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Hurricane Ivan Rapid Response
Florida Coastal High Water Mark (CHWM) Collection
FEMA-1551-DR-FL

Final Report

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Prepared by:

URS Group, Inc.
200 Orchard Ridge Drive
Suite 101
Gaithersburg, MD 20878

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Introduction

Hurricane Ivan was rated as the most powerful hurricane to hit the Caribbean in 10 years. On September 7 and 8, 2004, it damaged 90 percent of the homes in Grenada and caused catastrophic damage as it swept over Grenada, Barbados, and the other islands in the area. By Thursday morning on September 9, Ivan's sustained winds reached 160 mph, making it a rare Category 5 hurricane on the Saffir-Simpson scale. By Monday September 13, it skirted western Cuba with winds clocked at 156 mph.

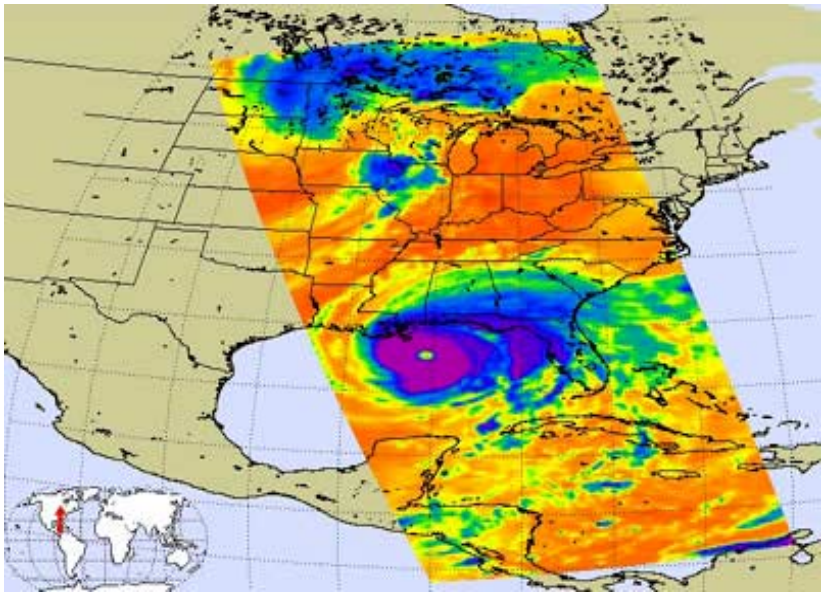

Figure 1. Hurricane Ivan Approaches

Hurricane Ivan was one of the strongest and most destructive hurricanes to hit Florida's Panhandle coast in recorded history and the most severe since Hurricane Opal in 1995. The image of Hurricane Ivan (Figure 1) was acquired by the Atmospheric Infrared Sounder (AIRS) infrared, microwave, and visible sensors on September 15 at 1:30 pm local time as the storm moved into Alabama (http://www-airs.jpl.nasa.gov/multimedia/image_releases/2004/hurricane_ivan.html). Ivan approached the Florida and Alabama area at Category 4 strength, moving north at 14 mph. Maximum sustained winds were reported to be 135 mph and extended 105 miles from the center, while tropical storm-force winds extended 290 miles from the center. Figure 1 shows how the storm looked through an AIRS Infrared window channel. It reveals a very large eye about 75 km (50 miles) across.

The storm path as it made landfall is shown in Figure 2. The hurricane began affecting the Panhandle on September 13, 2004 and made landfall on September 16, 2004 as a Category 3 Hurricane with maximum sustained winds near 130 mph and storm surges over 8 feet. Storm surge with associated wave action was reported at +15 to +20 feet above mean sea level. The hurricane's strongest winds were located east-northeast of the storm center. This aspect coupled with the higher, on-shore directed winds, associated storm surge, and accompanying breaking waves resulted in much of Ivan's destructive impact on the Florida Panhandle coast and Gulf Shores, Alabama. As the hurricane moved through Florida, wind and wave action disrupted utilities, caused damage, and created localized flooding. The State of Florida Department of Environmental Protection (DEP) issued an Emergency Final Order stating that the Hurricane caused widespread damage in the following areas: Bay, Escambia, Franklin, Gulf, Okaloosa, Santa Rosa, Washington, and Walton Counties. The hurricane continued to move toward the

north-northeast and brought devastating flooding to the Appalachians and southern New England.

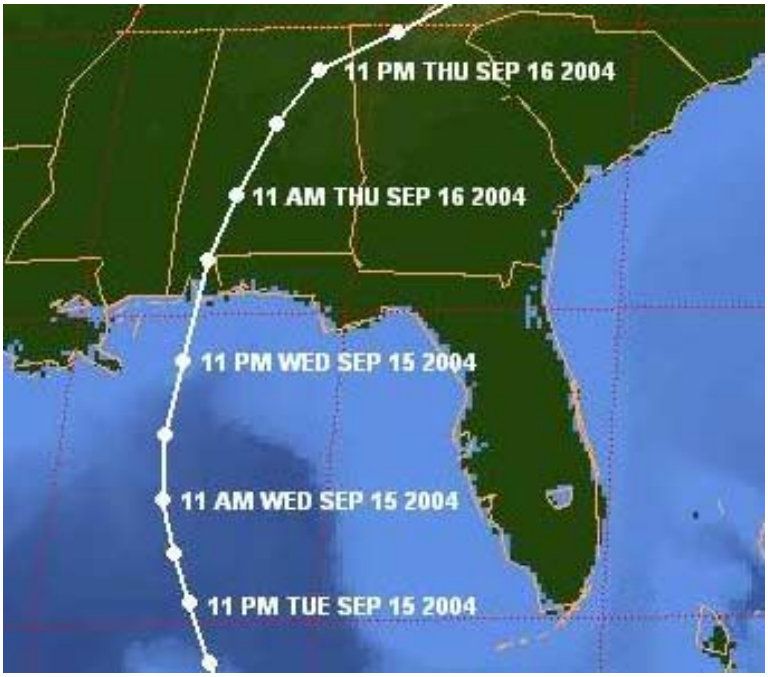

Figure 2: Hurricane Ivan Storm Path

Other notable wind data were measured by the Florida Coastal Monitoring Project (FCMP) and made available through PRNewswire-FirstCall. For the first time ever, homes instrumented as part of the FCMP captured wind pressure data on buildings subjected to the direct impact of hurricane force winds. From Hurricane Ivan:

- A house 3 miles east of Big Lagoon State Park in the Florida Panhandle was subjected to 91 mph gust winds in the eastern eyewall of Hurricane Ivan. These 3-second gusts were measured in a suburban area at a height of 21 feet. (The equivalent 33 feet 3-second gust speeds for a corresponding open exposure location, typical meteorological reference conditions, correspond to 117 mph. This equivalent 117 mph gust speed represents the highest wind speeds reported to date from any of the various meteorological stations deployed in the region.)
- A sonic anemometer operated by the University of Oklahoma reported a 109 mph gust at Gulf Shores Airport.
- An FCMP tower near Fairhope, Alabama reported a gust speed of 90 mph and clearly experienced the passage of the eye.
- An FCMP tower at the Pensacola Airport reported a peak gust of 106 mph in open terrain.

- A house toward the Eastern end of Gulf Breeze was subjected to 82 mph gust winds. These 3-second gusts were measured in a suburban area at a height of 19 feet. (The equivalent 33 feet 3-second gust speeds for a corresponding open-exposure location would be 109 mph.)

Ivan reformed into a tropical depression on September 22, 2004 in the Gulf of Mexico after having traveled in a circular motion through the southeastern United States causing tremendous flooding (see Figure 3). An interesting development occurred on September 20 as a small surface low, caused by the southern remnants of Ivan, moved across the Florida peninsula. As it continued west across the northern Gulf of Mexico, the system organized and took on tropical characteristics. On September 22, the National Weather Service determined that the low was in fact a result of the remnants of Ivan and named it accordingly.

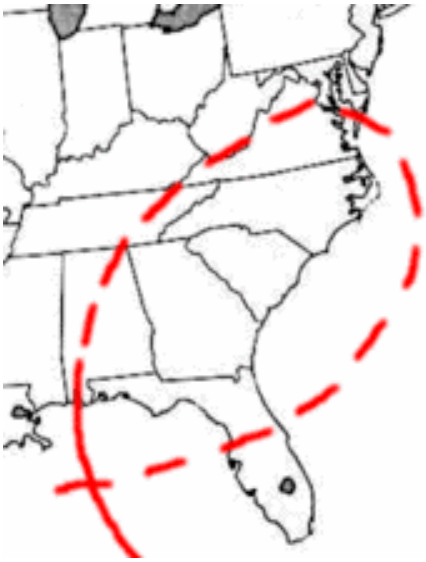

Figure 3: Hurricane Ivan Reforms and Returns

Notice was given in the Federal Register, in a letter dated September 16, 2004, that the President declared a major disaster under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act for damage in certain areas in Florida resulting from Hurricane Ivan (FEMA-1551-DR, Florida; http://www.fema.gov/news/eventcounties.fema?id=3687). The declaration provides the necessary Federal assistance to meet immediate needs and to help Florida recover as quickly as possible. Declared Florida counties under disaster declaration FEMA-1551-DR-FL are shown on Figure 4.

Individual Assistance was provided to: Bay, Calhoun, Escambia, Franklin, Gadsden, Gulf, Holmes, Jackson, Leon, Liberty, Okaloosa, Santa Rosa, Taylor, Wakulla, Walton, and Washington counties with the September 16, 2004 declaration. Okaloosa County was included with Amendment No. 1 to the Notice of a Major Disaster Declaration, September 17, 2004.

Figure 4: Disaster Declaration Map – Florida

Source: http://www.gismaps.fema.gov/2004graphics/dr1551/dec_1551.pdf

Public Assistance was provided to: Bay, Calhoun, Citrus, Dixie, Escambia, Franklin, Gadsden, Gulf, Holmes, Jackson, Jefferson, Leon, Levy, Liberty, Okaloosa, Santa Rosa, Taylor, Wakulla, Walton, and Washington for assistance for debris removal and emergency protective measures, including direct Federal assistance, at 100 percent Federal funding of the total eligible costs of Categories A and B for a period of up to 72 hours. Consistent with the requirement that Federal assistance be supplemental, any Federal funds provided under the Stafford Act for Public Assistance will be limited to 75 percent of the total eligible costs.

Amendment No. 2 to the Notice of a Major Disaster Declaration, September 25, 2004 included: Charlotte, Collier, Lee, Monroe, and Sarasota Counties for emergency protective measures (Category B) under the Public Assistance program, Jefferson County for Public Assistance (Categories C through G), and Bay, Calhoun, Escambia, Franklin, Gadsden, Gulf, Holmes, Jackson, Leon, Liberty, Okaloosa, Santa Rosa, Wakulla, Walton, and Washington Counties for Public Assistance (Categories C through G).

Amendment No. 4, November 3, 2004 included: Citrus County for emergency protective measures (Category B) under the Public Assistance Program.

Hazard Mitigation Grant Program (HMGP): All counties in the State of Florida are eligible to apply for assistance under the HMGP.

URS Group, Inc. was contracted by the Federal Emergency Management Agency (FEMA) under the Hazard Mitigation Technical Assistance Program (HMTAP) to assist in the Hurricane Ivan disaster recovery. Assistance provided by this Task Order includes collection and survey of Coastal High Water Marks (CHWMs). This report summarizes the methodologies used to flag the CHWM locations and survey the elevations established during the hurricane. This is an important step in assisting communities in establishing flood hazard areas and to prevent future loss of life and property damage.

Hurricane Ivan caused both coastal and riverine flooding. The resulting high water marks were flagged and surveyed along coastal locations. The purpose of this report is to document the flagging and surveying of the CHWMs, estimate the storm surge at each location, and discriminate between storm surge and wave action.

The data collected is invaluable to Federal, state, and local recovery efforts. The data assists in identifying areas of significant damage in order to target resources needed for disaster recovery. It also helps to establish the magnitude and recurrence interval of the flood and erosion events caused by the hurricane along various areas of the coast. This data collection is also beneficial for future use in (a) accurately assessing the benefits to be expected from flood mitigation efforts, (b) prioritizing the flood mitigation efforts pursued following the hurricane, and (c) for use in making HMGP decisions.

Area of Study

The area FEMA identified to be covered by the Coastal High Water Study Team extends from the Alabama-Florida line eastward to the area of the coastal municipality of Destin, Florida, and northward into the Florida Panhandle to encompass Perdido, Escambia, Blackwater, and Choctawhatchee Bays. The observations were taken at discrete points distributed along the open Gulf coast, the seaward and landward sides of the barrier islands, within the Bays and on the shores of several small embayments including Santa Rosa Sound, Bayou Chico, Bayou Texar, and Grand Lagoon. The lower east side of Blackwater Bay proved to be inaccessible due to the presence of swampland. Other areas that were inaccessible include the eastern end of Perdido Key, and three areas on Santa Rosa Island, including the western end of Santa Rosa Island from Little Sabine Bay to Fort Pickens, a large area between Pensacola Beach and Navarre Beach, and the area east of Navarre Beach in Eglin Air Force Base.

The study area was set through discussions with Dr. Shabbar Saifee of the FEMA Disaster Field Office after some of the National Oceanic and Atmospheric Agency (NOAA) SLOSH model output had been reviewed. URS also performed a half-day field reconnaissance where it was noted that the water levels were rising well above the normal high tide level as far east as St. Marks (Wakulla County) Florida. URS staff observed during the storm that the estimated surge was 4 to 5 feet above high tide at its peak in St. Marks. Discussions were held with Dr. Stephen Baig at the NOAA National Hurricane Center to determine whether the widespread effect of Hurricane Ivan was of interest to the NOAA modelers. They confirmed interest, and therefore a few widely spaced coastal high water marks were obtained east of the area of Hurricane Ivan's main impact. This approach was discussed with FEMA and approved. Generally the CHWMs were concentrated in the westernmost counties of Escambia and Santa Rosa. These relatively closely spaced data points were collected because of their significant impact and because the NOAA SLOSH model results indicated a complex pattern to the surge with significant differences in the surge level from one side of an island or bay to another. The relatively dense distribution of CHWMs extended to western Okaloosa County because major hurricane damage could be traced that far from the point of landfall.

Table 1: Number of CHWMs Surveyed by County

County	Number of CHWMs Surveyed
Escambia	57
Santa Rosa	39
Okaloosa	31
Walton	3
Bay	3
Franklin	2
Total =	135

There are a series of NOAA tide gages across the Panhandle area that provided direct measurements of the surge elevations. However, the gage at Pensacola failed before the main surge developed. Table 2 shows the gages from which useful data were obtained.

Table 2: NOAA NWS Gage Stations During Hurricane Ivan

Station ID	Name	Longitude (West)	Latitude (North)	Hurricane Ivan Peak Elevation (Ft) MLLW
8728690	Apalachicola, FL	84° 58.9' W	29° 43.6'N	5.19
8729108	Panama City, FL	85° 40.0'W	30° 12.8'N	4.70
8729210	Panama City Beach, FL	87° 12.7 'W	27° 38.2'N	6.44

MLLW = mean lower low water

In addition to the NOAA tide gages, water levels were recorded on coastal gages maintained by the U.S. Army Corps of Engineers (USACE) Mobile District Office and the U.S. Coast Guard (USCG). Table 3 lists these data sources

Table 3: Peak Water Elevations During Hurricane Ivan Reported in USACE-Mobile September 2004 Report

Name	Longitude (West)	Latitude (North)	Hurricane Ivan Peak Elevation (Ft) NGVD29
Pensacola Bay at Fort McREE (USCG)	87.289722	30.34500	9.70
Escambia Bay West Bank at HWY 90	87.194167	30.546944	12.92
Escambia Bay West Bank 1.5 miles N of I-10	87.175278	30.520556	12.12
GIWW at Gulf Breeze, FL	87.156389	30.352222	10.30
Yellow River near Milton, FL	86.924444	30.571111	9.66
Fort Walton Brooks Bridge	86.600000	30.400000	6.12
GIWW at Choctawhatchee Bay (HWY 331)	86.168889	30.411944	5.51
Destin at Choctawhatchee Bay (USCG)	86.525833	30.391944	5.39
GIWW at West Bay, FL (HWY 79	85.858611	30.293889	6.60
St Andrew Bay at Panama City, FL	85.666667	30.152778	4.94
Apalachicola River at Apalachicola, FL	84.995278	29.733056	5.10
GIWW at St. George Island, FL	84.876944	29.687222	3.55
Carrabelle River at Carabelle, FL	84.675833	29.851667	5.04

NGVD 29 = National Geodetic Vertical Datum of 1929
GIWW = Gulf Intracoastal Waterway

Additional information about the surges could also be estimated from the U.S. Geological Survey (USGS) river gages that are located in some of the downstream reaches. Normally these gages are located above the normal tide level oscillations. However, the coastal surge was so

much larger than the normal tide heights that it propagated up the river as an easily distinguishable wave. Data were collected from a few of these gages where this signal was clearly evident. However, their peak elevations are estimated because the pre-storm river level is not known. Table 4 lists the U.S. Geological Survey gages that were used to provide data.

Table 4: U.S. Geological Survey Gages

Name	Longitude (West)	Latitude (North)	Hurricane Ivan Peak Elevation (Ft) NGVD 29
Yellow River near Milton, FL	86.924444	30.571111	9.66
Escambia River near Gonzalez, FL	87.258860	30.611860	9.50
Yellow River near Milton, FL	87.923570	30.569640	7.0
Perdido River near Barrineau Park, FL	87.440250	30.690470	16.20
Elevenmile Creek near Pensacola, FL	87.335800	30.498250	14.30

Another source of data is from a report written for the City of Destin, Florida. The report titled "Hurricane Ivan Summary of Coastal Storm Surge, City of Destin, Okaloosa County, Florida" was prepared by the City of Destin in cooperation with the City Engineer and Jones Edmunds and Associates, Inc. It lists three benchmarks and 43 CHWMs that were identified and surveyed in the immediate Destin area. The elevations are referenced to the National Geodetic Vertical Datum of 1988 (NAVD 88) and are in feet. Table 5 shows the data in tabular form and Figure 7 (Appendix A) shows these data spatially.

Table 5: City of Destin, Florida Coastal Storm Surge Data

Desc.	Elevation	Remarks
HWM 1	7.11	Sandpiper Cove Condominiums, address: 8108, south side of bldg., north side of Gulf Shore Drive
HWM 2	7.06	Sandpiper Cove Condominiums, address: 8108/8208, midpoint on south side of bldg., north of Gulf Shore Drive
HWM 3	7.13	Sandpiper Cove Condominiums, address: 8208, south side of bldg., north side of Gulf Shore Drive
HWM 4	10.56	Sandpiper Cove Condominiums, address: 1137, at north side of stairs entry, south side of Gulf Shore Drive
HWM 5	10.46	Sandpiper Cove Condominiums, at snack bar, east side of bldg., south side of Gulf Shore Drive
HWM 6	5.25	Address: 508 Vera Cruz Drive at driveway (east side) mark on landscape timber, south side of road
HWM 7	5.01	Address: 508 Vera Cruz Drive at garage, east side of bldg., south side of road
HWM 8	5.09	Address: 530 Norriego Road, south side of garage, east side of bldg., south side of road
HWM 9	5.07	Address: 522 Norriego Road, mark on wood post at carport, south side of road
HWM 10	4.94	Address: 520 Norriego Road, debris line west of driveway, south side of road
HWM 11	5.01	Address: 514 Norriego Road, mark on post, south side of road
HWM 12	12.60	Address: 520 Gulf Shore Drive, Aegean Condominium, mark on bldg., south side of road
HWM 13	8.95	Destin Pointe Complex, mark on boardwalk, north of Lands End Drive

Desc.	Elevation	Remarks
HWM 14	8.32	Destin Pointe Complex, northeast corner of Pool Cabanna, south side of road
HWM 15	9.20	Destin Pointe Complex, mark on bldg. # 65, south side of road
HWM 16	9.95	Destin Pointe Complex, mark on bldg. # 69, south side of road
HWM 17	9.32	Destin Pointe Complex, mark on bldg. # 65, south side of road
HWM 18	7.76	Destin Pointe Complex, mark on bldg. # 62, south side of road
HWM 19	9.49	Destin Pointe Complex, mark on bldg. # 59, south side of road
HWM 20	6.97	Destin Pointe Complex, mark on southeast corner of bldg. # 56, north side of road
HWM 21	7.08	Destin Pointe Complex, mark on stake, northeast corner of bldg. # 56, North side of road
HWM 22	11.33	Destin Pointe Complex, mark on stake in dunes, behind bldg. # 49
HWM 23	11.90	Destin Pointe Complex, mark on stake in dunes, behind bldg. # 49
HWM 24	6.69	Destin Pointe Complex, mark on stake behind bldg. # 24 & 22, east side of Gulf Breeze Drive
HWM 25	6.75	Destin Pointe Complex, mark on porch at bldg. # 13, west side of Gulf Breeze Drive
HWM 26	6.45	Destin Pointe Complex, mark on stake in front of bldg. # 17, west side of Gulf Breeze Drive
HWM 27	5.88	Destin Pointe Complex, mark on concrete, southwest corner of bldg. # 32 east side of Gulf Breeze Drive
HWM 28	8.65	Destin Pointe Complex, mark on stake, south side of bldg. # 25, east side of Gulf Breeze Drive
HWM 29	8.72	Destin Pointe Complex, mark on stake, south side of bldg. # 25, east side of Gulf Breeze Drive
HWM 30	8.55	Destin Pointe Complex, mark on stake, south side of bldg. # 25, east side of Gulf Breeze Drive
HWM 31	21.45	Stake at foam line, south of Scenic Hwy. 98, west of address # 2942.D in vacant lot
HWM 32	13.04	Address: 2942-D, mark on door, west side of bldg., south of Scenic Hwy. 98
HWM 33	12.29	Address: 4942-D, mark on south side of bldg., south of Scenic Hwy. 98
HWM 34	11.56	Address: 3500 (The Crab Trap), mark on walkway, south side of Scenic Hwy. 98
HWM 35	11.69	Address: 3500 (The Crab Trap), mark on inside of main landing to main entry, south side of Scenic Hwy. 98
Benchmark	11.12	Set 5/8" iron rod with cap # Ref. Pt. LB 2108, located 7 feet south of the south edge of pavement of Scenic Hwy. 98, at centerline of pavilion projected north for the Crab Trap
HWM 36	6.09	Clement E. Taylor Park, debris line on fence at west end, southwest corner of park
HWM 37	5.52	Clement E. Taylor Park, debris line on fence at west end, southwest corner of park
HWM 38	5.20	Clement E. Taylor Park, saltwater line along south side of park
HWM 39	5.57	Clement E. Taylor Park, saltwater line along southwest side of park
HWM 40	6.30	Clement E. Taylor Park, saltwater line along west side of park
Benchmark	7.81	Set cross-sections in southwest corner of pavilion, Northeast area of park
Benchmark	5.99	Set 16-P nail in power pole, 30 feet west of Joe's Bayou Boat Ramp
HWM-41	5.70	Joe's Bayou Park and Boat Ramp, mark on lath at debris line, northwest corner of park
HWM-42	5.73	Joe's Bayou Park and Boat Ramp, mark on lath at debris line, northwest corner of park
HWM-43	5.78	Joe's Bayou Park and Boat Ramp, mark on lath at debris line, northwest corner of park

Marking and Survey Methodology

Field and survey crews from URS and URS Team subconsultants, Dewberry and PBS&J, were deployed to interview residents, find evidence of coastal high water levels, take digital photographs, and survey CHWMs from Hurricane Ivan. Figures 5 and 6 show an example of both the flaggers' form and the surveyors' form used to record field information. During the flagging, field crews entered estimates of surge heights in the comments field on the flagger forms. These were visual estimates and were referenced to the normal range of the tides as best estimated by the observers. The purpose of these observations was to initially estimate water levels well before the surveyors' work was completed. The CHWM flagging crews were deployed on Tuesday September 28, 2004, shortly followed by the survey crews.

The survey crews followed the field crews and used static global positioning system (GPS) methods to determine an accurate elevation for each CHWM. Since static GPS requires an area with no tree cover to return an accurate result, in some cases it was necessary perform a short level loop survey from the GPS point to the CHWM. Wherever possible, the finished floor elevation of structures adjacent to the CHWM was collected. This information may be used at a later date for possible damage assessments or HMGP applications. CHWM locations were surveyed horizontally in North American Datum of 1983 (NAD 83), State Plane feet, and vertically in North American Vertical Datum of 1988 (NAVD 88) US survey feet. CHWM locations have been surveyed to within accuracies of 0.25 foot vertically and 10 feet horizontally with a 95% confidence level.

Figure 5: Sample CHWM Flagger Form

HIGH WATER MARK (HWM) REPORT - FLAGGERS

HWM ID	
HWM Address	
Date of Flagging/ Interview	
Date of Flood Event	
Name of Storm Event	
Stream Name/Flood Source	
Closest Municipality	
County	
State	

HWM Type	
HWM Object	
Location of HWM Object	
HWM Quality	
Type of Mark	
Directions to Flagger's Mark	
Vertical Dist from set point & description of set point	
Survey Needed	
Flagger HWM Latitude	
Flagger HWM Longitude	
Flooding Type	
Photo ID	
Photo Location/ Orientation	
Photo Description/Subject	
Comments	
Name of Flagger/Interviewer	
Unit Number	
Flagger Company	
Resident/Eyewitness Information	
Name	
Address	
Phone	
How Long Lived There	
Obtained Permission to Survey	

Figure 6: Sample CHWM Surveyor Form

HWM ID	
HWM Address	
HWM/Flood Elevation	
Survey Crew	
Survey Company	
Survey Date	
Survey Latitude	
Survey Longitude	
Northing	
Easting	
Vertical Datum	NAVD 88
Horizontal Datum	NAD 83
Survey Project	
Approx. First Floor Elevation	
Survey Comments	

Field crews noted CHWMs with characteristics such as surge, wave runup, and wave height. These designations on the survey sheets in the appendices represent the flagger's estimate of this characteristic based on a combination of physical flood evidence and interviews with witnesses at the time of collection. Surge represents the rise in the normal water level, wave runup indicates the height of water rise above the stillwater level due to water rush-up from a breaking wave, and wave height indicates CHWM elevation due to more direct wave action. Typically, surge CHWMs are associated with a slow rising flood that causes more water damage than structural damage. Wave height usually results in a higher elevation. All attempts were made to flag storm surge elevations, but in areas where surge characteristics were not obvious, wave runup or wave height were flagged. In some cases, witnesses might claim the flooding was associated with a storm surge when in fact the flooding was from wave runup or riverine flooding.

Elevation Conversion from NAVD 88 to NGVD 29 Using VERTCON

The elevations shown in the 1929 NGVD were derived from the VERTCON program and the existing 1988 NAVD elevation. The VERTCON software was developed by the National Geodetic Survey (NGS) Office to allow the conversion of data between different vertical data scales. VERTCON is available as an element of the NGS Geodetic Toolkit and can be downloaded from the NGS website: http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html.

VERTCON allows the user to compute the modeled difference in orthometric height for a given location specified by its latitude and longitude. Applying the VERTCON datum difference value to a specific elevation allows you to convert from one datum to another.

For example, a NAVD 88 elevation is 5.33 feet. Using the latitude and longitude, VERTCON computes a datum shift of (-)1.171 feet; to convert to the NGVD 29 elevation, SUBTRACT the datum shift from the NAVD 88 height. NAVD EL=5.33’ minus (-)1.171 feet equals NGVD 29 elevation of 6.50 feet.

Findings and Observations

The results of this survey are presented as a series of 13 maps that are shown on Figures 7 – 19 (Appendix A). The individual points are coded to differentiate between surge data (taken in places protected from the effects of waves), wave runup data (where the water line resulted from waves rushing up a slope) and wave height data (where wave crests caused the water mark). The relative quality of each data point is also represented. Further information about each point is given on data sheets in Appendices B-G.

As mentioned earlier, some outputs from the NOAA National Hurricane Center SLOSH model were used to plan the locations of the CHWMs. Damage was so extensive over the area that it was possible to designate general locations where data points would be most useful. Figure 8 shows an overview of locations where CHWMs were collected. Almost without exception, places with distinct water marks could be found within these general locations. One result is that the great majority of the data points represent watermarks from protected locations such as interior walls. On the other hand, the storm damage was so extensive that coastal roads were washed out or entirely buried with sand. These areas are shown as being inaccessible on the figures. Many of the Gulf beaches in this area are within parks or National Seashores. These natural areas contained scant record of the coastal storm surge compared to the built-up areas.

The NOAA SLOSH model prediction run output shows that the maximum surge conditions moved across the area as the storm tracked across the coast. The first major surge was along the open coast, appearing in Florida along Perdido Key. The highest CHWM elevations occur in this area (see Figure 9). Much of this barrier island was overtopped. Such overtopping of the barrier island would allow a huge volume of water to enter Big Lagoon, and this could explain the very high CHWM elevations along the mainland coast (Figure 9).

Figure 9 also shows that there was a noticeable difference in the CHWM elevation over the length of Perdido Bay. Both Ono Island and Innerarity Point have high ground well above the flood elevation. The tidal pass winds through the lower portion of the bay. It appears that bay water was displaced towards the upper bay faster than it could be refilled from the Gulf. This results in a differential in the CHWM elevations of about 3 feet over the 12-mile length of the open bay

Figure 10 shows the area between the entrance to Pensacola Bay and Garcon Point in the northwest corner. Much of the barrier island was subject to extensive damage by the surge. This includes overtopping and overwashing at many locations. The road was buried in many places, and access to the island was restricted for weeks. The surge along the Pensacola Beach Barrier Island may have been limited by the low height of the land. With nothing to back up against, the surge passed over the island into Santa Rosa Sound and lower Pensacola Bay. The differences in the CHWM elevations between the Gulf and Sound sides support this inferred surge behavior.

The Santa Rosa Peninsula, which lies behind the barrier island, has ground that is much higher than the maximum surge elevation. Figure 10 shows that the surge set-up along the southern

peninsula shoreline had elevations on the order of 11 and 12 feet. This is in contrast with values of 6 to 8 feet only 2 miles away across Santa Rosa Sound. These CHWM values also demonstrate that the volume of water within the Sound increased dramatically during the surge.

Figure 10 shows also that wind-driven water piled up along the south-facing shores of the Naval Air Station, the western suburb of Warrington, and the Port of Pensacola. This also brought high surge levels into Bayou Grande, Bayou Chico, and Bayou Texar. Maximum surge elevations throughout Pensacola Bay and the lower portions of Escambia and Blackwater Bays appear to have been on the order of 9-1/2 to 11 feet.

Figures 11 and 12 are centered on the Escambia and Blackwater arms of the estuary. In both cases there is a clear pattern of surge amplification towards the heads of these bays. The highest observed elevation in Escambia Bay was 16 feet in Floridatown at the north end of Escambia Bay. The Ward Basin is near the north end of Blackwater Bay just south of the I-10 highway. Here, the surge elevation reached close to 13 feet. In general, the CHWM elevations are a few feet higher along the shores of the arms of the estuary than in the main portion of Pensacola.

Figure 13 shows the eastern portion of Santa Rosa Sound near Navarre and the East Bay arm of the Pensacola Estuary. The CHWM elevations along the open Gulf shore are consistent with the values further west. Considerable portions of this part of the island were overtopped or overwashed. Much of the barrier island was inaccessible due to road damage and burial.

The mainland shore of Santa Rosa experienced a high surge that may have decreased slightly going east. However, this trend may be more apparent than real. Figure 14 continues to show high CHWM elevations along this shore. It was noted that there appeared to be a correlation between the surge levels along the north shore of Santa Rosa Sound and the amount of shielding provided by the barrier island. Much of this island is part of Eglin Air Force Base and is undeveloped. The height of the dunes varies along the island and there are patches of wooded areas. It was the regions between the dunes and wooded areas where overtopping and overwashing occurred.

Figures 14 and 15 show data taken at the eastern end of Santa Rosa Sound and near Fort Walton Beach. Only one point was found along the open Gulf shore of Barrier Island, and it is about 13 feet. Figure 14 shows data from east of East Pass, which is the inlet into Choctawhatchee Bay. Open Gulf CHWMs approaching this same 13-foot value have been located there as well. This suggests that a coastal surge was generally at 12 feet or higher along more than 90 miles of the Gulf shoreline between eastern Alabama and Destin, Florida. This open coast surge remained high much further to the east, but the land along the shore is high with varying relief so that the surge did not penetrate significantly behind the beach systems except at a few locations.

Figure 16 shows the CHWMs in the northern portion of Choctawhatchee Bay near Niceville. Again, the pattern of high values at the heads of the bays is seen. However, these values are not as high as those in Escambia and Blackwater bays, which are much closer to the storm track. Furthermore, the shoreline of northern Choctawhatchee Bay tends to be steep, so there was little inundation from the surge.

Figure 17 shows CHWMs taken on the eastern shore of Choctawhatchee Bay and along the open coast east of Destin. The coastal points show a marked decrease in elevations. This pattern continues eastward with a maximum elevation of 5 feet recorded at Apalachicola. CHWMs collected within Choctawhatchee and St. Andrews Bays also show decreasing values moving east.

Recommendations

The following recommendations discuss how FEMA can use the CHWM information to assist in the recovery effort from Hurricane Ivan:

- Compare the Hurricane Ivan CHWMs to the flood elevation data on the effective or preliminary Flood Insurance Rate Maps. These comparisons can help FEMA determine where the updated flood hazard data was supported by the flooding that occurred or where new detailed studies should be performed to update the maps, and can help illustrate deficiencies on the existing maps.

- An evaluation is needed of the recurrence intervals of the surge conditions across the area. This will vary from place to place owing to distance from the storm track and local geographic effects. Preliminary evidence suggests that much of the area that experienced the most severe surge conditions were exposed to more than 100-year conditions.

- Compare the Ivan CHWMs to CHWMs from other significant flood events. This will identify areas of repetitive flooding that can assist FEMA in determining locations that would make good flood mitigation projects.

- Complete detail-engineering analyses to determine flood elevations in the areas where deficiencies have been identified on the existing FEMA maps, or in areas where property loss occurred where no previous studies have been prepared.

- The locations and severity of the Ivan CHWMs can help FEMA identify areas of concern for future mitigation projects when funding for such projects becomes available.

- Use these CHWMs to evaluate the success of completed mitigation projects. The flood depths that occurred during Ivan can be used to estimate potential damage that could have occurred to structures that have been bought out and removed as part of mitigation projects already completed. Documentation of the “damages avoided” can be used as success stories to further support the mitigation efforts.

- The CHWMs can be used to create flood recovery inundation mapping for Hurricane Ivan. The inundation maps would provide a plan-view of the extent of flooding from Hurricane Ivan and can assist in determining the accuracy of existing FEMA flood maps. The inundation mapping would be a spatially correct Geographical Information System (GIS) coverage that could be provided to community officials to assist in disaster recovery. Note that under HTMAP Task Order 351, the CHWMs for Escambia, Santa Rosa, and Okaloosa Counties are being used for flood inundation maps.

- Provide this report on the Internet to aid public officials and the community in general in the recovery effort.