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Communication

Brief Communication: Analysis of the Fatalities and Socio-Economic Impacts Caused by Hurricane Florence

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Abstract: Florence made landfall on the southeastern coast of North Carolina (NC) generating torrential rainfall and severe flooding that led to 53 fatalities in three states (NC, SC, and VA) and $16–$40 billion in damage. Seventy-seven percent (77%) of the fatalities occurred in the rural flood plains of NC with Duplin county reporting a high of eight deaths. Approximately 50% of the total number of hurricane-related fatalities across the three states were vehicle-related. The predominant demographic at risk were males over the age of 50 years. The type of property damage was in line with other major hurricanes and predominantly affected residential structures (93% of the total number of damaged buildings). Florence is among the top 10 costliest hurricanes in U.S. history with approximately 50% of the damage projected as uninsured losses due to residential flooding. The cumulative 5-day rainfall resulted in major flooding along the Cape Fear, Lumberton, and Neuse rivers where many industrial waste sites (hog manure lagoons and coal ash pits) are located. Several of these waste sites located in the flood plain were breached and have likely cross-contaminated the waterways and water treatment operations. The observed extent of the flooding, environmental contamination, and impact to public health caused by Florence will add to the long-term disaster related mortality and morbidity rates and suggests an expansion of the 100-yr flood hazard zone to communicate the expanded risk to the public.

Keywords: Hurricane Florence; fatalities; property damage; socio-economic; environmental; natural hazards; hydrometeorological disasters; flooding

1. Introduction

Tropical cyclones occur throughout the world and are referred to as either typhoons or hurricanes depending on where they originate. In the North Atlantic, Central and Eastern North Pacific, the cyclones are referred to as "hurricanes". The same type of disturbance in the Northwest Pacific is called a "typhoon". The generic term "tropical cyclone" is more commonly used for storms originating in the South Pacific and Indian Ocean [1]. Their enormous energy, fueled by the moist air from warm oceans, causes catastrophic damage to life and properties. The combination of high wind speeds and storm surge coupled with rainfall induced inland flooding can cause devastation in the storm path and surrounding areas.

Tropical cyclones and flooding account for 50% of the 10 deadliest natural disasters recorded in human history—each of them responsible for more than 220,000 fatalities [2]. In the U.S. from 2001 to 2017 there were 1,236 fatalities reported by NOAA related to hurricanes, of which 82% are attributed to hurricanes in 2005 (Hurricane Katrina, Rita, and Wilma). Hurricane Katrina alone is responsible for approximately 1200 reported deaths, with 1000 in Louisiana and 200 in Mississippi. Additionally,

the top five costliest hurricanes on record occurring after 2000 cost a total of $500 billion of which 53% occurred in 2017 (Hurricane Harvey, Maria, and Irma). According to NOAA, 2017 was the costliest year with 16 distinct events greater than $1 billion totaling $306 billion, surpassing the previous record of $215 billion set in 2005 [3].

Concurrent to the increase in disaster event intensities, research of disaster fatalities is on the increase to improve risk models, provide a basis for policy reform, and strengthen public communication to minimize future casualties [4]. All hurricanes have unique relationships of cause and effect based on the specific hazards and location of impact. In the case of Katrina, the deadliest hurricane to make landfall in the U.S., a third of the fatalities (from the 771 analyzed) were due to the adverse public health conditions present in the aftermath of the hurricane. The majority of direct fatalities were a result of flooding resulting in victim drowning. The percentage of the overall population impacted by Katrina is in line with historical disaster records in the U.S. at 1%. [5]. However, disaster mortality has reached as high as 10.5% of the population in developing countries as reported by Chowdhury, Bhuyia et al. (1993) for the 1991 Bangladesh Cyclone [6].

As with many major natural disasters, hurricanes disproportionately affect the vulnerable sector of society. For instance 56% of the fatalities of hurricane Harvey [4] and 85% of the fatalities of hurricane Katrina were aged above 50 years [5]. The increased risk with age may be due to the increased physical limitations and their inability or resistance to evacuate from the designated hazard areas due to deeper roots of homestead. The young are also at risk as seen with the Bangladesh cyclone of 1991 in which 15.5% of the fatalities were minors (less than 14 years old) and 13.4% were above 50 years [6]. Gender disparity was not indicated in the mortality data for hurricane Katrina, however, a significant difference was seen in hurricane Harvey as 70% of the fatalities were male [4]. Even though this gender disparity is reflected in previous studies, the overall cumulative mortality data reported by NOAA only indicates a slight variation among genders (53% male, 42% female, and 5% unknown) in all hurricane-related mortalities since 2001 [7]. The greater tendency of males to be involved in high-risk activities such as driving during flooding and involvement in flash flood rescue efforts likely contributes to the higher male fatality rate [8].

From 1980–2017, the U.S. experienced 233 weather and climate-related disasters with damages of $1 billion ($2018) or greater for a total cost of more than $1.5 trillion [9]. The positive trend in damage and economic loss in the U.S. is a result of increasing disaster intensity and the increasing population density and property value along the coastal regions that are vulnerable to hurricane force winds, storm surge, and flooding. In the last two decades, the U.S. has experienced an increasing number of years with multiple hurricanes of strong intensity that caused damage of more than $3 billion ($2017) per event [10]. The year 2017 is the costliest and deadliest year on record with Harvey, Maria, Irma, and Nate resulting in excess of $280 billion and 3,260 deaths [11]. The second worst year is 2005 in which hurricanes Dennis, Katrina, Rita, Stan, and Wilma resulted in excess of $180 billion in damage and 2,280 deaths, with Katrina responsible for more than 70% of the total damage [12]. Hurricane Florence made landfall on 14 September 2018 at Wrightsville Beach just outside the city of Wilmington, North Carolina (NC) with winds that gusted at 105 mph causing torrential rains and flooding that resulted in high fatalities and economic impact. The following brief communication provides information on fatalities, property damage, and environmental impact caused by hurricane Florence based on best available data at the time of publication. Given the likely occurrence of other intense hurricanes in the near future, the timely assessment of this major hurricane can provide information useful to public safety officials and responders resulting in better preparation.

2. Data and Methods

The numerical data and descriptive information of the fatalities analyzed in this report were obtained through the North Carolina Department of Public Safety (NCDPS). Upon request, the natural hazards branch manager in the NC Emergency Management Division of the NCDPS provided a listing of direct and indirect fatalities caused by hurricane Florence. The fatality report included death date,

county, age, gender, type of death, incident summary, direct or indirect, and source of information. The NCDPS only reported one indirect death in Sampson County in which the death was due to chronic obstructive pulmonary disease (COPD) but was attributed to the hurricane since it disrupted power to the oxygen concentrator that ultimately caused the death. All of the other fatalities, including the two suicides, were classified as direct fatalities. The sources of information for the fatalities were listed as either the Office of the Chief Medical Examiner (OCME) and/or the State Highway Patrol (SHP). The SHP was a sole or collaborative source with the OCME for the majority of the motor vehicle (MV) related deaths. The unique circumstances for each death were placed into ten categories: clean up, CO poisoning, electrical, fire, medical, medical/clean up, MV crash, MV drowning, suicide, and wind/tree trauma. Basic Excel features of numerical functions, pivot tables, and charting were used to determine fatality statistics and generate graphs.

Data regarding economic damage and environmental losses caused by hurricane Florence were obtained from governmental sources such as the NC Office of Budget and Management, NCDPS, and EPA Office of Land and Emergency Management; financial and insurance consultants such as the Insurance Journal, AIR Worldwide, Karen Clark & Co., and CoreLogic; and news articles by Yahoo Finance, USA Today, and Newsweek. Furthermore, time series data of general Hurricane season fatalities was obtained from NOAA's National Weather Service. No quantitative analysis was performed on the post disaster economic and environmental information and was provided to highlight the immediate and potential impact of the hurricane for the purpose of recommending risk mitigation opportunities.

3. Motivation and Aim

The authors believe that there is advantage in providing best available post disaster information as soon as practical after a major disaster to promote risk reduction strategies while the event is recent. Public availability of disaster impact data (fatalities, damage, environmental) immediately after the disaster can benefit both public safety officials and the public. Timely confirmation of post disaster fatalities including cause and social vulnerability of the location of death can focus systematic improvements while recovery programs are ongoing, and the political momentum and financial support are available. The specific types of property damage based on immediate details of the observed extent of wind and water damage can highlight deficiencies in regional hazard classifications and engineering design criteria of infrastructure. Understanding the environmental short and long-term impacts caused by the torrential rains and subsequent flooding highlights the risk of the region's topography and industrial development providing impetus for policy change to reduce the extent of environmental damage in future disasters.

4. Results

Hurricane Florence made landfall as a Category-1 hurricane on 14 September 2018 at Wrightsville Beach just outside the city of Wilmington, North Carolina (NC) with wind gusts up to 105 mph. The National Hurricane Center reported Florence had sustained winds of 90 mph at landfall and was moving slowly westward at 6 mph [3]. Hurricane Florence at its peak over the open ocean had wind speeds in excess of 130 mph classifying it as Category-4 Hurricane but—after hitting wind shear off the coast—made landfall with wind speeds at Category-1 (74–85 mph). A mandatory evacuation was ordered for more than 1.2 million people covering nearly every county along North Carolina's coast, including Charleston, Beaufort, Berkeley, and Dorchester counties. The four states (Maryland, Virginia, North Carolina, and South Carolina) directly in the path of the Hurricane declared a State of Emergency. Hurricane Florence dropped two to three feet of rain, causing major flooding along the Cape Fear, Lumberton, and Neuse rivers. The Cape Fear River alone carried a discharge of more than 62,000 cubic feet of water per second. A total of 44,700 buildings were damaged, with 93% being residential buildings. Out of the total buildings affected, 8% were either completely destroyed or suffered major damage with a cost of more than $400 million (Figure 1).

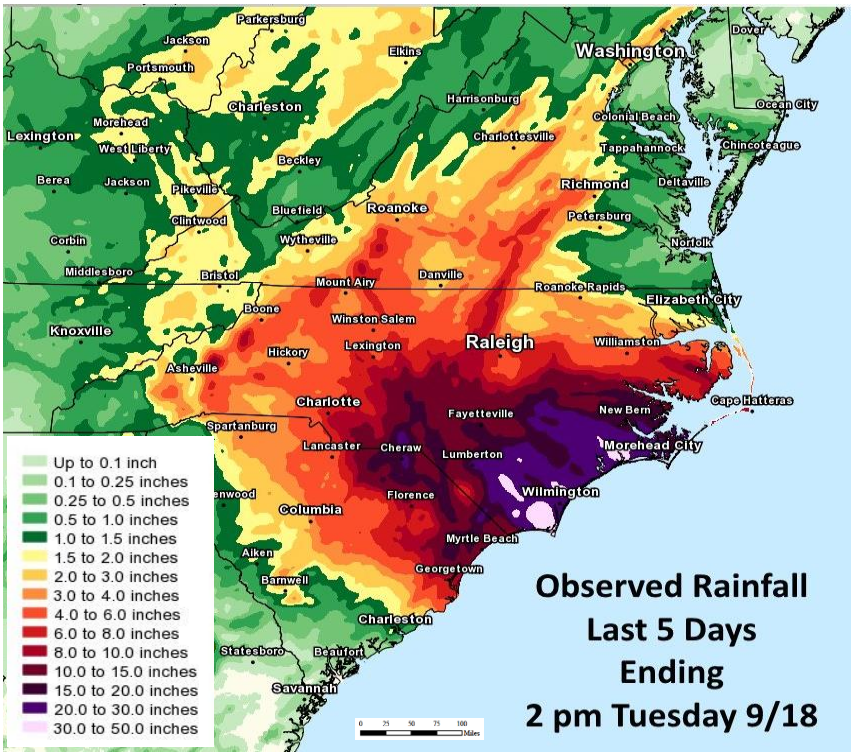

Figure 1. Hurricane Florence Rainfall Map (NWS Eastern Region Headquarters on 18 September 2018).

4.1. Fatalities

Hurricane Florence resulted in 53 total fatalities in three states with 41 in NC, 10 in SC, and 2 in VA. Forty of the total 41 fatalities in NC occurred within two weeks of the aftermath from 13–26 September 2018. One death, a 69-year-old male suicide possibly from despair of losing his home, occurred about one month later, on 22 October 2018. The extent of the catastrophe was spread across 20 counties in NC, with 50% occurring within five counties. Duplin county had the highest number of fatalities (eight) despite being one of the five least populated of the counties that incurred fatalities. Four counties (Lenoir, New Hanover, Onslow, and Robeson) reported three fatalities each. Florence-related deaths were reported in eight counties of South Carolina and two counties in Virginia. The baseline map in Figure 2 was obtained from the Centers for Disease Control and Prevention (CDC) mapping tool providing counties by social vulnerability index (SVI) [13]. Most of the fatalities occurred in counties with the highest SVI. The CDC SVI (2016) for Duplin county indicates that 90% of the county is rated in the top 75th percentile and the remaining in the 50th percentile for overall social vulnerability. Fifty percent (50%) of the county is in the 75th percentile for Household Composition/Disability which includes age and medical disabilities.

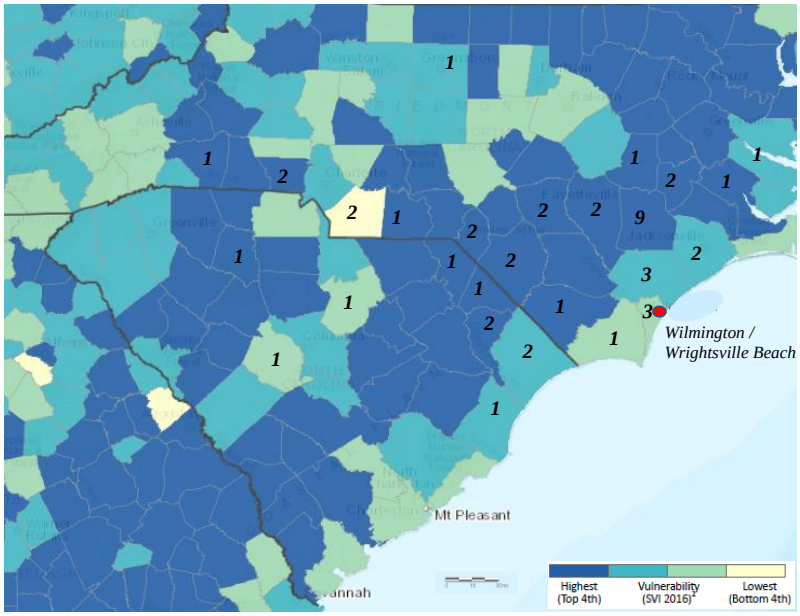

Figure 2. Hurricane Florence Fatalities per County Social Vulnerability in North and South Carolina.

The main cause of death due to Florence reported across all three states was vehicle-related, accounting for approximately 50% of the total fatalities. Motor Vehicle drowning was the major cause with approximately 32% of the total fatalities. This is in line with post hurricane Harvey (2017) fatality assessment in which 81% of the total fatalities were drowning victims [4]. All but two of the victims were males, supporting Jonkman and Kelman (2005) that high-risk activities such as driving during flooding are dominated by males. Efforts to increase awareness of risk to this demographic has the potential to significantly reduce the total fatalities. Specifically, with Florence the total fatalities would have been reduced by 30% in NC alone.

The fatality data of recent hurricanes suggests that inland flooding is the major cause of fatalities and is contrary to the report by Rappaport et al (2014) that suggested storm surge as the predominant cause of fatalities (49%) based on analysis of Atlantic tropical cyclones from 1963–2012 [14]. A contributing factor to inland flooding is the increase in the amount of precipitation generated in recent hurricanes. For instance, the highest recorded rainfall total in hurricane Harvey was more than 59 inches in Nederland, Texas according to Blake et al (2018) [15]. The National Weather Service reported that hurricane Florence generated rainfall totals as high as 36 inches in Swansboro breaking the previous record for the state of North Carolina. It is well established that warmer air has a higher water capacity and hurricanes are strengthened by warmer surface water. Given the positive trend in warmer average air and ocean temperatures hurricanes are likely to continue generating heavy rainfall resulting in extreme flooding.

Gender stratification by cause appears to be wider than the aggregated mortality reported by NOAA for hurricanes in the last two decades. Seventy-five percent (75%) of the fatalities were male (Figure 3). Only in the case of CO poisoning were males and females found equally vulnerable. All other causes exhibited a much higher risk to males than females. The highest margin of difference was seen in the case of Motor Vehicle Drowning where male deaths were more than three times their female counterpart. All five victims that were reported to have died by cleanup were males which is expected since males are more likely to be involved in clearing the debris off of rooftops and cutting damaged trees which are the main causes of fatalities in this case. The cleanup phase responsible for almost 10% of the total mortality (5 deaths) is an opportunity for risk mitigation through quicker service and dispatch of cleanup crews. The main cause of death for infants was recorded as wind/tree trauma, causing two out of the three infant fatalities. A mother and her infant child were tragically

killed after a tree fell on their house and the father in critical condition from injuries. The third infant was swept out of her mother's arms during an attempt to exit their vehicle trapped in a flash flood.

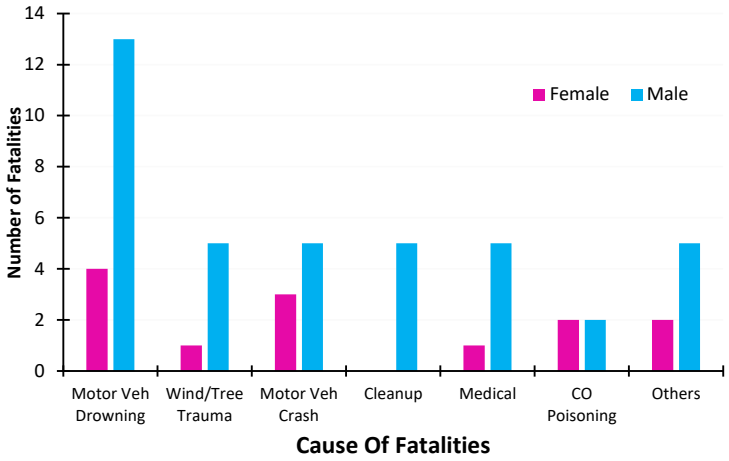

Figure 3. Gender distribution of the fatalities caused by hurricane Florence in North Carolina.

The age distribution of the fatalities caused by hurricane Florence indicates that males above the age of 50 are the most vulnerable sector of the population with 63% of the total fatalities in NC alone. The major cause of the fatalities was vehicle-related (Motor Vehicle Drowning and Motor Vehicle Crash) accounting for about 47% of the total fatalities with 75% of the victims of motor vehicle drowning over the age of 50 years. Temporal trending shows 75% of the fatalities occurred within five days of the landfall and 85% occurred within 10 days of the landfall (Figure 4). Ninety percent (90%) of all the fatalities due to hurricane Florence were assigned an exact date stamp of death (five fatalities did not). Temporal distribution of the fatalities highlights the predominant hazards over time. As expected, the causes of the fatalities in these first five days were more related to physical impacts of the storms and flooding. The fatalities occurring after five days were predominantly due to cleanup of the debris in the aftermath of the disaster.

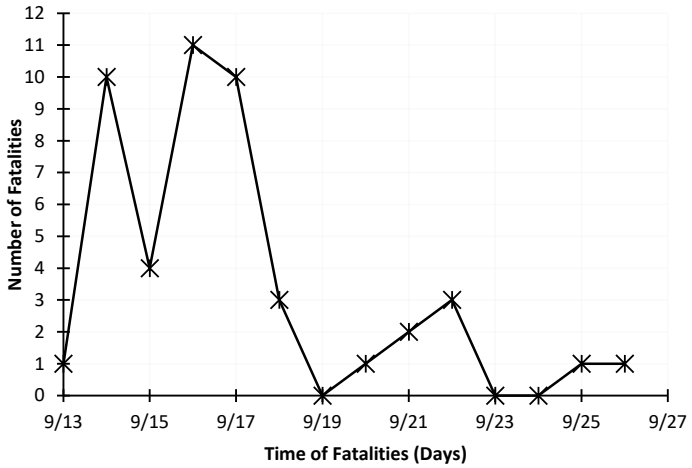

Figure 4. Temporal distribution of the fatalities caused by hurricane Florence in North Carolina.

4.2. Economic Loss

The NOAA estimates flooding damages from Florence to exceed those of hurricanes Matthew ($10.6 billion in 2016) and Floyd ($9.9 billion in 1999) [10]. USA Today reported on 18 September 2018 that the estimate of damage caused by hurricane Florence to homes, businesses, and public infrastructure is expected to total $16 billion to $20 billion. Oxford Economics estimates losses or damage to infrastructure of $30 billion to $40 billion. AP reported that an economic research firm

estimated that Florence caused around $44 billion in damage and lost output. Despite the tremendous devastation and damage estimates, the effect on the U.S. economy is likely to be modest in comparison to other recent hurricanes: Harvey ($125 billion), Sandy ($70 billion), and Katrina ($160 billion), highlighting the relationship of impact location to levels of damage. The economic loss is the highest on record for NC but the state ranks low on a relative wealth scale: $221 billion GDP (1.1% of the U.S GDP); employing 2M (1.4% of U.S. total); and a median residential property value of $80,000–$340,000 compared to more industrialized regions hit by Harvey, Sandy, and Katrina. Nevertheless, the extensive flood damage ranks Florence among the top 10 costliest hurricanes in U.S. history [16].

Hurricane Florence caused more water damage than wind damage which is not good from the financial standpoint of the home owner. Flood damage is typically excluded in homeowner's insurance policies, which moves the financial burden to the property owner or federal assistance (NFIP). Florence is estimated to have caused about $20 billion in uninsured flood losses [17]. Catastrophe modeling firm AIR Worldwide estimated that industry insured losses from Florence's winds and storm surge will range from $1.7 billion to $4.6 billion to include downed trees that caused damages to homes and automobiles, downed utility poles, and shingle loss with isolated cases of more extensive roof damage [18]. Karen Clark & Co. expects insured losses from Hurricane Florence to reach $2.5 billion which includes residential, commercial, and industrial properties [19]. Wind damage estimates provided by CoreLogic are between $1 billion and $1.5 billion [20]. The NC Office of Budget and Management estimates $17 billion of economic loss statewide with 34% business loss, 33% residential damage, and 14% agricultural [21]. The NC Agricultural Commissioner indicated that the impact to agriculture is likely to be significant because it was harvest time for so many of the major crops and the storm was severe in the top six agricultural counties. Initial estimates for crop damage and livestock losses to North Carolina's agriculture industry are expected to be over $1.1 billion: row crop losses are estimated at $986.6 million; forestry losses at $69.6 million; green industry losses at $30 million; vegetable and horticulture crop losses at $26.8 million; and livestock, poultry, and aquaculture losses are estimated at $23.1 million [22].

4.3. Environmental Impact

The environmental impact to the state of NC caused by Florence is largely a result of two major industries that generate waste sites: livestock (hog farming) and energy production (coal plants). The former producing pig manure and the latter coal ash waste. Waterkeepers Alliance (non-profit organization) estimates that 10 billion pounds of manure are generated per year in NC and stored in manure lagoons. The Florence rainfall exceeded the breach level of 36 inches of several lagoons that subsequently flooded rivers and the hog houses along the shoreline (about 60 are located within the 100-year floodplain). Breach of the lagoons washed the waste into estuaries killing fish and creating algae bloom (nitrification). This has been experienced in the past with lagoon breach and contamination of the water ways caused by hurricanes Matthew (2016) and Floyd (1999). The waste lagoons are concentrated in the southeastern part of the state. As of 26 September, the N.C. Department of Agriculture and Consumer Sciences reported that 5,500 hogs and 4.1 million chickens, turkey, and other poultry died as a result of hurricane Florence. The state Department of Environmental Quality indicated that 32 lagoons at 27 different facilities have discharged some amount of waste as flooding overtopped their berms with five lagoons having sustained some structural damage [23–25].

There are also 24 coal ash pits along the shoreline of major rivers and lakes in the state operated by Duke Energy, NC's primary power company. This gray coal ash contains potentially harmful amounts of mercury, arsenic, and lead which is known to have created an environmental problem in 2014 with a spill at a Duke power plant that coated 70 miles of the Dan river in toxic gray sludge. This event triggered state regulators to mandate a phase out of these coal ash pits by 2029 which reduced the number of pits flooded by Florence to some extent [26]. Two Duke Energy plants designed with on-site coal ash storage are located adjacent to the Neuse and Cape Fear rivers were also significantly flooded. Satellite surveillance appears to show some coal ash released from the two sites, but the amount is

not yet known. In Goldsboro, environmental groups that surveyed inactive coal ash basins normally covered in vegetation and tall trees noted those areas inundated by water from the Neuse river. They also noted a gray, floating scum on the water's surface that indicated the release of coal ash. Duke Energy confirmed the presence of coal ash outside of the storage basins, but the active ash ponds nearby did not appear to be affected by the flooding. In Wilmington, an unfinished coal ash landfill at the Lee plant breached during heavy rainfall on 15 September, dumping what Duke Energy estimates to be 2000 cubic yards of soil, water, and ash into a perimeter ditch and into Sutton Lake which is a public recreation area the company uses as a cooling pond.

A less voluminous but extremely dangerous environmental concern in the aftermath of Florence is toxic chemical contamination washed out of the surrounding soil of a local industrial chemical plant related to Teflon (Gen-X) manufacture. Heavy rains and flooding of the ground around the plant has likely washed the toxins out into the closest surface water (Cape Fear River). The flooding also caused several spills of untreated and partially treated wastewater in the southeastern part of the state. The Southside Wastewater Treatment Plant in Wilmington reported that 5.25 million gallons of partially treated wastewater escaped into the Cape Fear River. Camp Lejeune reported the release of about 84,000 gallons of untreated sewage of which 50% made it to the New River. Benson city, in Johnston County, estimated that 300,000 gallons of untreated wastewater was released over the course of about a week from several manholes and service locations with the sewage flowing into Driving Branch, a tributary in the Neuse River Basin. Due to the standing water polluted by organic material, a plague of mosquitos has inundated the flooded region of NC creating both a public nuisance and an effective medium for disease transmission [27].

The U.S. Environmental Protection Agency (EPA) has conducted preliminary inspections of 62 superfund sites that are on the National Priority List (NPL) with no infractions found as of 21 September 2018. Based on aerial surveillance, the Washington Post reports that several manure lagoons have turned a brownish color indicating that they have been submerged in flood waters known as being "overtopped". Other lagoons had serious structural damage to the walls with one wall rupture large enough to drive a vehicle through. This lagoon was empty suggesting that the untreated feces and urine, full of pathogens and chemicals, had already flowed downstream, leaving only some sludge at the bottom [28].

5. Discussion

Hurricane Florence caused a record amount of cumulative rainfall over five days up to 36 inches in the coastal county of Brunswick, NC. This massive amount of rain combined with hurricane-force winds caused a catastrophic event with a total of 53 fatalities across three states. NC experienced 41 deaths and 44,700 buildings damaged. More than 1.2 million people were given a mandatory evacuation orders across four states (Maryland, Virginia, North Carolina, and South Carolina) with the most severe in southeastern NC being declared a State of Emergency. Loss of life is influenced by both governmental emergency communication and public behavior to that warning and evacuation strategy. Hurricane Florence was also unique in that it is a shift from storm surge to predominant inland flooding fatalities. In contrast to the majority of previous Atlantic Ocean Tropical Cyclones that occurred from 1963–2012 in which storm surge caused the highest number of fatalities, the fatalities from Florence and Harvey were predominantly due to inland flooding. Further investigation is needed to draw any statistical conclusions between types of hurricanes and storm surge and non-coastal flooding, but climate change appears to be increasing the overall levels of rainfall per event. Every hurricane is a new opportunity to learn based on its unique hazard characteristics and storm path to improve preparation and response in future disaster events. Analysis and dissemination of disaster impact data in the immediate aftermath is of benefit to all stakeholders.

The analysis of direct fatalities due to Florence indicated that most (75%) fatalities occurred within five days of landfall and 85% occurred within 10 days highlighting the critical need for rapid response. The most vulnerable sector of the population were people over the age of 50 years accounting for 63%

of the fatalities in NC. The major cause of the fatalities were vehicle-related (Motor Vehicle Drowning and Motor Vehicle Crash) accounting for about 47% of the total fatalities. Assessment of fatalities caused by other hurricanes such as Katrina and Harvey support the prevalence of vehicle-related deaths with 37% and 31% of the total fatalities, respectively. Hurricane Florence is another opportunity for emergency and rescue authorities to increase public awareness of the risks of using a vehicle on flooded roads and driving into flash floods. Ten percent (10%) of the fatalities occurred as a result of incidents during cleanup procedure suggesting risk reduction opportunity through more timely cleanup service and educating the public on proper environmental health and safety procedures.

The long-term cost of economic recovery will be very high since most property damage was flood-related and is likely not included in homeowner insurance. Crop damage, particularly sweet potatoes, which were at peak harvest season, will have a significant impact on the agricultural economy. Exacerbating the devastation are the long term environmental and public health effects. High winds, torrential rains, and flooding cross-contaminate the environment which can result in public health concerns due to exposure to flood waters contaminated with organic waste and toxins. Infectious contact in congregate emergency facilities especially among the medical vulnerable can result in a significant increase in post disaster mortality and morbidity rates. Long durations of standing water exacerbate the insect population with mosquito infestations that can cause illness such as La Crosse encephalitis, West Nile virus, and eastern Equine Encephalitis [29]. Massive volumes of livestock manure lagoons and coal ash pits are located in the NC flood zone and along rivers shared with municipal drinking water treatment facilities, further increasing the risk of waterborne illness. The manure lagoons are also a breeding ground for parasites that can cause waterborne diseases such as cryptosporidiosis which is transmitted via the fecal–oral route from infected hosts. An increase in waterborne outbreaks from contamination of municipal water and recreational waters are expected given the extent and location of the flooding, as was experienced in Harris county in the aftermath of Harvey in which the number of reported cases of cryptosporidiosis increased three-fold [30].

This brief communication focused on the immediate impact with regards to direct fatalities, economic loss, and environmental disruption caused by a hurricane Florence due to torrential rainfall predominantly in the flood plains of North Carolina. An equally severe result of this hurricane will likely be the long-term effects of surface and groundwater contamination. It is important to note that recent efforts are starting to acknowledge the tremendous extent of fatalities that are not directly related but are a result of stressful and interrupted conditions leading to excess deaths several months after the disaster event. For example, a household-based survey published in the New England Journal of Medicine suggests that the number of excess deaths related to hurricane Maria in Puerto Rico is more than 70 times the official estimate and is a conservative estimate given survivor bias [31]. Changes in hospitalizations and fatalities in the hardest hit NC counties should be investigated for causes relatable to the environmental impact of Florence. Pre-disaster consideration of the social vulnerability profile and mitigation of high-risk industrial sites that are susceptible to flooding within the storm track can focus preventive measures in the most vulnerable areas. Hurricane Florence is another opportunity for public safety officials and governmental agencies to improve the socio-economic outcomes of future disaster events based on the successes and failures observed in the immediate aftermath of this disaster.

6. Conclusion

Hurricane winds and flooding are a serious risk to coastal and flood plain communities and it is imperative that evacuation decisions and the appropriate risk are communicated to the public as early as possible. The high number of vehicle-related deaths suggest that some residents may have delayed their departure from flood prone areas until after landfall which severely reduces the probability of successful evacuation. Appropriate guidance and penalty should be emphasized, particularly in the case of mandatory evacuation orders, to specify the departure time requirement, preferred evacuation routes based on departure location and destination, and accountability for non-compliance.

The disproportionate age of fatality victims suggests that there may be a gap in communication of risk to those over 50 years. Risk-focused communication accounting for differences in access to technology, cultural and societal barriers can improve the reach of early warning that may reduce this risk. Emergency authorities should diversify the way they broadcast their warning messages and storm update information through all the platforms including those in which non-millennials are usually more familiar. Social media is the most widely used medium of communication especially in case of emergencies but is disproportionately used by the younger age groups. Therefore, in addition to the social media, emergency authorities could use other means to propagate the warning and alert information to a wider societal bandwidth. Word of mouth can vastly improve the reach. Programs can encourage the youth to relay information that they receive through social media by either physical door to door contact or a simple telephone campaign.

The greatest economic impact is the loss of uninsured residential housing due to flooding and will take the longest to recover. Review of land management policy, flood risk attribution, and structural design requirements can reduce this risk. The aspect of fatality risk and property risk mitigation is further discussed in longitudinal research conducted at the University of Texas at San Antonio and published in the Journal of Geosciences entitled, *"Fatalities Caused by Hydrometeorological Disasters in Texas"* and *"Analysis of Damage Caused by Hydrometeorological Disasters in Texas"*, respectively [32,33]. It is also important to not overlook the extent of potential long-term illness and death due to disrupted health programs and water and ground contamination. The NC Medical Journal noted that NC communities located near hog concentrated animal feeding operation (CAFOs) have higher all-cause and infant mortality, mortality due to anemia, kidney disease, tuberculosis, septicemia, and higher hospital admissions/ED visits of Low Birth Weight (LBW) infants. Although not establishing causality with exposures from hog CAFOs, the findings support the need for future studies to determine factors that influence these outcomes, as well as the need to improve screening and diagnostic strategies for these diseases in NC communities adjacent to hog CAFOs [34]. Additionally, excess nitrates in groundwater, such as those associated with pig manure, are linked with health problems like blue baby syndrome in which nitrogen binds to the hemoglobin in a baby's blood and makes red blood cells unable to carry oxygen. causing the baby's skin to take on a bluish tint [35].

Coal ash waste includes heavy metals of arsenic, lead, and mercury that can cause cancer and nervous system impacts such as cognitive deficits, developmental delays, and behavioral problems. The Environmental Protection Agency (EPA) has found that living next to a coal ash disposal site can increase the risk of cancer or other diseases to as high as 1 in 50 [36]. Monitoring of spread and containment of manure and toxins into the NC waterways is a combined effort of advocacy groups (e.g., Waterkeepers Alliance and Earthjustice) and government agencies (USGS, EPA, and NCEQ) through water sampling and satellite surveillance. Long-term trend analysis of medical issues based on hospital records from people in the impact zone of the hurricane induced flooding is highly recommended to establish causality and understand the true impact of this disaster.

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Conflicts of Interest: The authors declare no conflict of interest.

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