EFFECTS of WATER INFRASTRUCTURE FAILURE ON RESPONSE CAPABILITIES AFTER HURRICANE KATRINA

By
Irmak Renda Tanali, D.Sc.
Senior Research Scientist, Institute for Crisis, Disaster, and Risk Management
The George Washington University
Program Director, Graduate School of Management and Technology
UMUC
rendatan@gwu.edu
and
John R. Harrald, Ph.D.
Professor of Engineering Management
Director, Institute for Crisis, Disaster, and Risk Management
The George Washington University
jharrald@gwu.edu

ABSTRACT

Hurricanes Katrina and Rita demonstrated the consequences of mankind's failure to reduce the vulnerability of physical infrastructure. The physical and human toll of these recent disasters and the slow and ineffective initial response efforts are connected to the near total failure of the city of New Orleans' critical public infrastructure. This has intensified the problems and suffering of victims, and impaired the capability of responders to react. The failure of the levee system left New Orleans under floodwater, the destruction of road systems has severely limited access to the city and the ability to evacuate stranded residents, and has prevented the delivery of critical relief and energy supplies during the most critical stages of the disaster. The inadequate federal preparation for and execution of the response to Katrina has been severely criticized and led the FEMA director to resign. The infrastructure loss is the main discriminator between this event and prior near catastrophic events in U.S. history such as Hurricane Andrew and the Northridge Earthquake. The relationship between infrastructure resilience and the effectiveness of response is not understood or appreciated by emergency managers. If this relationship is better understood through the experience of these recent disasters, it may help improve the mitigation of, response to, and recovery from future catastrophic events. This paper looks at the ramifications of water infrastructure failure from Katrina, and its effects on disaster response. Water infrastructure here is defined broadly as flood control systems and potable water supply infrastructure including dams, dikes, and levees; water treatment and delivery systems including water pipelines, water pumping stations, and wastewater collection and treatment systems, including sewage pipelines, pumping stations and the supporting equipment such as pumps and mechanical equipment, and supporting infrastructure such as power, roadways and bridges. What could have been done had there been better preparedness and response capability, and suggestions on better response for future catastrophic event scenarios are discussed in this paper.

Introduction: Hurricane Katrina's Wrath

On August 29, 2005, when Hurricane Katrina approached land near the Central Gulf Coast making its second landfall, it had already downgraded to a Category 3 storm with wind speeds nearly 125 miles per hour. Hurricane Katrina was in fact, the sixth-strongest storm ever recorded in the Atlantic basin and the first Category 5 hurricane of the 2005 Atlantic hurricane season (Knabb, Rhome & Brown, 2005). The tension was high among public officials that the damage to the impacted areas especially in this low lying city of New Orleans would be devastating. The powerful winds would rip apart structures and housing establishments in a wide area encompassing at least three states, Louisiana, Mississippi, and Alabama, and there would be many people left homeless spread around the impacted area. It turned out, not just the high winds, but the excessive rainfall and the subsequent overtopping and failure of parts of the levee system protecting the populous city of New Orleans, together with the infliction of heavy damage onto the coasts of Mississippi and Alabama, was the determinant of what made the Hurricane Katrina Disaster as the most destructive and costliest natural disaster in the history of the United States. The losses were estimated at US$75 billion by the National Hurricane Center (Knabb, Rhome, & Brown, 2005) and $105 billion has been requested to date by the Bush Administration for the repair and reconstruction of the region. Katrina is also the deadliest hurricane with over 1300 deaths (and many still missing) since the 1928 Okeechobee Hurricane (Associated Press, 2006). Even in March 2006, nine more dead bodies were recovered (IHT, 2006). The levee system that was initiated and incrementally developed over a period of 70 years that protected the City of New Orleans from Lake Pontchartrain and the Mississippi River failed due to the excessive storm surge and a host of other factors which will be described next. Within hours, 80% of the city was under water.

In the case of city's drinking water infrastructure, within a few days after the hurricane, the Environmental Protection Agency (EPA) estimated that 1,220 water systems in Louisiana, Mississippi, and Alabama were inoperable due to power loss (Copeland 2005). Both of New Orleans' major water treatment plants were inoperable due to excessive wind damage and floodwater inundation. Additionally, since potable urban water systems consist of pressurized pipelines with associated pumps, the power loss rendered pumps inoperable and the pumping stations were buried under floodwater. Even when the power was restored using generators, water was unsafe due to contamination and inadequate hydrostatic pressure caused by excessive cracks in water pipelines. It is worth noting that the city's water infrastructure was built more than 75 years ago. Just before Hurricane Katrina, the Sewer and Water Board had adopted a $1 billion capital improvement plan to replace its aging infrastructure. Two weeks after Hurricane Katrina, only 30% of the affected drinking water and 40% of affected wastewater facilities were restored (Copeland, 2005).

In fact, this was not the only major flooding that the Big Easy had seen. New Orleans had been regularly flooded since its founding in 1718. Much of the city is located below sea level and settled on a low-lying sedimental area between the Mississippi River and Lake Pontchartrain surrounded by marshes that functioned like a buffer zone to protect the city from the coastal storms. Louisiana's wetlands have been eroding at more than 25 square miles a year, "the equivalent of a football field every 15 minutes", which brought New Orleans "closer and closer to open water" before Katrina hit (Pittman, 2005). The erosion was due to the settlement and land management practices that the city officials had adopted due to the frequent flooding. The city has been maintained by a series of pumps since the 1910s in order to keep it constantly dry from flooding. However, pumping the city from groundwater has made the city more prone to frequent and costly flooding which was demonstrated when the 1927 great Mississippi floods hit the city killing at least 1,000 people and rendering about a million residents homeless. The decision thus was to construct a federally funded flood control levees and navigation training structures to protect the city from flooding and keeping the land dry. The levee system would "straightjacket" the Mississippi river, and "confine it to a single course" (Pittman, 2005). Although the city did face other serious hurricane and flooding disasters, like Fort Lauderdale Hurricane in 1947, Hurricane Betsy in 1965, and Hurricane Camille in 1969, the building and expansion of the levees made a false sense of safety among the public, in that controlling the river would dry out the city and decrease flooding. In fact, the levees, and the continuous pumping of the city from floodwaters led to the loss of sedimentation area which used to be in the form of a delta. With no floods and no sediments, the river started dumping its load straight into the sea. The loss of sedimentation meant the starvation of the wetlands, a natural hurricane barrier that protected the city before.

The false sense of security manifested itself in the encouragement of development within the levee-protected area and their further extension to include the Lake Pontchartrain and its vicinity later in the seventies (Faber, 2005). In fact, one of the major projected benefits that would justify the building of the levee system was the development of these wetlands and the subsequent increased gains from commercial and social activity. In order to keep it dry, the city was constantly being pumped from flood waters. The city had the most sophisticated drainage network in the country with about 200 miles of canals and 22 pumping stations capable of pumping 35 billion gallons of water a day out of the city (Pittman, 2005).

Why did the Levees Fail?

The levee system failed at different sections in the form of breaches, erosion and overtopping as a result of Hurricane Katrina generating an excessive storm surge swirling counterclockwise from the Gulf of Mexico, according to Peter Nicholson in his testimony on behalf of the American Society of Civil Engineers, before the Committee on Homeland Security and Governmental Affairs (Nicholson, 2005). The eastern facing coastal areas of

New Orleans and the lower Mississippi delta had the most impact with the surge being concentrated into the channels of the Mississippi River Gulf Outlet that fed into the Inner Harbor Navigational Channel, and the funneling of the surge in these channels resulted in widespread overtopping of the levees (p.4).

Nicholson elaborated that since multiple flood protection elements were built during different time periods by multiple authorities, there was a variation in the quality of design, construction materials, and practices (Nicholson, 2005, p.5). He goes on to assert that "when multiple authorities design and maintain multiple protection elements, the weakest (or lowest) segment or element controlled the overall performance [of the levee structure]." Furthermore his evidence suggests some segments of the levees did not overtop but suffered significant breaches that contributed to the excessive flooding. Additionally, underseepage and piping at or below the bases of earthen levees were assumed as the other contributing factors to levee breaches and failures (pp.5-6).

A complex levee system such as this one surrounding and protecting a highly dense area of population (205.4 persons per square miles) had been incrementally built in stages as the population gradually increased to nearly half a million in 2000. The building of large civil engineering projects such as this one requires approval and funding based on a benefit cost analysis which the future benefits of such projects should exceed the costs. The underlying assumptions in identifying and attaching dollar tags to projected benefits usually look at the projected income and profit from increased commercial activity due to the increasing number of residential and commercial settlements. However, one critical argument is that the projected costs and benefits in those feasibility studies may not have been sufficiently factored in the costs of disaster risks –in this case hurricane and flooding events - with their probabilities of occurrences and their potential consequences. With the history of frequent and excessive flooding and hurricane events, and a careful study of the subsequent disaster losses, the benefits of such large investments might have been easily overshadowed by the costly mitigation as well as reconstruction expenses. Risk-based acquisitions in capital investment programs of the federal government have only recently begun in early 2000s.

Infrastructure Failure and the Disaster Response

The national response system crafted over the last three years by the Department of Homeland Security was tested for the first time when Hurricane Katrina struck the Gulf Coast. The system failed to prevent needless human suffering and to minimize economic losses for many reasons. In this paper we examine the impact of infrastructure failure on the disaster response and postulate that the failure of physical infrastructure was one of the primary reasons that the government response was overwhelmed. Hurricane Katrina was a catastrophic event because it was actually two disasters. Comfort (2005, p.5) notes that "the first phase, the hurricane, could legitimately be called a natural disaster, as it was generated by meteorological activity beyond human control. The second phase, the breach of the levees and ensuing flood, can only be acknowledged as a man made disaster, after years of

neglected maintenance of the levee system, inadequate public education regarding the risk and severity of hurricanes in the region, and inadequate planning and preparedness training across jurisdictional levels…city, parish state, and federal." The resulting flooding of the city destroyed all of the critical physical infrastructure in New Orleans, making everyone in the area a victim and creating an untenable operating situation for first responders and state and federal emergency managers.

.

The Catastrophic Annex to National Response Plan (DHS, 2004) describes the attributes of an extreme event from the perspective of its demands on emergency management. These attributes remarkably described the actual impacts experienced in the aftermath of Hurricane Katrina. Jack Harrald, the co-author of this paper in his testimony before the House Committee on Government Reform Hearings, made the following observations (Harrald, 2005a, pp. 1-2) and in a recent paper in the *Annals of the American Academy of Political and Social Science* (Harrald, 2005b):

- *"A catastrophic incident may cause significant disruption of the area's critical infrastructure, such as energy, transportation, telecommunications, and public health and medical systems."* The total loss of infrastructure in New Orleans is one of the main discriminators between this event and prior near catastrophic events in U.S. history such as Hurricane Andrew and the Northridge earthquake. Post 9-11 infrastructure protection investments have focused on increasing the security of infrastructure, not in increasing its resilience. Hurricane Katrina was an infrastructure disaster. When the levees failed, all infrastructure systems (power, communications, water, energy, wastewater)necessary for human survival in New Orleans failed. Without the necessary infrastructure services, the medical, public health, and emergency response and law enforcement functions failed. The closure of the Port of New Orleans and the damage to oil refineries and facilities had severe national impacts.
-
- *"The response capabilities and resources of the local jurisdiction (to include mutual aid from surrounding jurisdictions and response support from the State) may be insufficient and quickly overwhelmed. Local emergency personnel who normally respond to incidents may be among those affected and unable to perform their duties."* The New Orleans leaders, emergency managers and first responders were all victims. The police and firefighters that responded were themselves, homeless, and were not reinforced by state and federal resources for days. The police, fire and emergency management personnel had no access to water, emergency power, or communications.

- *"Large numbers of people may be left temporarily or permanently homeless and may require prolonged temporary housing."* The peak shelter population for Katrina was over 250,000 people; at the time of this writing over 125,000 evacuees are in temporary shelter and many of them will require extended housing assistance. Typically shelter populations for hurricanes peak *before* the storm as evacuees flee

the potential impact areas, returning to their homes after the storm. In Louisiana, however, shelter populations peaked 4 days after the storm as victims were evacuated from New Orleans (FEMA, 9/3/05). The U.S. has only now begun developing a long term housing strategy.

- *"A catastrophic incident may produce environmental impacts…that severely challenge the ability and capacity of governments and communities to achieve a timely recovery*." Much of Southern Louisiana including New Orleans and Lake Ponchartrain became an environmental disaster area, and wastewater and sewage treatment plants were flooded and damaged. Oil spills approaching the volume of the *Exxon Valdez* spill require federal involvement in an environmental clean effort that may last a long time. The debris removal challenge in New Orleans has yet to be resolved as of this writing.

Comment [FV1]: Irmak – can this statement be supported with any references? Who proclaimed Southern Louisana as an "environmental disaster area" of the scale of Exxon Valdez?

The catastrophic impacts of Katrina, although predicted by many sources (for example, see Laska 2004), caught federal, and local officials unprepared, despite the wake-up calls such as Hurricane Ivan which was a near miss, and despite the fact that the federal ,state and municipal authorities had met frequently in the year leading up the Katrina. Both the governor or Louisiana, and the mayor of New Orleans asked FEMA for help just days before Katrina struck (Wisner & Walker, 2006). In spite of the catastrophic incident assumptions described above, historical experience has led emergency managers to believe that in a disaster (a) many people in the affected area will have access to food and water, and that (b) most emergency forces will not have to be self supporting. The critical importance of the survival of and/or rapid recovery of the water supply may be inferred from the historical statement of emergency priorities as (a) rescue and live saving, (b) water for drinking, (c) food, and (d) shelter. The only federal, state, and local forces that are truly self sustaining are the rescue and life saving teams. The government and non government forces that distribute commodities and provide shelter require significant supporting infrastructure. Without the availability of any drinking water supply, much of the water that can be brought into the impacted area must be reserved for emergency workers and FEMA was not prepared to deal with both to support its own forces and distribute water to hundreds of thousands of victims. The result was that the federal and state response to the flooding of New Orleans was managed from the Disaster Field Office in Baton Rouge and managers attempted to react to the overwhelming needs. The Sept 1 FEMA briefing stated that "USACE (US Army Corps of Engineers) was working on strategic plans for water distribution and wastewater treatment". On the same day, food and water air drops to the New Orleans were initiated (FEMA, September 1). An effective presence in New Orleans was not established until the *USS Bataan* was able to navigate the Mississippi several days after the disaster. The federal government had not prepared to deal with large populations without water, power, or sanitation. FEMA briefings note that the pre disaster stockpiled commodities included 419 trailers of bottled water, 619 trailers of ice, and 168 trailers of medical response equipments. (FEMA 8/29/05). Within 4 days of the disaster, 173 trailers of water had been deployed to the disaster area (FEMA 9/03/05). It is difficult to determine how much of this water was actually distributed to victims, as the local/state/federal response operation broke down.

Comment [FV2]: MRE = Meals Ready to Eat…are you sure this is medical response equipment?

Although the overwhelming and failure of local leadership and response capability was predicted, the federal response was not prepared to deal with the results. Henry Quarantelli (2005) notes that catastrophic impacts severely disrupt the social structure of the community when, "most, if not all, of the everyday community functions are sharply and concurrently interrupted." The result is the emergence of decentralized decision making, and Quarantelli notes that "the idea that there could be any centralized control imposed on these disparate decisions and varying community activities flies in the face of what researchers have found in crises." In other words, until the federal government could set up a field office in New Orleans, it was unaware of the scope of the need for basic services (food, water, shelter, power), the capacity and capability of local forces to assist in the effort, and the emergence of organizations and groups that were available to assist in the response effort.

The response to Hurricane Katrina will be described and discussed in after action and other government reports, in Congressional hearings, and in academic papers and books. One thing that is clear, however, is that the US was not prepared to deal with the comprehensive infrastructure failures caused by the Hurricane Katrina and the flooding of New Orleans. Response plans for catastrophic earthquake and other catastrophic hurricane scenarios that could produce similar infrastructure failures are similarly flawed. We have not adequately drawn the connection between the post disaster state of infrastructure and both the needs for life sustaining services and the capabilities of the response forces to deliver these services.

Infrastructure and Recovery

Recovery of New Orleans and southern Louisiana will be dependent upon the social and economic resilience of the area. This resilience will in turn be dependent upon the ability to recover the critical infrastructure. Infrastructure systems are unique in that both the public and private sectors play roles in establishing the need for infrastructure, and in owning, operating, and maintaining it. In southern Louisiana, decisions about rebuilding the city essentially are dependent upon interlocked infrastructure decisions. In particular, water and waste water must be available prior to rebuilding commercial and residential buildings. However, the city is unwilling and unable to reconstruct these physical infrastructure systems in areas that may not be rebuilt. Businesses and homeowners will not be able to rebuild unless they can obtain adequate insurance, and insurance availability is dependent upon the rebuilding and upgrading of the levee system. The cost benefit of upgrading the levee system is a function of the value of the physical property and economic production protected. Five months after Katrina, recovery and reconstruction plans and policies was caught by this circular logic. Water, waste water and power are the key infrastructure investments needed to break the loop. The existence of the services provided by these infrastructures are the precondition for reconstruction of devastated neighborhoods.

Conclusions

Hurricane Katrina's physical, economic, and social impacts make it the most devastating natural disaster in U.S. history. The social and economic impacts were significantly acerbated by the lack of resilience of the physical infrastructure in and around New Orleans. In particular, Katrina demonstrated that the survival and/or rapid restoration of the water supply is of critical importance to the response effort. Although the federal government was able to deliver over 13 million gallons of water to areas affected by Hurricane Katrina during the two weeks after the disaster (FEMA, Sept 13), it was not enough. Emergency managers must be able to predict the availability of water both to determine the needs for commodities and for identifying and countering constraints on response capabilities. The prediction of infrastructure damage and recovery must be part of response planning and therefore the analysis and modeling of infrastructure resilience is an essential element of preparedness. The urban planning and emergency management community should learn three lessons from Katrina. First, the short term human suffering and the long term social and economic impacts are dependent upon the resilience of critical infrastructure which includes the water infrastructure as defined previously, that is needed for human survival. The resilience means that there should be adequate supply of water for the victim population, there should be enough pressure to deliver the water, and it should be safe to use. Unless those three conditions are met, the area must be evacuated fully. Second, predicting infrastructure impacts is a key aspect of response planning. The behavior of the water systems under plausible disaster scenarios should be simulated and if the system still fails under the hypothesized scenarios, then adequate evacuation plans should be put in place and enforced. Third, critical infrastructure protection is far more than reducing the vulnerability to terrorist attack. As was demonstrated with Hurricane Katrina, the water infrastructure which is one of the essential components of human survival failed due to its networked and wide spread nature, and the complexity involved in designing, operating and maintaining such a system. The damages inflicted by natural hazards on such wide scale infrastructure systems are far more than what terrorists can alone achieve. The Department of Homeland Security has revitalized its catastrophic incident planning efforts since Hurricane Katrina. Hopefully, the infrastructure protection, emergency management, and planning components of DHS will collaborate and act upon these lessons. The relationship between infrastructure resiliency and response capability is not the issue of just the City of New Orleans or the U.S. In a globalizing world, there are many lessons that can be learned from this tragic event, and governments whose jurisdictions are prone to such large scale disasters in elsewhere in the US or in the world have a lot to learn from the lessons from Katrina.

References

Associated Press. (2006). More than 3,200 still missing from Katrina. *Breitbart.com.* Jan. 18, 2006. Retrieved Jan. 30, 2006 from http://www.breitbart.com/news/2006/01/18/D8F78L200.html

Comfort, Louise K. (2005). 2005. Fragility in disaster response: Hurricane Katrina, 29 August 2005. *The Forum*, *(3)*3.

Copeland, C. (2005). Hurricane damaged drinking water and wastewater facilities: Impacts, needs, and response. CRS Report for Congress. Retrieved April 18, 2006 from http://www.ncseonline.org/nle/crsreports/05oct/RS22285.pdf

Shaila Dewan. (2006). Recovery mission still on for Katrina's dead. *International Herald Tribune*. April 12, 2006. Retrieved April 12, 2006 from http://www.iht.com/articles/2006/04/11/news/katrina.php

DHS. (2004). *National Response Plan.* Retrieved January 30, 2006 from http://www.dhs.gov/dhspublic/interapp/editorial/editorial_0566.xml

Faber, S. (2005). Water resource needs following Hurricanes Katrina and Rita. *FDCH Congressional Testimony. Nov. 9, 2005.*

FEMA. (2005). Situation Report Briefings for Hurricane Katrina for August 29, September 1,2,3,4 and 13. Retrieved Jan. 30, 2006 from www.fema.gov

Harrald, J.R. (2005a). *Back to the drawing board: A first look at lessons learned from Hurricane Katrina*. Testimony before the House Committee on Government Reform Hearings. September 15, 2005. Retrieved Jan. 30, 2006 from http://reform.house.gov/UploadedFiles/GWU%20-%20Harrald%20Testimony.pdf

Harrald, J.R. (2005b). Agility and discipline: Critical success factors for disaster response. *Annals of the American Academy of Political and Social Sciences. (forthcoming)*

Knabb, R. D., Rhome, J.R., & Brown, D. P. (2005) *Tropical cyclone report: Hurricane Katrina 23-30 August 2005*. National Hurricane Center. Retrieved Jan. 30 2006 from http://www.nhc.noaa.gov/pdf/TCR-AL122005_Katrina.pdf

Laska, S. (2004). What if Hurricane Ivan had not missed New Orleans? *Natural Hazards Observer*, *22*(2). Retrieved Jan. 30, 2006 from http://www.colorado.edu/hazards/o/nov04/nov04c.html

Nicholson, P. (2005). Hurricane Katrina: Why did the levees fail? *Testimony before the Committee on Homeland Security and Governmental Affairs on behalf of the American Society of Civil Engineers*, Nov. 2, 2005.

Pittman, C. (2005). On the gulf: Too little, too late. *Planning*, *(71)*10, 10-15.

Quarantelli, H. (2005). *Catastrophes are different from disasters: Some implications for crisis planning and managing drawn from Katrina.* Disaster Research Center Working Paper, University of Delaware.

Wisner, B. & Walker, P. (2006). Katrina and Goliath: why the greatest military and economic power in the world didn't protect New Orleans. *HPN Humanitarian Practice Network*. Retrieved April 17th from http://www.odihpn.org/report.asp?ID=2773.