NATURAL HAZARDS CENTER

QUICK RESPONSE REPORT

Five Years and Two Hurricanes: A Return to San Salvador Island, Bahamas

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Introduction

San Salvador is a Bahamian island located 640 kilometers east-southeast of Miami, Florida, with a population of approximately 1,000 (Shanklee, 1994). Although small in physical area (19 kilometers long and 9 kilometers wide), San Salvador has great historical significance as the landing location of Christopher Columbus's expedition in the "New World." This fact and the island's Caribbean location make it attractive to tourists. In fact, an airport runway capable of accepting large commercial aircraft was recently built to support a Club Med Resort on the island's northwest side. In addition to tourism, the island supports the Gerace Research Center (GRC), which can accommodate 190 researchers and students who specialize in archeology, biology, geology, and marine science.

On September 14, 1999, the eye of Hurricane Floyd (a category 4 hurricane at the time) passed just 24 kilometers northeast of San Salvador Island. A team of five researchers arrived three days later to assess the damage to the physical, water resource, and tourism infrastructure (Gamble et al., 2000). A follow-up visit was made in late December 1999 to assess the clean-up progress. On September 2, 2004, the eye of Hurricane Frances (a category 4 hurricane at the time) passed directly over San Salvador Island. The same team of researchers was assembled and arrived on the island five days later. Another damage assessment, followed by mitigation recommendations, was completed after Hurricane Floyd was evaluated. Similar to 1999, a follow-up team assessed the progress of cleanup in late December 2004.

Methodology

The research focused on two goals:

1. Document structural and tourism infrastructure damage through photos and video footage.

2. Evaluate mitigation procedures used after Hurricane Floyd for effectiveness during Hurricane Frances.

Photo and video documentation was also completed in late December 2004 for damage extent evaluation. Rebuilding efforts and the extent of vegetation disruption will be assessed by comparing immediate post-impact images with and three-month lag images.

Frances: Immediate Evaluation

The Storm

On September 2, 2004, at approximately 3:00pm EDT, Hurricane Frances (a storm then rated a category 4 on the Saffir-Simpson hurricane intensity scale) made landfall on the small island of San Salvador, Bahamas. The National Hurricane Center's (NHC) 2:00pm EDT advisory indicated that Frances was moving west-northwest with a forward speed of 21 kilometers per hour^{-1}. Hurricane Hunter aircraft measured the central pressure of the storm at 949 millibars (mb), with estimated corresponding winds of 233 kilometers per hour^{-1}. At approximately 4:30pm EDT (during the relative calm of the eye) a satellite phone call

was placed from the GRC to a researcher in the United States. While this conversation is second-hand information, the message conveyed was that significant damage had occurred to the research center and it was unlikely that any un-reinforced structure would still be standing. The 5:00pm EDT NHC advisory stated that the storm's eye was still over San Salvador and was moving northwest at 16 kilometers per hr-1, and that the central pressure had dropped to 948 mb with an expected storm surge of 1.8 to 4.3 meters. A Campbell Scientific MetData 1 weather station located at the GRC indicated a surface pressure of 954 mb at 3:00pm EDT. Shortly after the 3:00pm observation, the weather station failed to collect reliable data. However, the hourly graph of these pressure data indicate that the 5:00pm NHC advisory was likely quite accurate with respect to the intensity estimate (Figure 1).

The Damage Survey (Storm Surge)

Estimates of storm surge height were conducted at three locations using a stadia rod, sighting level, and measuring tape. A surge height was determined through a transect from the position of wave break to the post storm debris line. Not surprisingly, the largest surge was found on the southern end of the island (the location of first landfall). Surge in this region was estimated at between 3.75 and 5.00 meters with extensive over-wash deposits on dune vegetation. The distance from wave break to debris was approximately 100 meters.

The Damage Survey (Structure Damage)

A quick survey of damage to residences and other structures was completed in the three most populous settlements on San Salvador: United Estates, Cockburn Town, and Victoria Hill. Observed damage to structures was placed in one of four damage categories to allow for comparative damage estimates for each location. The first damage category included structures with no damage, the second included structures with light damage such as missing shingles, broken windows, downed electrical wires and antennas, and broken window shutters. The third damage category included structures with heavy damage, such as large holes in the roof, partial loss of a roof, loss of doors or windows, and collapsed walls. Structures that experienced complete structural failure (i.e., no standing walls or roof) were placed in damage category four.

Of all the settlements on San Salvador, United Estates (Figure 2) experienced the greatest damage. Overall, 95% of the structures surveyed sustained some form of damage from the storm. Category 2 damage occurred to approximately 60% of the structures, and almost 30% of the structures in the settlement had category 3 or higher damage (mostly to roofs) (Table 1). Seven structures within United Estates experienced complete structural failure during Hurricane Frances. All of these structures were wood, with a majority showing evidence of rotten wood along anchor points along the building's foundation. The San Salvador Primary School (also in the United Estates) received heavy roof damage on the back side of the building, which resulted in damage to books and school materials. The lower building of the high school also sustained considerable roof damage. The San Salvador Lighthouse received little visible damage, but one of the lighthouse keeper structures sustained category 3 damage, and a metal communication tower was bent and blown down during the storm.

A survey of structures in Cockburn Town (Figure 2) indicated that 20% of buildings experienced category 3 damage, many homes had portions of their roofs missing (the research team recognizes that this was primarily from the hurricane but could have been post-hurricane construction efforts). Almost two-thirds of the structures in Cockburn Town received category 2 damage, with eight structures showing no signs of damage. Complete failure occurred for only two structures.

The research team was denied access to the Columbus Isle Club Med facility and was unable to survey damage on the grounds. However, observations made from the roads surrounding the complex indicated category 2 and 3 damage to many of the Club Med structures. Storm damage was not as extensive throughout the Victoria Hill settlement (Figure 2), and no buildings experienced structural failure. Most of the damage (almost 80%) was light, and only four structures received heavy damage (Table 1). Eight structures in this area received no observable damage from Frances.

Hurricane Floyd Mitigation Assessment

The research team studying Hurricane Frances had traveled to San Salvador, Bahamas, five years earlier to study Hurricane Floyd's impact on the island (see Quick Response Report #124). After the initial trip and assessment the research team suggested some mitigation techniques to the Bahamian government, specifically concerning damage noted in Hurricane Floyd. These mitigation strategies included the construction of a seawall to protect businesses and residences near the coast of the island. In addition, it was recommended that post-Floyd reconstruction include the use of hurricane straps along roof members and the use of concrete slab foundations for better wall anchoring, and that more weather stations be placed around the island for future post-storm analysis.

One business (Riding Rock Inn) heeded the advice and constructed a seawall and used hurricane straps during the reconstruction of their roof. During Hurricane Floyd the majority of the Inn's main building had been undercut by the surge, and a few of the outbuildings were lost to surge and wave energy. During the more powerful Hurricane Frances, the building sustained only shingle damage to the roof and no out-buildings were significantly damaged. However, significant beach erosion and some

significant undercutting of the road (which made it unsafe for travel) occurred at the end of the seawall.

The Club Med facility did not use any mitigation procedures and suggested in conversation that it is more cost effective to repair or rebuild rather than retro-fit existing structures. Although the number of weather stations across the island increased (mostly rain gauges related to other studies), data from these instruments did not prove useful, as the majority of the stations were damaged by wind-blown debris. It has been suggested that the weather stations be moved to locations that are less prone to debris.

Conclusions

The majority of meteorological observations recorded at the GRC on San Salvador are consistent with reports from the NHC, indicating that early reports of Hurricane Frances were accurate. However, the wind speeds recorded at the GRC were much lower than reported by the NHC. This discrepancy between the GRC observations and the NHC public advisories was due to inaccurate measurements on the GRC campus. The weather station anemometer has malfunctioned previously, and the damage surveyed by the authors on San Salvador is consistent with sustained winds in excess of 160 kilometers per hour.

The highest storm surge and greatest structural damage from Hurricane Frances occurred on the east and south sides of San Salvador. The authors believe the reason for the high storm surge and heavy damage in these areas is that these portions of the island were located in the northeast quadrant of the hurricane as it made landfall on the island. The track of the hurricane (southeast to northwest) combined with the atmospheric circulation around the hurricane (counter-clockwise) to increase the wind speed and storm surge in the front, right quadrant (Lutgens and Tarbuck, 2004). The direction of the highest winds recorded at the GRC further support this hypothesis.

Overall, the research team believes that the damage across San Salvador was less than expected for a direct hit from a hurricane of this magnitude. Several factors on San Salvador may have decreased the damage from this hurricane, including the use of concrete as the dominant building material, location of structures away from the beaches and shoreline, a low population on the eastern side of the island, and the protection afforded by dunes. The authors hypothesize that damage would have been much worse on San Salvador if more settlements with wood as the dominant building material had been located on the east side of the island, close to the ocean.

References

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