Hazard Mitigation Technical Assistance Program
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Hurricane Charley Rapid Response
Coastal High Water Mark (CHWM) Collection
FEMA-1539-DR-FL

Final Report

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Introduction

On August 10, 2004, Hurricane Charley developed from a tropical depression to a named tropical storm. Charley was upgraded from a tropical storm to a hurricane on August 11, and tracked west-northwest across the Caribbean, impacting the Cayman Islands, Jamaica, Puerto Rico, and Cuba.

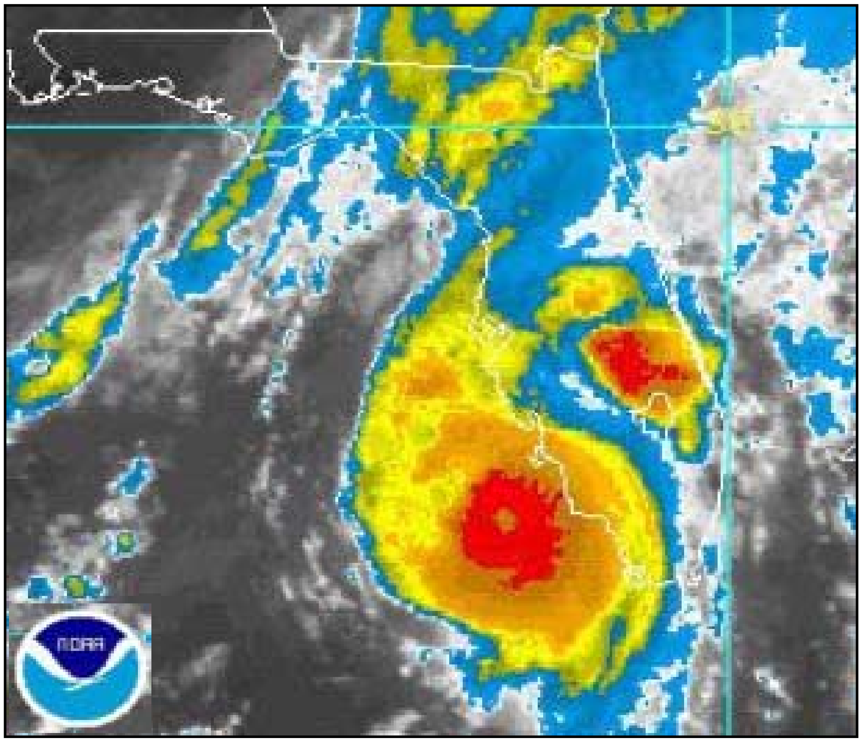


Figure 1. Hurricane Charley makes landfall.

Hurricane Charley made landfall on the Gulf Coast of Florida on Friday, August 13, 2004, just before 4:00 pm (Eastern Daylight Time, EDT). According to draft reports from the National Weather Service (NWS), the center of Charley crossed the barrier islands of Cayo Costa and Gasparilla at 3:45 p.m. as a Category 4 hurricane with estimated winds of 145 miles per hour (mph, 1-minute sustained). After crossing the barrier islands, Charley moved up Charlotte Harbor before making landfall at Mangrove Point, just southwest of Punta Gorda, at 4:35 p.m. By 5:30 p.m., the center was 5 miles west of Arcadia (Desoto County) and, at 7:30 p.m., was 4 miles west of Lake Wales (Polk County). At approximately 9:15 p.m., the storm slammed into Orlando International Airport. By 11:30 p.m., the hurricane was back over open water, having exited the Florida peninsula near Daytona Beach. By 2:00 a.m. EDT, the center was over the Atlantic about 45 miles north-northeast of Daytona Beach, with maximum sustained winds reported to be 85 mph (1-minute sustained). Figure 1 is a radar image of Hurricane Charley just prior to landfall.

The NWS and the National Hurricane Center reported that Hurricane Charley made landfall as a Category 4 hurricane with winds of up to 145 mph (sustained) and a minimum central pressure of 941 millibars. At the time of this report, the maximum wind speed obtained for the storm at landfall from NWS weather stations was a 2-minute sustained wind in Punta Gorda of 87 mph (at station PGD) and a 112-mph, 3-second gust wind speed (before failing) was also recorded at PGD; the associated pressure measured at the time of the recorded wind gust was approximately 964 millibars.

Other notable wind speeds from Hurricane Charley were recorded at the following locations:

- 90 mph (1-minute sustained) at the Cape Coral Airport – Florida Coastal Monitoring Project (FCMP)
- 105 mph (3-second gust) at the Orlando International Airport – NWS
- 92 mph (3-second gust) at the Sanford Airport just northeast of Orlando – NWS
- 69 mph (1-minute sustained) at the Daytona Beach Airport (with an 83-mph gust) – NWS

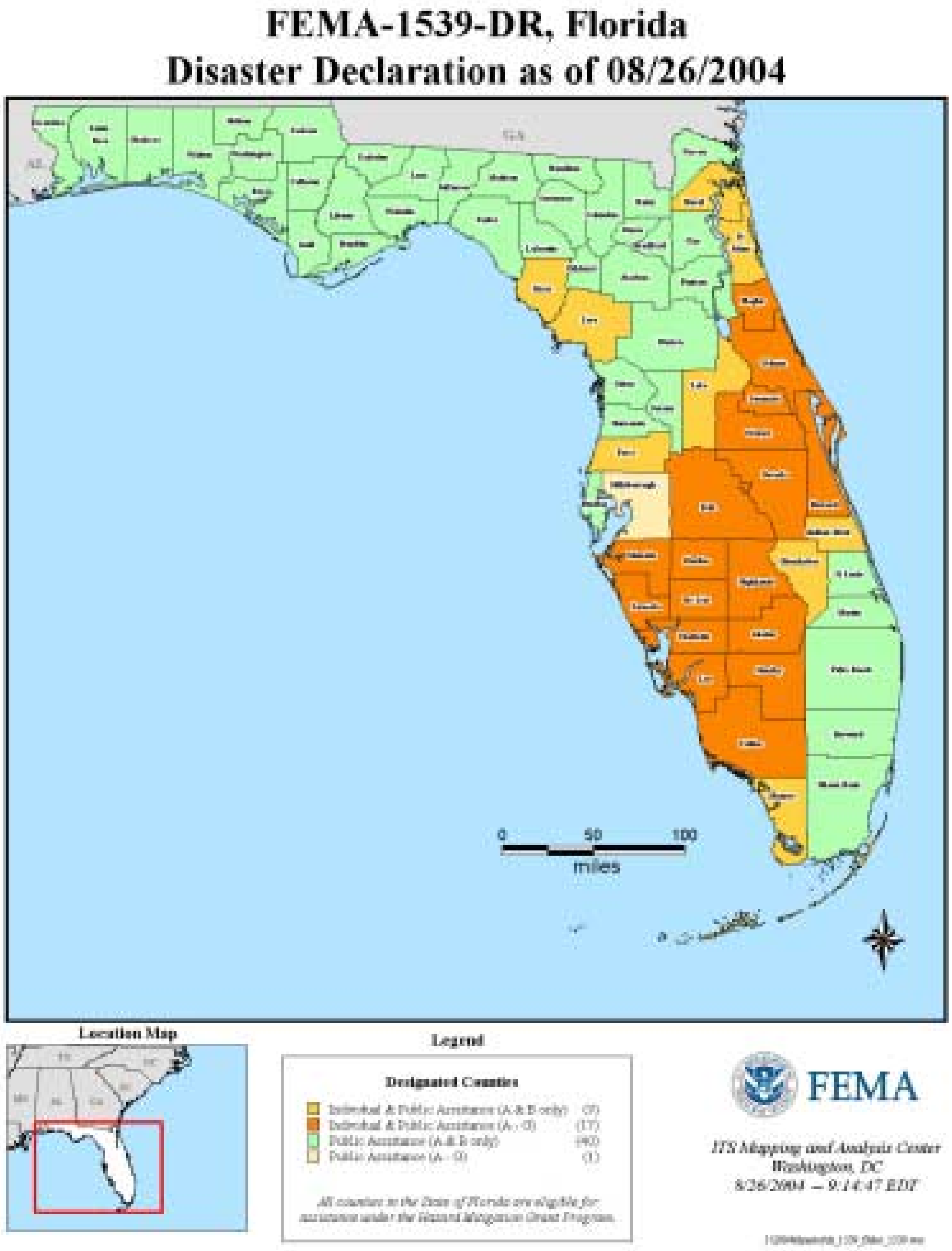
Hurricane Charley made landfall having very compact limits. The hurricane had an estimated radius of 6 miles and a diameter of 12 miles. Hurricane force winds extended outward up to 25 miles from the center, and tropical storm force winds extended outward up to 85 miles. As a result of the compact size of the storm and the northeastward turn the storm made prior to landfall, the storm surge was not as high as originally predicted. Reported wind gusts of 150 mph in Arcadia and 180 mph in Charlotte County at the Emergency Operations Center (EOC) could not be verified by measured data, and damage consistent with such wind speeds was not observed. Although it was reported that the storm was very compact and had some Category 4-level winds, the hurricane did not appear to generate water levels typical of a Category 4 hurricane, which are often in the range of 10 to 14 feet.

As the hurricane moved through Florida, wind and wave action disrupted utilities, caused damage, and created localized flooding.

A disaster declaration in response to Hurricane Charley was authorized by the Federal Emergency Management Agency (FEMA) for areas in Florida on August 13, 2004 (FEMA-1539-DR, Florida; http://www.fema.gov/news/eventcounties.fema?id=3455). The declaration provides the necessary assistance to meet immediate needs and to help Florida recover as quickly as possible. The following counties in Florida were designated for disaster declaration (see Figure 2): Brevard, Charlotte, Collier, DeSoto, Dixie, Duval, Flagler, Glades, Hardee, Hendry, Highlands, Indian River, Lake, Lee, Levy, Manatee, Monroe, Okeechobee, Orange, Osceola, Pasco, Polk, St. Johns, Sarasota, Seminole, and Volusia Counties. These declared counties were provided with Individual Assistance. Public Assistance (PA) Categories A&B have been provided to all Florida Counties. PA Categories C&G have only been provided to some counties.

URS Group, Inc. was contracted by FEMA under the Hazard Mitigation Technical Assistance Program (HMTAP) to assist in the 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 in preventing future loss of life and property damage.

Figure 2: Disaster Declaration Map



Source: http://www.fema.gov/news/event.fema?id=3455

As noted in Legend of Designated Counties, Public Assistance (PA) Categories A&B have been provided to all Florida counties. PA Categories C&G have only been provided to some counties.

Hurricane Charley 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 and (b) prioritizing the flood mitigation efforts pursued following the hurricane. The purpose of CHWM data collection is for use in calibrating the SLOSH model used to evaluate evacuation zones and notification times. Wave and surge data are also used in making Hazard Mitigation Grant Program (HMGP) decisions.

Area of Study

The area identified by FEMA to be covered by the Coastal High Water Study Team lay between Marco Island on the south and a location somewhat south of the town of Venice on the north. The observations were taken at discrete points distributed along the open Gulf coast, within Charlotte Harbor, and on the shores of several small embayments including the lower tidal sections of the Myakka, Peace, and Caloosahatchee Rivers. The majority of the shorelines not exposed to the open Gulf are lined with dense stands of mangroves, protected by low sea walls, or far from any road access. These limitations, combined with the general broad pattern of a low-to-insignificant surge within the Charlotte Harbor estuary near Punta Gorda and Port Charlotte, made the spacing of the observations irregular. Most of the data were taken in and around the most impacted locations where the storm crossed the island and mainland shores. There were significant spatial gradients in the observed heights in these zones. These are most probably related to the small radius of the storm and rapidly changing wind directions. Outside of the most impacted areas, the maximum surge height changed slowly with distance along the coast. This allowed the data points to be taken at wider spacings.

The study area was set by first conducting a coastal reconnaissance by URS personnel. This led to discussions with Todd Davidson and Sal Bucolo of FEMA at the Orlando, Florida Disaster Field Office (DFO) on August 19, 2004. At this meeting, using aerial photos of Florida's southwest Gulf coast and the information gathered during the field reconnaissance, it was determined the storm surge went from Naples in the south to just south of Venice in the north. Todd Davidson indicated a need to include the area south of Naples to Marco Island. This was agreed upon and the flagging was undertaken. The work was limited to collection of CHWMs in Charlotte, Collier, and Lee counties. Most of the observed CHWMs in Charlotte County were similar to each other and of low magnitude. There was much more variability in the Lee County observations. It was for these reasons that the most points were taken in Lee County. The least number of points were in Collier County where the spatial gradients between the CHWMs were relatively small. Table 1 shows the relative distribution of the points.

Table 1: Number of CHWMs Surveyed by County

County	Number of CHWMs Surveyed
Charlotte	11
Collier	9
Lee	39

The NOAA tide gauges that were operating in the area during the time of the hurricane and their Peak Elevation during the Hurricane are shown on Table 2. The value for the Ft. Myers gage is only slightly higher than the mean range of the tide, which is 0.95 foot.

Table 2: NOAA NWS Gage Stations During Hurricane Charley

Station ID	Name	Longitude (West)	Latitude (North)	Hurricane Charley Peak Elevation (Ft) MLLW
872511	Naples, FL	81° 48.4'	26° 7.8'	Gauge malfunctioned
8725520	Ft. Myers, FL	81° 52.3'	26° 38.8'	1.3
8726384	Port Manatee, FL	82° 33.8'	27° 38.2'	None above normal

MLLW – Mean Lower Low Water Tidal Datum

Marking and Survey Methodology

Field and survey crews from URS and URS Team subconsultants, Dewberry and PBS&J, were deployed to conduct resident interviews, find evidence of coastal high water levels, take digital photos, and to survey CHWMs from Hurricane Charley. Figures 3a and 3b show an example of both the flaggers' form and the surveyor's form used to record field information. During the flagging, field crews entered estimates of surge heights in the comments field found 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 get an initial estimate well in advance of time that the surveyors' work would be completed. The CHWM flagging crews were deployed on Monday, August 16, 2004, shortly followed by the survey crews. A brief meeting was held with Dr. Shabbar Saifee, FEMA Region IV Project Monitor, and Todd Davidson and Sal Bucolo, also of FEMA, on August 19, 2004 at the FEMA Orlando Disaster Field Office and the coverage area was discussed.

GPS survey crews followed the field crews and used static 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 to 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 Hazard Mitigation Grant Program applications. CHWM locations were surveyed horizontally in NAD 83 (90), State Plane feet, and vertically in NAVD 88 US survey feet. CHWM locations have been surveyed to within accuracies of 0.25 feet vertically and 10 feet horizontally with a 95% confidence level.

Figure 3a: Sample CHWM Flagger Form

HIGH WATER MARK (HWM) REPORT - FLAGGERS

Page 1	
HWM ID	
Stream Name	
Unit Number	
Name of Crew / Interviewer	
Company	
Date of flagging / Interview	
Date of flood event	
Name of storm event	
Address of HWM	
Location / Description of Mark	

Vertical Distance from set point & description of set point	
HWM Object	
Type of Mark	
Type of HWM	
HWM Quality	
Flood Type	
City	
County	
State	
Witness Information:	Name: Address: Telephone Number How long lived there: Obtained permission to survey?

Page 2	
HWM ID (from first page)	
Photo ID	
Photo Location / Orientation	
Photo Description / Subject	
Flagger HWM Latitude	
Flagger HWM Longitude	
Comments	

Figure 3b: High Water Mark (HWM) Report - Surveyor

HWM ID	
ADDRESS OF HWM	
Survey Date	
Surveyors	
Company	
Survey Accuracy (1)	
Projection	
Vertical Datum	NAVD 88
Horizontal Datum	NAD 83
Easting	
Northing	
HWM Elevation (2)	
First Floor Elevation (based on measurement from HWM)	

(1) Indicate survey method / equipment (since different equipment / methods have different accuracy)
(2) Note that the HWM is the line at the bottom of the tape or paint

Field crews noted CHWM characteristics such as surge, wave runup, and wave height. These designations on the survey sheets in the appendices represent the flaggers' estimates of these characteristics 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 still-water 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 corresponds to a higher flood 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 claimed the flooding was associated with a storm surge, when in fact the flooding was from wave runup or riverine flooding.

Several locations along the coast and bays experienced no rise in water levels, while others saw an actual decline during the storm. At these locations, water levels did not exceed the height of the bulkheads and seawalls enclosing the water body. The tops of these structures were surveyed to obtain a conservative estimate of surge heights. The rationale was that if the water level did not exceed these heights, then the storm surge was contained within these structures. An open black circle seen on the accompanying maps designates these points.

Elevation Conversion from NAVD88 to NGVD29 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 at 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, the NAVD88 elevation is 5.33 feet at UNIT 1-3. Using the latitude and longitude, VERTCON computes a datum shift of (-)1.171 feet; to convert to the NGVD29, SUBTRACT the datum shift from the NAVD88 height. NAVD EL=5.33’ minus (-)1.171 feet equals NGVD elevation of 6.502 feet.

Findings and Observations

Figure 4 (Appendix A) is a map of the area annotated with the CHWM unit ID's and surveyed elevations from coastal high water levels. Figure 5 (Appendix A) shows selected inset areas which were enlarged on subsequent figures to show greater detail in distinguishing between high water mark locations on the coast and those found in embayments, bays and estuaries These surveyed observations for the surge levels do include both surge height and wave run-up elevations relative to the North American Vertical Datum (NAVD) 88 vertical datum and the North American Datum (NAD) 83 horizontal datum.

Figure 4 and Figure 6, inset A (Appendix A) show that the overall pattern begins with high water elevations along the open coast at Marco Island of 4½ feet and those on inland coasts of between 1 and 1½ feet increasing to 4 to 6 feet at Naples. The height increases to 6 to 8 feet northward along the open Gulf coast at Estero Island (Fort Myers Beach) (see Figure 6, inset B). Heights of up to 6 feet were found along the causeway to Sanibel Island across the mouth of San Carlos Bay (Figure 7, inset C, Appendix A).

The coastal high water levels along the south-facing Sanibel Island shore were in the estimated range of 5 to 7 feet (Figure 7, inset D). Coastal levels increased to a maximum of about 7 to 8 feet on the west-facing shore of Captiva Island (Figure 8, inset E, Appendix A). Ralph Clark, a coastal engineer with the Florida Bureau of Beaches and Coastal Systems who visited the island, estimates that a breach across this island is on the order of 1,800 feet wide.

Gasparilla Island is just north of Cayo Costa Island. There appears to have been no significant surge on the open Gulf shoreline of Gasparilla Island.

Pine Island Sound lies between Captiva Island and Pine Island and it is north of Sanibel Island. The coastal high water levels along the sound-facing sides of Captiva and Sanibel Island were estimated between 2 and 3 feet. The coastal high water levels along the corresponding northwest shoreline of Pine Island were about 4 to 5 feet (Figure 2). For the southern shoreline of Pine Island, no flooding was observed.

Matlacha Pass is a relatively narrow waterway between the mainland and both Pine and Little Pine Island. This pass connects San Carlos Bay on the south to Charlotte Harbor at the north. Maximum coastal water levels along the Pine Island side of this pass observed were on the order of 4 feet. The eastern shore of this pass is entirely covered with a dense stand of mangroves and thus it is inaccessible.

The mile-wide Caloosahatchee River enters San Carlos Bay from the east. The high coastal water level opposite Cape Coral, which is on the north shore 3 to 9 miles upstream of the mouth, was about 3 feet. Further up this tributary estuary, in the eastern portion of Ft. Myers the high water level appeared to be on the order of 1½ to 2 feet. A point (unit2_32) taken approximately 25 miles up from the mouth of the river returned a surveyed elevation of 4.14 feet.

Charlotte Harbor is the name given to the portion of this estuary that is north of Pine Island south of the area of Port Charlotte. The Myakka River mouth enters from the west and the Peace River mouth from the east. These are about 1 to 1½ mile wide respectively. Punta Gorda lies on the east shore where the Peace River enters the Charlotte Harbor estuary. Observations along the Port Charlotte shoreline and up the lower Peace River showed that there was no significant storm surge. Water levels appear to have remained within the normal range of the tide and possibly even below this level. Along Charlotte Harbor south of Punta Gorda to the Charlotte-Lee County line, water levels appear to have gone as high as about 3 to 4 feet (Figure 8, inset F).

Finally, Gasparilla Sound lies behind the Gasparilla Island and the coastal high water level on the bay side of this island was about 2½ to 3 feet. Lemon Bay is behind Manasota Island about 10 miles south of Venice, Florida. This sound appeared to have witnessed no significantly increased water level elevation during the storm.

In summary, crews for surveying flagged 59 CHWM locations. The overall range of water level elevations on the open coast vary from 4½ feet NAVD on Marco Island in the south, to 8¼ feet NAVD on the north end of Estero Island, to 2½ feet NAVD on Cayo Costa Island. In the lower reaches of the Peace River and in the area of the mouth of the Myakka River, water levels did not reach normal high tide elevations. The geographic extent of these sites runs from Marco Island in the south, to just south of the town of Venice in the north. Out of the 59 surveyed CHWMs, 18 were clear maximum still water surge elevations and 25 were high quality marks designated as wave runup events. Of the remaining CHWMs, six are fair quality surge values, nine are fair quality wave runup values, and one is designated as a fair quality wave height event.

Recommendations

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

- Compare the Charley CHWMs to the flood elevation data on the effective or preliminary Flood Insurance Rate Maps. These comparisons can help FEMA make determinations on 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.

- Compare the Charley CHWMs to HWMs 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 analysis to determine flood elevations in the areas where deficiencies have been identified on the existing FEMA maps, or on areas where property loss occurred where no previous studies have been prepared.

- The locations and severity of the Charley 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 Charley 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 inundation mapping for Hurricane Charley. The inundation maps would provide a plan view look at the extent of flooding from Hurricane Charley and can assist in determining the accuracy of existing FEMA flood maps. The inundation mapping would be a spatially correct GIS coverage that can be provided to community officials to assist in disaster recovery.

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