A			Designated as a WWL Data Point NUAR.	Point is surrounded by undeveloped, swampy area. Point is a wrack line caught on a fence (5'2" to grade) and should not be designated as WWL.
RLAC-15-17 [3]	Lafourche	5.9	6	N/A			Extended marsh polygon to this point.	Point is surrounded by inaccessible, undeveloped, swampy area. Nearby HWMs are concentrated along highway.
RLAC-17-14	Plaquemines	1.2	2	N/A			Created new inland flood polygon extending from RLAC 17-09 to RLAC 13-01 using HWY 23 and marsh area polygon as boundary.	There was no existing inundation polygon in this area. A series of HWMs and WWLs, which were surveyed along State Highway 23, form a good wind water line. Water overtopped the levee but was stopped from spreading further inland by State Hwy 23.
RLAC-17-17	Plaquemines	1.2	2	N/A			Created new inland flood polygon extending from RLAC 17-09 to RLAC 13-01 using HWY 23 and marsh area polygon as boundary.	There was no existing inundation polygon in this area. A series of HWMs and WWLs, which were surveyed along State Highway 23, form a good wind water line. Water overtopped the levee but was stopped from spreading further inland by State Hwy 23.
RLAC-18-09	St. Mary	11.9		N/A			Designated as a WWL Data Point NUAR.	Point is a water line with a vertical distance to HWM of 9 feet. Other WWL points are further inland. This point should not have been designated as a WWL point.
RLAR-02-03 [2]	Jefferson Davis	22.7	28	N/A			Designated as a WWL Data Point NUAR.	Point is far away from existing inundation polygon and coast and is also isolated from other points. Point was taken at a bridge and the flooding only reached up to the river bank.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

Hurricane Rita
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Notes on Analysis of Wind Water Line Data Points

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAR-02-05 [2]	Calcasieu	5.8	2	2	1,050	------	Designated as a WWL Data Point NUAR.	Point fall inside of inundation area. Flaggers notes wrack line here and the flood depth at point is 5.8 ft. This is flat area so the flooding could have gone 1000 ft inland. Point should not have been designated as a WWL point.
RLAR-09-19	Calcasieu	12.3	14	2	15,000	------	Designated as a WWL Data Point NUAR.	The point is far away from existing inundation polygons and coast and is also isolated from other points. Flaggers noted wrack line here, which probably was caused by poor drainage.
RLAR-12-09	Vermilion	9.8	10	N/A			Extended inland flood polygon from RLAC 1-03 using 10-ft contours around tributary.	Flooding occurred along tributary as indicated in flagger form and photos. Flooding consistent with nearby HWMs RLAR-12-07 and RLAR-12-08.
RLAR-15-02 [2]	Livingston	4.1	2	N/A			Created inland flood polygon starting at RLAC 13-15 and connecting RLAR 15-02 to RLR1 15-06.	As this point is on a tributary of a lake, the area has a low elevation and includes undeveloped marshland. Flaggers noted this the point as a water line with a vertical distance to HWM of 0.5 ft.
RLAR-15-03 [2]	Livingston	3.1	22	N/A			Designated as a WWL Data Point NUAR.	Flaggers noted this point as a water line with a vertical distance to HWM as 4.5 ft. Point is at an elevation that is greater than the flooding elevation. Poor drainage is suspected to be the cause of the observed HWM. Point should not have been designated as a WWL.
RLAR-15-04 [2]	Livingston	4.2	2	N/A			Designated as a WWL Data Point NUAR.	Point is in a very low area, just 0-2 ft from a canal. Flaggers noted this as a water line with a vertical distance to HWM of 1.7 ft. Point should not have been designated as a WWL.
RLAR-15-06	St. Mary	5.7	6	N/A			Extended inland flood polygon to point using 6-ft contours and river boundaries.	Area has low elevations and includes undeveloped marshland. Flaggers noted this as a wrack line. Topography leads to the conclusion that this area should be included in the inundation polygon.
RLAR-15-08	St. Mary	3.5	4	N/A			Extended inland flood polygon to point using 6-ft contours and river boundaries.	Area has low elevations and includes undeveloped marshland. Flaggers noted this as a wrack line. Topography leads to the conclusion that this area should be included in the inundation polygon.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

Hurricane Rita
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Notes on Analysis of Wind Water Line Data Points

WWL Data Point Analysis								
WWL Data Point	**County**	**Surveyed Elevation** (ft NAVD 88)	**Data Point Ground Elevation** (from 2 ft contours)	**Flood Elevation from Original Debris Line or Flood Inundation Boundary** (from 2 ft contours)	**Distance to Original Flood Inundation Boundary** (ft)	**Distance to Original Debris Line** (ft)	**ACTION**	**EXPLANATION**
RLAR-15-09 2	Assumption	2.9	2	N/A			Designated as a WWL Data Point NUAR.	The surrounding area has low elevations and contains undeveloped marshland. Although the land is very flat, the point is a considerable distance from the coast line and the observed wrack line is likely the result of drainage. The point should not have been marked as a WWL. No photos of site were available.
RLAR-15-10 2	St. Martin	3.9	4	N/A			Designated as a WWL Data Point NUAR.	Area has low elevations and contains undeveloped marshland. Flaggers noted this as a wrack line. Although land is very flat, point is a considerable distance from the coast line and is likely the result of poor drainage. Point should not have been designated as a WWL.
RLAR-15-11	Assumption	2.7	2	N/A			Extended inland flood polygon to point using 6 foot contours and river boundaries.	Area has low elevations and includes a lake, a canal, and undeveloped marshland. The proximity and flatness of the surrounding land indicate that this area should be included in the inundation polygon or the swamp polygon. No photos of this site were available.
RLAR-15-12 3	St. Charles	2.8	2	N/A			No action.	There was no existing inundation polygon in this area. The point is isolated from other points and flagger photos indicate flooding did not overtop bulkhead.
RLAR-20-11 2	St. Tammany	6.9	10	N/A			Designated as a WWL Data Point NUAR.	There is no existing inundation polygon in this area. Flaggers noted that the flood source is Pearl Rive, but point is isolated from other points.
RLR1-15-06 2	Livingston	5.2	4	N/A			Extended inland flood polygon to point using 6-ft contours and river boundaries.	As this point is near the lake, the surrounding area has a low elevation and includes undeveloped marshland. Flaggers noted this as a water line with a vertical distance to HWM of 1.5 ft.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

WWL Data Point Analysis								
WWL Data Point	County	Surveyed Elevation (ft NAVD 88)	Data Point Ground Elevation (from 2 ft contours)	Flood Elevation from Original Debris Line or Flood Inundation Boundary (from 2 ft contours)	Distance to Original Flood Inundation Boundary (ft)	Distance to Original Debris Line (ft)	ACTION	EXPLANATION
CHWM's RLAC-11-21, 11-22, 11-23, 11-33, 11-27, and 11-25	Vermillion		6-8 ft	N/A			Extended debris line to follow CHWMs along State Highway 82 (approx 6-8' contour).	Flaggers found wrack and mud lines along Hwy 82 (road has a higher elevation than the surrounding area so it makes sense that debris would accumulate along the road). Land from coast to Hwy 82 is swampy, undeveloped area without access.

1. Designated as Do Not Use point by HWM QC Team. Subsequently not used by WWL team.
2. Beyond actual WWL and therefore beyond area shown on the map panels.
3. Not enough data point collected in proximity to this point to create full WWL.

Appendix E: Wind Water Line Maps

Appendix E contains the Wind Water Line Maps illustrating the location of the Wind Water Line from Rita along the Louisiana Coast.

Hurricane Rita
Louisiana
WWL Data Point Index

HWM_ID	Flooding Type	County	Later designated as DNU point by HWM data analysts. Subsequently not used by WWL team.	Not enough data points collected in proximity to this point to create full WWL.	Determined to be beyond actual WWL and therefore beyond area shown on any of the map panels. Most of these are riverine flooding.	Map Panel Name	Map Panel Number
RLAC-01-01	Coastal	Vermilion				Forked Island	65
RLAC-01-02	Coastal	Vermilion				Forked Island	65
RLAC-01-03	Coastal	Vermilion				Abbeville West	47
RLAC-01-04	Coastal	St. Mary				Morgan City	89
RLAC-01-05	Coastal	St. Mary				Ellerslie	86
RLAC-02-11	Riverine	Calcasieu	X		X		
RLAC-02-14	Coastal	Calcasieu	X		X		
RLAC-03-01	Coastal	Vermilion				Forked Island	65
RLAC-03-02	Coastal	Cameron				Bordreaux Lake	40
RLAC-03-03	Coastal	Calcasieu				Moss Lake	26
RLAC-03-04	Coastal	Vermilion				Abbeville East	48
RLAC-03-05	Coastal	Iberia				New Iberia	50
RLAC-03-06	Coastal	St. Mary				Kemper	70
RLAC-03-07	Levee	Terrebonne		X			
RLAC-04-01	Riverine	Calcasieu			X		
RLAC-07-02	Riverine	Calcasieu			X		
RLAC-08-01	Coastal	Calcasieu				Westlake	14
RLAC-08-02	Coastal	Calcasieu				Westlake	14
RLAC-08-03	Coastal	Calcasieu				Lake Charles	15
RLAC-08-04	Coastal	Calcasieu				Lake Charles	15
RLAC-08-07	Riverine	Calcasieu	X		X		
RLAC-09-12	Coastal	Cameron				Browns Lake	37
RLAC-09-14	Coastal	Calcasieu				Black Lake	25
RLAC-09-15	Coastal	Calcasieu				Sulphur	13
RLAC-09-16	Coastal	Calcasieu				Vinton	12
RLAC-09-18	Coastal	Calcasieu				Sulphur	13
RLAC-09-27	Riverine	Calcasieu				Orange	23
RLAC-09-41	Riverine	Calcasieu			X		
RLAC-09-42	Riverine	Calcasieu			X		
RLAC-09-43	Riverine	Calcasieu			X		
RLAC-09-44	Riverine	Calcasieu			X		
RLAC-09-45	Riverine	Calcasieu			X		
RLAC-10-02	Coastal	Calcasieu				Westlake	14
RLAC-10-16	Coastal	Cameron				Lake Charles SW	27

Hurricane Rita
Louisiana
WWL Data Point Index

HWM_ID	Flooding Type	County	Later designated as DNU point by HWM data analysts. Subsequently not used by WWL team.	Not enough data points collected in proximity to this point to create full WWL.	Determined to be beyond actual WWL and therefore beyond area shown on any of the map panels. Most of these are riverine flooding.	Map Panel Name	Map Panel Number
RLAC-11-24	Coastal	Vermilion				Kaplan South	46
RLAC-12-06	Riverine	Calcasieu			X		
RLAC-13-03	Coastal	St. Tammany				Mandeville	8
RLAC-13-04	Coastal	St. Tammany				Mandeville	8
RLAC-13-05	Coastal	St. Tammany				Mandeville	8
RLAC-13-06	Coastal	St. Tammany				Mandeville	8
RLAC-13-07	Coastal	St. Tammany				Slidell	10
RLAC-13-08	Coastal	St. Tammany				North Shore	21
RLAC-13-15	Coastal	St. Tammany				Madisonville	4
RLAC-14-13	Coastal	Vermilion				Abbeville East	48
RLAC-14-23	Levee	Orleans		X			
RLAC-15-14	Coastal	Lafourche		X			
RLAC-15-15	Coastal	Lafourche		X			
RLAC-15-16	Coastal	Lafourche		X			
RLAC-15-17	Coastal	Lafourche		X			
RLAC-17-14	Coastal	Plaquemines				Triumph	108
RLAC-17-17	Coastal	Plaquemines				Buras	107
RLAC-18-09	Coastal	St. Mary				Weeks	69
RLAR-02-03	Riverine	Jeff. Davis			X		
RLAR-02-05	Riverine	Calcasieu			X		
RLAR-09-19	Riverine	Calcasieu				Lake Charles	15
RLAR-12-09	Riverine	Vermilion				Abbeville West	47
RLAR-15-02	Riverine	Livingston			X		
RLAR-15-03	Riverine	Livingston			X		
RLAR-15-04	Riverine	Livingston			X		
RLAR-15-06	Coastal	St. Mary				Morgan City	89
RLAR-15-08	Riverine	St. Mary				Morgan City	89
RLAR-15-09	Riverine	Assumption			X		
RLAR-15-10	Riverine	St. Martin			X		
RLAR-15-11	Riverine	Assumption				Amelia	90
RLAR-15-12	Riverine	St. Charles		X			
RLAR-20-11	Riverine	St. Tammany			X		
RLR1-15-06	Riverine	Livingston			X		