**Report Format**

**Structure your report to include subheadings that allow you to organize your information and communicate it in a logical fashion**

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Use subheadings to organize smaller subsets and more specific information under a broader heading

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**APPENDIX – any charts or graphs you want to insert but are too long for your report. You can refer to them in your report by calling each appendix by a number ie) refer to Appendix 1**

**REFERENCES**

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**Exemplar – modified**

**Please note that this exemplar does not have APA 6th Edition In text citation**

**1. INTRODUCTION**

Despite the enormous impacts of floods, there is relatively limited insight into the factors that determine the loss of life caused by flood events. A review of historical flood events by Professor J. Smith of the University of Colorado showed that the number of fatalities due to a flood event is determined by the characteristics of the flood (depth, velocity, rise rate), the possibilities for warning, evacuation, and shelter, and the loss of shelter due to the collapse of buildings. (Smith, 2005) In the NOAA literature presented at a post event conference held by FEMA in 2009, several methods have been developed that can be used to assess the loss of life for flood events and to identify mitigation measures. (NOAA, 1999)  In general these methods consist of a quantitative relationship between the flood characteristics and the mortality in the flooded area. In this context mortality is defined as the number of fatalities divided by the number of people exposed. Mainly due to limitations in data collection and documentation, the existing methods and relationships have been derived based on events that occurred several decades ago, mainly in the 1950s and 1960s.

In late August 2005, the New Orleans metropolitan area suffered the destructive power of Hurricane Katrina. Large parts of the city flooded. The objective of this article is to present the available data and provide an analysis of the relationship between flood characteristics and mortality for the flooded parts of New Orleans.

Empirical relationships are developed by relating the observed spatial distribution of mortality to simulated flood characteristics. Analysis of this tragic event enables the analysis of the influence of different flood and event characteristics on mortality for such a recent event. Findings can be compared to existing studies and methods that have been derived for flooding of similar types of areas, i.e., low-lying areas protected by flood defenses.

The focus in this article is on the mortality during and directly after the flood event in the flooded areas of the city of New Orleans and the consequences for other areas are not treated in detail. A more comprehensive presentation of the available data regarding the fatalities and their causes and circumstances is found in Reference [4](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b4). Stephens *et al.*([5](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b5%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) provide an analysis of the longer term impacts of the event. Data regarding loss of life for states other than Louisiana that were affected by Katrina is not discussed in detail here. MMWR (Reference [6](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b6), pp. 239–242) provides a review of mortality for the states of Florida (14 fatalities) and Alabama (15 fatalities). It is estimated in press reports that more than 230 fatalities occurred in the state of Mississippi, but no official list of victims is available.

This study focuses on loss of life. Several sources provide comprehensive discussions of other types of consequences, such as economic losses,([7–11](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b7)) physical and mental health impacts,([6,12–14](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b6)) and pollution from industrial and household chemicals that mixed with floodwaters.([15–17](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b15)) A general analysis of different types of consequences is given in the report of the Interagency Performance Evaluation Taskforce.([10](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b10))

The outline of this article is as follows. After a general description of relevant events and processes during Hurricane Katrina ([Section 2](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss2)),[Section 3](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22ss3%22%20%5Co%20%22Link%20to%20section) reports the results of flood simulations that give insight into the flood characteristics. [Section 4](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss4) provides an overview of the available information regarding Katrina-related fatalities. Characteristics and circumstances of Katrina-related fatalities are described in[Section 5](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss5). The relationship between flood characteristics and mortality is analyzed in [Section 6](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss6). [Section 7](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss7) provides a discussion of various issues, such as a comparison with existing loss of life models and the uncertainties in the data. Concluding remarks and recommendations are given in [Section 8](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss8).

**2. GENERAL INFORMATION REGARDING HURRICANE KATRINA**

This section gives a general description of Hurricane Katrina, mainly focusing on the New Orleans area and issues most relevant for analysis of loss of life. Several other studies give a more comprehensive description of the characteristics of Hurricane Katrina,([18](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b18%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) and the performance of the flood protection system.([19–21](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b19))

**2.1. General Situation and Past Studies**

New Orleans is situated in the delta of the Mississippi River ([Fig. 1](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#f1)). The city and its surrounding suburbs make up a metropolitan area that is largely below sea level and entirely surrounded by levees (synonyms: flood defenses or dikes). Therefore, the area has a so-called polder,[1](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22fn1%22%20%5Co%20%22Link%20to%20note) bowl, or bathtub character. As a consequence of its geographical situation, the area is vulnerable to flooding from hurricanes, high discharges of the Mississippi River, and heavy rains.



**Figure 1.**Location of the city of New Orleans.

The possibility of a major storm surge flood disaster in New Orleans was already known long before Hurricane Katrina formed. In the 20th century the city experienced floods after hurricanes in 1915, 1947, and 1965 (Hurricane Betsy). During Betsy, an estimated 13,000 people were rescued from floodwaters and approximately 40 drowned in floodwaters. Numerous publications have reported the threats associated with hurricanes. In June 2002, the *Times-Picayune* newspaper published a five-part series entitled “Washing Away.” This series of articles claims that as many as 200,000 residents of the area would not be able to evacuate and that “between 25,000 and 100,000 people would die.”([22](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b22)) One year before Hurricane Katrina, a joint federal, state, and local planning exercise looked at a fictitious Hurricane Pam scenario: a slow moving Category 3 hurricane passes just west of New Orleans with a 20 ft (approximately 6.5 m) storm surge that overtops levees and inundates the entire city. In this scenario, search and rescue (S&R) crews would have to conduct over 22,000 boat and helicopter missions, 1.1 million people would experience long-term displacement, nearly 400,000 suffer injury or illness, and over 60,000 people would perish.([23](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b23))

**2.2. General Characteristics of Hurricane Katrina**

Hurricane Katrina formed as a tropical storm in the Atlantic Ocean southeast of Florida. On August 25, 2005 Katrina made landfall near Miami, Florida, as a Category 1 hurricane on the Saffir-Simpson scale. In Florida it resulted in 14 fatalities.([6](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b6%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) The storm weakened slightly as it crossed Florida and entered the Gulf of Mexico on August 26 as a tropical storm. Katrina quickly regained hurricane status and it began to take aim for southeast Louisiana (see [Fig. 2](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#f2)). Between August 26 and 28 the storm initially strengthened to a Category 5, peaking at 1:00 pm August 28 with maximum sustained wind speeds of 175 mph (280 km/h) and wind gusts up to almost 220 mph (350 km/h). Before making its second landfall near Buras, Louisiana, it weakened to a Category 3 status with sustained winds of 125 mph (200 km/h).



**Figure 2.**Track of Hurricane Katrina.

*Source*: Wikipedia; map from NASA; hurricane track from the U.S. National Hurricane Center.

**2.3. Preparation: Evacuation, Shelter in Place**

In the days before landfall, computer models predicted possible flooding of New Orleans. The first evacuation orders came early Saturday morning (August 27) for the outlying coastal areas, such as Plaquemines and St. Bernard parish.[2](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#fn2) Utilizing lessons learned one year earlier from Hurricane Ivan, state and local officials initiated the staged hurricane evacuation plan officially on Saturday. The next morning, shortly after Katrina was upgraded to Category 5 strength, Mayor Nagin issued a mandatory evacuation order for New Orleans. By the time storm conditions reached New Orleans, 430,000 vehicles had fled the metropolitan region using primary roads([24,25](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b24%22%20%5Co%20%22Link%20to%20bibliographic%20citations)) with an estimated additional 10,000–30,000 using secondary roads. Based on these traffic counts, Wolshon([24,26](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b24%22%20%5Co%20%22Link%20to%20bibliographic%20citations)) estimates that 1.1 million people, or 80% to 90% of the population at risk in southeast Louisiana, evacuated the area before the storm.

In addition to the evacuation of the general population, Hurricane Katrina forced the nursing homes and hospitals in the region to quickly make hard decisions about who to evacuate and in what way. These challenges presented no easy solutions, as both evacuation and sheltering-in-place presented risks to nursing home and hospital patients. Among the nursing homes in the area at risk, 21 homes evacuated before the storm and 36 did not.([27](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b27%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) Local authorities set up various shelters in the city. In St. Bernard parish, two schools were offered as shelters. In Orleans parish, the Superdome was set up as a shelter. Boyd([28](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b28%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) estimates that of the 72,000 people who remained in the city after the evacuation an estimated 26,000 individuals sheltered in the Superdome([29](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b29)) but in later estimates a number of 10,000 to 15,000 is used. Initially, the Superdome served its purpose as a shelter of late resort well. The problems that developed later mainly resulted from the heat and humidity, lack of supplies and delays in the post-storm evacuation, and the difficult conditions.

**2.4. Impacts: Levee Breaches and Flooding**

During its final landfall on August 29, Katrina's storm surge caused massive flooding and devastation along a 170-mile (approximately 270 km) stretch of the U.S. Gulf Coast. The entire coastline of the state Mississippi suffered massive destruction due to surge flooding. The storm surge also caused massive overtopping and breaching of levees around New Orleans. The flooded area of the city basically consists of three bowls: the central part of the city (Orleans), New Orleans East, and St. Bernard; see [Fig. 3](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#f3). The first flooding of residential areas in greater New Orleans occurred almost two hours before the storm's landfall. Between 4:30 am and 5:00 am water was already rising in the Industrial Canal.[3](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#fn3) The waters flowed into the Orleans bowl to the west, and into the New Orleans East bowl on the east side of the Industrial Canal. Later that morning more catastrophic breaching occurred along the southern arm of the Industrial Canal. Two major breaches in the floodwalls resulted in a rapidly rising and fast moving flood of the St. Bernard bowl, with catastrophic consequences.



**Figure 3.**Overview of flooded area, levee breach locations, and maximum water depths. (Breach locations are based on field observations and data of the LSU Hurricane Center. Water depth for the Orleans and St. Bernard bowls is based on flood simulations (see [Section 3](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss3)), water depth for New Orleans East is based on data provided by LSU Hurricane Center.)

Especially the neighborhood of Lower 9th Ward, which was closest to the breach, was most severely affected. In the Orleans bowl the levees in the 17th Street and London Avenue drainage canals failed, leading to floods in a large part of the central area. The New Orleans East bowl flooded more gradually due to a number of smaller breaches and overtopping cases. An area of approximately 260 km2 of the city flooded, at some locations more than 4 m deep. [Fig. 3](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#f3) gives an overview of the flooded area and the locations of the levee breaches. It took over 40 days to dewater the city.

**2.5. Aftermath: Search and Rescue Operations**

The flooding of large parts of metropolitan New Orleans necessitated a massive urban search and rescue effort that involved numerous local, state, federal, and private organizations. Individuals in peril had to be rescued from roofs and attics. Patients, staff, and family members had to be evacuated as hospitals and nursing homes flooded. In the five days that followed Hurricane Katrina, rescue workers completed an estimated 62,000 water, roof, and attic rescues by either boat or helicopter. Over 100 helicopters and 600 boats were utilized.([30](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b30%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) Reflecting their first priority to protect the lives of those trapped by the flood, search and rescue (S&R) teams initially transported people from attics and floodwaters to higher ground, such as elevated highways and bridges. Following this immediate rescue, available ground transportation was used to bring people to the Superdome, the Convention Center, and the I-10 Cloverleaf.([31](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b31%22%20%5Co%20%22Link%20to%20bibliographic%20citation)) The sheltering population at these locations continued to grow in the days that followed the hurricane. As the days passed before relief arrived, hunger, thirst, and desperation took hold. Finally, on Thursday, September 1, three days after Hurricane Katrina made landfall, buses began evacuating people from the Superdome. The evacuation of the Convention Center began the next day. When the poststorm evacuation of New Orleans finished on September 4, an estimated 78,000 displaced persons had been relocated to shelters set up across the nation.([32](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full%22%20%5Cl%20%22b32%22%20%5Co%20%22Link%20to%20bibliographic%20citation))In the first phase that covered approximately 10 days, search and rescue operations focused on saving the living. After that the sad task of recovering the deceased began.

**8. Concluding Remarks**

The flooding of New Orleans due to Hurricane Katrina showed the catastrophic consequences of large-scale floods. A preliminary data set that gives information on the recovery locations for 771 fatalities has been analyzed and this resulted in the following conclusions:

* 1

Two-thirds of the analyzed fatalities were most likely associated with the direct physical impacts of the flood and mostly caused by drowning. One-third of the analyzed fatalities occurred outside the flooded areas or in hospitals and shelters in the flooded area due to causes such as strokes, heart attacks, and lack of medical services. These fatalities were due to the adverse public health situation that developed after the floods. Overall, the elderly were the most vulnerable. Nearly 60% of fatalities were over 65 years and 85% of fatalities were over 51 years.

* 2

Similar to historical flood events, mortality rates were highest in areas near breaches and in areas with large water depths. The highest mortality fractions were observed near the severe breaches in Lower 9th Ward. An earlier proposed approach, in which mortality functions for different zones in a flooded area are distinguished, is also applicable to New Orleans. A relationship has been found between the water depth and mortality. One difference with earlier findings is that the data for New Orleans do not show an influence of the rise rate of the water on mortality.

* 3

The available data for New Orleans do not support the claim that mortality during a contemporary flood event is lower than during historical events. The overall mortality among the exposed population for this event was approximately 1%, which is similar to findings for historical flood events.

The derived mortality functions can be used to provide quantitative estimates of loss of life for different flood scenarios, either in deterministic (scenario) or probabilistic (risk) calculations. By combination with information on the probability of flood scenarios the risk to life can be quantified with different risk measures. The individual risk indicates the probability of death for a person at a certain location in the area. The societal risk expresses the probability of a disaster with many fatalities. These results can be used as input for decision making about the acceptable level of flood risk.([51](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b51)) Risk assessment will also be used for decision support in the development of plans for future protection of New Orleans against flooding.([52](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#b52)) The approach for loss of life estimation that has been described in [Section 6.1.1](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#ss6-1-1) of this article includes the most relevant factors that determine loss of life. With the method the effectiveness of measures to reduce the consequences of flooding, such as evacuation, shelter, compartment dikes, and land-use planning can be evaluated. The outcomes obtained with the method are also applicable to compile flood risk maps that indicate most hazardous areas and these results can also be used for risk communication and the preparation of emergency management strategies.

The presented results and analyses are preliminary. The analyzed mortality data are incomplete (they cover 69% of all fatalities in the state of Louisiana) and first estimates have been used for the estimation of the size of the population exposed. It is recommended to collect more accurate data regarding fatalities, the exposed population, and the flood characteristics. Important factors that deserve further investigation are the influence of the collapse of buildings and the effects of rise rate on mortality. Based on more complete analyses, an improved method for loss of life estimation may be derived from the New Orleans data in the future. Further cross-analysis of individual characteristics, death causes, and spatial patterns in fatality rates is recommended to gain more insight into the causes of death in different affected regions. Information regarding social factors (income, poverty, ethnicity) could be added in the analysis to gain more insight into the effects of social vulnerability factors.

**APPENDIX:**

**Appendix 1: STATISTICAL ANALYSIS FOR RACE AND GENDER**

In this simple and preliminary analysis the outcomes for gender and race for the fatality data set are compared with the characteristics of the overall population.

Data for the affected population were obtained from the Greater New Orleans Community Data Center for the pre-Katrina population. These data were derived from the U.S. Census of the year 2000. Data were used for Orleans and St. Bernard parishes as these correspond to the flooded areas and both sub data sets were combined to create one total data set (see [Table A1](http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01190.x/full#t3)). It is assumed that this total joint data set corresponds to the overall population. In this simple analysis it is also assumed that the gender and race distribution are spatially homogeneous; see also the short discussion at the end of this appendix.

|  | **Affected Area** | **Fatality Data Set** |
| --- | --- | --- |
| **Orleans Parish** | **St. Bernard Parish** | **Total** |
| 1. *Source*: U.S. Census Bureau. *Census 2000 Full-Count Characteristics (SF1)*. From a compilation by the Greater New Orleans Community Data Center; <http://www.gnocdc.org/prekatrinasite.html>, accessed November, 2008, and the fatality data set.
 |
| Population/number | 484,647 | 67,229 | 551,876 | 853 |
| Male | 46.9% | 48.3% | 47.1% | 50.6% |
| Female | 53.1% | 51.7% | 52.9% | 49.4% |
| *Racial and ethnic diversity* |
| Population/number | 484,647 | 67,229 | 551,876 | 818 |
| African American | 66.6% |  7.6% | 59.4% | 55.1% |
| White | 26.6% | 84.3% | 33.6% | 40.8% |
| Hispanic |  3.1% |  5.1% |  3.3% |  2.2% |
| Asian Pacific |  2.3% |  1.3% |  2.2% |  0.7% |
| Native American |  0.2% |  0.5% |  0.2% |  0.5% |
| Other |  1.2% |  1.2% |  1.2% |  0.6% |
| **Table A1.  Overview of Population Statistics for Gender and Racial Diversity for the Affected Area** |