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An Examination of the Emergency Water Supply of Healthcare Facilities in Southeast Louisiana

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AN EXAMINATION OF THE EMERGENCY WATER SUPPLY OF HEALTHCARE FACILITIES IN SOUTHEAST LOUISIANA

By:

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Abstract

Water is a crucial commodity, especially in the aftermath of disaster events. Healthcare facilities, such as hospitals, require a water supply for both every day and emergency processes. As required by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO), healthcare facilities must stock a sufficient amount of water for medical services following disaster events. The purpose of this research is to explore the capabilities of healthcare facilities regarding the water supply for emergency purposes. The study investigated the usage and preparedness trends of water supply in two hospitals in Southeast Louisiana. The hospitals selected for research allowed for comparing and contrasting of the capabilities of hospitals located in urban versus rural environments. The study identifies key issues and trends in the emergency water supply systems at the two hospitals. Common themes identified include the disparity of needs between the hospitals in their respective environments, an adaptive capacity in addressing emergency preparedness, and the need for spontaneous improvisation during crisis. The research also identifies future research opportunities, such as improved recommendations of salient rationing of resources and increasing use of cost-benefit reservoirs or water acquisition means. The improvement of the emergency water supply capability can be improved through collaboration with local emergency preparedness organizations, construction of water towers on or near hospital grounds, and the use of synergetic water reservoir capacity.

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List of Abbreviations

ANSI	American National Standards Institute
ASHE	American Society of Healthcare Engineers
ASHRAE	American Society of Heating, Refrigerators, and Air-conditioning Engineers
ATU	Arkansas Tech University
CDC	Centers for Disease Control
CH	Charity Hospital
DHS	Department of Homeland Security
EMS	Emergency Medical Services
FEMA	Federal Emergency Management Agency
FDA	Food and Drug Administration
GOHSEP	Governor's Office of Homeland Security and Emergency Preparedness
HAI	Healthcare Associated Infections
HRSA	Health Resources and Services Administration
HVA	Hazard Vulnerability Assessment
HVAC	Heating, Ventilation, Air-Conditioning
IC	Informed Consent
IRB	Institutional Review Board
JCAHO	Joint Commission on Accreditation of Healthcare Organizations
JIT	Just-In-Time logistics
l/p/d	liters per person per day
LSUHSC	Louisiana State University Health Science Center
MCI	Mass Casualty Incident
OLOSGH	Our Lady of the Sea General Hospital
OMC	Ochsner Medical Center
PET	Polyethylene Terephthalate
TMC	Texas Medical Center

Chapter One: Introduction

In the aftermath of a disaster, emergency supplies are necessary for many purposes. Water is one of the most basic essential commodities and is often in emergent needs in the timeframe immediately following a disaster. The supply of clean drinking water is pertinent to maintain hydration and to provide for adequate sanitation processes (Noji, 2005a). As water is usually provided by municipal suppliers, it may be absent as a result of damage to critical transportation infrastructure or storage facilities.

Hospitals are an important component of the community. Hospitals provide life-saving medical services and a considerable amount of employment opportunities (Mandich & Dorfman, 2014; Zimmerman, Nicogossian, & Stewart, 2005). Healthcare facilities cannot provide adequate services without a clean water supply. A hospital closure necessitated by the disruption of water supply can place the community in the unenviable position of being without a clean water supply, access to medical services, as well as a large provider of employment.

Clean water is of vital importance for the health care systems in everyday situations. Healthcare facilities such as hospitals must have appropriate resources to maintain normal operations. Water is needed for a variety of purposes in healthcare facilities, including food and drink, sanitation, sterilization, a variety of medical procedures (e.g., dialysis, wound cleaning), electrical generation, ventilation, sewage systems, and more. Hospital operations would be negatively affected if any one of these processes was compromised, possibly leading to the rationing of services and the closure of facilities.

Clean water serves a critical role in the response and recovery following extreme events. In the response phase, water is an indispensable resource for the treatment of traumatic injuries or other complications arising from a disaster. The occurrence of disruption of the water supply in such extreme events is rare but debilitating when it does occur (Sternberg, 2003). Research literature suggests that failure of traditional water supply for healthcare facilities is usually a result of an external disaster (Sternberg, 2003). In the response and recovery phases, water is an integral resource for providing medical care (Zimmerman et al., 2005). Thus, water is critically needed for long-term medical care of injuries and illnesses in the aftermath of disaster.

The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) oversees emergency water supplies for healthcare facilities. The JCAHO recommends a two to three-day (48-72 hours) supply of resources to maintain critical hospital functions in the event of an emergency (JCAHO, 2003). Welter, Bieber, Bonnaffon, Deguida, and Socher (2010) reported that a high proportion of the water supply is generally maintained in bottled form. The needs for water within hospitals are more diverse than strictly drinking water. Hick, Barbera, & Kelen (2009) advised increasing the amount of water in reserve to compensate for inadequate resources. Bottled water presents an ephemeral supply and should not be used to satisfy all water needs of a healthcare facility.

Several studies have reported poor preparedness and under-funding of disaster preparedness in healthcare facilities (Cherry & Tranier, 2008; DeLorenzo, 2007; Kaji & Lewis, 2006; Richter, 1997; Zimmerman et al., 2005). Deficiency of the emergency water supply can inhibit the disaster preparedness of hospitals, especially during catastrophic situations. Welter et al. (2010) stated, “The 2.5-day supply number has been based solely on bottled water stockpiles intended strictly for drinking.” (p. 70). As such, hospitals often maintain emergency water supply in bottled form.

Maintaining water supplies through bottled water is not necessarily cost-effective. Bottled water must be used or discarded by the expiration date. The storage of bottled water is problematic due to the effects of stagnation. Preventing bacterial growth is a primary concern for the water supply of healthcare facilities as they are providing medical care for an especially vulnerable population (Casini et al., 2014). Water storage is further complicated by the enormous amount of water necessary to maintain operations at healthcare facilities when a disruption to the traditional water supply occurs. Maintaining emergency water supplies with bottled water may not be practical for continuity of operations for all critical services in healthcare facilities. Bottled water supplies are not practical for use in fire prevention systems, the cooling of ventilation systems, many medical procedures, and other pertinent hospital functions.

Without continuous water supply, healthcare facilities must begin to consider rationing of resources and services. Previous instances of water supply failure significantly affected the course of evacuation, once the water supply was compromised and could not be immediately restored (Distefano, Graf, Lowry, & Sitler, 2006; Nates, 2004; Schultz, Koenig, & Lewis, 2003). The decision to evacuate is unfortunate, as times of disaster often create increased demand for the medical services that hospitals provide.

Purpose Statement

What are the exact needs and capabilities of healthcare facilities regarding water supply for use in emergency events? The purpose of this research is to explore the capabilities of healthcare facilities regarding the water supply for emergency management. The goal of this thesis is to expand the knowledge base to provide an understanding of future research needs for the emergency water supply of healthcare facilities. This research project focuses on hospitals in Southeast Louisiana. This study employed a mixed method design with a focus on the qualitative portion. This approach allowed for the identification of common themes in the healthcare system. This research is intended to contribute to future emergency water supply planning of healthcare facilities and related industries.

Summary

Natural and man-made disasters often create chaotic moments in the timeframe following devastating events. Many decisions occur in the heat of the moment, though spontaneous planning can be limited by careful preparation. Decisions made prior to disaster events can be very influential. Resources need to be optimally placed to address the needs of the community for emergency management purposes. An essential component of emergency management entails protecting vulnerable members of the population.

Healthcare facilities are often responsible for caring for the most vulnerable of the community. However, hospitals are unable to function following a disaster if they are not prepared with adequate staff and resources. Adherence to emergency preparedness guidelines is imperative and hospitals must recognize the full extent of needs throughout the facility. Storage of large amounts of water needed to continue services throughout healthcare facilities may contrast with the normal logistical procedures used to supply the facility on a day-to-day basis. A greater understanding of the needs and capabilities of hospitals along with productive community planning will produce more salient outcomes.

This thesis is presented in five sections. Following this introduction section, a detailed literature review considers the effects of disruption to water supplies for healthcare facilities. A methodology section details the rationale for the research instrument. The results section explains the findings. Finally, I discuss my findings, the need for comprehensive emergency preparedness in healthcare facilities, and suggestions for future practical applications and research.

Chapter Two: Literature Review

Water is a crucial commodity in the aftermath of disasters, especially in healthcare facilities. Many hospital functions rely on a clean water supply. Pertinent hospital functions include life-saving procedures as well as routine services. Unfortunately, many hospitals are not prepared for catastrophic events, especially in regards to the emergency water supply (Zimmerman et al., 2005). A lack of adequate water reserves could easily lead to dire circumstances, eventually necessitating hospital evacuation.

One of the most important functions of emergency management is providing adequate supplies in time of disaster: food and water being crucial commodities. Storing and maintaining food and water is a difficult task for emergency managers. The focus of this review is to recognize previous instances of interruption of medical services related to water supply disruption, identify the broad range of water needs for healthcare facilities, and understand mitigation and preparedness measures that are considered common practice among healthcare facilities in the United States.

This literature review is organized into four sections: (1) a brief review of emergency management principles and risk management for healthcare facilities, (2) examples and consequences of water supply interruption, (3) needs and uses of water in healthcare facilities, followed by (4) a general review of hospital preparedness. A combination of academic databases was utilized to complete the literature review including Google Scholar, EBSCOhost, and ProQuest. The literature search included a mix of key terms, including: “hospital,” “healthcare facilities,” “water supply,” “(critical) infrastructure,” “logistics (management),” interruption, disruption, “evacuation,” risk management, emergency response, preparedness. Specific areas of hospital functions were searched using terms such as “dialysis,” “ventilation,” “excreta,” and “sanitation.” Existing water storage capabilities terms were also included: “bottled water,” “expiration,” “PET properties,” “microorganisms,” and “reservoirs.” Research from all dates was considered, with an emphasis on research published after 2001.

Hospital Disaster Preparedness

Emergency management of disaster events involves many different components. The four major phases of emergency management are mitigation, preparedness, response, and recovery (Phillips, Neal, & Webb, 2012). The US Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA) describes mitigation as measures meant to limit damage and harm through analysis, insurance, or risk reduction actions (FEMA, 2017). Preparedness includes actions taken prior to, and in preparation of, a disaster that cannot be performed through mitigation (National Governors Association, 1979). Preparedness activities include logistical preparations, emergency planning, exercises, and warning systems. The concept of response includes a broad range of activities which occur after a disaster. The overall goal of recovery in emergency management following a disaster is to restore affected communities to their initial state or an improved community.

Far too often, first-hand accounts of disaster survivors describe horrific scenes. Traumatic injuries and public health issues can quickly become concerning, overwhelming, or detrimental. Healthcare facilities provide one the most crucial aspects of infrastructure in the local community where the disaster occurs. As such, citizens expect the medical community to understand its role and prepare appropriately to maintain medical services during times of crisis (Desforges & Waeckerle, 1991). There is a substantial amount of literature available recognizing the need for emergency preparedness in healthcare facilities (Cherry & Trainer, 2008; Kaji & Lewis, 2006; Richter, 1997; & Zimmerman et al., 2005).

Past research focused on how hospitals organize logistically for catastrophic situations (Cherry & Trainer, 2008; Hick et al., 2009; Schultz & Koenig, 2006; VanVactor, 2011; VanVactor, 2012). Two of these studies considered implications on the emergency water supply of healthcare facilities (Hick et al., 2009; Schultz & Koenig, 2006). Hick et al. (2009) and Schultz and Koenig (2006) focused on hospital needs during crisis events, while peripherally addressing water supply issues. Both studies focused on the overflow of patients in hospital emergency rooms, an issue that called for robust logistical supplies, including water resources.

There are many emergency preparedness processes to consider, especially in organizations as complex as healthcare institutions. Emergency preparedness relevant to healthcare facilities occurs internally and externally in the community. The ability to manage a Mass Casualty Incident (MCI) is the basis for providing more extensive preparedness for disaster situations (Adini et al., 2006). Current standards recommend that healthcare facilities prepare for the possibility of 48-72 hours of stand-alone capabilities (JCAHO, 2003). Local communities are also responsible for emergency preparedness and often collaborate with public health resources.

Community emergency preparedness coalitions or groups often utilize the input of a wide variety of interested stakeholders from public health, public safety, educational institutions, critical infrastructure, healthcare providers, and public administrators.

(JCAHO, 2005). Local communities commonly address health and medical response in their emergency operations plans (Braun et al., 2006). However, ineffective collaboration and coordination between communities and healthcare facilities limit effective preparation. Barriers to comprehensive preparedness include a lack of clarity recognizing responsible parties, obfuscation of critical preparedness elements, limited coordination with applicable state and federal resources, and the ability to secure and sustain funding (JCAHO, 2005). Rural communities are especially inhibited compared to larger, urban providers. Rural hospitals are generally constrained by fewer resources, such as staff and infrastructure, lack of excess capacity, less economic resources, reliance on volunteers, geography, and transportation difficulties, among other issues (JCAHO, 2005). The wide variety of stakeholders, underdeveloped funding mechanisms, and the infrequency of disaster events constrain comprehensive preparedness processes.

Risk management. Traditional risk management in healthcare facilities assumes an entirely different structure of risk perception than is commonly situated in the context of emergency preparedness. According to Zimmerman et al. (2005), "Risk management in the health services is historically related to reducing the impact of medical mistakes and managing the liability of accidents and malpractice" (p. 23). Historical views of risk management for healthcare facilities does not address comprehensive emergency management for disastrous scenarios which can occur due to unexpected hazardous events. Risk management of medical liability entails a narrow, internal viewpoint.

Hospitals are subject to vulnerability from internal or external events. Internal disasters include events such as fire, computer malfunction, or water supply failure. External vulnerability results from natural or man-made disasters. Sternberg (2003) defined an internal disaster as any sudden, hazardous event that disrupts normal operation. Sternberg (2003) also recognized a variety of uncertainties can lead to internal disasters. These uncertainties include hazard, incidental, sequential, informational, consequential, cascade, organizational, and background issues. Hazardous uncertainty arises from specific threats, such as a natural disaster. Incidental uncertainty refers to an accident that creates a larger threat. Sequential uncertainty occurs due to a series of events. Limited, excessive, or questionable information leads to confusion and informational uncertainty. Consequential uncertainty is that which is unexpected. Cascading uncertainty explains how failure in one system may affect other systems. Organizational uncertainty can be related to structure or personnel. Finally, background uncertainty refers to unknown external conditions or resources. With this large variety of uncertainties, it is impossible to respond to a specific event with limited resources. Thus, the primary goal of emergency preparedness is to plan for all-hazards by recognizing consistent patterns in response.

The all-hazards approach to emergency management is relevant to emergency preparedness in healthcare facilities. The all-hazards approach recognizes similarities among different types of disaster events (Phillips et al., 2012). Several studies have documented an increase in patients following a disaster, combined with staffing shortages (Bolut, Fedekar, Akkose, Ozguc, & Tokyay, 2005; Hick et al., 2009; Schultz & Koenig, 2006). Surge capacity is a term used to describe additional patient loads, which often occurs in the aftermath of catastrophic events. Surge capacity is defined as additional resource demand in relation to routine needs (Kelen & McCarthy, 2006). Kelen and McCarthy (2006) further explained surge capacity as the maximum amount of resources that can be delivered and utilized. Kelen and McCarthy's (2006) description of surge capacity relates to a broad array of institutions that may be faced with increased demand in relation to available resources. Schultz and Koenig (2006) provided a description of surge capacity specific to healthcare organizations recognizing the requirements needed for treatment of sudden, unforeseen increases in patient volumes. In general, the resources needed to treat specific volumes of patients are constant. In a surge situation, the necessary resources are increased due to unexpected and excessive demand.

Various benchmarks describe surge capacity preparation. In Israel, hospital's emergency operation plans are expected to address twenty percent higher volumes over average patient census during crisis situations (Schultz & Koenig, 2006). In the U.S., the Health Resources and Services Administration (HRSA) recommended the ability to treat between fifty and five hundred more patients for every 1,000,000 in population, depending on various scenarios, such as natural hazards or pandemics (HRSA, 2005). Increased patient loads have been noted between twenty-four and forty-eight hours following disaster events (Bolut et al., 2005). Bayram et al. (2013) utilized focus groups of hospital staff and administrators to identify resources pertinent to medical care during surge capacity. The research found increased need for a variety of necessary medical supplies during surge events. Prominent resources needed included copious amounts of intravenous fluids, along with lesser need for dialysate and sterile water (Bayram et al., 2013). The focus groups primarily focused on medical supplies, and results did not reflect the importance of critical infrastructure or essential commodities such as food and water.

Schultz and Koenig (2006) advised that emergency preparedness in healthcare facilities is best performed with suitable staff, supplies, structure, and systems management. This combination of components was termed the 4S standard by the authors. Staff must be both adequate in number and prepared to successfully complete goals. Supplies need to be sufficient to maintain operations throughout the emergency timeframe. The structure of the building must be stable, remaining intact throughout a disaster. Finally, the management structure must be prepared and organized sufficiently to provide effective leadership throughout a crisis situation. Schultz and Koenig (2006) reported that hospitals are constrained by governmental regulations, hospital standards, and internal policies. The hospital is vulnerable if any of the four components are compromised.

Supplies are a crucial component of Schultz and Koenig's (2006) 4S theory, as hospital preparations cannot progress without adequate resources. Several theories have addressed pre-positioning of relief supplies for use in case of disaster (Rawls & Turnquist, 2010; Van Wyck, Bean, & Yadavalli, 2011; Van Wyck & Yadavalli, 2011). Recent work based on computer modeling and focus on distribution. Rawls and Turnquist (2010) presented a mixed-integer computer algorithm for ideal placement of disaster relief supplies. Van Wyck and Yadavalli (2011) produced a computer algorithm model to address the preparation of relief supplies. A subsequent study by Van Wyck et al. (2011) refined the algorithm by adding a cost analysis function. However, these studies (Rawls & Turnquist, 2010; Van Wyck et al., 2011; Van Wyck & Yadavalli, 2011) did not address healthcare facility needs or specifically consider positioning supplies at or near hospitals, refugee camps, or where the population is likely to congregate in the aftermath of a disaster.

Other studies have focused on the delivery of relief supplies, such as how to best deliver water in the aftermath of disasters based on computer algorithms, with up-to-date data regarding transportation delays or route closures (Nolz, Doerner, & Hartl, 2010; Nolz, Semet, & Doerner, 2011). These studies emphasized transportation alternatives in the routing of relief supplies in the aftermath of disasters.

Little information is available regarding logistical management of supplies needed in crisis situations in healthcare facilities. There are four categories of inventory in healthcare facilities: cyclic, seasonal, safety and contingency (VanVactor, 2011). Cyclic inventory refers to items in stock that are constantly used and rotated. Seasonal inventory is added due to expected increases in demand during certain timeframes. An example of seasonal inventory includes additional heat packs that may be needed in winter months. Safety inventory includes commonly used items overstocked to surplus levels, but still needed on a routine basis. Contingency inventory includes rarely used items necessary for certain rare situations (e.g., anti-venom). An emerging trend in hospital supply has been through Just-In-Time (JIT) logistics (Cherry & Trainer, 2008; VanVactor, 2012). JIT creates efficiency through the delivery of supplies on an as-needed basis. The JIT theory contrasts with the tenets of emergency preparedness where relief supplies are stored until needed.

Auditing tools are used to determine water supply needs of healthcare facilities. Routine water supply needs can be calculated by average daily sewerage rates. Several auditing tools are available to help healthcare organizations understand risks, needs, and capabilities. Commonly used auditing software programs are available through the American Society of Healthcare Engineers (ASHE), Kaiser Permanente, and HCPro, Inc. (Campbell, Trockman, & Walker, 2011). Auditing tools can be very useful, especially if facilities make appropriate adjustments to problem areas. However, “Too many of our nation’s hospitals have become complacent over disaster preparedness. They develop a document to meet a licensure requirement of a Joint Commission of Healthcare Organizations standard” (Richter, 1997, p. 1). Richter stated these sentiments nearly twenty years ago and there is not much reason to believe that the culture of emergency preparedness in healthcare facilities has completely changed since. A more recent study reported the 48 to 72-hour threshold is being prepared for primarily with bottled water intended solely for drinking purposes (Welter et al., 2010). Thus, for auditing purposes, the drinking water needs throughout healthcare facilities are the primary consideration. However, the true water needs of healthcare facilities are much more diverse.

The process to supply a healthcare facility on a daily basis is complex. Supply of a hospital may be difficult, if not impossible, in the aftermath of disasters. Conceivably, healthcare facilities could request the assistance of federal agencies responding to disaster events following a presidential disaster declaration. Federal relief would be onerous and require the assistance of several agencies (Byrne, 2008). Several regulatory processes must be followed for federal agencies to provide disaster relief supplies. A more robust supply stockpile, within the facility, would allow for conventional operations to resume for a longer duration (Hick et al., 2009). Effective preparation through adequate supply and redundancy can be vital as hospitals are expected to continue operations without outside support (Arbodela, Abraham, Richard, & Lubitz, 2006). Water is one of the most important relief supplies as healthcare facilities cannot operate without a water supply.

Lack of preparedness. In general, hospitals perform emergency preparedness functions through exercises and drills. Exercises and drills allow for staff development of organizational structure and additional medical training. Emergency preparedness, through drills and exercises, improves the capabilities of staff members and the management system as noted by Schultz and Koenig (2006). However, preparedness drills are expensive, especially when performed with large staffs. Hospitals may find it difficult to provide resources to plan for emergency situations which are uncertain to occur in the future.

Limited numbers of disaster exercises and drills lead to a general lack of preparedness in healthcare facilities. An early study by Waeckerle, in 1991, detailed how disasters are sudden and unexpected, thus necessitating more planning for hospitals and medical personnel. Kaji and Lewis (2006) found poor preparedness levels among hospitals in Los Angeles, California. Wise (2006) also noted poor emergency planning for healthcare facilities. The author found better outcomes occurred with enhanced planning processes (Wise, 2006). Preparedness exercises and planning are important, but hospitals also require adequate infrastructure to function properly.

The structure of the hospital building is just as important as the administration, equipment, and infrastructure. Schultz and Koenig (2006) noted the importance of the structure to withstand the impact of disaster. Vulnerability assessments can help to pinpoint weak spots and guide preparedness planning. Two studies have called for hospitals to prepare further by providing more in-depth vulnerability assessments

(Arbodela et al., 2006; Kuwata & Takada, 2007). Vulnerability assessments can provide increased understanding of protection measures available for specific threats endemic to certain geographic locales, such as earthquake or flood zones.

Instances of Emergency Water Supply Disruption

There have been multiple instances in which hospitals have had to cope with interruption to the emergency water supply. There were 286 hospital evacuations between 1950 and 2005 (Distefano et al., 2006). Twenty-two of these instances were full-hospital evacuations. It is difficult to pinpoint the exact number of evacuations related to water supply disruption. Past research shows several examples of water supply disruption affecting healthcare facilities. Past examples include the 1993 flood, the Northridge Earthquake, Tropical Storm Allison, Hurricane Katrina, Hurricane Sandy, and others.

1993 flood. The 1993 flood affected the Iowa Methodist Medical Center in July 1993 when the swollen Des Moines and Raccoon Rivers caused extraordinary flooding in Des Moines, Iowa. The flooding contaminated the municipal water supply, leading to water supply interruption for three weeks (Sternberg, 2003). Hospital employees immediately recognized the danger to the water supply and were able to shut off the flow of water from the municipal supply. Closing off the external water supply ensured no decontamination occurred within the hospital system. A review by Ramsey (1994) portrays a harrowing and extraordinary tale where the hospital was able to maintain operation throughout the ordeal. Water was supplied to the hospital via tanker trucks and 5-gallon containers. The effort to resupply the facility was adequate to provide for critical services. Rationing of water resources was necessary, such as limiting shower usage and laundry services. A limited number of necessary surgeries were performed and autoclave sanitizing was performed with the bottled water. Bottled water was also used for excreta removal via toilet flush. The hospital remained on partial power due to stand-by generators requiring water for cooling. The resupply of water via alternate sources did not facilitate usage for the water-cooled generator system. Eventually, the National Guard provided a 50,000-gallon water bladder with water purification occurring within the facility.

Northridge Earthquake. The Northridge Earthquake occurred in the early morning hours of January 17, 1994 in Northridge, California. The earthquake registered 6.7 on the Richter scale and caused widespread damage. The earthquake forced the evacuation of eight hospitals (DiStefano et al., 2006). Two of the hospitals utilized partial evacuations and six performed complete evacuations (Schultz et al., 2003). Five of these facilities reported non-structural damage to water supply infrastructure as a critical factor in the decision to evacuate. The affected hospitals recognized that their water supply was compromised. The facilities would also face difficulty enlisting assistance from outside agencies due to the scope of damage to the overall region. Over 1,000 patients were transferred to alternative facilities throughout this event. The vulnerability of California hospitals persisted as a follow-up report showed 46% of hospitals in the region were in danger of structural failure in the event of a similar size earthquake. Additionally, 91% were in danger of non-structural damage of the type that caused the majority of evacuations (Schultz et al., 2003).

Tropical Storm Allison. Tropical Storm Allison affected Houston, Texas in June 2001. Tropical Storm Allison was characterized as an extraordinary rain event leading to extensive flooding in the metropolitan Houston area. This storm system severely affected the Texas Medical Center (TMC), which included thirteen hospitals and two medical schools with over 6,000 patients. Tropical Storm Allison caused $2 billion in damage to TMC (Distefano et al., 2006). Nates (2004) reported how Mount Herman Memorial (MHM) became isolated due to loss of electricity, communication, and water supply. MHM evacuated their facility and remained closed for thirty-eight days. The effects of Tropical Storm Allison highlighted the importance of protecting electricity, water supplies, and other critical infrastructure.

Hurricane Katrina. Hurricane Katrina was a Category 4 hurricane that significantly affected Mississippi and Southeast Louisiana in August and September of 2005. Hurricane Katrina led to the inundation of the majority of the city of New Orleans throughout the month of September. The flooding impacted multiple hospitals in the city of New Orleans, leading to an inability to provide medical services at these facilities (Klein & Nagel, 2007). Area hospitals stocked up on additional emergency water supplies after advanced warnings were issued and prior to hurricane landfall. Butcher (2006) presented an account of one of the larger hospitals in the region, Charity Hospital (CH), located in downtown New Orleans. CH had 14,000 gallons of water on hand at the time of Hurricane Katrina's landfall. Nonetheless, the duration of events led to a dire situation at CH, such as shortages of water for dialysis, personal hygiene, fire-fighting capabilities, and waste removal (Brevard et al., 2008). A review of the circumstances that affected the hospitals during Hurricane Katrina and its aftermath calls for further risk-based planning and enhancing improvisational abilities (Edwards, 2009). Hurricane Katrina was a defining moment for hospital preparedness and healthcare facilities.

Hospitals across the country have since recognized the implications of inadequate preparedness (Powell, Hanfling, & Gustin, 2012). The size and scope of the disaster, the number of hospitals impacted, and the extent of the population affected by Hurricane Katrina provides an ideal scenario for future planning.

Hurricane Sandy. Hurricane Sandy was a Category 3 hurricane that caused widespread destruction in New Jersey and New York in November 2012. The storm left widespread flooding in the surrounding regions, affecting hospitals in New York City. Two New York City hospitals required evacuation after the fuel pumps used for electrical generation were flooded (Redlener & Reilly, 2012). The flooded fuel pumps were located in the basement of these facilities. A ladder patrol was formed to bring fuel directly to the generators. This effort was unsustainable, leading to the call for the evacuation. Redlener and Reilly (2012) reported that healthcare facilities must do a better job of learning from previous disaster experiences and putting knowledge learned into future planning. Although the generators were raised in these facilities, not all the infrastructure required for their use was adequately protected.

Other scenarios. Hurricane, earthquakes, and other disasters are exceptional events. History tells us that these types of events happen from time to time. However, it does not take a disaster on a grand scale to cause operations at hospitals to be severely impacted. The 1993 flood, the Northridge Earthquake, Tropical Storm Allison, Hurricane Katrina, and Hurricane Sandy are not the only examples of water supply disruption affecting hospitals as there are several other similar instances to note.

The water supply of healthcare facilities can become comprised through a variety of means. Causes of disruption may seem minor at the onset and then grow into a larger problem. For example, an event occurred in Seattle, WA in 1997 due to a sewer blockage (Sternberg, 2003). The blockage of the sewer line eventually backed-up excreta into several departments of the hospital. The excreta back-up interrupted laboratory and radiological services, and caused partial evacuation of the facility (Sternberg, 2003). While this is an isolated incident, hospitals across the country could be affected by this type of slow-moving scenario.

More uncommon situations do occur. Different geographic localities are vulnerable to their own specific sets of risks. Manuel (2014) provides a recent example of a man-made disaster impacting healthcare facilities when a chemical spill contaminated the Elk River and a municipal water supply in West Virginia. Local hospitals experienced a surge of over 600 patients with related complaints. Two hospitals, Thomas Health System and Charleston Area Medical Center, scrambled to locate an adequate clean water supply (Kloc, 2014). Both hospitals maintained services with assistance involving collecting water supplies and rationing laundry services and personal hygiene services. Eventually, a local psychiatric hospital provided laundry services via an in-house water-recycling wash system. A water-recycling laundry service is the type of system that helps facilities to remain resilient through challenging situations.

Community members expect healthcare facilities to provide medical services in the aftermath of disasters. Hospitals are a crucial component of a community's infrastructure that provides patient care, as well as being a significant economic driver in the community. However, when a disaster strikes, hospitals remain vulnerable assets. The previous examples demonstrated that hospitals are especially vulnerable to flooding, but also to hurricanes, earthquakes, and failure of critical municipal services. The ability to locate alternate water supplies when necessary is valiant, but not an ideal situation. Bottled water, truck delivery, and the use of military (often National Guard) or fire department equipment is the last resort and provides only minimal amounts of water services. Further, the use of military equipment or fire department resources hinders those agencies from completing their primary missions. Rationing and then evacuation of facilities are often the unfortunate and inevitable next steps.

The dire circumstances of the hospitals in New Orleans during Hurricane Katrina and the hospitals in California during the Northridge Earthquake illustrate the catastrophic situations that can occur within healthcare facilities. In both instances, multiple regional medical centers were affected by water supply failure. Outside help was stretched thin, and the only option available was a mass evacuation.

Hospital evacuation. Hospital evacuation challenges comprise an under-researched area, although this topic has received some attention recently. Disetfano et al. (2006) described both internal and complete (external) evacuations. Internal evacuations are more common scenarios and include horizontal and vertical evacuations. Horizontal evacuations occur along the same level of the facility away from the danger area. Vertical evacuations refer to moving patients to another floor of the same hospital. Adini, Laor, Cohen, and Israeli (2012) provided an explanation of both internal and external evacuations. Adini et al. (2012) described four types of evacuations: internal relocation, evacuation without staff (transfer), full evacuation of patients and staff members, and early discharge of patients. Internal relocation entails the horizontal and vertical evacuations described by Distefano et al. (2006). Evacuation without staff occurs when a hospital transfers a patient to a safe alternate facility, usually via ambulance. A full evacuation of patients and staff members requires transport and the availability of alternate facilities. Early discharge of patients occurs with lower acuity patients that can follow-up with outpatient care. Transferring of patients and early discharges allow for opening space which may be needed for additional patients associated with surge capacity in the aftermath of disasters.

Taaffe, Kohl, and Kimbler (2005) explained preliminary decision making for when to declare a hospital evacuation. Their research addressed a combination of factors including the risks of evacuation decisions and outcomes, while considering the availability of resources and previous training of staff. Risks and resource demands are constantly shifting throughout disaster events. Taaffee et al. (2005) concluded that more detailed research and simulations need to be prepared as well as detailed planning and drills to facilitate the execution of mass evacuations

Evacuation is difficult for patients and staff. The level of risk to patients of an evacuation varies depending upon patient acuity levels (Taaffe et al., 2005). Evacuation can require much more effort than simply putting a patient in a vehicle and moving them. Powell et al. (2012) stated, “Evacuation decisions are complex – to evacuate prematurely places patients at risk, whereas waiting too long can have devastating consequences” (p. E1). Some patients may require intensive care, such as medication administration, ventilation, and other life support equipment. Acceptable facilities and transportation must be located and arranged. Transportation of patients with high-needs must be accomplished by Emergency Medical Services (EMS), via either ground or air transport. Patients on life support may need to be placed on alternate, portable ventilation machines, and other equipment. The change in equipment can drastically affect the status of these patients.

Conceivably, a healthcare facility could declare an evacuation, or begin early discharges, with advanced warning preceding a disaster event. Pre-evacuation occurred prior to Hurricane Irene by three hospitals of the Northshore-Long Island Jewish Health System in New York in 2011 (Verni, 2012). The evacuation was generally considered successful, in that patients were safely evacuated in a timely manner to appropriate facilities.

How to best employ the evacuation of a hospital is an area that has recently seen improved research to demonstrate the methods necessary to complete such a complex task. Bish, Agra, and Glick (2014) presented a model that evaluated patient needs against vehicle transport types and accepting facilities. However, the modeling made several assumptions which are difficult to equate into a practical model that is occurring during catastrophic events. Assumptions included readily-available ambulance transport, fixed load, and precise transport times. The model provided by Bish et al. (2014), built on a previous model by Childers (2010), considered the patients' needs, but did not consider transportation and facility availability. Other studies have focused upon which resources (e.g., transportation vehicles, staff) to determine appropriate transportation requirements based on patient needs (Taaffe, Johnson, & Steinmann, 2006; Tayfur & Taaffe, 2007). In the last several years, increasing amounts of research have been published detailing how to accomplish hospital evacuation. However, gaps in the literature remain regarding precise conditions that necessitate an evacuation.

Water Supply Systems

A hospital cannot effectively continue operational processes without water. The JCAHO reported that hospitals should be prepared to continue services for 48-72 hours following a disaster event without any outside assistance (JCAHO, 2003). Ideally, hospitals will be able to return to normal supply routines or identify alternatives within the 48 to 72-hour window. Once the plumbing is compromised, the piping is out of service until properly sanitized. To fulfill the need, hospitals must maintain an adequate supply of water without counting on water that is remaining in the pipes following a compromise. There may be ways to ration water to certain vital areas through a greater understanding of general needs.

Food and water. The most basic need of water is for hydration. The lower limit of water necessary for hydration purposes is one gallon per person daily (Butcher, 2006). In healthcare facilities, drinking water for emergency events is often stored in bottled water form. Bottled water can be purchased and stocked in individual bottles, gallon containers, or multi-gallon containers. Bottled water supplies can have several other uses as well. Besides hydration purposes, water is also used in healthcare facilities for food preparation. Most hospitals have kitchen facilities and dining areas in-house. Water is necessary for a variety of functions of food preparation processes.

Sanitation and sterilization. Cleanliness is a crucial function of healthcare facilities. Cleaning duties are most often performed through sanitation procedures. Cleanliness is defined as the removal of dirtiness, while disinfection is the eradication of microorganisms (Mazzola, Jozala, Novaes, Moriel, & Pena, 2009). Common sanitation practices utilize chemical disinfectants diluted with water. Chemical disinfectants can be applied via spray, as well as handwashing techniques (Saad, 2007). Disinfectants are widely used due to their cost-effectiveness but do not remove all microorganisms. Hand-washing has a long-established tradition in healthcare facilities for the prevention of Healthcare-Associated Infections (HAIs) (Ellingson et al., 2014). Most hospitals have policies that require hand washing procedures at multiple steps in the patient care continuum. Hand washing can be performed with traditional soap and water, as well as with alcohol-based sanitizers. Alcohol-based sanitizers decrease the risk of HAIs and have proven to be cost-effective (Chen et al., 2011). HAIs are incrementally more frequent in developing countries lacking these practices (Bennett et al., 2015). A combination of traditional hand-washing coupled with the use of alcohol-based sanitizers is common practice in healthcare facilities to prevent the spread of infection. Checks and balances are used to ensure proper sanitation of the water supply and handwashing techniques.

Sterilization in the hospital setting is the most effective technology for the removal of microbes. Mazzola et al. (2009) defined sterilization as the complete destruction of microorganisms. Steam sterilization, also known as autoclaving, is the commonly accepted method. Autoclaving requires a combination of water heated to steam mixed with chemical disinfectants for optimum sterilization (Jabbari et al., 2012). Autoclave sterilization is heavily dependent upon water and electricity usage.

Medical functions. A large array of medical functions, including various treatments and diagnostic testing procedures, are dependent upon water supply. Diagnostic tests that rely on water supply include x-ray machines, computer topographical tests, and certain lab procedures (Welter et al., 2010). Diagnostic testing does not require intensive amounts of water. However, water is necessary for the cooling processes of some non-invasive testing procedures.

Many medical treatments require a clean water supply to varying degrees. Dialysis is a life-saving treatment for patients with renal failure. Dialysis treatment requires intensive amounts of water. Dialysis is administered through a compound named Dialysate. A typical dialysis schedule requires 576 liters (152 gallons) of Dialysate weekly (Ward, 2005). Dialysate is composed primarily of water combined with concentrates of calcium, magnesium, potassium, and sodium. IV fluids are also primarily composed of water along with other components. Normal Saline, .9% Sodium Chloride, is also diluted with water, which in turn is used to dilute many other medications. It is paramount that clean water is used in Normal Saline and Dialysate compounds as contaminants can be detrimental to patients with vulnerable renal or immune systems.

Heating, ventilation, and air-conditioning. Structural ventilation is performed constantly with Heating, Ventilation and Air-Conditioning (HVAC) machines in healthcare facilities. Water is needed for cooling processes of many HVAC systems. Several organizations provided input in the guidance of design and construction of ventilation systems for healthcare facilities. These groups include American National Standards Institute (ANSI), American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE), and the ASHE. Together they formed standards and regulations known as ANSI/ ASHRAE/ ASHE 170 (Ninomura & Hermans, 2008). It is important that the ventilation processes are able to provide controlled airflow in operating and isolation rooms. Some newer HVAC models are water-free. However, older model HVACs are water cooled.

Sewerage systems. Excreta are the opposite of clean water supply. Excreta are generally removed through sewerage systems which are maintained by municipal services. Municipal providers are generally responsible for maintaining the external aspects of sewerage systems. Sewerage back-up creates an atmosphere of poor hygiene and sanitation, leading to increased incidents of diarrhea, malaria, and other communicable diseases (Noji, 2005a, 2005b). Sewerage systems do not require a clean water supply to remove excreta. Non-potable water is acceptable to use for excreta removal.

Other hospital systems. Various other hospital functions are dependent upon water supply. Fire-fighting capabilities are an essential tool in the event of emergency. The ability to internally prevent fire damage is vital when emergency services are deployed elsewhere, such as in an emergency situation. Portable fire extinguishers are an alternative. Portable fire extinguishers are not a complete defense for the protection of healthcare facilities.

Water is also needed for laundry services. Low energy and low-water use washing machines are commercially available and becoming increasingly more common. New technological advances have made water-recycled laundry equipment an option as well. Water-recycled laundry services are not a standard practice in hospitals. There is a notable absence of scientific literature to explain the importance and alternatives in regards to the water supply used for fire-fighting and laundry services in healthcare facilities.

Infrastructure interdependency. It is important to note how many of the critical systems in healthcare infrastructure relate to each other. For example, computer systems are powered by electrical systems and electricity production relies on water systems for cooling purposes. Zimmerman et al. (2005) classified four critical infrastructure systems: electricity, water, telecommunication, and transportation. These systems are vulnerable to cascading and sequential uncertainties as defined by Schultz and Koenig (2006). The interrelation of systems creates dependency which could exacerbate a disruption that occurs within any one system at the wrong moment (Arbodela et al., 2006). Hanada, Itoga, Takano, and Kudou (2007) demonstrated how temporary losses of electricity could negatively affect vital healthcare equipment. A loss of power could impact life support equipment by resetting devices and returning them to default settings. The interdependency of critical infrastructure systems increases the vulnerability of healthcare facilities and highlights the importance of maintaining critical operations.

Review of water needs. Water supply in healthcare facilities is a complex system with multiple needs for a variety of processes. Dialysate can be stored in 5-gallon containers. Bottled water can be stored for food and water. Non-potable water is adequate for laundry, fire-fighting, ventilation, and electricity generation can be stored separately from potable supplies. The different requirements for water creates the need for a multi-faceted system where water is stored separately depending on use and container options, such as IV bags for IV fluids, bottled water for hydration, and reservoir for laundry purposes. These diverse supplies are then delivered through various means for specific processes.

Water Supply Storage

Emergency water supplies can be maintained in healthcare facilities through a variety of storage options. The U.S. Department of Health and Hospitals (DHH), Center for Disease Control (CDC) and Prevention (CDC, 2012) offers general guidance for available storage mediums. Options available for water storage include reservoirs, bladder -type containers, and bottled water. It may be acceptable to use non-potable water to perform many functions in healthcare facilities, such as laundry, fire-fighting capabilities, and sewerage removal. Utilizing non-potable water sources may not be feasible for certain facilities. The plumbing systems of hospitals are not generally capable of separating and diverting potable and non-potable water.

Examination of current practices sheds more light on actual preparedness measures. An audit performed by Louisiana State University Health Sciences Center (LSUHSC, 2007) reported that the Shreveport facility uses 28,000 gallons of water daily. LSUHSC-Shreveport maintained 17,000 gallons of water for emergency purposes. The emergency water supply available to LSUHSC-Shreveport represented an eight to ten-hour supply. The audit shows a drastic disconnect between JCAHO recommendations and actual practices. LSUHSC's plan for water supply failure also included requesting the assistance from the State of Louisiana, Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP).

Limited research is available explaining practical trends of current emergency water supply storage. Saad (2007) described several hospitals in Egypt that utilized storage tanks. The review of case studies as previously noted often shows a strict reliance on bottled water supply (Brevard et al., 2008; Butcher, 2006) or delivery by third party contractor in the aftermath of disaster (Kloc, 2014; Ramsey, 1994). It is quite possible, most likely probable, that multiple hospitals are contracting with the same third party vendors to supply water in the event of an emergency.

Contracting with the same vendors can create an over-reliance on one contractor, or a select few, to provide water supply to multiple regional hospitals following a disaster event. Resupply in the aftermath of a disaster relies on the assumption that transportation routes and supply chains remain intact. Bottled water supply is acceptable for certain purposes, but it is difficult for a healthcare facility to maintain a supply of bottled water capable of fully servicing the facility for up to three days.

Issues with bottled water. Bottled water is generally labeled with an expiration date. However, according to the Food and Drug Administration (FDA), water does not expire (Posnick & Kim, 2002). An early study by Hunter and Bruges (1987) tested bottled water and found minute amounts of bacteria and ph above advertised levels. The bacteria and ph levels remained below FDA thresholds. This research examined mineral waters prior to bottling and did not consider the changes to the water product post bottling. More recent studies have begun to look at how storage affects bottled water. In 2006, a study by Shotyk, Krachler, and Chen found high levels of the metal antimony, Sb_2S_3, in bottled water. This study did not specifically address storage but led to further research. In 2007, Shotyk and Krachler noted leaching of antimony with prolonged storage. The findings did not exceed FDA regulations, but they did prove that leaching of the properties of the polyethylene terephthalate (PET) bottles was occurring continuously. Greifenstein, White, Stubner, Hout, and Whelton (2013) performed similar research which examined various storage climates. Their study focused on long-term storage of bottled water in Iraq and Afghanistan. Greifenstein et al. (2013) found that ph, odor quality, and antimony of bottled water increased with prolonged storage in extreme environments. The ph level and odor levels exceeded FDA recommendation, while antimony remained under FDA levels and was only detected after 28 days at 60°C. The various studies do not expose a lethal risk, but they do explain why bottled water cannot be maintained in storage indefinitely. Concerns also apply to reservoir water.

Reservoir water considerations. Reservoirs store large volumes of water. In the aftermath of Hurricane Katrina, many facilities in Southeast Louisiana moved to install well-bore emergency water supply infrastructure. Supply of water via well-bore is not economically feasible in all locations, though, due to geography and depth of aquifers. The use of water wells (when possible) or storage reservoirs is an effective way to maintain large volumes of water. However, reservoirs are not generally utilized by healthcare facilities.

Reservoir water must constantly be cycled and periodically cleaned and sanitized. Microorganisms will grow in the reservoir if the water is not periodically cycled (Casini et al., 2014). Hot water should be stored at a temperature of at least 140ºF; and hot water pipes should maintain a recirculating temperature of 122ºF to inhibit the growth of Legionella bacteria (Fathers, 2004). Reservoir maintenance requirements should not preclude healthcare facilities from considering reservoirs. Further, there is an opportunity for healthcare facilities to work with local municipal water services to provide the necessary infrastructure for emergency water needs.

Summary

There are many needs for water to maintain the continuity of operations in healthcare facilities. Several water storage options are available for healthcare facilities that can be used routinely or strictly for emergency events. The results of interruption to the water supply for healthcare facilities are catastrophic for the organization as well as the community. Hospital standards call for the capacity to operate 48-72 hours without assistance (JCAHO, 2003). The practices of healthcare facilities relating to emergency water supply may not fully address the situations that a hospital can encounter in the event of an emergency. An over-reliance on bottled water (Welter et al., 2010) and the expectation for increased numbers of patients in the aftermath of disaster (Al-Kattan & Abboud, 2009; Bolut et al., 2005; Hick et al., 2009) complicates preparation of an emergency water supply.

Previous research has provided differing recommendations regarding optimal water requirements needed in extreme conditions. Butcher (2006) recommended one gallon of water per day, per person, including staff. The one-gallon recommendation should be utilized only for survival needs of hydration purposes only. Noji (2005b) estimated fifteen to twenty liters (four to five gallons) of clean water per person daily. Noji's recommendation is interesting as clean water excludes non-potable needs. Gleick (1996) advised that each person should be allotted fifty liters of water per day, a little more than thirteen gallons. All water uses are figured into the fifty-liter recommendation, including bathing, sanitation, hygiene, and food preparation. However, Gleick's (1996) study included sub-categories for bathing and sanitation/ hygiene. In the sanitation category, a considerable amount of water resources is devoted to laundry services. In total, Gleick (1996) recommended fifteen liters per person per day (l/p/d) for bathing and twenty l/p/d sanitation/ hygiene purposes. Gleick's (1996) recommendation is comparable with Noji's (2005b) reference of fifteen to twenty l/p/d, when excluding bathing and laundry uses.

Due to discrepancies in needs versus capabilities, some studies called for a more robust supply through planning for up to 96 hours of stand-alone capabilities for healthcare facilities (Hick et al., 2009; Welter et al., 2010). Calling for the additional supply capacity recognizes the inadequate resources available for emergency events. A 96-hour recommendation errs on the side of caution, considering the importance of healthcare facilities to the community, especially in disaster response and recovery functions.

Healthcare facilities have many considerations to take into account, including financial pressure. Funding for disaster preparedness is a delicate issue which is generally insufficient (Cherry & Trainer, 2008). Further analysis by DeLorenzo (2007), reported that funding for hospital preparedness is often generated through general tax revenues. Communities are dependent on healthcare facilities for medical services, as well as employment opportunities (Zimmerman et al., 2005). The economic benefits of a large employer, such as a hospital, are a crucial component of the recovery process in the aftermath of disasters.

The literature review shows that studies specific to the hospital water supply infrastructure for catastrophic situations are limited. Research on the preparedness of healthcare facilities has not always addressed the full range of needs required for comprehensive emergency preparedness. Current research is lacking in practical and theoretical ideas regarding how to provide adequate amounts of water to healthcare facilities following a disaster. Fully understanding the phenomenon of the emergency water supply can help to further develop comprehensive hospital preparedness.

Chapter Three: Methodology

The purpose of this sequential, explanatory mixed methods research is to explore the capabilities of healthcare facilities regarding water supply during emergency events. Hospitals continuously require water to provide services. The water supply needs in healthcare facilities extend into the time of emergency events. The research design is meant to recognize common themes and future research opportunities relating to the topic of emergency water supply in healthcare facilities.

The literature review shows the wide variety of water needs within hospitals and the vulnerability of the infrastructure of healthcare facilities to disaster events. Regulatory agencies, such as the JCAHO, require healthcare facilities to be prepared for interruption in traditional services and supply processes. The literature review shows gaps in preparedness and how hospitals have difficulty providing water resources when the traditional water supply is disrupted.

The first phase of the research included collecting quantitative data focused on internal variables describing regular water usage and capabilities that would affect an emergency event. The following phase consisted of qualitative interviews with those responsible for the emergency water supply of healthcare facilities. The interviews provided an in-depth explanation of how hospitals would react in the event of an emergency to provide water resources to patients and hospital staff.

Research Design

The initial design of the research was based on a quantitative approach. The plan consisted of surveys administered to the facility operators of healthcare facilities. The results of the surveys would then be cross-checked with hospital audit records. However, it was found that JCAHO audits are performed with a self-designated letter grade system. The JCAHO recognizes six essential preparedness components: communication, resources, safety/ security, staff, utilities, and clinical/ support services (The Joint Commission, 2016). The six components are then separated into subsections. Periodic reviews of systems are administered via the Hazard Vulnerability Assessment (HVA) and the facility assigns a letter grade for the result. A satisfactory grade would report the facility has met mandated standards for the appropriate section. An unsatisfactory grade would demand the facility make appropriate adjustments followed by reevaluation.

The self-designated letter grade system proved unrealistic to provide quantitative data for analytic techniques. Further, an absolute grade system did not fully represent the various contexts of water preparation, storage, and utilization. Therefore, an alternate means of inspection was developed in a mixed methods approach. As the study concerned the human subject, an application was submitted to the Institutional Review Board (IRB) at Arkansas Tech University (ATU) with a design for the Informed Consent (IC) paperwork and research instrument. The IRB application was subsequently approved in September 2016.

The mixed methods research design enabled the researcher to fully understand the needs and capabilities of hospitals regarding their water supply. The approach required a combination of data collection and interview results performed in an explanatory sequential order as described by Cresswell (2014). The quantitative portion allows for confirmation or refutation of a theory or hypothesis. The qualitative section permits exploration and discovery.

The quantitative data was collected through the use of an internet-based, cross-sectional survey. The survey was created on the web platform QuestionPro. QuestionPro is known as an economic, user-friendly toolkit and allows for rapid generation, collection, and analysis of results. The core survey items explicitly addressed the dependent variable (average water usage), the independent variable (total water capacity), and moderating variables to determine hospital's preparedness for emergency events regarding water supplies.

Shift in research design. Limited survey responses necessitated a shift in methods further along in the data collection process. A decision was made to prioritize the qualitative data according to an outline provided by Morgan (1998). This qualitative approach allowed for complementing the limited amount of quantitative data and further understanding the decision-making process in emergency events. A similar shift in research design was adopted by McGraw, Zvonkovic, and Walker (2000). McGraw et al. (2000) recognized that limited amounts of survey respondents compromised the validity of their study. The authors then utilized their quantitative results to select a subsample of the initial target population and to prioritize the qualitative results. The example set by McGraw et al. (2000) thus served as a template for the approach to this thesis.

The second phase of the research design was qualitative. This section included in-depth interviews that delved into internal and external factors found to affect the needs and capabilities of healthcare facilities in relation to water supply. Recognizing the sequence and priority is the starting point to begin a mixed methods research project. A combination of quantitative and qualitative methods can complement each other, and thus provide a more robust analysis (Green, Caracelli, & Graham, 1989). The mixed methods approach is especially useful when many factors can influence the dependent variable (Morgan, 1998). The multiple ways water is used in hospitals and the variety of storage mediums are consistent with a design needed to explore complex factors.

Figure 1. shows how qualitative data analysis progressed in six steps as recommended by Cresswell (2014). This analysis flow was adopted for the study.

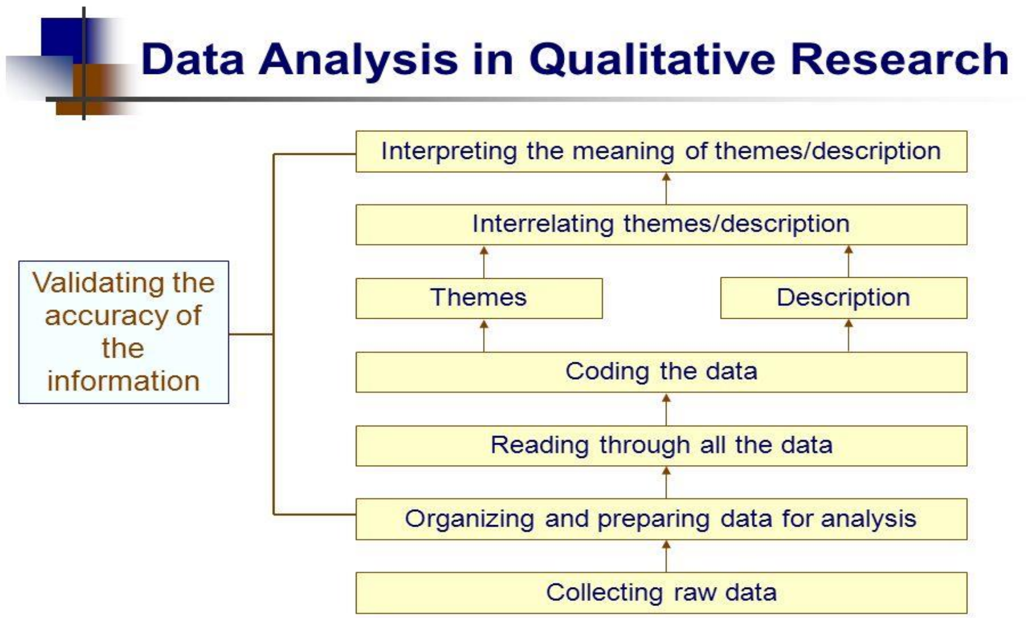

Figure 1. Validating qualitative results (Cresswell, 2014)

An additional benefit of the research design which was utilized is the ability to compare and contrast the preparedness processes of two functionally different facilities: urban and rural. The capabilities of both the facilities represent a microcosm of changes that have gradually been occurring in the healthcare industry for the last several decades. Physicians have been slowly congregating towards network-centered practices. Large health systems have begun to dominate the healthcare market (Ricketts, 2000). Rural providers have limited capabilities due to increasing costs and decreasing reimbursements, while at the same time having difficulty recruiting and maintaining staff and specialist physicians (Ricketts, 2000). However, the importance of the hospital to the local, rural community cannot be understated. Rural hospitals are often located in areas susceptible to natural and environmental hazards (Edwards, Kang, & Silenas, 2008) and have a significant impact on the local economy (Mandich & Dorfman, 2014; Zimmerman et al., 2005). Despite the challenges, rural hospitals comprise 1,829 facilities out of a total of 5,564 in the United States (AHA, 2017). Rural hospitals remain a mainstay of the American healthcare environment nowadays and in the near future.

The Quantitative Phase

The goal of the quantitative phase of the research was to identify and confirm areas requiring further reflection. The quantitative data was collected using an internet-based, cross-sectional survey (Cresswell, 2014), that was self-developed on the web platform QuestionPro. The principal survey questions addressed the dependent variable (average water usage) and independent variable (total water capacity) for use as predictors to determine how a hospital prepares for and responds to emergency events regarding water supply disruption. The survey then considered several moderating variables to further delineate needs or separate capacity mediums. Finally, the survey allowed respondents to utilize an open-ended question to describe if alternative plans were in place for the acquisition of water resources.

The criteria for selecting participants was contingent on locating and soliciting those responsible for the emergency water supply of healthcare facilities. As such, the sampling for the quantitative portion was convenience in nature. The facility manager of the hospital is considered the most knowledgeable regarding the water supply capacity.

Some institutions may place control of the water supply under different departments and different personnel. An attempt was made to distribute quantitative cross-sectional surveys to the facility managers (or appropriate personnel) of twenty healthcare facilities across Louisiana. Solicitation was made to the targeted healthcare facilities through e-mail or phone call. An explanation of the research as outlined in the IRB application was then provided for those facilities that returned contact. The research was then explained to those in charge of the emergency water supply, as well as a copy of the IC form and a web link to the research instrument. The initial attempt to contact twenty healthcare facilities led to insufficient survey respondents. The survey population was thus increased to fifty healthcare facilities in Louisiana. A total of five respondents completed the research instrument.

The limited number of respondents would not warrant the significance of the quantitative analysis. To fill the gap of the dataset and explore the context of responses, the study was further extended to the qualitative section. Focusing on qualitative inspection is consistent with many mixed methods research approaches from other disciplines. According to Clark, Huddleston-Casas, Churchill, Green, and Garrett (2008), "many studies reported only rudimentary analytic techniques, such as reporting percentages and means for the quantitative data" (p. 1561). The quantitative analysis of the research design was utilized to recognize core competencies of the survey populations. The quantitative data may be briefly discussed and used for reliability and verification.

The Qualitative Phase

The data collected from the quantitative section showed clear differences in the needs and capabilities of urban hospitals compared to their rural counterparts. The amounts of water used on a daily basis and stored for emergency purposes was markedly greater for the urban facilities. From the five survey respondents, three represented rural hospitals while the other two hospitals were in an urban setting. Interviews were set up with those responsible for the emergency water supply at two hospitals. For the qualitative phase, participants were purposively selected from each of the two groups, rural and urban.

A telephone interview was conducted with the Emergency Preparedness Coordinator for Ochsner Medical Center (OMC) in Jefferson, LA. A face-to-face interview was also conducted with the Facility Supervisor for Our Lady of the Sea General Hospital (OLOSGH) in Galliano, LA. Interviews were conducted by recording handwritten notes and then immediately transcribing verbatim. The information collected was then transcribed and coded according to common themes. Finally, I combined major findings, such as direct quotes, in table format.

The choices of these two respondents represented a wide disparity of hospital capabilities. OMC is a fully-functioning, Level 2 trauma center in Jefferson Parish, Louisiana, capable of admitting nearly 500 patients. A gradual shift has been occurring in the healthcare delivery system over the last several decades leading to networks of increasing numbers physicians and sizes healthcare facilities. OMC is the center of a large healthcare conglomerate in Southeast Louisiana, termed Ochsner Health System which includes over thirty hospitals and 2,700 physicians (Ochsner, 2014).

OLOSGH is a rural hospital in Lafourche Parish, Louisiana. OLOSGH has general surgery availability, no further specialty care services, and can accommodate less than fifty patients. The US Department of Health and Human Services, Centers for Medicare and Medicaid Services (2016) defines rural hospitals in several categories, including Critical Access Hospitals (CAHs). CAHs provide around-the-clock emergency care in rural areas and have twenty-five or fewer inpatient beds.

The capabilities of the hospitals selected for the qualitative portion are extremely diverse. The research design is intended to provide an investigation of the preparedness trends regarding the water supply for emergency purposes. Interview and survey results are presented in Chapter Four.

Chapter Four: Results

As stated in Chapter Three, the need of healthcare facilities in contrast to the capabilities is a prominent theme. Needs are described as water used, and can further be broken down into subgroups, such as how much water is needed for a particular action or process. Capabilities can be considered ways that water can be stored or delivered. In general, needs, and capabilities can be described on a daily basis, during normal operations.

The overall needs of healthcare facilities must be understood before separating into sub-groups. OMC used between 5,000 and 10,000 gallons of water on a daily basis. OLOSGH reports less than 5,000 gallons of water used daily. Neither facility had significant reservoir or storage capability. Preparedness planning for water supply interruption at OMC was robust, as shown in the statement in Table 1.

Table 1

Responses to Emergency Water Supplies

Question	OMC	OLOSGH
Explain the activities the hospital would take in the event of an emergency.	"A lot stems around facilities. We have two water wells…They are able to provide non-potable water."	"We will fill up storage containers and place a few of those in the hallways…They are sixty-gallon containers…We could use this to flush toilets, etc."

The planning process to construct the water wells at OMC began following Hurricane Katrina. This infrastructure was federally-funded and distributed by state agencies (LRA, 2009). It is interesting to note that the water wells were only capable of providing a non-potable water supply. In contrast, the planning process at OLOSGH was heavily dependent on municipal water supplies as evidenced by the response in Table 2. Sixty-gallon containers allowed the facility to have a minimal supply capacity. The storage containers were utilized in an *ad hoc* manner. The containers could only be utilized if they were filled prior to compromise of the municipal water supply.

Table 2

Responses to Water Supply Capabilities Change

Question	OMC	OLOSGH
How would capabilities change with advanced warning?	"Facility services handles this. They can shut the ice machines down to save the reserves that are in the system. The gallons are brought in from an alternate location. We can also stock up with extra gallons and liters."	"First, we bring in extra bottled water, then fill the containers. The hospital would probably try to discharge or transfer as many patients as possible."

OMC and OLOSGH are located in areas particularly vulnerable to tropical storms and hurricane events. Both facilities had repeated instances of emergency situations in the recent past, including Hurricane Andrew, Hurricane Katrina, and Hurricane Gustav. OMC was one of the few hospitals that remained open and accepting new patients during Hurricane Katrina and subsequent flooding of the greater New Orleans area. Both OMC and OLOSGH have become accustomed to emergency events with a prior warning as a result of previous experiences with hurricanes and other incidents.

The hospitals present different approaches to disaster preparedness for emergency events with prior warnings. OLOSGH would attempt to evacuate patients, if possible, before an impending emergency event. Transferring patients limits the population that is present and allows for available space to accommodate additional patients which may arrive at the facility. Beyond that, the facility planned to continue critical services and prepare additional stocks of water resources through the sixty-gallon containers and additional bottled water supplies.

OMC's approach was focused on providing additional supplies and conserving where possible. OMC did not express any plans to evacuate their patients unless necessary. Following Hurricane Katrina, OMC, which did not flood, provided 45,000 bottles of water or bottled products to staff members, patients, family, National Guard, security agencies, and personnel of various federal agencies (Ginsberg, 2006). Conservation measures, such as shutting down ice machines, can limit the needs of the facility. Ice is a luxury during an emergency event, and these resources can be directed towards more pertinent uses.

The actions of OMC following Hurricane Katrina portrayed the operations through difficult times. However, it must be stressed that the well water can be utilized for non-potable use only, and planning for potable water supplies is contingent on the use of bottled water products.

Table 3

Responses to Bottled Water Storage

Question	OMC	OLOSGH
How much bottled water is kept?	"We usually keep around 5,000 gallons."	"A couple of hundred gallons, less than five hundred."

Both OMC's and OLOSGH's emergency potable water supply planning was centered around the use of bottled water, as explained in Table 3. Both hospitals planned to increase reserve supply of bottled water in the event of an imminent emergency. Neither respondent was concerned with the expiration of bottled water products. Ginsberg (2006) noted the use of 45,000 bottles of water product distributed following Hurricane Katrina at OMC. 45,000 units of bottled water products represent a significant increase over the normal stock levels. It must be noted that OMC was a location for a FEMA medical clinic following Hurricane Katrina. FEMA may have provided a large proportion of the bottled water products.

Neither OMC nor OLOSGH reported any reservoir capacity. The water wells at OMC did not connect to a storage medium. The reliance on bottled water for emergency preparation was identified. Further understanding of the expected population at the facilities at the time of an emergency event was further investigated.

Table 4

Responses to Expected Patients and Staff Members

Question	OMC	OLOSGH
What is the average in-patient admission count?	"I believe it is around 380."	"Thirteen, I believe."
What is the maximum amount of patients that the hospital can accommodate?	"Somewhere near 500."	"Twenty-five on the floor, eight in the emergency room, and four in the ICU."
How many employees would be at the facility in the event of an emergency?	"800-1200. As low as 500-1000 on team A."	"I would guess twenty-five to fifty."

The population in Table 4 represents the true needs of the facilities during an emergency event. The needs of OLOSGH were a fraction of OMC. OLOSGH reported a maximum occupancy rate of fifty staff members and thirty-seven patients. The occupancy rate was dependent upon the number of patients at the hospital. It was reported in the interview that the hospital "would probably try to discharge or transfer as many patients as possible." The average patient census on a daily basis was around thirteen at OLOSGH. As such, the expected service population in emergency was closer to sixty, which included both staff members and patients.

OLOSGH's emergency water supply included about 500 gallons of bottled water. 60 staff members and patients at OLOSGH would require 237 gallons of water in 25 hours according to Gleick's (1996) recommendation. 500 gallons of water would be adequate to maintain hydration and other water purposes of OLOSGH for approximately 48 hours. The storage containers can be used for non-potable purposes, but these supplies will diminish rapidly, and are limited in available applications.

OMC expected between 1180 and 1580 patients and staff members present at the hospital in the event of an emergency. The Emergency Response Plan (ERP) distinguishes an emergency team (Team A) and a recovery team (Team B). Team A is generally expected to reside within the facility until the danger passed and business operations return to a normal state. Adequate water supplies must be provided to the total expected population.

OMC's capabilities were less clear. 1000 members on Team A, combined with 380 average patients would require 5,464 gallons of water at 15 l/p/d levels. However, well water can be utilized for all non-potable purposes. The non-potable water can be used for laundry, showering (not bathing), fire suppression systems, and to be diverted for critical infrastructure uses. OMC's existing stock of about 5,000 gallons of bottled water would not amount to 15 l/p/d for 1,380 staff members and patients over two or more days. Acquisition of potable supplies may be required to maintain facility services at OMC.

Table 5

Responses to Dialysis Capabilities

Question	OMC	OLOSGH
How would dialysis be handled during an emergency event?	"The thing we are not able to address well is dialysis. They would have to be sent out of the system…"	"That's all done out-patient…through the clinic."

Table 5 addresses a particularly difficult area for hospitals in preparation of patients with advanced renal needs. OLOSGH did not report renal services, so the supply of dialysate was not an issue in this case. However, OMC performed in-patient, outpatient, and emergency dialysis. Ward (2005) reported a typical dialysis patient requires 152 gallons of dialysate per week. The typical dialysis patient undergoes three dialysis treatments per week, equaling about fifty gallons per treatment; an extraordinary number that can add up quickly with only a few renal patients. On average, OMC used between 250-500 gallons of dialysate daily and stored about 500 gallons of dialysate. Re-supply of dialysate could be complex, requiring delivery from specific suppliers. OMC recognized that the supply of dialysate is inadequate during an emergency event and the difficulty of acquiring additional dialysate.

Table 6

Responses to Rationing of Water Supplies

Question	OMC	OLOSGH
Are there any plans in place regarding rationing of water supplies if needed?	“We provide armbands for essential personnel. This limits the total that we have to provide for. We do not want to limit consumption…But we do not want to provide extra, unnecessary resources.”	“I do not know that. I imagine administration would determine if it came to that.”

Neither OMC nor OLOSGH had any significant plans in place to ration water resources according to Table 6. OMC planned to utilize the activation teams. The activation teams limited the amount of employees present. Limiting the number of employees on campus can quantify an estimate that the facility can use to prepare adequate resources. Neither facility had agreements in place to acquire water supplies through a third-party vendor.

The information provided in interviews is consistent with general trends found in the quantitative portion of the research. The research results are also consistent with publicly available material from other hospitals in the region, such as the LSUHSC (2007) audit. LSUHSC–Shreveport maintained an eight to ten-hour supply of readily available water with preparations in place for additional spontaneous acquisition. According to Welter et al. (2010), many hospitals rely on bottled water for an emergency water supply. Reliance on bottled water is a prominent theme among the results of this study. To truly affect positive preparedness, hospitals should consider the full range of needs and a large scale of reserve water supply. A closer analysis should account for the community involvement in the planning of infrastructure, eventually ensuring the resilience of healthcare facilities.

The resources of the two hospitals chosen for this study showed stark differences in a variety of areas. Planning for emergency events is manifested through the extent of available resources. Both hospitals recognized the difficulty in adequately providing for their staff members and patients if regular routines were disrupted for an extended timeframe.

OLOSGH has limited capabilities on a routine basis, such as specialty care services. OLOSGH planned to remain open throughout an emergency but transfer patients out of the system if possible. The transfer plan is comparable with the evacuation of hospitals in New York prior to Hurricane Irene, as detailed by Verni (2012). Transferring patients also creates additional space in the event of a surge in patients following a disaster event.

OMC's preparations were much more robust. OMC withstood the onslaught of Hurricane Katrina and built mitigation infrastructure since then. The water wells should provide salient benefits in a dire situation. OMC did recognize that dialysis patients may need to be transferred, but otherwise was prepared to maintain operations throughout an emergency event if possible. However, the ability to provide potable water for staff members and patients for longer than 24 hours is dependent upon acquiring additional supplies, either immediately before or during the aftermath of a disaster event.

The preparedness planning of hospitals entails a wide diversity of needs with water supplies comprising one facet. Both facilities appear to have learned lessons from previous disaster events in the region. These experiences are manifested in the storage of resources, pre-planning to acquire additional supplies, and use of activation teams to limit populations. However, the consistent reliance on bottled water to cover water needs, especially potable services, remains alarming.

Chapter Five: Conclusion

As stated in Chapter Four, general trends about emergency water supplies were recognized during the interview process. These trends include hospital needs, hospital capabilities, opportunities to improvise, and areas that are not adequately covered. Clear differences can be noted regarding the capabilities of urban versus rural hospitals. The hospitals in Southeast Louisiana are in a specific geographic region that is prone to natural and technological disasters, especially hurricane events. This location necessitates the regular application of emergency preparedness procedures. Waeckerle (1991) noted deficiencies in disaster preparedness measures among healthcare facilities. Wise (2006) found more salient outcomes with prior planning processes, and called for "the resources to handle all people who present and at the same time also be able to adequately resupply consumed resources" (p. 1151). Prior planning must consider not only immediate needs, but also foresee future needs and gaps in capabilities.

Organizations should recognize poor preparedness procedures by learning from their own previous experiences, as well as the success and failures of like-minded organizations. The hospitals in Southeast Louisiana noticed the plight of other hospitals in the region that have been negatively affected by disaster events and adjusted accordingly where possible. Hurricane Katrina was a landmark event that focused the world's attention on Southeast Louisiana. Vulnerable populations were left in undesirable, sometimes dire, situations. Healthcare facilities were severely impacted. Many of the hospitals in the region were unprepared for the catastrophe, as shown by Brevard et al. (2008).

The literature review showed the diverse needs of water resources within healthcare facilities. The literature review also revealed how a wide variety of events, both internal and external, can cause a range of systems failures. Critical infrastructure systems are dependent upon each other (Arbodela et al., 2006; Hanada et al., 2007; Schultz & Koenig, 2006), and water supply is a common theme in the continuity of operations of healthcare facilities.

Major Findings

Rural healthcare facilities, such as OLOSGH, are at a disadvantage for developing robust disaster preparedness planning. Financing is routinely constrained. The lack of funding prohibits preparedness measures which may assist the facility in ensuring a stand-alone capacity as recommended by the JCAHO (2003).

A certain adaptive capacity can be noted in the preparedness planning of the hospitals included in the research. In systems management, adaptive capacity can explain responses to changes in the external environment or recovery when changes affect internal processes (Dalziell & McManus, 2004). Systems change can occur by utilizing existing resources, new applications for existing resources, or by creating new response mechanisms.

Existing resources are utilized in OLOSGH emergency preparations plan. Transferring patients out of the hospital system is an action that occurs on a regular basis. OLOSGH is a rural hospital that does not have many specializations, such as cardiovascular, neurological, etc. Patients requiring advanced levels of care must be routinely transferred to appropriate, alternate facilities. The decision to enhance movement of these patients out of the hospital system following advanced warning of an impending disaster event shows recognition of limited hospital services and resources. The implementation of storage containers to increase water supply is also an example of utilization of existing resources. However, the use of this type of storage medium in a healthcare facility is inconsistent with acceptable water sanitation practices.

Both OLOSGH and OMC's ability to allocate water during an emergency event is based on limiting personnel. OLOSGH's plan to deliver water resources through an emergency event is contingent upon provision of bottled water combined with maintaining small patient and staff counts. Limiting patient census numbers may be possible with advanced warning by discharging or transferring patients. However, the hospital may easily be left in an undesirable position following a sudden, unexpected event.

Robust preparedness measures at OMC are consistent with the additional capacity available to urban facilities. OMC is the center of a large hospital network with significantly greater resources than its smaller competitors. OMC's emergency preparedness plans show a much wider range of adaptive capacity.

The use of emergency activation teams is a well-practiced response. The teams are separated to give each other adequate recovery time. Assigning team members entry/ exit armbands is a new application of previous resources. Limiting the number of staff members present also lessens the amount of resources necessary to maintain the facility. Dialysis is an area of significant concern for renal patients following a disaster event. OMC must transfer renal patients out of their system only in the event of an emergency, primarily due to dwindling supply of dialysate. Finally, the drilling of water wells is a novel response implemented to address a recognized shortage.

Solutions and Future Directions

In order to gain a greater understanding of the issue of the emergency water supply of healthcare facilities it will be necessary to provide a wider scale of research. This research project comprises a unique locale that had recently been severely affected by Hurricane Katrina. The hospitals in this study, especially OMC, have made considerable updates to their emergency preparedness capabilities since that time. The use of water wells is one example of structural upgrades to OMC's emergency preparedness planning. However, the use of well water may not be feasible for all geographic regions.

The cost of water wells increases in environments with elevated topographical features. A greater understanding must be gained of the cost-benefit of various types of storage mediums. Cost-benefit modeling can help individual hospitals recognize specific alternatives that best fit their environment. Effective cost-benefit analysis of the water supply of healthcare facilities can only occur with the assistance of multiple departments within hospital administration.

Finally, it must be understood that it may not be possible to prepare for every situation or to provide indefinite resources in the event of certain disasters. In these cases, it is important to make effective use of all resources. Some uses of the water supply that are necessary on a daily basis may possibly be temporarily withheld in emergency situations. Rationing can include delaying processes, such as laundry services. Rationing does not need to strictly be defined as withholding resources. Computer algorithms can provide modeling features to explain how water resources can be diverted for the most pertinent uses.

Synergies can be considered that may have alternate daily functions but are able to provide emergency capacity. An example would include a swimming pool that is used for physical therapy. The water in the swimming pool can be used as a storage reservoir and diverted for use when necessary. An elevated swimming pool, such as on a rooftop, can also provide adequate water pressure.

Finally, community preparedness forums offer one of the greatest opportunities to enact positive improvement to policy initiatives on the local level. The presence of healthcare facilities is beneficial to communities both economically and for medical services (Mandich & Dorfman, 2014; Zimmerman et al., 2005). Community preparedness coalitions need to recognize the limitations of the water supply in healthcare facilities and the consequences of inadequate supply to vulnerable populations. Stakeholders involved in community preparedness coalitions include organizations and individuals in position to provide water supply initiatives, such as public works, critical infrastructure providers, public administrators, along with healthcare organizations (JCAHO, 2005). Collaboration between these key stakeholders should prioritize access of water supplies to healthcare facilities during extreme events. Water towers or reservoirs should be built on or near hospital grounds. Close access could ensure that water supply be diverted to hospitals in the event of catastrophe. A dedicated storage medium could ensure that water supplies are diversified, with bottled water adding to reserves. A water tower in close proximity seems to be an ideal solution that can assist healthcare facilities in providing for vulnerable populations.

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