HURRICANE FRAN STORM SURGE ASSESSMENT

by

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ABSTRACT

This paper describes Hurricane Fran as it approached the North Carolina Coast on September 3, 1996, until land fall on September 5th. An overview of the impact in damage and lose of life is presented. The storm surge analysis conducted by the Corps of Engineers for the Federal Emergency Management Agency is summarized. High water marks were identified and recorded at 211 locations. Water level time history is presented at six locations, and water discharge rates at 13 positions along the North Carolina coast. Inundation maps were developed for the surge effected coastal regions.

KEY WORDS: hurricane; storm surge; high water mark; inundation maps; Hurricane Fran.

1. INTRODUCTION

Hurricane Fran after striking the North Carolina coast on September 5, 1996, moved inland effecting Virginia, Maryland, and West Virginia causing over five billion dollars in damage. In the aftermath of this storm a detailed study was taken under the direction of the Federal Emergency Management Agency to evaluate the storm surge and inundation that resulted from Hurricane Fran. A summary of that evaluation is presented here to include high water mark data, time history of the storm surge, inundation maps, and inlet water flows.

2. OVERVIEW OF IMPACT

Hurricane Fran slammed into North Carolina's southern coast with sustained winds of approximately 115 MPH, and gusts as high as Hurricane Fran slammed into North Carolina's southern coast on September 5th with sustained winds of approximately 115 MPH, and gusts as high as 125 MPH. At some point, 1.7 million customers in North Carolina and 400,000 customers in Virginia lost electricity. The death toll was at 36, including 23 in North Carolina. Flooding has also been a severe problem in North Carolina, Virginia, West Virginia, and Maryland. Fran produced rainfall amounts of over 10 inches in parts of eastern North Carolina and western Virginia.

Damages for homes and businesses in North Carolina were approximately $2.3 billion. Damages/costs related to the public (debris removal, roads and bridges, public buildings, utilities, etc.) was about $1.1 billion for NC. Agricultural damage (crops, livestock, buildings) in North Carolina was over $700 million. Wake County (Raleigh and vicinity) alone reported over $900 million in damage to residential and commercial property. Finally, forestry/timber losses for the state exceeded $1 billion.

Taken collectively, total damages/costs for North Carolina was near $5 billion. With the addition of lesser damages for states to the north, the storm's total cost excessed $5 billion, making Fran the third most costly hurricane in U.S. history, moving Opal (1995) into fourth place. However, it's important to note that the figures for earlier storms are not adjusted for inflation. Just prior to landfall of Fran, a small portion of western North Carolina-

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in the Bat Cave, Chimney Rock, Lake Lure areas--received up to 11 inches of rain in a 3 hour period. The rains were the result of nearly stationary, very heavy thunderstorms associated with an upper level low pressure system. Severe damage to property in the immediate area resulted, with about 70 homes and businesses being destroyed or significantly damaged. Figures 1 and 2, are GOES-8 IR images of Hurricane Fran prior to land fall on September 4 and 5. Figure 3 is an image at land fall or September 5th.

3. HURRICANE FRAN HIGH WATER MARKS AND INUNDATION MAPPING

3.1. Purpose

Hurricane Fran made landfall along the North Carolina coast in the vicinity of Carolina Beach, NC on September 5, 1996. As a result of this storm, The Wilmington District of the Corps of Engineers (COE) was tasked by the Federal Emergency Management Agency (FEMA) to locate high water marks along the coastal area impacted by the storm and produce inundation mapping based on these high water marks. The purpose of this report is to present the high water mark data and other information developed during this study.

3.2. High Water Marks

High water mark data was collected following the hurricane at various locations along the coastal areas of North Carolina impacted by the surge from Hurricane Fran. This data was collected by personnel from three organizations. Dewberry and Davis, a consulting engineering firm under contract to FEMA, collected preliminary data on the coastal beaches immediately following the storm. The data they collected was compiled in a report for FEMA titled Hurricane Fran North Carolina High Water Mark Survey and Coastal Inundation Mapping, dated September, 1996. The U.S. Geological Survey (USGS) also collected high water mark data along the beaches following the storm.

The COE was tasked with the mission of collecting additional high water marks where needed and producing inundation maps. Most of the data collected by the COE was in areas which were inaccessible immediately following the storm and along the coastal creeks along the west side of the Atlantic Intracoastal Waterway(AIWW) impacted by the storm surge. Data was collected from Southport, NC north to Beaufort, NC. In collecting the high water marks an attempt was made to collect both inside and outside marks. A total of 211 high water marks were collected.

3.3. Method of Collection High water data was collected based on visual observations by personnel who were familiar with collection of highwater mark data. The high water marks were identified in the field and the location along with other pertinent information was described on data forms. A picture of the high water mark was taken at each location. Figures 4 thru 7 are examples of the pictorial data developed for each high water mark.

3.3.1 Coordinates The geographic location of the HWM's were described using latitude and longitude. The coordinates of the high water marks were determined in the field using the Geographic Positioning System(GPS). The coordinates of the marks taken by Dewberry and Davis were determined based on a dual frequency Differential Geographic Positioning System(DGPS). The procedure is described in their report. The coordinates of the marks taken by the USGS and COE were determined using a hand held GPS unit. The locations were later verified in the office with the use of topographic maps.

3.3.2 Elevations Elevation of high water marks taken by Dewberry and Davis were determined using DGPS as mentioned above and described in their report. The elevation of marks taken by the USGS and COE were determined using conventional survey methods. Bench mark elevation data from USGS and various other sources was obtained and used for vertical control. Elevations were obtained by conventional leveling using two 2- man survey teams. Representatives of the COE were in the field with the survey teams to coordinate the effort.

Table 1 is a sample of the data collected for each of the 211 high water mark sites.

3.4 Inundation Mapping

Storm surge mapping was accomplished using the Arc-Info 7.04 Unix Geographic Information System (GIS) software and constructed GIS datasets. The base GIS datasets were obtained from the State of North Carolina Center for Geographic Information and Analysis (NCCGIA) consisted of the following:

1. NC County Lines
2. NC Roads (primary and secondary)
3. NC Hydrography (water and land)

These datasets were used for the overall base mapping of the inundated areas.

The inundation line for the storm was developed using USGS 1:24000 scale quadrangle sheets. The line was first delineated on the quad sheets utilizing the HWM elevations and locations obtained in the field. The line was then digitized and entered into the Arc-Info data base and overlaid on the base maps. HWM location points collected in the field were also converted to a GIS dataset and overlaid on the maps. The limits of mapping for the inundation line were set at points where the inundation became insignificant.

Listed below are the Quadrangle sheets used to produce the inundation limits.

Southport, NC	Spicer Bay, NC
Kure Beach, NC	Sneads Ferry, NC
Carolina Beach, NC	New River Inlet,
Hubert, NC	Wrightsville Beach, NC
Scotts Hill, NC	Browns Inlet, NC
Tampstead, NC	Swansboro, NC
Topsail, NC	Salter Path, NC
Holly Ridge, NC	

A sample inundation map is shown in figure 8 for the Wrightsville Beach Area. The maps are printed at a scale of 1:24000 and are identified by the same name as the USGS quad sheets used to produce the inundation limits. The HWM numbers shown on the map are referenced to Table 1 as HWM ID numbers.

4. Storm Surge

Tide levels along the North Carolina and South Carolina Coast for the time period during the storm were available at five locations. Location information on the five gages are listed below.

Gage Name	Mean Tide Level (ft)	Peak During Fran (ft)
Myrtle Beach, Springmaid Pier	2.73	7.3
Wilmington, NC	2.20	7.1
Beaufort, Duke Marine Lab	1.60	6.4
Hatteras Ocean Gage	1.90	4.0
Oregon Inlet	1.00	2.9

The tide range for the period at the Wilmington is shown graphically in figure 8.

The storm surge was also recorded at one location along the AIWW by Mr. Spencer Rogers, NC Sea Grant at his residence which is located on the western side of the AIWW between Carolina Beach and Wrightsville Beach, NC. These observations give a very accurate record of the storm surge along the New Hanover County coast line. The plot of the surge is shown on figure 9.

5. Stream Gages

There are no USGS recording stream gages in the

coastal area impacted by the storm which would have recorded the storm surge. There are, however, gages on all of the major inland rivers which recorded stream flow data during the storm which show the effects of the rainfall associated with the storm on the inland rivers and streams. Data was furnished by the USGS at the gages shown in table 2.

6. CONCLUSIONS

The assessment of the storm surge during Hurricane Fran was one of the most comprehensive under taken. The data collection and report format used is expected to become a standard for future events of similar importance by the Federal Emergency Management Agency.

The data collected during this assessment on high water marks, storms surge time history, and inlet discharge rates will be used to validate and refine storm surge predictive models by the U.S. Army Corps of Engineers.

These data will also be used in a study currently underway by the Corps of Engineers to evaluate the performance of beach areas protected by Federal projects versus beaches that are not protected. Beaches in both categories were impacted by Hurricane Fran.

7. ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of Mr. Linwood Rogers of the U.S. Army Corps of Engineers Wilmington District for the data and report information on the storm surge from Hurricane Fran.

8. REFERENCES

Hurricane Fran High Water Marks and Inundation Mapping Report, U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, September 1996 .

Hurricane Fran-North Carolina High Water Mark Survey and Coastal Inundation Mapping, Dewberry and Davis Inc., Engineering Consultants, September 1996.

Hurricane Fran Images, National Oceanographic and Atmospheric Administration, Silver Springs, MD, September 1996.

Table 1
Pertinent High Water Mark Data-Coastal North Carolina

HWM ID	HWM Field Number	Inside(I) or Outside(O)	Type Line	Quadrangle Sheet	Latitude	Longitude	Elevation (ft, msl)	Obtained By
SOUTHPORT-KURE BEACH-CAROLINA BEACH AREA								
1	hwm 2010	O	Debris	Southport	33°55'01.38282"	78°01'04.07487"	5.4	Dewberry and Davis
2	hwm 2011	O	Debris	Southport	33°53'59.41651"	78°03'51.12476"	11.2	Dewberry and Davis
3	hwm 2013	O	Debris	Southport	33°53'59.41651"	78°03'51.30939"	12.2	Dewberry and Davis
4	NH-2F	O	Mud	Kure Beach	33°57'51.11887	77°55'17.31822'	8.4	U.S. Geological Survey
5	hwm2014	O	Debris	Kure Beach	33°58'10.66001"	77°55'08.05241"	12.5	Dewberry and Davis
6	NH-60-KB	I	Mud	Kure Beach	33°58'25.92355"	77°54'52.85720"	14.1	U.S. Army Corps of Engineers
7	NP-3P	O	Debris	Kure Beach	33°58'51.55023"	77°54'48.18686"	14.0	U.S. Geological Survey
8	NH-4P	O	Mud	Kure Beach	33°58'54.67583"	77°54'42.74307"	14.8	U.S. Geological Survey
9	NH-61-KB	I	Mud	Kure Beach	33°59'00.65651"	77°54'42.32002"	14.0	U.S. Army Corps of Engineers
10	hmw2018	O	Debris	Kure Beach	33°59'12.64196"	77°54'42.01731"	15.1	Dewberry and Davis
11	NH-5F	O	Mud	Kure Beach	33°59'15.81296"	77°54'37.14494"	14.5	U.S. Geological Survey
12	hwm2017	O	Debris	Kure Beach	33°59'21.23023"	77°54'36.26851"	15.4	Dewberry and Davis
13	hwm2015	O	Debris	Kure Beach	33°59'32.48636"	77°54'33.77071"	15.3	Dewberry and Davis
14	NH-6P-B	O	Debris	Carolina Beach	34°00'19.38965"	77°54'14.67800"	15.2	U.S. Geological Survey
15	NH-6P-C	O	Mud	Carolina Beach	34°00'20.04577"	77°54'13.95665"	14.9	U.S. Geological Survey
16	NH-6P-A	O	Debris	Carolina Beach	34°00'22.04308"	77°54'14.93977"	10.3	U.S. Geological Survey
17	NH-8P	O	Mud	Carolina Beach	34°00'42.57287"	77°54'04.64222"	13.5	U.S. Geological Survey
18	NH-7G	O	Mud	Carolina Beach	34°00'40.51155"	77°54'04.23011"	13.2	U.S. Geological Survey
19	NH-9P	O	Mud	Carolina Beach	34°00'42.34586"	77°54'03.62369"	13.6	U.S. Geological Survey
20	NH-62-CB	I	Mud	Carolina Beach	34°00'58.80906"	77°53'57.52466"	13.5	U.S. Army Corps of Engineers
21	NH-11P	0	Mud	Carolina Beach	34°01'27.76556"	77°53'44.99743"	11.5	U.S. Geological Survey
22	NH-10G	O	Mud	Carolina Beach	34°01'28.76047"	77°53'47.75225"	9.0	U.S. Geological Survey

Gage Location	Drainage Area (sq. mi)	September Discharges (cfs) Mean	Min.	Max.
Tar River near Tar River, NC	167	62.2	.28	671
Neuse River near Falls, NC	771	182	67.8	463
Neuse River near Clayton, NC	1150	339	136	661
Trent River near Trenton, NC	168	122	4.56	1577
New River near Gum Branch, NC	94	86.5	4.25	887
Deep River near Ramseur, NC	349	227	17.7	1934
Deep River at Moncure, NC	1434	740	24.1	10580
Cape Fear River at Fayetteville, NC	4395			
Cape Fear River at William O. Husk L&D	4852	1601	935	2927
Cape Fear River at Lock # 1 nr Kelly, NC	5255	1976	985	3609
Hood Creek near Leland, NC	21.6	27.1	.51	75.1
Black River near Tomahawk, NC	676	544	13.4	3319
Waccamaw River at Freeland, NC	680	621	.31	4825

Table 2. Water Discharge Rates at North Carolina River Inlets

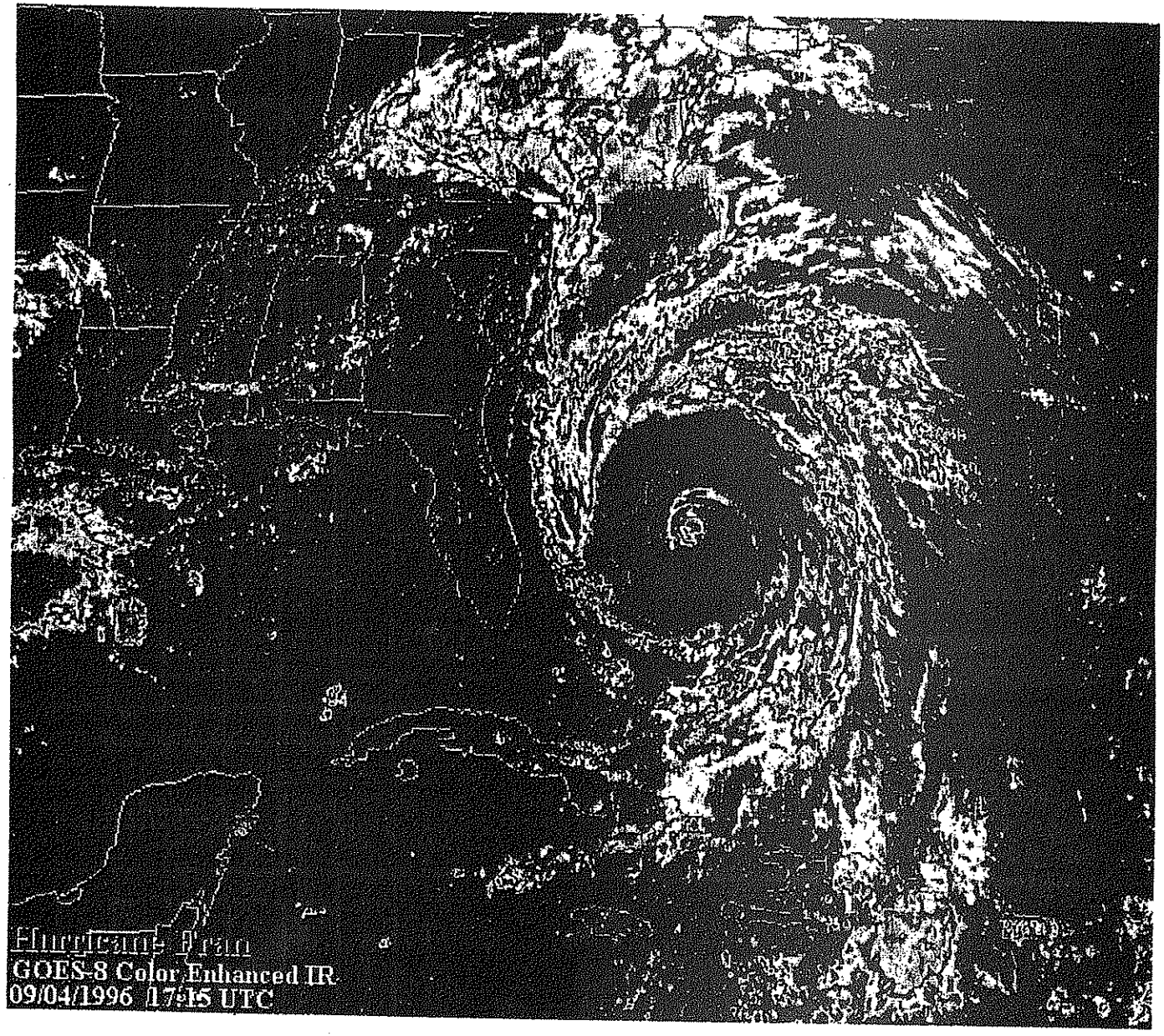


Figure 1. GOES-8 Image of Hurricane Fran on September 4, 1996

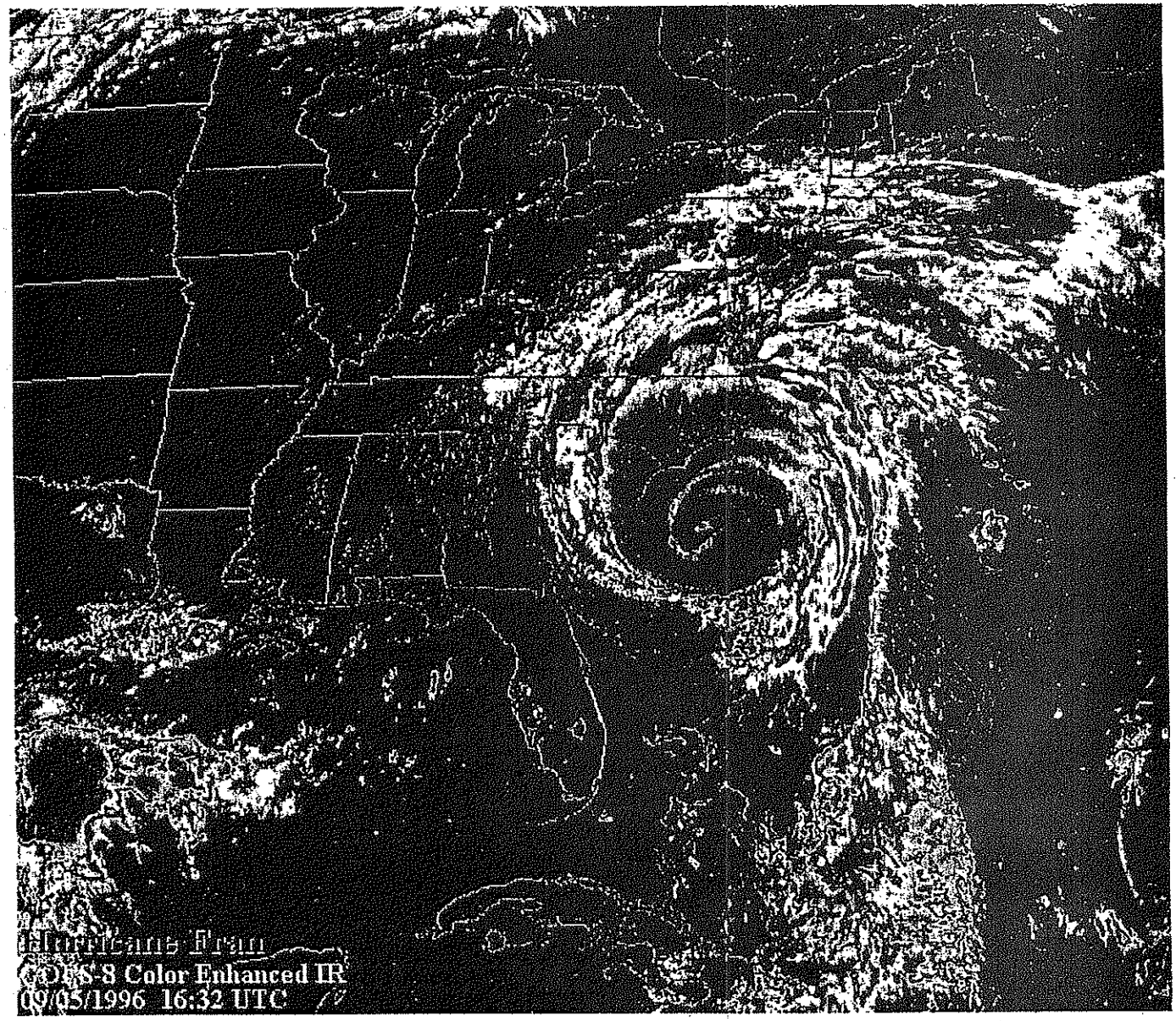


Figure 2. GOES-8 Image of Hurricane Fran on September 5, 1996 Before Landfall

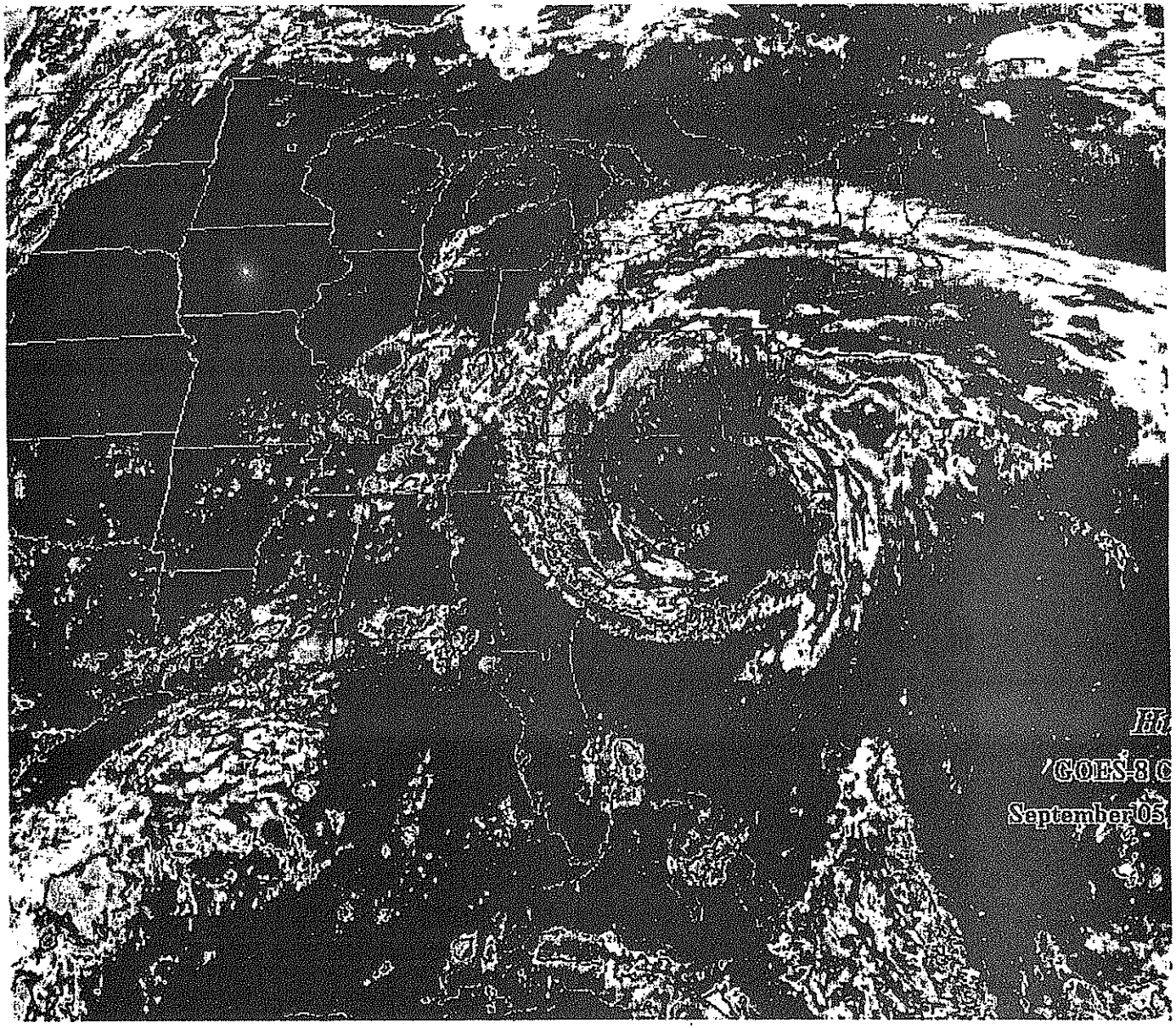
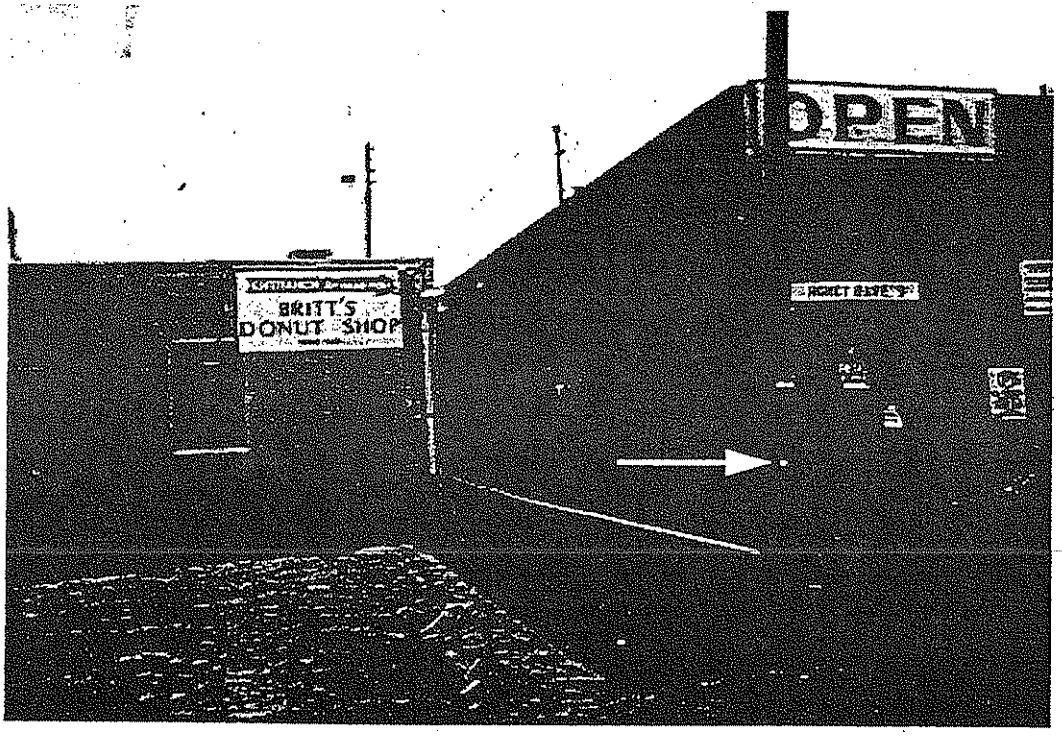


Figure 3. GOES-8 Image of Hurricane Fran on September 5, 1996 at Landfall



Hurricane Fran, September 1996

HWM Number:	NH-13P	**Taken By:**	US Geological Survey
HWM Elevation (ft, msl):	9.5	**Date Taken:**	08 Sept 1996
Latitude:	34° 02'01.2758"	**Longitude:**	77° 53'32.8701"
HWM Type:	Mud Line	**Outside or Inside:**	Outside
USGS 7.5 minute Quadrangle Sheet:	Carolina Beach, NC		
Nearest Town:	Carolina Beach, NC		
Address:	Intersection of Raleigh Ave. and Woody Hewett Ave.		
Remarks:	High water mark is behind Britts Donut Shop and Honeybears. Mark is on telephone pole 46 inches above parking lot.		

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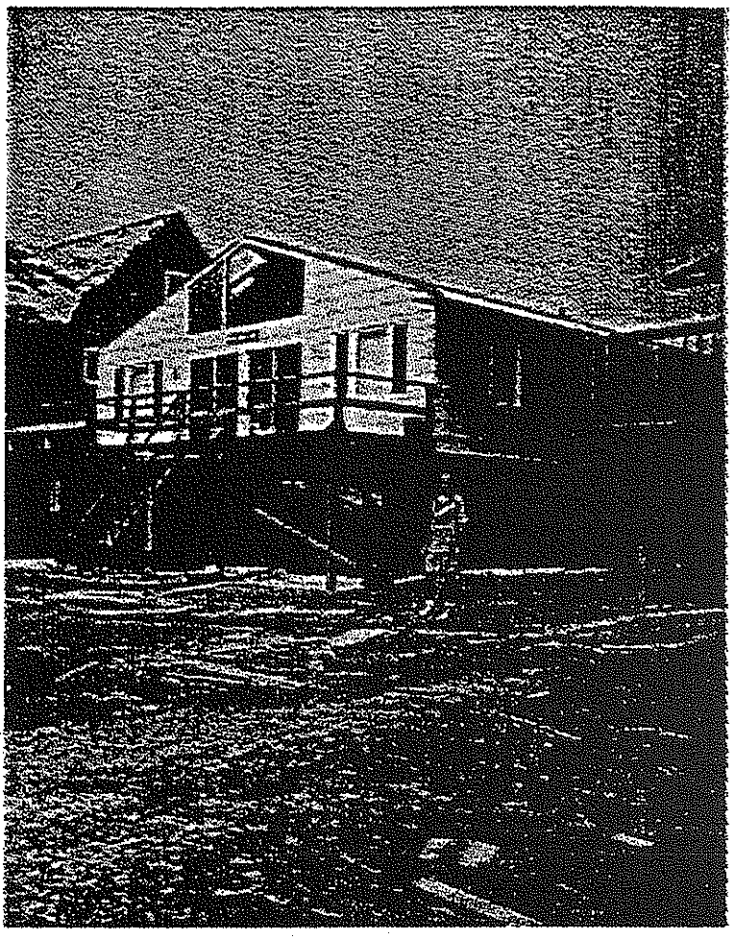
Wilmington District

Figure 4. High Water Mark at Carolina Beach, NC

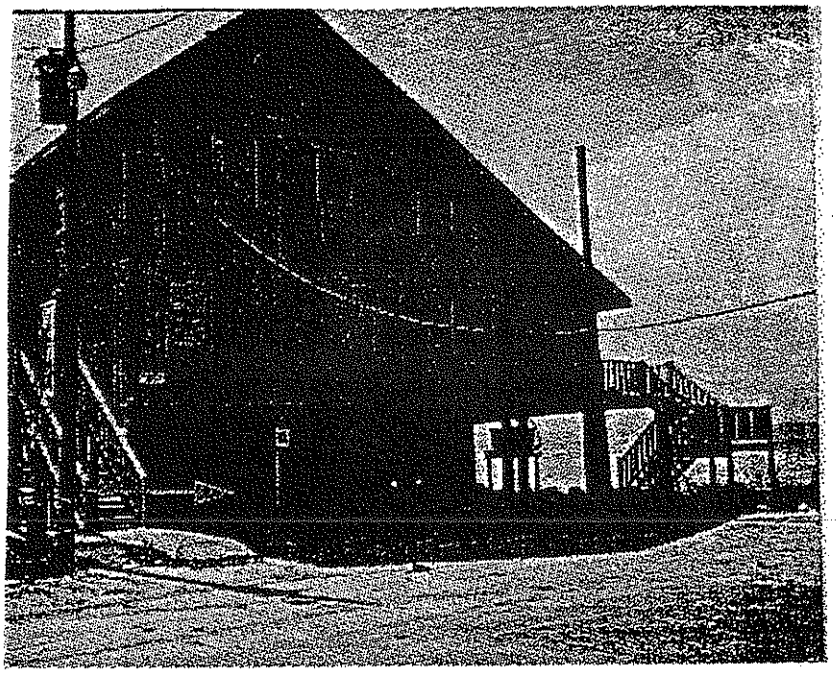


Hurricane Fran, September 1996

HWM Number:	C-1	**Taken By:**	U.S. Geological Survey
HWM Elevation (ft, msl):	13.9	**Date Taken:**	07 Sept 1996
Latitude:	34° 24'06.06"	**Longitude:**	77°35'01.32"
HWM Type:	Debris Line	**Outside or Inside:**	Outside
USGS 7.5 minute Quadrangle Sheet:	Holly Ridge, NC		
Nearest Town:	Topsail Beach, NC		
Address:	2319 South Shore Drive		
Remarks:	Debris Line in front yard.		

US Army Corps of Engineers
Wilmington District

Figure 5. High Water Mark at Holly Ridge, NC



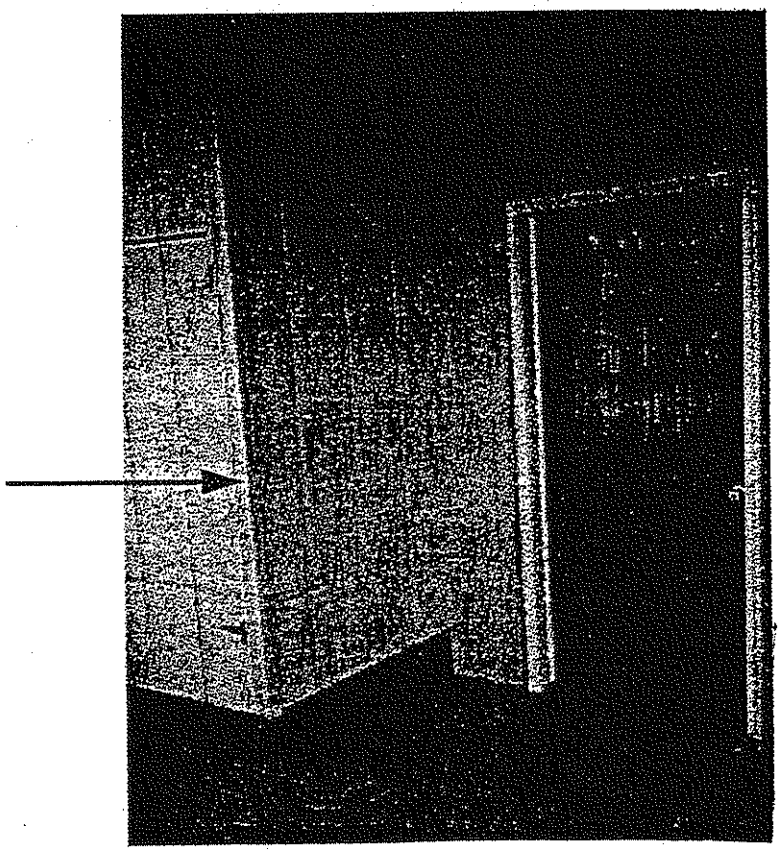


Figure 6. Two High Water Mark Locations Wrightsville Beach, NC

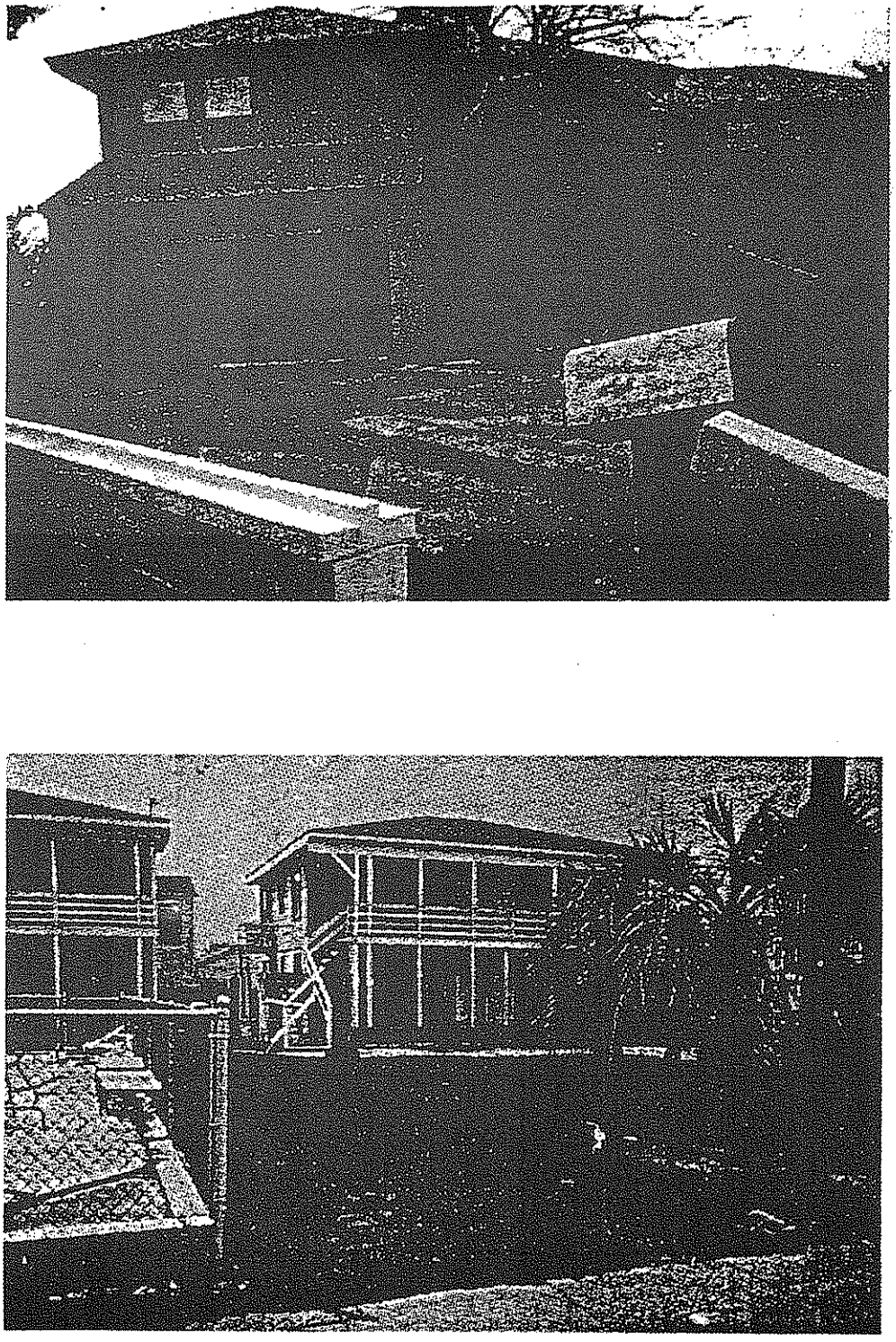


Figure 7. Two High Water Mark Locations Hampstead, NC

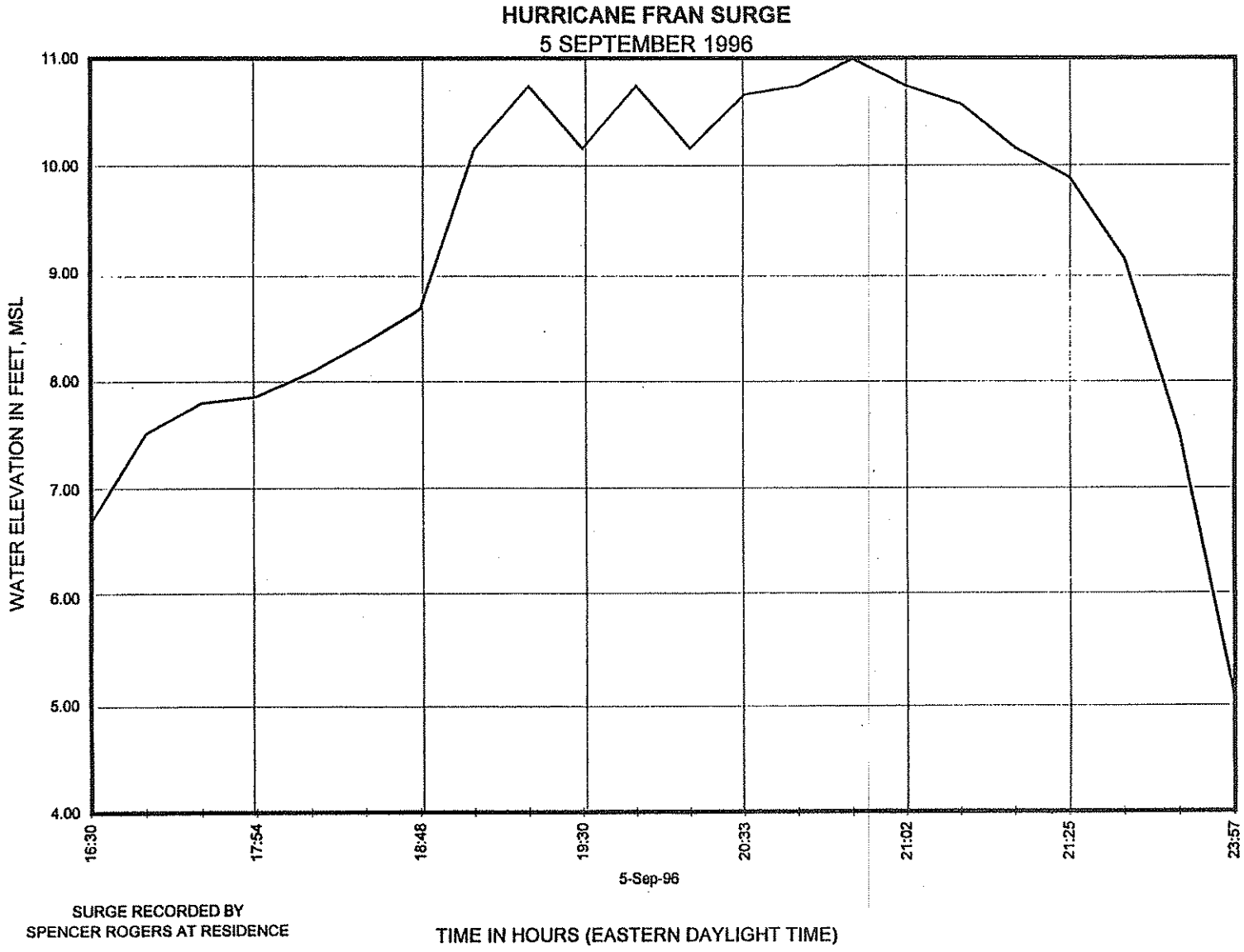


Figure 9. Storm Surge Time History at Spencer Rogers Residence

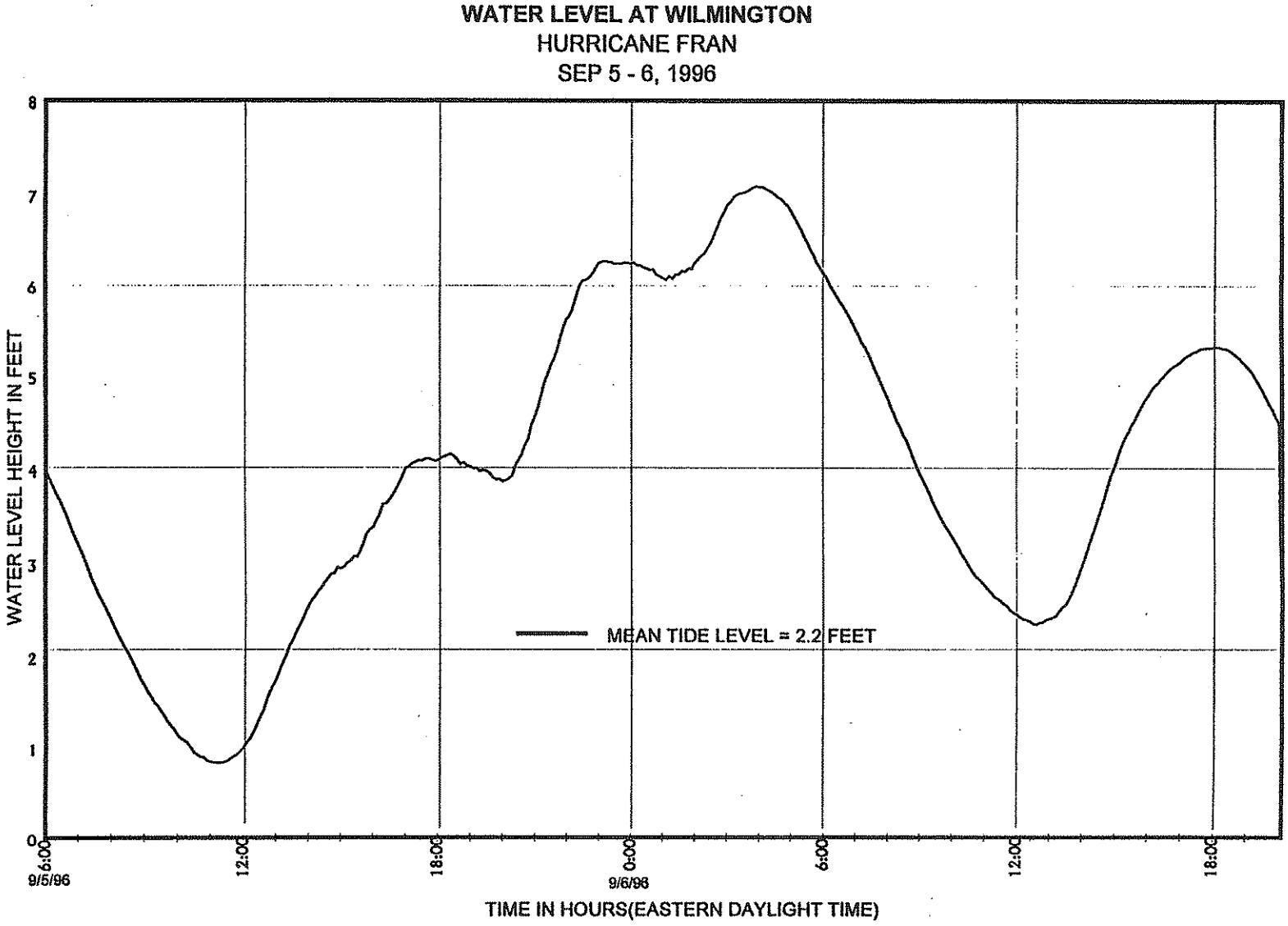


Figure 8. Water Level Time History at Wilmington, NC